OYSTER REEF RESILIENCY DESIGN GUIDE

About This Guide

Oyster reefs are a valuable resource for coastal communities, offering many benefits to aquaculture, water quality, and shoreline protection. Oyster reefs can naturally keep pace with relative sea level rise (RSLR) and therefore are a valuable tool to maintain the health of coastal ecosystems. This guide will provide concise guidance on how to plan for and design oyster reef enhancement and construction projects, particularly under future RSLR scenarios.

Conceptual

Develop project goals and identify existing constraints. These are important factors that will shape the design and construction of an oyster reef project.

Determine project goals	Evaluate site characteristics	Determine basic design components
• Water quality improvement • Erosion protection • Habitat creation • Biodiversity • Economic resource (fisheries) • Education and research opportunities • Recreational benefits • Public Involvement	• Hydrodynamics: water depth, wave exposure, tide and current characteristics • Water quality: pathogens, contaminants, turbidity, dissolved oxygen, salinity • Substrate characteristics • Existing constraints: species populations, disease, human uses and traffic, harvesting demand, physical or jurisdictional barriers • Likely future *RSLR projections*	• Budget • Timeline • Structure type(s) and configuration • Overall dimensions and project area footprint • Locate and obtain the oyster seed/loose spat • Review Texas A&M's *Oyster Reef Habitat Suitability and Quality Maps*

Engineering/Design

Develop a detailed plan for configuration and construction of an oyster reef based on the project goals and site constraints to provide a strong basis for a healthy oyster reef.

Complete design and supporting calculations	Develop construction plan	Complete permit applications
• Geotechnical analysis • Hydrodynamic analysis • Water quality analysis • Structural components – type, quantity, configuration • No-adverse impact analysis • Reference sites or natural analogs to inform design	• Cost • Schedule • Deployment logistics • Materials acquisition and storage • Sediment control	• Permit-level plans • Address review comments

Permitting

Plan for and complete necessary permitting activities to ensure the project has a robust design and does not adversely impact the surrounding environment or socioeconomic activity. An engineer should also be identified during this step to complete permit-level (and subsequent) design/installation plans.

Identify project partners	Identify potential permits needed	Typical review agencies
• Federal/State • Local • Non-profit • University • *Tribal*	• **USACE Nationwide Permit:** 27 – Aquatic Habitat Restoration, Enhancement, and Establishment Activities • **TPWD:** Permit to Introduce Fish, Shellfish or Aquatic Plants into Public Waters • **GLO:** Surface Lease if located on State-owned submerged lands	• USACE • TPWD • EPA • USFWS • GLO • US Coast Guard

Monitoring

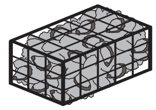
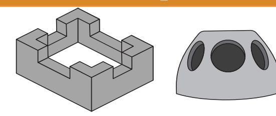
Continued monitoring of an oyster reef enhancement or construction project using metrics aligned with project goals can aid in tracking the success of the reef after construction.

- Oyster population: colonization, recruitment, size, density, disease, harvesting (if applicable)
- Water quality
- Structural stability of reef components
- Secondary benefits: biodiversity, change in other species population, shoreline change, fishery use, recreational use, socio-economic benefits

Engineering Considerations for Oyster Reef Enhancement

Structure Type

The site characteristics including hydrodynamic and substrate conditions as well as the project budget and timeline will be the primary considerations when selecting what type(s) of structures to use in an oyster reef project.

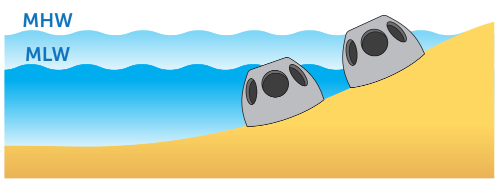
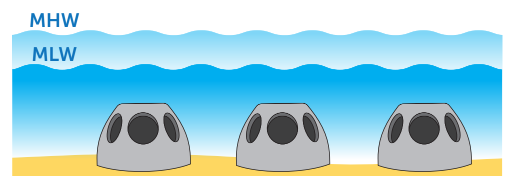
None	Simple	Complex
		
Existing reefs are managed through programmatic actions such as oyster harvesting restrictions. An existing reef in good health that does not need to be harvested would be a good candidate for this approach.	Placement of loose, bagged, or caged cultch materials along the bottom of a water body. This type of reef structure is useful in water that is not particularly dynamic, areas with low wave action, or a reef that only needs to be built up a small amount.	Installation of large rocks or pre-fabricated structures (e.g. reef balls) for oyster colonization. This structure type is typically used in areas with high wave activity or as a shoreline stabilization alternative (if this is the desired intent of the project).

INCREASING PROJECT COST & ENGINEERING EFFORT →

← *DECREASING TIME NEEDED FOR STABLE POPULATION*

Tidal Location

The location and water depth of project will play a considerable role in whether a reef is subtidal or intertidal; however, the sizing of project components can also affect whether the reef is exposed at lower tide conditions. The level of reef submergence can affect how quickly oysters will colonize and grow as well as the efficacy of the reef for wave attenuation and shoreline protection.

Intertidal	Subtidal
 	
Oyster reef constructed at a water depth within the tidal range; intermittently wet and dry.	Oyster reef constructed at a water depth below low tide and up to 35 feet deep[13]; remains submerged during typical tide cycle.

INCREASING PROJECT COST →

← *INCREASING WAVE ATTENUATION*

Harvesting

Oyster harvesting allowances will likely be dependent on local agency determinations (i.e. TPWD), any economic or recreational goals for a project, and any water quality concerns identified for a particular site.

None	Limited	Intense
No human collection of oysters either to protect oyster population or due to water quality concerns.	Lower impact and lower volume harvesting of oysters, typically done by tonging or hand collection.	Higher impact and higher volume harvesting of oysters.

ECONOMIC RETURN & TIME NEEDED FOR STABLE POPULATION →

Costs

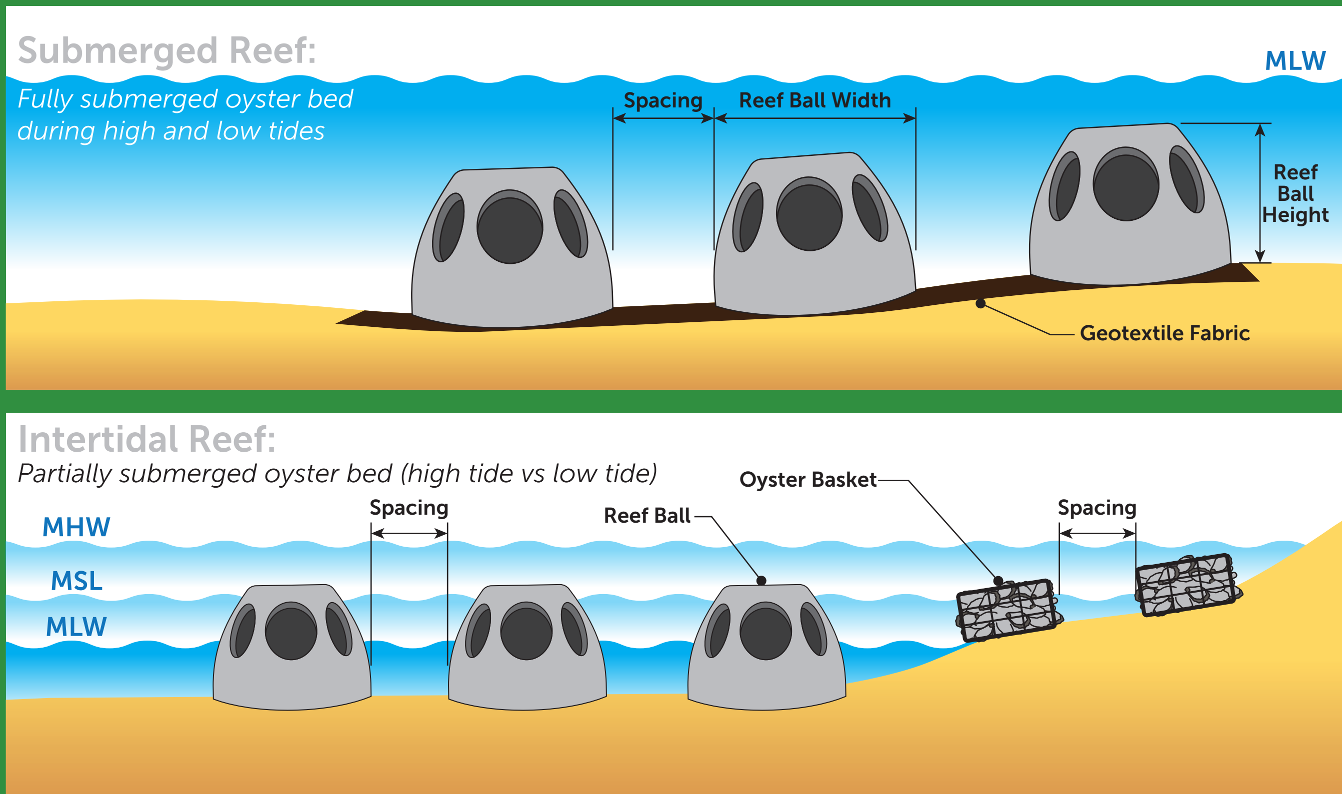
These costs are estimates for planning purposes only, and may require significant refinement based upon specific site conditions. Economies of scale may reduce costs for large-scale projects.

Materials	Installation[1]
• Oyster Restoration Projects: $200-400/linear foot (includes installation)[12] – Reef Ball: $5-265/ball[1] depending on size (ranges from 9" to 3') – Oyster Castle: $6.25/castle (12"x12"x8")[4] – Oyster Cage: $100-200/cage[3] (3/4- to 1-inch cages sized 3'x4') – Loose Spat: $20-40/1,000 seeds[2] (est. 100,000 seed oysters/acre)[9] – Loose Cultch: $10-20/pound[2] (est. 200-400 cubic yards/acre)[10][11] – Riprap Stone: $25-75/ton[5]	• Shoreline Deployment: $1000/day • Barge Deployment: $20,000/day • Pre- and Post-Deployment Surveys: $2,000/site

Example Sketches for Oyster Reef Enhancement

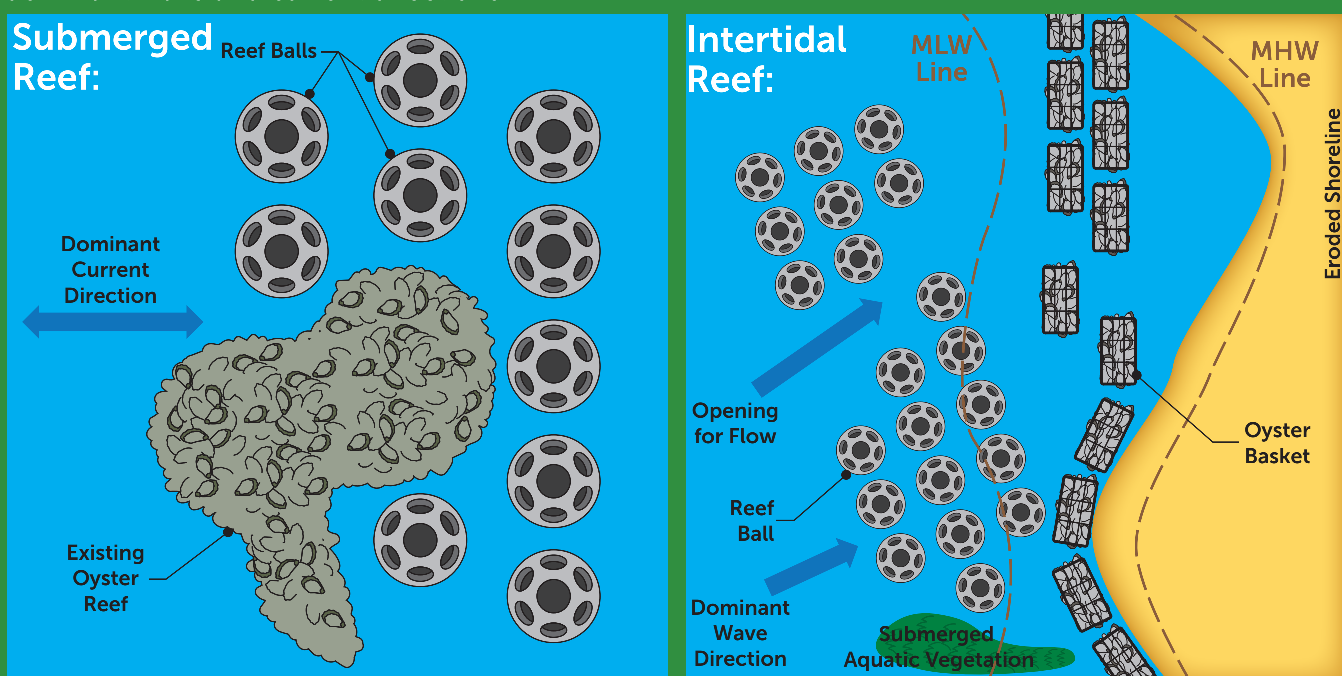
PROFILE-VIEW

A profile view illustrating spacing of oyster reef components and typical elevations relative to tidal datums.



PLAN-VIEW

A plan view illustrating arrangement of oyster reef components, identify any project constraints, dominant wave and current directions.



Tidal datums shown include MLW-Mean Low Water, MHW-Mean High Water, and MSL-Mean Sea Level.

Resiliency for Oyster Reef Enhancement

	Concerns	Effect on Oysters	Solutions
Salinity	• Droughts reduce freshwater input to bays and estuaries causing a spike in salinity • RSLR creates new hydraulic connections with higher salinity Gulf of Mexico	• Dermo infection and mortality rates increase with salinities above 12-15 ppt[6]	• Select sites with high circulation and high/reliable freshwater inflows to reduce susceptibility to salinity fluctuations • Select disease resistant oysters for restoration project
Temperature	• Increasing annual temperatures • Runoff from precipitation events causing localized water temperature spikes	• Dermo infection and mortality rates increase with temperatures above 20°C and rapidly intensify above 25°C[6]	• Select sites with high circulation to reduce susceptibility to temperature fluctuations • Select disease resistant oysters for restoration project
Dissolved Oxygen	• Higher water temperatures hold less O_2 • Nutrient rich runoff can cause algal blooms, leading to excess O_2 consumption during decomposition of the phytoplankton	• Oxygen necessary for oyster survival • Dermo infection and mortality rates increase in low oxygen waters	• Lowest oxygen rates occur near bottom of water column, utilizing a vertical reef design with castles or reef balls can maintain healthy populations above hypoxic zone
Depth	• RSLR shifts the tidal range upwards	• Oyster growth rates decrease when oysters remain submerged	• Intertidal oysters will naturally maintain pace with increasing sea level up to a rate of 11 cm/year[8]
Sedimentation	• Runoff from precipitation events • Coastal storms causing erosion and suspension of seabed • Harvesting practices suspending sediment	• Deposition on hard substrate prevents spat settlement • Smothers live oysters, affecting respiration and feeding or increasing fatalities	• Reefs utilizing vertical configurations have portions above higher sedimentation near bed level • Arrangement of reef rows perpendicular to predominant flow directions are less prone to sedimentation[7] • Submerged reefs less prone to sediment accumulation that is due to wave action
Harvesting	• Harvesting rates exceed oyster colonization and growth rates	• Depletion of self-sustaining oyster population	• Prohibit or limit oyster harvesting allowances, limits can be to type of oyster harvesting and to quantities
Ocean Acidification	• Increase in atmospheric carbon concentrations largely absorbed by the ocean (~30%) • Decreasing pH (increasing acidification) in coastal waters	• Reduction in the availability of carbonate ions utilized by calcifying and shell-building organisms • Adversely impacts survival, growth, and physiology	• Buffer water either manually (intake systems for aquaculture) or naturally (placing oyster reefs near mangroves, seagrass beds, or other habitats that buffer pH of surrounding water) • Select oyster seed/spat that is more resilient to lower pH levels when outplanting

Additional Information and Resources:

- **[1] Oyster Reef Ball Material and Installation Costs:** *https://reefinnovations.com*
- **[2] Oyster Loose Spat and Loose Cultch Price:** *https://baywatchoysterseeds.com/cultch-prices*
- **[3] Oyster Cage Cost:** *https://hoopersisland.com/equipment-item/bottom-cages/*
- **[4] Oyster Castle Cost:** *https://alliedconcrete.com/products/oyster-castles/*
- **[5] Riprap Stone Cost:** *https://www.glo.texas.gov/coast/coastal-management/forms/files/living-shoreline/living-shorelines-in-texas.pdf*
- **[6] Oyster Diseases:** *https://www.vims.edu/_docs/oysters/oyster-diseases-CB.pdf*
- **[7] Sedimentation impacts on Oyster Reefs:** *https://www.researchgate.net/publication/301537698_Sediment_Suspension_and_Deposition_Across_Restored_Oyster_Reefs_of_Varying_Orientation_to_Flow_Implications_for_Restoration*
- **[8] Depth of Sea Level Rise and Oyster Survivability:** *https://www.nature.com/articles/nclimate2216*
- **[9] Oyster Mariculture in Texas:** *https://tpwd.texas.gov/fishboat/fish/commercial/com_cf/faqs.phtml#M14*
- **[10] TPWD Oyster Restoration in Galveston Bay:** *https://tpwd.texas.gov/newsmedia/releases/?req=20171009a*
- **[11] TPWD Oyster Restoration in Galveston Bay and Sabine Lake:** *https://tpwd.texas.gov/newsmedia/releases/?req=20140508b*
- **[12] NOAA Nature-Based Solutions Costs:** *https://coast.noaa.gov/data/digitalcoast/pdf/nature-based-solutions-installation-maintenance.pdf*
- **[13] Eastern Oyster Information:** *https://www.chesapeakebay.net/discover/field-guide/entry/eastern_oyster*