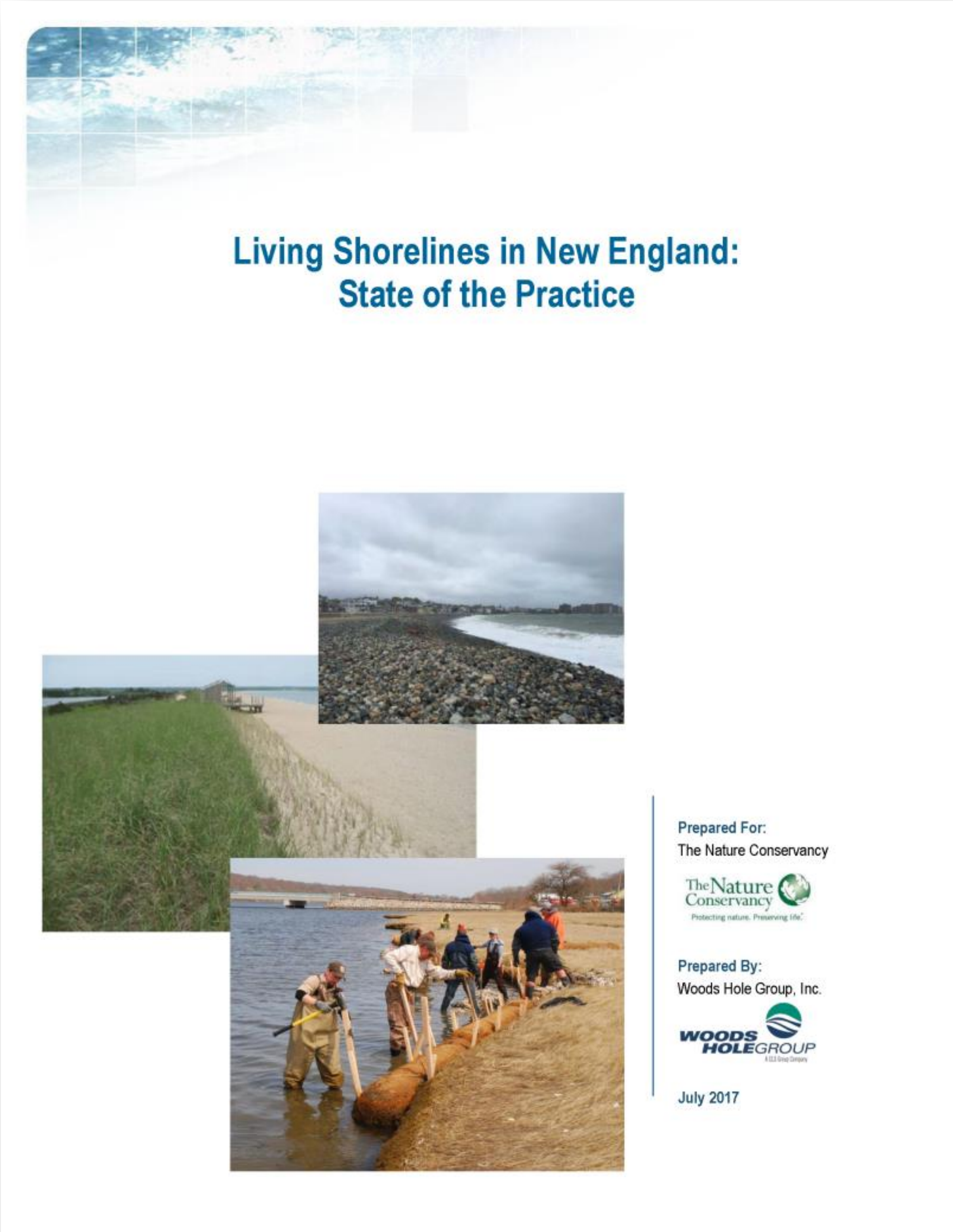
Living Shorelines in New England:
State of the Practice

Prepared For:
The Nature Conservancy

Prepared By:
Woods Hole Group, Inc.

July 2017

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Massachusetts Office of
Coastal Zone Management

Profile Page Living Shoreline Categories	Specific Terminology Used in Other Sources
1. Dune Restoration (Natural)	Dune nourishment
	Dune restoration
2. Dune Restoration (Engineered Core)	Artificial dunes
	Dune nourishment
	Cobble berm
3. Beach Nourishment	Beach nourishment
	Cobble berm
4. Coastal Bank Protection (Natural)	Coir rolls with vegetation
	Natural fiber blankets
	Regrading
	Natural fiber logs (or bio-logs)
5. Coastal Bank Protection (Engineered Core)	Regrading w/sand tubes
	Bank stabilization with coir envelopes
6. Natural Marsh Creation/Enhancement	Enhancement of marsh
	Creation of coastal wetlands
	Fringe marsh creation
7. Marsh Creation/Enhancement (w/Toe Protection)	Fringe marsh constructed with oyster or mussel shells
	Fringe marsh constructed with bio-logs
	Marsh sill or reef balls with planted marsh
8. Living Breakwaters	Oyster or mussel reef
	Reef balls

Dune – Natural: Duxbury Beach

Beach Nourishment: Barnstable Long Beach

Beach Nourishment: Revere Beach

Beach Nourishment: Winthrop Shores

Photo courtesy of Applied Coastal Research and Engineering

Case Study

Winthrop, MA Beach Nourishment

Applied Coastal Research & Engineering, Inc. designed the Winthrop Beach Nourishment Program to provide storm protection to an upland urban area fronted by a seawall originally constructed in 1899. The project utilized 460,000 cy of compatible sediment to nourish approximately 4,200 linear feet and to create the equilibrated designed berm width of 100 feet. Once the beach nourishment was completed in late 2014, the high tide shoreline was pushed more than 150 feet from the seawall, with a gradual slope extending approximately 350 feet offshore.

Winthrop Shores, Winthrop, MA
Photo courtesy of Applied Coastal Research & Engineering

Project Proponent	Massachusetts Division of Conservation and Recreation (DCR)
Status	Phase 1: 2013; Phase 2: 2014
Permitting Insights	Offshore sediment source was denied by Army Corps after a 12-year permitting process. Conservation Permit required from NHESP to address potential impacts to Piping Plovers.
Construction Notes	Upland derived mix of sand, gravel and cobble to match the existing beach sediments was required, where the nourishment was provided from two sources: sand borrow (80%) and naturally rounded cobble & gravel (20%).
Maintenance Issues	Cobble berms have begun forming along the beach, which conflicts with community recreation goals, requiring additional sand for aestheitcs.
Final Cost	Permitting: $2,000,000 (including attempt to permit offshore borrow site. Construction: $22,000,000 (included work on coastal engineering structures).
Challenges	Trucking through the community: urban community with two roads in and out, as well as roadway damage and air quality impacts associated with 16,000+ truck trips. Public perception of compatible sediment.

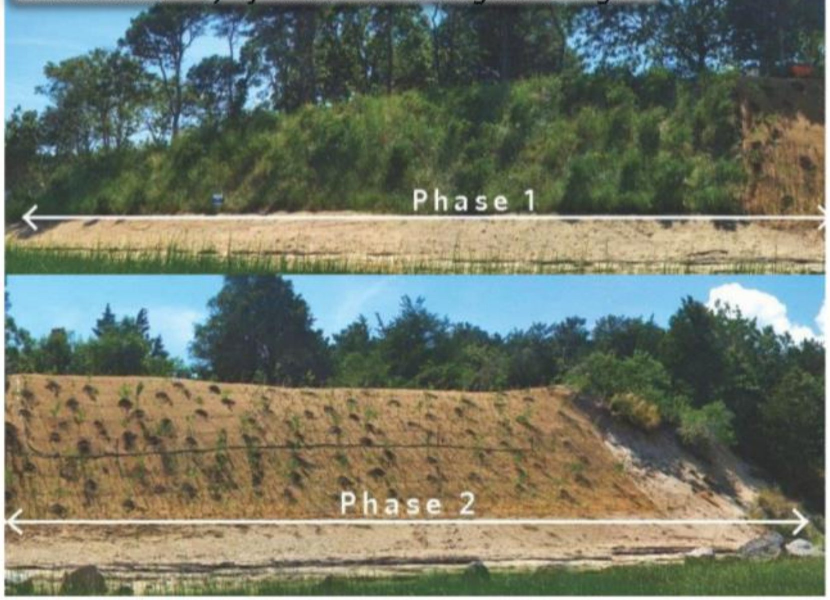
Coastal Bank – Natural: Orleans

Case Study

Coastal Bank Stabilization, Orleans, MA

Wilkinson Ecological Design developed a plant-focused coastal bioengineering project, determined not to be a coastal engineering structure by the local municipality and MA DEP. The project included a robustly anchored fiber roll array at the bottom of the bank and intensive planting and stabilization through the remainder of their coastal bank, which falls within a mapped FEMA Velocity Zone.

Pleasant Bay Bank Stabilization, Orleans, MA
Photos courtesy of Wilkinson Ecological Design



Project Proponent	Private property owners. The project spans three properties with multiple owners.
Status	Phase 1 constructed in 2010, Phase 2 constructed in 2013 and Phase 3 constructed in 2015.
Permitting Insights	The project involved one permit under the MA Wetlands Protection Act for each phase, three wetland permits in total.
Construction Notes	Regraded the over steepened bank, installed six rows of coir rolls at the toe of bank, installed natural fiber blankets on the bank face above the coir rolls, planted the bank face with native, salt-tolerant grasses and shrubs, and covered fiber rolls with sand.
Maintenance Issues	Monitor vegetation monthly throughout the growing season to ensure plant success; temporary irrigation for first three years; monitor coir rolls twice annually and after storms. Replant and retighten fiber roll anchoring system as needed.
Final Cost	Permitting: $10,000 Construction: $1,000/ linear foot Maintenance : $8,000/yr
Challenges	No substantial challenges in the permitting, construction or maintenance phases of work and has performed well through storms.

Marsh Creation/Enhancement w/ Toe Protection: Chatham

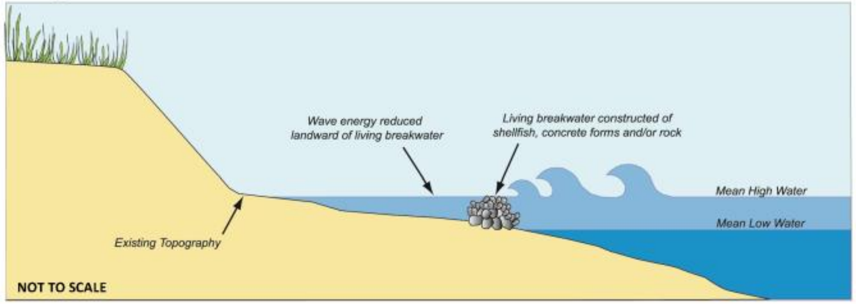
Living Breakwater – Stratford, CT

Living Breakwater

Living breakwaters are constructed nearshore to break waves on the structure rather than on the shoreline to reduce erosion and promote accumulation of sand and gravel landward of the structure. They are typically larger than sills and constructed in deeper water in more energetic wave climates, and have the potential to enhance habitat.

Objectives: break waves, dissipates wave energy, erosion control, habitat creation

Design Schematics



Design Overview

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Habitat Components	Shellfish reef. Complex structure for fisheries habitat.
Durability and Maintenance	Concrete reefs or living resources (e.g. shell bags) will break down over time, while precast concrete forms and stone will last longer. The degradation of the shell bags over time is often a desired characteristic if they are being used to temporarily break waves while a system behind it is reestablishing or a natural living system is establishing itself on this substrate.
Design Life	Shell bags, concrete forms, and stone provide the foundation for living breakwaters; concrete forms and stone provide more time for natural recruitment of shellfish and marine algae.
Ecological Services Provided	Can become valuable substrate for marine organisms, as well as provide shelter and habitat for many fish, crab and other mobile species.[14] Can dampen wave energies and increase sediment retention.[10] Because shellfish are filter feeders, oyster/mussel reefs can improve water quality.[11] As the living breakwaters become colonized with marine species, they provide recreational benefits such as fishing and snorkeling.[11]
Unique Adaptations to NE Challenges (e.g. ice, winter storms, cold temps)	Reef Balls installed in Stratford, CT withstood significant icing during the 2014-2015 winter.[14] Need to consider where in the tidal range shellfish will be placed if they're used: too high in the intertidal area may result in freezing and loss of shellfish.

Case Study

Stratford, CT Reef Balls

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Reef Ball Breakwater, Stratford, CT
Photo courtesy of Jennifer Mattei

Project Proponents	Sacred Heart Uni.(Project Lead), Audubon Society (Site Manager); DuPont Company (Site Owner)
Status	In Progress (Reef construction: Complete; Marsh & Dune Restoration and Upland work: Continuing
Permitting Insights	DABA had concerns about 'wild' oysters settling on the reef and possibly harboring diseases that might affect the aquaculture industry of Long Island Sound. So far, this has not been a problem.
Construction Notes	A restoration team of land managers, restoration ecologists and environmental engineers is key for designing and deploying a living shoreline. The study of local bathymetry, storm wind and wave trajectory, sediment loads and causes of erosion are imperative for proper placement of artificial reefs used to protect newly restored saltmarshes.
Maintenance Issues	Previous attempts of dune restoration prior to artificial reef construction highlight the importance of comprehensive restoration planning, and construction sequencing.
Final Cost	To be determined
Challenges	Initial dune installation (2012) was eroded by storms before the artificial reef and saltmarsh were installed. Slight field modifications to reef ball placement due to natural rock outcroppings.

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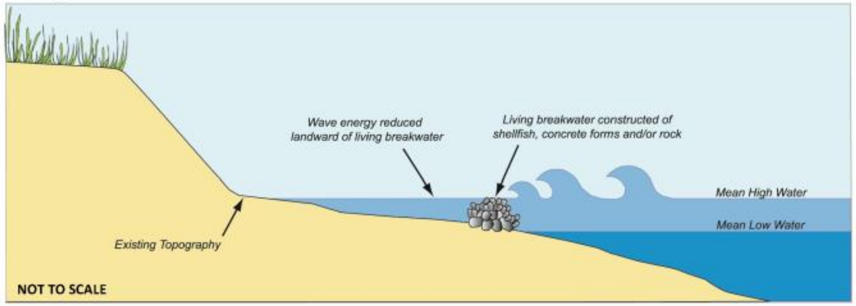

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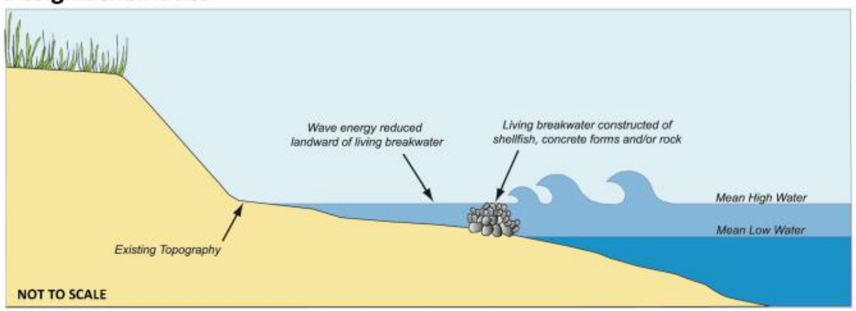

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Status	In Progress (Reef construction: Complete; Marsh & Dune Restoration and Upland work: Continuing
Permitting Insights	DABA had concerns about 'wild' oysters settling on the reef and possibly harboring diseases that might affect the aquaculture industry of Long Island Sound. So far, this has not been a problem.
Construction Notes	A restoration team of land managers, restoration ecologists and environmental engineers is key for designing and deploying a living shoreline. The study of local bathymetry, storm wind and wave trajectory, sediment loads and causes of erosion are imperative for proper placement of artificial reefs used to protect newly restored saltmarshes.
Maintenance Issues	Previous attempts of dune restoration prior to artificial reef construction highlight the importance of comprehensive restoration planning, and construction sequencing.
Final Cost	To be determined
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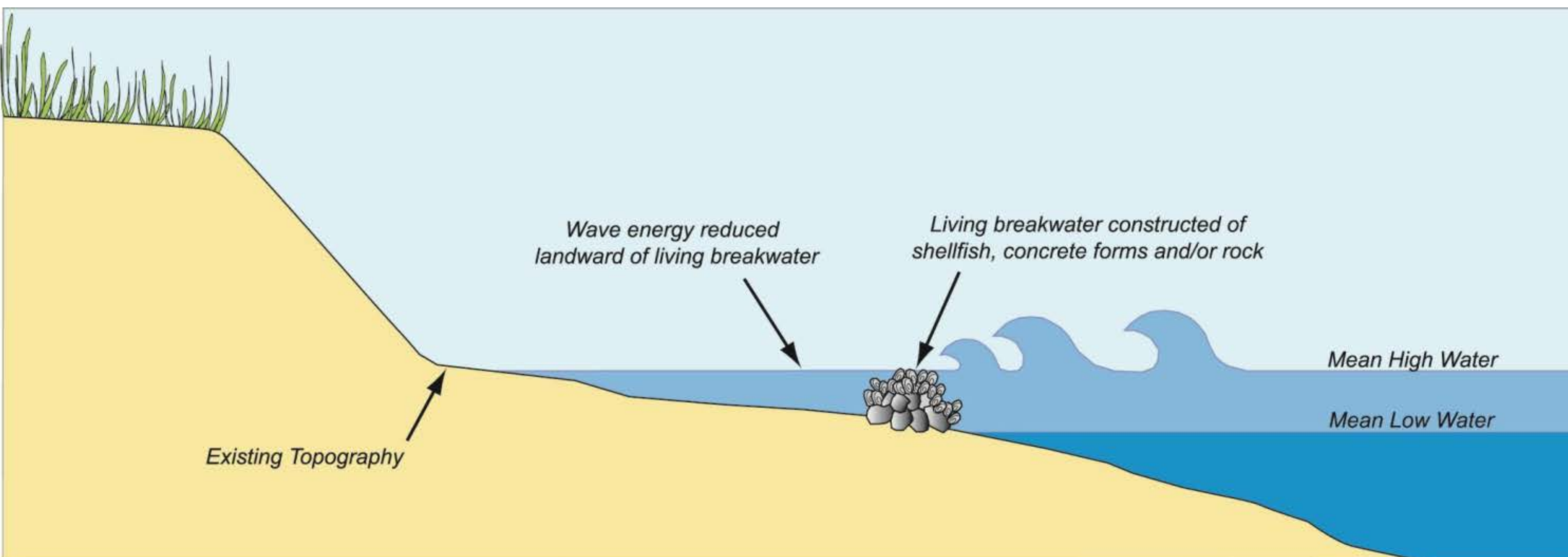

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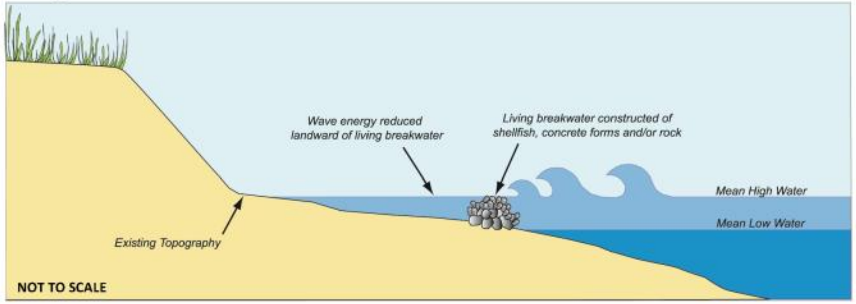

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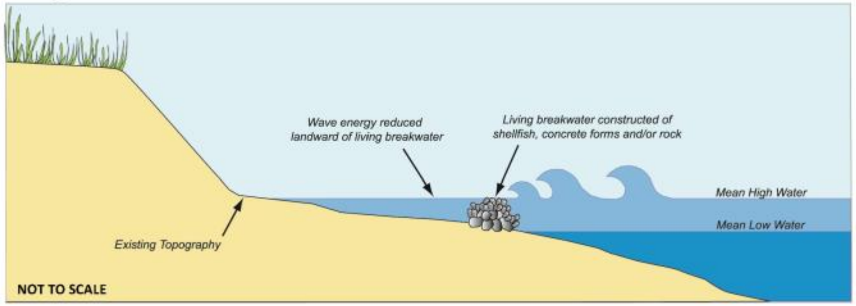

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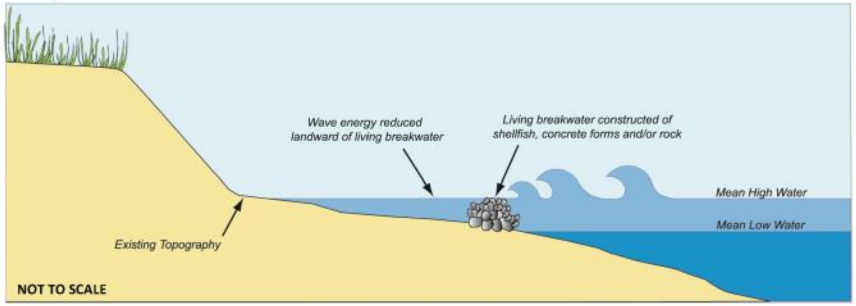

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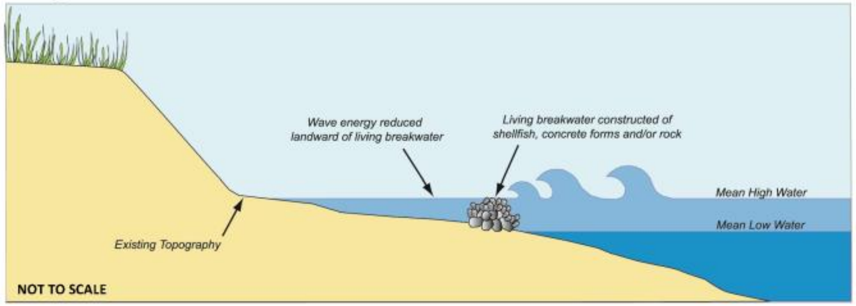

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Unique Adaptations to NE Challenges (e.g. ice, winter storms, cold temps)	Reef Balls installed in Stratford, CT withstood significant icing during the 2014-2015 winter.[14] Need to consider where in the tidal range shellfish will be placed if they're used: too high in the intertidal area may result in freezing and loss of shellfish.

Case Study

Stratford, CT Reef Balls

Beginning in 2010, the Stratford Point project has focused on restoring and managing 28 acres of coastal upland and 12 acres of intertidal habitat using an integrated whole ecosystem approach. The creation of a 1,000-foot living shoreline started with the construction of an artificial reef, using pre-cast reef balls, at mean tide elevation (~ 75 ft. offshore), in conjunction with restoration of low and high marshes and dune shoreward of the artificial reef. In addition, upland shrub, coastal forest and meadow mosaic is being restored to improve bird and pollinator habitat.

Reef Ball Breakwater, Stratford, CT
Photo courtesy of Jennifer Mattei

Project Proponents	Sacred Heart Uni.(Project Lead), Audubon Society (Site Manager); DuPont Company (Site Owner)
Status	In Progress (Reef construction: Complete; Marsh & Dune Restoration and Upland work: Continuing
Permitting Insights	DABA had concerns about 'wild' oysters settling on the reef and possibly harboring diseases that might affect the aquaculture industry of Long Island Sound. So far, this has not been a problem.
Construction Notes	A restoration team of land managers, restoration ecologists and environmental engineers is key for designing and deploying a living shoreline. The study of local bathymetry, storm wind and wave trajectory, sediment loads and causes of erosion are imperative for proper placement of artificial reefs used to protect newly restored saltmarshes.
Maintenance Issues	Previous attempts of dune restoration prior to artificial reef construction highlight the importance of comprehensive restoration planning, and construction sequencing.
Final Cost	To be determined
Challenges	Initial dune installation (2012) was eroded by storms before the artificial reef and saltmarsh were installed. Slight field modifications to reef ball placement due to natural rock outcroppings.

Reef Ball Breakwater, Stratford, CT
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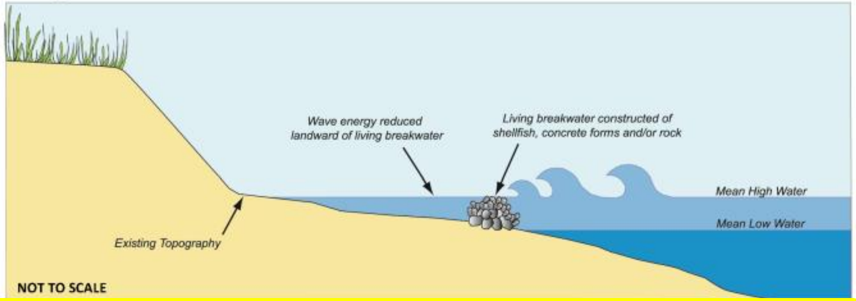
Living Breakwater

Living breakwaters are constructed nearshore to break waves on the structure rather than on the shoreline to reduce erosion and promote accumulation of sand and gravel landward of the structure. They are typically larger than sills and constructed in deeper water in more energetic wave climates, and have the potential to enhance habitat.

Objectives: break waves, dissipates wave energy, erosion control, habitat creation

Design Schematics



Design Overview

Design Overview	
Materials	Living reef materials (oysters/mussels). Shellfish reefs can be constructed with bagged or loose shell to provide the same erosion control as rock sills but with additional ecosystem benefits.[11] Precast concrete forms or stone.
Habitat Components	Shellfish reef. Complex structure for fisheries habitat.
Durability and Maintenance	Concrete reefs or living resources (e.g. shell bags) will break down over time, while precast concrete forms and stone will last longer. The degradation of the shell bags over time is often a desired characteristic if they are being used to temporarily break waves while a system behind it is reestablishing or a natural living system is establishing itself on this substrate.
Design Life	Shell bags, concrete forms, and stone provide the foundation for living breakwaters; concrete forms and stone provide more time for natural recruitment of shellfish and marine algae.
Ecological Services Provided	Can become valuable substrate for marine organisms, as well as provide shelter and habitat for many fish, crab and other mobile species.[14] Can dampen wave energies and increase sediment retention.[10] Because shellfish are filter feeders, oyster/mussel reefs can improve water quality.[11] As the living breakwaters become colonized with marine species, they provide recreational benefits such as fishing and snorkeling.[11]
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Permitting Insights	DABA had concerns about 'wild' oysters settling on the reef and possibly harboring diseases that might affect the aquaculture industry of Long Island Sound. So far, this has not been a problem.
Construction Notes	A restoration team of land managers, restoration ecologists and environmental engineers is key for designing and deploying a living shoreline. The study of local bathymetry, storm wind and wave trajectory, sediment loads and causes of erosion are imperative for proper placement of artificial reefs used to protect newly restored saltmarshes.
Maintenance Issues	Previous attempts of dune restoration prior to artificial reef construction highlight the importance of comprehensive restoration planning, and construction sequencing.
Final Cost	To be determined
Challenges	Initial dune installation (2012) was eroded by storms before the artificial reef and saltmarsh were installed. Slight field modifications to reef ball placement due to natural rock outcroppings.

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Maintenance Issues	Previous attempts of dune restoration prior to artificial reef construction highlight the importance of comprehensive restoration planning, and construction sequencing.
Final Cost	To be determined **~ $120K for reef balls**
Challenges	Initial dune installation (2012) was eroded by storms before the artificial reef and saltmarsh were installed. Slight field modifications to reef ball placement due to natural rock outcroppings.

Living Breakwater

Although breakwaters are often considered coastal engineering structures, a gapped living breakwater allows habitat connectivity and greater tidal exchange and can be used in combination with other living shorelines practices to reduce the wave energy allowing the establishment of a beach or vegetated (typically marsh) shoreline in its lee.


Oyster bags for a living reef at Gandy's Beach NJ
Photo courtesy of Mary Conti, TNC NJ

Regulatory and Review Agencies

Maine	Municipal Shoreland Zoning, Municipal Floodplain, ME Dept. of Environmental Protection, ME Land Use Planning Commission, ME Coastal Program, ME Department of Marine Resources, ME Department of Inland Fisheries and Wildlife, ME Geological Survey, and ME Submerged Lands Program.
New Hampshire	Local Conservation Commission, NH Natural Heritage Bureau, NH Department of Environmental Services (Wetlands Bureau, Shoreland Program, and Coastal Program), and NH Fish & Game Department.
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Federal (for all states)	U.S. Army Corps of Engineers, National Marine Fisheries Service, U.S. Environmental Protection Agency, and U.S. Fish and Wildlife Service.

Siting Characteristics and Design Considerations

Selection Characteristics	Detail
ES Energy State	Moderate to high. Suitable for most areas, except those in the highest wave energy environments.[2] Concrete forms are generally stable under most wave conditions due to the size and weight of the units, and have been shown to attenuate wave energy and reduce erosion in a low to moderate wave energy locations; one study found that Reef Balls could reduce wave heights by 60%.[7] Using additional rows of Reef Balls can decrease this even more.[7]
EE Existing Environmental Resources	Coastal beach; mud flat; subtidal
SR Nearby Sensitive Resources	Endangered and threatened species. If the project is proposed in or adjacent to habitat for protected wildlife species or horseshoe crab spawning areas, there may be limitations on the time of year for construction. Shellfish beds, submerged aquatic vegetation, and essential fish habitats will restrict where a living breakwater can be constructed.
TR Tidal Range	Low to middle. In areas with a large tidal range, these structures would have to be extremely large to continue to provide protection functions,[2] or could be sited closer to shore. Best suited for low to medium tidal range areas.
EL Elevation	MLW to MHW; subtidal. Located intertidally or subtidally, but typically designed with crest elevation at MHHW, therefore quickly overtopped during storms; not effective at dealing with storm surge events.[10]
IS Intertidal Slope	Flat to steep. The breakwater itself will not be impacted by the intertidal slope[7], but other project components, such as a marsh planted behind the breakwater, may have specific slope requirements.
BS Bathymetric Slope	Flat to steep. The bathymetric slope will influence the size and type of waves that impact the structure, and thus should be considered in the wave analysis.[7]
ER Erosion	High to low. Assuming wave energy is the primary driver of coastal erosion at the site, an appropriately sized and placed breakwater should be capable of mitigating the erosional problem under most conditions.[7]
Other Characteristics	**Detail**
Ice Sensitivity	Current guidance suggests sizing stone so that the median stone diameter is two to three times the maximum expected ice thickness.[7] In colder climates, oysters/mussels should be submerged (below MLW) to prevent them from freezing during the winter months.[7]
Climate Vulnerability	The effectiveness of a breakwater will be reduced over time as sea level rise gradually reduces the freeboard of the structure. Living reef breakwaters have some capacity to adapt to changing conditions, as long as sea level rise is relatively slow.[7]
Surrounding Land Use	Projects need to be planned alongside other competing water uses such as boating, fishing, shellfishing, and aquaculture. Consideration should be given to potential conflicts with existing navigable waters.

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Photo courtesy of MassWildlife

Photo courtesy of DMF

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Massachusetts

Conservation Commission

Massachusetts Environmental Policy Act

Department of Environmental Protection

- Waterways & Water Quality

Division of Fisheries & Wildlife

- Natural Heritage & Endangered Species Program

Office of Coastal Zone Management

Federal

U.S. Army Corps of Engineers

National Marine Fisheries Service

U.S. Environmental Protection Agency

U.S. Fish & Wildlife Service

NOAA

NROC
Northeast Regional
Ocean Council

NERACOOS