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# DRAFT INTEGRATED FEASIBILITY REPORT AND ENVIRONMENTAL IMPACT STATEMENT/ ENVIRONMENTAL IMPACT REPORT (EIS/EIR)

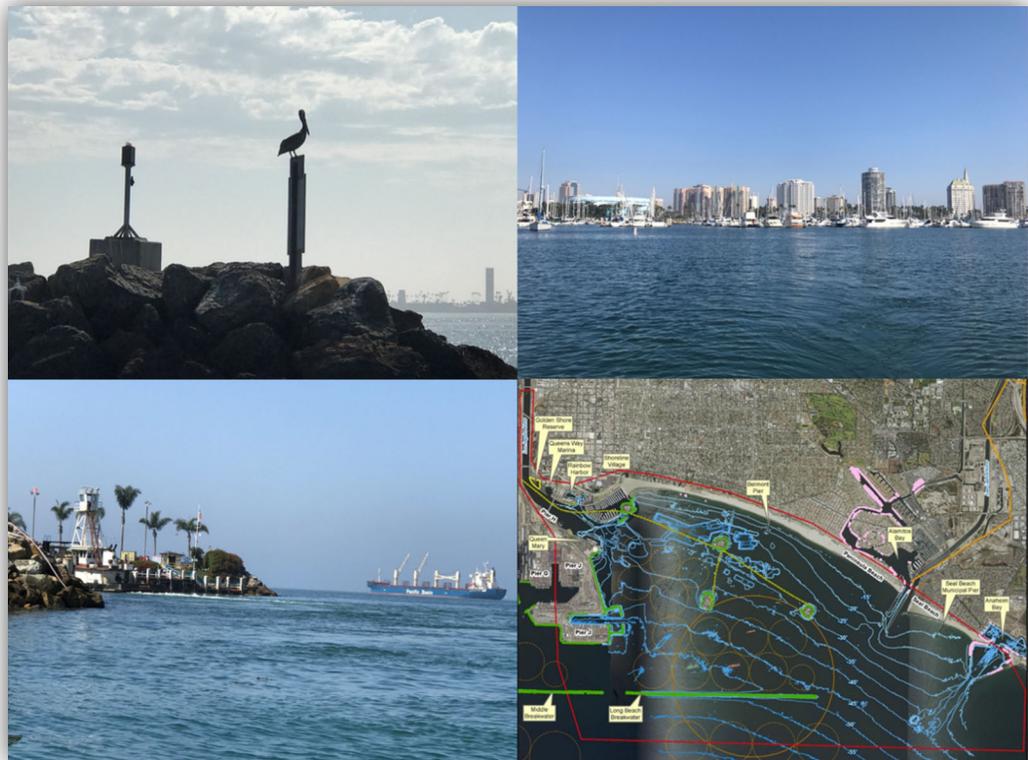
## APPENDIX D: HABITAT EVALUATION AND MODEL DOCUMENTATION

### EAST SAN PEDRO BAY ECOSYSTEM RESTORATION STUDY

Long Beach, California

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November 2019



US Army Corps  
of Engineers®

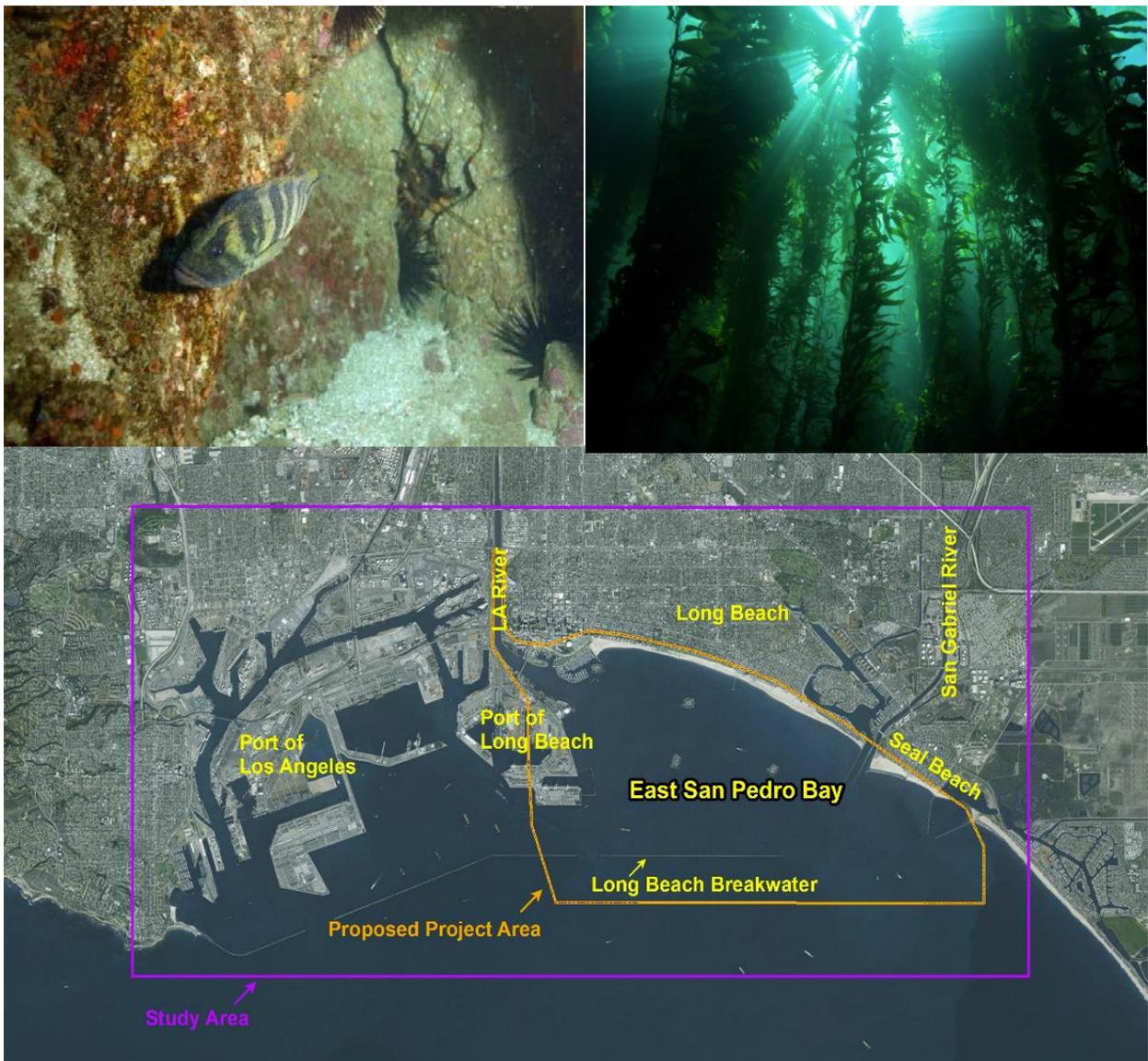


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# SOUTHERN CALIFORNIA COASTAL BAY ECOSYSTEM MODEL

## MODEL DOCUMENTATION

May 4, 2018



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# Table of Contents

Background .....	4
Model Background and Purpose.....	4
Introduction .....	6
Habitat Parameters and Response Curves.....	8
Rocky Reef (non-kelp) .....	8
Kelp Forest .....	14
Eelgrass .....	18
Oyster Reef .....	23
Tidal Salt Marsh.....	25
Sandy Islands.....	30
Calculating Habitat HSI Score.....	37
Summary of Data used in Model Development.....	37
Model Quantification.....	38
Model Evaluation .....	39
Spatial Data and Model Application .....	39
Geographic Range of Model Applicability.....	49
Considerations for Model Application .....	50
References .....	50
Figure 1. Revised Conceptual Model of the East San Pedro Bay Ecosystem and Target Habitat Types.....	7
Figure 2. Rocky Reef Connectivity Curve .....	9
Figure 3. Rocky Reef Relief Index Values. ....	10
Figure 4. Rocky Reef Residence Time Curve. ....	12
Figure 5. Rocky Reef Substrate Index Values.....	13
Figure 6. Kelp Temperature Curve. ....	14
Figure 7. Kelp Substrate Index Values.....	15
Figure 8. Regional Kelp Depth Curve. ....	16
Figure 9. Local Kelp Depth Curve. ....	17
Figure 10. Eelgrass Circulation Curve.....	18
Figure 11. Eelgrass Depth Curve. ....	20
Figure 12. Eelgrass Percent Fines Curve. ....	21
Figure 13. Eelgrass Temperature Curve.....	22
Figure 14. Oyster Salinity Curve.....	23
Figure 15 Oyster Depth Curve.....	24
Figure 16. Tidal Marsh Elevation Curve. ....	25
Figure 17. Tidal Marsh sediment Grain Size Index Values. ....	26
Figure 18. Tidal Marsh Salinity Curve.....	27

Figure 19. Tidal Marsh Connectivity index values. ....	28
Figure 20. Tidal Marsh Habitat Size Curve. ....	29
Figure 21. Sandy Islands Curve of Vegetation Cover for Least Tern. ....	30
Figure 22. Sandy Islands Curve of Vegetation Cover for Snowy Plover. ....	32
Figure 23. Sandy Islands Effective Size Curve. ....	33
Figure 24. Sandy Islands Elevation Curve.....	34
Figure 25. Sandy Islands Grain Size Index Values. ....	35
Figure 26. Sandy Islands Distance Curve.....	36
Figure 27. Alternative 1, East San Pedro Bay ecological restoration study. ....	40
Figure 28. Map of Habitat type and HSI scores developed for Alternative 1. ....	41
Figure 29. Alternative 4, East San Pedro Bay ecological restoration study. ....	43
Figure 30. Map of Habitat type and HSI scores developed for Alternative 4. ....	44
Figure 31. Alternative 12, East San Pedro Bay ecological restoration study. ....	46
Figure 32. Map of Habitat type and HSI scores developed for Alternative 12. ....	47
Figure 33. Map of geographic range of model applicability. Model range highlighted in blue.....	49
Table 1. Technical Advisory Council members and affiliation. ....	5
Table 2. Rocky Reef Connectivity Equations. ....	9
Table 3. Rocky Reef Relief Index Equations. ....	11
Table 4. Rocky Reef Residence Time Equations.....	12
Table 5. Rocky Reef Substrate Equations.....	13
Table 6. Kelp Temperature Equations.....	14
Table 7. Kelp Substrate Equations. ....	15
Table 8. Regional Kelp Depth Equations. ....	16
Table 9. Local Kelp Depth Equations.....	17
Table 10. Eelgrass Circulation Equations. ....	19
Table 11. Eelgrass Depth Equations.....	20
Table 12. Eelgrass Percent Fines Equations.....	21
Table 13. Eelgrass Temperature Equations. ....	22
Table 14. Oyster Salinity Equations. ....	23
Table 15. Oyster Depth Equations. ....	24
Table 16. Tidal Marsh Elevation Equations. ....	25
Table 17. Tidal Marsh Sediment Grain Size Categories. ....	26
Table 18. Tidal Marsh Grain Size Equations.....	26
Table 19. Tidal Marsh Salinity Equations. ....	27
Table 20. Tidal Marsh Connectivity Equations.....	28
Table 21. Tidal Marsh Habitat Size Equations.....	29
Table 22. Sandy Islands Equations for Vegetation Cover for Least Tern. ....	31
Table 23. Sandy Islands Equations for Vegetation Cover for Snowy Plover. ....	32
Table 24. Sandy Islands Effective Size Equations.....	33
Table 25. Sandy Islands Elevation Equations. ....	34
Table 26. Sandy Islands Grain Size Equations. ....	35
Table 27. Sandy Islands Distance Equations. ....	36
Table 28. Modeling outputs for Alternative 1. ....	42
Table 29. Modeling outputs for Alternative 4. ....	45

## Background

The East San Pedro Bay (Bay) is located along the Pacific coast within the city of Long Beach, California. The Bay, like many along the Southern California coast, has undergone extensive human modification as the result of development of navigation channels, installation of piers and breakwaters and other alterations for human use. These modifications have resulted in the loss of critical habitat types, such as estuary wetlands, decreased biodiversity and reduction of natural habitat that support a variety of wildlife and marine species. In response to the loss of ecosystem structure and function, a partnership between the U.S. Army Corps of Engineers (USACE) and the City of Long Beach (City) was formed to investigate potential restoration measures that could recover and restore lost ecosystem structure and function.

In 2015, the Los Angeles District (District) began a feasibility study to determine if there is a federal interest in restoring the ecosystem within the Bay. As part of the feasibility study, a quantitative ecological model is needed to quantify potential benefits of proposed restoration measures. Model outputs, combined with estimated costs per restoration measure, will then be used in the planning process along with the National Environmental Policy Act (NEPA) analysis and other considerations to recommend a tentatively selected plan (TSP) for the restoration of the Bay. Additionally, the model used in the calculation of benefits per restoration alternative needs to be approved or certified for use by the USACE. In February 2016, in pursuit of an ecosystem planning model, the District convened an initial model development workshop. The workshop was used to develop an early ecosystem conceptual model that refined the District’s knowledge of the drivers, stressors and functions that interact to form the ecosystem of the Bay. The initial conceptual model was refined in November 2016 and serves as a template for a quantitative ecosystem model described in this report (Figure 1).

## Model Background and Purpose

The Southern California Coastal Bay Ecosystem Model (Bay Model) was developed to assist in the planning process of the East San Pedro Bay Ecosystem Restoration Feasibility Study (Study). The study purpose was to recommend actions that will restore lost ecosystem structure and function and increase native biodiversity of the Bay. The Bay sits in the middle of the Southern California Bight, a coastal region from Point Conception by Santa Barbara to the Mexico border. This region has a rare Mediterranean climate only found in a few regions on earth. The Southern California Bight acts as a transition between multiple warm and cold-water masses from the Pacific subarctic, Pacific equatorial, to the North Pacific. As a transition zone, many native aquatic species from the different water masses move through the Southern California Bight.

In 2015, the Los Angeles District began the Study to determine if there is a federal interest in restoring the ecosystem within the Bay. During a USACE feasibility study, a quantitative ecological model is needed to quantify potential benefits of proposed restoration measures. Model outputs, combined with estimated costs per restoration measure, will then be used in the planning process along with the NEPA analysis and other considerations to recommend a tentatively selected plan (TSP) for the restoration of the study area. Additionally, the model used in the calculation of benefits per restoration alternative needs to be approved or certified for use by the USACE. Ecological models may be developed in a variety of ways, however, this type of study is considered a partnership between the USACE and the City of Long Beach with close collaboration of other agencies and organizations. This type of partnership requires the use of a model development strategy that allows for inputs from a variety of sources, encourages consensus on model parameters and ownership of model outputs. A mediated model development process was used to develop the East San Pedro Bay Habitat Evaluation Model.

In February of 2016 in pursuit of an ecosystem planning model the Los Angeles District convened an initial model development workshop. The workshop included members of the Los Angeles District’s study team, engineers, biologists, hydrologist, economists and program managers. The workshop was used to develop an early ecosystem conceptual model that refined the Los Angeles District’s knowledge of the drivers, stressors and functions that interact to form the ecosystem of the Bay (Figure 1). A second workshop, November 2016, was conducted to develop the conceptual model into a quantitative model. The second workshop included the study team and members of the study’s Technical Advisory Council (TAC). The TAC is an organization that provides critical insight and advice to the study team and the City of Long Beach during the planning phases of the study. The TAC includes representatives from several state and federal resource agencies as well as marine biologists from local universities and local organizations (Table 1).

**TABLE 1. TECHNICAL ADVISORY COUNCIL MEMBERS AND AFFILIATION.**

<b>Technical Advisory Council Participant</b>	<b>Affiliation</b>
Adams, Loni	California Department of Fish and Wildlife
Avery, Jon	U.S. Fish and Wildlife Service
Chesney, Bryant	National Oceanic and Atmospheric Administration
Gillett, David	Southern California Coastal Water Research Project
Nye, LB	California State Water Resources Control Board
Paznokas, William	California Department of Fish and Wildlife
Pondella, Daniel	Occidental College
Simon, Larry	California Coastal Commission
Whitcraft, Christine	California State University Long Beach

The purpose of the Model is to assist in the planning phase of an ecosystem restoration project focused on restoring coastal ecosystems that are located within the Southern California Region in North America. The Model is able to capture the quality or suitability of habitat types associated with coastal ecosystems. For the purposes of the Model, habitat quality or suitability is defined as the ability of a

particular habitat to support species of concern. As the suitability of a habitat increases, so does the likelihood that habitat will support a given suite of species. The model is able to capture the baseline conditions and predict increases in habitat quality under different future restoration scenarios in a given study area, given the study area is located in within the Southern California Region of North America. Application outside of the model domain would need additional scrutiny for appropriate applicability. It should be noted that the Model, though generically referred to as habitat evaluation model, is not meant to represent as or be tied to the formal Habitat Evaluation Procedures Process or Handbook developed by the U.S. Fish and Wildlife Service.

The Model is designed as a spatially-explicit, grid based model that uses a series of habitat specific linear equations to calculate habitat suitability for restoration of the following habitat types: rocky reef, kelp forest, eelgrass, oyster reef, tidal salt marsh and sandy islands. The model is composed of six habitat types, each with a series of 2-6 variables that are assigned a dimensionless Suitability Index (SI) value that represents the relationship between an environmental variable and habitat suitability for the habitat of interest. Each SI is represented quantitatively as a series of linear suitability curves, with a minimum value of 0 for unsuitable to 1.0 for optimal habitats. Suitability curves are formulated as step-functions with linear approximations between each step. A habitat specific HSI score is calculated as the geometric mean of the individual SI values and represents the overall suitability of a particular location for restoration (Pollack et al. 2012). Data and equations are imported into a GIS and applied to specific geo-referenced locations. The geospatial location of each habitat type is considered so that location specific data can be used to calculate SI values for each variable of interest. Spatial coverage of habitat (acreage) can then be used in combination with habitat HSI scores to calculate Habitat Units, as described in the “Calculating Habitat HIS” section of this document.

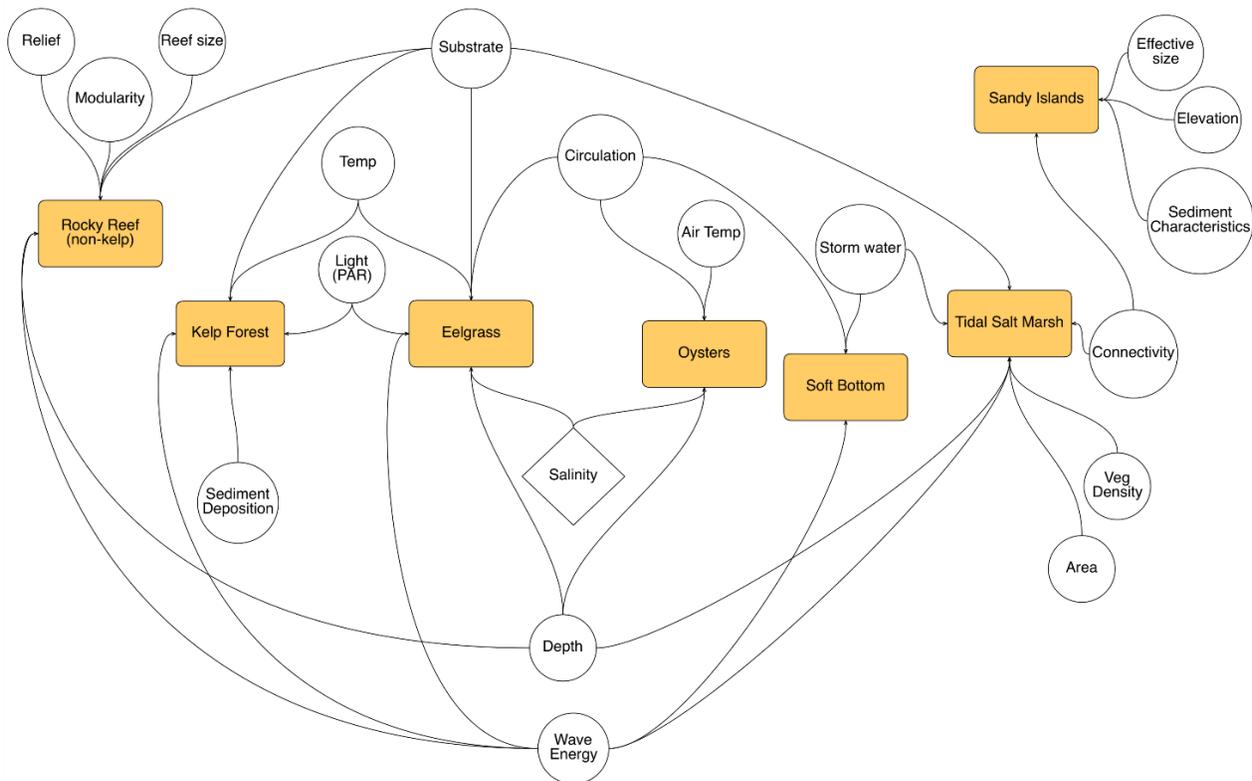
This document is intended to provide documentation of the Model’s technical details, use and relevant information for USACE model certification (EC 1105-2-412, PB 2013-02).

## Introduction

This report presents the results of steps taken to further the development of a quantitative ecosystem model that will be used to recommend a TSP for the restoration of the Bay for the USACE planning process. This report presents a refined conceptual model as well as the quantification process used in the model development process. Prior to these steps, model conceptualization was developed through workshops and meetings between the District planning branch, the Study’s Technical Advisory Committee (TAC), the City of Long Beach and the Engineer Research and Development Center (ERDC). For purposes of this report here is a brief review of model objectives and limitation:

- to be able to distinguish between proposed restoration alternatives, including the Future without Project alternative;
- to be able to include input from other agencies and stakeholders once a conceptual model or model framework has been developed;
- to be relevant to habitats of interest and at the ecosystem level, not just the species; and
- to communicate benefits derived from a recommended restoration plan.

This model is not meant to project absolute system changes, but relative differences between proposed restoration alternative actions.



**FIGURE 1. REVISED CONCEPTUAL MODEL OF THE EAST SAN PEDRO BAY ECOSYSTEM AND TARGET HABITAT TYPES.**

The conceptual Habitat Suitability Model (Figure 1) was further refined during a workshop held in November 2016. This workshop was led by ERDC and participants included representatives from the District, the City and TAC members. The revised model initially focused on seven habitat types being considered as part of the restoration effort: rocky reef (non-kelp), kelp forest, eelgrass, oyster reef, soft bottom substrate, tidal salt marsh and sandy/bird islands. Soft bottom substrate was subsequently removed from the list of habitat types to model leaving six habitat types. For each habitat type, individual conceptual models were considered to identify critical physical or chemical parameters and develop mathematical curves describing the relationships between the parameters and the habitat of interest (i.e. curve development). When identifying parameters, a distinction was made between design and model parameters. Model parameters were defined as parameters that are critical for determining an index of habitat suitability. Parameters that drive placement or construction of restoration alternatives (e.g., sediment color for Sandy Islands habitat) were designated as design parameters or design considerations. Design parameters were considered during the formulation of the restoration alternatives, but excluded from the model.

## Habitat Parameters and Response Curves

The following sections describe critical parameters that were identified by subject matter experts (SMEs) on the TAC within the November 2017 workshop. For each habitat parameter, a curve was developed by the SMEs using a combination of expert knowledge of a particular habitat and parameter as well as related published results from peer reviewed literature. For each habitat model parameter, we provide a visual description of the curve as well as a series of mathematical equations that describe the curve. In addition, details regarding the information used to develop each curve (i.e., expert opinion and literature) are summarized for individual parameters.

We approached the modeling of habitat benefits conservatively in that we assume the benefits per habitat type do not extend beyond the boundaries of the habitat itself. While this is a conservative approach, it does not overestimate the benefits of a specific habitat type.

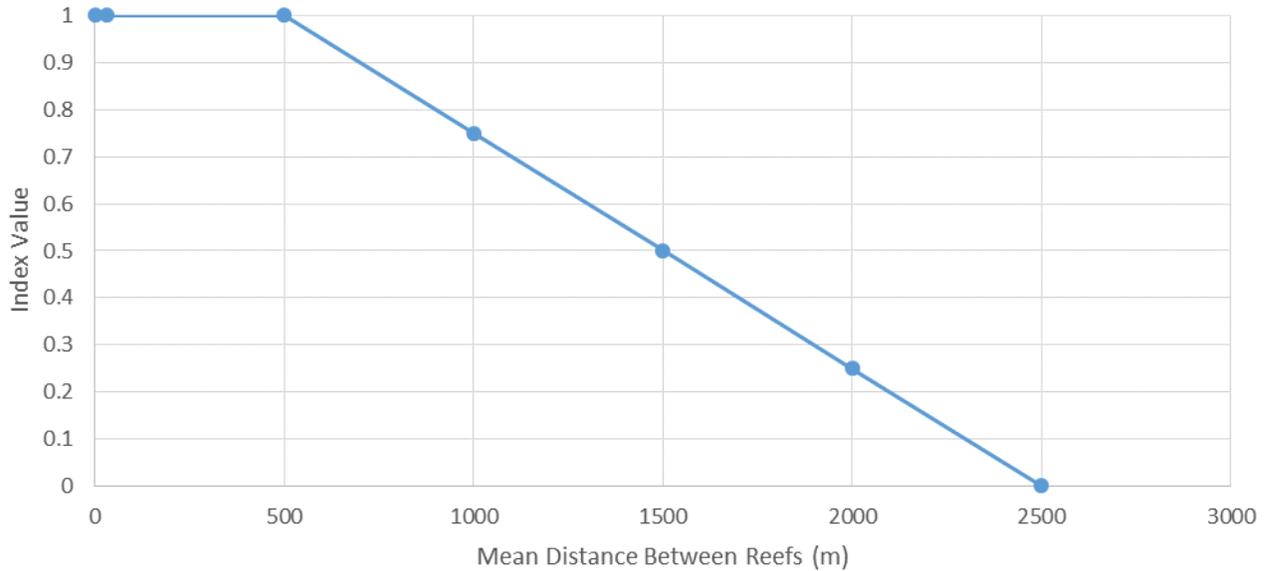
The temporally dynamic input variables were generated from the hydrodynamic and water quality models (provided by Everest Consulting). Based on all available information, a two-week average for Hydro-WQ parameters is the minimum time period for which an ecological response could be observed in nature. In general, the hydrodynamic and environmental conditions in East San Pedro Bay have a biphasic cycle, changing between summer and winter. We analyzed the data provided from the summer and winter runs for the hydrodynamic/WQ models, and generated mean conditions for model parameters for both summer and winter. We then ran a sensitivity analysis to determine which season was limiting for each habitat type. Results indicated that summer conditions were the most extreme and most critical for determining habitat suitability, so the Model uses summer values.

### Rocky Reef (non-kelp)

Critical parameters identified for the rocky reef habitat include connectivity as measure of distance between reefs, reef relief and residence time as a measure of circulation. In addition, a categorical substrate parameter indicating the presence or absence of suitable substrate is critical to development and presence of rocky reef habitat. The rocky reef and the structure it provides (hard substrate, crevices, etc.) are valuable habitat for many species including target species such as the black abalone. Kelp may also opportunistically establish on rocky reef substrate even in cases in which the reef was not established as a kelp restoration site.

## Connectivity

Connectivity is indicative of the distance between rocky reef habitats. As determined by the TAC, 0-500m was designated as a reasonable distance for species to cross between reefs, maintaining ideal connectivity. At distances greater than 500m, we modeled a linear decline in index value that converged to zero at 2500m.



**FIGURE 2. ROCKY REEF CONNECTIVITY CURVE**

**TABLE 2. ROCKY REEF CONNECTIVITY EQUATIONS.**

Variable	Equation	Eq#
$0 \leq \text{Distance} \leq 500$	$HSI_{\text{Distance}} = 1 + (0 * \text{Distance})$	(1)
$500 < \text{Distance} \leq 2500$	$HSI_{\text{Distance}} = 1.25 + (-0.0005 * \text{Distance})$	(2)
$2500 < \text{Distance}$	$HSI_{\text{Distance}} = 0 + (0 * \text{Distance})$	(3)

### Reef Relief

Reef relief represents a categorical parameter based on relief type. Relief is measured as a combination of slope and elevation of reef height off bottom, and ranges from horizontal (flat) to vertical (wall) with the following designations (Pondella et al 2015; Greene et al 1999):

Flat = 0-0.1m elevation and 0-5° slope;

Low = 0.1-0.5m elevation;

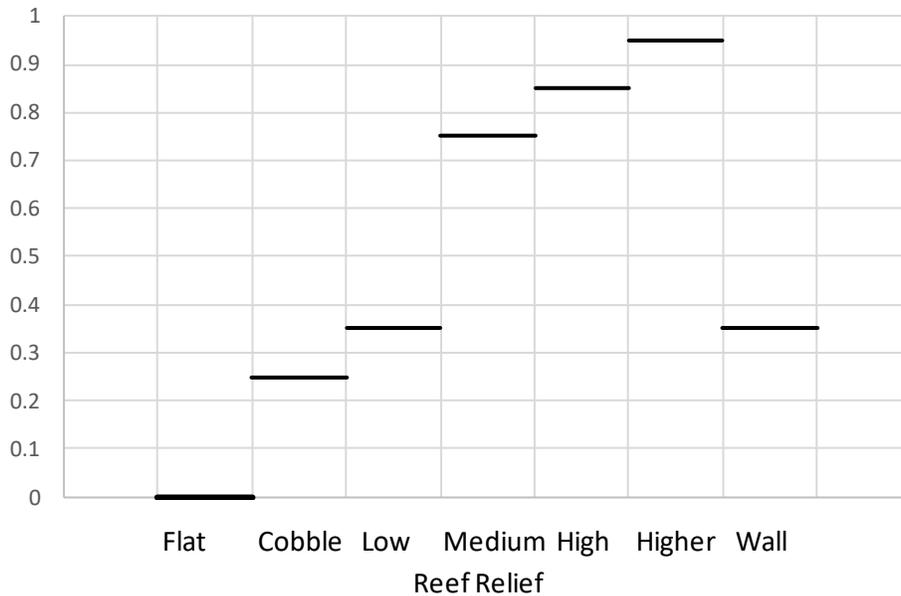
Medium = 0.6-1.0m elevation;

High = 1-2m elevation;

Higher > 2m elevation; and

Wall = vertical slope of at least 90°.

Most reefs are between 1-3 m in height. Quality of rocky reef habitat has been measured as biomass production. Middle and higher relief reefs are most productive, small and flat relief reefs and walls have low production. Index values associated with each reef type were determined by SMEs in the TAC. In general, increased topographic relief also increases surface areas (Pondella et al. 2015).



**FIGURE 3. ROCKY REEF RELIEF INDEX VALUES.**

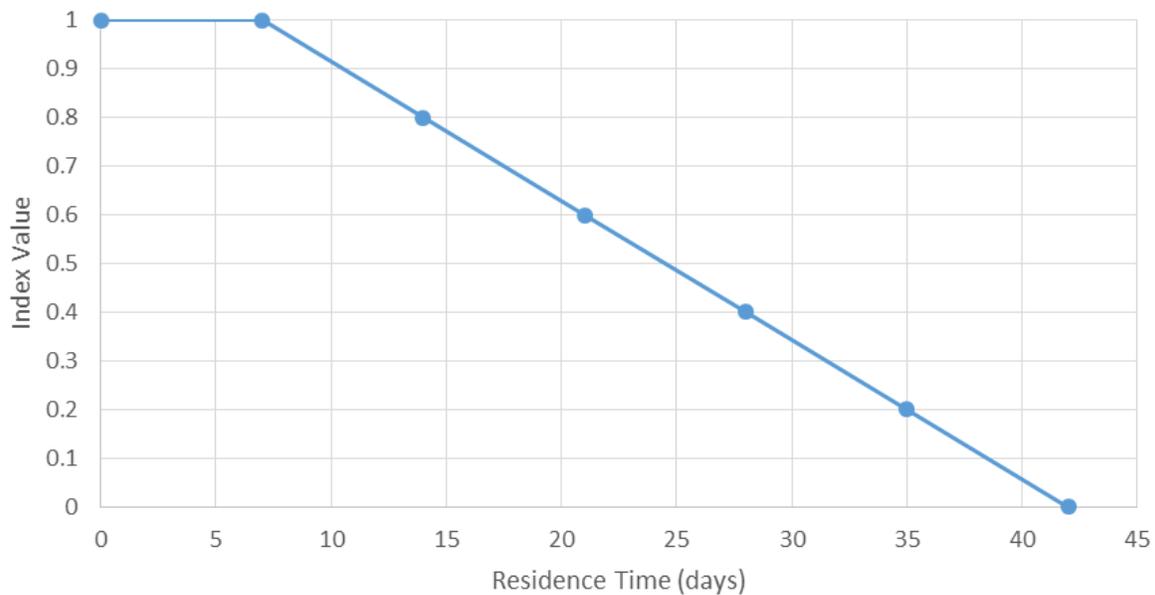
Index values, as developed by the TAC and Pondella et al 2015, and Pondella personal communication, are presented in Table 2.

**TABLE 3. ROCKY REEF RELIEF INDEX EQUATIONS**

Relief category	Index Value
Flat	0
Cobble	0.25
Low	0.35
Medium	0.75
High	0.85
Higher	0.95
Wall	0.35

### Residence Time

In a separate, related effort of the Study, a particle tracking study was developed for the bay to determine residence time with the Bay and to identify predicted circulation impacts due to proposed structural changes (such as breakwater removal or notching). This model was completed by RECON Environmental, Inc. for the LA District. For the habitat model, residence time, as determined by RECON Environmental, Inc. is used as a proxy for water circulation within the system. Higher circulation, corresponding to short water residence time, is more beneficial to species occupying rocky reef habitat than low circulation (long residence times) for a number of reasons including plankton replenishment, and improved nutrient and water quality (Lowe and Bray 2006). While the residence data are specific to one locality (East San Pedro Bay), the resulting residence time curve (Figure 4), represents a reasonable relationship between residence time and index values the is appropriate for use in localities within the regional domain.



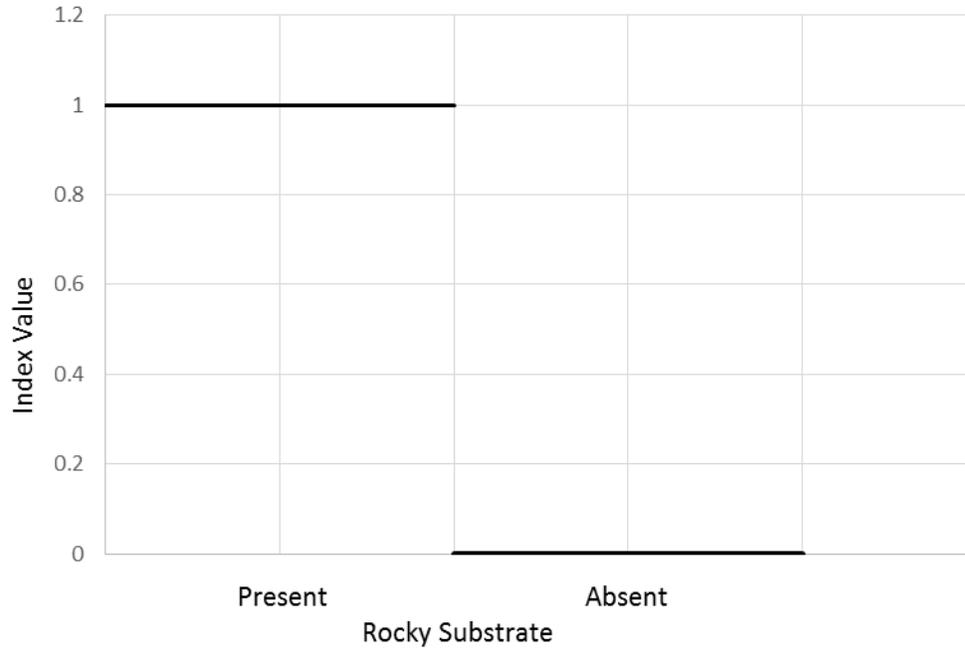
**FIGURE 4. ROCKY REEF RESIDENCE TIME CURVE.**

**TABLE 4. ROCKY REEF RESIDENCE TIME EQUATIONS.**

Variable	Equation	Eq#
$7 \leq \text{Residence Time} < 14$	$HSI_{\text{Residence Time}} = 1.0002 + (-0.0143 * \text{Residence Time})$	(1)
$14 < \text{Residence Time} \leq 42$	$HSI_{\text{Residence Time}} = 1.201 + (-0.0286 * \text{Residence Time})$	(2)
$42 < \text{Residence Time}$	$HSI_{\text{Residence Time}} = 0 + (0 * \text{Residence Time})$	(3)

### Substrate

Substrate type represents a categorical parameter. As rocky reefs require hard substrate (Pondella et al 2015), the substrate index value is equal to 1 when suitable rocky substrate is present and the index value is equal to 0 when hard substrate is absent.



**FIGURE 5. ROCKY REEF SUBSTRATE INDEX VALUES.**

**TABLE 5. ROCKY REEF SUBSTRATE EQUATIONS**

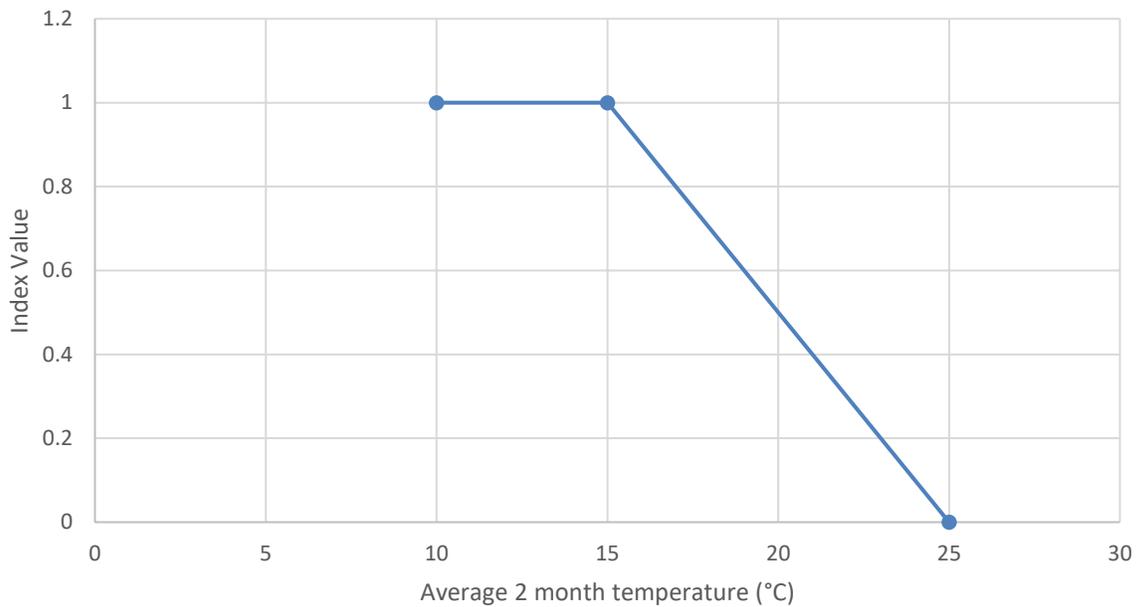
Substrate Category	Index Value
Absent	0
Present	1

## Kelp Forest

Critical parameters identified for the kelp forest habitat included water temperature, substrate and depth as an indicator of wave energy.

### Temperature

There is a well-documented relationship between water temperature and density and nutrient concentrations essential for kelp growth (Jackson 1983). There is also a strong negative correlation between temperature and nitrate, the nutrient most likely to limit growth in the southern California Bight (North et al. 1982) When water temperatures are above 15°C, concentrations of nitrate are negligible and growth becomes limited (Zimmerman and Kremer 1984, Tegner and Dayton 1987 and references therein).



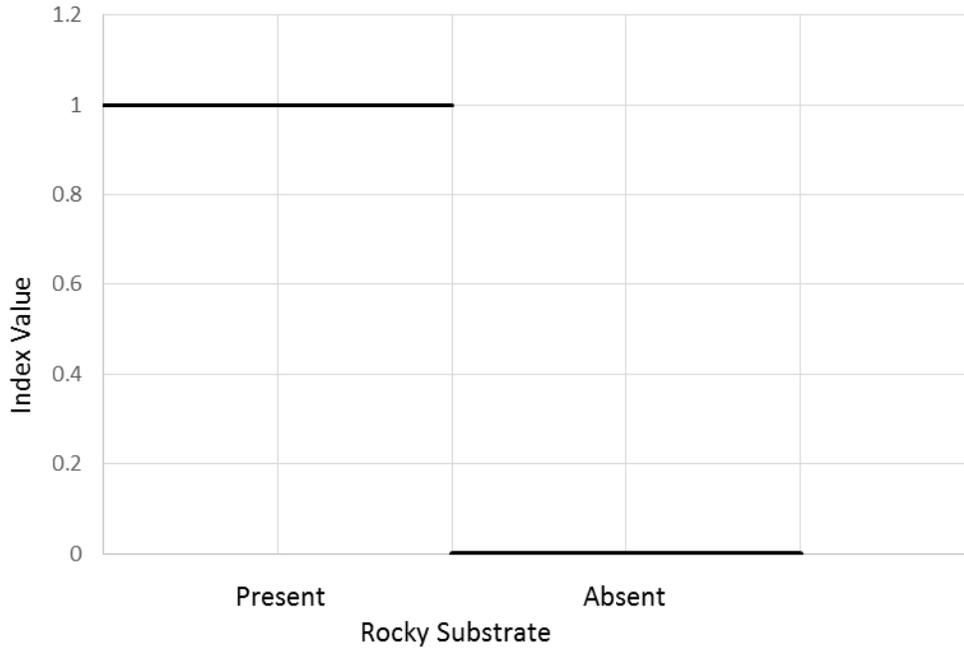
**FIGURE 6. KELP TEMPERATURE CURVE.**

**TABLE 6. KELP TEMPERATURE EQUATIONS.**

Variable	Equation	Eq#
$10 \leq \text{Mean two month Temperature} < 15$	$HSI_{Temp} = 1 + (0 * Temp)$	(1)
$15 < \text{Mean two month Temperature} \leq 25$	$HSI_{Temp} = 2.5 + (-0.1 * Temp)$	(2)
$25 < \text{Mean two month Temperature}$	$HSI_{Temp} = 0 + (0 * Temp)$	(3)

### Substrate

Substrate type represents a categorical parameter. When suitable rocky substrate is present, the substrate index value is equal to 1 and when substrate is absent, the index value is equal to 0 (See North 1971).



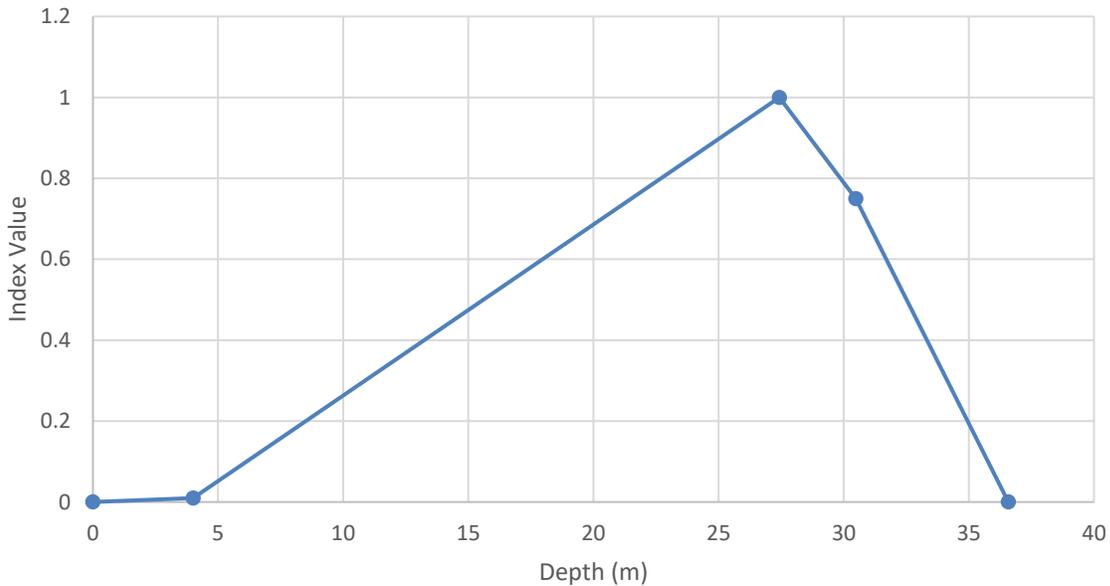
**FIGURE 7. KELP SUBSTRATE INDEX VALUES.**

**TABLE 7. KELP SUBSTRATE EQUATIONS**

Substrate Category	Index Value
Absent	0
Present	1

## Depth

In Southern California, near offshore islands with clear water, kelp can grow at depths of over 30m (Feder et al. 1974). In coastal waters that are typically more turbid, kelp grows in depths as shallow as ~ 3 or 4 m (Zimmerman and Kremer 1984, Feder et al. 1974). Figure 8 and Table 5 represent a regional HSI curve and corresponding equations based on the historical literature (Feder et al. 1974; Zimmerman and Kremer 1984).

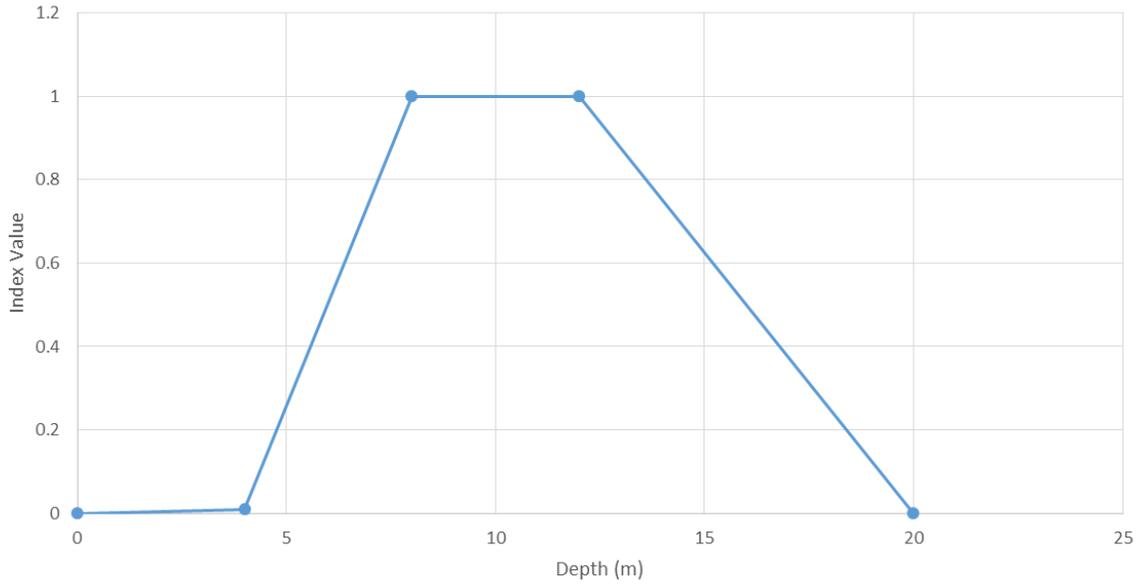


**FIGURE 8. REGIONAL KELP DEPTH CURVE.**

**TABLE 8. REGIONAL KELP DEPTH EQUATIONS.**

Variable	Equation	Eq#
$0 \leq \text{Depth} < 4$	$HSI_{\text{Depth}} = 0 + (0.0025 * \text{Depth})$	(1)
$4 < \text{Depth} \leq 27.4$	$HSI_{\text{Depth}} = -0.1576 + (0.0422 * \text{Depth})$	(2)
$27.4 < \text{Depth} \leq 30.5$	$HSI_{\text{Depth}} = 3.2494 + (-0.082 * \text{Depth})$	(3)
$30.5 < \text{Depth} \leq 36.6$	$HSI_{\text{Depth}} = 4.4988 + (-0.123 * \text{Depth})$	(4)
$36.6 < \text{Depth}$	$HSI_{\text{Depth}} = 0 + (0 * \text{Depth})$	(5)

Review of the kelp depth curves by members of the TAC highlighted some potential local differences in the observed contemporary kelp-depth relationship within East San Pedro Bay. Specifically, the ideal depth and depth range of existing kelp habitat within the bay is more shallow than predicted on a regional scale (Chesney and Pondella, personal communication). As a result, we used the following modified curves as a local assessment of Kelp depth HSI.



**FIGURE 9. LOCAL KELP DEPTH CURVE.**

**TABLE 9. LOCAL KELP DEPTH EQUATIONS.**

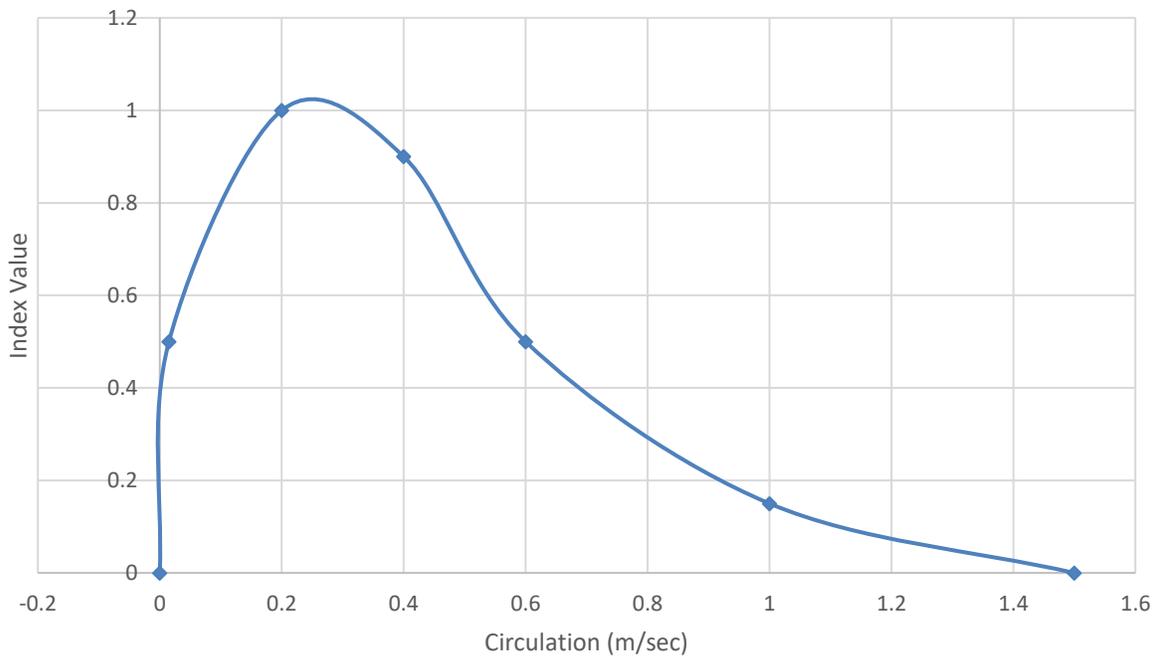
Variable	Equation	Eq#
$0 \leq \text{Depth} < 4$	$HSI_{\text{Depth}} = 0 + (0.0025 * \text{Depth})$	(1)
$4 < \text{Depth} \leq 8$	$HSI_{\text{Depth}} = -0.98 + (0.2475 * \text{Depth})$	(2)
$8 < \text{Depth} \leq 12$	$HSI_{\text{Depth}} = 1 + (0 * \text{Depth})$	(3)
$12 < \text{Depth} \leq 20$	$HSI_{\text{Depth}} = 2.5 + (-0.125 * \text{Depth})$	(4)
$20 < \text{Depth}$	$HSI_{\text{Depth}} = 0 + (0 * \text{Depth})$	(5)

## Eelgrass

The eelgrass habitat, focused on *Zostera* sp., has the following critical parameters: water circulation, depth, substrate, and temperature. Additional design considerations include salinity and wave energy. Salinity could conceptually serve as a go/no go point within the conceptual model. If wave energy is included, it would show a curve similar to the wave energy curve for kelp, with a smaller area of optimum than kelp, and smaller values on the x-axis. In terms of design considerations, wave energy is critical, as too much wave height in a shallow depth is detrimental to eelgrass habitat.

### *Circulation*

The index value for circulation is described in Figure 10 and is based on experience from SMEs as determined by TAC. This relationship is based on regional knowledge, but also depicts a reasonable regional curve. While *Zostera* requires flow over habitat, wave energy also has sheer stress that may uproot plants (Koch 2001).



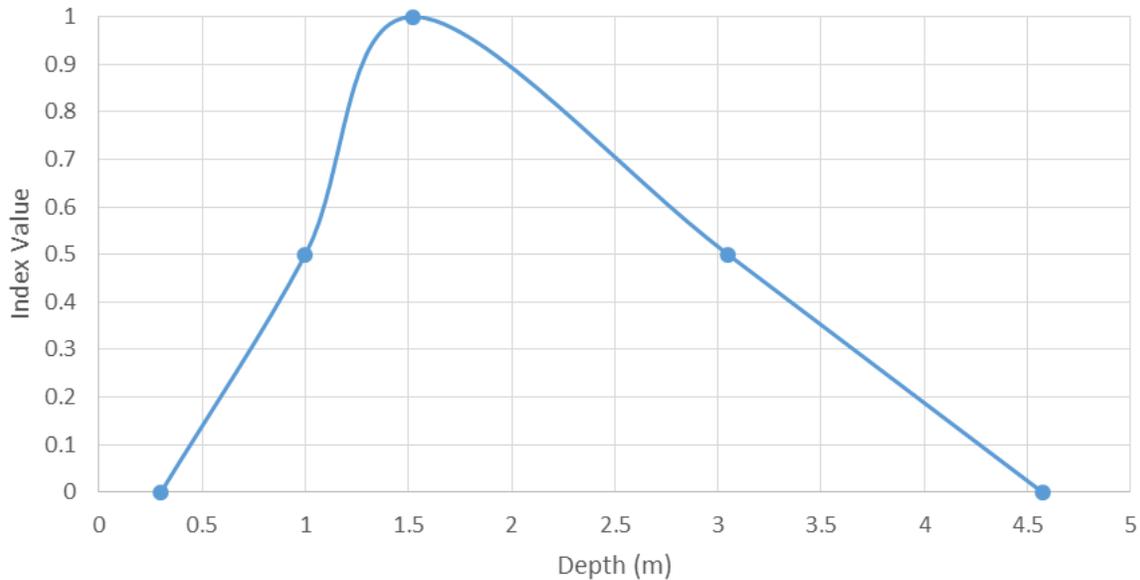
**FIGURE 10. EELGRASS CIRCULATION CURVE.**

**TABLE 10. EELGRASS CIRCULATION EQUATIONS.**

Variable	Equation	Eq#
$0 \leq \text{Circulation} < 0.015$	$HSI_{\text{Circulation}} = 0 + (33.3333 * \text{Circulation})$	(1)
$0.015 < \text{Circulation} \leq 0.02$	$HSI_{\text{Circulation}} = 0.4595 + (2.027 * \text{Circulation})$	(2)
$0.02 < \text{Circulation} \leq 0.04$	$HSI_{\text{Circulation}} = 1.1 + (-0.5 * \text{Circulation})$	(3)
$0.04 < \text{Circulation} \leq 0.06$	$HSI_{\text{Circulation}} = 1.7 + (-2 * \text{Circulation})$	(4)
$0.06 < \text{Circulation} \leq 1.0$	$HSI_{\text{Circulation}} = 1.025 + (-0.875 * \text{Circulation})$	(5)
$1.0 < \text{Circulation} \leq 1.5$	$HSI_{\text{Circulation}} = 0.45 + (-0.3 * \text{Circulation})$	(6)
$1.5 < \text{Circulation}$	$HSI_{\text{Circulation}} = 0 + (0 * \text{Circulation})$	(7)

## Depth

Critical depth values were identified from unpublished data (Merkel and Associates) that is being finalized by National Marine Fisheries Service (NMFS). At depths that are exposed (above Mean Low Low Water (MLLW)) eelgrass may occur in some situations, but is not expected to occur within the Bay area due to stress from a combination of wave energy and beachgoer trampling. As a result, the TAC determined to limit the eelgrass depth curve to depths below MLLW. At depths greater than ~1.5 m, water clarity and photosynthetically active light become reduced, limiting photosynthetic ability.



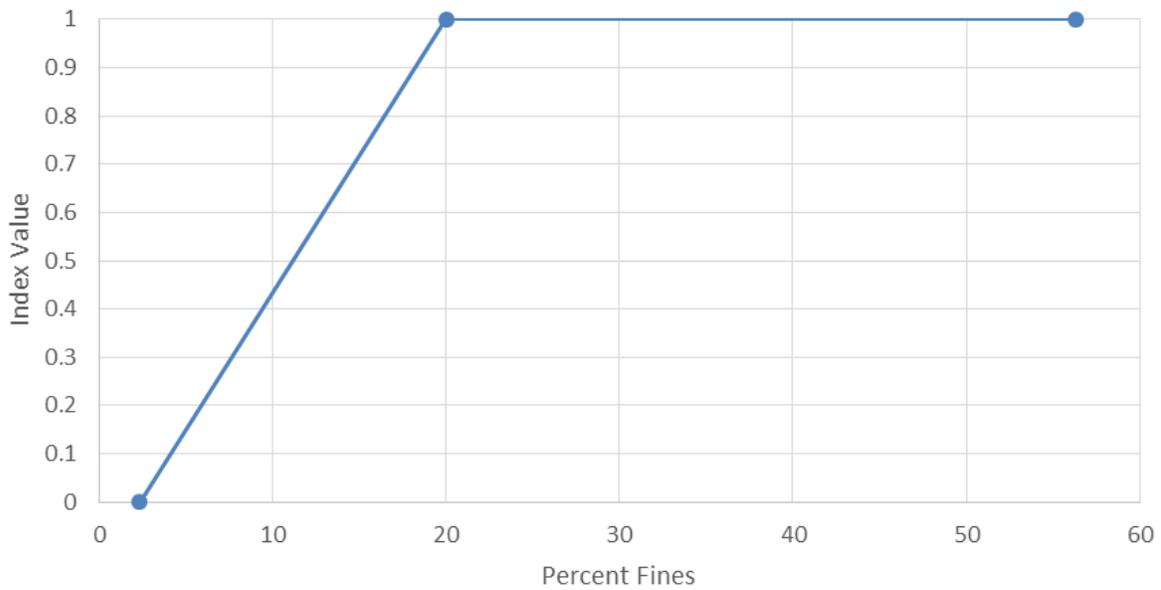
**FIGURE 11. EELGRASS DEPTH CURVE.**

**TABLE 11. EELGRASS DEPTH EQUATIONS.**

Variable	Equation	Eq#
$0.3 \leq \text{Depth} < 1$	$HSI_{\text{Depth}} = 0.2143 + (0.7143 * \text{Depth})$	(1)
$1 < \text{Depth} \leq 1.524$	$HSI_{\text{Depth}} = -0.4542 + (0.9542 * \text{Depth})$	(2)
$1.524 < \text{Depth} \leq 4.572$	$HSI_{\text{Depth}} = 1.5 + (-0.3281 * \text{Depth})$	(3)
$4.572 < \text{Depth}$	$HSI_{\text{Depth}} = 0 + (0 * \text{Depth})$	(4)

## Substrate

Our assumptions include the fact that the majority of current substrate conditions are sand and, with the exception of rocky reef, does not include gravel, cobble or boulders. Substrate conditions with < 20% silt and clay are ideal for seagrass restoration (Vaudry 2008, Koch 2001). Sediments within beds of SAV are finer than the sediments in adjacent, unvegetated areas (Koch 2001, Wanless 1981, Almasi et al. 1987), leading to a decrease in porewater exchange with the water column (Huettel and Rusch 2000) and potential increase in nutrient concentrations within the sediments (Kenworthy et al. 1982, Koch 2001). The range of percent fines used to develop eelgrass curves and equations (2.3 – 56.3%; Figure 12 and Table 9) represent the range of percent fines in sediments in which *Z. marina* colonizes (Koch 2001).



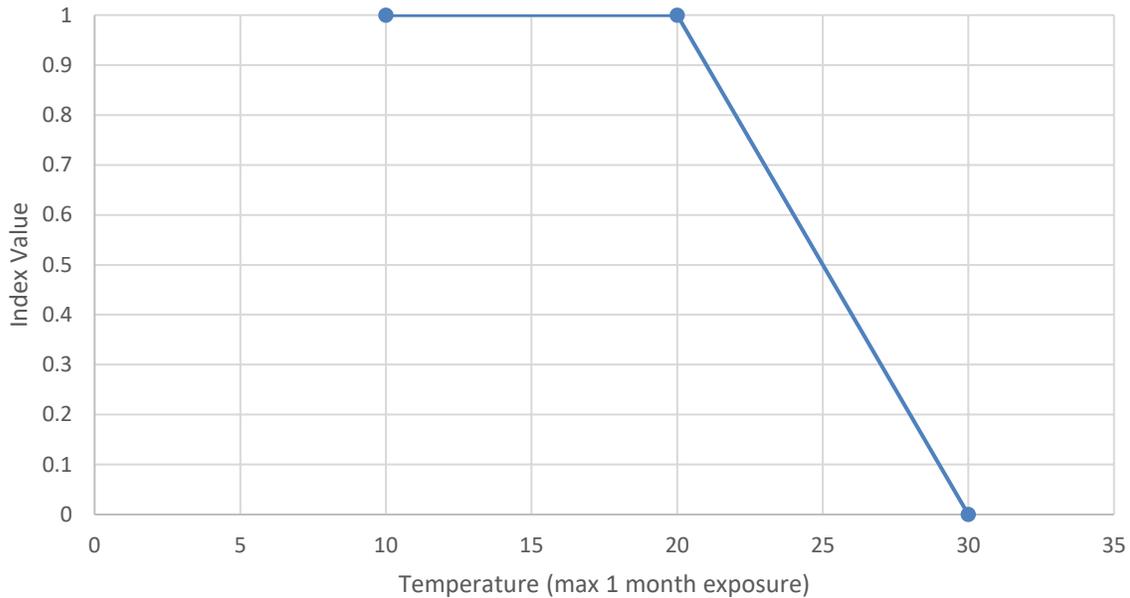
**FIGURE 12. EELGRASS PERCENT FINES CURVE.**

**TABLE 12. EELGRASS PERCENT FINES EQUATIONS.**

Variable	Equation	Eq#
$2.3 \leq \text{Percent Fines} < 20$	$HSI_{\text{percent Fines}} = -0.13 + (0.0565 * \text{Percent Fines})$	(1)
$20 < \text{Percent Fines} \leq 56.3$	$HSI_{\text{percent Fines}} = 1 + (0 * \text{Percent Fines})$	(2)
$56.3 < \text{Percent Fines}$	$HSI_{\text{percent Fines}} = 0 + (0 * \text{Percent Fines})$	(3)

## Temperature

Critical values of temperature (°C) were determined from Moore and Jarvis, 2008. Typical winter temperature ranges may slow eelgrass growth, but survival is not impacted in the 10-20°C range. However, summer temperature ranges between 20-30°C cause stress and plant mortality (Moore and Jarvis 2008). Monthly values of temperature should be used as inputs for this parameter.



**FIGURE 13. EELGRASS TEMPERATURE CURVE.**

**TABLE 13. EELGRASS TEMPERATURE EQUATIONS.**

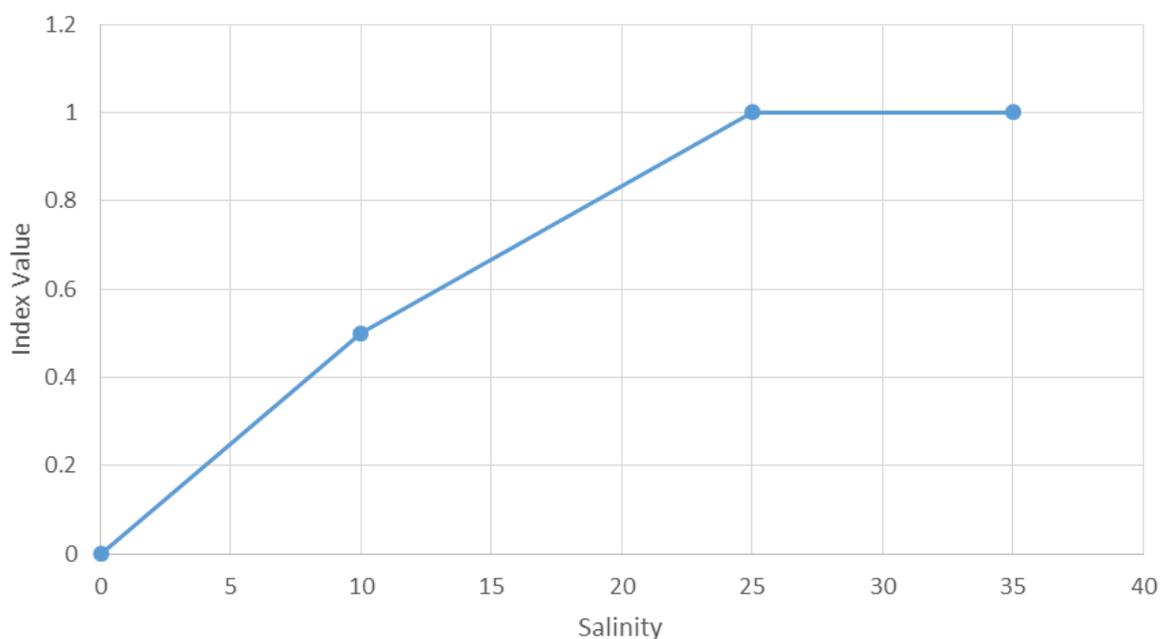
Variable	Equation	Eq#
$10 \leq \text{Temperature} < 20$	$HSI_{\text{Temperature}} = 1 + (0 * \text{Temperature})$	(1)
$20 < \text{Temperature} \leq 30$	$HSI_{\text{Temperature}} = 3 + (-0.1 * \text{Temperature})$	(2)
$30 < \text{Temperature}$	$HSI_{\text{Temperature}} = 0 + (0 * \text{Temperature})$	(3)

## Oyster Reef

Primary parameters identified for oyster reef habitat were salinity and depth, which are similar parameters to other index-based oyster models (Soniati and Brody 1988 , Swannack et al. 2015). Note that these parameters are not directed at juveniles, but at adult survival. Oysters require hard substrate for attachment, but substrate was not included as a parameter because substrate placement is a design consideration in the Bay. An assumption of this model is that if the proper substrate is placed in the Bay, then oyster substrate is not limiting. Other factors that were considered but not included in the current model were ocean acidification, public access (may be more of a placement/design consideration), and Total Maximum Daily Load (TMDL) (due to liability for tissue contamination).

### Salinity

Salinity of less than 25 parts per thousand (ppt) is suboptimal, greater than 25 is optimal, and salinities less than 10 ppt are detrimental to oysters (Hopkins, 1937).



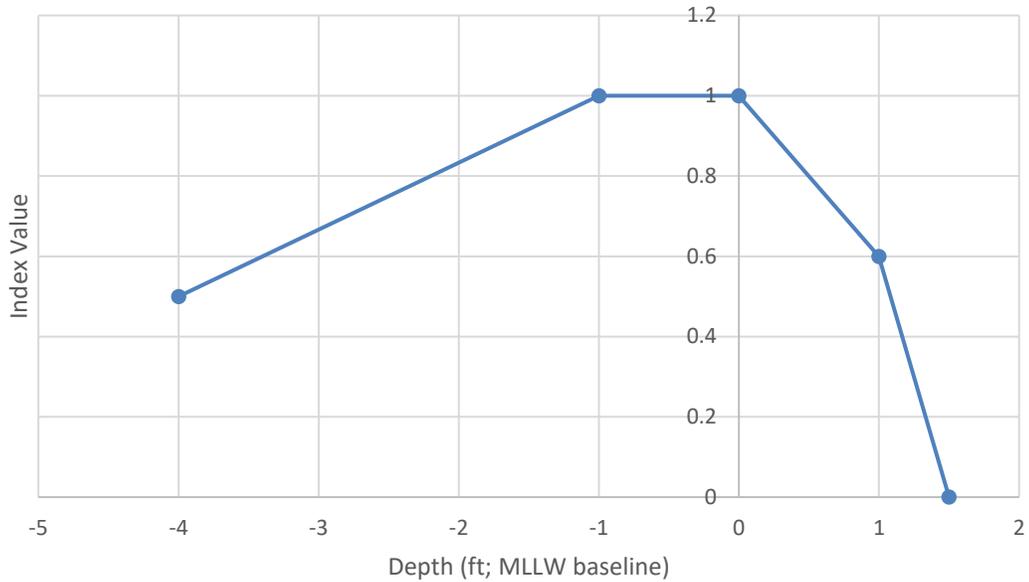
**FIGURE 14. OYSTER SALINITY CURVE.**

**TABLE 14. OYSTER SALINITY EQUATIONS.**

Variable	Equation	Eq#
$0 \leq \text{Salinity} < 10$	$HSI_{\text{Salinity}} = 0 + (0.05 * \text{Salinity})$	(1)
$10 \leq \text{Salinity} < 25$	$HSI_{\text{Salinity}} = 0.1675 + (0.0333 * \text{Salinity})$	(2)
$25 < \text{Salinity} \leq 35$	$HSI_{\text{Salinity}} = 1 + (0 * \text{Salinity})$	(3)

## Depth

Optimum depth for adult oysters is 1 to -2 feet from MLLW (Baker 1995). Although -2 ft MLLW is an optimal depth, exposure to changing air temperatures will limit mortality at this depth, lowering the index value.



**FIGURE 15 OYSTER DEPTH CURVE.**

**TABLE 15. OYSTER DEPTH EQUATIONS.**

Variable	Equation	Eq#
$-4 \leq Depth < -1$	$HSI_{Depth} = 1.1667 + (0.1667 * Depth)$	(1)
$-1 < Depth \leq 0$	$HSI_{Depth} = 1 + (0 * Depth)$	(2)
$0 < Depth \leq 1$	$HSI_{Depth} = 1 + (-0.4 * Depth)$	(3)
$1 < Depth \leq 1.5$	$HSI_{Depth} = 1.8 + (-1.2 * Depth)$	(4)
$1.5 < Depth$	$HSI_{Depth} = 0 + (0 * Depth)$	(5)

## Tidal Salt Marsh

Tidal salt marsh parameters include elevation, salinity, substrate (grain size), and connectivity (distance to other wetlands and marsh size). Marsh connectivity is coupled to persistence (stability, resilience, etc.), and freshwater flow (river flow) resulting from storm events.

### Elevation

Comprehensive studies of Southern California salt marsh habitat have identified ideal elevation ranges and thresholds that define high and low marsh boundaries. These data are summarized in the curve below (Zedler et al. 1982). These elevations are tied to the duration of maximum tidal exposure (E) and submersion.

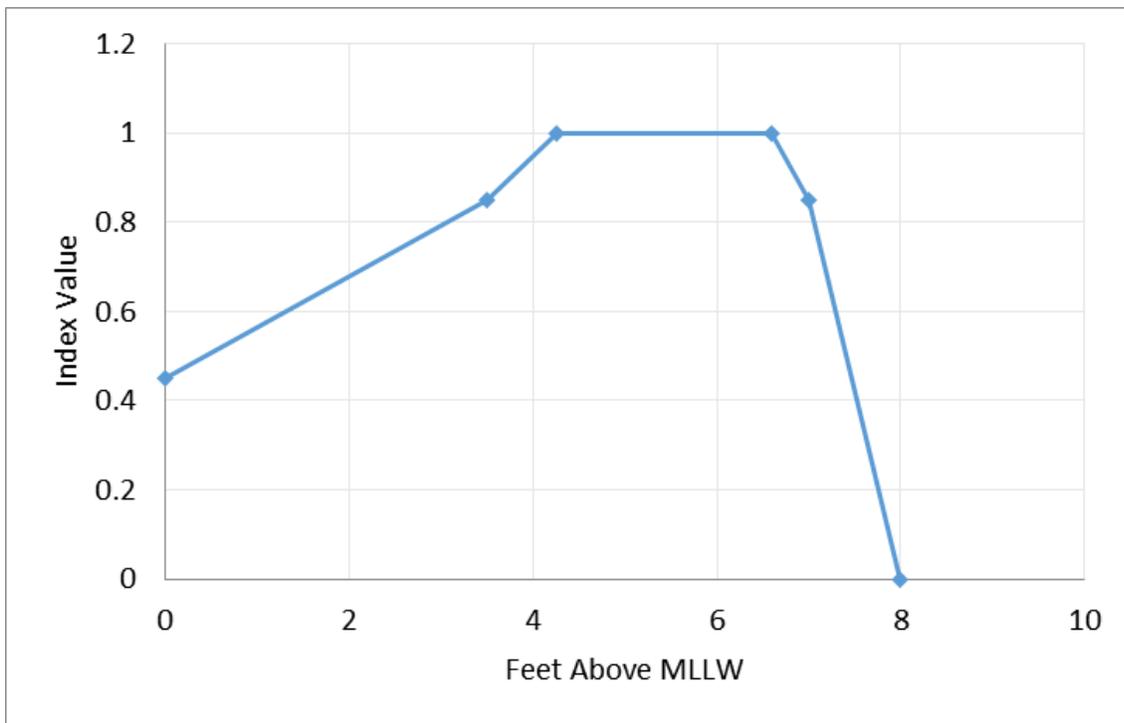


FIGURE 16. TIDAL MARSH ELEVATION CURVE.

TABLE 16. TIDAL MARSH ELEVATION EQUATIONS.

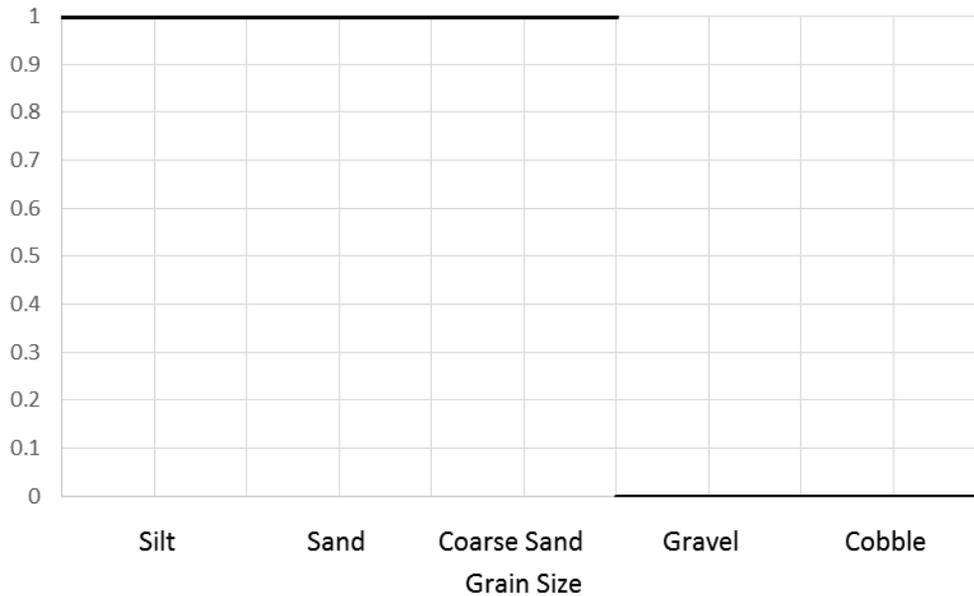
Variable	Equation	Eq#
$0 \leq \text{feet above MLLW} < 3.5$	$HSI_{\text{feet above MLLW}} = 0.45 + (0.1143 * \text{feet above MLLW})$	(1)
$3.5 < \text{feet above MLLW} \leq 4.25$	$HSI_{\text{feet above MLLW}} = 0.15 + (0.2 * \text{feet above MLLW})$	(2)
$4.25 < \text{feet above MLLW} \leq 6.6$	$HSI_{\text{feet above MLLW}} = 1 + (0 * \text{feet above MLLW})$	(3)
$6.6 < \text{feet above MLLW} \leq 7$	$HSI_{\text{feet above MLLW}} = 3.475 + (-0.375 * \text{feet above MLLW})$	(4)
$7 < \text{feet above MLLW} \leq 8$	$HSI_{\text{feet above MLLW}} = 6.8 + (-.85 * \text{feet above MLLW})$	(5)
$8 < \text{feet above MLLW}$	$HSI_{\text{feet above MLLW}} = 0 + (0 * \text{feet above MLLW})$	(6)

### Grain Size

Based on measurements of surface sediment texture and grain size, silts and sands are ideal for marsh systems (Zedler et al. 1982). Sediment grain size categories are based on the Krumbein phi/Wentworth scale and are summarized below in Table 18.

**TABLE 17. TIDAL MARSH SEDIMENT GRAIN SIZE CATEGORIES.**

Wentworth Grain Size Class	$\phi$ scale	Particle size range
Silt	8 to 4	3.9–62.5 $\mu$ m
Sand	4 to 1	0.0625-0.5mm
Coarse Sand	1 to -1	0.5-2.0mm
Gravel	-1 to -6	2.0-64mm
Cobble	-6 to -8	64mm-256mm



**FIGURE 17. TIDAL MARSH SEDIMENT GRAIN SIZE INDEX VALUES.**

**TABLE 18. TIDAL MARSH GRAIN SIZE EQUATIONS**

Substrate Category	Index Value
Silt, Sand & Coarse Sand	1
Gravel & Cobble	0

## Salinity

Southern California coastal marshes experience wide ranges in salinity which can include long periods of hypersaline conditions in drought years (Zedler et al. 1982). Salinity can be an important driver of species community composition and plant condition. Salinity was measured over a two week period in summer.

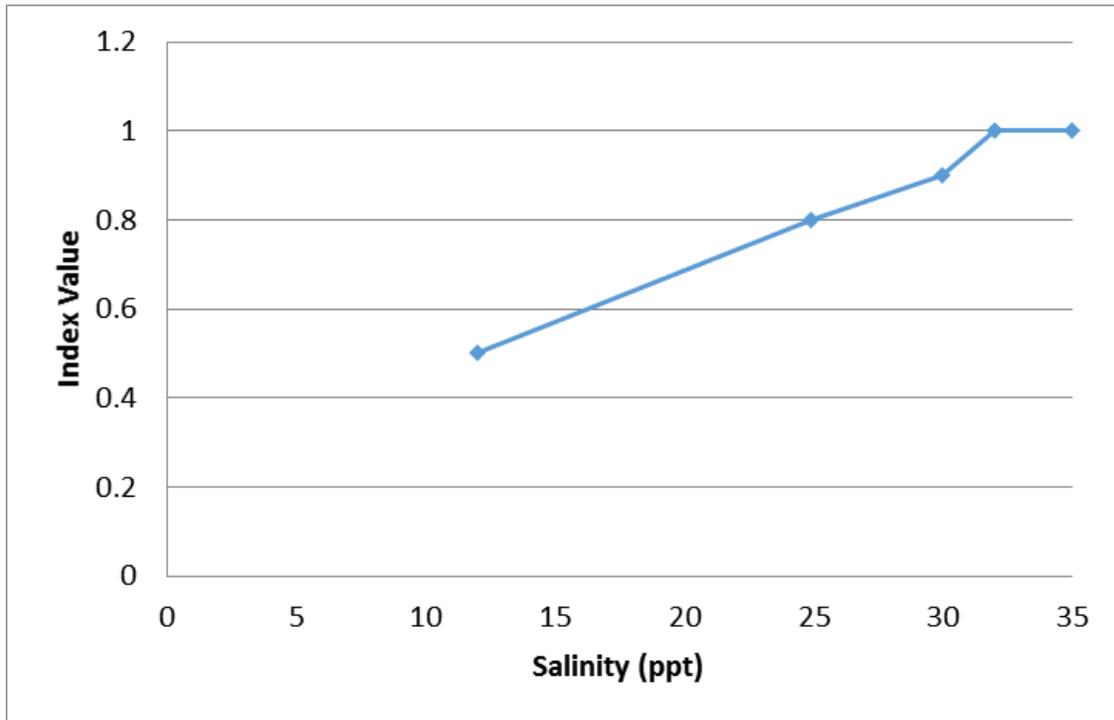


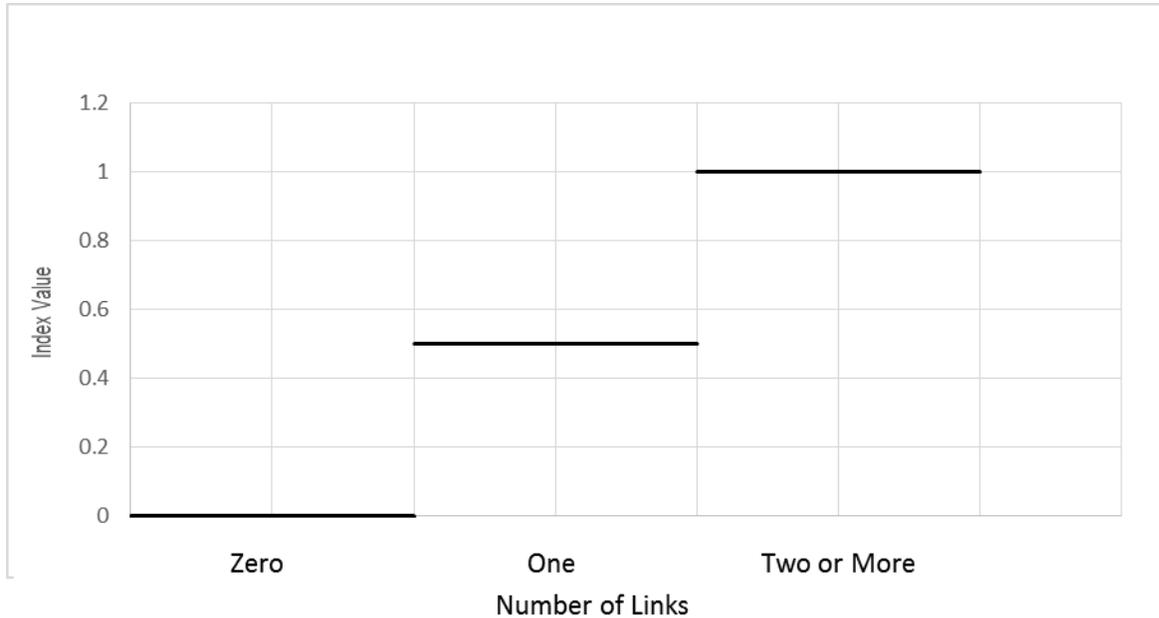
FIGURE 18. TIDAL MARSH SALINITY CURVE.

TABLE 19. TIDAL MARSH SALINITY EQUATIONS.

Variable	Equation	Eq#
$12 \leq \text{salinity} < 24.925$	$HSI_{\text{salinity}} = 0.2217 + (0.0232 * \text{salinity})$	(1)
$24.925 < \text{salinity} \leq 30$	$HSI_{\text{salinity}} = 0.309 + (0.0197 * \text{salinity})$	(2)
$30 < \text{salinity} \leq 32$	$HSI_{\text{salinity}} = -0.6 + (0.05 * \text{salinity})$	(3)
$32 < \text{salinity} \leq 35$	$HSI_{\text{salinity}} = 1 + (0 * \text{salinity})$	(4)

## Connectivity

The degree of connectivity between individual tidal marshes can influence foraging and recruitment behavior of fish, birds, and other organisms (West and Zedler 2000, Siegel et al 2010) and is often considered an important element of restoration efforts. We used a categorical approach to assessing tidal marsh connectivity by quantifying the minimum positive number of possible linkages between tidal marshes within the area of interest. For example, if one tidal marsh is present within the model domain, there would be zero linkages corresponding to an index value of zero. If two tidal marshes were present, there would be 1 linkage corresponding to an index value of 0.5 (Figure 19).



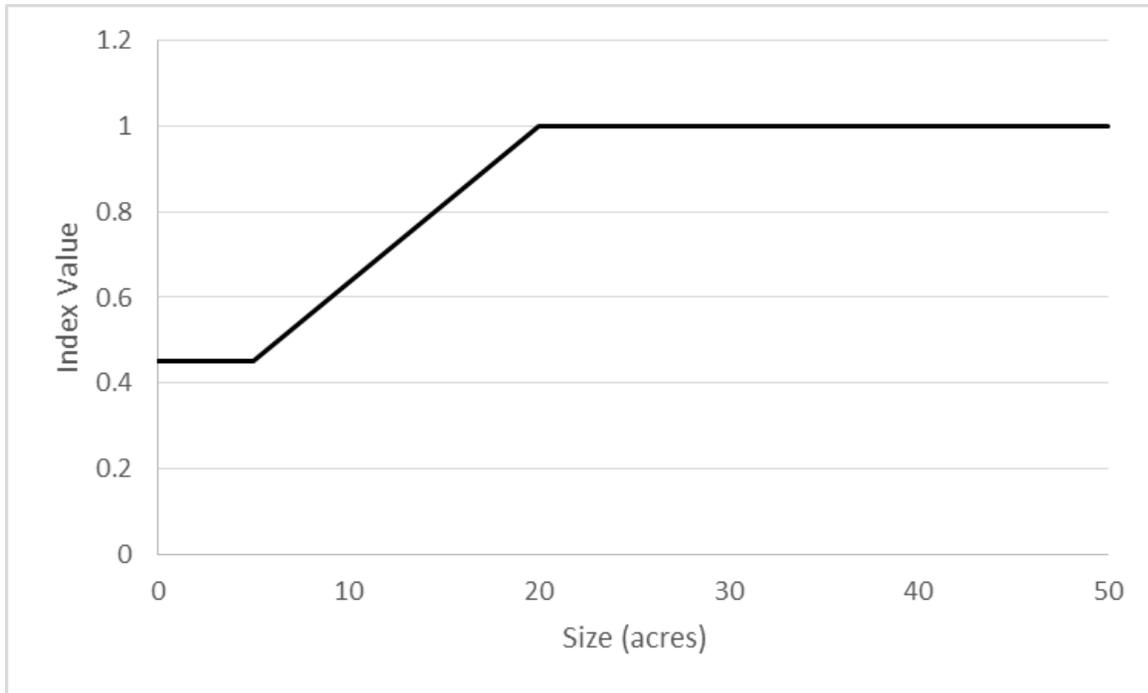
**FIGURE 19. TIDAL MARSH CONNECTIVITY INDEX VALUES.**

**TABLE 20. TIDAL MARSH CONNECTIVITY EQUATIONS**

Number of Links	Index Value
Zero	0
One	0.5
Two or more	1

### Tidal Marsh Habitat Size

The size (e.g., acreage) of marsh habitat is important as there is a significant interaction between size and the dynamics of species interactions (Long and Burke 2007). Smaller patches have greater edge effects resulting in increased physical stress (e.g., wind and dehydration) as well as behavioral stress (e.g., increased predation) (Long and Burke 2007). Conversely, larger habitat patches often experience decreased overall stress. The suitability of marsh size is based on observations by the TAC. Between 1-5- acres of marsh size is less than optimal, while greater than 20-acres is optimal marsh size.



**FIGURE 20. TIDAL MARSH HABITAT SIZE CURVE.**

**TABLE 21. TIDAL MARSH HABITAT SIZE EQUATIONS**

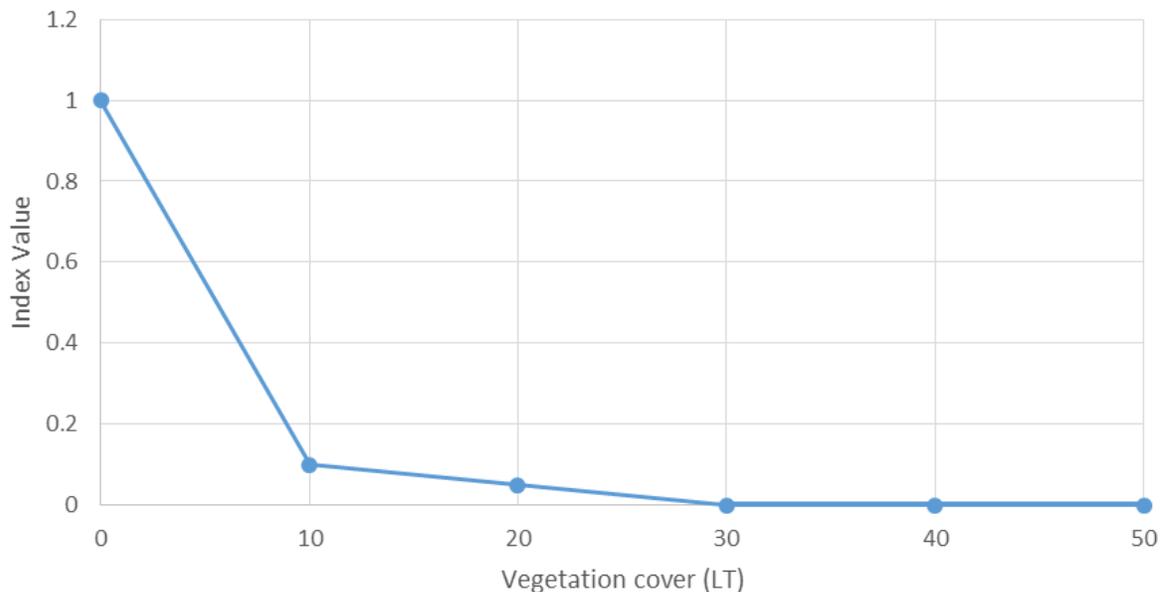
Variable	Equation	Eq#
$0 \leq \text{marsh size (acres)} < 5$	$HSI_{\text{marsh size}} = 0.45 + (0 * \text{marsh size})$	(1)
$5 < \text{marsh size (acres)} \leq 20$	$HSI_{\text{marsh size}} = 0.266 + (0.0367 * \text{marsh size})$	(2)
$20 < \text{marsh size (acres)}$	$HSI_{\text{marsh size}} = 1 + (0 * \text{marsh size})$	(3)

## Sandy Islands

The goal of providing sandy Island habitat is to increase habitat for the California least tern (*Sterna antillarum browni*) and the snowy plover (*Charadrius nivosus*). While the birds are similar in some aspects of their life history and habitat utilization, there are some species-specific considerations that require the development of separate curves for each species. Critical parameters identified for the sandy islands habitat included vegetation cover (%) for least tern, vegetation cover (%) for plover, effective size of the island, elevation, sediment characteristics (color, sediment grain size) and distance from occupied habitats for bird foraging. Note that seagrass habitat could be an incidental benefit to formation of sandy islands. Design considerations include the linear length of beach (longer is better for snowy plover and there may be a minimum length needed), beach slope (gentler slope is preferred), and sediment color (e.g., least tern generally utilize white or tan sediments, while brown/gray sediments are suboptimal). When applying this suite of equations, the results generated will provide habitat suitability values for both least terns and snowy plovers. The curves that should only be applied to one of the species are noted in the description.

### *Vegetation Cover Least Tern*

Sparse or no vegetation cover is a major driver in least tern reproduction (Kotliar and Burger, 1986) Nesting success is greater when nests are in open, sparsely vegetated areas.



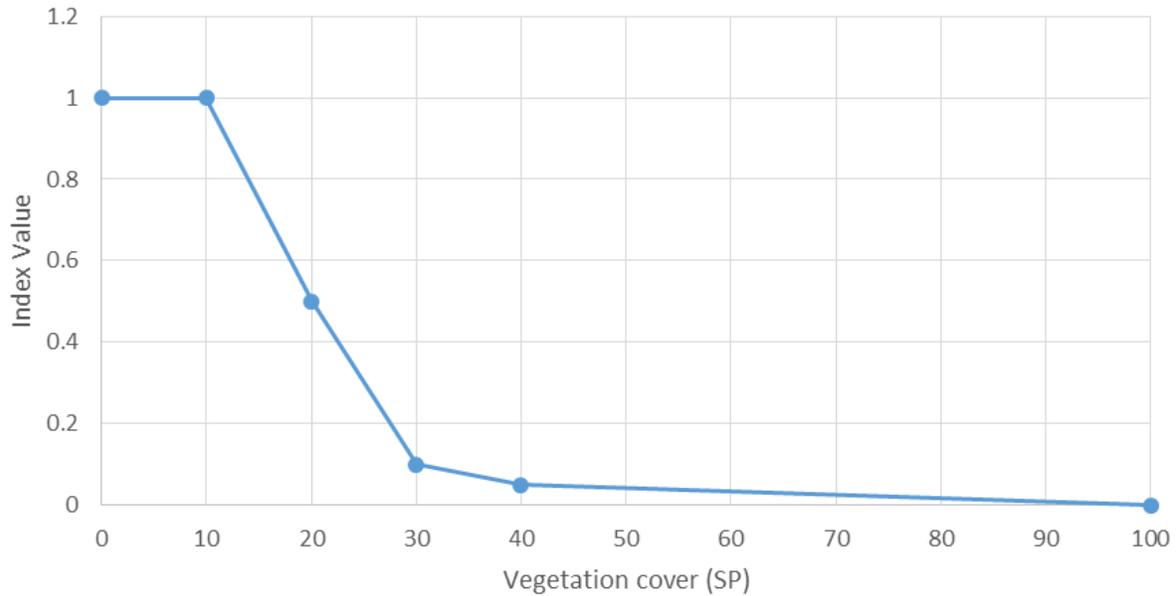
**FIGURE 21. SANDY ISLANDS CURVE OF VEGETATION COVER FOR LEAST TERN.**

**TABLE 22. SANDY ISLANDS EQUATIONS FOR VEGETATION COVER FOR LEAST TERN.**

Variable	Equation	Eq#
$0 \leq \text{Percent Vegetation LT} < 10$	$HSI_{\text{Percent Vegetation LT}} = 1 + (-0.09 * \text{Percent Vegetation LT})$	(1)
$10 < \text{Percent Vegetation LT} \leq 30$	$HSI_{\text{Percent Vegetation LT}} = 0.15 + (-0.005 * \text{Percent Vegetation LT})$	(2)
$30 < \text{Percent Vegetation LT}$	$HSI_{\text{Percent Vegetation LT}} = 0 + (0 * \text{Percent Vegetation LT})$	(3)

### Vegetation Cover Snowy Plover

Like least terns, vegetative cover is a major driver in snowy plover reproduction (Saalfeld et al. 2012), but snowy plover nesting success increases with vegetation cover, until cover exceeds 10%, then declines with patches containing 40% cover or greater resulting in poor habitat for reproduction.



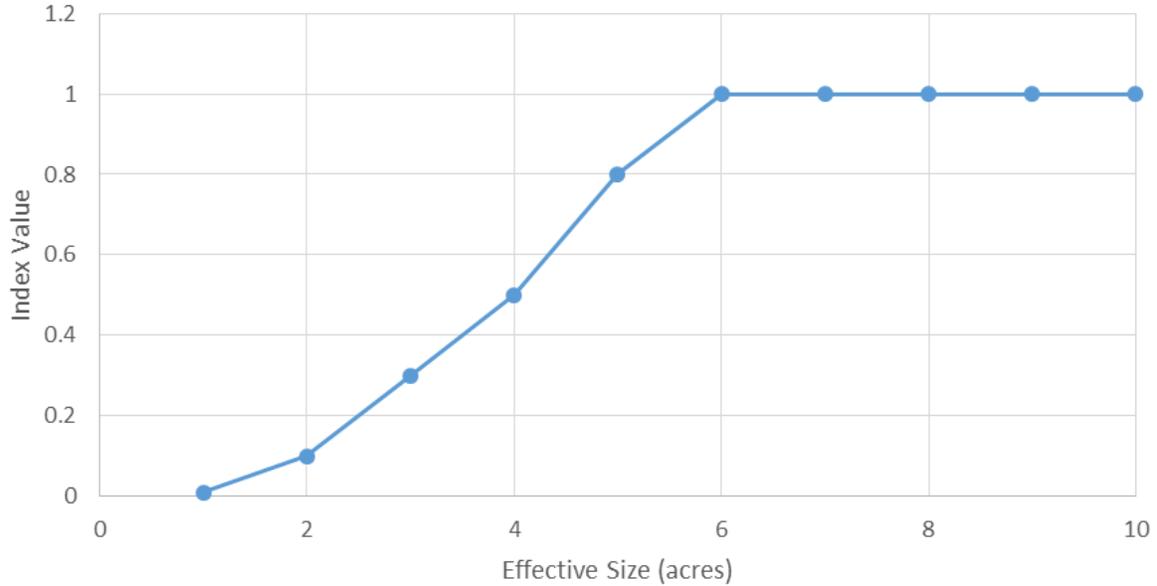
**FIGURE 22. SANDY ISLANDS CURVE OF VEGETATION COVER FOR SNOWY PLOVER.**

**TABLE 23. SANDY ISLANDS EQUATIONS FOR VEGETATION COVER FOR SNOWY PLOVER.**

Variable	Equation	Eq#
$0 \leq \text{Percent Vegetation SP} < 10$	$HSI_{\text{Percent Vegetation SP}} = 1 + (0 * \text{Percent Vegetation SP})$	(1)
$10 < \text{Percent Vegetation SP} \leq 20$	$HSI_{\text{Percent Vegetation SP}} = 1.5 + (-0.05 * \text{Percent Vegetation SP})$	(2)
$20 < \text{Percent Vegetation SP} \leq 30$	$HSI_{\text{Percent Vegetation SP}} = 1.3 + (-0.04 * \text{Percent Vegetation SP})$	(3)
$30 < \text{Percent Vegetation SP} \leq 40$	$HSI_{\text{Percent Vegetation SP}} = 0.25 + (-0.005 * \text{Percent Vegetation SP})$	(4)
$40 < \text{Percent Vegetation SP} \leq 100$	$HSI_{\text{Percent Vegetation SP}} = 0.08 + (-0.0008 * \text{Percent Vegetation SP})$	(5)
$100 < \text{Percent Vegetation SP}$	$HSI_{\text{Percent Vegetation SP}} = 0 + (0 * \text{Percent Vegetation SP})$	(6)

## Effective Size

The size of a sand island can impact both least tern and snowy plover reproductive success. Small islands will limit the size of nesting colonies. It is assumed that larger islands provide more realized (effective) nesting habitat for both species. However, there is a threshold above six acres where the increase in habitat suitability does not increase beyond optimal. This curve applies to both species.



**FIGURE 23. SANDY ISLANDS EFFECTIVE SIZE CURVE.**

**TABLE 24. SANDY ISLANDS EFFECTIVE SIZE EQUATIONS.**

Variable	Equation	Eq#
$1 \leq \text{Effective Size} < 2$	$HSI_{\text{Effective Size}} = -0.08 + (0.09 * \text{Effective Size})$	(1)
$2 < \text{Effective Size} \leq 4$	$HSI_{\text{Effective Size}} = -0.3 + (0.2 * \text{Effective Size})$	(2)
$4 < \text{Effective Size} \leq 5$	$HSI_{\text{Effective Size}} = -0.7 + (0.3 * \text{Effective Size})$	(3)
$5 < \text{Effective Size} \leq 6$	$HSI_{\text{Effective Size}} = -0.2 + (0.2 * \text{Effective Size})$	(4)
$6 < \text{Effective Size}$	$HSI_{\text{Effective Size}} = 1 + (0 * \text{Effective Size})$	(5)

## Elevation

Elevation is a critical parameter because it is indicative of island area that is exposed during high tides. The relationship between snowy plovers and vegetative cover dictates an elevation threshold at which survival and nesting success are greatest. Briefly, snowy plovers utilize sparsely vegetated areas to nest. Lower elevations are exposed to tidal inundation, which generally maintain a beach-like shoreline (i.e., free of vegetation). Conversely, higher elevations will more likely become vegetated to the point where there is uniform, dense vegetation. Snowy plovers are less likely to occupy and colonize areas that are densely vegetated or are more prone to human access and disturbance (Webber et al 2013). There is not a maximum elevation for least terns—they will nest in any open sandy area on an island. This curve should be applied to both species.

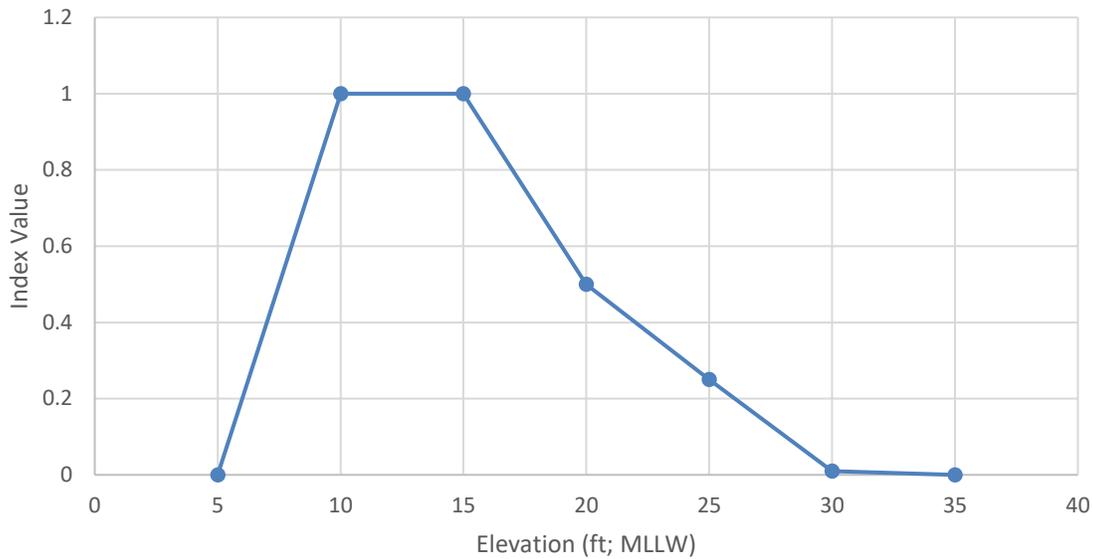


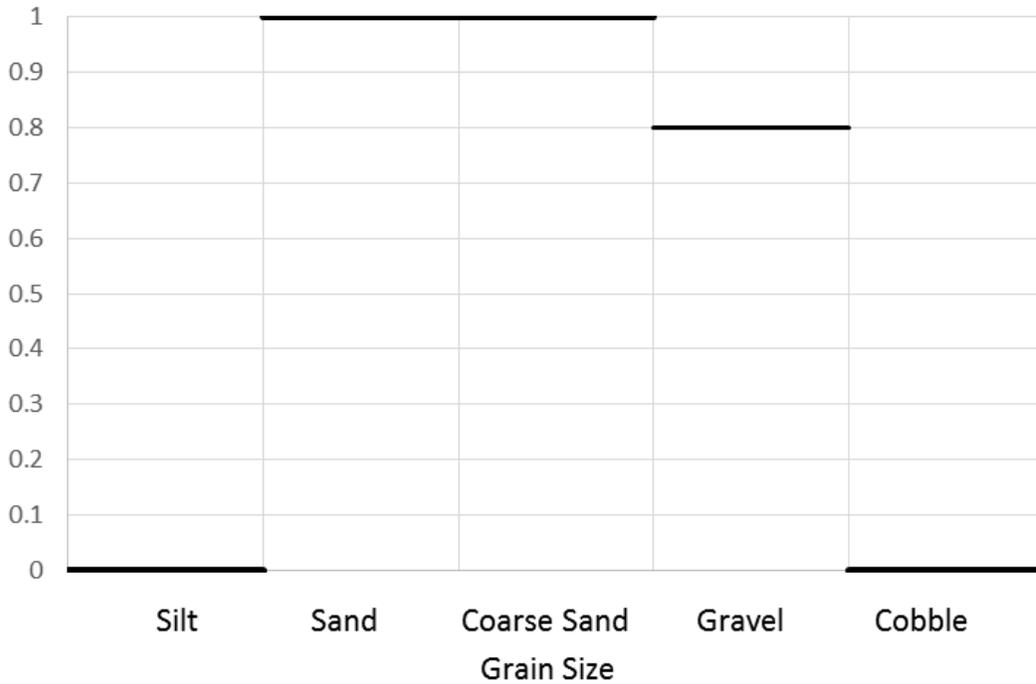
FIGURE 24. SANDY ISLANDS ELEVATION CURVE.

TABLE 25. SANDY ISLANDS ELEVATION EQUATIONS.

Variable	Equation	Eq#
$5 \leq \text{Elevation (MLLW)} < 10$	$HSI_{\text{Elevation (MLLW)}} = -1 + (0.2 * \text{Elevation (MLLW)})$	(1)
$10 < \text{Elevation (MLLW)} \leq 15$	$HSI_{\text{Elevation (MLLW)}} = 1 + (0 * \text{Elevation (MLLW)})$	(2)
$15 < \text{Elevation (MLLW)} \leq 20$	$HSI_{\text{Elevation (MLLW)}} = 2.5 + (-0.1 * \text{Elevation (MLLW)})$	(3)
$20 < \text{Elevation (MLLW)} \leq 25$	$HSI_{\text{Elevation (MLLW)}} = 1.5 + (-0.05 * \text{Elevation (MLLW)})$	(4)
$25 < \text{Elevation (MLLW)} \leq 30$	$HSI_{\text{Elevation (MLLW)}} = 1.45 + (-0.048 * \text{Elevation (MLLW)})$	(5)
$30 < \text{Elevation (MLLW)} \leq 35$	$HSI_{\text{Elevation (MLLW)}} = 0.07 + (-0.002 * \text{Elevation (MLLW)})$	(6)
$35 < \text{Elevation (MLLW)}$	$HSI_{\text{Elevation (MLLW)}} = 0 + (0 * \text{Elevation (MLLW)})$	(7)

*Sediment Grain Size*

Sediment Grain Size is based on categories (see Table 18 – Tidal Marsh). Sand and coarse sand are ideal and have an index value of 1. Gravel is intermediate with an index value of 0.8. Cobble and silt are undesirable with index values of 0. This curve applies to both species. Index values were determined by SME opinion of the TAC members.



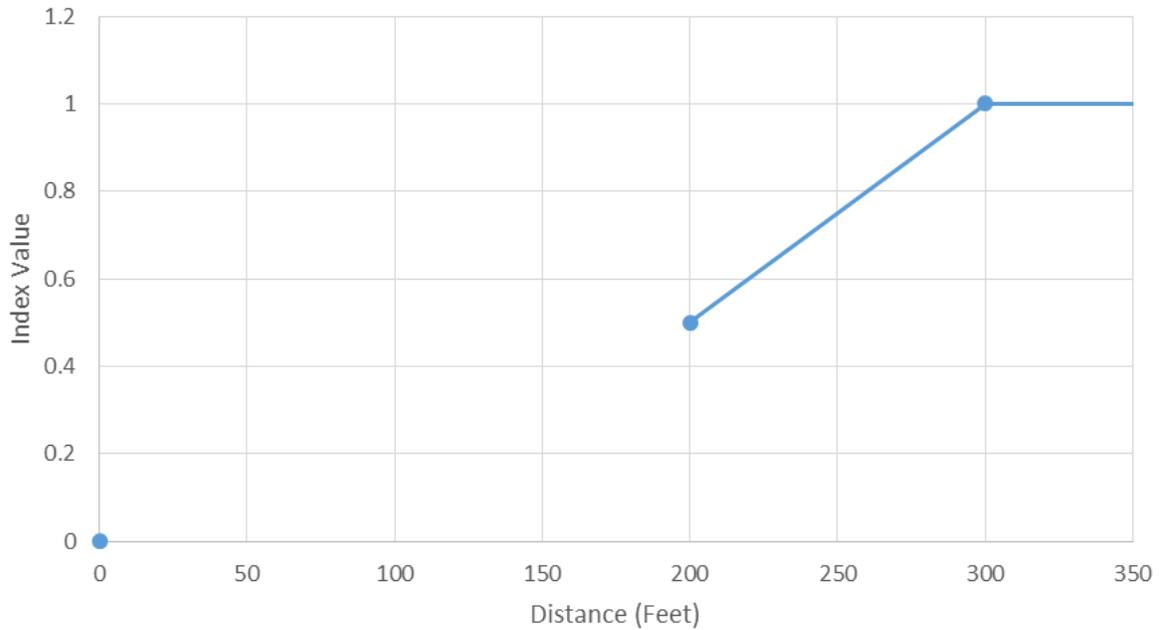
**FIGURE 25. SANDY ISLANDS GRAIN SIZE INDEX VALUES.**

**TABLE 26. SANDY ISLANDS GRAIN SIZE EQUATIONS**

Substrate Category	Index Value
Silt	0
Gravel	0.8
Coarse Sand	1
Sand	1

## Distance

Successful nesting and survival for bird species depends, in part, on limiting access by terrestrial predators to nesting sites. This model assumes that optimal placement for an island is at least 300 m from other islands or the mainland (both measured as straight-line distances), as informed by TAC members.



**FIGURE 26. SANDY ISLANDS DISTANCE CURVE.**

**TABLE 27. SANDY ISLANDS DISTANCE EQUATIONS.**

Variable	Equation	Eq#
$0 \leq Distance < 200$	$HSI_{Distance} = 0 + (0 * Distance)$	(1)
$200 < Distance \leq 300$	$HSI_{Distance} = -0.5 + (0.005 * Distance)$	(3)
$300 < Distance$	$HSI_{Distance} = 1 + (0 * Distance)$	(4)

## Calculating Habitat HSI Score

This document has described six different habitat types (rocky reef, kelp forest, eelgrass, oyster reef, tidal salt marsh and sandy islands) and the critical parameters used in the model to determine habitat suitability indices. Each habitat type had between 2 and 6 critical parameters that were identified by the TAC and for which curves and equations were developed.

For each habitat type, values from these individual curves are combined to calculate a habitat suitability index score (HSI score). The HSI score is a geometric mean of all individual habitat index values for a given habitat. For a set of numbers  $\{X_i\}^N$   $i=1$ , the geometric mean is:

$$\left( \prod_{i=1}^N x_i \right)^{1/N} = \sqrt[n]{a_1 a_2 \dots a_n}$$

The size and location of each habitat type under consideration in the model is identified in a GIS framework prior calculation of HIS indices or scores. The appropriate values of each parameter corresponding to the physical location of each habitat type is then determined by the user. Habitat index values for each habitat are determined for each parameter based on the curves and equations described within this document and the parameter values determined by the user. Once habitat indices are calculated, a combined HSI score can be calculated for each habitat type and location. Habitat units (HU) are the product of the HSI score and the area of a given habitat type. HUs for different habitat types are additive.

## Summary of Data used in Model Development

<i>Habitat Type</i>	<i>Parameter</i>	<i>Unit</i>
<b>Rocky Reef</b>	Connectivity	distance between reefs (m)
	Reef Relief	Categorical
	Residence Time	Residence time by week
	Substrate	Categorical
<b>Kelp Forest</b>	Temperature	average two month temperature °C
	Substrate	Categorical
	Depth	feet
<b>Eelgrass</b>	Circulation	cm/second
	Depth	feet
	Substrate	Percent Fines (silt and clay particles)
	Temperature	Maximum °C/month
<b>Oyster Reef</b>	Salinity	ppt
	Depth	feet

<b>Tidal Salt Marsh</b>	Elevation	Feet above MLLW
	Salinity	ppt
	Substrate Grain Size	Categorical
	Connectivity	Number of links between discrete marshes
<b>Sandy Islands</b>	Vegetation Cover - Least Tern	Percent Cover
	Vegetation Cover – Snowy Plover	Percent cover
	Effective Size	acre
	Elevation	feet
	Sediment Grain Size	Categorical
	Distance	meter

## Model Quantification

Although there are a number of peer reviewed, spatially explicit habitat suitability index models available (Brooks et al 1997, Brown et al 2000, Koh et al 2016), many of focus on a single habitat or species in a particular region. As our goal is to address a number of habitats simultaneously, our approach required addressing each habitat in a consistent manner to allow for an integrated evaluation of various habitat HIS values in one region. Although there are HIS models already developed for some of the habitats included in our model (e.g., eelgrass: Zhou et al 2016; oyster reef: Swannack et al 2014, Barnes et al 2007), most of the habitat types that we considered do not have existing HSI models that are useful at the habitat scale. In some cases, there are species specific models associated with habitats we included, but these models do not take into account suitability from a holistic habitat perspective. For example, Lowe et al (2003) model habitat suitability of Kelp Bass within kelp habitat, but the model does not indicate suitability for the kelp itself. In cases in which the appropriate habitat was modelled (e.g. eelgrass), the region in which the model was developed was not compatible with Southern California (Zhou et al 2016). Due to these limitations, it was necessary to develop the new model presented in this document. To our knowledge, this is the first HIS model developed within the USACE that incorporates multiple habitat types simultaneously.

In our approach, we used guidance from subject matter experts, as well as peer reviewed literature and available data to identify critical parameters or variable for each habitat. When individual parameter curves, certain parameters required units of time or space. The scale was determined by the relationship between the parameter and habitat of interest. For example, eelgrass and kelp habitats both included Temperature as a critical parameter used to calculate Habitat HSI. For eelgrass, the temperature was evaluated as a maximum monthly value, while a two month average temperature was used for kelp habitat. In computing HSI values, Model results represent a snapshot of immediate HIS conditions given

current data values. To determine HSI values through time, the underlying data used to calculate HIS values must also project through time. As such, any time steps developed through use of the model are reliant on the temporal and spatial accuracy and assumptions included in the data provided by the model user.

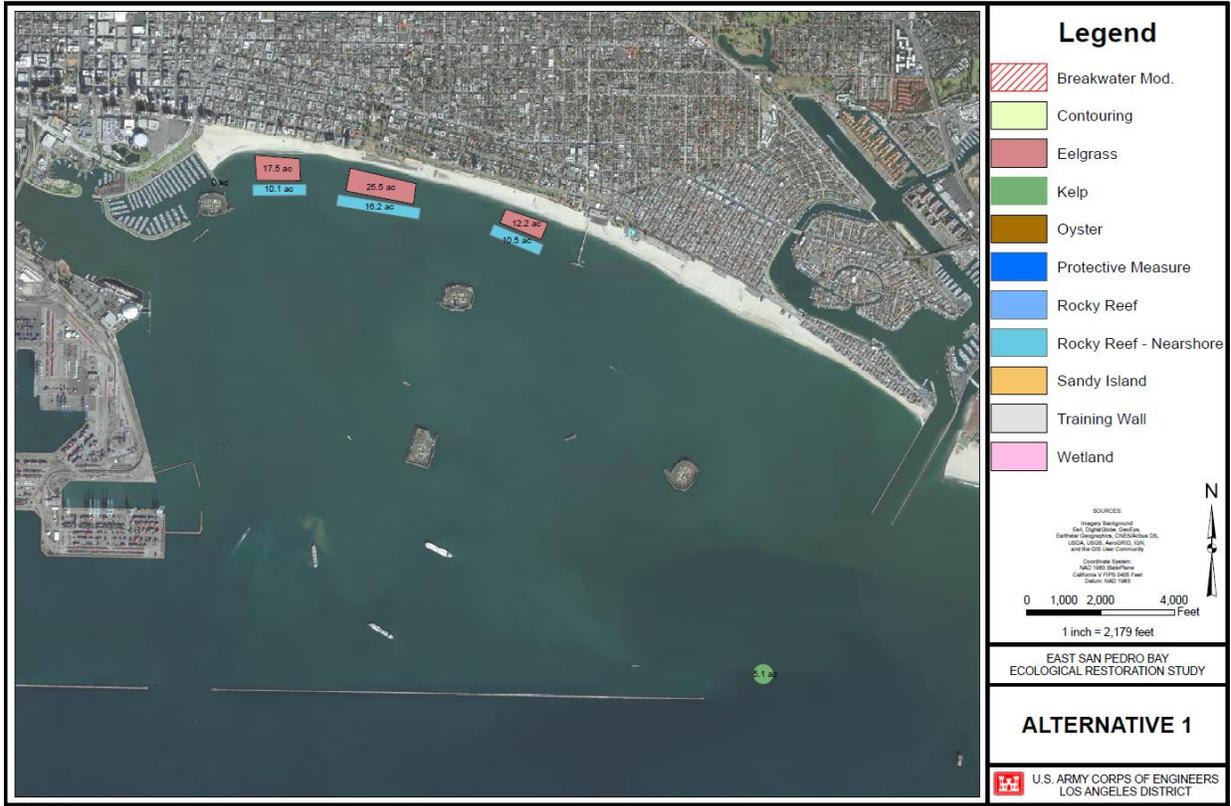
## Model Evaluation

This model is appropriate for use in the Southern California region because it relies on peer-reviewed results as well as subject matter expert opinion to support the assumptions and relationships between parameters and habitat, and consequently, the shape and math supporting the established curves. The model relies on the user to provide input data (i.e. parameter conditions) that is in a geospatial format. The HSI equations are then applied to the input data in such that the habitat specific HSI curves are applied in the appropriate geo-spatial area (i.e., in the footprint of the proposed restoration site for the habitat of interest).

## Spatial Data and Model Application

The equations discussed in the previous sections were applied in a GIS in order to subset spatial data variables (e.g. Salinity, Temperature, Connectivity, etc. as defined for the appropriate habitat of interest) and to compute an overall habitat HSI. We selected three alternative restoration plans as case studies to illustrate the application of the Model. Through evaluation of the examples, we intend to illustrate how the Model can be utilized. The following sections describe the application of the Model in two restoration scenarios, while Appendix A provides a detailed GIS guide. All data were processed in ESRI's ArcGIS 10.0/10.1 software (ArcInfo).

Several alternative restoration scenarios incorporating the six habitat types as well as structural modifications were evaluated in the East San Pedro Habitat Evaluation study. In each alternative, habitat types can be of varied sizes and in different spatial orientations within East San Pedro Bay. The first example restoration plan, Alternative 1, contains three eelgrass beds with three adjacent nearshore rocky reefs (Figure 27). The Habitat HSI scores, as calculated using model equations in a geospatial framework, are mapped in Figure 28 with a breakdown of HSI values reported per parameter, and by habitat type (Table 28). Habitat HSI scores range from 0 to 0.67 in year 0 and increase over time (table 28).



October 2017

FIGURE 27. ALTERNATIVE 1, EAST SAN PEDRO BAY ECOLOGICAL RESTORATION STUDY.

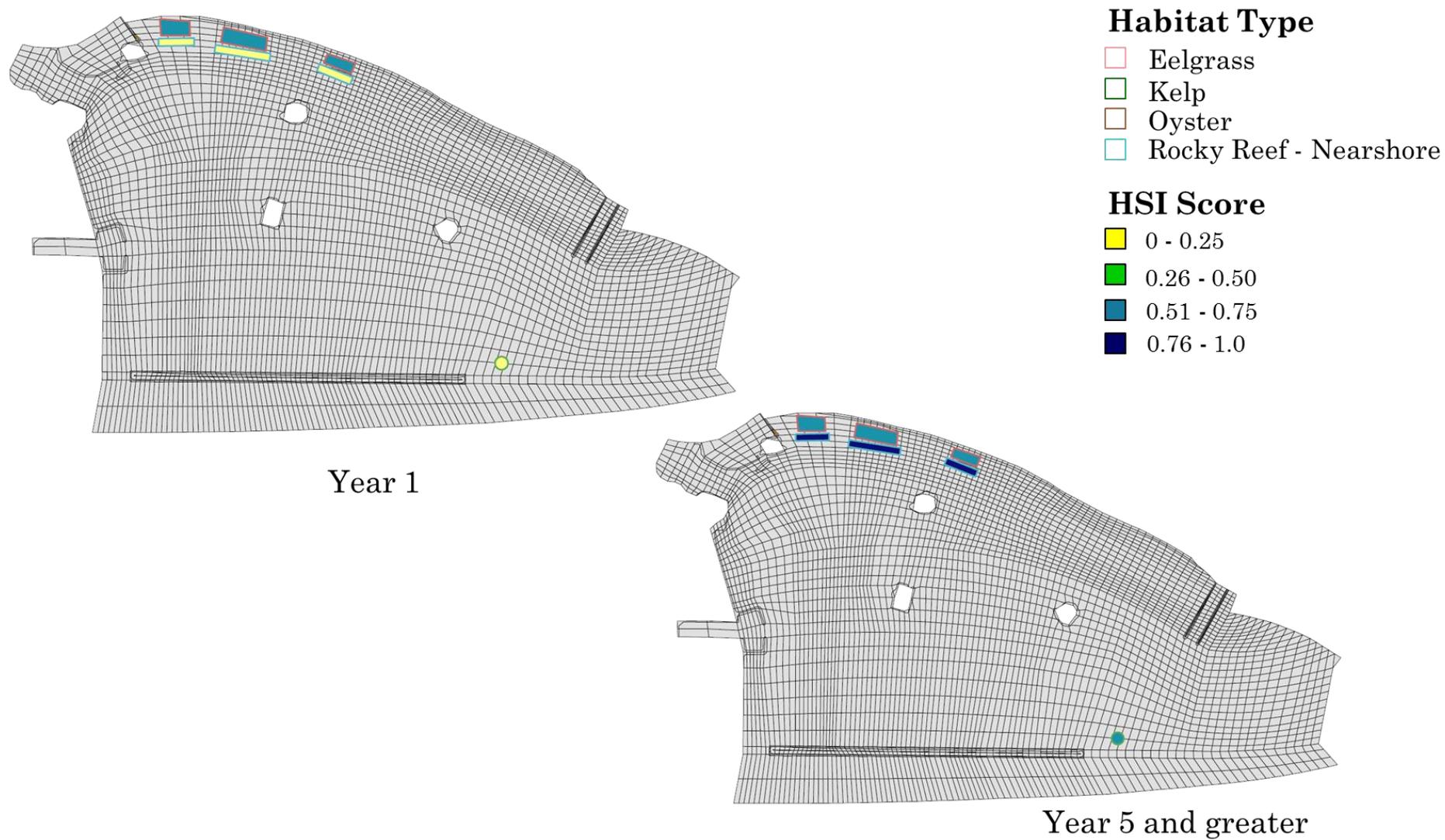


FIGURE 28. MAP OF HABITAT TYPE AND HSI SCORES DEVELOPED FOR ALTERNATIVE 1.

**TABLE 28. MODELING OUTPUTS FOR ALTERNATIVE 1.**

East San Pedro Bay Ecosystem Restoration Modeling Outputs					
		Baseline		Yr 5	
Alternative 1	Unit	Value	HSIndex	Value	HSIndex
<b>Rocky Reef (nearshore)</b>					
Connectivity	meter	0.00	0.01	264.35	1.00
Reef Relief	flat to wall	Flat	0.01	Low	0.48
Residence Time	days (1-43)	1.16	1.00	1.10	0.98
Substrate	Present/Absent	Absent	0.01	Present	1.00
<b>HSI Score</b>			<b>0.03</b>		<b>0.83</b>
<b>Eelgrass</b>					
Circulation	m/sec	0.11	0.71	0.07	0.66
Depth	meter	4.26	0.28	3.56	0.36
Substrate	% silt-clay	43.89%	1.00	43.89%	1.00
Temperature	Celsius	17.90	1.00	17.90	1.00
<b>HSI Score</b>			<b>0.67</b>		<b>0.70</b>
<b>Kelp (open water)</b>					
Temperature	Celsius	17.90	0.71	17.90	0.71
Substrate	Present/Absent	Absent	0.00	Present	1.00
Depth	m (0-37)	14.01	0.75	13.28	0.84
<b>HSI Score</b>			<b>0.00</b>		<b>0.84</b>
<b>Oyster Reef (LA River)</b>					
Salinity	ppt	32.72	1.00	32.72	1.00
Depth	meter	4.91	0.00	-0.93	0.90
<b>HSI Score</b>			<b>0.00</b>		<b>0.95</b>

The second example restoration plan, Alternative 4, contains three eelgrass beds with three adjacent nearshore rocky reefs, two offshore rock reef and five kelp beds (Figure 29). The Habitat HSI scores, as calculated using model equations in a geospatial framework, are mapped in Figure 30 with a breakdown of HSI values reported per parameter, and by habitat type (Table 29). Habitat HSI scores range from 0 to 0.67 in year 0 and increase over time (Table 29).



FIGURE 29. ALTERNATIVE 4, EAST SAN PEDRO BAY ECOLOGICAL RESTORATION STUDY.

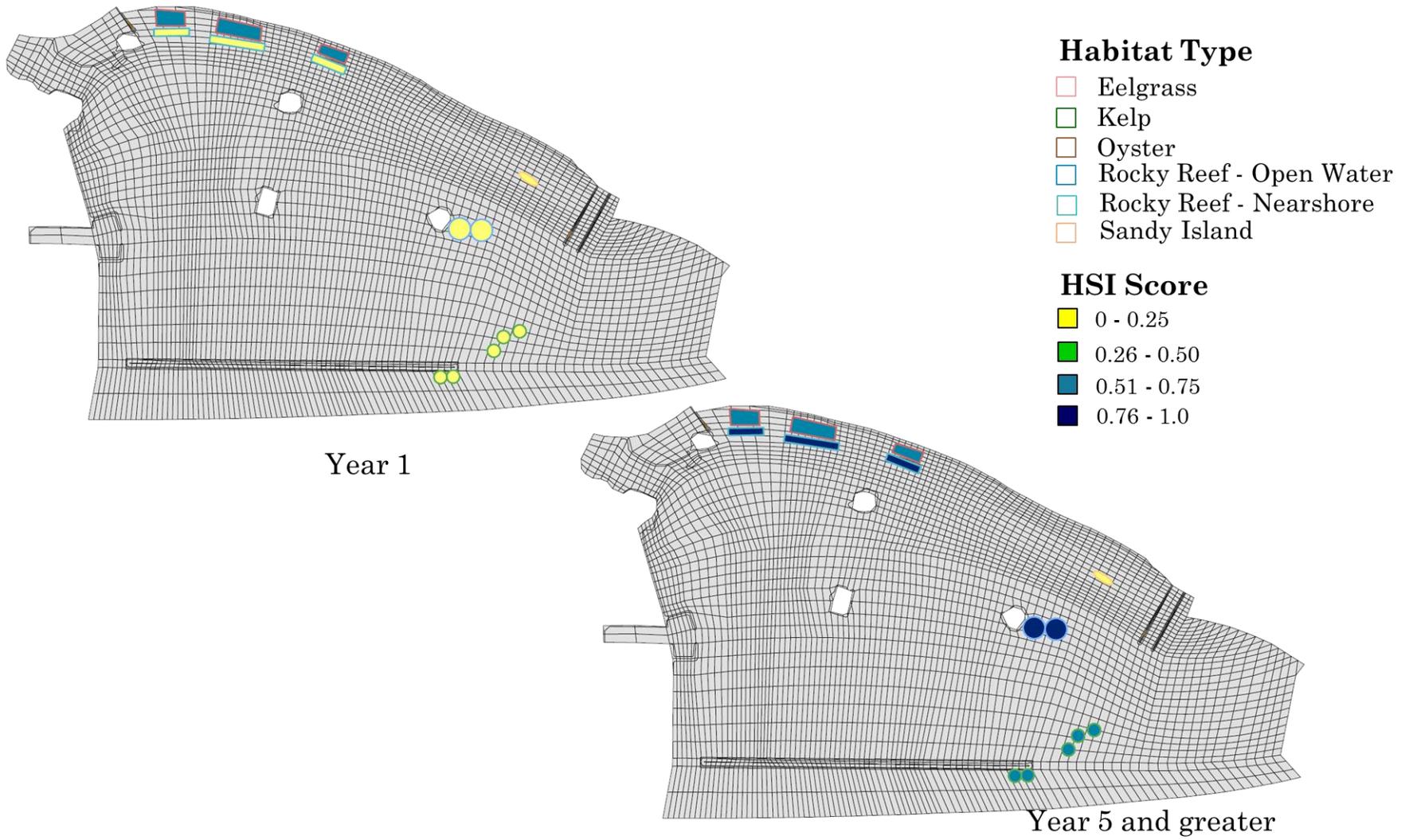


FIGURE 30. MAP OF HABITAT TYPE AND HSI SCORES DEVELOPED FOR ALTERNATIVE 4

**TABLE 29. MODELING OUTPUTS FOR ALTERNATIVE 4.**

East San Pedro Bay Ecosystem Restoration Modeling Outputs					
		Baseline		Yr 5	
Alternative 4	Unit	Value	HSIndex	Value	HSIndex
<b>Rocky Reef (nearshore)</b>					
Connectivity	meter	0.00	0.00	264.35	1.00
Reef Relief	flat to wall	Flat	0.00	Low to Med	0.48
Residence Time	days (1-43)	1.16	1.00	1.10	0.98
Substrate	Present/Absent	Absent	0.00	Present	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.83</b>
<b>Eelgrass</b>					
Circulation	m/sec	0.11	0.71	0.07	0.66
Depth	meter	4.26	0.28	3.56	0.36
Substrate	% silt-clay	43.89%	1.00	43.89%	1.00
Temperature	Celsius	17.90	1.00	17.90	1.00
<b>HSI Score</b>			<b>0.67</b>		<b>0.70</b>
<b>Island (nearshore)</b>					
Vegetation Cover - Least Tern	% cover	NA	0.00	2.33%	0.79
Vegetation Cover - Snowy Plover	% cover	NA	0.00	2.33%	1.00
Effective Size	acres	NA	0.00	4.44	0.63
Elevation	MLLW	NA	0.00	2.21	0.56
Sediment Grain Size	silt to cobble	NA	0.00	Coarse mix	0.67
Distance	feet	NA	0.00	205.33	0.68
Sediment color	white to brown/gray	NA	0.00	White/Tan	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.74</b>
<b>Oyster Reef (nearshore)</b>					
Salinity	ppt	32.78	1.00	32.78	1.00
Depth	meter	5.58	0.00	-1.95	0.77
<b>HSI Score</b>			<b>0.00</b>		<b>0.88</b>
<b>Rocky Reef (open water)</b>					
Connectivity	meter	0.00	0.00	<2	1.00
Reef Relief	flat to wall	Flat	0.00	Low to Med	0.49
Residence Time	days (1-43)	1.00	1.00	1.05	0.99
Substrate	Present/Absent	Absent	0.00	Present	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.84</b>
<b>Kelp (open water)</b>					
Temperature	Celsius	17.90	0.71	17.90	0.71
Substrate	Present/Absent	Absent	0.00	Present	1.00
Depth	m (0-37)	13.28	0.84	12.57	0.91
<b>HSI Score</b>			<b>0.00</b>		<b>0.86</b>
<b>Oyster Reef (LA River)</b>					
Salinity	ppt	32.70	1.00	32.70	1.00
Depth	meter	3.69	0.00	-1.47	0.88
<b>HSI Score</b>			<b>0.00</b>		<b>0.94</b>
<b>Kelp (breakwater)</b>					
Temperature	Celsius	17.90	0.71	17.90	0.71
Substrate	Present/Absent	Absent	0.00	Present	1.00
Depth	m (0-37)	16.02	0.50	13.53	0.57
<b>HSI Score</b>			<b>0.00</b>		<b>0.74</b>



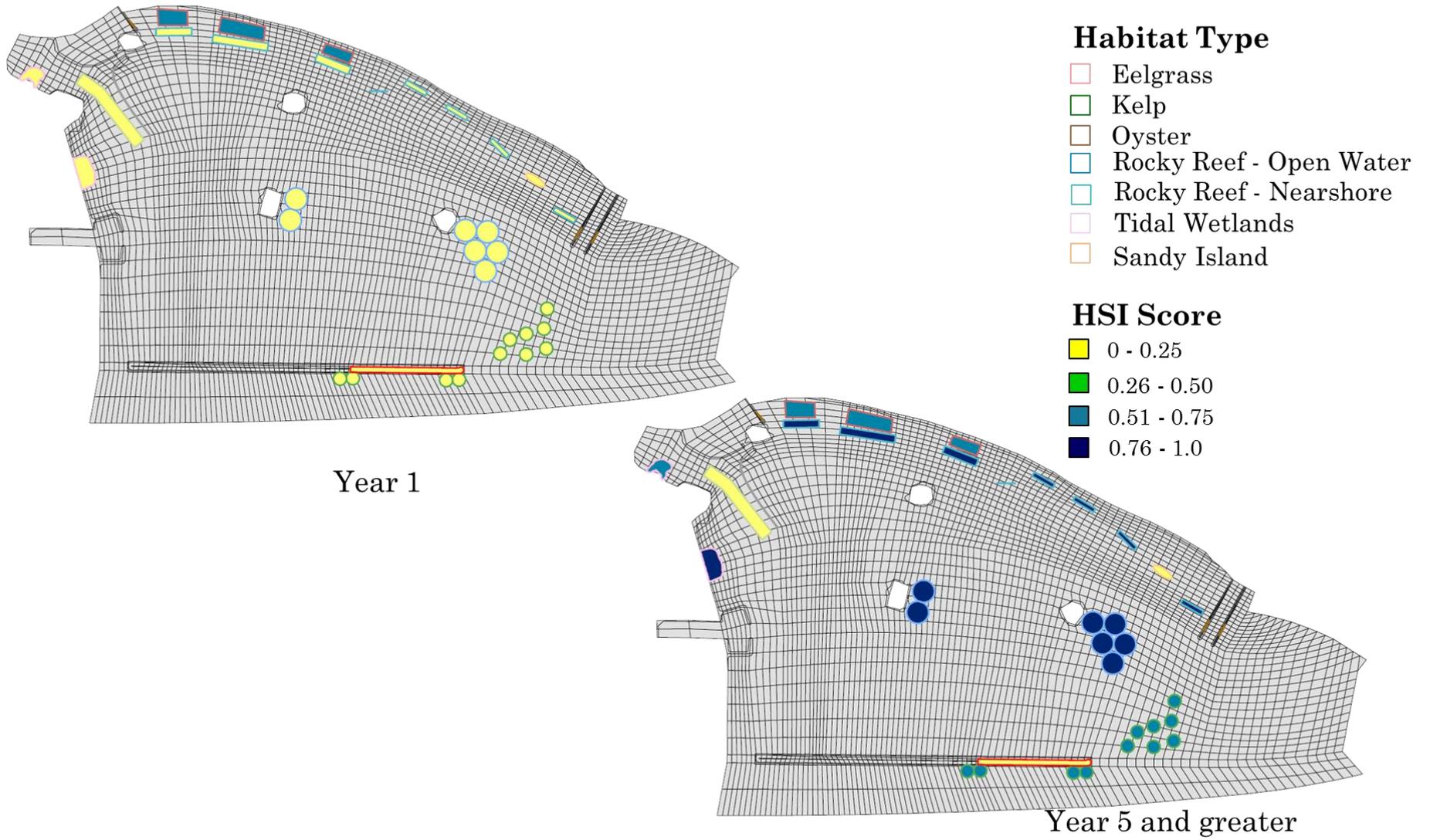


FIGURE 32. MAP OF HABITAT TYPE AND HSI SCORES DEVELOPED FOR ALTERNATIVE 12.

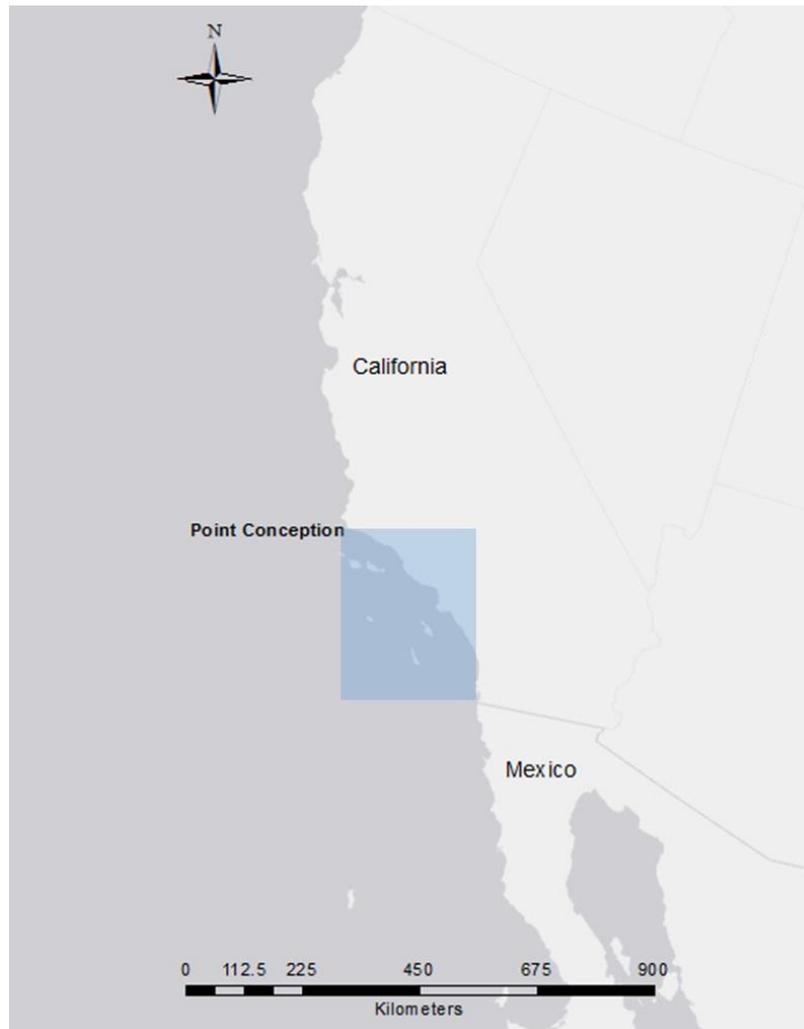
**TABLE 30. MODELING OUTPUTS FOR ALTERNATIVE 12.**

East San Pedro Bay Ecosystem Restoration Modeling Outputs					
Alternative 12	Unit	Baseline		Yr 5	
		Value	HSIndex	Value	HSIndex
<b>Rocky Reef (nearshore)</b>					
Connectivity	meter	0.00	0.00	230.32	1.00
Reef Relief	flat to wall	Flat	0.00	3.12	0.63
Residence Time	days (1-43)	1.13	1.00	1.07	0.99
Substrate	Present/Absent	Absent	0.00	Present	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.89</b>
<b>Eelgrass</b>					
Circulation	m/sec	0.11	0.71	0.10	0.72
Depth	meter	4.26	0.28	3.56	0.36
Substrate	% silt-clay	43.89%	1.00	43.89%	1.00
Temperature	Celsius	17.90	1.00	17.90	1.00
<b>HSI Score</b>			<b>0.67</b>		<b>0.71</b>
<b>Oyster Reef (nearshore)</b>					
Salinity	ppt	31.68	1.00	31.52	1.00
Depth	meter	4.00	0.00	-1.84	0.80
<b>HSI Score</b>			<b>0.00</b>		<b>0.89</b>
<b>Island (Nearshore)</b>					
Vegetation Cover - Least Tern	% cover	NA	0.00	2.33	0.79
Vegetation Cover - Snowy Plover	% cover	NA	0.00	2.33	1.00
Effective Size	acres	NA	0.00	4.44	0.63
Elevation	MLLW	NA	0.00	2.19	0.56
Sediment Grain Size	silt to cobble	NA	0.00	Coarse mix	0.67
Distance	feet	NA	0.00	205.33	0.68
Sediment color	white to brown/gray	NA	0.00	White/Tan	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.74</b>
<b>Rocky Reef (open water)</b>					
Connectivity	meter	0.00	0.00	<2	1.00
Reef Relief	flat to wall	Flat	0.00	Low to Med	0.48
Residence Time	days (1-43)	0.95	1.00	1.00	0.99
Substrate	Present/Absent	Absent	0.00	Present	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.83</b>
<b>Kelp (open water)</b>					
Temperature	Celsius	17.90	0.71	17.90	0.71
Substrate	Present/Absent	Absent	0.00	Present	1.00
Depth	m (0-37)	12.34	0.91	11.65	0.95
<b>HSI Score</b>			<b>0.00</b>		<b>0.88</b>
<b>Oyster Reef (LA River)</b>					
Salinity	ppt	32.70	1.00	32.65	1.00
Depth	meter	3.69	0.00	-1.47	0.88
<b>HSI Score</b>			<b>0.00</b>		<b>0.94</b>
<b>Tidal wetland (LA river)</b>					
Depth	feet	2.16	0.70	-0.78	0.09
Salinity	psu	29.12	0.90	29.03	0.93
Size	acre	0.00	0.00	10.00	0.63
Substrate Grain Size	categories	Coarse sand	1.00	Coarse mix	1.00
Connectivity	#links	0.00	0.00	≥2	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.55</b>
<b>Tidal wetland (Port)</b>					
Depth	feet	8.95	0.40	0.86	0.27
Salinity	psu	32.98	1.00	31.21	1.00
Size	acre	0.00	0.00	18.60	0.95
Substrate Grain Size	categories	Coarse mix	0.80	Coarse sand	1.00
Connectivity	#links	0.00	0.00	≥2	1.00
<b>HSI Score</b>			<b>0.00</b>		<b>0.76</b>
<b>Kelp (breakwater)</b>					
Temperature	Celsius	17.90	0.71	17.90	0.71
Substrate	Present/Absent	Absent	0.00	Present	1.00
Depth	m (0-37)	16.79	0.40	14.80	0.54
<b>HSI Score</b>			<b>0.00</b>		<b>0.73</b>

These examples demonstrate how the model equations can be used to calculate HSI values by parameter and aggregate these values using a geometric mean to calculate habitat HIS scores. Given different input data between year 0 and year 5, we see an increase in overall score due to changes in the parameter values. Interpretation of results should be considered critically by model users and stakeholders. Model results represent a line of data interpretation to help inform decision making, but the results should not be the sole basis for decision making.

## Geographic Range of Model Applicability

This model is intended for use within coastal Southern California, from Point Conception to the southern California border (Figure 33). Point Conception (near Santa Barbara, California, USA) is a coastal region notable for the large number of species range limits associated with a transition in water temperature and oceanographic features (Altman et al, 2013).



**FIGURE 33. MAP OF GEOGRAPHIC RANGE OF MODEL APPLICABILITY. MODEL RANGE HIGHLIGHTED IN BLUE.**

## Considerations for Model Application

Before applying the ESPB model, please review the following considerations:

- 1) The ESPB model was developed specifically to provide insight into choosing among different potential scenarios for restoring combinations of different habitat types for large scale restoration in the bays and estuaries of Southern California. The model was not evaluated under conditions to restore single habitats, or for areas outside of the Southern California region.
- 2) In general, marginal habitat is often the focus of ecosystem restoration projects. Areas that have suitable hard substrate for oysters or kelp may already support a healthy populations and would not be identified as areas in need of restoration. If an area has been identified for restoration, yet hard substrate is the single lacking element for high quality habitat, then polygons representing hard substrate should be added to any substrate data layers used when executing the ESPB model.
- 3) The ESPB model is designed to be flexible regarding data input and spatial scales and can take input from hydrodynamic models, monitoring stations, scientific literature, and expert opinion. Cell size and spatial extent can vary, but the spatial extent must be large enough to include both suitable and unsuitable habitats. One limitation for input data is that a value must be available for each cell within the spatial domain.
- 4) The ESPB model was intentionally designed to only include the minimum factors required for restoration suitability for each of the habitat types. Given the complexities of restoring and sustaining ecosystems over time, other local conditions may influence sustainability, which should likewise be considered for determining restoration potential.
- 5) The ESPB was developed for use by technical experts with knowledge of the biology and ecology of the ESPB system. A moderate level experience in GIS processing using ESRI software is required to use the model.

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## Appendix A: GIS User Guide for Application of the East San Pedro Habitat Evaluation Model

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General GIS methods are discussed in the *Spatial Data and Model Application* section of the model documentation report, in which four case studies (different restoration alternatives considered for the East San Pedro Ecosystem Restoration Study) are illustrated in the application of the Habitat Evaluation Model (Model). The purpose of this Appendix is to provide additional detail in the form of a step-by-step guide for conducting the GIS portion of the analysis and assumes a basic level of knowledge of ArcGIS software and GIS expertise. Analysis was conducted in ESRI's ArcGIS 10.5 software but the process of using Model equations to develop Habitat Suitability Indices (HSIs) can be performed within any GIS that the user is familiar with. Examples from the four case studies are provided within the model documentation (*Spatial Data and Model Application*), illustrating different model results. Conducting such analyses in other locales with different data types may result in variations in data manipulation and geo-processing. Regardless, the application of the Model is the same, and this guide provides the detailed steps used to conduct the analysis in a GIS software environment.

---

### 1. Study Area and Pre-processing

*Study area extent and cell size were determined as a function of both area of interest in terms of the project goals as well as data availability.*

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#### East San Pedro Bay

This study area was selected because it is the subject of an extensive restoration planning study that incorporates multiple habitat types (rocky reef, kelp forest, eelgrass, oyster reef, tidal salt marsh and sandy islands). Environmental and biophysical data corresponding to each of the 23 parameters identified as critical for the respective 6 habitat types were provided for the region. The Model is designed to be flexible regarding data input and spatial scales and can take input from hydrodynamic models, monitoring stations, scientific literature, and expert opinion. Cell size and spatial extent can vary, but the spatial extent must be large enough to include both suitable and unsuitable habitats and a value must be available for each cell within the spatial domain. All data are clipped to the study area (using the Geoprocessing Menu's Clip Tool) and reprojected to the same projection (using the Data Management Toolbox, Projections and Transformations Toolset, Define Projection and/or Project Tool).

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## 2. Developing HSI and Habitat HSI Scores

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### *General Processing Steps:*

- A data layer containing values for each parameter of interest (at least one value per grid cell) is imported into the GIS spatial domain for ESPB.
- Each habitat type is considered separately. For each habitat type, the associated layers for each critical parameter are included as separate data layers.
- For each habitat type-parameter combination, the parameter equations described in *Habitat Parameters and Response Curves* are calculated for each cell within the grid domain and a parameter specific HSI layer is created for each habitat-parameter combination. For example, for Oyster Reef habitat, two separate HSI layers are created, one using the Oyster Reef-Salinity curve (*page 23*) and one using the Oyster Reef-Depth curve (*page 24*). The field calculator is used to apply a series of conditional statements and equations (if-then-else) to each specific cell for each habitat type. For example, for oyster habitat salinity the following conditional statements (presented as pseudocode) used:

- *if salinity ≤ 0 and salinity < 25 |  $HSI_{salinity} = 0.04 * Salinity$*
- *if salinity ≤ 25 or salinity ≤ 30 |  $HSI_{salinity} = 1$*

- To determine the Habitat HSI Score, a geometric mean of all of the individual habitat-parameter HSI scores is calculated and a new layer corresponding to the Habitat HSI Score is created. For a set of numbers  $\{X_i\}_{i=1}^n$ , the geometric mean is:

$$\left( \prod_{i=1}^n x_i \right)^{1/n} = \sqrt[n]{a_1 a_2 \dots a_n}$$

- Using this process, a Habitat HIS Score layer with values for the entire spatial domain is created for each of the six habitat types.
- A map of each restoration alternative under consideration is then merged with each Habitat HSI Score layer to determine the location and area of habitat, by type, within each proposed alternative. Habitat HSI Score values are then extracted for the proposed restoration locations. These scores are presented for each alternative by Habitat type.
- HIS Scores can be combined with habitat acreage to calculate habitat units and compare restoration alternatives.



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**TABLE OF CONTENTS**

1

2 **1 INTRODUCTION ..... 1-1**

3 1.1 ECOSYSTEM RESTORATION AND THE CORPS PLANNING PROCESS ..... 1-1

4 1.2 CORPS ECOSYSTEM RESTORATION POLICY AND APPROACH..... 1-2

5 1.3 STUDY SIGNIFICANCE ..... 1-2

6 1.4 STUDY GOALS AND OBJECTIVES ..... 1-4

7 1.5 PLANNING ASSUMPTIONS AND CONSIDERATIONS ..... 1-6

8 **2 REGIONAL SETTING ..... 2-8**

9 2.1 SAN PEDRO BAY ..... 2-9

10 2.1.1 CLIMATE ..... 2-10

11 2.1.2 HISTORICAL CONDITIONS ..... 2-10

12 2.1.3 ANTHROPOGENIC ALTERATIONS AND EFFECTS ON HABITAT ..... 2-11

13 **3 HABITATS OF SAN PEDRO BAY ..... 3-12**

14 3.1 HABITATS NOT TARGETED FOR RESTORATION ..... 3-13

15 3.2 HABITAT CONVERSION AND RESTORATION TRADE-OFFS..... 3-16

16 3.3 HABITAT TYPES TARGETED FOR RESTORATION ..... 3-16

17 3.3.1 TARGET HABITAT: SUBTIDAL ROCKY REEF ..... 3-17

18 3.3.2 TARGET HABITAT: KELP BEDS ..... 3-20

19 3.3.3 TARGET HABITAT: EELGRASS ..... 3-22

20 3.3.4 TARGET HABITAT: OYSTER REEFS ..... 3-24

21 3.3.5 TARGET HABITAT: COASTAL WETLANDS ..... 3-25

22 3.3.6 TARGET HABITAT: SANDY ISLANDS ..... 3-27

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3  
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5  
6  
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10  
11  
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13  
14  
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16  
17

**LIST OF TABLES**

- Table 1.** Species function by habitat matrix
- Table 2.** Habitat classification cross walk

**LIST OF FIGURES**

- Figure 1.** Map of the southern California, including general circulation patterns in the southern California Bight.
- Figure 2.** Diagram of a basic continental shelf

1 **1 INTRODUCTION**  
2

3 This Appendix summarizes important peer reviewed literature, reports, and other information used to  
4 support the habitat modeling and habitat assessment analysis of the alternatives proposed for the U.S  
5 Army Corps of Engineers’ (USACE or Corps) East San Pedro Bay (ESPB) Ecosystem Restoration Feasibility  
6 Study (Project). The documentation and user guide for the Habitat Evaluation Model (HEM) developed  
7 for this Study can be found in Appendix D.

8 This Appendix does not attempt to provide a full accounting of the biological environment of the Study  
9 Area nor duplicate environmental information already presented in the associated Integrated Feasibility  
10 Report (IFR). The intent of this Appendix is to provide quantitative or qualitative justification and  
11 rationale on the Study’s objectives, assumptions, restoration targets, and decisions point as they pertain  
12 to biological and associated physical conditions for habitats targeted for restoration within the Proposed  
13 Project Area. Results and conclusions from this Appendix will provide the Study’s non-Federal sponsor,  
14 resource agencies, and public with supporting information to assist in understanding this study’s  
15 underlying assumptions and interpreting the quantitative output from the HEM. All attempts have been  
16 made to ensure that the information included within this Appendix is consistent with the most recent  
17 previous biological baseline studies conducted for San Pedro Bay, as well as incorporates the guidance  
18 of subject matter experts.

19 A glossary of technical terms and definitions is also included to aid the reader.  
20

21 **1.1 ECOSYSTEM RESTORATION AND THE CORPS PLANNING PROCESS**  
22

23 Ecosystem restoration is the process assisting the recovery ecosystem structure, function, and dynamic  
24 processes that have been degraded, damaged or destroyed ([SER Primer 2004](#)). The Corps Planning  
25 method provides a means to systematically work through this process by (1) identifying problems and  
26 opportunities and (2) inventorying and forecasting conditions, and formulating, evaluating, and  
27 comparing alternative restoration scenarios (or plans) in order to select the best, most cost effective  
28 restoration alternative for implementation and construction.

29 Evaluating habitat quality or suitability through a habitat assessment is the approach most often used to  
30 compare restoration alternatives. Habitat assessment serves to quantify restoration benefits that inform  
31 the cost effectiveness and cost-benefit analyses that contribute to the comparison of alternative plans  
32 developed during the Corps Planning process. In this context, habitat (i.e., the setting where a group of  
33 organisms live, interact, and reproduce) is considered a proxy for ecosystem function as a whole. In  
34 other words, if the appropriate combination of habitats is present, the entire system will function as  
35 intended. Habitat information is frequently viewed in parallel with species-specific information to gain  
36 insight to various uses, structures, and functions existing within a landscape or site.

37 However, improving the quality of the environment in the public interest, especially in densely  
38 populated urban areas, represents a significant challenge for the Corps. Limitations can stem from  
39 institutional barriers, the lack of few successful precedents, and limited availability of guidance on  
40 conducting ecological restoration in a dense urban environment. Challenges can further occur when

1 attempting to integrate expertise from various disciplines and multiple, sometimes divergent, interests  
2 and goals. Complexity of a topic can result in issues with timing, capacity, communication, and  
3 collaboration as the process unfolds. Navigating this complexity while simultaneously achieving stated  
4 project goals is an inherent challenge of the Corps planning process.

## 6 **1.2 CORPS ECOSYSTEM RESTORATION POLICY AND APPROACH**

8 The objective of any Corps ecosystem restoration project is to restore degraded ecosystem structure,  
9 function, and dynamic processes to a less degraded, more natural condition. Even partial restoration  
10 may provide significant and valuable improvements to degraded ecological resources (USACE 2000).  
11 Under Corps authority (WRDA 1996), restoration opportunities that are associated with wetlands,  
12 riparian and other floodplain and aquatic systems are the ones most appropriate for Corps involvement.

13 Restored ecosystems should mimic, as closely as possible, conditions that would occur within the  
14 Proposed Project Area in the absence of human changes to the landscape and hydrology. Indicators of  
15 successful restoration would include the presence of a large variety of native plants and wildlife, the  
16 ability of the area to sustain larger numbers of key indicator species or more biologically desirable  
17 species, and the ability of the restored area to continue to function and produce the desired habitat  
18 benefits with a minimum of continuing human intervention (USACE 2000).

19 Additional guidance for ecosystem restoration in the Civil Works Program assures that civil work  
20 investments in ecosystem restoration have the intended beneficial effects and would be conducted in  
21 the most cost effective manner (USACE 2000). Corps guidance requires that the ecosystem related  
22 benefits of proposed alternatives be subjected to detailed economic analysis, allowing an explicit  
23 comparison of the costs and benefits associated with the alternatives. Consequently, it is necessary that  
24 the environmental benefits of the alternatives be based on some quantifiable unit of value. Because  
25 restoration value is difficult to quantify from a fiscal perspective, the Corps calculates the value and  
26 benefits of its ecosystem restoration projects using established habitat evaluation methodologies,  
27 rather than calculating benefits in strict monetary terms. Comparing the alternatives in this manner  
28 facilitates the determination of the most cost-effective restoration alternative that meets restoration  
29 goals (USACE 2000).

## 31 **1.3 STUDY SIGNIFICANCE**

33 Coastal habitats are an indispensable part of the nation's significant natural resources (USCOP 2004).  
34 The embayments, marshes and estuaries along the southern California coast are considered among the  
35 most productive habitats on the Pacific coast (Dailey et al. 1993). These environments are characterized  
36 by a unique physical landscape comprised of structurally complex habitat types including rocky reefs,  
37 seagrass communities, kelp beds, sandy shorelines, and wetlands, features of which not only define  
38 California's coastal ecosystems, but are key to the survival of many species dependent on them. Coastal  
39 habitats also sustain much of the Nation's economy (USCOP 2004). In southern California, coastal serve

1 as the major economic engine for the State and are home to a substantial proportion of its residents and  
2 industry.

3 Bays and estuaries, in particular, are coastal habitats that support substantial biological diversity and  
4 perform essential ecosystem services i.e., benefits that humans derive from properly-functioning  
5 ecosystems (MEA 2005). They serve as breeding and nursery areas for a wide array of coastal fishes,  
6 provide habitat for unique assemblages of fishes, and support large populations of small fishes that are  
7 important forage for high level consumers in the ecosystem. In addition to providing essential habitat  
8 for fisheries, estuaries can play a role in improving water quality, serve as buffers for coastal upland  
9 property, and enhance the well-being of local citizens via the outdoor and recreational opportunities  
10 they provide. Estuaries and coastal areas are also home to many ports and industrial areas, and the  
11 communities that depend on them. They play vital roles in supporting the U.S. economy by providing  
12 access for maritime trade.

13 As development along the coast has increased, alterations to this landscape have threatened many of  
14 these physical features and their associated habitats. In southern California, for example, estuarine  
15 wetlands have been eliminated by 75 percent to 90 percent as a result of filling or dredging in the last  
16 century (Ferren et al. 1995). In addition, the persistence of these habitats is expected to be the most  
17 vulnerable to the effects of climate change and sea level rise over time. Sustaining complex physical  
18 processes and habitat structures depends on restoring and maintaining key habitats, addressing  
19 shoreline management, and supporting efforts to adapt to the uncertainties of climate change. With  
20 75% of California's population living within coastal communities, and as southern California's coastal  
21 habitats continue to face unprecedented pressures associated with water supply, population growth  
22 and development, it is critical to address these ever-increasing challenges to coastal marine ecosystems.  
23 Preservation and enhancement of existing coastal and estuarine habitats are critical components to the  
24 sustainability of these habitats.

25 Harbors, in particular, are artificial habitats formed by breakwaters that slow the movement of water  
26 and affect other changes making them in some ways similar to natural, semi-enclosed bays and  
27 estuaries. These habitats are frequently characterized by calm, nutrient-rich waters and a variety of  
28 substrates. The protected rocky environment on the leeward side of a breakwater becomes an  
29 important and distinct habitat for shallow, subtidal fishes. Due to the limited amount of natural bay-  
30 estuarine habitat in southern California as a result of human activities, the numerous harbors of the  
31 region supplement or replace the few natural estuaries as nursery areas for juvenile fishes (Stephens  
32 1978). Los Angeles/Long Beach Harbor is such a habitat that in recent years has been shown to support  
33 diverse and abundant fish faunas (Horn 1980). For these reasons, harbors represent valid opportunities  
34 for focused restoration efforts in the region.

35 Communities in coastal areas of southern California are experiencing environmental changes that create  
36 uncertainty and challenges for future adaptation, such as (1) accelerating rates of shoreline erosion due  
37 to increased storminess and amplified wave heights associated with climate change, and (2) disruption  
38 of coastal resources due to shifts in seawater chemistry tied to ocean acidification. These two problems  
39 are connected in nearshore habitats via kelp forests and their interaction with surrounding waters. Kelps  
40 and other aquatic vegetation have the capacity to attenuate ocean waves, and by means of their  
41 photosynthetic activities, can alter the carbonate chemistry of seawater. Such effects suggest that the  
42 above challenges could serve as simultaneous targets for amelioration through restoration of degraded

1 kelp forests. In addition, estuaries and vegetated habitats along the shoreline can play a significant role  
2 in reducing shoreline erosion, increasing habitat for important species, and providing recreational areas  
3 for human use. Recognizing that the biology and physical processes of coastal and marine habitats are  
4 inextricably linked (i.e., what restores one protects the other), restoration of coastal and marine habitats  
5 can have a net positive effect on the delivery of cultural services (e.g., recreation), provisioning services  
6 (e.g., increase in biotic resources), climate regulation, storm protection, water quality enhancement,  
7 and conservation of native biodiversity.

#### 8 **1.4 STUDY GOALS AND OBJECTIVES**

9

10 Given the above, the USACE Los Angeles District, city of Long Beach, and key agencies and stakeholders  
11 developed specific planning objectives to guide the formulation and evaluation of restoration  
12 alternatives and the development of a recommended plan for the Study (Project). The overall Study  
13 objective is to restore target “complex” aquatic habitat types historically present in the greater San  
14 Pedro Bay ecosystem, inclusive of kelp reef, rocky reef, eelgrass, oyster beds, sandy emergent islands,  
15 and coastal wetlands, of sufficient quantity and quality to support diverse resident and migratory  
16 marine and terrestrial species associated with the bay. Three (3) associated sub-objectives, refined  
17 throughout the formulation process, were developed for the Project:

- 18 a. Increase the extent (total area) of complex aquatic habitats within the Proposed Project  
19 Area.

20  
21 Rationale: Currently, the Proposed Project Area offers one of the few opportunities within  
22 San Pedro Bay to conduct large-scale restoration of nearshore and open water habitats  
23 within a protected embayment. Current habitat conditions in the Proposed Project Area are  
24 characterized by a general lack appropriate substrate conditions (e.g., gently sloping  
25 topography in the intertidal zone, areas of protected shallow water, hard and/or rocky  
26 surfaces) to support marine communities, such as kelp forests, eelgrass beds, and rocky reef  
27 species to the extent that they once occurred in the Southern California Bight (SCB).  
28

- 29 b. Increase the diversity and spatial heterogeneity of complex aquatic habitat types within the  
30 Proposed Project Area.

31  
32 Rationale: Habitat heterogeneity plays an important role in structuring ecological  
33 communities, as heterogeneous habitats (both spatially and structurally) generally support  
34 increased species density, richness, and diversity across terrestrial freshwater, and marine  
35 ecosystems. Habitat heterogeneity influences fundamental processes that organize  
36 communities, including species coexistence, dispersal recruitment success and mortality  
37 predation risk resource acquisition and the strength of trophic cascades (Paxton et al. 2017)  
38

- 39 c. Increase the overall connectivity of complex aquatic habitat types within the Proposed  
40 Project Area by restoring habitat areas in a way to facilitate the movement of species  
41 between habitat nodes to support and enhance existing food webs.

42  
43 Rationale: Connectivity is a defining characteristic of marine ecosystems (Carr et al.  
44 2003). The persistence of many species depends on individuals successfully migrating  
45 among multiple, connected, patches or habitats (Sale et al. 2005; Hastings and Botsford

1           2006). Increased connectivity can benefit all life stages of marine organisms: larval,  
2           juvenile, and adult. For example, Brown et al. (2016) suggest connectivity between  
3           different types of habitats that occur in sheltered environments (e.g., seagrass, salt  
4           marshes) potentially have desirable characteristics for biodiversity conservation and can  
5           support local fisheries through spatial coupling and linkages between species life-history  
6           types.  
7

8           The increased interchange between adjacent habitat types in terms of nutrient cycles, colonization, and  
9           recruitment of species would help to maintain or increase biodiversity and ecosystem function within  
10          the Proposed Project Area. Organisms, organic matter and nutrients are transferred between habitat  
11          types, for example, between freshwater and the ocean via estuaries, pelagic (open water) and  
12          nearshore coastal waters, and kelp beds, seagrasses, and rocky reefs (Fairweather & Quinn 1993). The  
13          goal of restoration within a sheltered environment like ESPB should not only increase the amount and  
14          types of habitats within the bay (addressing sub-objectives 1 and 2), but create synergistic increases in  
15          overall species diversity, and sustain this diversity over time. For example, increases in fish species  
16          diversity abundance can be achieved through increases in nearshore nursery habitat for larval fish, as  
17          well as through increased habitat for juveniles on adjacent open water reefs. This can lead to higher  
18          retention of species within an area over the long term, resulting in desirable characteristics for regional  
19          biodiversity conservation and support for local fisheries (Brown et al. 2016). Fish species diversity  
20          provides a central linkage in the analysis of marine food webs, and therefore, can serve as a reasonable  
21          and cost-effective indicator of habitat value across a wide range of marine habitats (Bond et al. 1999).

#### 22          Habitat “Node” Approach to Restoration

23  
24          The proposed Project for ESPB takes a nodal approach to habitat restoration. A habitat node is area or  
25          patch of habitat associated with a physical location. Nodes can be isolated habitat patches or can be  
26          connected to some extent by edges between adjacent nodes. An edge between two nodes implies there  
27          is some ecological connectivity or exchange between the nodes, such as via propagule dispersal or  
28          material (e.g., nutrient) flow (Urban and Keitt 2001).  
29

30          Nodes in any landscape (or in this case, seascape) contribute significantly to the integrity of the larger  
31          ecosystem by supporting meta-populations (assemblages of local populations connected by migration)  
32          (Hanski & Gilpin 1991). By increasing patch sizes and reducing the distances between them, colonization  
33          among populations improves (Hanski & Thomas 1994). Meta-populations depend on propagule  
34          dispersal and movements or organisms between nodes to persist, and such dispersal is in turn  
35          dependent on the connectivity of the landscape (Schippers et al. 1996). Improving nodal connectivity  
36          help to address aquatic habitat fragmentation.  
37

38          Nodes may be larger or smaller. Large habitat nodes support colonization of the smaller nodes by  
39          organisms, while smaller nodes act as peripheral refuge habitat (Rudd et al. 2002). Large nodes tend to  
40          have high biodiversity and provide important breeding and seeding habitat for smaller nodes, as well as  
41          edge species and transients. Smaller nodes are partly or entirely dependent on individuals immigrating  
42          from the larger nodes as they have a higher rate of extinction and therefore need to be repopulated  
43          constantly (Hansson 1991; van Apeldoorn et al. 1992). Smaller nodes (those under 250-acres) may not  
44          be able to support large numbers of species on their own, but are able to provide important peripheral

1 habitat to species in the larger nodes (Hansson 1991). Generally, nodes have a greater overall  
2 interaction when they are larger and closer together (Linehan et al. 1995).

3  
4 The connectivity of habitats and concept of nodes is germane to the determination of the habitat  
5 “benefit area” for this Project. For USACE restoration projects, habitat units based on modeling results  
6 are typically used to predict and quantify environmental benefits gained from a project. These units can  
7 be spatially distributed throughout the project area. In the case of ESPB, the habitat model is based on  
8 the placement of discrete structural elements (hardscape) that are assumed to provide ecosystem  
9 benefit (i.e., functional lift) to the project area immediately or over time. However, the actual area of  
10 benefit is functionally much larger than this due to the increased interchange (connectivity) between  
11 adjacent habitat types as described above. In this case, the actual benefit area includes the space taken  
12 up by the actual physical structures themselves (e.g., rocks for kelp, shoals, oyster platforms, etc.) along  
13 with ALL the intervening space WITHIN a cluster of hard structures expected to be colonized by rocky reef  
14 organisms over time (e.g., the interstitial space between two adjacent rocks) and BETWEEN the grouping  
15 of clusters (e.g., between an open water rocky reef and a near shore shoal/eelgrass bed). It is assumed  
16 that this interchange between is beneficial, although this is not explicitly quantified in the results of the  
17 HEM.

## 18 19 **1.5 PLANNING ASSUMPTIONS AND CONSIDERATIONS**

20  
21  
22 In this report, the term “restoration” includes creating and enhancing habitat (or the conditions for  
23 habitat establishment). The restoration goals are not intended to return habitats in ESPB to conditions  
24 that may have existed in the past, but improve upon conditions that exist today, with restoration targets  
25 based on what is known about ecosystem services provided by habitats, limiting factors, and the  
26 potential for habitats to be created or enhanced within the bay. Restoration is also designed with the  
27 long-term in mind, and planning must therefore account for expected long-term changes. For this  
28 Project, restoration is targeted to locations and situations where long-term success is most likely.

29  
30 The goals of this proposed restoration Project for ESPB are intended to focus on habitats rather than  
31 individual species (except for those habitats that are created by a single or dominant species, e.g.,  
32 eelgrass or oyster beds). This approach avoids prioritizing some species over others. The key decisions  
33 and planning considerations described below were developed by the Project Delivery Team (USACE and  
34 city of Long Beach), with extensive input from the Project’s Technical Advisory Committee (TAC) and  
35 consultants. The following key decisions were made when identifying the goals for this Project:

- 36  
37     ▪ The geographic scope of the Proposed Project Area is a defined area within ESPB, located  
38     offshore from the city of Long Beach, California. However, conditions in ESPB have a  
39     relationship to the habitats (subtidal, intertidal, and transitional) of the greater San Pedro Bay  
40     ecosystem. Restoration within the Proposed Project Area would benefit the greater ecosystem  
41     of the SCB in the form of incidental, unquantified secondary benefits, including contingencies for  
42     resiliency of the ecosystem to climate change:
  - 43  
44         ○ Restoration within the Proposed Project Area could support higher abundance of taxa in  
45         the region and support more significant regional connections to nearby ecological

1 zones. Restoration could provide regional connectivity for wildlife movement and  
2 hydrologic processes between the project area and the greater port complex.

3  
4 ○ There would be greater potential for future direct connections to the other habitat  
5 restoration projects in San Pedro Bay, Alamitos Bay and the lower Los Angeles River.

6  
7 ○ Restoration within the Proposed Project Area could increase existing population levels  
8 for various state and federally managed fisheries to support agency initiatives and  
9 contribute to local economies.

- 10  
11 ■ For the purposes of this restoration Project, “subtidal habitat” includes all submerged areas of  
12 the bay as they pertain to rocky reef, kelp beds, and eelgrass communities. The Project also  
13 addresses certain “intertidal habitats,” such as tidal wetlands and sandy shores associated with  
14 emergent islands. The water column and other sub-tidal soft bottom habitats of the bay were  
15 not included in the Project’s restoration goals (see section 3.1.1 below).  
16  
17 ■ This Study avoids setting priorities among habitats; however, restoration of some habitats may  
18 result in conversion of others. For example, some soft substrate may be lost through restoration  
19 efforts focused on eelgrass or rocky reefs.  
20  
21 ■ Muddy soft-bottom habitat is essential for some species and supports valuable ecosystem  
22 services. Although soft bottom habitat is plentiful in the bay, it is still threatened by various  
23 activities.  
24  
25 ■ Available information about existing conditions in the bay serves as a baseline for this Project.  
26  
27 ■ The goals of the Project build upon opportunities and information developed by existing  
28 projects, including in-the-water monitoring, restoration, mitigation, and research projects in the  
29 greater San Pedro Bay.  
30  
31 ■ Because there is a great deal of uncertainty about the functions and value of the habitats and  
32 the utility and likely success of restoration, this document recommends using an adaptive  
33 management approach in implementing and achieving the goals.  
34  
35 ■ The Project’s goals and objectives take into account the extent of scientific understanding of  
36 each habitat with a focus on enhancing, creating, or restoring particular habitats.  
37  
38 ■ Subtidal rocky outcrops, subtidal shoals, and tidal wetlands support valued ecosystem services  
39 and are under threat from human activities and climate change in the SCB, thus a restoration  
40 focus on these features is warranted for ESPB. Opportunities for restoration for these features  
41 are based on uncertain techniques, so this document emphasizes applying restoration methods  
42 experimentally and adapting accordingly.  
43

44 The Study operates with the underlying assumption that active restoration approaches are beneficial in open  
45 marine and coastal systems where biogenic structures, such as semi-terrestrial saltmarsh vegetation, intertidal  
46 and subtidal seagrass beds, kelp beds, and rocky reefs, have been lost, reduced, or degraded ([Geist and Hawkins](#)  
47 [2016](#)). Biogenic structuring species act as “ecosystem engineers” ([Jones et al. 1994](#)) and restoring such species not

only adds structure to habitat but also influences ecosystem functioning and ultimately services. Higher plants such as seagrasses and those from saltmarshes, seaweeds and the symbiotic algae associated with reefs are also important primary producers. In the case of macrophytic plants and algae, these provide much primary production that is either directly consumed by grazers or indirectly consumed in detrital food web (Geist and Hawkins 2016).

In most cases, biological attributes will follow structural and physical improvements through processes such as natural re-colonization (Pander et al. 2016). Increasing structural complexity that leads to an array of microhabitats, such as the creation of crevices (Aguilera et al. 2014; Coombes et al. 2015; Loke et al. 2015) that boost biodiversity, can be incorporated at the design phase of projects (Moschella et al. 2005; Firth et al. 2014), retrofitted (Evans et al. 2016) and put in place during routine maintenance (Bulleri and Chapman 2010). Such approaches can particularly benefit populations of overexploited or threatened species (Martins et al. 2010; Perkol-Finkel et al. 2012). Such habitat creation can provide at least some ecosystem services and biodiversity, especially in urban areas, and offset biodiversity loss in adjacent areas (Martin and Haney 2005).

## 2 REGIONAL SETTING

San Pedro Bay is located within the SCB, an oceanographically defined region of southern California that extends from Point Conception, California in the northwest to Cabo Colnett, Baja California, in the south-east, and is bounded to the west by the California Current (SCCWRP 1973; Dailey et al. 1993; Figure 1). The SCB includes an area of approximately 78,000 km<sup>2</sup> with a shoreline distance of over 300 km (Dailey et al. 1993).

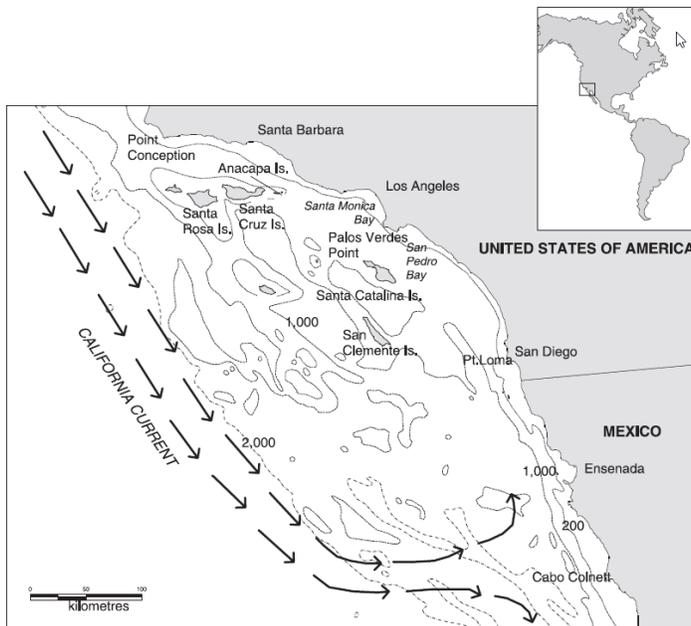


Figure 1. Map of the southern California, including general circulation patterns in the SCB (after Hickey 1993)

The SCB is a rich ecosystem; over 5000 species of invertebrates, 480 species of fish, and 195 species of marine birds are found in this region (Dailey et al. 1993). The diversity found in the SCB is due, in part, to its transitional zonation between two biogeographic provinces. The San Diegoan Province to the south

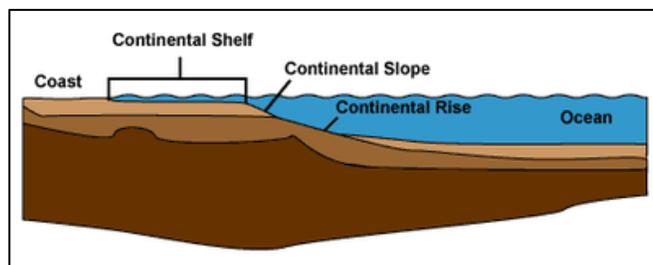
1 introduces sub-tropical species while the Oregonian Province to the north introduces temperate species  
2 into the SCB (Briggs 1974). Each of these provinces has distinctive biota. For example, more than 70% of  
3 all algal species found in California occur in the SCB; half of these species have their northern or  
4 southern range endpoints located within the SCB (Murray and Bray 1993).

5  
6 The SCB has undergone tremendous changes over the last 100 years resulting from natural and  
7 anthropogenic alteration of the coastal zone. Rapid urbanization represents risk to the coastal ecology  
8 by encroachment of habitat and by contributing anthropogenic contaminants to the coastal  
9 environment. The loss of coastal habitat has reduced some ecosystems to critically small areas. For this  
10 reason, ecosystem restoration planning projects represent a vital conservation strategy for significant  
11 habitats that have been degraded, depleted, or are now scarce in the region.

## 14 2.1 SAN PEDRO BAY

15  
16 San Pedro Bay is located on the San Pedro Shelf, a relatively broad (~ 30 miles long) continental shelf  
17 (Fig. 2) located near the middle of the SCB between Point Fermin (southeastern tip of the Palos Verdes  
18 Peninsula) on the northwest and Newport Bay/Corona del Mar bluffs at the southeast. The San Pedro  
19 Shelf is one of the broadest mainland continental shelf segments between Monterey, California, and the  
20 United States-Mexico border. The entire shelf covers approximately 400 km<sup>2</sup> and is shallower than 100  
21 m water depth. San Pedro Sea Valley, San Gabriel Canyon, and Newport Canyon cut into the slope off  
22 San Pedro Shelf at the west, south, and southeast, respectively. Approximately 75 to 80 percent of the  
23 San Pedro Shelf segment is composed of low-relief, sediment-covered seafloor, and the remaining 20 to  
24 25 percent is composed of rock outcrop interspersed with boulders and cobbles (Wong et al. 2012).

25 The Palos Verdes peninsula separates San Pedro Bay from Santa Monica Bay to the northeast. San Pedro  
26 Bay is naturally sheltered from the north by the Palos Verdes Peninsula and the southwest by Santa  
27 Catalina Island. Waves approach the Bay through corridors from the west and south (Gorsline and Grant  
28 1972). During the summer, the largest waves are associated with the southern swell, produced by  
29 storms in the South Pacific (Horrer 1950).



31  
32 **Figure 2.** Basic composition of a continental shelf like located at continental margins with sediment (light brown),  
33 rocks (middle brown) and the mantle of the earth (dark brown)

34 At the north end of the bay, an 8.4 mile long artificial breakwater (wall) extends east from Palos Verdes  
35 and protects the harbors of Los Angeles and Long Beach. The breakwater has two openings to allow  
36 ships to enter the ports of Los Angeles and Long Beach. These openings divide the breakwater into three

1 sections: the San Pedro Breakwater, the Middle Breakwater, and the Long Beach Breakwater. The San  
2 Pedro and Middle breakwaters protect the ports of Los Angeles and Long Beach respectively and were  
3 constructed between 1899 and 1942. The 2.2 mile Long Beach Breakwater is the eastern most section of  
4 the breakwater. The Long Beach breakwater was authorized through the Federal River and Harbor Act of  
5 1940. Construction of the breakwater by the federal government began in 1941 and was completed in  
6 1949. The breakwater is 60 feet high and composed of sand and granite boulders.

#### 8 2.1.1 CLIMATE

9 Average annual precipitation within the region is highly variable and terrain-dependent, averaging  
10 fifteen (15) inches annually and mainly occurring during the winter months (November through April).  
11 Due to the atmospheric dominance of the stable marine layer, significant precipitation is rare between  
12 May and October.

13 During the winter months Pacific storms often push cold fronts across California from northwest to  
14 southeast. These storms and frontal systems account for the vast bulk of the area's annual rainfall. Such  
15 rainy season storms are migratory, with wet and dry periods alternating during the winter and early  
16 spring with irregularity in timing and duration. Rainfall patterns average 3.68 inches of rainfall in  
17 February to 0.01 inches of rainfall in July.

18 The highly developed conditions within the contributing watersheds to the bay facilitate most  
19 stormwater flows generated by the rainfall to be routed through curbs, gutters, catch basins, and storm  
20 drains to the subwatersheds, and eventually to the bay and the Pacific Ocean.

#### 22 2.1.2 HISTORICAL CONDITIONS

24 San Pedro Bay is essentially a multi-river flood plain delta formed as detritus deposited by the Los  
25 Angeles River, San Gabriel River, Santa Ana River and several minor streams discharged into the ocean  
26 ([Wiegel, 2009](#)). During the wet, mild winter, these rivers are still the primary source of sediments to the  
27 Bay ([Emery 1960](#)).

28 Extensive sand dunes sloughs and other wetland areas historically existed in Long Beach, Belmont Shore  
29 and Alamitos Bay ([Dorr 1976/1985](#); [USACE 1986](#); [Larkey 1990](#)). George Davidson, of the U.S. Coast  
30 Survey, wrote the following about San Pedro Bay and the contiguous coastal wetlands and floodplain in  
31 1892, as quoted by U.S. Senator Stephen M. White in a speech in the US. Senate ([White 1896, p. 42](#)):

32 *"The bay is the northwestern limit of a very extensive plateau of comparatively shoal water along the*  
33 *seaboard from Point Fermin to about Newport, and the whole country behind the shore is sandy and so*  
34 *low that in winter it is flooded for miles inland by the rains and the overflowing of the low banks of the*  
35 *numerous streams frequently changing their course. The detritus from these streams is moving seaward*  
36 *and principally to the westward over this plateau and helping to current."*

1     2.1.3   ANTHROPOGENIC ALTERATIONS AND EFFECTS ON HABITAT

2  
3    *A Changed Estuary*

4    The environment of the San Pedro Bay is now much different from what was described historically.  
5    During the past century, the shape, size, and composition of the bay has been altered by natural events  
6    (e.g., floods, droughts, earthquakes) and ocean waves have modified its beaches, with large wave events  
7    having caused beach erosion and destroyed or damaged buildings and infrastructure.

8    Human activities have also had profound effects on the bay’s coastal and marine ecosystems. The  
9    conversion of shorelines from tidal salt marsh to rip-rap/seawall, diversion of water from upstream  
10   waters (preventing it from flowing into the bay), addition of innumerable structures to its edges and  
11   bottom, removal of submerged rocks, and the plying of the bay with ships, boats, trawls, and dredges  
12   have changed baseline conditions considerably. Coastal structures (harbor entrances, river mouth  
13   jetties) have been built. Construction and maintenance dredging have been performed in the bay  
14   entrance, navigation channels, turning basins, marinas, and river channels. The beaches are extensively  
15   used, and many have been nourished for decades by the addition of sediment obtained from dredging  
16   navigation projects, from "offshore borrow pits/ areas." Jetties, wharves, breakwaters and enclosed dock  
17   basins have long been a feature of coastal regions with many estuaries being dredged and straightened to help  
18   navigation, and concerns about flooding have led to the proliferation of coastal armoring ([Airoidi et al. 2005](#)).  
19   Artificially created or highly modified marine habitats are now a common feature worldwide, especially so in  
20   highly urbanized environments like San Pedro Bay.

21   Activities associated with fishing, marinas, shipping and ports, dredging, sand mining, transportation,  
22   recreation and industry have particularly had significant impact on the Bays subtidal habitats. Subtidal  
23   habitat is also threatened by invasions of non-naïve species (as a result of human actions, most non-  
24   intentional) legacy pollutants (such as a variety of chemicals formerly used in industry), and modern-day  
25   pollution from “point sources,” such as industry and sewage treatment plants, as well as “non-point sources,” such  
26   as the runoff from residential streets and inputs to local watersheds.

27   The course of the rivers that discharge to the bay have also changed over time due to both natural  
28   events and human modifications. In the small, steep canyons of the upper watersheds, dams, debris  
29   retention structures levees, and other river control structures have been built. In addition, sediment  
30   (sand, gravel, silt, clay) has been trapped in reservoirs and debris retention structures. Sand and gravel is  
31   also mined from river beds. This has resulted in a substantial decrease in the natural supply of sediment  
32   to the bay. During the warm, dry summer, most of the river water is now diverted upstream to recharge  
33   groundwater. Below these diversions, the rivers have a minor flow composed of dry-weather runoff,  
34   treated domestic sewage, and industrial discharges.

35   This loss and degradation of the ecosystem has decreased the value and extent of bay habitats for many species.  
36   The biomass of wetland and subtidal vegetation has been reduced, resources of which likely provided copious food  
37   resources to humans and animals alike in the past. The intricate matrix of wetland channels, with their three-  
38   dimensional surfaces, has been filled in to build ports and marinas. The resulting loss of habitat complexity probably  
39   reduced the abundance of many types of estuarine and marine organisms and the productivity of pelagic and  
40   benthic food webs.

1 Despite these changes and challenges, estuarine life persists and, in some cases, flourishes in the bay.  
2 This “novel” ecosystem now supports a diverse and surprising number of fauna with anthropogenic  
3 structures and a mix of native and invasive species (Hobbs et al. 2009; Wensink and Tiegs 2016). As a  
4 result, ESPB offers unexpected habitats of ecological value and the potential for creating and enhancing  
5 ecosystem function of existing habitats.

6

### 7 **3 HABITATS OF SAN PEDRO BAY**

8

9 Consideration of significant resources (e.g., habitats) is central to the USACE plan formulation process,  
10 especially in the context of ecosystem restoration planning because non-monetary outputs (values) are  
11 a consideration. Per Engineer Regulation 1105-2-100, significance of resources and effects will be  
12 derived from institutional, public, or technical recognition. Institutional recognition of a resource or  
13 effect means its importance is recognized and acknowledged in the laws, plans, and policies of  
14 government and private groups. Technical recognition of a resource or an effect is based upon scientific  
15 or other technical criteria that establish its significance. Public recognition means some segment of the  
16 general public considers the resource or effect of the resource to be important (USACE 2000). The  
17 importance of these resources, information specific to East San Pedro Bay, and restoration of these  
18 resources, is further described in more detail in the following sections.

19 A number of significant habitats are found in or associated with San Pedro Bay, the subtidal zone being a  
20 critical piece of this ecosystem. Subtidal habitat, as defined here, includes all of the submerged area  
21 beneath the bay’s water surface: mud, sand, shell, rocks, artificial structures, shellfish beds, eelgrass  
22 beds, macroalgal (kelp) beds, and the water column above the bay bottom.

23 Throughout the SCB, including San Pedro Bay, the dominant bottom environment consists of sandy and  
24 muddy sediments (Emery 1960; Dailey et al. 1993). Sandy and muddy sediments (i.e., soft-bottom)  
25 consists of patches of sediment differing in grain size (e.g., gravel, sand, silt, clay), and are characterized  
26 by much less relief than hard-bottom habitats. Soft-bottom habitats are most extensive on the mainland  
27 shelf, slopes, and basins of the SCB. Sediments with high percentages of sand generally dominate shelf  
28 areas, whereas sediments with high percentages of silt generally dominate slopes and basins. Various  
29 species of seagrass are commonly associated with soft-bottom areas in nearshore zones.

30 Hard bottom areas (e.g. rocky outcrops, artificial structures, shell mounds) provides substrate for  
31 attachment of algae and sessile organisms, and crevices for refuge for mobile organisms. Habitats  
32 associated with hard-bottom frequently have abundant algal cover in shallow water. Along the mainland  
33 shelf of the SCB, rocky bottoms are most commonly found inshore near rocky headlands, along edges of  
34 submarine canyons, as outcroppings on the shelf, and at the shelf break. Only rarely do outcrops  
35 naturally occur in deep water (e.g., Santa Monica Bay and San Pedro Bay).

36 In addition to the subtidal zone, the intertidal zone is a unique habitat due to tidal influences. Exposed  
37 to the air at low tide and underwater at high tide, this area represents a continuum of habitat types  
38 from the bottom of the bay to tidal wetlands (e.g. mudflats), and transition zones (e.g. sandy beaches)  
39 to upland areas (e.g., sandy islands and dunes). Intertidal zone-associated habitats represent some of  
40 the most imperiled habitats in the SCB.

1 **3.1 HABITATS NOT TARGETED FOR RESTORATION**  
2

3 It should be noted that muddy soft-bottom (with the exception of sandy-bottom eelgrass habitat in  
4 nearshore areas) and the water column were not targeted specifically targeted for restoration, as the  
5 goals of this restoration effort focused on habitat creation and enhancement of rare or limited habitat  
6 types within the project area as discussed above. The following provides rationale for why the water  
7 column and soft-bottom sediments were not considered for study.

8 Water Column  
9

10 The water column is the water covering submerged substrate of the bay, including all volume between  
11 the bay’s bottom substrate and the water surface. The bay’s water column is both the medium for each  
12 of the other sub-tidal habitats (e.g. eelgrass, kelp, rocky reef) and technically a separate habitat in its  
13 own right. The water column is important for transporting material and organisms to and from the other  
14 habitats, and many estuarine organisms live their lives entirely within the water column. Pelagic  
15 organisms are those associated with the water column and tend to move with and within the water.  
16 Because water-column processes influence other habitats, understanding these processes is essential  
17 for managing the other habitats.  
18

19 For the purposes of this IFR, the water column was not called out as a separate habitat measure with  
20 specifically defined restoration targets. Benthic habitats (e.g., eelgrass, kelp reefs) are assumed to  
21 include the overlying water column for the purposes of setting and achieving goals for those habitats.  
22 For example, the movement of propagules (e.g., eelgrass seeds, kelp sporophytes) among beds is  
23 mediated by water motion, and therefore this motion must be considered in efforts to restore or  
24 enhance these habitats. In this case, the bay location and placement of substrates is critical so that  
25 these surfaces have the best chance of being passively colonized by the marine species that are  
26 appropriate to the habitat type being restored.  
27

28 Although the existence of the water column is not threatened habitat type in the SCB, water quality  
29 could become degraded. The greatest concerns for protecting the water column in ESPB are reducing  
30 contaminants and improving water quality for marine organisms, predominantly fish. The effects of  
31 emerging contaminants (hormones, antibiotics, and other pharmaceuticals) on bay resources are a  
32 growing area of concern. Many of these pollutants are entering the bay through the rivers that drain to  
33 the bay, including the Los Angeles, and San Gabriel Rivers. For example, there are five storm drain  
34 basins, situated 100-200 feet above the water’s edge, that collect, convey and discharge runoff to the  
35 Long Beach City beaches that are known to be impaired by indicator bacteria.  
36

37 It is known that stressors originating in the contributing watersheds to a bay can impact affect estuarine  
38 water quality, which in turn can affect the abundance and/or quality of habitats, such as submerged  
39 aquatic vegetation or rocky reefs. The linkages from watershed stressors to water quality and then to  
40 the habitat themselves are modulated by estuarine characteristics. However, a complete analysis of  
41 these interactions was beyond the scope of the current planning study for a number of reasons.  
42 Because issues of water quality are under the purview of other existing agencies operating under  
43 various laws and authorities, such as the federal Clean Water Act and the California Porter-Cologne  
44 Water Quality Control Act, this IFR does not address them. Furthermore, pelagic organisms (those living  
45 primarily in the water column) move with the water and therefore are not subject to water quality  
46 stressors in the same way as benthic (bottom-dwelling) organisms.

1  
2 From a technical standpoint, an informative water quality analysis would require access to robust data  
3 sets that are not currently not available at the scale of the entire bay and for all habitats. Such a data set  
4 could support a multivariate analysis in which causal pathways could be statistically traced from  
5 watershed stressors through intermediate water quality variables to habitat effects (e.g., [Pugesek et al.](#)  
6 [2003](#); [Ahronditsis et al. 2007](#)).

7  
8 In terms of implications for ESPB model development, although models can potentially explain  
9 variations in habitat abundance under the low abundance conditions as they have persisted in the bay  
10 for some time, models do not necessarily explain the reason for decline itself. In order to explore the  
11 complete chain of causal linkage from landscape characteristics to water quality and then from water  
12 quality to habitat (like eelgrass), a bay-wide statistical analysis would need integrated data on the  
13 geographical characteristics, water quality, and habitat responses for the entire San Pedro Bay. The  
14 required data were available for geographical characteristics and for habitat abundance, but not water  
15 quality. There are just not enough current water quality data for analysis of habitat effects at the whole-  
16 bay scale. Water quality samples are collected from various stations within the bay, with fewer stations  
17 in certain areas and their placement is not consistent among the various sample years. Therefore, the  
18 point data cannot be integrated to give a spatially and temporally integrated measure that represents  
19 the entire San Pedro Bay estuary. In other words, the water quality cannot be made commensurate with  
20 integrated, whole estuary/bay values of the habitat response and geographic characteristics.

#### 21 Soft-bottom Sediments

22  
23  
24 It is recognized that soft-bottom marine habitats comprised of soft sediments (i.e., underwater  
25 substrates comprised of sand, silt and mud) are an important component of the ESPB project area and  
26 the greater SCB ecosystem. Most of southern California coastal subtidal areas are characterized by soft  
27 bottom, with only occasional small rocky patches. Such areas provide little support for reef associated  
28 sport fishes or for development of the marine life rocky reef-associated fishes require for food and  
29 habitat.

30  
31 Patches of soft sediment differing in grain size (e.g., gravel, sand, silt, clay) provide distinct habitats to  
32 different species of benthic organisms, used for both shelter and foraging grounds. Subtidal soft-bottom  
33 environments also provide habitat for sand dollars (*Dendraster* spp.), sand stars (*Astropecten* spp. &  
34 *Luidia* spp.), sea pens (*Stylatula* spp.), as well as many species of polychaetes, crustaceans, gastropods,  
35 rays, and flat fishes; however, polychaetous annelids (worms) dominate in most un-impacted regions.  
36 These bottom organisms are near the base of the food web that in turn support an abundant and  
37 diverse assemblage of bottom-dwelling fishes. Soft-bottom fish found in the bay include flatfishes,  
38 rockfishes, sculpins, combfishes, and eelpouts. Some of these fish, such as California halibut  
39 (*Paralichthys californicus*), California scorpionfish (*Scorpaena guttata*), barred sand bass (*Paralabrax*  
40 *nebulifer*), and white croaker (*Genyonemus lineatus*), also account for a significant percentage of  
41 recreational fish catches from piers and boats ([Bay et al. 2015](#)).

42 With the exception of soft-bottom nearshore areas that support eelgrass beds, soft bottom benthic  
43 habitats were not included in the HEM for ESPB for a number of technical and logistical reasons. Benthic  
44 soft-bottom substrates (i.e., sand and mud) predominate in an overwhelming percentage of the marine  
45 area along the SCB ([Ambrose 1994](#); [Schiff et al. 2000](#)), including east San Pedro Bay. Soft-bottom habitat  
46 is considered the most extensive benthic habitat, particularly on the mainland shelf, slopes, and basins

1 off the southern California coast. Soft-bottom habitat consists of sandy and muddy sediments with  
2 much less relief than hard bottom habitat. Thus, conversion of habitat from soft-bottom to hard-bottom  
3 habitats (e.g., rocky reefs, kelp forests) on the scale proposed under the Project would not significantly  
4 reduce the total available soft-bottom habitat to those species that rely on it. For example, relative to  
5 the predominant expanses of soft-bottom and other types of hard-bottom habitats in the southern  
6 California marine environment, kelp forests are relatively rare, with an average total of approximately  
7 88 square kilometers (34 square miles) of canopy coverage in the SCB, including the Northern and  
8 Southern Channel Islands ([Murray and Bray 1993](#)). This coverage constitutes approximately 0.1 percent  
9 of the 78,000-square-kilometer (30,116-square-mile) area of the SCB ([Dailey et al. 1993](#)). Furthermore,  
10 increasing the extent of kelp beds along the southern California coast would provide conditions that  
11 favor the production of water column feeding fishes that are less likely to feed from contaminated  
12 benthic (sediment) communities and may therefore be less likely to accumulate contaminants.

13 Although soft-bottom substrates support a diversity of marine life, current habitat conditions in the  
14 Proposed Project Area of ESPB are characterized by a general lack of hard (or rocky) substrate conditions  
15 to support specific marine communities, such as kelp forests and rocky reef communities, to the extent  
16 that they once occurred in the SCB. In a study that ranked the value of various marine habitats found  
17 within the SCB base on fish guilds, kelp beds, shallow artificial reefs, and wetlands were all ranked higher  
18 than the five soft-substrate habitats evaluated in the study in terms of fish species diversity ([Bond et al.  
19 1999](#)). In addition to the greatly enhanced habitat values exhibited on some hard substrates, there was  
20 also a decrease in habitat value with increased depth over soft bottom substrates. Subtidal sand-bottom  
21 environments are also economically important to nearshore fisheries, which trawl for white croaker, and  
22 various flatfish. Because of their low productivity, subtidal soft-bottom communities are often  
23 considered to be less important than more productive rocky reef environments, which promote  
24 increased species richness and biological productivity ([NOAA 2017](#)).

25 The ability to effectively measure restoration success for soft-bottom habitats was also a factor for why  
26 these habitats were not included in the HEM. The particle (grain) size of soft sediments in the Study Area  
27 vary naturally due to local conditions. For example, grain size co-varies naturally with depth on the  
28 mainland shelf of the SCB, and as a result, soft-bottom marine communities are often defined by depth  
29 ([Bergen et al. 1999](#); [Jones 1969](#)), making it difficult to determine a specific and/or meaningful optimum  
30 input for the model parameter. Furthermore, the soft bottom habitats of the Bay has been extensively  
31 modified by human activities. Coastal structures (harbor entrances, river mouth jetties) have been built.  
32 Construction and maintenance dredging has been performed in bay entrances, navigation channels,  
33 turning basins, marinas, and river channels. The beaches are extensively used, and many have been  
34 nourished for decades by the addition of sediment obtained from dredging navigation projects, from  
35 offshore "dredge pits" (also called "offshore borrow pits"). Because of the abundance of borrow pits  
36 within the Study Area and the fact that these areas tend to be located in areas used extensively by  
37 commercial shipping navigation, a management decision was made to exclude all borrow pits from the  
38 habitat analysis. Because the borrow pits areas would be excluded, the HEM would not be applicable to  
39 any large depressions naturally occurring within the ocean floor. For these reasons, soft bottom habitats  
40 were not factored into the habitat model.

41

42

1 **3.2 HABITAT CONVERSION AND RESTORATION TRADE-OFFS**  
2

3 Ecological restoration is not a substitute for conservation of ecosystems, but where ecosystems are  
4 already heavily degraded, it may be a necessary or even a more efficient strategy. Natural recovery is  
5 preferred in the absence of major environmental stressors, but in systems where the major stressor(s)  
6 cannot be removed or significantly reduced, restoration interventions should be considered and  
7 implemented as essential components of ecosystem management. Although the process of restoring a  
8 single species or particular ecosystem function(s) can be accomplished, it may come at the cost of other  
9 ecosystem elements. Understanding these trade-offs can helping guide restoration efforts ([Abelson et](#)  
10 [al. 2016](#)).

11 For example, it is recognized that bottom disturbance via placement or construction of artificial  
12 structures is a potential stressor of concern across several subtidal habitats in San Pedro Bay. Although  
13 the value of soft-bottom sediments are clearly recognized and efforts to preserve and protect these  
14 habitats should be encouraged wherever appropriate, protection goals for this habitat (by far the most  
15 abundant subtidal habitat type in San Pedro Bay; see Table 3-1 in the IFR: Change in Habitat/Resource  
16 Type by Alternative) should not limit restoration efforts for more desirable complex habitats (e.g.,  
17 eelgrass, rocky reefs) that seek to increase biodiversity. Due to the sheer abundance of soft-bottom  
18 sediments within the project area (but correspondingly fewer sustainable opportunities to actually  
19 restore it), replacement or conversion of soft-bottom to other habitat types at suitable locations is a  
20 valid restoration strategy.

21 In cases where improved ecosystem services for an area are a key goal of the restoration, but extreme  
22 abiotic changes to the system have occurred as associated ecosystem services have been lost (as in the  
23 case of San Pedro Bay), changing of the structure and/or function to reverse this decline and form a  
24 healthier ecosystem (e.g., changing the substratum type or sediment grainsize), even if it differs from what  
25 historically existed prior to human interference, would enable the renewal of ecosystem services in the  
26 form of a “target-designed novel ecosystem” that achieve multiple outcomes that meet multiple  
27 restoration objectives ([Abelson et al. 2016](#)).

28  
29 **3.3 HABITAT TYPES TARGETED FOR RESTORATION**  
30

31 Current habitat conditions in the proposed project area of ESPB are characterized by a general lack  
32 appropriate substrate conditions (e.g., gently sloping topography in the intertidal zone, areas of  
33 protected shallow water, hard and/or rocky surfaces) to support marine communities, such as kelp  
34 forests, eelgrass beds, and rocky reef species to the extent that they once occurred in the SCB. These  
35 important coastal biogenic habitats (e.g. tidal salt marshes, rocky reefs, seagrass beds, and kelp beds)  
36 occur in close proximity to densely populated coastal regions and as such are among some of the most  
37 heavily used and impacted environments on earth ([Weslawski et al. 2004](#); [Lotze et al 2006](#)). Rocky reefs  
38 kelp forests, seagrass, and estuaries are also all currently considered Habitats of Particular Concern  
39 (HAPC), a discreet subset of Essential Fish Habitat (EFH) by the U.S. Regional Fishery Management  
40 Councils (<http://www.fisherycouncils.org>). HAPCs provide important ecological functions and/or are

1 especially vulnerable to degradation. Intertidal habitats such as wetlands and transitional habitats such  
2 as sandy shore are also under extreme threat and limited in the region.

3 For these reasons, restoration alternatives (or plans) were developed for six target habitat types: (1)  
4 subtidal rocky reef, (2) kelp forest, (3) eelgrass beds, (4) oyster beds, (5) coastal wetland, and (6)  
5 emergent sandy islands, comprising a range of intertidal and subtidal habitats. Restoration goals focused  
6 on creating more area of these habitats and/or the conditions to facilitate their establishment) within  
7 the bay. Each target habitat type is discussed in turn below, with rationale for sizing of restoration  
8 features and the species associated with each habitat type. Species lists are not intended to be  
9 exhaustive, but provide example ecological endpoints and a measure of functional equivalency for the  
10 habitat type to be restored. A companion habitat species matrix is also included by habitat type ([Table](#)  
11 [1](#)). The species listed in Table 1 generally correspond to those listed in the appendix narrative. The goal  
12 was to focus on species both indicative of the habitat to be restored, as well as those that play a key  
13 ecological role or function for the habitat type. In addition, a classification cross walk between ESPB  
14 habitat types and other classification systems (e.g., [Cowardin 1979](#)) is found in [Table 2](#).

15

### 16 3.3.1 TARGET HABITAT: SUBTIDAL ROCKY REEF

17

18 Rocky reef habitats are comprised of rock outcrops (e.g. granite, limestone, basalt) of varying relief.  
19 Rocky habitat encompasses boulders to bedrock i.e., rock that is large enough so as not to be normally  
20 moved by currents. Rocky reefs can take a variety of forms, each of which can support a different  
21 associated biological community. Southern California rocky reefs are among some of the most diverse  
22 and productive marine ecosystems in the world. Rocky reefs can support giant kelp forests, providing  
23 food, shelter, and nursery grounds for many marine species. Artificial structures, including jetties,  
24 breakwaters, and rip-rap can also support rocky reef communities ([MBC Applied Environmental Sciences](#)  
25 [1988](#)).

26 Rocky reefs can be located in the *rocky intertidal zone* where they are intermittently exposed or in the  
27 *rocky subtidal zone* where they are always submerged. Distinct tidal zonation is observed, with  
28 increasing numbers of species with increasing depth ([Pondella et al. 2011](#)). Subtidal rocky reefs,  
29 although completely submerged even at low tide, still receive enough light for photosynthesis. They are  
30 inhabited by algae, invertebrates, and groundfishes. Perennially submerged rock outcrops in the  
31 nearshore zone provide important refuges for juvenile and smaller fishes in addition to surface area for  
32 colonization of algae and invertebrates. Rocky reefs in deeper water that do not receive enough light  
33 for photosynthesis and are dominated by sessile invertebrates and groundfishes. Most rocky reefs,  
34 regardless of the zone in which they are located, are beneficial because of the physical structure they  
35 provide to support some aspect of the marine ecosystem.

36 Shoals are underwater ridges, banks, or bars consisting of, or covered by, sand or other unconsolidated  
37 material, resulting in shallower water depths than surrounding areas. The term *shoal complex* refers to  
38 two or more shoals (and includes adjacent morphologies, such as troughs separating shoals) that are  
39 interconnected by past and or present sedimentary and hydrodynamic processes. Although shoals are  
40 typically composed of sand, they could be composed of any granular matter that the moving water has  
41 access to and is capable of shifting around (for example, soil, silt, gravel, cobble, or even boulders). The

1 grain size of the material comprising a shoal is related to the size of the waves or the strength of the  
2 currents moving the material, but the availability of material to be worked by waves and currents is also  
3 important ([Rutecki et al. 2014](#)).

4 Reef-associated fish species have been documented on shoals and shoal complexes adjacent to or  
5 containing hard-bottom substrate (reef patches, oyster reefs, and rock outcroppings) in the South  
6 Atlantic and Florida Straits, indicating that the hard-bottom features influence the local shoal fish  
7 assemblage and increase species diversity in these shoal areas ([SAFMC 1998](#), [Zarillo et al. 2009](#)).

8

### 9 3.3.1.1 RATIONALE FOR ROCKY REEF FORM AND SIZING

10

11 Any target for an optimum or minimum size for a rocky reef or rocky reef complex, in terms of  
12 restoration, would vary by individual species needs. [Ambrose and Swarbrick \(1989\)](#) suggest that a large,  
13 complex reef (i.e., 50 ha or larger) constructed from a natural substrate, such as quarry rock, could  
14 furnish many different habitat and microhabitat types. Placed in an appropriate location, it could  
15 support a rich assemblage of algae and associated invertebrates, thereby providing food for a number of  
16 fish species.

17 Giant kelp (*Macrocystis pyrifera*) was the dominant biogenic habitat structure on almost all reefs  
18 surveyed for [Pondella et al. \(2011\)](#). A kelp bed with a canopy size of at least five acres would be likely to  
19 persist during extended periods of unfavorable conditions (e.g., El Niño events). However, both patch  
20 size and patch isolation play into probability of extinction ([Schiel and Foster 2015](#)). Giant kelp has  
21 relatively short spore dispersal distance(s), so more isolated patches may not rebound following  
22 disturbance.

23 However, smaller sized reefs have been shown to support a greater fish density while larger reefs have  
24 higher biomass density from larger, but fewer, individuals ([Bohnsack et al. 1994](#)). Multiple small reefs  
25 support more individuals and more species than one large reef of equal material. Fishes recruited by  
26 larval settlement accounted for 36% of the total resident abundance but only 2% of total biomass. As  
27 reef size increased, older juvenile or adult colonists comprised a greater percentage of total biomass  
28 (94% to 99%).

29 Smaller reefs may also be better for overall species recruitment to the reef. There was a significant  
30 decline in mean total biomass of larval settlers as reef size increased ([Bohnsack et al. 1994](#)). This is  
31 evidence that mortality of larval settlers is higher on larger reefs due to increased competition and  
32 predation from larger resident populations and larger individual fishes.

33 Several small reefs have greater edge effect in that they offer more ecotone habitat based on a higher  
34 ratio of perimeter to reef area. Additionally, dispersing fauna may have a better chance of locating  
35 several small reefs than one large reef ([Bohnsack 1991](#)). Further, because small reefs have higher fish  
36 density, they could support more species by chance ([MacArthur and Wilson 1967](#)).

### 37 3.3.1.2 SPECIES ASSOCIATED WITH ROCKY REEF HABITATS

38

1 In terms of fish, kelp bass, barred sand bass, and spotted bay bass inhabit both kelp-dominated or non-  
2 kelp, rocky reef systems (D. Pondella, pers. comm.). In the Port of Long Beach and environs, all three  
3 species frequently co-occur. Other common species for both habitats include garibaldi, California  
4 sheephead, rock wrasse, black perch, blacksmith, and seniorita. The following species are suggested as  
5 representative for the non-kelp rocky reef ecosystem overall. However, given the relatively shallow  
6 depths at which habitat restoration activities will occur within San Pedro Bay, rocky reefs that support  
7 giant kelp and those that do not support giant kelp are expected to support a similar mix of species (D.  
8 Pondella, pers. comm.).

9 Invertebrates:

- 10     ▪ California spiny lobster (*Panulirus interruptus*): The California spiny lobster an important coastal  
11 nearshore predator that regulates the population of several key invertebrate species such as  
12 purple urchins and the mussel species *Mytilus californianus*. They also act as hosts to other  
13 marine organisms, such as sponges, hydroids, barnacles, serpulida, krill-like amphipods and  
14 nemertean (*Carcinonemertes wickhami*) (Eminike, et al. 1990; Lafferty 2004; Lindberg 1955). The  
15 species is highly sought in both commercial and recreational fisheries (Barsky 2001).  
16
- 17     ▪ Abalone (*Haliotis* spp.): Abalones are marine gastropod mollusks that live on intertidal and  
18 subtidal rocky substrate. Depending on the species, this habitat may include bare rock, surf  
19 grass, kelp forest, or deep, sub-canopy-forming kelps. Biological interactions include  
20 competition within and among species, predator/prey interactions, disease, and parasite/host  
21 interactions. Ocean conditions have been found to shape the dynamics that influence abalone  
22 populations (Dayton and Tegner 1984). Kelp forest community dynamics for some abalones are  
23 further confounded by human activities such as fishing (Tegner and Dayton 2000) and pollution.  
24 Subtidal abalone are typically closely associated with the kelp species that provide food and  
25 shelter. Factors that impact kelp abundance may in turn also affect abalone populations.  
26
- 27     ▪ California mussel (*Mytilus californianus*): Mussel beds play several important roles within marine  
28 ecosystems. Mussels are filter feeders. They draw in large amounts of seawater to trap  
29 phytoplankton, their food source. One mussel can filter 2-3 liters/hour (up to 350 liters of  
30 seawater daily) – equivalent to three full bathtubs. As the mussels filter the water, they also  
31 remove sediments and other substances that make the water murky.

32 Mussel beds provide a habitat for other marine organisms, such as juvenile fish invertebrates  
33 and. For example, *M. californianus* beds provide structural habitat used by many small  
34 crustaceans and other invertebrates and fish (Paine and Suchanek 1983). The shared  
35 biogeochemical functions of water clarification and bio-deposition make all suspension-feeding  
36 bivalves a valued provider of ecological services to shallow-water ecosystems (Grabowski and  
37 Peterson 2007). Because mussels are declining in abundance throughout their  
38 range, the group good intertidal species, they may be a good intertidal candidate species for  
39 investigating the effect of climate change impacts on marine species (D. Pondella, pers. comm.).

40 Fish: In general, fish species diversity has been shown to provide a central linkage in the analysis of  
41 marine food webs, which suggests that fish diversity is reasonable and cost-effective indicator of habitat  
42 value across a wide range of marine habitats.

- 1       ▪ Blacksmith (*Chromis punctipinnis*): In rocky reef habitats, blacksmith can transport substantial  
2       amounts of nutrients from their feeding areas (seagrass beds or open water) to their resting  
3       areas in the reef in the form of fecal products (Meyer et al. 1983). Bray et al. (1981) calculated  
4       that blacksmith feces contribute an average of 23 mg and a maximum of 60 mg of carbon per  
5       square meter per night to smaller crevices in the reef. Geesey et al. (1984) showed that  
6       migrating blacksmith contribute to an input of phosphorus and trace minerals to crevices in  
7       reefs and other rocky areas.  
8
- 9       ▪ Barred sand bass (*Paralabrax nebulifer*): Due to their abundance, barred sand bass play a  
10      significant role in the energetic balance and the structural progression of the marine  
11      environment, especially for estuaries and harbors (Allen et al. 1995). Like other serranids, the  
12      species has a high economic importance in nearshore and recreational fisheries of southern  
13      California and Ensenada, B.C., Mexico (Hammann and Rosales-Casiin 1990; Rodriguez-Medrano  
14      1993).  
15

### 16       3.3.2 TARGET HABITATT: KELP BEDS

17

18      Kelps are large brown seaweeds (macroalgae) associated with colder waters of the Northern  
19      Hemisphere. Kelp beds are complex, 3-dimensional marine habitats which can support over 700  
20      described or known species, encompassing marine mammals, birds, fishes, and invertebrates (Graham  
21      2004). Kelp forests are important to the physical and biological processes of nearshore environments.  
22      They add structural complexity to the water column and provide food, substrate, and shelter for a  
23      variety of vertebrate and invertebrate species (Quast 1968; Leighton 1971; Wing and Clendenning 1971;  
24      Edwards 1980; Harrold and Pearse 1987; Duggins et al. 1989). Due to their large size, kelps can physically  
25      alter and reduce currents and waves (Foster and Schiel 1985; Koehl and Alberte 1988), decrease light  
26      intensity (Pearse and Hines 1979; Reed and Foster 1984) and increase sedimentation (Eckman et al.  
27      1989).

28      Because almost all kelp forests occur on hard substrata (North 1971), the distribution of kelp and other  
29      surface-canopy-forming macroalgae is partially dependent on the extent of available hard substratum  
30      for suitable attachment and growth (Dayton and Oliver 1985). Kelp attached to hard-bottom substrate  
31      provide vertical structure of the habitat to the sea surface. This increases the complexity of the habitat,  
32      with tangled holdfasts at the bottom, columns of kelp stipes in midwater, and a dense canopy of kelp  
33      blades at the surface. For many invertebrates, this substrate also provides a source of food. Kelp beds  
34      are typically found at depths shallower than 100 feet, being limited by light penetration (Quast 1968).

35      Along the southern California coast, giant kelp (*Macrocystis pyrifera*) is the largest species colonizing  
36      rocky (less frequently sandy) subtidal habitats and has the highest productivity and biomass per square  
37      meter of all the kelps. Beds of giant kelp represent one of the most diverse, productive, and dynamic  
38      ecosystems in southern California (Mann 1973; Dayton 1985; Barnes and Hughes 1988; Graham 2004),  
39      with over 200 species of algae, invertebrates, fishes, and mammals are known to inhabit giant kelp beds  
40      (North 1971; Foster and Schiel 1985). Kelp beds are patchily distributed along the southern California  
41      coast, with large beds in the Santa Barbara area, on the Palos Verdes Shelf, near Point Loma, and on the  
42      Channel Islands (CSWQCB 1964). Unlike hard-bottom habitats such as rocky reefs, the distribution and

1 extent of giant kelp beds changes more readily, as kelps are dislodged by storm swells or die off during  
2 periods of low nutrients (Stull 1995).

3 Giant kelp is a very important component of coastal and island communities in southern California,  
4 providing food and habitat for numerous animals (North 1971; Foster and Schiel 1985; Dayton 1985).  
5 Giant kelp is known as a biological facilitator (*sensu* Bruno and Bertness 2001), where its three-  
6 dimensional structure and the complexity of its holdfast provides substrate, refuge, reduction of  
7 physical stress, and a food source for many fish (Carr 1989) and invertebrates grazers (Duggins et al.  
8 1990). Stands of kelp can also affect flow characteristics in the nearshore zone, thus enhancing  
9 recruitment (Duggins et al. 1990), which further acts to increase animal biomass in the vicinity. For these  
10 reasons, giant kelp is also of great importance to sport and commercial fisheries. Drift kelp (wrack) and  
11 associated dissolved organic matter also provide an energetic resource to populations of species both  
12 within and around kelp beds (Harrold and Reed 1985; Duggins et al. 1989; Tegner and Dayton 2000;  
13 Graham et al. 2007). Water birds commonly use kelps to line their nests.

14 Kelps forests provide a variety of commercial and ecosystem services to people. An example of this is  
15 the harvesting of kelp for algin, a product used as a gelling agent in foods, pharmaceuticals, and water  
16 and fireproofing fabrics. The presence of the habitat itself also provides important ecosystem services.  
17 Ocean currents are slowed by drag from the large kelps. Creating a calmer habitat, this current  
18 reduction also decreases wave action onshore. By altering the waves, kelp forests reduce erosion,  
19 decreasing expensive property protections or replacement. Many outdoor enthusiasts dive or kayak  
20 among kelp forests providing important recreational and tourism benefits. Kelp is also an important  
21 habitat for a number of recreationally and commercially important fishery species (NOAA 2019).

### 23 3.3.2.1 RATIONALE FOR KELP BED SIZING

24  
25 No standard sizing guidelines are available for kelp bed restoration. Five acres was used as the minimum  
26 size by for a giant kelp restoration project conducted in Laguna Beach, California (MBC Aquatic Sciences,  
27 pers. comm.). Because this project developed from an interest in the protection and preservation of  
28 giant kelp communities in the Southern California Bight, it is an appropriate regional example for the  
29 Project in ESPB. A kelp bed with a canopy size of at least five acres would be likely to persist during  
30 extended periods of unfavorable conditions (e.g., El Niño events). However, both patch size and patch  
31 isolation play into probability of extinction (Schiel and Foster 2015). Giant kelp has relatively short spore  
32 dispersal distance(s), so more isolated patches may not rebound following disturbance.

### 34 3.3.2.2 SPECIES ASSOCIATED WITH KELP BEDS

- 35  
36
- 37 ▪ California spiny lobster (see associated information for Rocky Reef)
  - 38 ▪ Sea urchins: Sea urchins are typically spiny, globular animals, echinoderms. As a group, they are  
39 central in structuring marine benthic communities, both as grazers and prey, and are

1 economically valuable in fisheries. Their grazing limits algal biomass, and they are preyed upon  
2 by many predators (Pearce 2006).

- 3
- 4 ▪ Giant kelp bass (*Paralabrax clathratus*): Giant kelp bass are a recreationally and commercially  
5 important fish species associated with kelp beds.
- 6
- 7 ▪ Garibaldi (*Hypsypops rubicundus*): Garibaldi was the designated as the official marine fish of  
8 California in 1995
- 9

### 10 3.3.3 TARGET HABITAT: EELGRASS

11

12 Submerged aquatic vegetation (SAV), including seagrasses, constitute a critical habitat in nearshore  
13 ecosystems, serving as a nursery ground for many fishes and invertebrates and providing numerous  
14 ecosystem services, including sediment stabilization, filtration of pollutants, and carbon storage (Larkum  
15 et al. 2006). The term “SAV” refers collectively to all species of underwater flowering plants. In the  
16 Proposed Project Area of ESPB, SAV includes sago pondweed (*Stuckenia pectinata*, formerly  
17 *Potamogeton pectinatus*), eelgrass (*Zostera marina* L.), and other species of seagrass, including the  
18 surfgrasses (*Phyllospadix torreyi* and *P. scouleri*), and widgeongrass (*Ruppia maritima*). However,  
19 because eelgrass is much more extensive than other SAV within the project area, its role and restoration  
20 potential are understood better than for other SAV.

21 Eelgrass is a community structuring plant that forms highly productive beds in both subtidal and  
22 intertidal habitats in shallow coastal bays and estuaries, as well as within semi-protected shallow soft  
23 bottom environments of the open coast. It is the most common species of seagrass occurring in the  
24 embayments of the SCB (Dailey et al. 1993), and functions as important nursery habitats for a diverse  
25 variety of organisms (Beck et al. 2001), including economically important fishes and invertebrates in  
26 southern California (Allen et al. 2002; Hoffman 1986).

27 It is possible that the construction of rock shoals within the nearshore zone may impact the availability  
28 of existing eelgrass associated with sandy bottom within nearshore areas of the project area. These  
29 areas can serve as spawning areas for market squid (*Loligo opalescens*), an important commercial  
30 species in California. In addition, sheltered, shallow soft-bottom areas in certain locations (e.g., inside  
31 the Los Angeles and Long Beach Harbor breakwaters) provide important nursery areas for several fish  
32 species, including California halibut.

33 In order to avoid and minimize these undesired effects, specific locations of each constructed reef,  
34 including nearshore shoal placement, will be studied during the Preliminary Engineering and Design  
35 (PED) phase of the project and selected such that limited natural habitats, like existing eelgrass beds,  
36 are not directly covered or compromised by project activities. Because of the inter- and intra-annual  
37 variation in the spatial extent of existing eelgrass, any analyses and modeling will need to be updated  
38 to reflect most current conditions so that the placement and construction of nearshore shoals has  
39 minimal (if any) impact to existing resources.

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### 3.3.3.1 RATIONALE FOR EELGRASS BED FORM AND SIZING

Recommendations for specific targets for eelgrass restoration base on size (acreage) are lacking in the literature. Several studies have identified important considerations predictive to eelgrass transplant success, but sizing (area) was not included. Generally, substrate, temperature, salinity, nutrients, wave energy, depth and light are key considerations, rather than targets based on size alone.

It is uncertain if there is any relationship between the size or shape of a seagrass bed and its functional attributes; this is true for both planted beds and natural beds (Fonseca 1998). This is an area of study needing much additional work. However, in regard to functional success, even small patches (1-2 m<sup>2</sup>) demonstrate higher diversity of larger invertebrates than un-vegetated areas. Thom (2001) suggests that larger scale restoration projects have more of a chance to be successful. In general, both transplant size and success increased with time, but there is no indication that size increase is the reason for improvement.

From a monitoring perspective alone, Bernstein et al (2011) suggest that eelgrass habitats of 20 m or more contribute significantly to the overall regional estimates of extent of the resource. South of Point Conception, eelgrass grows primarily in subtidal habitat and the 20-acre minimum size criterion removes systems with marginal, ephemeral, and/or small amounts of habitat that do not contribute significantly to the overall regional estimate of extent. However, there is no scientifically consistent method for applying the 20-acre criterion as a restoration target for sizing eelgrass beds.

Canopy height of eelgrass shoots provides an estimate of the three-dimensional complexity of the habitat and, thus, may be a functional attribute of habitat utilization. Evans and Short (2005) found this to be a useful metric for estimating habitat use. It also seems to be increasingly used in eelgrass monitoring programs (Duarte and Kirkman 2001).

Density of eel grass turions with a patch may also be a more informative restoration target than patch area. Bernstein et al. (2011) suggest that a minimum density of 100 eelgrass turions/m<sup>2</sup> may be a sufficient to maintain survival and reproductive needs of obligate and transient marine species by facilitating creation of conditions conducive to the recruitment of eelgrass propagules and growth of new eelgrass habitat over time (Bernstein et al. 2011).

### 3.3.3.2 SPECIES ASSOCIATED WITH EELGRASS

Bay Pipefish (*Syngnathus leptorhynchus*): Bay pipefish have been used as an indicator species for monitoring eelgrass habitats because of the species dependency on these habitats and its important role in the biomass (as a common resident) and functional ecology (as an important role in the production of organic detritus) of eelgrass beds (Fritzsche 1980; de Graaf 2006).

Bay pipefish and black surfperch were shown to have a greater association with eelgrass habitat, and epibenthic invertebrate assemblages begin to differentiate between the eelgrass and oyster reef habitats. Eelgrass presence increased the occurrence of certain fish species among oyster reef structures

1 (bay pipefish, shiner surfperch, and saddleback gunnel), suggesting that restoring the two habitats in  
2 proximity to each other can increase the richness of species present (Boyer et al. 2017).

### 3 4 3.3.4 TARGET HABITAT: OYSTER REEFS 5

6 Oysters live in salty or brackish waters on all U.S. coasts, clustering on older shells, rock, piers, or any  
7 hard, submerged surface. They fuse together as they grow, forming colonial communities of dense  
8 aggregations of rock-like “reefs”. Oyster reefs can provide numerous beneficial biogeochemical  
9 functions and ecosystem services, such as filtering particles, including phytoplankton, particulate organic  
10 matter, inorganic particles, and planktonic larvae of some marine invertebrates, from the water column  
11 and discharging bio-deposits. Filtering is a process that removes phytoplankton and biotic and abiotic  
12 particulates from suspension, clarifies the water column, transfers organic- and nutrient-rich  
13 particulates to the bottom, and may reduce settlement of some native marine invertebrates, and (Dame  
14 1996; Newell 2004; Dumbauld et al. 2009).

15 Not all species of oysters are true reef builders. Pacific oysters (*Crassostrea gigas*), also known as  
16 Japanese Miyagi oysters, build structural reefs that project up into the water column in areas otherwise  
17 characterized by relatively flat sedimentary bottom, providing important habitat for other organisms  
18 (Coen et al. 2007; Grabowski and Peterson 2007). However, this habitat provisioning service is less  
19 pronounced in non-reef forming bivalves, such as the Olympia oyster (*Ostrea lurida*), the species native  
20 to the U.S. West Coast (including San Pedro Bay). The Olympia oyster is relatively small and usually is  
21 found attached to rocks or dead shells. Beds formed by this native species of oyster are not nearly as  
22 large or extensive as those formed by the Eastern oyster (*Crassostrea virginica*). In general, the Olympia  
23 oyster is no longer found anywhere in abundance within its historical range and oyster reefs in the  
24 classical sense do not exist on the West Coast as they do along the East and Gulf Coasts of the United  
25 States. Currently, Pacific oysters are the species representing the bulk of the mollusk biomass in the Bay.  
26 This species was introduced to California as a result of importation for cultivation (MBC 2016).

27 Pinnix et al. (2005) found that fish abundance was significantly greater in oyster culture habitats  
28 compared to eelgrass and mudflat habitats in Humboldt Bay, California. However, there was no  
29 difference in abundance between eelgrass and mudflat habitats. This suggests that oyster culture  
30 operations may attract a larger number of fish compared to eelgrass and mudflat habitats. It is well  
31 established that fish are attracted to structure and the greater abundance in the culture areas may be  
32 due to the increased structure in the water column that the culture provides.

#### 33 34 3.3.4.1 RATIONALE FOR OYSTER REEF SIZING, STRUCTURE, AND PLACEMENT 35

36 Two “universal metrics,” density and size frequency distribution, are recommended for oyster  
37 restoration monitoring oyster (Baggett et al. 2004). The density of adult oysters at a site can serve as a  
38 cumulative indicator of its appropriateness for conservation or restoration. Moderate to high adult

1 densities result from one or more years of significant recruitment and survival. Densities in Newport Bay  
2 and San Diego Bay generally average 592/ft<sup>2</sup> and 2357/m<sup>2</sup>, respectively (Wasson et al. 2015).

3 In terms of specific restoration target densities for oysters, adult density per square foot of hard  
4 substrate may not represent density at larger scales (e.g., acres), because there is very limited hard  
5 substrate. A site that has a million oysters within an acre should have greater conservation value than a  
6 site that has a thousand oysters per acre, and far greater than one that has ten oysters per acre, even if  
7 all those sites have the same density per square foot. Therefore, it is important to establish where to  
8 draw the line around a site of interest and whether or not to include the full tidal range encompassing  
9 all colonized hard substrate (Wasson et al. 2015). An order-of-magnitude estimate of the total number  
10 of oysters living at a site may serve as a good initial indicator of the site's relative conservation value.

11 Current smaller-scale restoration projects in southern California have ranged from deploying small  
12 structures to assess recruitment patterns and best methods, to larger-scale mixed-species restoration  
13 projects with both physical and biological objectives in a “living shorelines” model.

#### 15 3.3.4.2 SPECIES ASSOCIATED WITH OYSTER BEDS

17 Olympia oysters, the species native to the Proposed Project Area, are primarily estuarine and generally  
18 not found on the open coast (Baker 1995). The species' natural habitat includes rocks in areas near the  
19 expanse of the low tide, and mudflats and gravel bars in estuaries and bays (Nosho 1989). In southern  
20 California, they are most abundant around the -0.3 m tide mark (Wasson et al. 2015), Mean Lower Low  
21 Water (MLLW), but have been reported from as high as 1 m above MLLW to depths of 10 m (Baker  
22 1995). They require hard substrate on which to settle. Although Olympia oysters tolerate a range of  
23 salinity levels, low salinity exposure can reduce reproduction (Oates 2013), and cause death in severe  
24 cases (Gibson 1974). Cheng et al. (2015) found that juvenile Olympia oysters suffered significant  
25 mortality when exposed to salinity levels below 10 for five or more days. Thresholds may show local  
26 adaptation and vary across regions.

27 Oyster reefs in general create important habitat for hundreds of other marine species. Species like  
28 mussels, barnacles, and sea anemones settle on them, creating abundant food sources for commercially  
29 valuable fish species. Oyster reefs provide habitat to forage fish, invertebrates, and other shellfish. They  
30 also provide a safe nursery for commercially valuable fish and invertebrate species

#### 32 3.3.5 TARGET HABITAT: COASTAL WETLANDS

34 Among coastal ecosystems, coastal wetlands are considered some of the most productive ecosystems  
35 on Earth. Coastal wetlands include saltwater and freshwater wetlands located in coastal zones that are  
36 influenced by fluctuating water levels. Wetlands provide a high number of valuable benefits to humans,  
37 including raw materials and food, coastal and shoreline protection, erosion control, water purification,  
38 maintenance of natural communities of plants, animals, and fisheries, and carbon sequestration.  
39 Wetlands also provide other vital ecosystem services that have not always been appreciated by humans.

1 Wetlands help regulate climate, store surface water, control flooding, replenish aquifers, promote  
2 nutrient cycling, serve as critical nursery areas for fisheries, and provide opportunities for education,  
3 recreation, and tourism. No wetland provides all these services, and the level of any service varies  
4 among wetlands. The location of a wetland, its size, shape, source of water, ecological characteristics,  
5 and how it is managed determine the kinds and levels of service it can provide

6 Estuarine wetlands are distinguished from non-saline estuarine wetlands (i.e., brackish or freshwater  
7 estuarine wetlands), by the obvious dominance of salt-tolerant species of emergent vascular vegetation,  
8 such as cordgrass (*Spartina* spp.), pickleweed (*Sarcocornia* spp.), and salt grass (*Distichlis* spp.) along the  
9 foreshore of the wetland and along the immediate banks of the larger tidal channels that tend to  
10 dewater at low tide. Non-saline wetlands tend to be dominated by species that don't tolerate high  
11 salinities, such as cattails (*Typha* spp.), rushes (*Schoenoplectus* species), and willows (*Salix* spp.)

12 A coastal estuarine wetland consists of the vegetated marsh plain, its pannes, potholes, hummocks, and  
13 other habitat elements of the plain, as well as the natural levees, shell beds, submerged plant beds, and  
14 other habitat elements created or supported by tidal processes and associated with tidal channels  
15 (CWMW 2014). Estuarine wetland ecosystems provide important habitat linkages between marine,  
16 aquatic and terrestrial ecosystems. Linkages between aquatic and terrestrial habitats allow wetland-  
17 dependent species to move between habitats to complete life cycle requirements. For estuarine  
18 wetlands, the function of upland transitions as refuge for intertidal wildlife during extreme high tides is  
19 especially important. The entrained canopies of estuarine wetland vegetation entrap debris including  
20 coarse plant litter that is lifted into the canopies by rising tides. As the tide goes out, the material is left  
21 hanging in the plant cover. Over time, these entrained canopies can gain enough density and thickness  
22 to provide important shelter for many species of birds and small mammals that inhabit estuarine  
23 wetlands. Most passerine birds and rails that nest in estuarine wetlands choose to nest below an  
24 entrained canopy because it protects them from avian predators, including owls and raptors such as  
25 northern harriers.

26

### 27 3.3.5.1 RATIONALE FOR WETLAND SIZING, STRUCTURE, AND PLACEMENT

28

29 No generalized recommendations for the sizing of constructed wetlands exist. PWA and Faber (2004)  
30 offer several design considerations for wetlands when planning, including specific suggestions based on  
31 the size of channels and intertidal buffers. They also offer specific designs to support wetland  
32 invertebrates, fish and birds. Callaway and Simenstad (2015) offer recommendations to improve success  
33 in wetland restoration and creation, but no restoration sizing guidelines were provided.

34

### 35 3.3.5.2 SPECIES ASSOCIATED WITH COASTAL WETLANDS

36

37 California killifish (*F. parvipinnis*): The California killifish (*F. parvipinnis*) is a common and abundant  
38 shallow-water species in southern California estuaries (Horn and Allen 1985) and a key component of  
39 the estuarine food web (Kwak and Zedler 1997). For example, *F. parvipinnis* are key consumers of  
40 invertebrate prey and an important link in the transfer of energy between intertidal and subtidal areas

1 (Kwak and Zedler 1997; Johnson 1999). Killifish are also important in the diet of piscivorous birds, which  
2 are highly valued by the bird- watching public.

3 Arrow goby: Although little quantitative data are available to establish the importance of gobies in bay-  
4 estuarine trophic structures, their sheer abundance indicates that they would have significant position in  
5 the food web (Brothers 1975). Gobies make available the high production of eelgrass (*Zostera marina*),  
6 green algae (e.g., *Ulva* sp.), diatoms, and marsh plants to higher level carnivores. By consuming large  
7 numbers of small crustaceans and worms that directly or indirectly feed on plants or plant detritus,  
8 gobies serve to channel substantial amounts of energy to the large predators in the ecosystem. Goby  
9 larvae may be equally important in the planktonic segment of bay-estuarine food webs (Horn 1980).

10

### 11 3.3.6 TARGET HABITAT: SANDY ISLANDS

12 Exposed sandy beaches, whether associated with shores or emergent islands, provide an important  
13 transitional habitat between land and sea. Sandy beach and adjacent surf zone ecosystems are  
14 important foraging areas for wildlife and fishes, accumulate sand that can buffer the impacts of storms,  
15 filter vast volumes of seawater delivered by waves and tides, process large quantities of organic detritus  
16 and contribute to nearshore nutrient cycling, and harbor unique and endemic biodiversity. The amount  
17 of wrack and plankton cast onto sandy beaches is dynamically linked to adjacent ecosystem features,  
18 ocean climate and the population dynamics of intertidal invertebrates. However, despite their ecological  
19 importance and connectivity with other marine ecosystems, sandy beach ecosystems are not as well  
20 studied as other ecosystem features and are often overlooked in coastal conservation efforts (Dugan et  
21 al. 2010).

22 Coastal protection is arguably one of the most valuable services provided by sand shore ecosystems  
23 especially in the face of extreme storms, tsunamis, and sea level rise. As waves reach the shoreline they  
24 are attenuated by the beach slope and, at high tide, also by the foredune, a structure immediately  
25 behind the beach where sand accumulates in hills or ridges parallel to the shoreline. Beaches vary in  
26 their ability to attenuate waves depending on a continuum in their morphology (Carter 1991; Hesp and  
27 Short 1999; Short 1999). Coastal dunes can provide maintenance of wildlife in the form of habitat for  
28 fish, shellfish, birds, rodents, and ungulates, which have been captured or cultivated for food since  
29 humans first colonized the coast (Carter 1990; Pye and Tsoar 1990).

30 In the past 20 years it has become increasingly apparent that small emergent sandy islands are  
31 important to the conservation of a diverse group of nesting waterbirds. More than 30 species of colonial  
32 waterbirds and shorebirds, including gulls, terns, skimmers, herons, and egrets, depend heavily on both  
33 natural and man-made islands for nesting; this has been documented in the Great Lakes (Scharf 1978),  
34 the Gulf Coast from Texas to Florida (Landin and Soots 1978), along the Atlantic Coast from New York  
35 and New Jersey (Burger and Lesser 1978; Burger and Gochfeld 1990, 1991) to Virginia (Erwin 1979,  
36 1980).

37 In southern California, areas of exposed sand on shores or island support diverse and abundant  
38 invertebrate macrofaunal communities (Dugan et al. 2000; Dugan, Hubbard et al. 2003). Invertebrate  
39 macroinfauna can attain an abundance of >80,000 individuals and biomass of >10 kgm<sup>-1</sup> of shoreline on  
40 southern California beaches (Dugan et al. 2000, 2003). Such macrofauna may be increasingly important

1 as prey resources for shorebirds, as the function, quality, and availability of coastal wetlands decrease  
2 regionally.

3 Sandy beach ecosystems are strongly linked with other nearshore ecosystems. For example, beach food  
4 webs rely largely on subsidies from adjacent ecosystems, thus the amount of wrack and plankton  
5 delivered to these food webs is dynamically linked to the features of adjacent ecosystems and nearshore  
6 ocean characteristics. The condition of beach ecosystems can in turn affect the reproductive success of  
7 fishes and birds that rely on areas of open, sandy habitat.

8  
9 The connectivity of sandy shore/island habitat with rocky and kelp reefs provides many synergistic  
10 relationships that benefit both type of habitats and multiple species habitats. Rocky/kelp reefs provide  
11 a wrack source for sandy islands and are nutrient recipients from emergent islands used by shorebirds.  
12 Rocky reefs, in turn, provide foraging habitat for piscivorous (fish-eating) birds.

13

#### 14 3.3.6.1 RATIONALE FOR SANDY ISLAND, SIZING, STRUCTURE, AND PLACEMENT

15

16 Islands between 2 and 10 ha in size are used more often by nesting shore birds than very large or very  
17 small islands (Erwin et al. 1995). Larger islands are not used if mammals are able to reach them or when  
18 they support a population of nest-predators year-round. Alternatively, very small islands may be unable  
19 to support adequate amounts of vegetation for large numbers of birds or may not attract enough birds  
20 to form a critical social mass for nesting. Larger islands can support more abundant and diverse  
21 populations of wading birds, but creating islands greater than 10 ha is not usually logistically feasible for  
22 most created habitats. Therefore, the rule of thumb should be to create as large a colony as possible  
23 without compromising other habitat requirements (e.g., set-back distances).

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#### 25 3.3.6.2 SPECIES ASSOCIATED WITH SANDY ISLANDS

26

27 Southern California’s coastal areas, including its shorelines, estuaries, bays, and harbors, provide several  
28 types of habitat for large numbers of shorebirds and wading birds, including the Federally endangered  
29 California least tern (*Sterna antillarum browni*). This species utilizes sandy coastal areas for nesting,  
30 preferring undisturbed, open sandy/gravelly areas near a lagoon, estuary or bay that are kept free of  
31 vegetation by the tide. The California least tern is listed as “endangered” under the federal Endangered  
32 Species Act in 1973, and under the California Endangered Species Act in 1984. This species has  
33 historically nested within the larger Study Area surrounding ESPB, and known protected nesting sites are  
34 located adjacent to the Port of Los Angeles’ largest container terminal on Pier 400.

35 The Federally threatened western snowy plover (*Charadrius nivosus nivosus*) is another shorebird species  
36 that has been occasionally observed during migration at the California Least Tern nesting site on Pier  
37 400 (Keane Biological Consulting 2007). A few individuals also have been observed at Point Fermin and  
38 Cabrillo Beach outside the breakwater (Ryan et al. 2009).

1 Shore birds play an important role in mass and energy fluxes across estuarine food webs. Studies have  
2 shown that shorebirds can have an important predatory impact on the standing crop of invertebrate  
3 populations and remove a substantial proportion of the annual production of benthic macrofauna (e.g.,  
4 [Goss-Custard 1980](#); [Baird and Milne 1981](#); [Smit 1981](#); [Baird et al. 1985](#)). On beaches and other sandy  
5 shores, both snowy plover adults and chicks depend largely on prey resources associated with  
6 macroalgal wrack making them important species to consider as potential indicators of ecosystem  
7 condition and connectivity in baseline evaluations of marine protected areas ([Dugan et al. 2015](#)).  
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**GLOSSARY**

*Assemblage*: A grouping of species that occur together in a single area, such that they have the reasonable opportunity for daily interaction with each other

*Base year*: the year when the proposed project is expected to be operational.

*Biogenic habitat*: Biogenic habitats are habitats created by plants and animals. This may be the organism itself, such as a seagrass meadow or a bed of oysters, or arise from an organism’s activities, such as the burrows created by crabs. Biogenic habitat-forming species perform other important roles within the ecosystem (Morrison et al. 2008).

*Biotope*: A specific area of the habitat that includes recurring, persistent, and predictable biological associations, such as plants, attached sessile fauna, and unattached but relatively non-motile fauna and bacterial colonies (Madden et al. 2005). *Macrocystis pyrifera* in kelp beds and *Zostera marina* in eelgrass beds are examples of biotopes.

*Breakwater*: A physical structure constructed on coasts as part of coastal management to reduce coastal erosion or to protect a boat/ship anchorage from the effects of both weather and wave intensity. Breakwaters dissipate energy and create relative calm water in their lee side (the side opposite of the windward or seaward side).

*Complex habitat*- Habitats with complex physical structure in terms of the diversity, size, amount and spatial arrangement of the structural features that are used as a habitat by organisms (Flores et al. 2016). The physical structure of a habitat (e.g., habitat complexity) shapes how species co-exist and interact and thus drive ecosystem processes. The amount and arrangement of habitat structure can affect ecosystem functioning because, over longer time scales, complexity increases the possibilities for niche differentiation (i.e., ‘maximizes’ species richness and abundance)

*Connectivity*: The degree to which the movement of water, nutrients and species among habitat patches is facilitated and not impeded by the seascape or other structures.

*Demersal*: A species that lives on or near the sea bottom for at least part of its life cycle.

*Ecological niche*: The role an organism plays in its respective community, i.e. decomposer, primary producer, etc.

*Ecosystem*: A complex or grouping habitats that are influenced by similar hydrologic, geomorphologic, chemical, or biological factors.

*Ecotone*: A transition area or interface region between two ecosystems where two biological communities meet and integrate. The interface between hard bottom and soft bottom marine communities is an example of an aquatic ecotone.

*Estuary*: A small semi-enclosed coastal body of water with a free connection with the open sea within which seawater is measurably diluted by freshwater from land drainage. This dilution of seawater must occur for at least one month of the year for the water body to “estuarine” (Josselyn et al. 1993).

- 1  
2 *Guild (or ecological guild)*: Any group of species that exploit the same resources, or who exploit different  
3 resources in related ways. It is not necessary that the species within a guild occupy the same, or even  
4 similar, ecological niche.  
5
- 6 *Habitat*: The physical unit of the environment employed directly by the biota for food, shelter,  
7 spawning, and/or refuge (Madden et al. 2005). Descriptive terms of habitat include substrate, energy,  
8 composition, and biological association.  
9
- 10 *Habitat Node*: A node is area or patch of habitat associated with a physical location. Nodes can be  
11 isolated habitat patches or can be connected to some extent by edges between adjacent nodes. An edge  
12 between two nodes implies there is some ecological connectivity or exchange between the nodes, such  
13 as via propagule dispersal or material flow.  
14
- 15 *Hard-bottom species*: organisms that are commonly associated with reef or rocky substrata.  
16
- 17 *Infauna*: Bottom-dwelling organisms that burrow into soft substrates that lack secure attachment sites  
18 (such as shallow, soft-bottom habitats) to prevent from being washed away by currents.  
19
- 20 *Intertidal zone*: The area that is above water at low tide and under water at high tide (i.e., the area  
21 between tide marks). Also known as the foreshore, seashore or littoral zone. Habitats located in the  
22 intertidal zone are collectively termed “intertidal habitats”. Intertidal habitats can be characterized as  
23 having either hard (e.g. rocky reef) or soft bottom (e.g. eelgrass bed) substrates.  
24
- 25 *Kelp forest*: An underwater ecosystem formed in shallow water characterized by the dense growth of  
26 several different species known as kelps. Kelp “anchors” called holdfasts grip onto rocky substrates.  
27 From the holdfasts, kelp plants grow toward the water's surface.  
28
- 29 *Keystone species*: A species that exerts a strong influence on the dynamics of other species within an  
30 ecosystem. A keystone species is one on which other species in an ecosystem largely depend, such that  
31 if it were removed, the ecosystem would change drastically.
- 32 *Macrohabitat*: Spatially large and complex geomorphic, hydromorphic or vegetative structures that  
33 support multiple biological associations, and possess homogenous local climate, hydrology, and  
34 chemistry (Madden et al. 2005).
- 35 *Nearshore zone*: The area extending from the shoreline to depths generally less than 20 feet (6 m).
- 36 *Open water zone*: The area extending from the seaward edge of nearshore to depths generally greater  
37 than 20 feet (6 m).
- 38 *Residence Time\**: The average amount of time during which a volume of water remains within a water  
39 body before continuing through its hydrological cycle. The time involved may vary from days for small  
40 shallow bays to millions of years for deep underground aquifers with very low values for hydraulic  
41 conductivity. Knowing the residence time for a body of water is one way to determine the concentration  
42 of pollutants in the water body and how this may affect the local population and marine life. Sometimes  
43 discussed in terms of water budget for hydrologic studies.

1 *Rocky reef*: A submerged rock outcrop with varying relief, creating refuges for juvenile and smaller fishes  
2 in addition to surface area for colonization of algae and invertebrates. A rocky reef can support the  
3 growth of kelp, but does not have to include kelp.

4 *Shoal*: An underwater ridge, bank, or bar consisting of, or covered by, sand or other unconsolidated  
5 material, rising from the bed of a body of water to near the surface.

6 *Shoal or reef complex*: Two or more shoals or reefs (and adjacent morphologies, such as troughs) that  
7 are interconnected by past and/or present sedimentary and hydrographic processes.

8 *Soft-bottom species*: organisms that are commonly associated with sand or mud substrata.

9 *Subtidal zone*: The area below the intertidal zone that is continuously covered by water. This zone is  
10 much more stable than the intertidal zone. Also known as the sublittoral zone. Habitats located in the  
11 subtidal zone are collectively termed “subrtidal habitats”. Subtidal habitats can be characterized as  
12 having either hard (e.g. rocky reef) or soft bottom (unconsolidated) substrates.

13 *Water-column species*: pelagic organisms (typically fish) that feed on prey that is suspended in the water  
14 column (e.g., pelagic zooplankton).

15

16 *Zone*: characterizes the vertical zonation (i.e., benthic, water column, and littoral) of coastal and marine  
17 regions.

18 *\*For the ESPB project, current velocities and salinity concentrations were used in the HEM as a proxy for true  
19 residence time. A particle tracking analysis was also conducted to provide insight on how long a typical parcel of  
20 water remains within the bay and the path taken that provides a representation of how the system changes due to  
21 the structural modifications.*

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**Table 1.** Species function by habitat type matrix

ESPB HABITATS*	TAXON	ASSOCIATED SPECIES	Habitat Association	Feeding technique	Function 1 Keystone and/or potential indicator species for the habitat type	Function 2 Predatory species that regulates the population of other species	Function 3 Important host species to other organisms	Function 4 Important prey species for other organisms	Function 5 Habitat-forming "foundation" or "ecosystem engineering" species	Function 6 Important in nutrient cycling for food webs	Function 7 Important commercial and recreational marine fishery	Conservation Status Notes	
ROCKY REEF	invertebrate	California spiny lobster ( <i>Panulirus interruptus</i> )	benthic; pelagic larvae	predator		X	X				X	Most economically important lobster on American West Coast; CDFW sets and enforces regulations pertaining to recreational fishing	
		California mussel ( <i>Mytilus californianus</i> )	benthic	filterer	X			X	X				
		sea star ( <i>Pisaster</i> sp.)	benthic	predator	X	X							
	fish	blacksmith ( <i>Chromis punctipinnis</i> )	substrate associated	water column foragers, schooling, selective feeding, usually benthic refugers, diurnal			X				X		
		barred sand bass ( <i>Paralabrax nebulifer</i> )	substrate associated	non-schooling, diurnal, engulfer			X				X	X	
		California scorpionfish ( <i>Scorpaena guttata</i> )	substrate associated	nocturnal; ambush predator			X						

East San Pedro Bay Ecosystem Restoration Study – Appendix D: Habitat Evaluation and Model Documentation

ESPB HABITATS*	TAXON	ASSOCIATED SPECIES	Habitat Association	Feeding technique	Function 1 Keystone and/or potential indicator species for the habitat type	Function 2 Predatory species that regulates the population of other species	Function 3 Important host species to other organisms	Function 4 Important prey species for other organisms	Function 5 Habitat-forming "foundation" or "ecosystem engineering" species	Function 6 Important in nutrient cycling for food webs	Function 7 Important commercial and recreational marine fishery	Conservation Status Notes	
KELP FOREST	plant/alga	giant kelp ( <i>Macrocystis pyrifera</i> )			X				X				
	invertebrate	sea urchins (echinoderms)	benthic	grazer				X		X	X		
		whelks (sea snails)	benthic	predator, scavenger				X					
	fish	kelp rockfish ( <i>Sebastes atrovirens</i> )	Substrate	nocturnal			X				X		
		garibaldi ( <i>Hypsypops rubicundus</i> )	Substrate	Benthic forager, schooling/non schooling, diurnal, specialist, territorial, sometimes herbivore		X							Designated as the official marine fish of California in 1995
		giant kelpfish ( <i>Heterostichus rostratus</i> )	Substrate	Non-schooling, diurnal, engulfer								X	
		kelp bass ( <i>Paralabrax clathratus</i> )	Substrate, but enters water column	Non-schooling, diurnal, engulfer								X	

East San Pedro Bay Ecosystem Restoration Study – Appendix D: Habitat Evaluation and Model Documentation

ESPB HABITATS*	TAXON	ASSOCIATED SPECIES	Habitat Association	Feeding technique	Function 1 Keystone and/or potential indicator species for the habitat type	Function 2 Predatory species that regulates the population of other species	Function 3 Important host species to other organisms	Function 4 Important prey species for other organisms	Function 5 Habitat-forming "foundation" or "ecosystem engineering" species	Function 6 Important in nutrient cycling for food webs	Function 7 Important commercial and recreational marine fishery	Conservation Status Notes	
EELGRASS	plant/alga	eelgrass ( <i>Zostera maritima</i> )		NA	X				X			Designated Essential Fish Habitat and a Habitat of Particular Concern under the 1996 Magnuson-Stevens Fishery Conservation and Management Act	
	invertebrate	tube anemones (ceriantharians)	benthic	siphon					X	X			
	fishes	giant kelp fish ( <i>Heterostichus rostratus</i> )				X						X	
		spotted sand bass ( <i>Paralabrax maculatofasciatus</i> )			Non-schooling, diurnal, engulfer							X	
		barred sand bass ( <i>Paralabrax nebulifer</i> )			Non-schooling, diurnal, engulfer							X	
		shiner surfperch ( <i>Cymatogaster aggregata</i> )	Water column and substrate		Benthic forager, schooling, often benthic refuging, diurnal, picker				X				
bay pipefish ( <i>Syngnathus leptorhynchus</i> )			suction (suspensorial abduction)	X									

East San Pedro Bay Ecosystem Restoration Study – Appendix D: Habitat Evaluation and Model Documentation

ESPB HABITATS*	TAXON	ASSOCIATED SPECIES	Habitat Association	Feeding technique	Function 1 Keystone and/or potential indicator species for the habitat type	Function 2 Predatory species that regulates the population of other species	Function 3 Important host species to other organisms	Function 4 Important prey species for other organisms	Function 5 Habitat-forming "foundation" or "ecosystem engineering" species	Function 6 Important in nutrient cycling for food webs	Function 7 Important commercial and recreational marine fishery	Conservation Status Notes	
COASTAL WETLAND	plant/alga	Pacific cordgrass ( <i>Spartina foliosa</i> )	low marsh zone	NA					X				
		pickleweed ( <i>Salicornia sp.</i> )	mid-marsh plain	NA					X				
	invertebrate	horn snails ( <i>Cerithideopsis californica</i> )	benthic				X	X					
	fishes	silverside (atherinopsidae)							X				
		diamond turbot ( <i>Hypsopsetta guttulata</i> )	benthic	digger and extractor							X		
		arrow goby ( <i>Clevelandia ios</i> )	benthic	hider (in holes and crevices), diurnal					X		X		
		California killifish ( <i>Fundulus parvipinnis</i> )	Water column and substrate	Benthic forager, schooling, often benthic refuging, diurnal, picker				X	X		X		
	avian	western sandpiper ( <i>Calidris mauri</i> )	mid- and low-marsh plain; pannes and ponds	benthic surface probers, grazers of biofilm on surface of mudflats	X	X					X		
	SANDY ISLAND												
		invertebrate	Pacific sand crab ( <i>Emerita analog</i> )	terrestrial	burrower				X			X	

*East San Pedro Bay Ecosystem Restoration Study – Appendix D: Habitat Evaluation and Model Documentation*

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		California beach hopper ( <i>Megalorchestia californiana</i> )	terrestrial	burrower				X		X		
	avian	snowy plover ( <i>Charadrius nivosus</i> )	terrestrial	visual foragers, probers		X				X		federally listed as threatened
		California least tern ( <i>Sterna antillarum browni</i> )	terrestrial	inshore feeder, hovering/diving		X				X		federally listed as endangered
OYSTER REEF	invertebrate	Olympia oyster ( <i>Ostrea lurida</i> )	intertidal, sessile	filterer	X				X		X	

\* "ESPB habitats" is a generic term used for illustrative Project purposes.

Figure 2. Habitat classification cross walk

ESPB Habitat	Cowardin Class	Generic Type	Habitat	Description
Coastal salt marsh	Emergent wetland	Coastal wetland/tidal salt marsh	Coastal wetlands	Patchwork of sand flats, mud flats, and saltmarshes
			Saltmarshes	Low coastal vegetated plain frequently flooded by tidal flow
Eelgrass	Aquatic bed (rooted vascular)	Shallow vegetated	Seagrass beds	Beds of rooted, flowering plants (four species)
Kelp or kelp forest	Aquatic bed (algal)		Kelp forest or kelp bed	Kelps, fucoids, and other complex, erect macroalgae
			Benthic algae	Bushy, flat, or crustose algae
Oyster reef	Reef	Biogenic reefs and beds	Oyster reef	Three-dimensional structures created by oysters, mussels, or marine polychaete worms spanning intertidal to subtidal areas
			Mussel beds	
			Worm reef	
Rocky reef	Rock bottom	Hard structure	Rocky shore	Intertidal rock, boulders, and cobble
NA	NA		Rocky reef	Subtidal rock, boulders, and cobble
			Artificial substrates	Manmade structures constructed of hard substrates (e.g. rip-rap, pier support footing)
Emergent island	Unconsolidated shore	Exposed sandy beach	Sandy shore	Transitional habitat between land and sea with no or sparse vegetation
Soft-bottom*	Unconsolidated bottom	Soft bottom	Intertidal flats	Intertidal mud and sand flats
			Subtidal soft bottom	Subtidal mud, sand, and mixed sediments
Open water*	NA	Open water	Shallow open water	Water depths shallower than 30 m but not directly next to the coast

\* denotes a habitat type not targeted by the Project for restoration