Submerged Aquatic Vegetation (SAV)

BIGHT '23




Southern California Bight
2023 Regional Monitoring Program
Volume VIII

SCCWRP Technical Report 1488

Southern California Bight 2023 Regional Monitoring Program: Volume VIII. Submerged Aquatic Vegetation (SAV)

Jill Tupitza[1], David Gillett[1], Adriana Le Compte Santiago[1], Jan Walker[1], Christine Whitcraft[2], Hannah Lyford[3]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA

[2]California State University, Long Beach, Long Beach, CA

[3]University of California, Santa Barbara, Santa Barbara, CA

September 2026

Technical Report 1488

BIGHT '23 SAV COMMITTEE MEMBERS AND PARTICIPATING LABORATORY STAFF

Member	Affiliation
Chad Loflen	San Diego Regional Water Quality Control Board
Lauren Hubbell	Santa Ana Regional Water Quality Control Board
Terri Reeder	Santa Ana Regional Water Quality Control Board
Kat Beheshti	San Onofre Nuclear Generation Station Mitigation Project (SONGS-MP)/UC Santa Barbara
Christine Whitcraft	California State University Long Beach
Lizzie Duncan	NOAA – Channel Islands National Marine Sanctuary
Hannah Lyford	UC Santa Barbara/ NOAA CINMS
Vanessa van Deusen	NOAA – Channel Islands National Marine Sanctuary
Byrant Chesney	NOAA Fisheries
Dan Lawson	NOAA Fisheries
Ken Schiff	SCCWRP
Keith Merkel	Merkel & Associates, Inc.
Hannah Lyford	UC Santa Barbara
Marco Sigala	Moss Landing Marine Laboratories
William Jakl	
Justin Gill	
Johnathan Casey	Aquarium of the Pacific
Adam Obaza	Paua Marine Research Group

FOREWORD

The 2023 Southern California Bight Regional Monitoring Survey (Bight '23) is a collaborative effort to provide a large-scale integrated assessment of the Southern California Bight (SCB). The Bight '23 survey is the continuation of previous regional monitoring surveys conducted on a five-year cycle since 1994. This regional collaboration represents the joint efforts of over 100 organizations. Bight '23 is organized into seven elements: (1) Sediment Quality, including Toxicity, Chemistry, and Benthic Infauna, (2) Microbiology, (3) Shellfish Bioaccumulation, (4) Trash and Microplastics, (5) Ocean Acidification, (6) Estuarine Assessment, and (7) Submerged Aquatic Vegetation (SAV). Copies of this report on SAV, as well as other Bight element reports, workplans, and quality assurance plans can be downloaded at https://www.sccwrp.org/about/research-areas/regionalmonitoring/southern-california-bight-regional-monitoring-program/bight-program-documents/.

The SAV element, which is focused on eelgrass, was added in 2023 to the Southern California Bight Regional Monitoring Program.

ACKNOWLEDGEMENTS

This project is the result of hard work from a community of practice dedicated to improving our collective understanding of aquatic health in the Southern California Bight. The authors wish to thank the Bight SAV Committee for their invaluable insights on the study design, supporting protocols, data analysis, and interpretation of results. We also wish to thank all staff within participating laboratories for expertise in improving field protocols for the region and beyond. The following organizations were instrumental in field sampling efforts: Merkel & Associates LLC, Moss Landing Marine Laboratories, San Onfre Nuclear Generation Station Mitigation Project, NOAA Channel Islands National Marine Sanctuary, and the Whitcraft Lab at California State University Long Beach. We also wish to thank Katelin Lally, Megan Warren, Jarrod Gaut, and Andrea Benitez for their laboratory assistance, as well as Robert Butler, Duy Nguyen, and Alondra Gonzalez for their efforts in data management.

Executive Summary

Background

Submerged Aquatic Vegetation (SAV), specifically seagrasses, are a unique ecological, economical, and socially important component of Southern California's coastal ecosystem. These perennial aquatic plants can grow in expansive meadows across the soft sediments of the shallow coastal zone that serve as hotspots for productivity and biogeochemical cycling, as well as provide structurally complex habitat between the water column and the sediment surface. Eelgrass (*Zostera marina*) is the most common species of SAV within the embayments of the Southern California Bight. Healthy, intact eelgrass beds support a variety of ecosystem functions and services not provided by other coastal habitats.

The condition of eelgrass is a key, but under-monitored, aspect of characterizing the health of the region's coastal waters. Because of its position at the interface between the water and the sediment, estimating the condition of eelgrass provides insight into the health of the waterbody where it grows, with insights into water column processes such as eutrophication, sediment loading, and elevated water temperature. Bioassessment of eelgrass condition can provide these insights to aquatic health through the lens of the plant, which other monitoring program components that measure water column parameters alone may be less sensitive to.

Study Objectives and Approach

The goal of this study was to provide regional-scale estimates of eelgrass condition within the estuaries and embayments of the Southern California Bight. A baseline bioassessment of eelgrass condition and a tool for ongoing monitoring efforts is essential to managers interested in supporting data-informed eelgrass ecosystem functions with specific conservation or restoration action. Data were collected through a multi-agency community of practice, which refined and intercalibrated a series of standard lab and field protocols. Forty-seven sampling sites from across the Southern California Bight were selected via a stratified random sampling design, as well as 12 additional targeted sites of interest to the community of practice (hereafter, the 'Bight SAV Committee'). Sampling sites were stratified across three waterbody types – estuaries, small embayments, and large embayments. Strata were assigned different weights based on relative area of each waterbody type, enabling estimation of condition over all embayment area throughout the region. Condition of each eelgrass site was assessed using a condition assessment framework designed to interpret condition through the lens of support for seven key ecosystem functions - carbon sequestration, substrate stabilization, nekton and waterfowl habitat provisioning, primary and secondary production, and water quality improvement. Overall eelgrass condition and condition relative to each component ecosystem function were categorized in quartiles as Lowest Observed, Moderate, Good or Best Observed, relative to regional distributions. We generated this initial condition assessment using this framework previously described as the Zostera Ecosystem Function Reporter (ZEFR) (Gillett et al. 2026).

Study Findings

This first regional survey of eelgrass condition as part of the Southern California Bight Regional Monitoring Program – 'The Bight Program' - indicated that the region's eelgrass beds were in reasonably good condition relative to the best functioning eelgrass observed within the region. Across the entire region, 11% of the eelgrass beds were within the Best Observed Condition category, 45% were in the Good Condition category, 31% were in Moderate Condition, and only 12% of the region's eelgrass were in the Lowest Observed Condition category. Eelgrass overall condition did vary slightly across strata (waterbody type), with small embayments having the majority of their area (59%) in Moderate Condition. Conversely, large embayments and estuaries were dominated by eelgrass in Good Condition – 48% and 36%, respectively. Each stratum had <15% of eelgrass area in Best Observed Condition. Estuaries had the largest area of any single stratum (21%) in the Lowest Observed Condition category.

Among the component ecosystem functions at the Bight-wide scale, nearly a third of the total Bight-wide eelgrass area was in the Best Observed Condition category for Carbon Sequestration. Substrate Stabilization, Primary Production, and Secondary Production had their highest percent of Bight-wide eelgrass area in Good Condition. Conversely, the majority of Bight-wide eelgrass area was in the Moderate Condition category for Nekton Habitat Utilization, Waterfowl Habitat, and Improving Water Quality.

The results of this initial survey should be considered an initial assessment of condition, as the present survey only used a single year of data to benchmark structural metrics and condition categories. Furthermore, the scoring of each structural metric within the index is based upon a relative distribution of available observations. As additional regional data become available to better capture the spatial and temporal variability of eelgrass, the thresholds of individual structural metrics, and possibly condition categories, may shift. Condition categories will ultimately stabilize as more data is compiled and integrated into the index. We leveraged this initial condition assessment using the ZEFR tool to draw insights on the tool itself, including both its utility for management and areas in need of further validation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

Submerged Aquatic Vegetation (SAV), specifically seagrass, is an ecologically, economically, and culturally important coastal resource worldwide. These flowering marine plants are globally distributed throughout most temperate coastal waters. Four different taxa of seagrass (*Zostera marina, Zostera pacifica, Ruppia maritima,* and *Phyllospadix spp.*) are endemic to Southern California, but both species of *Zostera* (eelgrass) are the dominant vegetation in estuaries and embayments throughout the region (Bernstein et al. 2011). *Zostera marina,* in particular, is the most common species within estuaries and enclosed embayments the Southern California Bight.

Where present, eelgrass supports a variety of expected functions within a healthy ecosystem: carbon sequestration, substrate stabilization, nekton and waterfowl habitat provisioning, primary and secondary production, and water quality improvement. These functions underpin ecosystem services that benefit both human populations as well as sensitive coastal ecosystems (Ruiz-Frau et al. 2017). As a habitat-forming organism, eelgrass creates structural complexity absent in unvegetated sediments through a network of above ground shoots and below ground rhizomes. This matrix enhances productivity of epiphytes, microbes, and benthic infauna/epifauna while creating refuge and foraging habitat for juvenile fishes, benthic invertebrates, and migratory species, including anadromous fish and birds (Heck et al. 2003; Simenstad 1994, Cimon et al. 2021).

In addition to these biological benefits, eelgrass also baffles sediment from the water column and facilitates burial around its rhizomes, which results in increased coastal stability, improved water quality, and enhanced carbon sequestration. Eelgrass occupies hundreds of acres of shallow, soft-bottom coastal habitat in Southern California, though the exact extent is currently undefined (Sherman & DeBruyckere 2018). Eelgrass acreage and distribution vary ephemerally in response to both regional and local environmental conditions, including light availability, depth, and temperature (Cabello-Pasini et al. 2003).

Ecosystems supported by eelgrass face multiple stressors along the Southern California Bight, including pressure from coastal development, pollution, dredging, invasive species, human recreation, extractive industry, as well as broader pressures associated with climate change (Hughes et al. 2017, Cimon et al. 2021). One particularly thorny threat in the region is the ongoing infestations of *Caulerpa*, a genus of invasive macroalgae, which has been actively managed in Newport Bay and San Diego Bay, and is known to dampen ecosystem function of eelgrass (Anderson, 2005; SCCAT, 2021). The effects of stress from invasive species, or from any other stressor listed above, occur within environmental gradients shaped by geomorphology, hydrodynamics, and water quality (Blake & Duffy, 2016). Measuring and understanding eelgrass condition within this context, and how it responds to stressors, requires an approach that captures both the natural variability of the system as well as its response to stress.

Traditional bioassessment frameworks typically focus on organisms as a resource living in the target habitat (e.g., benthic fauna, nekton). However, certain types of organisms (i.e., habitat engineers) can also serve as a habitat for other organisms (e.g., seagrasses, kelp, shellfish reefs). Resource focused bioassessment frameworks typically use estimates of condition based on community measure(s) (species richness, abundance, health, or size) (Borja et al. 2008). As a habitat, which is how seagrass is generally viewed, estimates of condition are often based on areal or volumetric extent, or simple presence (De Clippele et al. 2017; Whitcraft et al. 2025; Blanch, 2025). However, eelgrass can function dually as both a biological resource and a habitat for other organisms; therefore limiting an assessment to only one approach may not fully capture its ecological role. To accommodate this duality, one can evaluate condition from the perspective of ecosystem functions that encompass both the resource and habitat aspects of an organism (Bernstein et al. 2011; McCune et al. 2020; Gillett et al. 2026). This type of bioassessment framework integrates multiple indicators into ecological condition and has given rise to a comprehensive assessment tool (Gillett et al. 2026).

Management and regulatory frameworks underscore the need for a comprehensive eelgrass assessment tool. The largest need stems from the California Eelgrass Mitigation Policy (CEMP), which mandates “no net loss” of ecological functioning and addresses this primarily through compensatory mitigation projects (NOAA National Marine Fisheries Service 2014). However, these mitigation projects are not currently supported by any tool that measures loss of function (Levrel et al. 2012). Secondarily, eelgrass is considered Essential Fish Habitat (EFH) under the Magnusen-Stevens Act and could be used as an indicator of designated beneficial uses (BU) under the California State Water Resources Control Board, including spawning (SPWN), estuarine habitat (EST), and wildlife habitat (WILD).

Both the EFH and BU frameworks prioritize the functioning of eelgrass, demonstrating the need for monitoring approaches that estimate condition based on function at relevant spatial scales. However, the repeated direct measurement and monitoring of ecosystem functions is not feasible at regional scales. A more reasonable alternative is to use structural and compositional metrics of eelgrass beds to approximate the different ecosystem functions eelgrass would be expected to provide (see McCune et al. 2020; Gillett et al. 2026).

Objectives

The 2023 Southern California Bight Regional Monitoring Program - ‘The Bight Program’ – SAV Survey represents an ongoing, coordinated effort to advance eelgrass monitoring and assessment across the whole of Southern California. Building on recommendations across scientific, regulatory, and management communities (Bernstein et al. 2011), we applied a regional monitoring framework designed to address key management questions related to eelgrass condition. We adopted a bioassessment approach (Gillett et al. 2018; McCune et al. 2020), which evaluates ecosystem functions based on their relationships with measurable structural attributes of eelgrass. We use the Zostera Ecosystem Function Reporter (ZEFR) developed in Gillett et al. 2026 to evaluate eelgrass condition using regional monitoring data. This study is the first large-scale deployment of this condition assessment approach, which is based on the distribution of *Zostera marina* structural metric data across a comparable biogeographic scale. Our goals for this survey focused on two central questions:

(1) What is the regional condition of eelgrass in the estuaries and embayments of the Southern California Bight?
(2) Are there differences in the patterns of overall condition and ecosystem functions between various estuary types in the region?

This baseline assessment of eelgrass condition and ecosystem function and how it varies across the region according to estuary type is the first step for managers to be able to measure changes and track progress of conservation/restoration action quantitatively.

II. METHODS

Study Design

We employed a probabilistic tessellated sampling design to provide robust statistical inferences from the sampled population of eelgrass to the true population of the region, (Stevens & Olsen 2003, 2004, Olsen & Peck 2008). The sample frame, from which sites were selected, represented approximately 55,000 acres of eelgrass in mainland embayments and estuaries from Point Conception, CA in the north to the US-Mexico border in the south. The GIS layer with the eelgrass basemap of Southern California can be accessed here: (https://sccwrp.maps.arcgis.com/apps/webappviewer/index.html?id=fbd66a9bc6174ad7a5cf90b3d5b9405c).

We constructed the sample frame from an aggregation of previously collected diver, side-scan, and drone imagery surveys of eelgrass beds across the region from 2015-2022 (Merkel and Associates, 2016; Merkel and Associates 2023). Information from summer 2022 targeted reconnoitering supplemented this initial basemap with information on smaller, under-sampled embayments and estuaries in the northern parts of the Southern California Bight (e.g., Hollister Ranch lagoon, Gaviota estuary, Refugio estuary). We surveyed these areas for the presence of eelgrass by paddling and snorkeling their waters, and recording the presence (or absence), and type of any SAV that was observed. We then digitized these observations into polygons for inclusion into the base map. Lastly, we amended the base map following consultations with local seagrass experts across the region. This process resulted in a single GIS layer of eelgrass extent and presence data from which sample sites could subsequently be selected.

To ensure the inclusion of waterbodies of different sizes and land uses in the random site selection process, we divided the sample frame into three strata prior to sample site selection (i.e., a stratified unequal design (e.g., Olsen & Peck 2008, Gillett et al. 2022). The strata were based upon environmental setting/typology (Doughty 2019) and adjusted as needed based upon the Bight SAV Committee members' experience with different systems. The three strata were defined to be:

- Large embayments (24 sampling locations) – Enclosed or semi-enclosed waterbodies greater than 8 km^2 in area that have a permanent connection to the open ocean (e.g. San Diego Bay, Lower Newport Bay).
- Small embayments (11 samplings location) – Enclosed or semi-enclosed waterbodies less than 8 km^2 in area that have permanent connections to the open ocean (e.g. Newport Back Bay, Marina del Ray).
- Estuaries (12 sampling locations) – Small enclosed waterbodies with a distinct connection to upland freshwater sources and permanently maintained (Anaheim Bay, Batiquitos Lagoon), or seasonal/ephemeral connection to the open ocean (San Elijo Lagoon).

We divided the sample frame into 500m^2 cells that each represented a potential sample site. Approximately ten sample sites were randomly selected without replacement from each stratum (47 in total) using the sample_strat function in the R package spSurvey (v5.5.1) (Dumelle et al. 2023). Additional sites were surveyed opportunistically once at least ten sites per strata were completed.

Given the ephemeral nature of eelgrass beds that expand and contract in extent from year to year, we identified 30 additional sites for each stratum to serve as replacement sites (i.e., overdraw sites) in case any of the initial 10 sample sites lacked vegetation in 2024. The Bight SAV Committee identified eleven additional sites of special interest according to management priorities, after the probabilistic sample draw (Figure 1). We surveyed and then assigned a stratum based on their respective waterbodies post-hoc for downstream analysis.

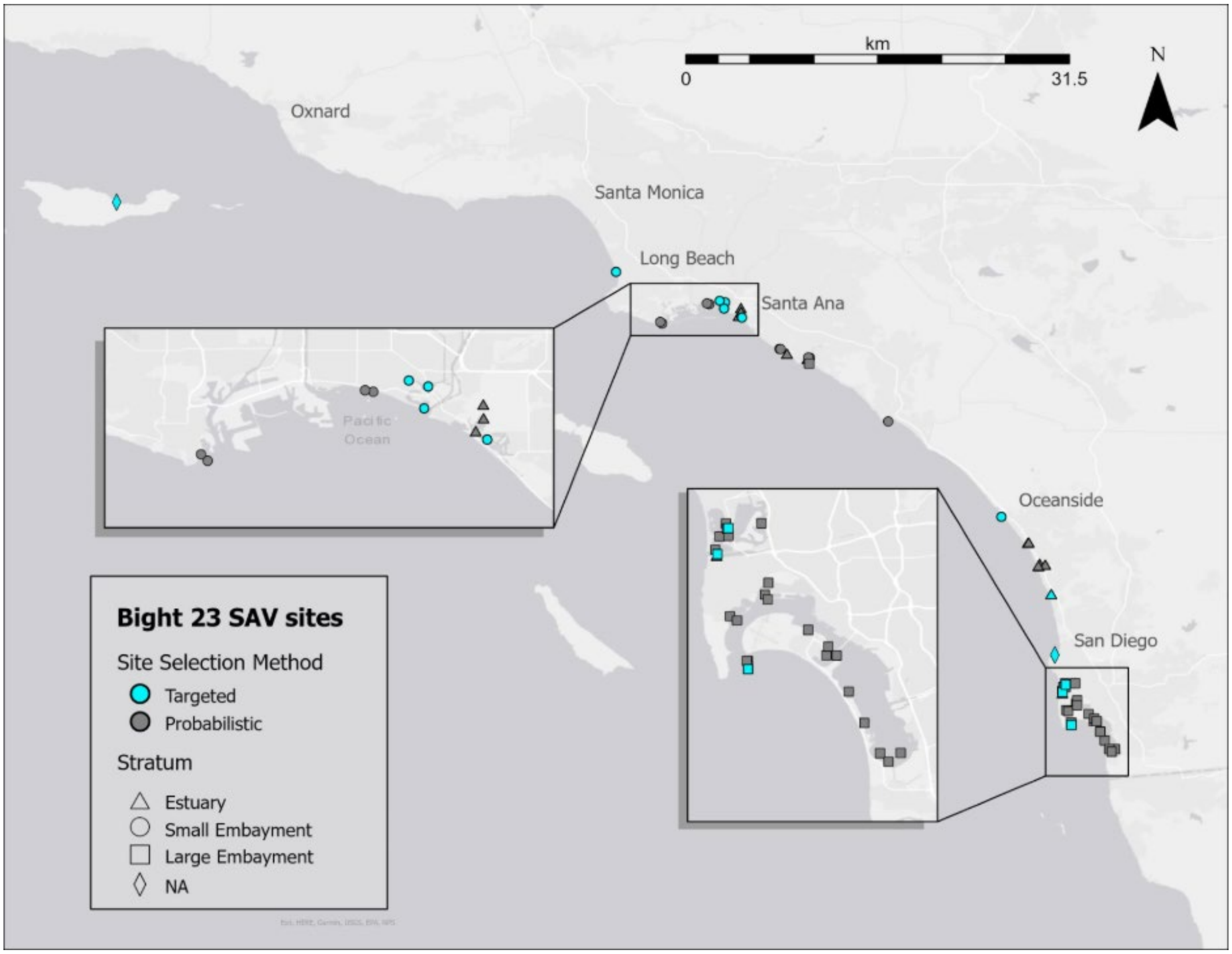

Figure 1. Map of sites, stratum, and site selection method across the Southern California Bight.

Field Collection of Structural Metrics

Teams of SCUBA divers recorded field measurements and collected material from the subtidal portions of eelgrass beds. Any intertidal portions of the eelgrass at a location were omitted from sampling. Field protocols for sampling and safety are fully detailed in McCune et al. (2020) and the Bight 2023 SAV Workplan. In brief, if seagrass was present at a site, divers measured the perimeter of the bed. For every ten eelgrass beds, dive teams chose a random bed for a second measurement, as a field replicate. When determining the extent of a given bed, plants were considered to be of the same bed if there was less than 3m of bare sediment between plants. To determine the transect and quadrat pattern, we classified the eelgrass at a sample site into one of four different bed types:

- Patch: a discrete aggregation of plants that is approximately 3m or less along its longest axis.

- Bed: a discrete aggregation of plants that is greater than 3m and less than 75m along its longest axis.
- Meadow: an expansive aggregation of plants that is greater than 75m along its longest axis and more than 20m along its shortest/shallow-to-deep axis.
- Fringing bed: a discrete aggregation of plants that is less than 3m along its shortest shallow-to-deep axis and less than 75m along its longest axis.

SCUBA divers laid transects across each bed according to bed type. For the Ideal bed, three transects (Inner, Mid, Outer) were laid along the longest axis, nominally parallel to the shoreline, and one transect (Cross) was laid from the shallow-to-deep axis of the bed (Figure 2A). The Inner and Outer transects were laid approximately 1m inside the closest edge of the bed. The Mid transect was laid directly across the middle, and to the degree possible, leaving approximately 3m between the Inner and Outer transects (Figure 2A). Divers placed the Cross transect to orthogonally bisect the three other transects.

The basic unit of sampling along the transects were 0.25 m^2 quadrats placed at equidistant points along each transect – 3 each along the Inner and Outer transects, 5 along the Mid transect, and 2 along the Cross transect. At each transect, divers visually estimated percent cover of eelgrass and percent floating macroalgae. Additionally, divers also recorded shoot density and flowering shoot density in each quadrat. Flowering shoots are defined here as those with distinct spathes (leaf structure enclosing flowers) present on their apical ends.

At the first, second, and third quadrats on the Mid transect and the two quadrats from the Cross transect, above and below ground eelgrass material was collected. To delineate plants to sample, a 10 cm diameter ring was placed in the center of each quadrat (Figure 2). All above ground (shoots, nodes, and epiphytes) and below ground (rhizomes and roots) material were collected within the footprint of the 10 cm ring. Below ground material was gently rinsed to remove excess sediment.

Adjustments to this method were made according to bed type. At patches, divers randomly placed two quadrats and collected cores from within both quadrats. Meadows received the same sampling scheme applied to Ideal beds were applied to Meadows, except that a perimeter was drawn within the bed with the approximate dimensions of an ideal bed (50m x 20m). Narrow beds were limited to two shoreline parallel transects and one Cross transect, and fringing beds were limited to one shoreline parallel transect and no Cross transect, as appropriate given the length of the shallow-to-deep axis of the bed. For further details, schematics, and SOPS, refer to the B23 SAV Workplan document.

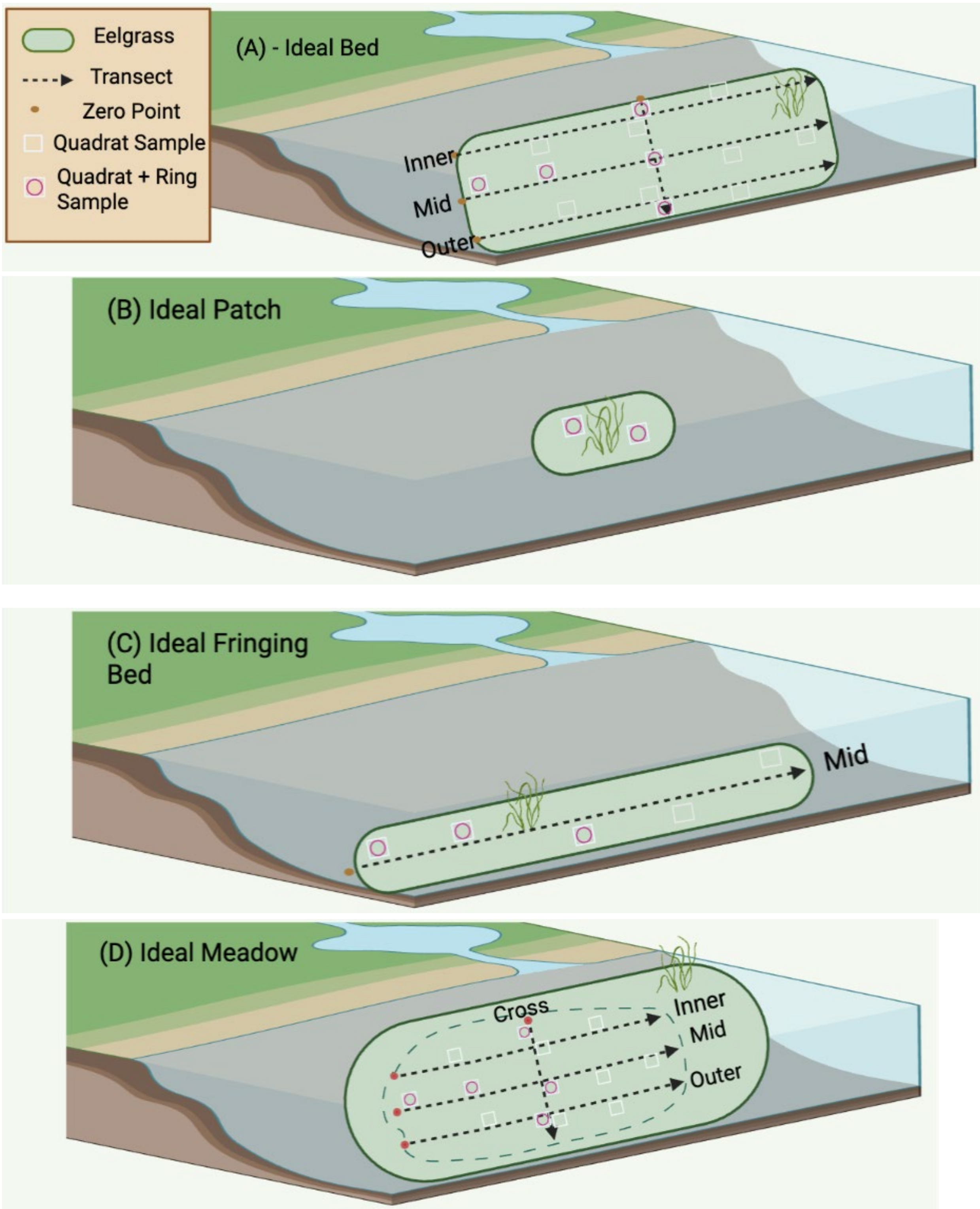

Figure 2. Schematic depicting the transect and quadrat sampling scheme for different growth forms of eelgrass: A. The Ideal Bed, B. The Ideal Patch, C. The Ideal Fringing Bed, and D. The Ideal Meadow. Any intertidal portions of given location were omitted from sampling.

Laboratory Measurement of Structural Metrics

Laboratory teams counted above ground shoots and leaves per each shoot for each ring-based sample. Epiphytic material was gently removed from each leaf with a scalpel or glass microscope slide and was pooled together for biomass measurement. Length of the of the longest leaf within each shoot was recorded as shoot height, and the width of that longest leaf was recorded as shoot width. The total area of all the leaves in each shoot was measured with a leaf area meter (LI-COR™ LI-3100C Area Meter) or a calibrated benchtop scanner and ImageJ image analysis software (https://imagej.net/ij/) and recorded as leaf area.

All epiphytic tissues, above ground eelgrass tissue, and below ground eelgrass tissue were blotted dry and measured for wet mass. Each type of tissue was then dried at 60°C for 48 hours and measured for dry mass. A subsample of approximately 2.5 - 3 mg was clipped from each dried tissue sample to measure TOC/TN. Dried samples were subsequently combusted at 500°C for 8 hours and measured for ash free dry mass. The mass of each TOC/TN subsample was multiplied by the ash:dry mass ratio to produce a corrected AFDM for each tissue type, to correct for the removal of tissue. Further details, including SOPs used in this study and proposed for future studies, can be found in the B23 SAV Workplan document.

Condition Assessment

Eelgrass condition was quantified using the framework outlined in McCune et al. (2020) (Figure 3) and the ZEFR assessment tool developed in Gillett et al. (2026). This approach to setting condition thresholds uses a regional population of eelgrass structural measures as a point of comparison for evaluating a given site. Structural measures from the probabilistic sites (30 sites) in this study alone were used to define the population distributions of each structural metric for *Zostera marina* (Figure 4).

In brief, individual eelgrass structural metric measurements (e.g. shoot height, shoot density, leaf area) were averaged within each site to create a metric value (Figure 4). The metric values for a given site were then binned relative to their position within the regional population (1 = lowest quartile, 4 = highest quartile). An arithmetic mean was performed from these quartile scores for structural metrics, following the conceptual models in Figure 3 for each of the seven ecosystem functions (Primary Production, Carbon Sequestration, Substrate Stabilization, Secondary Production, Nekton Habitat, Waterfowl Habitat, Water Quality) to produce Ecosystem Function scores for a given site. Ecosystem function scores (1-4) were then binned into four categories: Lowest Observed, Moderate, Good, Best Observed: scores 1.00 to 1.75 = Lowest Observed; scores 1.76 to 2.50 = Moderate; scores 2.51 to 3.25 = Good; scores 3.26 to 4 = Best Observed. The selection of four bins was based on the spread of regional data across the three strata. All seven ecosystem function scores were then averaged together for each site to produce an Overall Condition score, which was binned into the same four condition categories used for the Ecosystem Functions. Here, we present Overall Condition scores and Ecosystem Functions for each site surveyed as well as area-weighted by strata (embayment type). Detailed scores can be found in Appendix B.

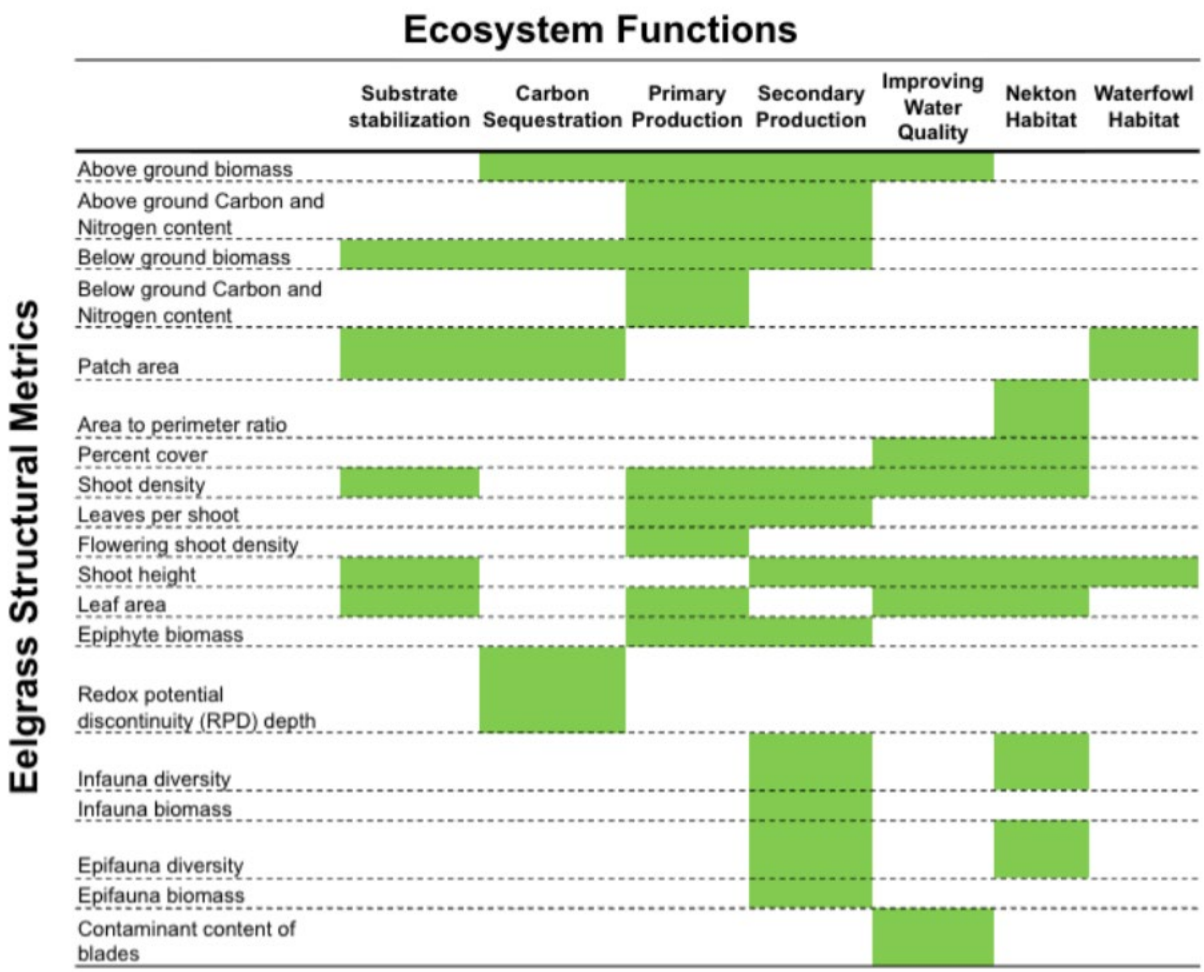

Figure 3. Conceptual model of relationships between structural metrics and ecosystem functions of seagrass (McCune et al. 2020).

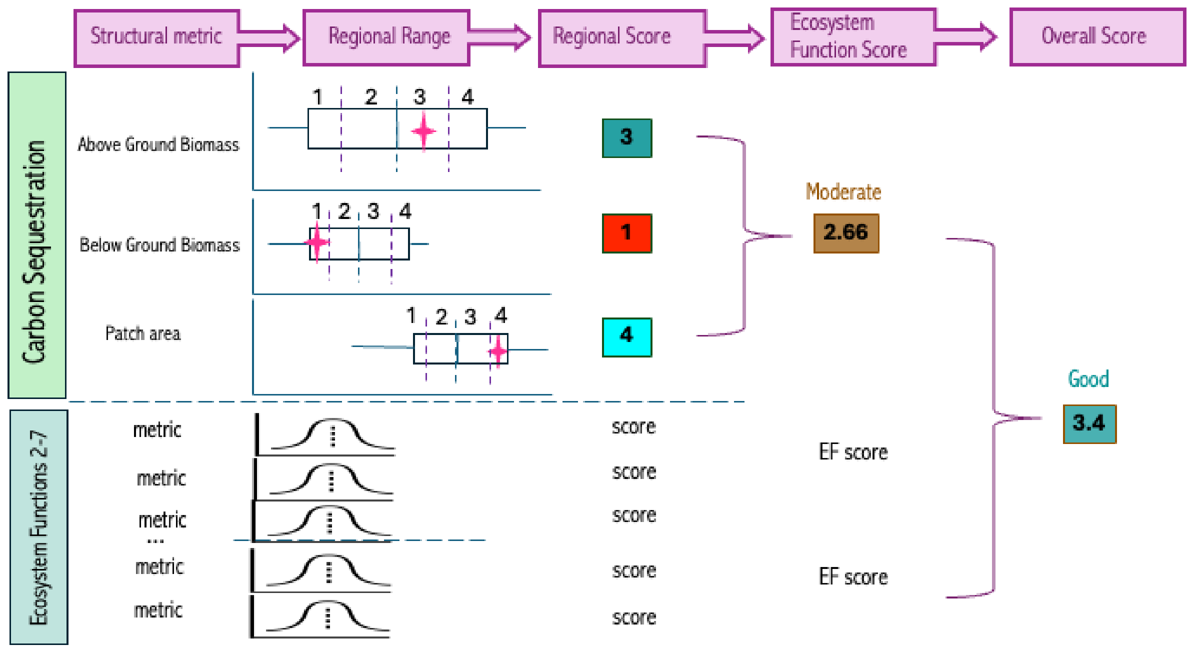

Figure 4. Schematic diagram of ZEFR scoring structure.

Statistical analyses of natural and stressor gradients

Area-weighted estimates of Overall Condition and seven Ecosystem Function Conditions were calculated using the cat_analysis() function in R 'spsurvey' package (Dumelle et al. 2023, v5.6.0). Area estimates and 95% confidence intervals were calculated for each stratum using strata-based area weights from sample draw information, and the Horvitz-Thompson estimator (Horvitz 1952). Targeted sites were excluded from the area-weighted estimates, as they were outside the probabilistic sampling design, but were retroactively assigned to a stratum based on their respective waterbody for downstream analysis of natural and stressor gradients.

Non-metric multidimensional scaling based on a Euclidean distance matrix of the seven individual function scores at each site using vegdist() and metaMDS() in R 'vegan' package (Oskanen et al 2022, v.2.7-2) were used to visualize site-to-site dissimilarity based on ecosystem function. Each column of the matrix held one of the seven ecosystem functions, and each row held the function scores at each site. Each site was plotted in two-dimensional space, with vectors for each function calculated based on envfit() from R 'vegan' package (Oskanen et al 2022, v.2.7-2). Ellipses that encompass 95% of sites (points) at each level (waterbody) were drawn using R 'ggplot2' package (v.4.0.2). Centroids were also plotted based on the mean NMDS1 and NDMS2 values for each waterbody.

Percent macroalgae cover measured at each site was used to evaluate the condition assessment tool's responsiveness to a direct stressor. The effect of average percent macroalgae (predictor) at each site on Overall Eelgrass Condition score (response variable) was evaluated using a simple linear regression.

Distance from nearest ocean inlet for each site was used as an integrative proxy variable to capture both anthropogenic upland influence (i.e., elevated water column nutrients, contaminants, and sediment concentrations) and reduced circulation (i.e., elevated water temperature, reduced dissolved oxygen, and more variable salinity) impacts to the eelgrass. *Zostera marina* has a salinity range of 10-25 ‰, and is known to be impacted by freshwater influence (Nejrup & Pedersen, 2008). Distance to inlet (km) was characterized "as the fish swims" using ArcGIS Pro (version 3.6.0). The effect of distance to inlet (predictor) on Overall Eelgrass Condition score (response variable) was evaluated using a simple linear regression. The effect was further evaluated by stratum. We hypothesized that locations closer to an ocean inlet would be less stressful to eelgrass due to more stable marine conditions (e.g., better water clarity, cooler, more saline water) than those located further inland within their embayment, subject to seasonal salinity anomaly, higher water residence times, and potentially higher pollution loads from upland influence.

We evaluated whether the protection status of a site (MPA vs. Non-MPA) had any influence on eelgrass condition or ecosystem function. While MPA status alone is not a good proxy for direct physical stress, it was a relevant aspect to explore, as it could help managers understand the impacts of MPA designation over time. We also considered the different levels of specific protections at each MPA to understand if actions that can minimize ecological stress (fishing, boating, anchoring) are reflected in site eelgrass condition. Site protection categories were determined by overlaying the site coordinates with California Department of Fish and Wildlife's Interactive MPA (Marine Protected Area) Map. Each eelgrass sample site was categorized, in decreasing level of protection, as either "No Take", "Limited Take" or "Unprotected", based on activities permitted in each MPA. A few remaining sites were categorized as "National Wildlife Refuge". The effect of protection status on Overall Eelgrass Condition scores was evaluated using pairwise comparisons (Mann-Whitney U). We hypothesized that the level of site protection may be reflected in the estimated eelgrass condition, either due to protections creating better conditions for eelgrass habitat, or eelgrass habitat in *a priori* good condition receiving protections, but that overall eelgrass condition would not vary based on nominal site protection status (MPA vs. Non-MPA).

Quality Assurance and Quality Control

The goal of the QA/QC effort was to ensure the degree to which the data generated by study participants was comparable and complete. Through quality control practices such as field intercalibration, field and lab resampling, and error tracking, we ensure high data quality for subsequent analyses. Each quality control practice is summarized in the subsections below. Full details can be found in the B23 SAV Workplan.

Evaluating Data Quality from New Methods

The 2023 survey was the first formal attempt to monitor the region's eelgrass beds in a cooperative manner between multiple agencies. It was the first application of the field, laboratory, and analytical methods co-developed by the Bight SAV Committee. Moreover, this type of quantitative bioassessment has not typically been done for eelgrass or other types of SAV. Consequently, there was very little data available to understand the expected methods/measurement error or from natural site to site variability. Therefore, there were no pre-existing data quality objective (DQO) targets to reference. The Bight SAV Committee and the field crews offered anecdotal insights into field and lab measurement variability at individual sites or waterbodies but not regionally.

Continuing to build out our dataset of eelgrass structural measures and condition assessment scores through regional surveys like the Bight Program or site-specific monitoring programs will allow for the development of DQO guidelines in the future. In the absence of numerical DQOs, post-survey debriefings were conducted with field and laboratory crews to better understand the potential sources of error in the dataset and get feedback on the methodology. Errors occurring through data entry, their sources, and their fixability were tracked and summarized in Appendix E.

Field

Before data collection in Fall 2024, a field intercalibration was hosted in April 2024 to ensure quality of visual data recorded and samples collected were consistent across participating field teams. Teams included CSULB, NOAA Fisheries, Merkel & Associates, LLC, Moss Landing Marine Lab, Paua Marine, and Marine Taxonomic Services LTD. As part of this exercise, teams of divers were asked to perform observational quadrat surveys (three transects, five points along each transect, two different beds). This included (1) recording percent cover of eelgrass and shoot count, and (2) recording water depth from a diver's computer. Results from each team and qualitative notes about diver confidence in methods were compared as a learning exercise. In addition to practicing field data collection, laboratory SOPs were also discussed and refined prior to official data collection.

Field replicates were included to represent 10% of the total number of beds. Duplicate visual surveys as well as above and below ground eelgrass collections were proposed at these points as a QA/QC measure. Due to time and tidal constraints, as well as diminished visibility after the first visual survey, only one true field replicate was taken. High quality field data was still anticipated given the reproducibility of data from the field intercalibration as well as the comparability of the one field replicate. Several concurrent field replicate measures were proposed in the original workplan but were not taken during this Bight Program cycle due to logistical or funding constraints.

Laboratory

The primary objective of laboratory quality assurance measures was to understand both reproducibility of data and sources of error. A target of 10% of observational measurements were re-measured in the lab and labeled as laboratory replicates. Re-measurement of these replicates included: shoot count, leaves per shoot, shoot height, shoot width, and leaf area. This resampling approach lays the foundation for future Data Quality Objectives for a more quantitative approach to quality assurance and control of data.

III. RESULTS

2024 Eelgrass condition assessment

Most of the surveyed eelgrass area within the Southern California Bight was classified in either Good Condition (40.41%) or Moderate Condition (36.99%) (Figure 5, Figure 6, Appendix Table B3). On either extreme, 13.49% of the area Bight-wide was in Lowest Observed Condition and 9.10% was in Best Available Condition. Overall eelgrass condition differed across strata, with 54.54% of area in the small embayment strata in Moderate Condition. The other two strata showed a different pattern, with 41.66% and 33.33% of area in the large embayment and estuary strata, respectively, classified in Good Condition. All strata had their smallest percentage (less than 20% area in all strata) of area in Best Available Condition. Estuaries had the largest area of any stratum (25.00%) in Lowest Observed Condition. Targeted sites with *Zostera marina* had comparable overall condition scores to probabilistic sites (Figure 7). Two out of the total 30 probabilistic sites, and eight out of the eleven targeted sites were not scorable since they were dominated by *Zostera pacifica* (Appendix Table A2). *Z. pacifica* is known to have a distinct morphology from *Z. marina* (Coyer et al, 2013). Consequently, the structural thresholds derived from *Z. marina* plants in the ZEFR index may not be applicable to *Z. pacifica* beds. As a precautionary measure, the *Z. pacifica* dominated sites were omitted from the condition assessment. A list of sites not scorable due to *Z. pacifica* can be found in Appendix A. A full site list with condition categories can be found in Appendix B.

Condition relative to ecosystem function

Beyond the assessment of overall condition, the ZEFR approach allows for the deconstruction of the overall condition score into different ecosystem function scores (Appendix Table B1). At the scale of the entire Bight, the largest amounts of eelgrass in Best Available Condition were from the Carbon Sequestration (28.80%) and Waterfowl Habitat (11.47%) perspectives (Figure 8). In contrast, Primary Production (0.67%) and Secondary Production (1.89%) had the lowest amounts in Best Available Condition (Figure 8). The Secondary Production (49.34%) function had the largest amount of area in Good Condition, while eelgrass at the regional scale was predominantly in Moderate Condition, relative to all other ecosystem functions.

Comparisons between targeted and probabilistic sites exhibited some differences across three of seven ecosystem functions. Carbon Sequestration, Secondary Production, and Substrate Stabilization scores were classified in Good Condition at targeted sites (medians = 3.5, 2.8, 2.75, respectively) and in Moderate Condition at probabilistic sites (medians = 2.5, 2.4, 2.5) (Figure 7). Nekton Habitat and Waterfowl Habitat medians were the same across both site types. All other functions had slight differences in median value but were classified in the same condition across both site types (Figure 7).

Across strata, five of seven ecosystem functions in small embayments had their greatest area classified in Moderate Condition, while Carbon Sequestration had the greatest area classified in Lowest Observed Condition, and Waterfowl Habitat had the greatest area in Good Condition (Figure 9). In large embayments, six of seven ecosystem functions had the greatest area classified in Moderate Condition. Secondary Production function had the greatest area classified in Good Condition (Figure 9). In estuaries, Secondary Production had the greatest area classified in Good Condition, whereas Carbon Sequestration and Substrate Stabilization had the most area in Lowest Observed Condition, and Waterfowl Habitat had equal amounts of area in either Moderate Condition or Best Observed condition, with no area in Lowest Observed Condition (Figure 9). Maps of each estimated ecosystem function across the Southern California Bight can be found in Appendix C. Tables of ecosystem function scores across strata and across the SCB can be found in Appendix B.

Non-metric multidimensional scaling showed separation of sites along the NMDS1 axis by overall condition category (Figure 10). Waterbodies with the majority of sites scoring in Lowest Observed or Moderate Overall Condition (Seal Beach NWR (Case Pond), Santa Ana River, and San Elijo Lagoon) were positioned to one side of the ordination (Figure 8, Figure DX). Waterbodies which had the most sites in with Best Observed or Good Overall Condition scores (Agua Hedionda Lagoon, Batiquitos Lagoon, Magnolia Marsh, Mission Bay, San Diego Bay [Zuniga Jetty], and Oceanside Harbor) were positioned on the opposite side of the ordination (Figure 10).

Substrate stabilization and Water Quality had the strongest negative associations with the NMDS1 axis (p-value < 0.001). Carbon Sequestration, Waterfowl Habitat, Nekton Habitat, and Primary and Secondary Production had the strongest associations with the NMDS2 axis (p-value < 0.001). Carbon sequestration had a positive association with NMDS2 axis and Nekton Habitat and Waterfowl Habitat ecosystem functions had a negative association with the NMDS2 axis.

Index responsiveness to potential stressors and natural gradients

Average percent macroalgae cover at each site had a negative, but not significant relationship with overall condition score. Lower overall scores were associated with higher percent macroalgae cover within the dataset, though sites with high percent macroalgae cover were underrepresented within the dataset. In contrast, neither central depth nor latitude had any significant linear relationship with overall eelgrass index score.

Distance-to-inlet had a significant (p = 0.0329) negative relationship with overall condition score. When stratified, only sites in large embayments demonstrated this trend of higher overall condition scores in areas closest to the inlet (Figure 11). Index scores in small embayments and estuaries did not change with distance to inlet. With only one site as an exception, large embayments had distances from inlet greater than 6 km, by nature of the size of the measured embayments.

Site protection status was considered at a nominal level of Protected vs. Unprotected based on site MPA status, and on a more specific level (No Take, Limited Take, National Wildlife Refuge, Unprotected). Wilcoxon rank-sum (Mann-Whitney U) test comparisons indicated no significant difference in Overall Condition between Unprotected and Protected areas . In addition, there were no observed differences in overall score with protection status across strata.

At the Ecosystem Function level, there were no observed differences at Protected sites versus Unprotected sites, when sites with any level of protection were defined as “Protected” . Unprotected sites had significantly higher estimated Substrate Stabilization and Secondary Production functions than NWR sites, when sites were defined at more specific regulatory levels (Appendix Figure D5). Data distribution across specific site protection status was uneven. Complete results for exploratory analyses can be found in Appendix D.

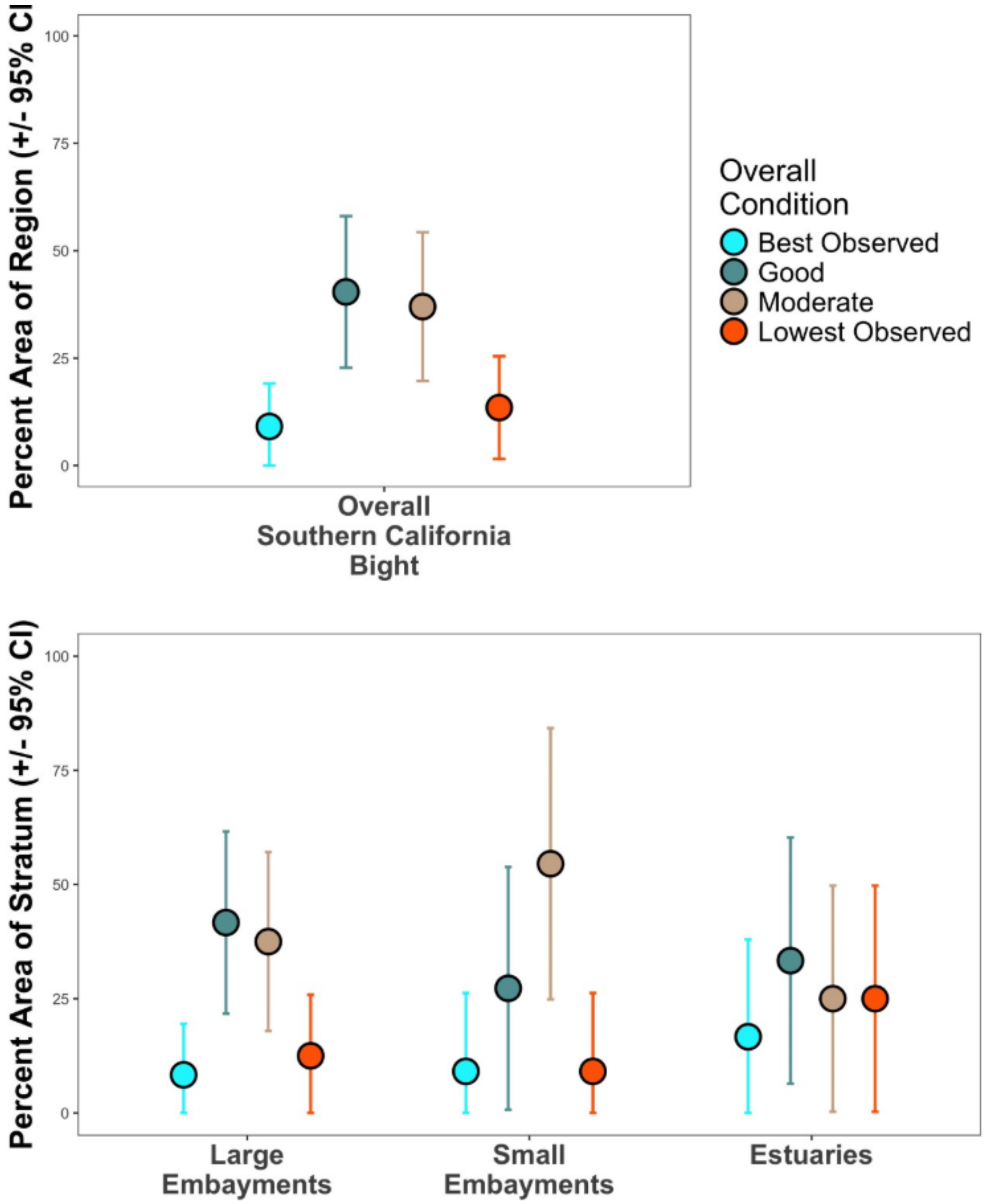

Figure 5. Percent area estimates (with 95% confidence intervals) of overall eelgrass condition score overall (top) and by stratum (bottom). The points represent area estimates derived using the Horvitz-Thompson estimator and the error bars represent the stratum-based confidence intervals.

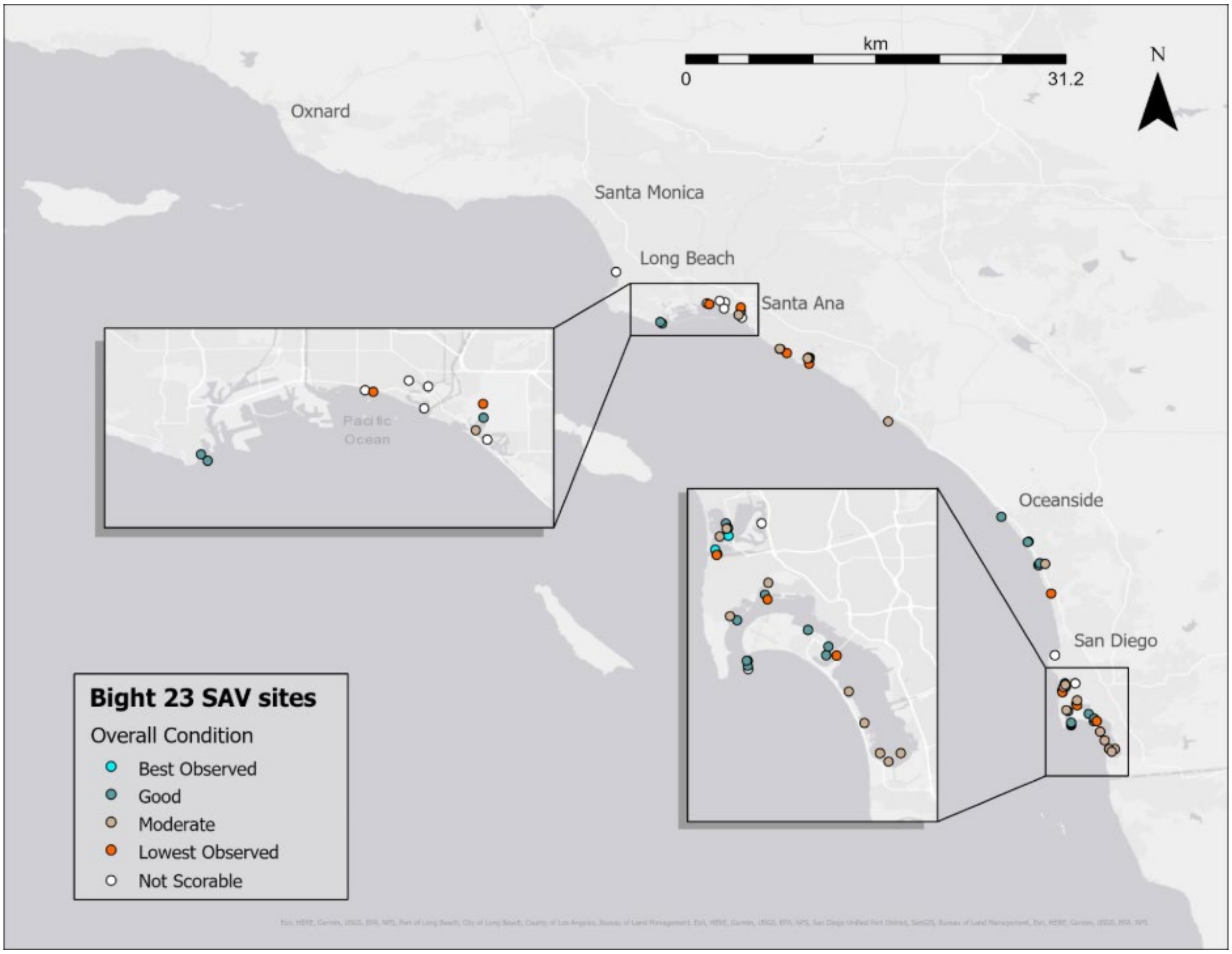

Figure 6. Geographic distribution of overall eelgrass condition throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

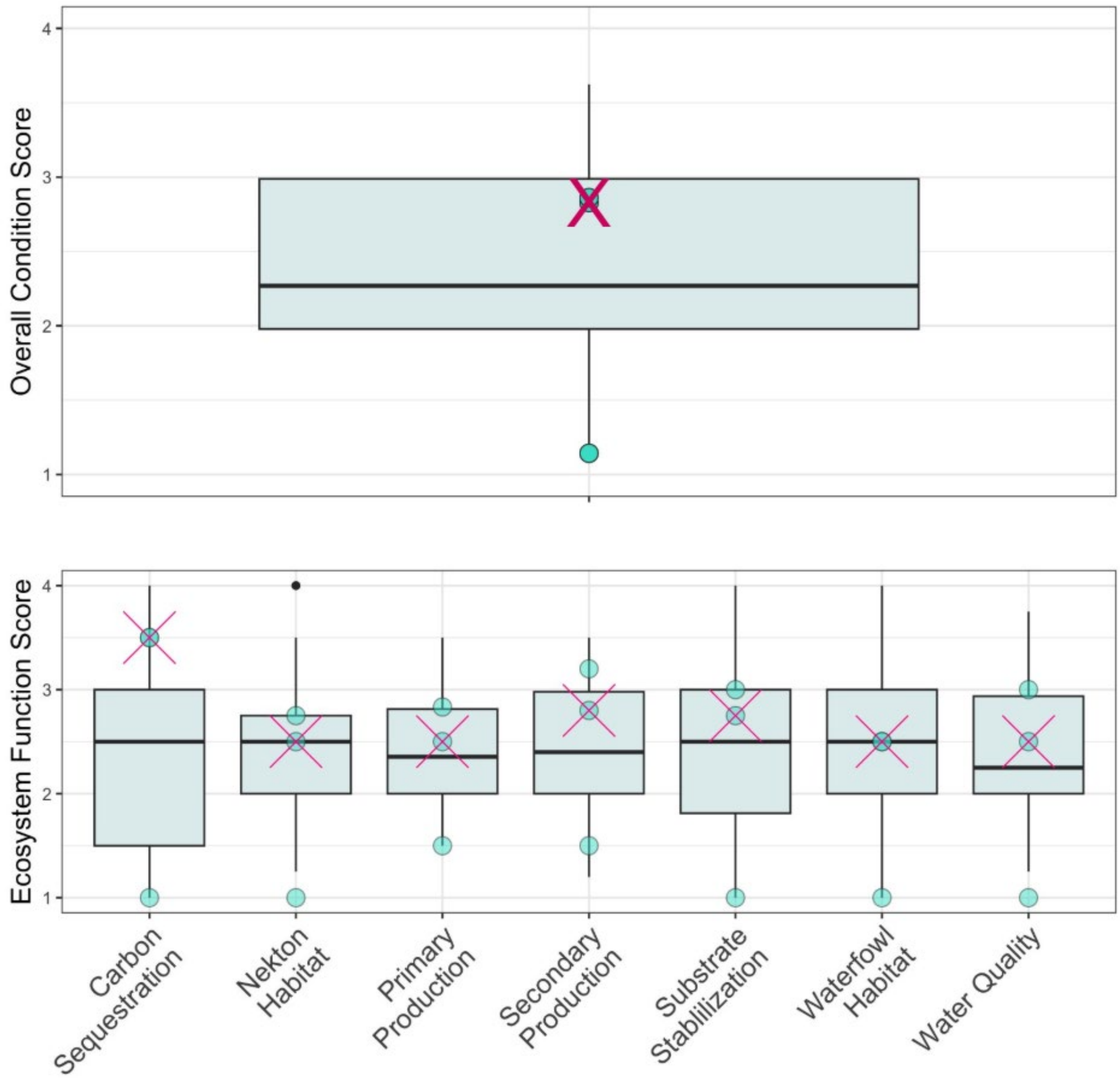

Figure 7. <u>Top</u>: Boxplots of probabilistic sites' overall condition scores, with targeted sites as points and the median of overall condition score of targeted sites as a pink mark. <u>Bottom</u>: Boxplots of probabilistic sites' ecosystem functions scores, with 11 targeted sites as points and the median of each ecosystem function score of targeted sites as a pink mark. The midline of each box represents the median score of probabilistic sites, the IQR is the 25th and 75th percentiles of score data, and the whiskers are 1.5 x IQR.

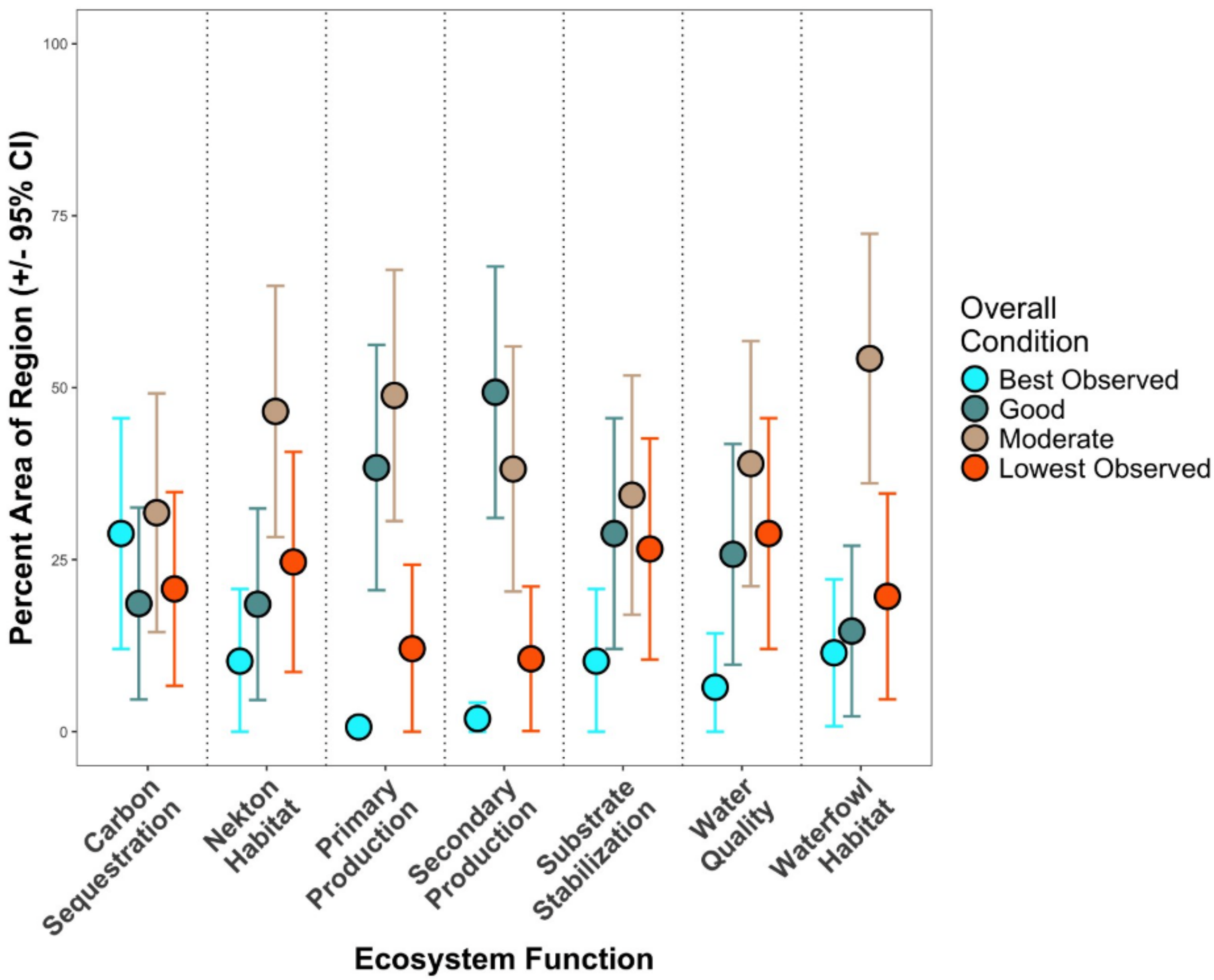

Figure 8. Percent area estimates (with 95% confidence intervals) of the seven ecosystem function scores in each of the four condition categories. Points represent the mean area estimates and error bars represent the 95% confidence intervals derived using the Horvitz-Thompson estimator.

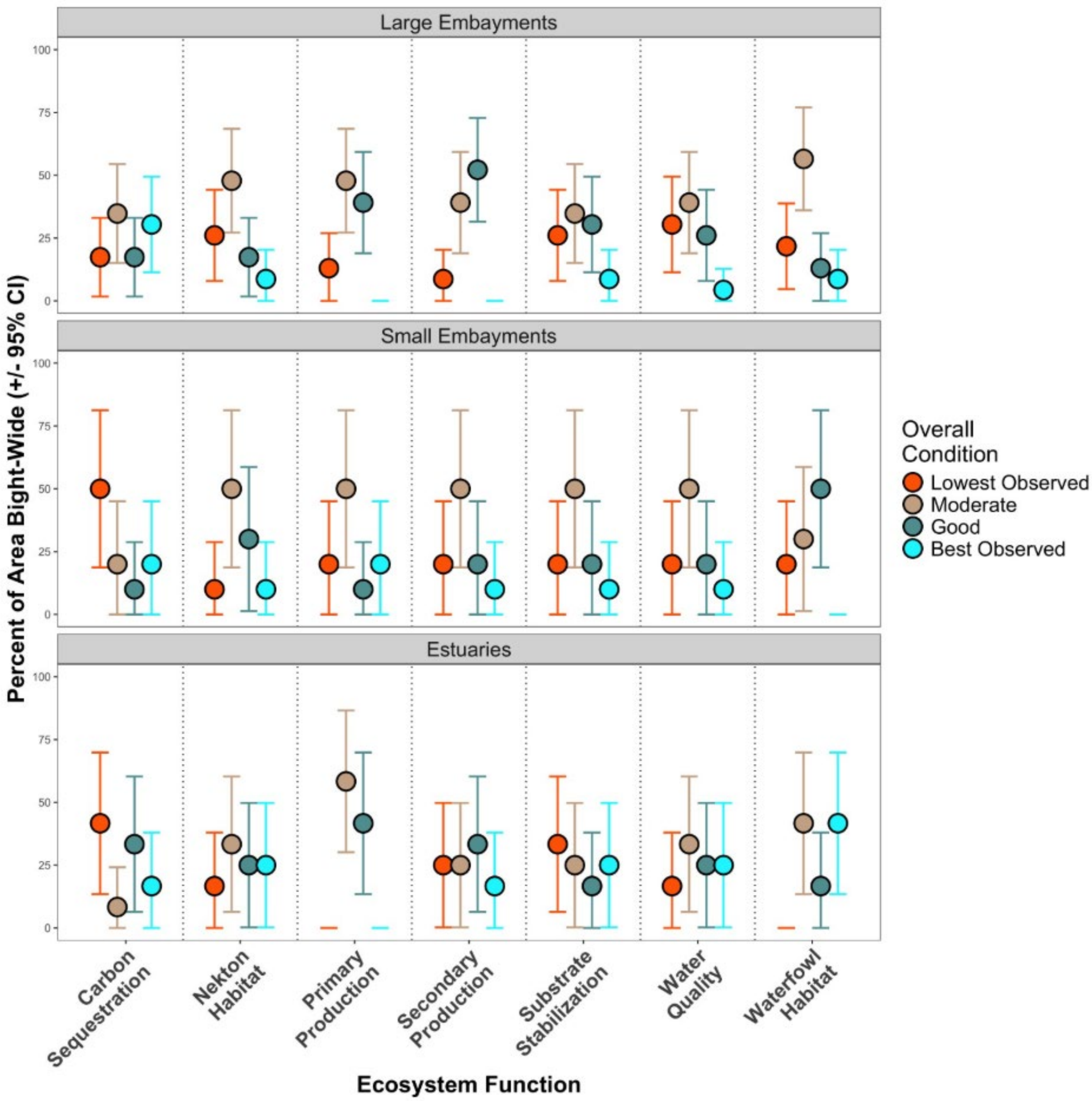

Figure 9. Percent area estimates (with 95% confidence intervals) of each of the seven ecosystem function scores in each of the four condition categories. Points represent area estimates derived from the Horvitz-Thomspon estimator and error bars represent stratum-based confidence intervals.

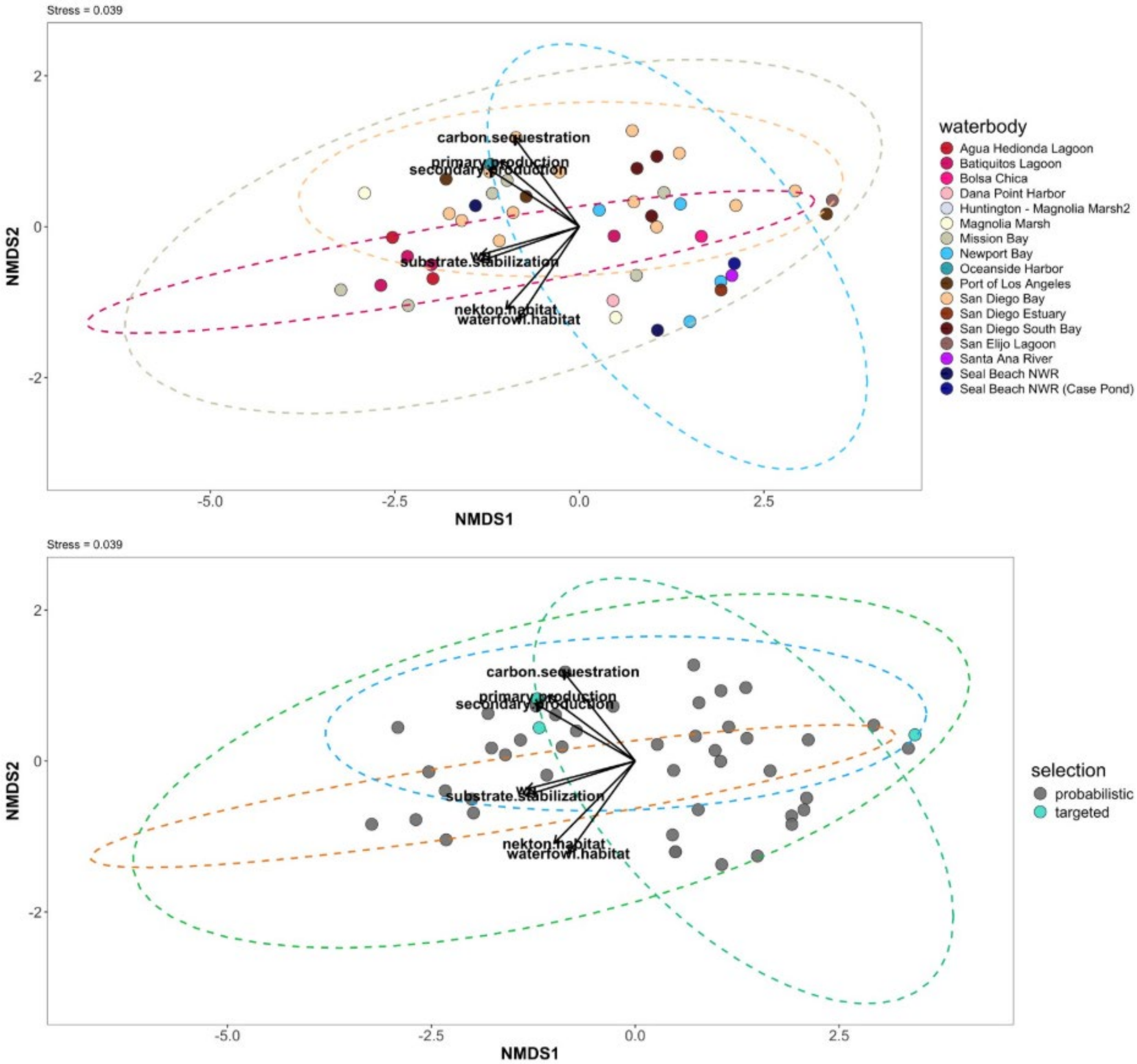

Figure 10. Two-dimensional non-metric multidimensional scaling (nMDS) ordination of ecosystem function scores at each site by (top) waterbody, and (bottom) site selection.

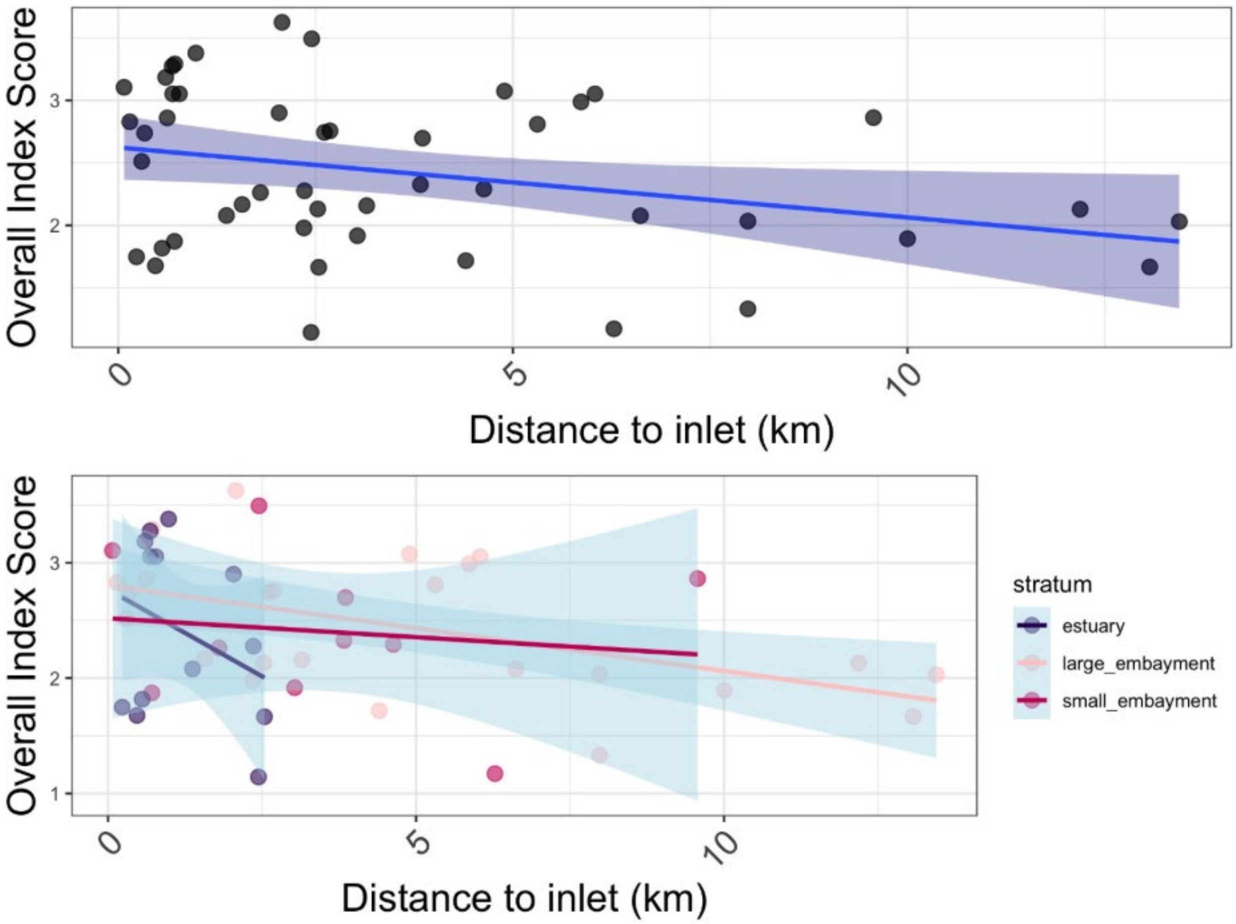

Figure 111. Overall eelgrass index scores with distance to inlet (km). (Top) All sites with a negative and significant (p = 0.0329) relationship (Overall Index Score = 2.62 - 0.056 *(Distance-to-inlet). (Bottom) All sites colored by strata. No significant relationships in linear regression models. Shaded areas represent 95% confidence intervals for each linear regression model.

IV. Discussion

Overall estimate of regional condition

This study represents the first regional-scale assessment of eelgrass condition in the Southern California Bight, as well as the first application of the ZEFR index developed in Gillett et al. 2026 for *Zostera marina*. From the perspective of the ecosystem functions that healthy and intact eelgrass beds should provide to their environment, eelgrass across the Southern California Bight region was predominantly classified in either Good or Moderate Condition, comprising over three-quarters of the total sample frame area of 55,000 acres of eelgrass. A smaller proportion of area was estimated at the extreme categories, with similar areal representation in Best Observed and Lowest Observed conditions. This finding represents an important baseline data point: the majority of eelgrass of the region is functioning reasonably well. This can now be the foundation for tracking changes moving forward through time and further refining the ZEFR tool. This baseline will also allow for the evaluation of management action, restoration effort, or the regional effects of disease, invasion, or extreme events.

In addition to providing a regional assessment, this survey effort established a suite of standard operating procedures supported by a scientific community of practice. Field intercalibration and subsequent data review improved data quality, consistency in practices, and identified key sources of error. This effort provides a foundation for future refinements of field and laboratory protocols, Data Quality Objectives, and the index itself (Appendix E). Future survey efforts can be supported by these refinements and lead to the generation of high-quality data that is comparable through time.

Estimating condition through ecosystem function

Estimating eelgrass condition from the perspective of individual ecosystem functions based on eelgrass structural metrics provides managers with direct means to link restoration and protection actions to desired ecological outcomes. The ZEFR tool facilitates this link by integrating the structural attributes of eelgrass associated with different ecosystem functions. This assessment approach is not designed to evaluate the extent and magnitude of ecosystem function for all components of the region (non-eelgrass vegetated sediment, unvegetated sediment, water column, or marsh). It is only designed to provide insight into the condition of observable eelgrass in a system.

For example, eelgrass condition from the perspective of Waterfowl Habitat ecosystem function supported in estuaries had the most area estimated in the Best Observed Condition. Waterfowl Habitat scores within estuaries are linked to higher shoot densities observed in those systems, in contrast to the other two strata. This observation is corroborated by a large body of estuarine literature, as well as a growing repository of citizen science data, emphasizing the importance of estuaries as bird habitat (Masto et al. 2025; Whitcraft et al. 2025). The alignment between the observed and previously reported relationship between shoot density and waterfowl habitat in estuaries suggests that the ZEFR tool accurately estimates condition based on this ecosystem function. Direct validation of Waterfowl Habitat, as well as the six other functions, remains a priority next step to include in future studies to increase confidence in the management applications of the ZEFR tool. In its current form, the ZEFR tool can provide relative estimates on condition both overall and through the lens of supported functions. However, it was not intended as a quantitative measure of any individual functions governed by complex rate processes, such as carbon sequestration.

By incorporating structural metrics of the individual plants and the bed as a whole, the ZEFR tool provides a more informative assessment of condition and insight into ecosystem functioning than approaches based on the presence or absence of SAV. Current methods that assess holistic estuary condition are based in the assumption that simple eelgrass presence equates to waterfowl habitat support. However, presence/absence does not account for the structural qualities of eelgrass that determine the level of ecosystem function provided (O'Connor et al. 2025). In contrast, our approach can narrow possible courses of management action to bolster lower scoring eelgrass beds to actions that are likely to impact the desired ecosystem function, such as creating conditions favorable for robust shoot density, which in turn, supports the Waterfowl Habitat ecosystem function. The nested, function-based framework enables both initial condition and condition from the perspective of individual ecosystem functions of eelgrass beds. It also allows for the tracking of functional outcomes through time following management action.

Patterns in ZEFR scores can be used to inform management actions for a given waterbody. However, low scores component scores may not always indicate ecological impairment of that function. In some cases, low component scores for a particular function or set of functions may simply reflect an environmental setting less conducive to that function. For example, eelgrass condition from the perspective of Carbon Sequestration had the lowest scores relative to other functions regionally, as well as in small embayments and estuaries. Low carbon sequestration scores, influenced by low above and/or belowground biomass measured within a bed, may be a result of the naturally dynamic conditions of a Southern California estuary or small embayment. This type of environmental setting can induce seasonally stressful conditions, such as low salinity events, concentration of pollutants, and associated high estuary residence times due to lack of connection to the sea (Munsch et al. 2023). Small embayments and estuaries also have a larger perimeter to area ratio than large embayments, which may concentrate stress associated with coastal development, which is ubiquitous along the Southern California coastline (Shelton et al. 2016; Mehinto et al. 2025). Surrounding land use, which changes with environmental setting, especially uses that alter hydrology and sediment flow adjacent to eelgrass beds, can have a profound impact on carbon sequestration in eelgrass (Watanabe & Kuwae, 2021). Only some of these land use characteristics are within management control, such as flood control, dredging, and artificial breaching, but many are reflective of the natural setting (seasonal mouth opening and/or natural freshwater inputs from streams and rivers). Condition expectations for eelgrass should be contextualized by stratum and also informed by the overall environmental setting.

Eelgrass beds, meadows, and patches are ephemeral structures, expanding and contracting at annual and multi-year scales. As such, the extent of eelgrass from year-to year in the region and within individual waterbodies will vary depending on local conditions. Because it is dependent upon the presence of eelgrass, the ZEFR index (or any eelgrass-specific bioassessment tool) cannot provide insight into the health of waterbodies where there is no eelgrass growing. The absence of eelgrass within embayments may indicate that small bodies of water with seasonal mouth openings can produce conditions that range from stressful to completely unsupportive of eelgrass. Extensive and frequent spatial mapping efforts are necessary to confirm this observation. Bioassessment approaches like SCCWRP's proposed Tier 1 eelgrass assessment tool (McCune et al. 2021) that compare eelgrass presence and extent relative to environmental expectations are required to help evaluate the health of unvegetated waterbodies. As an example, none of the northernmost estuaries of the Southern California Bight supported resident eelgrass during the period of data used to create our sample frame (2015-2022), so this survey cannot speak to the overall health or support of different ecosystem functions in that large portion of the region.

Managers interested in facilitating any specific ecosystem function, like carbon storage, within a given system should first consider whether the desired level of ecosystem functioning is achievable within the context of the system, which may be dependent upon the ability of eelgrass to grow within a system. Only then should they consider mitigation of stressors within that system that could be affecting long-term carbon storage within eelgrass. A similar logical order should follow for any given ecosystem function that could benefit from management intervention.

The California Eelgrass Mitigation Policy mandates "no net loss of ecosystem functioning of eelgrass," but historical survey efforts to evaluate whether this mandate has been upheld have focused on mapping acreage in the absence of any tool that enables a direct approach to assessing function (NOAA Fisheries, 2014; Merkel & Associates, 2024). One study, in which a multifunctionality index was developed to evaluate seagrass restoration success, found that that measuring seagrass structural metrics and ecosystem functions is important for understanding loss or gain of function (Beheshti et al. 2021). In this study, regionally low carbon sequestration scores in estuaries and small embayments demonstrate that while there may be a considerable areal extent of eelgrass present, which many practitioners may equate with a value judgement of 'good condition', all ecosystem functions may not be adequately supported. The present monitoring and assessment framework used in the Bight SAV Monitoring element is an improvement on previous strategies that assume a simple positive linear linkage between areal extent and ecosystem function.

This function-based approach also allows for the ecological phenomenon that at moderate level of disturbance, changes to ecosystem function are often not directional (positive, negative, or neutral) and do not affect each ecosystem function equitably (Gough et al. 2024). In the context of the current study, disturbance that reallocates resources (e.g. storms, fires within the watershed) may account for poor water quality and nekton support, but increased carbon burial from sediment flows, as long as the sediment is not enough to overwhelm and bury the eelgrass itself. For example, a few individual sites in San Diego Bay had estimated Carbon Sequestration in Best Observed condition, but Nekton and Waterfowl Habitat in Moderate Condition. Evaluating each function individually, separate from overall condition or areal extent, may be more habitat appropriate than other gradient-based index structures (Beheshti et al. 2022).

Index response to stressors and MPA status

One of the most salient regional threats to eelgrass is encroaching macroalgae, including native *Ulva* and invasive *Caulerpa*, that can overgrow and outcompete eelgrass. Accounts of macroalgae overgrowth have opened a regional management need to assess how eelgrass condition is affected by overgrowing macroalgae.

Future surveys should explicitly incorporate areas of *Caulerpa* infestation, to ensure that the ZEFR tool is responsive to this invasive threat to eelgrass. All species of *Caulerpa* appear on the top 100 worst invasive species list as well as the US Federal Noxious Weed List, due to its ability to rapidly spread and impair ecosystem functions and biodiversity (Waters et al. 2024). Eelgrass beds in South San Diego Bay, some of which have been treated for *Caulerpa* infestations since October 2023, were estimated in Lowest Observed to Moderate Condition. Beds in proximity to treatment areas scored notably lower in Nekton Habitat and Water Quality ecosystem functions, both of which may be affected by *Caulerpa* infestations. This is a conditional indication that the ZEFR tool may be responsive to legacy impacts of *Caulerpa* infestations, but future surveys are needed to increase certainty to a level that can be used by management to robustly assess impacts of *Caulerpa* infestation on eelgrass.

We can also use future eelgrass monitoring to answer more specific questions at the intersection of anthropogenic and natural factors that may impact eelgrass. Eelgrass beds within large embayments exhibit differences in condition based on their distance to the inlet, with higher scores estimated closer to the inlet of large embayments (Mission Bay, San Diego Bay). Distance to inlet is an indirect measurement of both pollution and natural differences in environmental stability. Beds closest to the inlet are further from upland sources of pollution and are under stable marine influence/low estuary residence times typically less stressful to eelgrass (stable salinity, low turbidity) (Shelton et al. 2016). Beds further from the inlet may be exposed more regularly to freshwater flows (natural), pollution (anthropogenic), confounded by higher water residence times. Since the ZEFR tool is sensitive to this gradient in large water bodies, it is important for a manager to consider that the expectation of eelgrass condition may not only change according to embayment type, but also by embayment size, as well as other related factors that influence hydrodynamics and local estuarine chemistry. More refined, spatially explicit measures of turbidity, chlorophyll a, temperature, etc. – like those available from remote sensing or data logger networks – would most likely facilitate teasing out the patterns in eelgrass condition relative to stressor exposure.

Considerations for future ZEFR users and index refinement/validation

This study is the first practical application of the ZEFR tool developed in Gillett et al. 2026 and characterizes the overall condition of eelgrass throughout the Southern California Bight. This tool was designed to allow management and regulatory communities to better understand eelgrass condition from the perspective of the ecosystem functions it provides (Bernstein et al. 2011, NOAA National Marine Fisheries Service 2014). By design, this prototype index benchmarks the condition of the eelgrass relative to distribution of structural metric magnitudes across the region. As we only have data from the Autumn of 2024 (Gillett et al 2026 and the present study), the assessment benchmarks (i.e., the 25th, 50th, or 75th percentiles of each structural metric) do not incorporate any meaningful inter-annual variability (e.g., Middelboe et al. 2003, Thom et al. 2003, Ward & Amundson 2019). As more eelgrass structural data are collected across the region, the associated benchmarks of condition may shift. As subsequent surveys of eelgrass across the region are conducted, the temporal breadth of the baseline data will increase and that temporal variability will be accounted for when creating assessment condition benchmarks. Once a broad enough spatial and temporal data set for each of the structural metrics is available, the condition benchmarks for each metric can be made more permanent. However, given the shifting baselines of associated with climate change and sea level rise, periodic recalibrations of the index may be required in the future.

The ZEFR tool is new within the region and is of interest to ecosystem managers in other parts of the state (Gillett et al. 2026). To be useful, a bioassessment index is one that is consistent across natural gradients but is responsive to stressor exposure (Strong et al. 2014; Mazor et al. 2016). Patterns in the present survey indicated that the index remained insensitive to some natural gradients and was seemingly responsive to some measures of stress. We evaluated estimated eelgrass condition as it relates to a natural gradient (water depth), a somewhat direct stressor (macroalgae), a mixed (natural and anthropogenic) driver of condition (distance to inlet) and a management relevant designation (protection status). While this observed insensitivity to one natural gradient in this study is encouraging, a more directed evaluation of ZEFR response to both stressor and natural gradients that may influence eelgrass is needed.

The ZEFR tool does not require calibration across depth in future monitoring efforts and can be applied to *Zostera marina* beds across a shallow subtidal (< 30 ft) depth range. Water depth at the center of a given bed did not show any significant relationship with condition, nor any individual ecosystem function, suggesting that the index is not influenced by depth along the observed range of 0.8m - 10.4m. Across the whole of the Pacific coast, irradiance, water temperature, and population genetics (among other natural factors) vary. Differences in these underlying seasonal and physiological parameters will likely lead to different expectations of normal structural dimensions (i.e., shoot height, leaf area, and biomass) of a healthy eelgrass plant along its natural geographic range, irrespective of any additional limitations caused by exposure to stress (Hughes et al. 2009, Duffy et al. 2022). ZEFR would require recalibration at depths > 30 ft as well as in other geographies associated with different structural dimensions of *Zostera marina*.

While the ZEFR tool provides an estimation of overall condition and ecosystem function of eelgrass, it is not “out-of-the-box" ready for application to other species of SAV. The established structural metric distributions are based strictly on subtidal *Zostera marina* within embayments of the Southern California Bight and would need to be adapted for other species. For example, beds dominated by *Zostera pacifica*, *Ruppia maritima,* or mixed species beds should not be evaluated using this tool without caution and potential modification. Different species of SAV will have different growth forms (e.g., *R. maritima*) or morphology (e.g., *Z. pacifica*) relative to *Z. marina*. Similarly, the intertidal portions of monocultural *Z. marina* beds will potentially have different growth rates that will impact the structural dimensions of the plants (e.g., Cabello-Pasini et al. 2003; Jarvis et al. 2012; Clausen et al. 2014) and therefore how the index would evaluate them.

The relative proportion of subtidal to intertidal portions of an eelgrass bed will shift moving northward from the Southern California Bight, with a greater proportion of eelgrass becoming intertidal (Sherman & DeBruyckere 2018). The ZEFR structure-function approach to assessment is still valid in predominantly intertidal eelgrass. However, the shift in microhabitat will most likely impact the morphology of the plants (in addition to any latitudinal variability), which will necessitate the use of a newer, more habitat/regionally appropriate calibration dataset to benchmark the scoring of each structural metric. While we found no relationship between condition scores and latitude within the Southern California Bight region, we caution any practitioner using the tool at broader or different geographies outside of California without recalibrating and using an adequately large SAV structural dataset.

Echoing McCune et al. (2021), validation exercises linking the combinations of structural metrics to measures of ecosystem function (e.g., Blanch 2025) need to be conducted; ideally in concert with future eelgrass assessment studies. These types of focused studies can be used to validate the conceptual models and, as needed, refine the combination of structural metrics in each model or the shape of the model (i.e., direct, inverse, unimodal) to most accurately reflect ecosystem functioning of eelgrass.

V. CONCLUSIONS

The Bight '23 SAV monitoring survey provided a regional bioassessment of eelgrass condition throughout the Southern California Bight:

- **This was the first regional application of the Zostera Ecosystem Function Reporter (ZEFR) bioassessment tool**

The ZEFR is a prototype tool developed in the Regional Eelgrass Survey of Condition and Quality in 2026 that uses structural metrics to infer seven ecosystem function and estimate eelgrass condition. We piloted this tool using a stratified probabilistic sampling approach across a 55,000 acre sample frame of available eelgrass presence data extending from Point Conception to the US-Mexico border. A total of 59 eelgrass beds across this region were scored for overall condition and ecosystem function using an area-weighted approach based on strata (embayment type). Results from this study represent a potential approach for assessing eelgrass condition across the region. Prior to widespread adoption of this approach, the structural metrics used to estimate individual ecosystem functions must be validated across the three embayment types included in this study. Our condition estimates represent a regional baseline of eelgrass condition across the Southern California Bight.

- **The majority of the region's embayment eelgrass was in either Good or Moderate Condition**

At the scale of the entire Bight, 40% of the eelgrass area captured in the sample frame was in Good Condition and 37% was in Moderate Condition. In contrast, less area was estimated in the extreme categories. Approximately 13% was in Lowest Observed Condition and 9% was in Best Observed Condition.

- **The distribution of the four condition categories was unequal across the different strata (embayment type).**

Eelgrass from the large embayment and estuary strata were in relatively better condition than eelgrass from the small embayment stratum. Approximately 64% of the eelgrass from the small embayment strata were in the bottom two condition categories. In contrast, the eelgrass from the large embayment and estuaries strata had less than 50% area estimated within the bottom two condition categories. These condition estimates suggest that baseline expectations for eelgrass are not consistent across these three embayment types.

- **At the regional scale, the majority of eelgrass within the sampling frame was in Moderate Condition from the perspective of the component eelgrass ecosystem function condition scores.**

A feature of the ZEFR assessment approach is that the condition of eelgrass can be assessed in total or from the perspective of key ecosystem functions associated with eelgrass. The majority (31.82% - 54.25%) of eelgrass area scored in Moderate Condition for six out of the seven ecosystem functions evaluated (Carbon Sequestration, Nekton Habitat, Substrate Stabilization, Water Quality, and Waterfowl Habitat). Eelgrass beds evaluated was in the best condition (49.34% in Good Condition) from the perspective of supporting Secondary Production. Interestingly, from the perspective of Carbon Sequestration, eelgrass condition varied evenly among the four condition categories

VI. RECOMMENDATIONS

Based on the results of this study, the Bight ’23 SAV Committee recommends that future eelgrass survey, studies, and applications to validate the ZEFR tool be prioritized based on short-term needs and long-term goals of regional eelgrass assessment.

Short term priority needs:

- **Validate conceptual models linking eelgrass structural measures to ecosystem function**

The underpinnings of the ZEFR condition assessment framework are a series of conceptual models linking different structural measures of eelgrass plants and beds to key ecosystem functions eelgrass is expected to support in coastal embayments. These models were the product of consensus-based expert opinion of an 8-member panel and relationships from the SAV literature. While providing a sound foundation, it was always intended that these relationships would be validated and improved as needed, with direct, experimental studies linking eelgrass structure to each of the functions. Ideally, these validations should encompass eelgrass from the region or in California and span all embayment types. Recent efforts have begun this process with the Nekton Habitat conceptual model and similar efforts should follow for the six remaining function models. Given the coastal management and general public interest in blue carbon and other climate amelioration concepts, particular emphasis and priority should be focused on validating the Carbon Sequestration model.

- **Implement routine spatial inventories of eelgrass to support future condition monitoring**

The spatial extent and distribution of eelgrass beds, patches, and meadows can vary through time. As such, keeping an up to date and accurate inventory of eelgrass throughout the region is a difficult, yet keenly important first step in conducting bioassessment surveys like this one. The present study used the best available historical (2015-2022) mapping efforts combined with targeted reconnaissance efforts, but this only allowed a focus on eelgrass in embayments due to a paucity of available spatial extent data in the mainland and Channel Islands coastal waters. Routine mapping of eelgrass and other SAV species is necessary to support any future assessment surveys. These efforts will likely necessitate incorporation of far-field (satellite and fixed wing aircraft) near-field (arial drone and sonar) remote sensing technologies as echoed in the California Ocean Protection Council's recent priorities for wetland mapping (SFEI & SCCWRP, 2025).

Long-term goals:

- **Incorporate trend analysis components into future condition surveys**

The current study represents an important initial baseline estimate for eelgrass throughout the SCB in 2024. While the insights we can draw from this survey are valuable, they are limited in utility because they are based on a single year of data and have not been validated through *in situ* studies across embayment types. Future surveys using a validated ZEFR tool within the Bight Regional Monitoring program or other similar efforts will allow for a regional assessment of eelgrass condition on a recurring basis for trend analysis. Furthermore, adding a consistent site revisit component into future surveys would support trend analysis and expand geographic scope.

- **Investigate eelgrass response to various stressors and management protections**

Future surveys should consider the inclusion of targeted sites that are exposed to a range of stressors, including human use (boating, recreation, land use) or infestation by invasive species such as *Caulerpa*. Surveys should also consider inclusion of sites that will provide insights of how management interventions impact eelgrass condition and function, including different levels of site protection (No Take and Limited Take MPAs, California 30x30 designations) and/or levels of restoration (natural vs. restored beds).

- **Create a crosswalk of condition assessment results and management priorities**

The California Eelgrass Mitigation Policy (CEMP) mandates "no net loss" of eelgrass ecosystem functioning. The ZEFR assessment framework focuses on the condition of eelgrass from the perspective of supporting ecosystem functioning, but it was not explicitly designed to interface with the CEMP goals. Developing a consensus application and interpretation of results between the regulatory agencies, academics, restoration practitioners and managers will only improve the utility of the tool as a way to assess site-specific conditions and regional eelgrass status. Furthermore, it may help to sure eelgrass mitigation is fulfilled.

VII. Literature Cited

Anderson, L.W.J. California's Reaction to Caulerpa Taxifolia: A Model for Invasive Species Rapid Response*. *Biol Invasions* 2005, *7* (6), 1003–1016. https://doi.org/10.1007/s10530-004-3123-z.

Bernstein, B., K. Merkel, B. Chesney, M. Sutula. 2011. Recommendations for a Southern California Regional Eelgrass Monitoring Program - SCCWRP Technical Report 632. Costa Mesa, CA.

Blake, R.E.; J.E. Duffy. Influence of Environmental Stressors and Grazer Immigration on Ecosystem Properties of an Experimental Eelgrass Community. *Journal of Experimental Marine Biology and Ecology* 2016, *480*, 45–53. https://doi.org/10.1016/j.jembe.2016.03.007.

Blanch, C. 2025. Correlates of fish abundance and community composition in eelgrass beds in Southern California (Masters Thesis). California State University Long Beach.

Cabello-Pasini, A., R. Muniz-Salazar, D.H. Ward. 2003. Annual variations of biomass and photosynthesis in Zostera marina at its southern end of distribution in the North Pacific. Aquat Bot 76: 31−47

Cimon, S.; A. Deslauriers, M. Cusson. 2021. Multiple Stressors and Disturbance Effects on Eelgrass and Epifaunal Macroinvertebrate Assemblage Structure. *Mar. Ecol. Prog. Ser. 657*, 93–108. https://doi.org/10.3354/meps13546.

Clausen, K., D. Krause-Jensen, B. Olesen, N. Marbà. 2014. Seasonality of Eelgrass Biomass across Gradients in Temperature and Latitude. *Mar. Ecol. Prog. Ser. 506*, 71–85. https://doi.org/10.3354/meps10800.

Coyer, J. A., G. Hoarau, J. Kuo, A. Tronholm, J. Veldsink, J.L. Olsen. 2013. Phylogeny and temporal divergence of the seagrass family Zosteraceae using one nuclear and three chloroplast loci. *Systematics and Biodiversity*, *11*(3), 271–284. https://doi.org/10.1080/14772000.2013.821187

Doughty, C.L., K.C. Cavanaugh, R.F. Ambrose, E.D. Stein. 2019. Evaluating regional resiliency of coastal wetlands to sea level rise through hypsometry-based modeling. Glob Chang Biol 25:78–92.

Dumelle, M., T. Kincaid, A.R. Olsen, M. Weber. 2023. spsurvey: Spatial Sampling Design and Analysis in R. Journal of Statistical Software, 105(3), 1-29. doi:10.18637/jss.v105.i03

Friess, D.A., Z.I. Shribman, M. Stankovic, N. Iram, M.M. Baustian, C.J. Ewers Lewis. 2024. Restoring Blue Carbon Ecosystems. *Camb. prisms Coast. futures 2*, e9. https://doi.org/10.1017/cft.2024.9.

Gillett, D.J., K. McCune, E.D. Stein. 2018. Development of a Monitoring and Assessment Framework for Submerged Aquatic Vegetation (SAV) Technical Report #1 – Monitoring and Assessment Framework. 13p. Southern California Coastal Water Research Project, Costa Mesa, CA.

Gleason, M., E. Fox, S. Ashcraft, J. Vasques, E. Whiteman, P. Serpa, E. Saarman, M. Caldwell, A. Frimodig, M. Miller-Henson, J. Kirlin, B. Ota, E. Pope, M. Weber, K. Wiseman. 2013. Designing a Network of Marine Protected Areas in California: Achievements, Costs, Lessons Learned, and Challenges Ahead. *Ocean & Coastal Management 74*, 90–101. https://doi.org/10.1016/j.ocecoaman.2012.08.013

Hansen, J., M. Reidenbach. 2012. Wave and Tidally Driven Flows in Eelgrass Beds and Their Effect on Sediment Suspension. *Mar. Ecol. Prog. Ser. 448*, 271–287. https://doi.org/10.3354/meps09225.

Heck, K.L. Jr., G. Hays, R.J. Orth. 2003. Critical evaluation of the nursery role hypothesis for seagrass meadows. Mar Ecol Prog Ser 253:123−136

Herrera-Silveira, J.A., E.B. Palafox-Juárez, J.E. Mendoza-Martínez, J.L. Montero Muñoz, C. Teutli Hernández. 2025. Landscape configuration in seagrass meadows and its influence on carbon stock in reef lagoon systems. Front. Mar. Sci. 11:1320194. doi: 10.3389/fmars.2024.1320194

Hughes, B.B., S.C. Lummis, S.C. Anderson, K.J. Kroeker. 2018. Unexpected Resilience of a Seagrass System Exposed to Global Stressors. *Global Change Biology 24* (1), 224–234. https://doi.org/10.1111/gcb.13854

Jarvis, J.C., K.A. Moore, W.J. Kenworthy. 2012. Characterization and ecological implication of eelgrass life history strategies near the species’ southern limit in the western North Atlantic. Mar Ecol Prog Ser 444: 43−56

Levrel, H., S. Pioch, R. Spieler. 2012. Compensatory mitigation in marine ecosystems: Which indicators for assessing the “no net loss” goal of ecosystem services and ecological functions?. Marine Policy, 36(6), 1202-1210.

Masto, N.M., K.D. Dunham, M.G. Brasher, K.M. Ringelman, J.M. Osborn, B. Avers, T. Bidrowski, M. Ervin, O.E. Jones, B.W. Loges, D. McClain, W.A. Phelps, R. Vanausdall, J.D. Lancaster, O.J. Robinson. 2025. Citizen Science Generates Reliable Migration Chronologies to Supplement

Professional Surveys for Waterfowl Habitat Management. *Ornithological Applications 127* (3), duaf030. https://doi.org/10.1093/ornithapp/duaf030.

Mazor, R.D., A.C. Rehn, P.R. Ode, M. Engeln, K.C. Schiff, E.D. Stein, D.J. Gillett, D.B. Herbst, C.P. Hawkins. 2016. Bioassessment in Complex Environments: Designing an Index for Consistent Meaning in Different Settings. *Freshwater Science 35* (1), 249–271. https://doi.org/10.1086/684130.

Mehinto, A., D. Greenstein, K. Schiff. 2025. Southern California Bight 2023 Regional Monitoring Program: Volume I. Sediment Toxicity Technical Report 1433. Costa Mesa, CA.

Merkel & Associates Inc. 2014a. 2014 San Diego Bay Eelgrass Inventory.

Merkel & Associates Inc. 2014b. Southern California Bight Regional Eelgrass Surveys.

Merkel & Associates Inc. 2024. 2023 San Diego Bay Eelgrass Inventory Update. San Diego, CA. NOAA/ National Marine Fisheries Service West Coast Region Protected Resources Division, San Diego, CA.

Nejrup, L.B., M.F. Pedersen. 2008. Effects of salinity and water temperature on the ecological performance of Zostera marina. Aquat Bot 88: 239−246. https://doi.org/10.1016/j.aquabot.2007.10.006

NOAA National Marine Fisheries Service. 2014. California Eelgrass Mitigation Policy and Implementing Guidelines.

Mtwana Nordlund, L., E.W. Koch, E.B. Barbier, J.C. Creed. 2016. Seagrass Ecosystem Services and Their Variability across Genera and Geographical Regions. *PLoS ONE 11* (10), e0163091. https://doi.org/10.1371/journal.pone.0163091

O’Connor, K., B. Fulkerson, J. Walker, E. Stein, C.R. Whitcraft, J. Huckeba. 2025. Estuary Marine Protected Area Fall 2023 Data Analysis Report Technical Report 1430. Costa Mesa, CA.

Oksanen, J., G. Simpson, F. Blanchet, R. Kindt, P. Legendre, P. Minchin, R. O'Hara, P. Solymos, M. Stevens, E. Szoecs, H. Wagner, M. Barbour, M. Bedward, B. Bolker, D. Borcard, T. Borman, G. Carvalho, M. Chirico, M. DeCaceres, S. Durand, H. Evangelista, R. FitzJohn, M. Friendly, B. Furneaux, G. Hannigan, M. Hill, L. Lahti, C. Martino, D. McGlinn, M. Ouellette, E. Ribeiro Cunha, T. Smith, A. Stier, C. Ter Braak, J. Weedon. 2025. vegan: Community Ecology Package. doi:10.32614/CRAN.package.vegan

Olsen, A.R., D.V. Peck. 2008. Survey design and extent estimates for the Wadeable Streams Assessment. J North Am Benthol Soc 27:822–836.

Ruiz-Frau, A., S. Gelcich, I.E. Hendriks, C.M. Duarte, N. Marbà. 2017. Current State of Seagrass Ecosystem Services: Research and Policy Integration. *Ocean & Coastal Management 149*, 107–115. https://doi.org/10.1016/j.ocecoaman.2017.10.004.

San Francisco Estuary Institute (SFEI) and Southern California Coastal Water Research Project (SCCWRP). 2025. Tracking Coastal Habitat Change Over Time: Considerations for a Statewide Mapping Program. SFEI Publication No. 1246. SCCWRP Publication No. 1438. Richmond, CA. April 2025, pp. 76. Produced for California Ocean Protection Council (OPC).

Shelton, A.O., T.B. Francis, B.E. Feist, G.D. Williams, A. Lindquist, P.S. Levin. 2017. Forty Years of Seagrass Population Stability and Resilience in an Urbanizing Estuary. *Journal of Ecology 105* (2), 458–470. https://doi.org/10.1111/1365-2745.12682.

Sherman, K., L.A. DeBruyckere. 2018. Eelgrass Habitats on the U.S. West Coast. State of the Knowledge of Eelgrass Ecosystem Services and Eelgrass Extent. A publication prepared by the Pacific Marine and Estuarine Fish Habitat Partnership. 67.

Simenstad, C.A. 1994. Faunal Association and Ecological Interactions in Seagrass Communities of the Pacific Northwest Coast. 11-18 in: S. Wyllie-Echeverria, Olso AM, and Hershman J (eds), Seagrass Science and Policy in the Pacific Northwest. EPA 910/R-94-004. Environmental Protection Agency. Seattle, WA.

Stevens, D.L., A.R. Olsen. 2004. Spatially Balanced Sampling of Natural Resources. J Am Stat Assoc 99:262–278.

Stevens, D.L., A.R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics 14:593–610.

Strong, J.A., E. Andonegi, K.C. Bizsel, R. Danovaro, M. Elliott, A. Franco, E. Garces, S. Little, K. Mazik, S. Moncheva, N. Papadopoulou, J. Patrício, A.M. Queirós, C. Smith, K. Stefanova, O. Solaun. 2015. Marine Biodiversity and Ecosystem Function Relationships: The Potential for Practical Monitoring Applications. *Estuarine, Coastal and Shelf Science 161*, 46–64. https://doi.org/10.1016/j.ecss.2015.04.008.

USEPA. 1971. Method 160.2, Residue, Non-Filterable (Gravimetric, Dried at 103-105°C). U.S. Environmental Protection Agency, Washington, D.C.

Watanabe, K., T. Kuwae. 2021. An unintended ecological benefit from human intervention: The enhancement of carbon storage in seagrass meadows. *Journal of Applied Ecology*, 58, 2441–2452. https://doi.org/10.1111/1365-2664.13977

Welschmeyer, N.A. Fluorometric analysis of chlorophyll *a* in the presence of chlorophyll *b* and pheopigments. Limnol Oceanogr. 1994;39: 1985–1992.

Whiftcraft, C., E. Stein, J. Walker, B. Spies, R. Dagit, R. Ambrose, K. Johnston, J. Tupitza, A. Le Compte Santiago. 2025. Santa Monica Bay National Estuary Program State of the Bay Technical Chapter: Coastal Wetlands. Southern California Coastal Water Research Project. Technical Report 1460. Costa Mesa, CA.

APPENDIX A – SAMPLING DETAILS AND EELGRASS STRUCTURAL METRICS

Table A1. List of sites within each waterbody, stratum, site protection status, and site selection method.

.	Masterid	Stratum	Site protection status	Site selection
Agua Hedionda Lagoon	904AHT001	estuary	U	probabilistic
Batiquitos Lagoon	904BLT001	estuary	U	probabilistic
Mission Bay	906MBECSR	large_embayment	U	probabilistic
Mission Bay	906MBMCSC	large_embayment	U	probabilistic
Mission Bay	906MBVCSA	large_embayment	U	probabilistic
Mission Bay	906MBVINC	large_embayment	U	probabilistic
Mission Bay	906MBVIYP	large_embayment	U	probabilistic
San Diego Bay	910ZNJN01	large_embayment	U	probabilistic
San Diego Bay	910ZNJN02	large_embayment	U	probabilistic
San Diego Bay	912SDBCPB	large_embayment	U	probabilistic
San Diego Bay	912SDBSLB	large_embayment	U	probabilistic
San Diego Bay	912SDCBVP	large_embayment	U	probabilistic
San Diego Bay	912SDNOST	large_embayment	U	probabilistic
San Diego Bay	912SDSBPO	large_embayment	NWR	probabilistic
San Diego Bay	912SDSIWB	large_embayment	U	probabilistic
San Diego Bay	912SDSSSC	large_embayment	U	probabilistic
San Diego Bay	912SDT001	large_embayment	U	probabilistic
San Diego Bay	912SDT003	large_embayment	U	probabilistic
Santa Ana River	B23-SAV-001	estuary	U	probabilistic
Batiquitos Lagoon	B23-SAV-002	estuary	U	probabilistic
Seal Beach NWR (Case Pond)	B23-SAV-005	estuary	NWR	probabilistic
Seal Beach NWR	B23-SAV-006	estuary	NWR	probabilistic
Batiquitos Lagoon	B23-SAV-007	estuary	No Take	probabilistic
Agua Hedionda Lagoon	B23-SAV-008	estuary	U	probabilistic
Seal Beach NWR	B23-SAV-009	estuary	NWR	probabilistic
Port of Los Angeles	B23-SAV-011	small_embayment	U	probabilistic
Huntington - Magnolia Marsh2	B23-SAV-012	small_embayment	U	probabilistic
Magnolia Marsh	B23-SAV-012	small_embayment	U	probabilistic
Newport Bay	B23-SAV-014	small_embayment	Limited Take	probabilistic
Port of Los Angeles	B23-SAV-015	small_embayment	U	probabilistic
Newport Bay	B23-SAV-018	small_embayment	Limited Take	probabilistic

Port of Los Angeles	B23-SAV-020	small_embayment	U	probabilistic
San Diego South Bay	B23-SAV-022	large_embayment	U	probabilistic
San Diego Bay	B23-SAV-023	large_embayment	NWR	probabilistic
Newport Bay	B23-SAV-025	large_embayment	U	probabilistic
San Diego Bay	B23-SAV-026	large_embayment	U	probabilistic
San Diego South Bay	B23-SAV-027	large_embayment	NWR	probabilistic
San Diego Bay	B23-SAV-029	large_embayment	U	probabilistic
San Diego South Bay	B23-SAV-030	large_embayment	U	probabilistic
Newport Bay	B23-SAV-031	small_embayment	U	probabilistic
Bolsa Chica	B23-SAV-032	estuary	Limited Take	probabilistic
Batiquitos Lagoon	B23-SAV-035	estuary	U	probabilistic
San Diego Estuary	B23-SAV-036	estuary	U	probabilistic
Magnolia Marsh	B23-SAV-063	small_embayment	U	probabilistic
Port of Los Angeles	B23-SAV-064	small_embayment	U	probabilistic
Dana Point Harbor	B23-SAV-066	small_embayment	U	probabilistic
Mission Bay	B23-SAV-092	large_embayment	U	probabilistic
Alamitos Bay	B23-SAV-901	small_embayment	U	targeted
Alamitos Bay	B23-SAV-902	small_embayment	U	targeted
Alamitos Bay	B23-SAV-903	small_embayment	U	targeted
Alamitos Bay	B23-SAV-904	small_embayment	U	targeted
San Diego Bay (Zuniga Jetty)	B23-SAV-905	large_embayment	U	targeted
Mission Bay	B23-SAV-906	large_embayment	U	targeted
San Elijo Lagoon	B23-SAV-907	estuary	No Take	targeted
Mission Bay	B23-SAV-908	large_embayment	U	targeted
King Harbor	B23-SAV-909	small_embayment	U	targeted
Oceanside Harbor	B23-SAV-910	small_embayment	U	targeted
La Jolla Cove	B23-SAV-991	NA	No Take	targeted
Prisoner's Harbor	SantaCruzIsland	NA	U	targeted
Santa Cruz Island	B23-SAV-Santa Cruz Island	NA	targeted	

Table A2. Sites not scorable due to dominance of *Zostera pacifica*.

masterid	stratum	waterbody	selection
B23-SAV-064	small_embayment	Port of Los Angeles	probabilistic
B23-SAV-092	large_embayment	Mission Bay	probabilistic
B23-SAV-901	small_embayment	Alamitos Bay	targeted
B23-SAV-902	small_embayment	Alamitos Bay	targeted
B23-SAV-903	small_embayment	Alamitos Bay	targeted
B23-SAV-904	small_embayment	Alamitos Bay	targeted
B23-SAV-905	large_embayment	San Diego Bay (Zuniga Jetty)	targeted
B23-SAV-906	large_embayment	Mission Bay	targeted
B23-SAV-909	small_embayment	King Harbor	targeted
B23-SAV-991	NA	La Jolla Cove	targeted

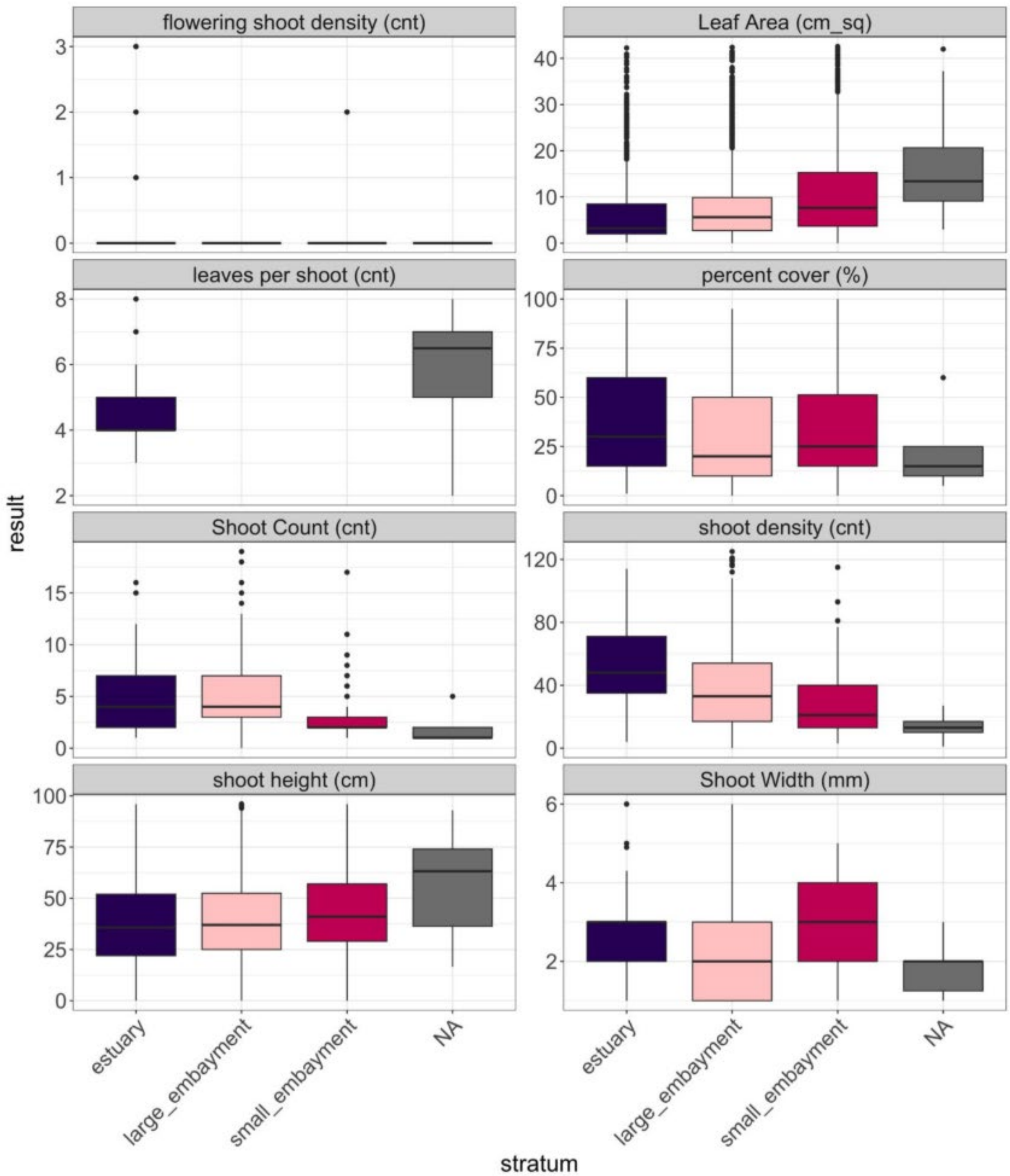

Figure A1. Eelgrass structural metric data by stratum – part 1.

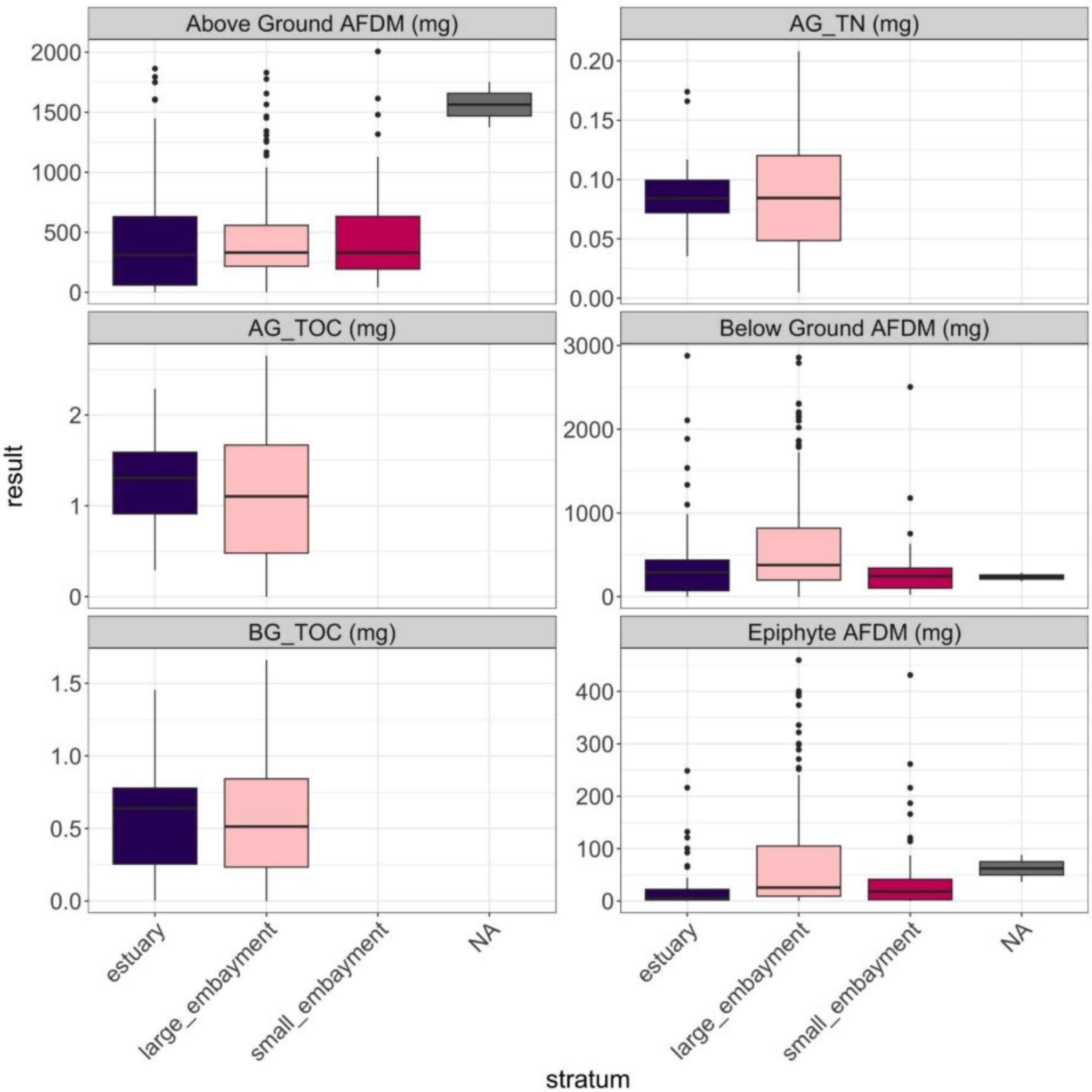

Figure A2. Eelgrass structural metric data by stratum – part 2.

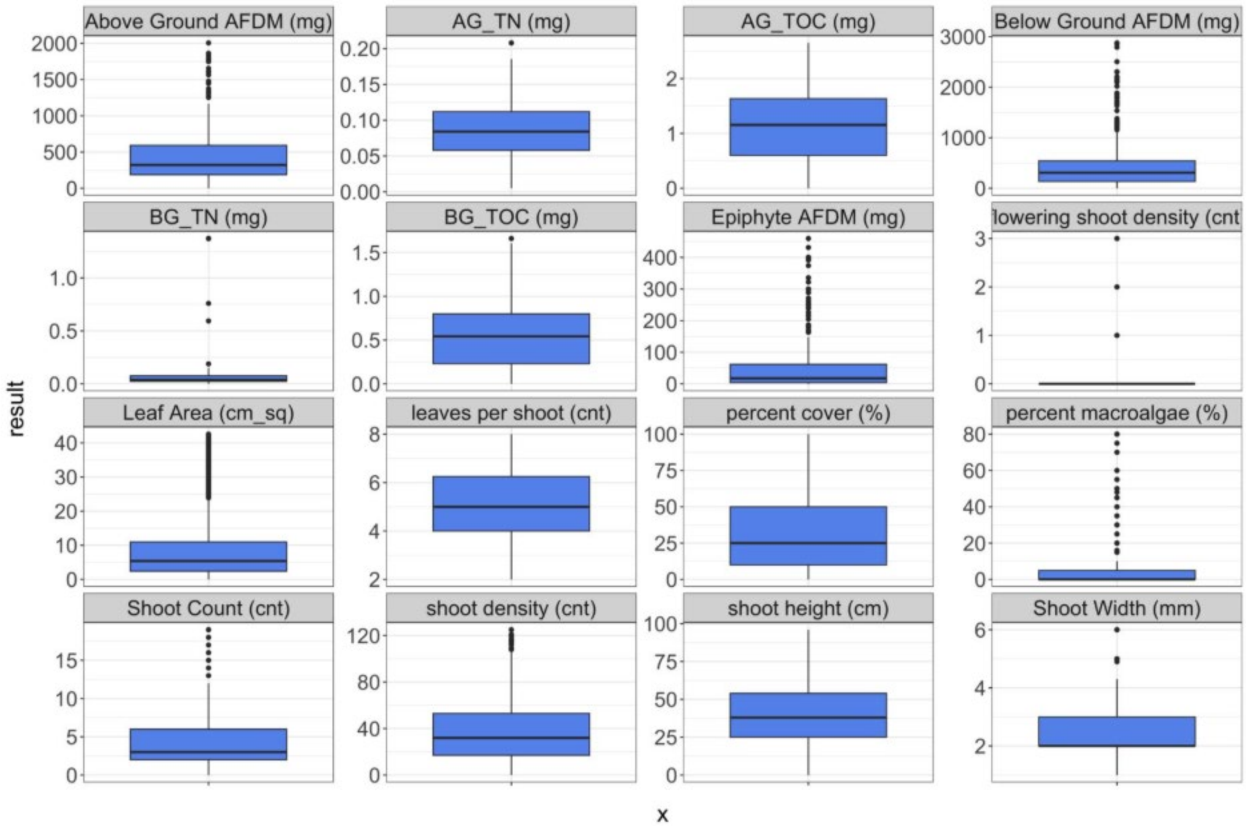

Figure A3. Eelgrass structural metrics from the Southern California Bight in 2023-2024. The midline of each box represents the median value for each structural metric. The upper and lower bounds of the box represent the interquartile range (IQR, 25^th^ and 75% percentiles of data), Whiskers are 1.5 x IQR for each metric, and anything outside that range is plotted as an outlier point.

APPENDIX B – EELGRASS INDEX AND FUNCTION SCORES

Table B1. Site by site ecosystem function scores and overall eelgrass condition scores.

stratum	waterbody	masterid	Overall Score	Condition Category	Substrate Stabilization	Carbon Sequestration	Primary Production	Secondary Production	Water Quality	Nekton Habitat	Waterfowl Habitat
estuary	Agua Hedionda Lagoon	B23-SAV-008	3.38	best observed	3.25 - Good	3.5 - Best Observed	3 - Good	3.4 - Best Observed	3.5 - Best Observed	3.5 - Best Observed	3.5 - Best Observed
	Agua Hedionda Lagoon	904AHT001	3.05	good	3.75 - Best Observed	3 - Good	2.88 - Good	3.17 - Good	2.75 - Good	3.25 - Good	3.5 - Best Observed
	Batiquitos Lagoon	B23-SAV-035	3.27	best observed	3 - Good	3 - Good	3.17 - Good	3 - Good	3.75 - Best Observed	3.5 - Best Observed	3.5 - Best Observed
	Batiquitos Lagoon	904BLT001	3.05	good	3.5 - Best Observed	3 - Good	3.13 - Good	3.5 - Best Observed	3.5 - Best Observed	3.5 - Best Observed	4 - Best Observed
	Batiquitos Lagoon	B23-SAV-002	3.18	good	3.5 - Best Observed	3 - Good	2.88 - Good	2.92 - Good	3.25 - Good	3.25 - Good	3.5 - Best Observed
	Batiquitos Lagoon	B23-SAV-007	2.28	moderate	2.33 - Moderate	2 - Moderate	2.5 - Moderate	2.1 - Moderate	2.5 - Moderate	2.5 - Moderate	2 - Moderate
	Bolsa Chica	B23-SAV-032	1.82	moderate	1.75 - Lowest Observed	1.5 - Lowest Observed	2.17 - Moderate	1.7 - Moderate	1.75 - Lowest Observed	1.75 - Lowest Observed	2 - Moderate
	San Diego Estuary	B23-SAV-036	1.75	lowest observed	1.5 - Lowest Observed	1 - Lowest Observed	1.83 - Moderate	1.4 - Lowest Observed	2.25 - Moderate	2.25 - Moderate	2 - Moderate
	San Elijo Lagoon	B23-SAV-907	1.14	lowest observed	1 - Lowest Observed	1 - Lowest Observed	1.5 - Lowest Observed	1.5 - Lowest Observed	1 - Lowest Observed	1 - Lowest Observed	1 - Lowest Observed
	Santa Ana River	B23-SAV-001	1.68	lowest observed	1.5 - Lowest Observed	1 - Lowest Observed	1.83 - Moderate	1.4 - Lowest Observed	2 - Moderate	2 - Moderate	2 - Moderate
	Seal Beach NWR	B23-SAV-009	2.90	good	2.5 - Moderate	3.5 - Best Observed	2.5 - Moderate	2.8 - Good	3.25 - Good	2.75 - Good	3 - Good
	Seal Beach NWR	B23-SAV-006	2.08	moderate	2 - Moderate	1 - Lowest Observed	2 - Moderate	1.8 - Moderate	2.25 - Moderate	2.5 - Moderate	3 - Good
	Seal Beach NWR (Case Pond)	B23-SAV-005	1.66	lowest observed	1.75 - Lowest Observed	1 - Lowest Observed	2 - Moderate	1.4 - Lowest Observed	1.75 - Lowest Observed	1.75 - Lowest Observed	2 - Moderate
large embayment	Mission Bay	906MBMCSC	3.29	best observed	3.75 - Best Observed	3 - Good	2.63 - Good	3.17 - Good	3 - Good	3.5 - Best Observed	4 - Best Observed

	Mission Bay	906MBVIYP	3.63	best observed	4 - Best Observed	3.5 - Best Observed	2.88 - Good	3.25 - Good	3.75 - Best Observed	4 - Best Observed	4 - Best Observed
	Mission Bay	906MBECSR	2.74	good	3.5 - Moderate	3.5 - Best Observed	2.38 - Moderate	2.83 - Good	3 - Good	2.5 - Moderate	2.5 - Moderate
	Mission Bay	B23-SAV-908	2.83	good	2.75 - Good	3.5 - Best Observed	2.5 - Moderate	2.8 - Good	3 - Good	2.75 - Good	2.5 - Moderate
	Mission Bay	906MBVCSA	2.17	moderate	2.5 - Moderate	1.5 - Lowest Observed	2.25 - Moderate	2.42 - Moderate	1.75 - Lowest Observed	2.25 - Moderate	2.5 - Moderate
	Mission Bay	906MBVINC	1.98	moderate	1.75 - Lowest Observed	2.5 - Moderate	1.69 - Lowest Observed	1.92 - Moderate	2.25 - Moderate	1.75 - Lowest Observed	2 - Moderate
	Newport Bay	B23-SAV-025	1.72	lowest observed	1.75 - Lowest Observed	1 - Lowest Observed	1.67 - Lowest Observed	1.6 - Lowest Observed	1.75 - Lowest Observed	2.25 - Moderate	2 - Moderate
	San Diego Bay	910ZNJN01	2.74	good	2.75 - Good	3.5 - Best Observed	3 - Good	3.17 - Good	2.5 - Moderate	2.25 - Moderate	2 - Moderate
	San Diego Bay	910ZNJN02	2.86	good	3 - Good	3.5 - Best Observed	2.94 - Good	3.08 - Good	2.5 - Moderate	2.5 - Moderate	2.5 - Moderate
	San Diego Bay	912SDBCPB	2.99	good	3 - Good	3.5 - Best Observed	2.5 - Moderate	2.67 - Good	3.25 - Good	3 - Good	3 - Good
	San Diego Bay	912SDBSLB	2.81	good	3.25 - Good	3 - Good	2.5 - Moderate	2.67 - Good	2.5 - Moderate	2.75 - Good	3 - Good
	San Diego Bay	912SDCBVP	3.07	good	3 - Good	3.5 - Best Observed	2.69 - Good	3.08 - Good	3.25 - Good	3 - Good	3 - Good
	San Diego Bay	912SDSIWB	2.76	good	3 - Good	3 - Good	2.63 - Good	2.67 - Good	2.75 - Good	2.75 - Good	2.5 - Moderate
	San Diego Bay	912SDT001	3.05	good	2.5 - Moderate	3.5 - Best Observed	2.88 - Good	3.17 - Good	3 - Good	2.5 - Moderate	2.5 - Moderate
	San Diego Bay	912SDT003	2.51	good	2.75 - Good	3 - Good	2.75 - Good	2.58 - Good	2.25 - Moderate	2.25 - Moderate	2 - Moderate
	San Diego Bay	B23-SAV-026	1.67	lowest observed	1.25 - Lowest Observed	1.5 - Lowest Observed	2.17 - Moderate	2 - Moderate	1.75 - Lowest Observed	1.5 - Lowest Observed	1.5 - Lowest Observed
	San Diego Bay	B23-SAV-029	1.33	lowest observed	1 - Lowest Observed	1.5 - Lowest Observed	1.67 - Lowest Observed	1.4 - Lowest Observed	1.5 - Lowest Observed	1.25 - Lowest Observed	1 - Lowest Observed
	San Diego Bay	912SDNOST	2.16	moderate	2.5 - Moderate	2.5 - Moderate	2.69 - Good	2.69 - Good	1.5 - Lowest Observed	1.75 - Lowest Observed	1.5 - Lowest Observed

	San Diego Bay	912SDSBPO	2.03	moderate	2.25 - Moderate	2 - Moderate	2.13 - Moderate	1.83 - Moderate	2 - Moderate	2 - Moderate	2 - Moderate
	San Diego Bay	912SDSSSC	1.89	moderate	2.25 - Moderate	2.5 - Moderate	2 - Moderate	2 - Moderate	1.5 - Lowest Observed	1.5 - Lowest Observed	1.5 - Lowest Observed
	San Diego Bay	B23-SAV-023	2.13	moderate	2 - Moderate	2.5 - Moderate	2.17 - Moderate	2 - Moderate	2.25 - Moderate	2 - Moderate	2 - Moderate
	San Diego South Bay	B23-SAV-022	2.13	moderate	1.75 - Lowest Observed	2.5 - Moderate	2.5 - Moderate	2.4 - Moderate	2 .25 - Moderate	2 - Moderate	1.5 - Lowest Observed
	San Diego South Bay	B23-SAV-027	2.08	moderate	1.75 - Lowest Observed	2 - Moderate	2.33 - Moderate	2.2 - Moderate	2.25 - Moderate	2 - Moderate	2 - Moderate
	San Diego South Bay	B23-SAV-030	2.03	moderate	2 - Moderate	2.5 - Moderate	2.33 - Moderate	2.4 - Moderate	1.5 - Lowest Observed	1.5 - Lowest Observed	2 - Moderate
small embayment	Dana Point Harbor	B23-SAV-066	2.29	moderate	2.5 - Moderate	1.5 - Lowest Observed	2.33 - Moderate	2.2 - Moderate	2 - Moderate	2.5 - Moderate	3 - Good
	Huntington - Magnolia Marsh2	B23-SAV-012	2.26	moderate	2.5 - Moderate	1.5 - Lowest Observed	1.83 - Moderate	2 - Moderate	2.25 - Moderate	2.75 - Good	3 - Good
	Magnolia Marsh	B23-SAV-063	3.49	best observed	3.5 - Best Observed	4 - Best Observed	3.5 - Best Observed	3.2 - Good	3.75 - Best Observed	3.5 - Best Observed	3 - Good
	Magnolia Marsh	B23-SAV-012	2.26	moderate	2.5 - Moderate	1.5 - Lowest Observed	1.8 - Moderate	2 - Moderate	2.25 - Moderate	2.75 - Good	3 - Good
	Newport Bay	B23-SAV-014	1.87	moderate	2.25 - Moderate	1 - Lowest Observed	1.5 - Lowest Observed	1.6 - Lowest Observed	1.75 - Lowest Observed	2.5 - Moderate	2.5 - Moderate
	Newport Bay	B23-SAV-018	1.92	moderate	1.75 - Lowest Observed	2 - Moderate	2.17 - Moderate	2 - Moderate	2 - Moderate	2 - Moderate	1.5 - Lowest Observed
	Newport Bay	B23-SAV-031	2.33	moderate	2 - Moderate	2.5 - Moderate	2.33 - Moderate	2.2 - Moderate	2.75 - Good	2.5 - Moderate	2 - Moderate
	Oceanside Harbor	B23-SAV-910	2.86	good	3 - Good	3.5 - Best Observed	2.83 - Good	3.2 - Good	2.5 - Moderate	2.5 - Moderate	2.5 - Moderate
	Port of Los Angeles	B23-SAV-011	3.10	good	3 - Good	3.5 - Best Observed	3.33 - Best Observed	3.4 - Best Observed	2.75 - Good	2.75 - Good	3 - Good
	Port of Los Angeles	B23-SAV-015	2.70	good	2.75 - Good	3 - Good	2.83 - Good	2.8 - Good	2.5 - Moderate	2.5 - Moderate	2.5 - Moderate
	Port of Los Angeles	B23-SAV-020	1.17	lowest observed	1 - Lowest Observed	1 - Lowest Observed	1.5 - Lowest Observed	1.2 - Lowest Observed	1.25 - Lowest Observed	1.25 - Lowest Observed	1 - Lowest Observed

Table B2. Percent area-weighted ecosystem function scores by stratum, including upper and lower 95% confidence intervals.

Ecosystem Function	Stratum	Condition	Percent Area Estimate	Lower 95% CI	Upper 95% CI
substrate stabilization	estuary	Lowest observed	33.33	6.38	60.29
substrate stabilization	estuary	Moderate	25.00	0.24	49.76
substrate stabilization	estuary	Good	16.67	0.00	37.98
substrate stabilization	estuary	Best Observed	25.00	0.24	49.76
substrate stabilization	large_embayment	Lowest observed	26.09	7.94	44.23
substrate stabilization	large_embayment	Moderate	34.78	15.10	54.46
substrate stabilization	large_embayment	Good	30.43	11.42	49.45
substrate stabilization	large_embayment	Best Observed	8.70	0.00	20.34
substrate stabilization	small_embayment	Lowest Observed	20.00	0.00	45.04
substrate stabilization	small_embayment	Moderate	50.00	18.70	81.30
substrate stabilization	small_embayment	Good	20.00	0.00	45.04
substrate stabilization	small_embayment	Best Observed	10.00	0.00	28.78
carbon sequestration	estuary	Lowest Observed	41.67	13.47	69.86
carbon sequestration	estuary	Moderate	8.33	0.00	24.14
carbon sequestration	estuary	Good	33.33	6.38	60.29

carbon sequestration	estuary	Best Observed	16.67	0.00	37.98
carbon sequestration	large_embayment	Lowest Observed	17.39	1.73	33.05
carbon sequestration	large_embayment	Moderate	34.78	15.10	54.46
carbon sequestration	large_embayment	Good	17.39	1.73	33.05
carbon sequestration	large_embayment	Best Observed	30.43	11.42	49.45
carbon sequestration	small_embayment	Lowest Observed	50.00	18.70	81.30
carbon sequestration	small_embayment	Moderate	20.00	0.00	45.04
carbon sequestration	small_embayment	Good	10.00	0.00	28.78
carbon sequestration	small_embayment	Best Observed	20.00	0.00	45.04
primary production	estuary	Lowest Observed	0.00	0.00	0.00
primary production	estuary	Moderate	58.33	30.14	86.53
primary production	estuary	Good	41.67	13.47	69.86
primary production	estuary	Best Observed	0.00	0.00	0.00
primary production	large_embayment	Lowest Observed	13.04	0.00	26.96
primary production	large_embayment	Moderate	47.83	27.18	68.47
primary production	large_embayment	Good	39.13	18.96	59.30
primary production	large_embayment	Best Observed	0.00	0.00	0.00
primary production	small_embayment	Lowest Observed	20.00	0.00	45.04

primary production	small_embayment	Moderate	50.00	18.70	81.30
primary production	small_embayment	Good	10.00	0.00	28.78
primary production	small_embayment	Best Observed	20.00	0.00	45.04
secondary production	estuary	Lowest Observed	25.00	0.24	49.76
secondary production	estuary	Moderate	25.00	0.24	49.76
secondary production	estuary	Good	33.33	6.38	60.29
secondary production	estuary	Best Observed	16.67	0.00	37.98
secondary production	large_embayment	Lowest observed	8.70	0.00	20.34
secondary production	large_embayment	Moderate	39.13	18.96	59.30
secondary production	large_embayment	Good	52.17	31.53	72.82
secondary production	large_embayment	Best Observed	0.00	0.00	0.00
secondary production	small_embayment	Lowest Observed	20.00	0.00	45.04
secondary production	small_embayment	Moderate	50.00	18.70	81.30
secondary production	small_embayment	Good	20.00	0.00	45.04
secondary production	small_embayment	Best Observed	10.00	0.00	28.78
water quality	estuary	Lowest Observed	16.67	0.00	37.98
water quality	estuary	Moderate	33.33	6.38	60.29
water quality	estuary	Good	25.00	0.24	49.76
water quality	estuary	Best Observed	25.00	0.24	49.76
water quality	large_embayment	Lowest Observed	30.43	11.42	49.45

water quality	large_embayment	Moderate	39.13	18.96	59.30
water quality	large_embayment	Good	26.09	7.94	44.23
water quality	large_embayment	Best Observed	4.35	0.00	12.78
water quality	small_embayment	Lowest Observed	20.00	0.00	45.04
water quality	small_embayment	Moderate	50.00	18.70	81.30
water quality	small_embayment	Good	20.00	0.00	45.04
water quality	small_embayment	Best Observed	10.00	0.00	28.78
nekton habitat	estuary	Lowest Observed	16.67	0.00	37.98
nekton habitat	estuary	Moderate	33.33	6.38	60.29
nekton habitat	estuary	Good	25.00	0.24	49.76
nekton habitat	estuary	Best Observed	25.00	0.24	49.76
nekton habitat	large_embayment	Lowest Observed	26.09	7.94	44.23
nekton habitat	large_embayment	Moderate	47.83	27.18	68.47
nekton habitat	large_embayment	Good	17.39	1.73	33.05
nekton habitat	large_embayment	Best Observed	8.70	0.00	20.34
nekton habitat	small_embayment	Lowest Observed	10.00	0.00	28.78
nekton habitat	small_embayment	Moderate	50.00	18.70	81.30
nekton habitat	small_embayment	Good	30.00	1.32	58.68

nekton habitat	small_embayment	Best Observed	10.00	0.00	28.78
waterfowl habitat	estuary	Lowest Observed	0.00	0.00	0.00
waterfowl habitat	estuary	Moderate	41.67	13.47	69.86
waterfowl habitat	estuary	Good	16.67	0.00	37.98
waterfowl habitat	estuary	Best Observed	41.67	13.47	69.86
waterfowl habitat	large_embayment	Lowest Observed	21.74	4.69	38.78
waterfowl habitat	large_embayment	Moderate	56.52	36.04	77.01
waterfowl habitat	large_embayment	Good	13.04	0.00	26.96
waterfowl habitat	large_embayment	Best Observed	8.70	0.00	20.34
waterfowl habitat	small_embayment	Lowest Observed	20.00	0.00	45.04
waterfowl habitat	small_embayment	Moderate	30.00	1.32	58.68
waterfowl habitat	small_embayment	Good	50.00	18.70	81.30
waterfowl habitat	small_embayment	Best Observed	0.00	0.00	0.00

Table B3. Percent area-weighted overall eelgrass condition scores by stratum, including upper and lower 95% confidence intervals.

Type	Stratum	Condition Category	Percent Area Estimate	Lower 95% CI	Upper 95% CI
stratum	estuary	best observed condition	16.67	0.00	37.97
stratum	estuary	good condition	33.33	6.39	60.28
stratum	estuary	moderate condition	25.00	0.25	49.75
stratum	estuary	lowest observed condition	25.00	0.25	49.75
stratum	large_embayment	best observed condition	8.33	0.00	19.51
stratum	large_embayment	good condition	41.67	21.73	61.60
stratum	large_embayment	moderate condition	37.50	17.92	57.08
stratum	large_embayment	lowest observed condition	12.50	0.00	25.87
stratum	small_embayment	best observed condition	9.09	0.00	26.24
stratum	small_embayment	good condition	27.27	0.71	53.84
stratum	small_embayment	moderate condition	54.55	24.84	84.25
stratum	small_embayment	lowest observed condition	9.09	0.00	26.24
All_Sites	All Sites	best observed condition	9.10	0.00	19.10
All_Sites	All Sites	good condition	40.41	22.76	58.06
All_Sites	All Sites	moderate condition	36.99	19.67	54.31
All_Sites	All Sites	lowest observed condition	13.49	1.55	25.44

Table B4. Percent area-weighted estimated ecosystem function scores for the overall Bight, including upper and lower 95% confidence intervals.

Ecosystem Function	Condition Category	Percent Area Estimate	Lower 95% CI	Upper 95% CI
substrate.stabilization	Lowest observed	26.56	10.48	42.63
substrate.stabilization	Moderate	34.39	17.00	51.77
substrate.stabilization	Good	28.80	12.03	45.57
substrate.stabilization	Best Observed	10.26	0.00	20.75
carbon.sequestration	Lowest observed	20.75	6.67	34.83
carbon.sequestration	Moderate	31.82	14.47	49.17
carbon.sequestration	Good	18.62	4.67	32.58
carbon.sequestration	Best Observed	28.80	12.03	45.57
primary.production	Lowest observed	12.07	0.00	24.27
primary.production	Moderate	48.88	30.62	67.13
primary.production	Good	38.38	20.55	56.21
primary.production	Best Observed	0.67	0.00	1.65
secondary.production	Lowest observed	10.59	0.08	21.11
secondary.production	Moderate	38.18	20.37	56.00
secondary.production	Good	49.34	31.06	67.61
secondary.production	Best Observed	1.89	0.00	4.22
wq	Lowest observed	28.80	12.03	45.57
wq	Moderate	38.96	21.13	56.78
wq	Good	25.78	9.74	41.82
wq	Best Observed	6.46	0.00	14.30
nekton.habitat	Lowest observed	24.67	8.67	40.67
nekton.habitat	Moderate	46.55	28.30	64.80
nekton.habitat	Good	18.52	4.61	32.44
nekton.habitat	Best Observed	10.26	0.00	20.75
nekton.habitat	Total	19.66	4.69	34.62
waterfowl.habitat	Lowest observed	14.63	36.10	72.39
waterfowl.habitat	Moderate	54.25	2.23	27.02
waterfowl.habitat	Good	11.47	0.80	22.14
waterfowl.habitat	Best Observed	16.94	4.97	28.92

APPENDIX C – MAPS OF EELGRASS CONDITION

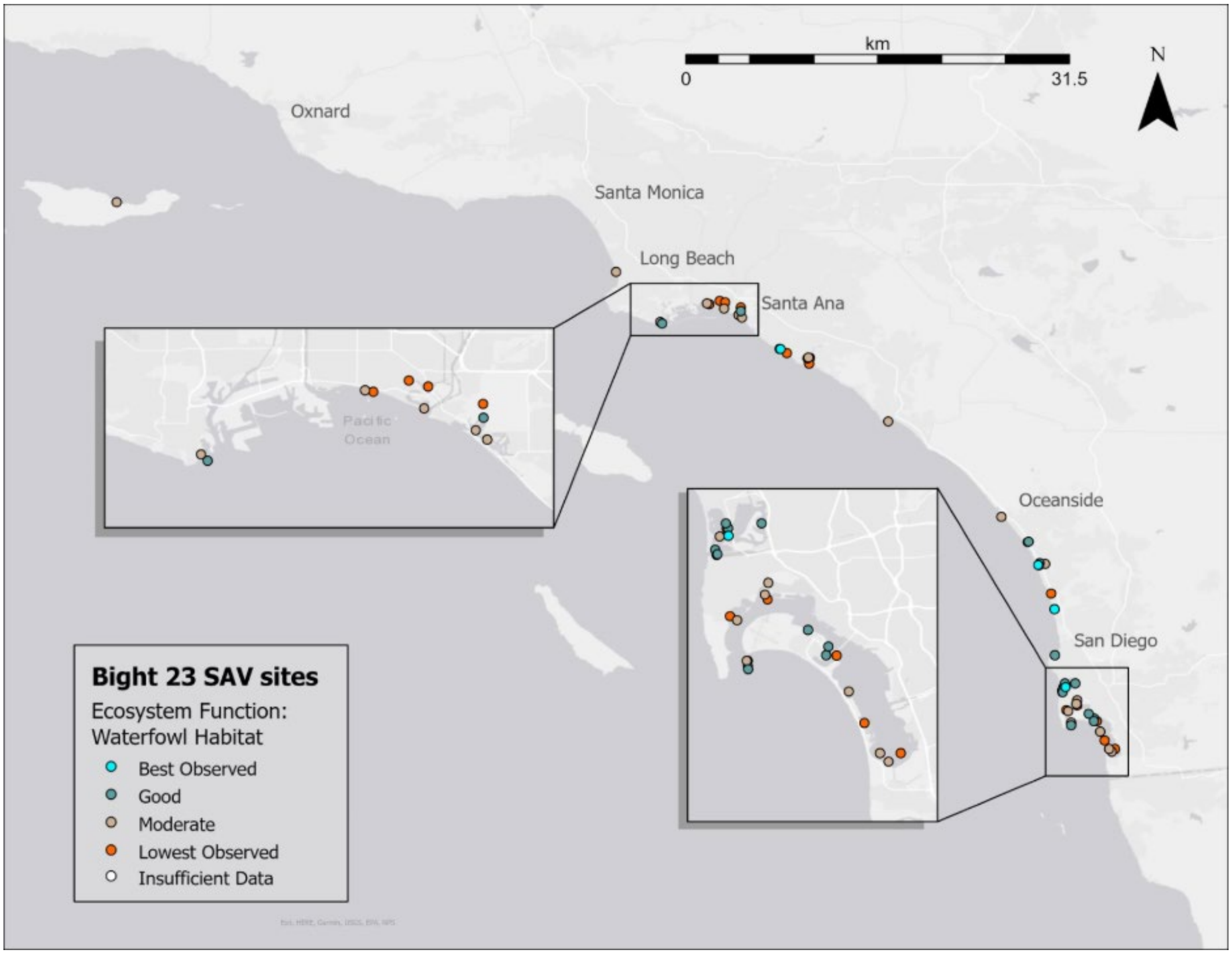

Figure C1. Geographic distribution of estimated nekton habitat ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

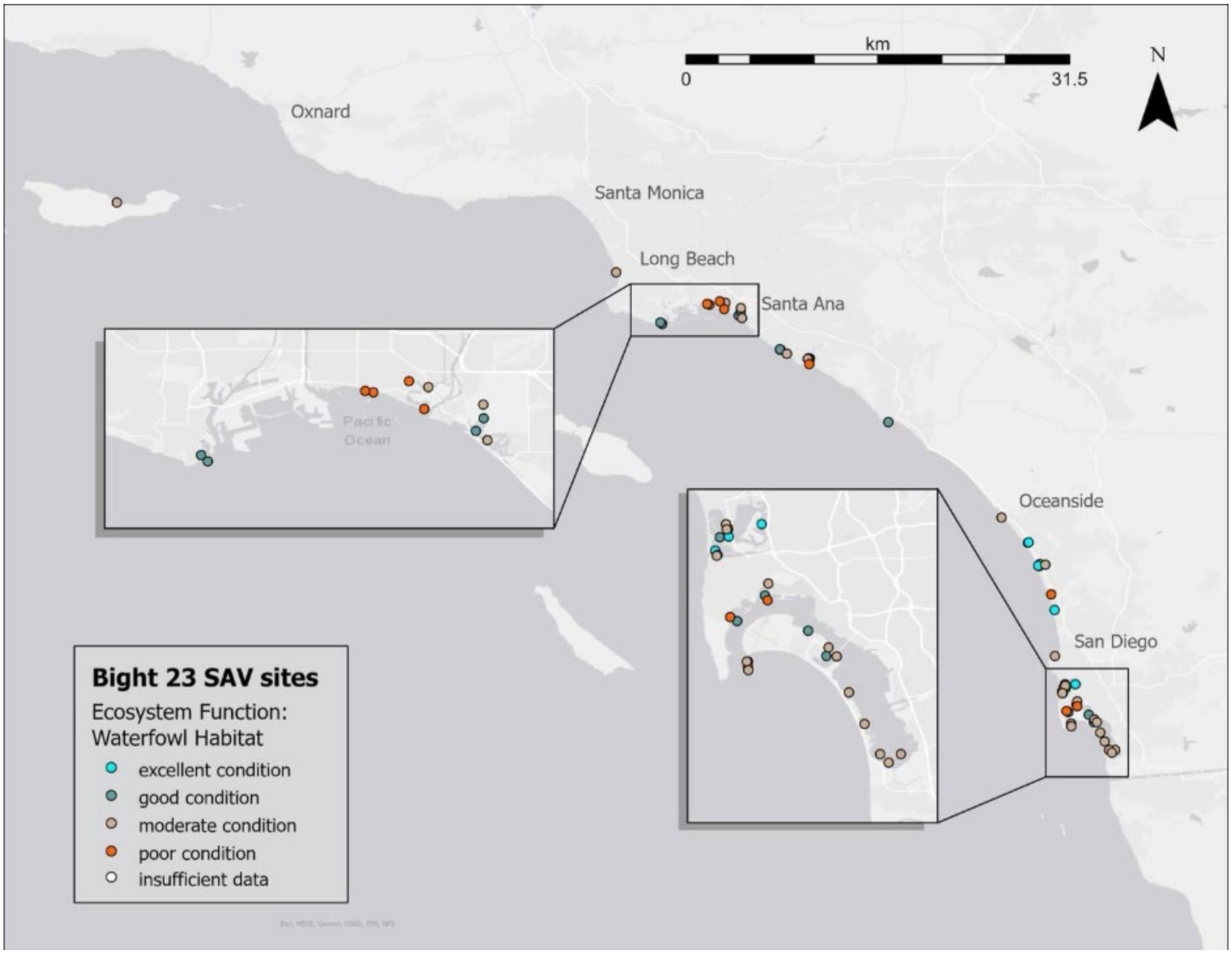

Figure C2. Geographic distribution of estimated waterfowl habitat ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

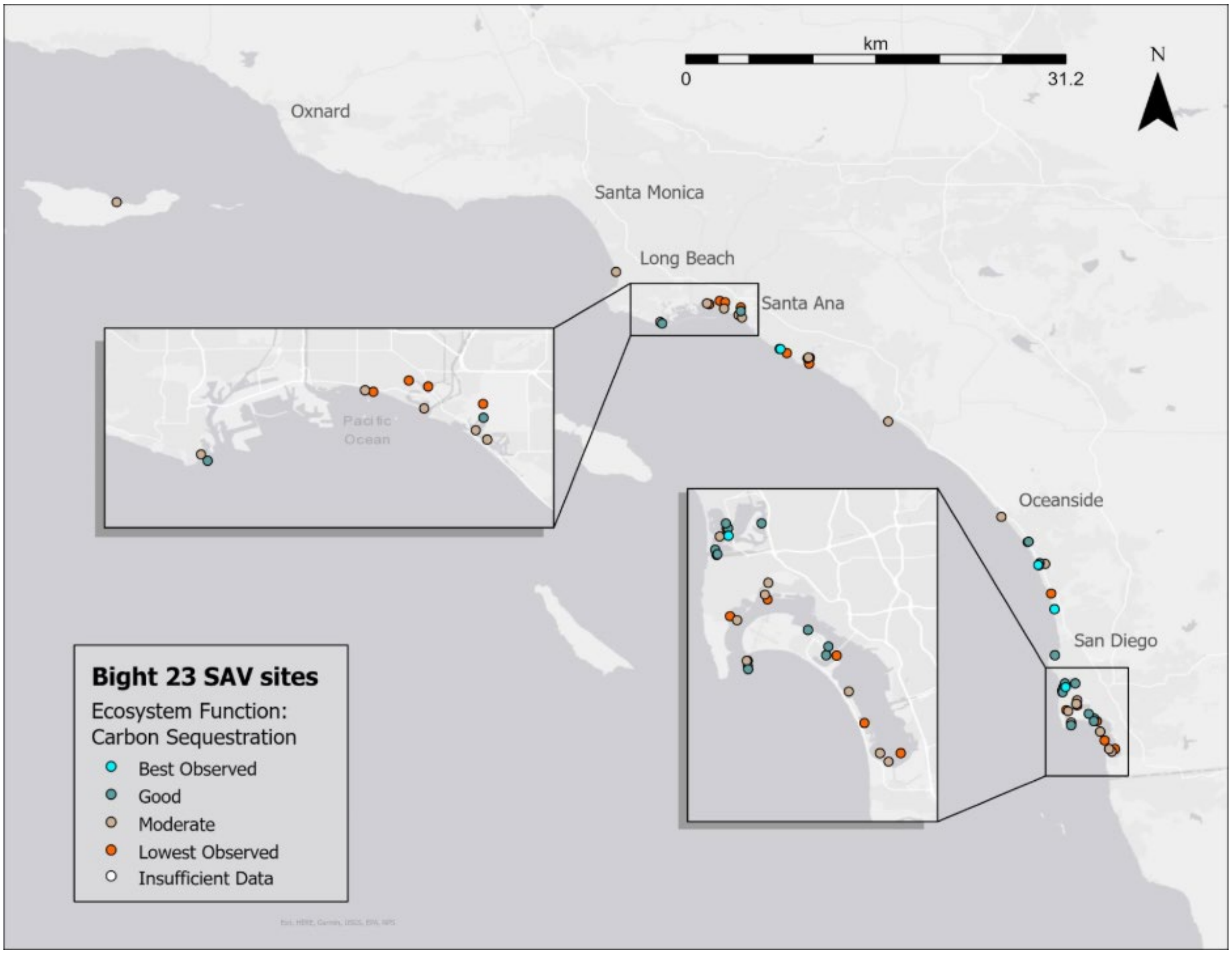

Figure C3. Geographic distribution of estimated carbon sequestration ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

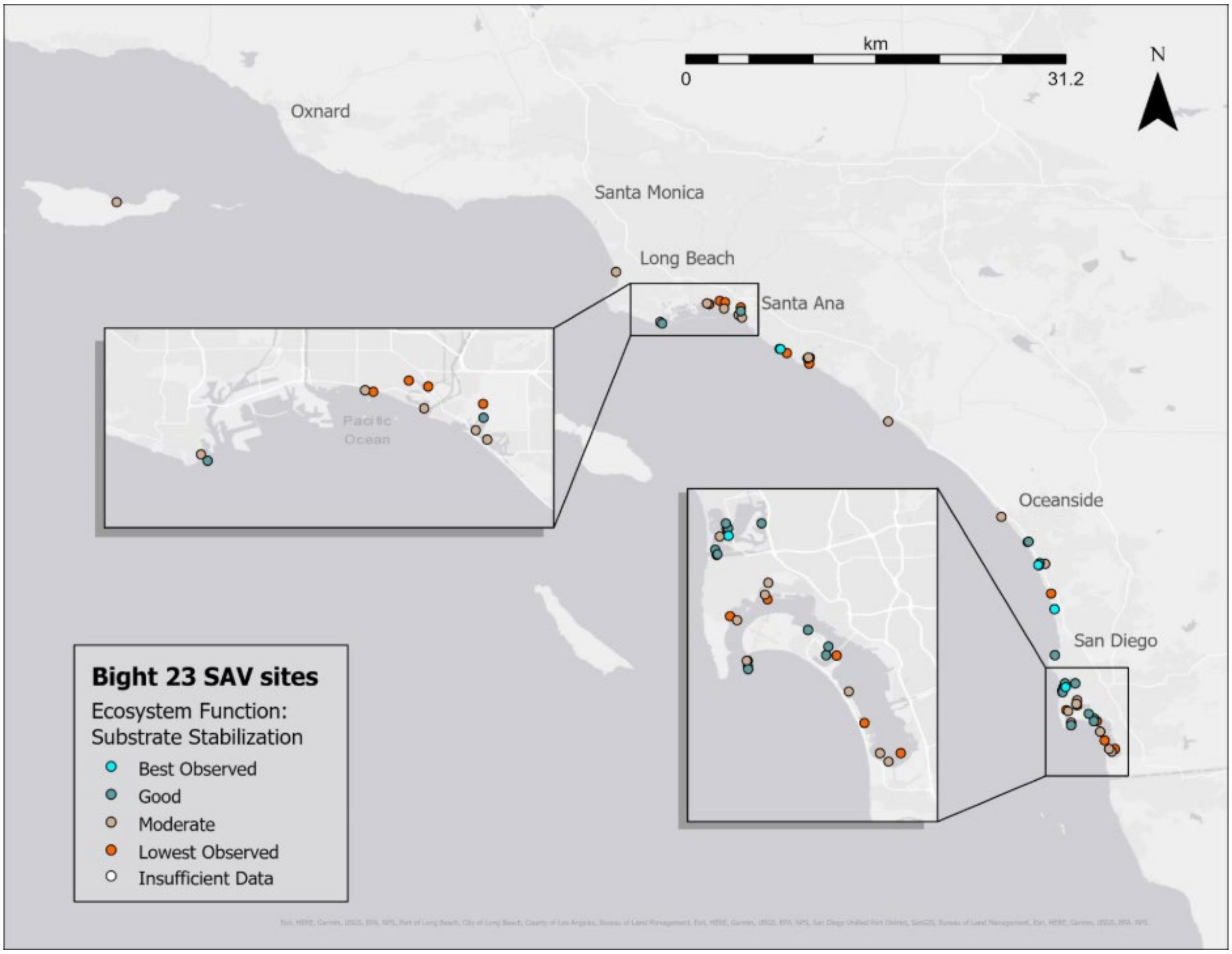

Figure C4. Geographic distribution of estimated substrate stabilization ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

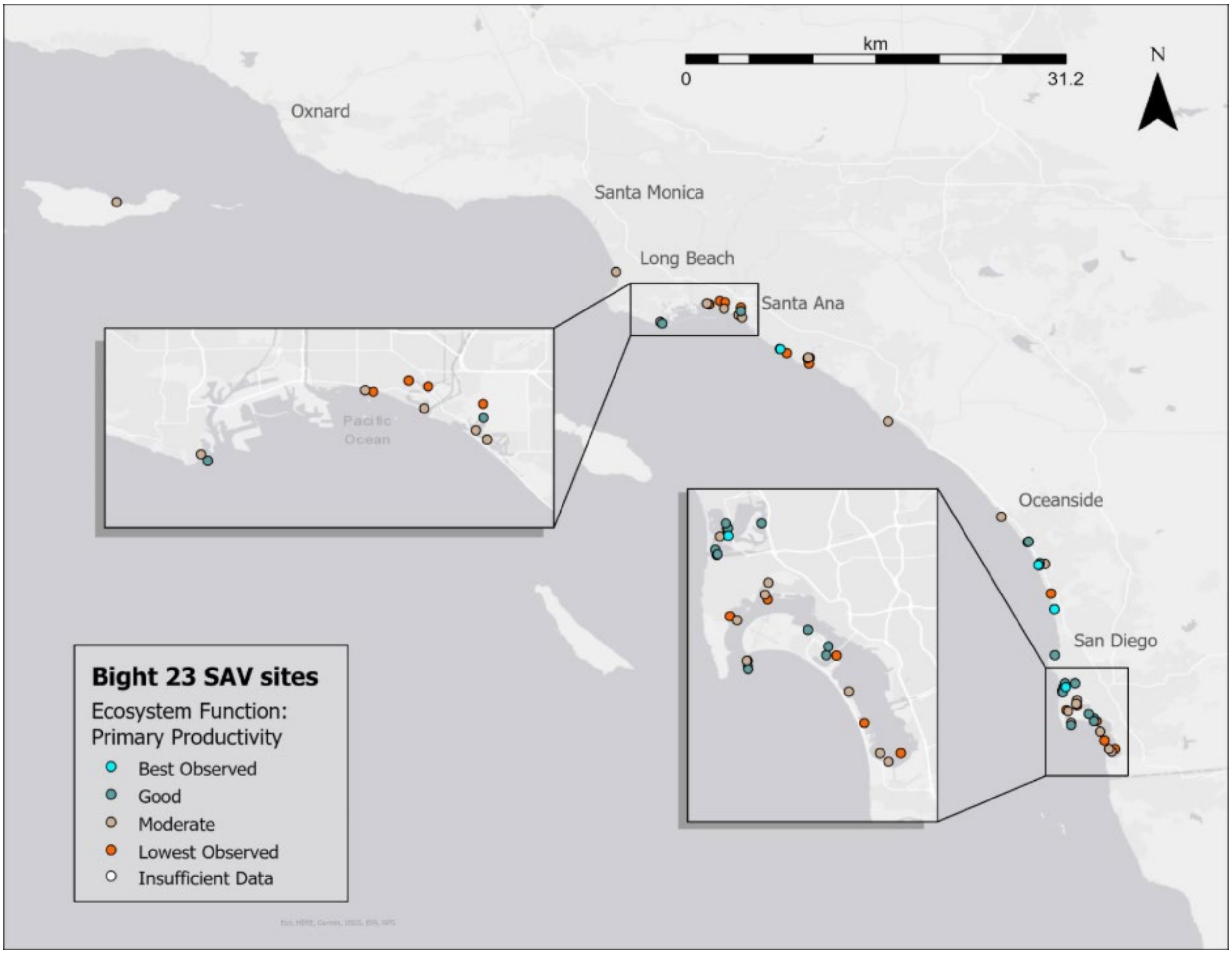

Figure C5. Geographic distribution of estimated primary production ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

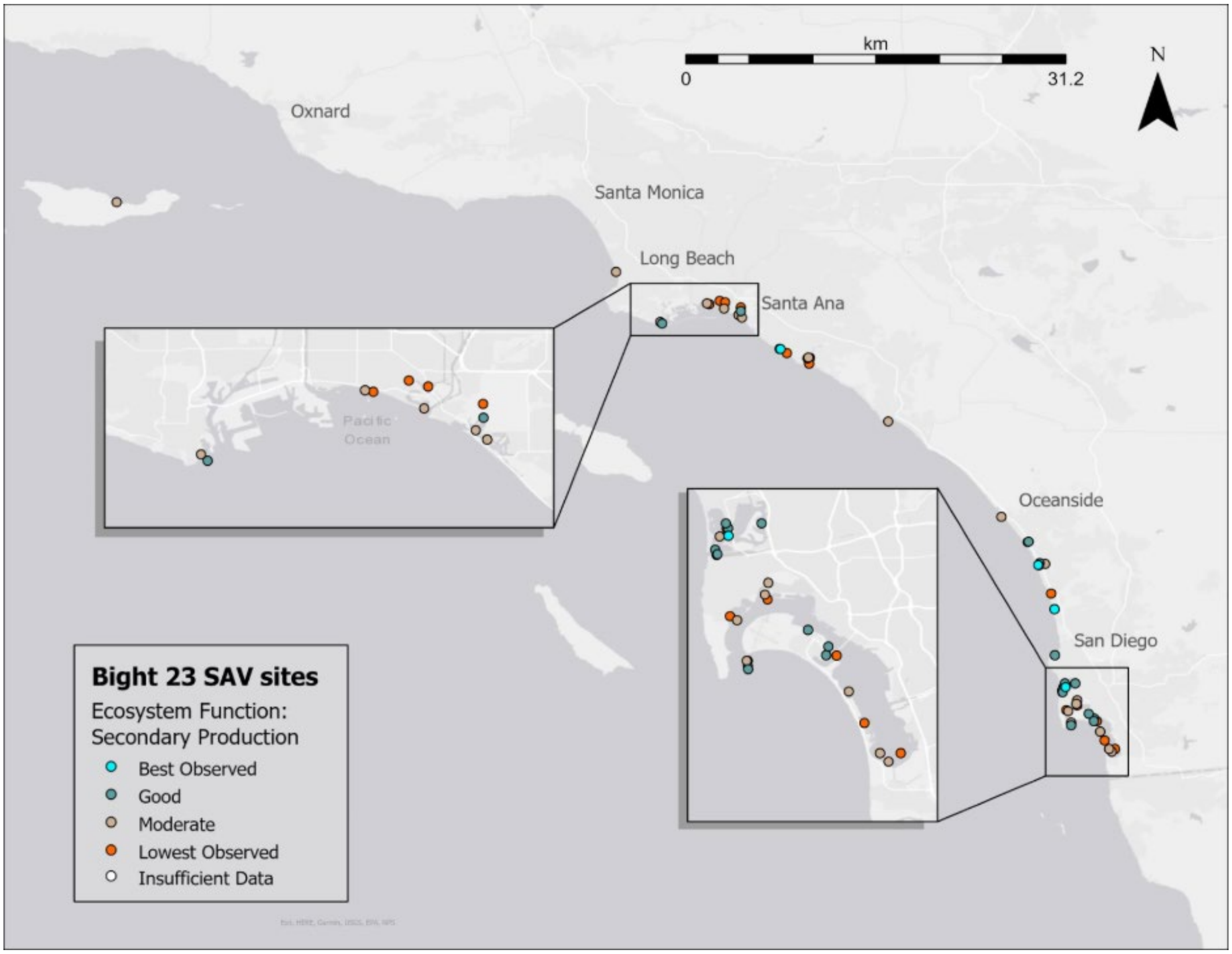

Figure C6. Geographic distribution of estimated secondary production ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to overall eelgrass condition categories.

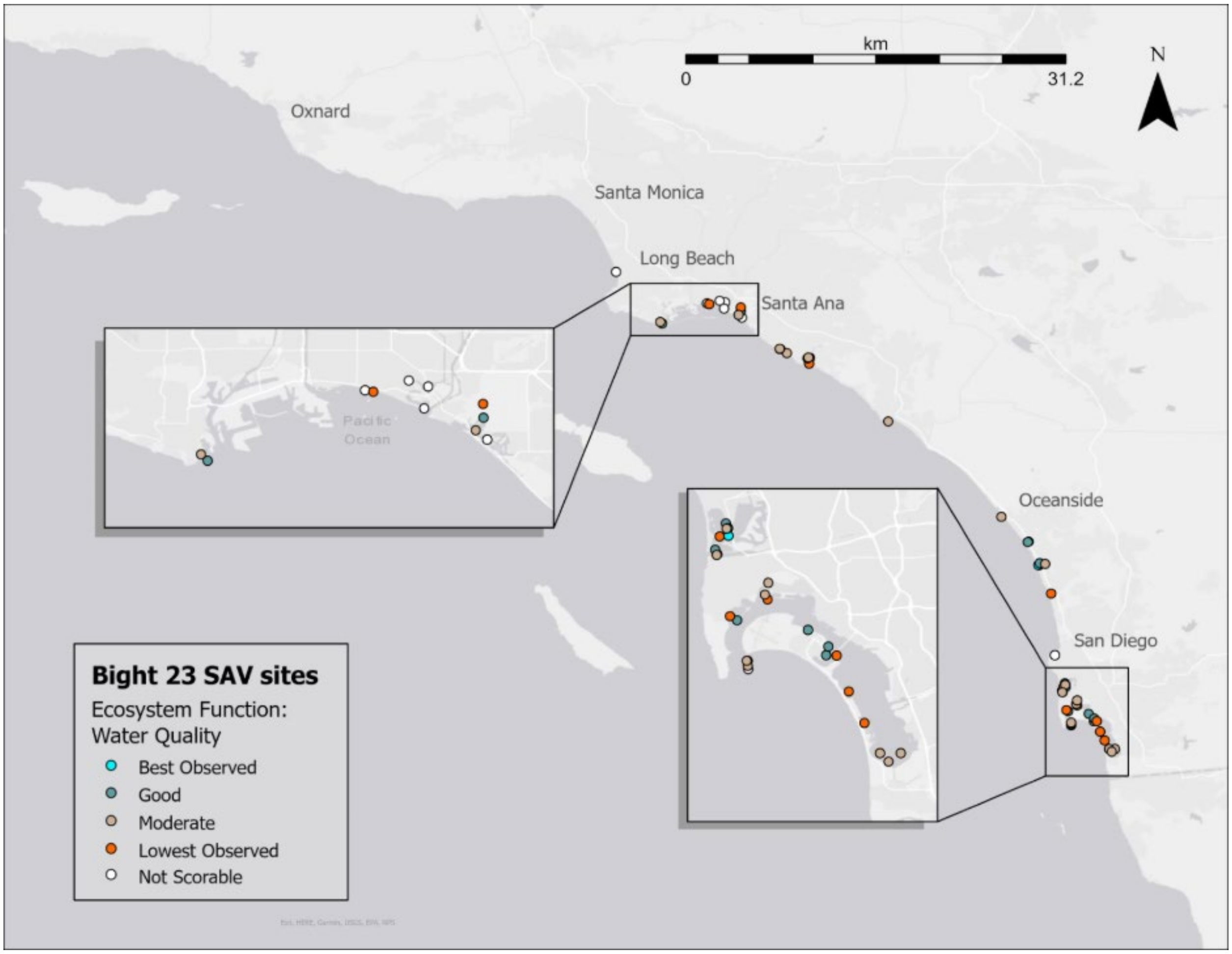

Figure C7. Geographic distribution of estimated water quality ecosystem function throughout the Southern California Bight. The legend shows point color corresponding to water quality condition categories.

APPENDIX D – EXPLORATORY ANALYSES

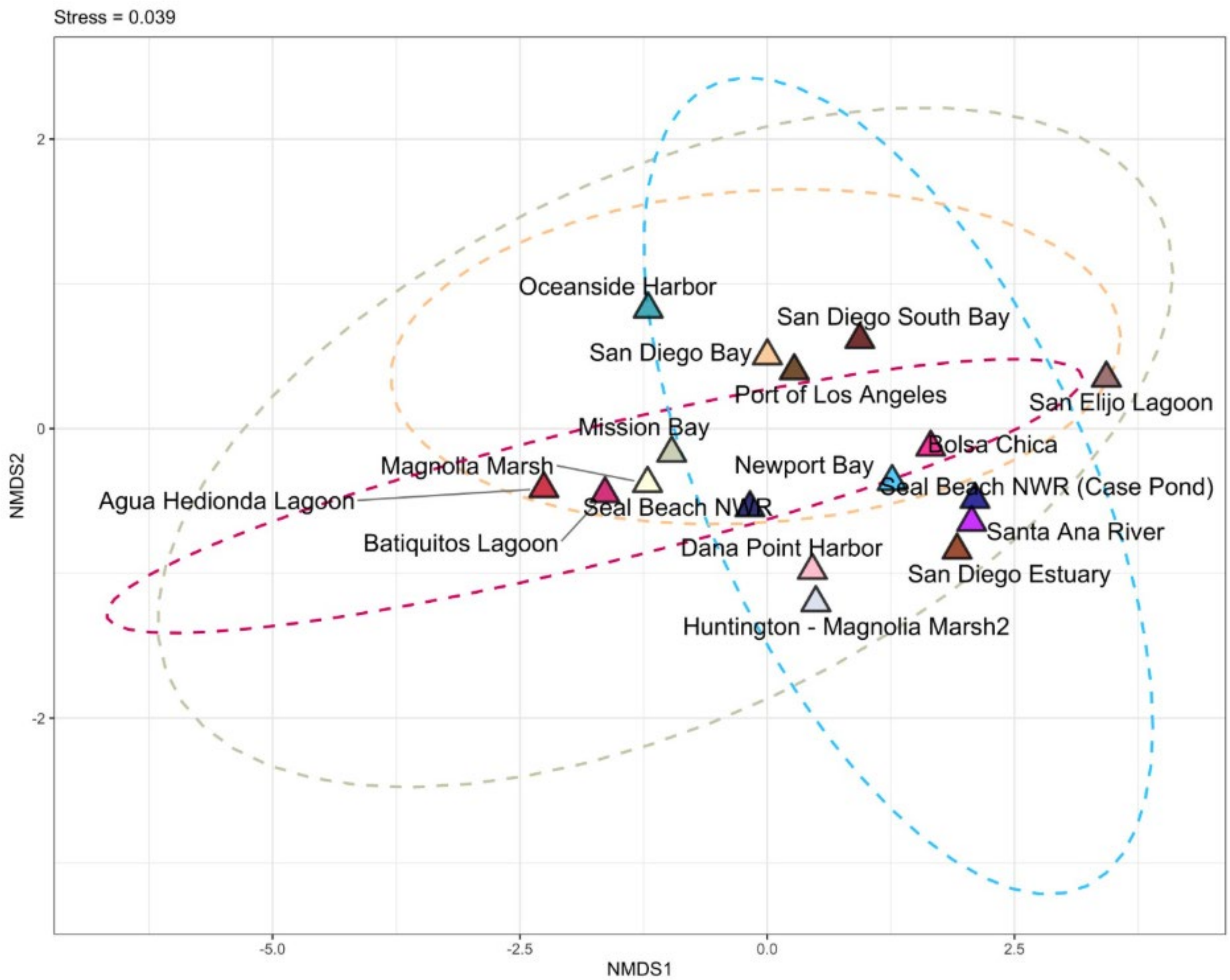

Figure D1. Non-metric multidimensional scaling plot of ecosystem function scores at each waterbody. Points represent centroids from multiple sites at each waterbody. Points and ellipses are both color-coded by waterbody.

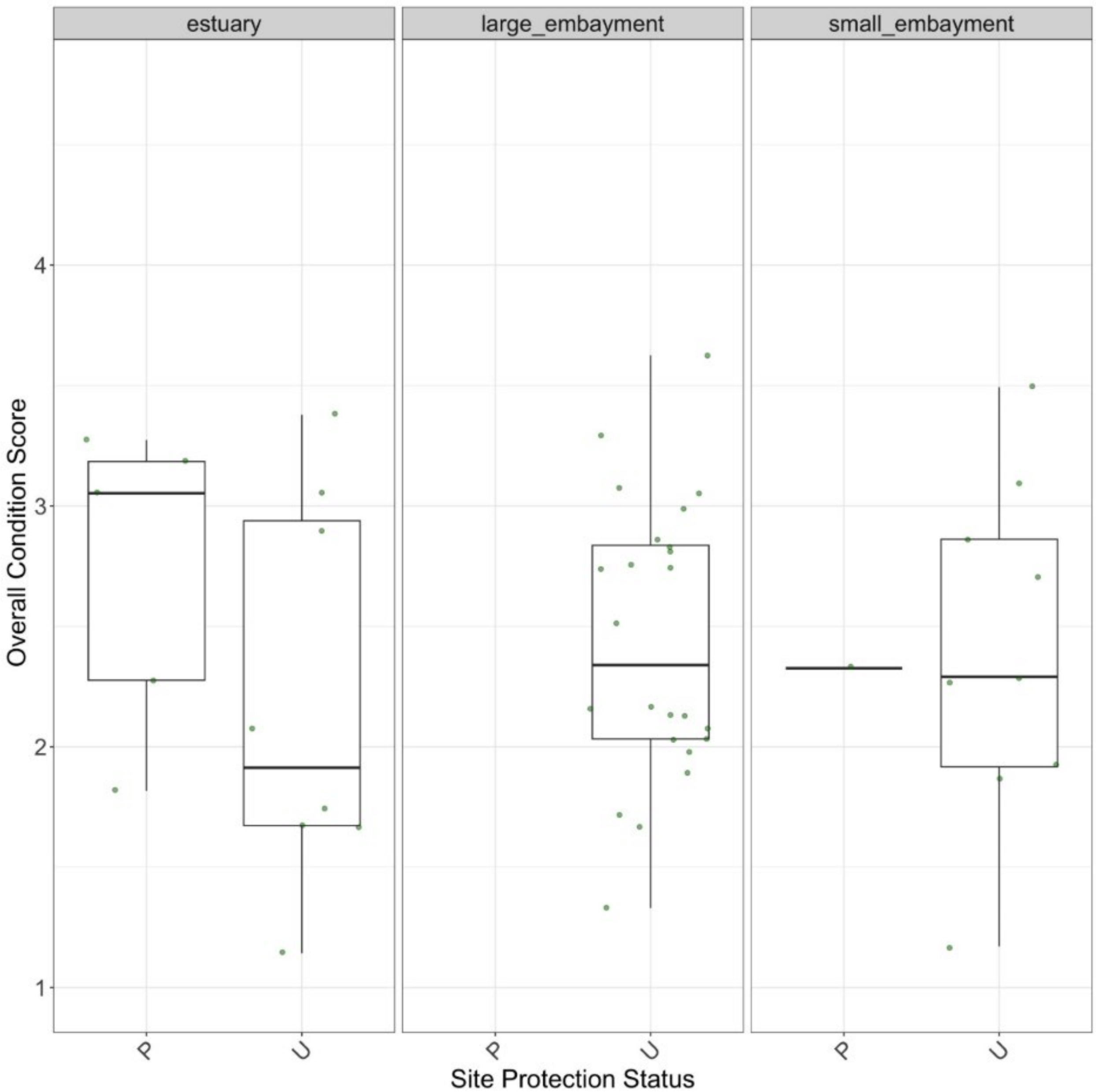

Figure D2. Overall eelgrass condition scores by nominal site protection status. P = "protected", "U" = unprotected. Protected sites include areas within designated Marine Protected Areas (no take, limited take, State Marine Reserves, State Marine Conservation Areas). Unprotected sites are areas that are not protected from take in some way, including National Wildlife Refuges. T-test comparisons indicate no significant differences between protection status in any stratum.

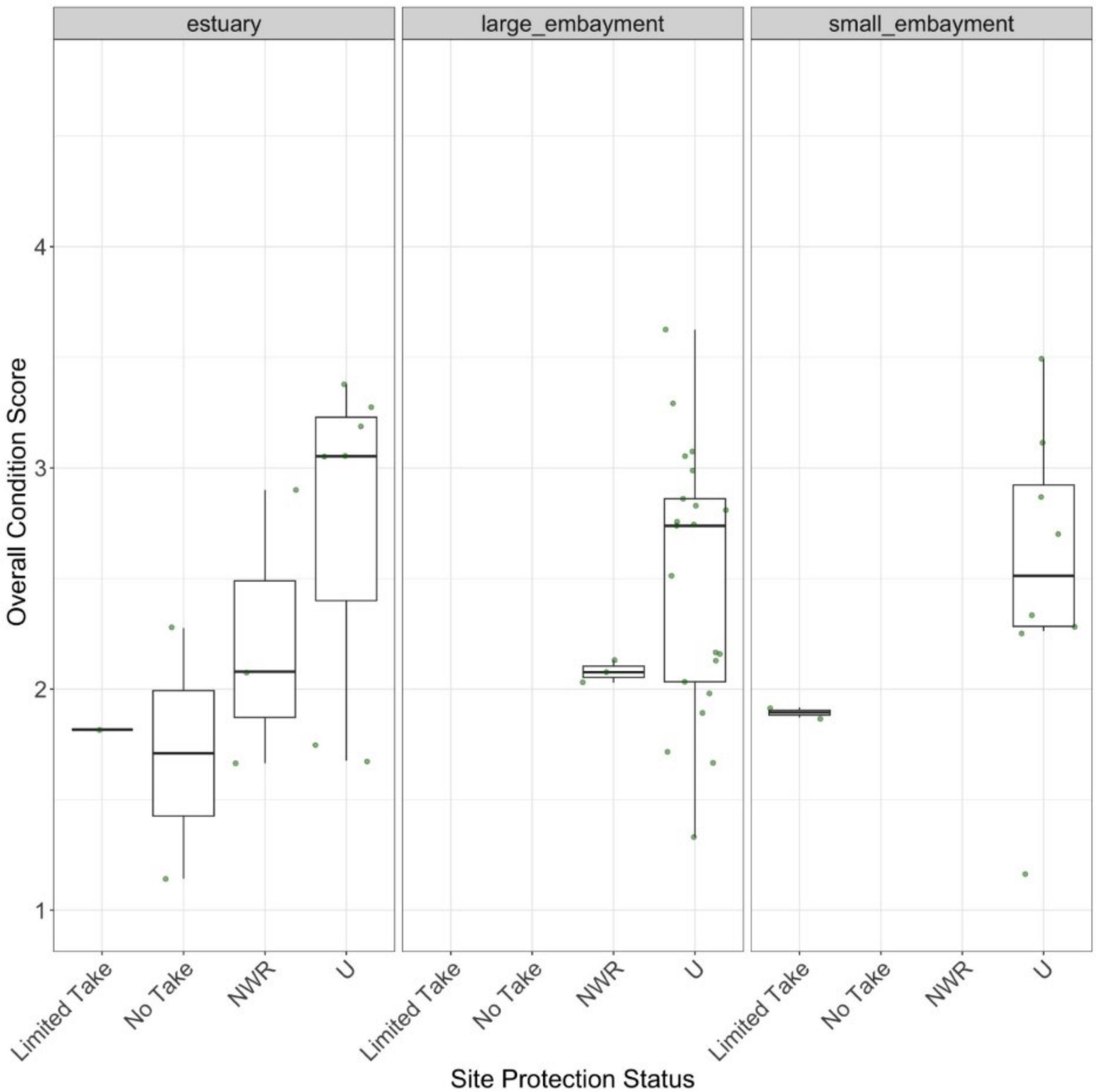

Figure D3. Overall eelgrass condition scores by specific site protection status. "No Take" = MPAs with no take, "Limited Take" = MPAs with limited take regulations, not including scientific collection, "NWR" = National Wildlife Refuges, "U" = unprotected. Wilcox test shows no significant differenced between groups.

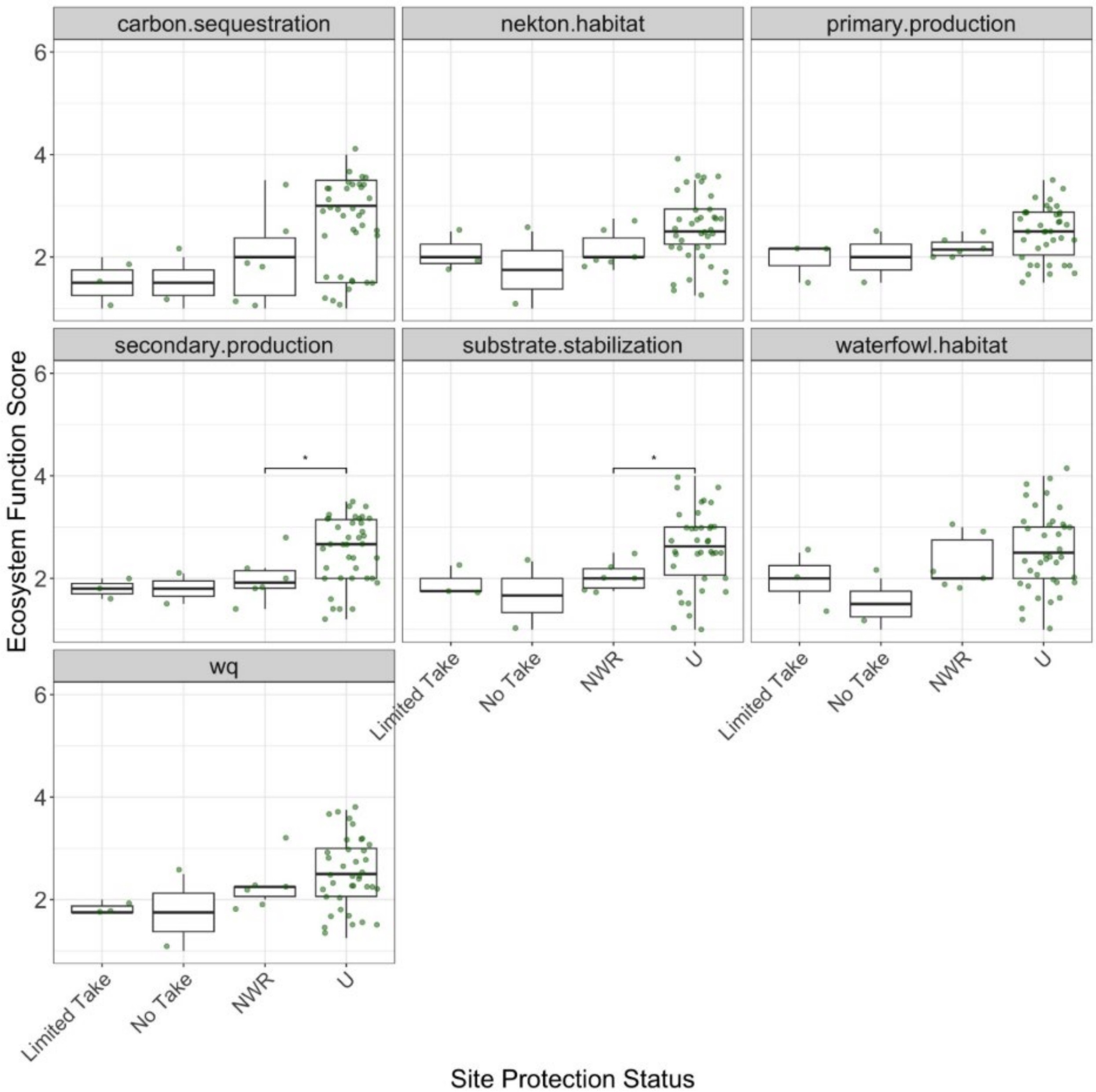

Figure D4. Eelgrass ecosystem function scores by specific site protection status. "No Take" = MPAs with no take, "Limited Take" = MPAs with limited take regulations, not including scientific collection, "NWR" = National Wildlife Refuges, "U" = unprotected.

APPENDIX E - DATA QUALITY ASSURANCE AND CONTROL

Table E1. QA/QC summary based on submitted data. Exercise in gathering information about the nature of errors that arise in a community of practice.

Category	Discrepancy	Counts	Fixable?
Unclear SOP	Mislabeled site	1	1
	Data not collected	7	0
	Duplicate (field)	1	Not needed
	Reason for overdraw not documented	3	3
	Overdraw replacement not documented	2	2
Misinterpretation/translation error	Duplicate	3	3
	Mislabeled data point	15	15
Missing item	Missing datapoint	4	0
	Missing date	3	3
	Missing site label	10	10

Table E2. Lessons learned from field based on Bight SAV Committee feedback.

Issue	Category	Potential solution	Analysis needed to move forward
Cross-parallel method too time-consuming	Modification requested	Rely on cross-parallel method	Within-bed variability study comparing both methods (completed)
Two diver passes per quadrat result in marked loss of visibility for second diver	Modification requested	One pass only	Establish DQO to define and control error rates between divers
Potential team-to-team variability	Identification of potential issue	Build in more preset quadrat stations for future intercalibration exercises	Same as solution
Meadow protocol eliminates edge effects	Identification of potential issue	Consider mapping a standard area for all bed types	Comparison between standard area data (future) and non-standard area (current data)