Habitat Restoration Approaches to Improve Community and Ecosystem Resilience

Systems Approach to Geomorphic Engineering Webinar Series
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Hadley, MA

Photo: NOAA
1. Reduce the impacts of coastal storm surge, wave velocity, sea level rise and associated natural threats on coastal and inland communities.

2. Strengthen the ecological integrity and functionality of coastal/inland ecosystems to protect communities and to enhance fish and wildlife and their associated habitats.

3. Enhance our understanding of the impacts of storm events and identify cost effective, resilience tools that help mitigate for future storms.
USFWS Conservation Design
Resilience Projects

Projects designed to provide ecosystem and community resilience to flooding, storm surge, SLR and increased storm events

- Marsh Restoration
- Beach Restoration
- Aquatic Connectivity
- Science Support Tools

http://www.fws.gov/hurricane/sandy/
Measuring Success
Are Resilience Projects Effective?

Program Assessment:

• Identify ecological system performance metrics
• Identify socio-economic performance metrics
• Link ecological performance metrics with the socio-economic metrics
• Enhanced data collection (performance metrics), modeling, and analysis
• Provide results to evaluation/assessment of DOI project contributions to coastal resilience (5-10 year timeframe)
DOI Metrics Expert Group Report provides Ecological Performance Metrics

Organized by Coastal Feature

- Beach, Barrier Island, and Dunes
- Nearshore Shallow and Nearshore Deep
- Riverine and Riparian Zone
- Marshes and Wetlands
- Uplands and Watersheds
- Maritime Forests and Shrublands
- Estuaries and Ponds
- Grey infrastructure
- Green Infrastructure

Identifies Abiotic, Biotic, and Structural Metrics
3. Overview of Metric Workgroups

- Organized metrics around coastal features (project comparison)
- Identify core metrics (abiotic, biotical, structural)
- Peer review

**DOI Sandy Program**

**Core Performance Metrics:**
A set of performance metrics that are applied to multiple projects and at the full range of temporal and spatial scales to represent a change in resilience in one or more coastal features.

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<tr>
<th>Natural and Artificial Coastal Features</th>
<th>Primary Objectives and Ecosystem Services</th>
<th>Recommended Core Performance Metrics</th>
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</thead>
</table>
| **Beach System: Beach, Barrier Island, and Dunes** (for back bay areas, see Estuaries and Ponds) | Beaches and Dunes:  
1) Restore or improve beach habitat to enhance resilience of fish, wildlife, and plants, and their habitats (e.g., spawning, migration stopovers, critical habitats)  
2) Restore/improve dune habitat to enhance resilience of coastal infrastructure by reducing flooding extent and attenuating wave energy  
3) Improve/sustain beach/barrier island ecological system and community resilience to storm surge events  
4) Enhance understanding of natural system dynamics including immediate storm responses, natural recovery from disturbance events, and natural adaptation capacities and tendencies.  
5) Improve recreation/aesthetics | Beaches and Dunes:  
Biotic  
- Vegetation cover of dunes pre and post event  
- Fish and wildlife population/recruitment/overwintering/stopover weight/health relative to other mitigating factors (e.g. other threats throughout range: site and species specific)  
Abiotic  
- Post-storm volume of sand in the active shoreface  
- Recovery rates of beach and dunes |
| Breaches:  
1) Manage breach occurrences to maximize ecosystem function and reduce risks to built infrastructure, human health, and human safety. | Breaches:  
Biotic  
- Fish and wildlife population/recruitment/overwintering/stopover weight/health changes relative to other mitigating factors (e.g. other threats throughout its range: site and species specific)  
Abiotic  
- Volumes of material in flood and ebb shoals  
- Water flow and current dynamics  
- Water quality: temperature, salinity, pH, dissolved oxygen, turbidity, nutrients, contaminants  
- Water level changes, especially in back bays |
| Structural/Engineering  
- Beach width, elevation, volume, shoreline position (post-event)  
- Dune characterization (height, width, length, texture, substrate) | Structural/Engineering  
- Monitoring of breach morphologic changes |
Ecological Monitoring
Core Metrics

Marsh Restoration
- Nekton abundance, species richness
- Salt marsh plant community monitoring
- Water Quality
- Marsh surface elevation change trend
- Marsh accretion and erosion
- Groundwater dynamics

Aquatic Connectivity
- Fish migration rates and patterns
- Invasive species extent, mobility
- Fish assemblage/abundance
- Habitat availability
- Riparian plant communities, pre and post
- Water temperature, salinity
- Flooding extent and depth
- Sediment composition and contaminants
- River Flow and depth

SET Installation

Norton Dam, CT
Ecological Monitoring
Core Metrics

**Beach and Dune Restoration**
- Fish, wildlife population, recruitment, overwintering, stopover weight
- Vegetation cover of dunes, pre and post
- Dune characterization
- Beach width, elevation, volume, shoreline position
- Post-storm volume of sand in active shoreface

**Living Shorelines**
- Oyster length/frequency
- Oyster coverage & population
- Vegetation cover
- Water temperature, salinity
- Vertical accretion rates
- Shoreline position
- Wave and Current Energy
**Objective:** Develop socio-economic metrics and assign to each project

- Classify 167 projects (project activity, project outcome)
- Develop resilience framework to organize and assign metrics
- Identify methodologies and data for measures
- Causal mapping to develop socio-economic metrics and link to ecological metrics

The Result

- RFP Issued by NFWF Oct. 24, 2016
- Ecological monitoring & data collection
- Monitoring socio-economic impacts
- Resilience assessment of DOI & NFWF Projects
Phase I Evaluation

- To what extent did projects do what they said they were going to do?
- What ecological benefits were realized individually and collectively?
- What socioeconomic benefits were realized individually and collectively?
- How cost effective were the resilience activities in achieving ecological and socioeconomic resilience benefits?
Hurricane Sandy Evaluation Products

- Core Ecological Metrics of Resilience (available)
- Core Socioeconomic Metrics of Resilience (available)
  - Resilience Monitoring Database (Dec. ‘18)
  - Phase I Evaluation w/Seven Case Studies (April ’18)
  - 5-7 Years of Monitoring Data (annually 2017-2023)
  - Phase II Evaluation (Dec. ’23)

www.nfwf.org/hurricanesandy
www.doi.gov/hurricanesandy
Prime Hook NWR
Marsh & Beach Restoration

- On the western shore of the Delaware Bay, in southern DE
- Established in 1963
- 10,132 acres, primarily wetlands
- Refuge divided into management units
- Dune breaches are in Units I & II
• ~4000 acres of freshwater impoundments
• Tidal water restricted by water control structures
• Culverts between Unit II and Unit III
• Successful freshwater impoundment management for 20+ years
Issues

- Freshwater impoundment management unsustainable
- Substantial historic accretion deficit
- Elevation deficit has led to peat collapse and conversion to open water
- Impacts to habitat, wildlife, and coastal communities

Hurricane Sandy Disaster Relief Funds

- $19 M in *Recovery Funds* - Fore beach, dune, back barrier platform
- $19.8 M in *Resilience Funds* - Marsh restoration
Prime Hook NWR
Beach & Marsh Restoration

Restore a Barrier Beach & Salt Marsh Complex

• Close breaches
• Dredge a network of tidal channels
• Eliminate water control structures
• Remove road and alterations to roads and/or culverts
• Use dredge material to augment marsh

Prime Hook National Wildlife Refuge (Photos: USFWS)
Prime Hook NWR
Beach & Marsh Restoration

The Result

- **Restored Hydrology**
  - Establish tidal channels

- **Restored ecosystem services**
  - Storm surge and flood protection
  - Carbon Sequestration
  - Habitat

- **Increased public support**

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Restoring hydrology, recreating channels (Photo: USFWS)

Sand Pumping to Close Breaches (Tim Boyle, USACE)

Replanting saltmarsh vegetation (Photo: USFWS)
Abiotic & Biotic Monitoring

- Water Monitoring
- Sediment Monitoring
- Marsh Elevation, Accretion
- Groundwater Influence
- Vegetation Communities
- Bird Communities
- Fish Communities
<table>
<thead>
<tr>
<th>Metric</th>
<th>Methods</th>
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</table>
| **Nekton abundance, species richness**      | • Ditch nets & Throw traps (SMI); 1x/yr  
• Fyke/Clover Trap/Electofishing; 3x/yr  
• Acoustic tagging; continuous              |
| **Salt marsh plant community (spp composition, % cover, areal coverage)** | • 50m radius plot (SMI/SHARP); 1x/yr  
• NVDI remote sensing; 1x/yr  
• MidTRAM habitat attribute metrics; 1x/yr  
• Photo Points; 1x/yr                        |
| **Water quality**                           | • YSI EXO sondes (or similar); continuous  
• Nutrient grab samples; monthly              |
| **Marsh surface elevation change trend**    | • Surface Elevation Tables (SET); 1x/year  
• MidTRAM habitat attribute metrics; 1x/yr  
• Aerial LiDAR surveys; Year 1 and Year 5    |
| **NEW – local tide levels/datums**          | • HOBO water level loggers; continuous                                                                                           |
| **Marsh accretion and erosion**             | • Feldspar horizons at SETs; 2x/year  
• Sediment flux monitoring; continuous        |
| **Groundwater dynamics**                    | • HOBO water level loggers on marsh surface; continuous for defined durations, e.g. 1-2 months  
• GDSNWR - 25 sites have groundwater level monitoring; 11 have continuous recordings |
## Ecological Monitoring
### Core Beach & Dune Metrics

<table>
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<th>Methods (multiple projects)</th>
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<tbody>
<tr>
<td>Vegetation cover of dunes pre and post event</td>
<td>GIS analysis of orthophotos</td>
</tr>
<tr>
<td>Dune characterization (height, width, length, texture, substrate, and change over time)</td>
<td>Dune profiles (NPS (NCBN) Coastal Topography Protocol; LiDAR, Grain size analysis; Digital Elevation Models</td>
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<tr>
<td>Beach characterization (width, elevation, volume, shoreline position and change over time)</td>
<td>Beach profiles NPS (NCBN) Coastal Topography Protocol; Shoreline position NPS (NCBN) Shoreline Position Protocol; Digital Elevation Models</td>
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<td>Dune Crest Position – change over time</td>
<td>Dune profiles Digital Elevation Models</td>
</tr>
<tr>
<td>Dune Volume – change over time</td>
<td>Digital Elevation Models</td>
</tr>
<tr>
<td>Shorebird nest success (piping plover and American oyster catcher)</td>
<td>Number of nests/nest attempts and clutch sizes Signs of predators and disturbance; Fledglings</td>
</tr>
<tr>
<td>Shorebird nest elevation</td>
<td>Nest location (GPS); Nest elevation (DEM)</td>
</tr>
</tbody>
</table>
Delaware Bay – An Important Place

- One of the world’s most significant migratory shorebird stopovers
- Critical foraging area for Red Knot
- World’s largest spawning population of Horseshoe Crabs
- Important area for ecotourism
Hurricane Sandy Impacts

- 70% decrease in optimal horseshoe crab spawning habitat (Niles, 2012)
- Loss of sand, exposure of debris, threats to marshes and infrastructure.
Delaware Bay Beach Habitat Resilience Project

- 5 beaches selected; Reeds, Pierces Point, Kimbles, Moores, Cooks
- $1.65 million budget
- Restored 1.5 miles, 80-foot-wide berm, 45,500 tons of sand
- Removed about 800 tons of debris
Science Behind Restoration Efforts

Beach template design by Stockton College Coastal Research Center

Oyster aquaculture to provide additional protection.
Science to Achieve Biological Outcomes

Before

- Shorebird Banding / Weight Measurements

After

- Horseshoe Crab Tagging
- Shorebird Abundance
- HC egg abundance
- Restored, control, and unrestored beaches
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<tr>
<td><strong>Beach Profile</strong></td>
<td>Topography/Elevation; Transects, RTK GPS surveys Control and restored Beaches NAD 83/NAVD 88 Horizontal and vertical datums</td>
</tr>
<tr>
<td><strong>Sand Transport</strong></td>
<td>Wind, Wave &amp; Nearshore currents, Littoral Environment Observation Data Collection Program USACE</td>
</tr>
<tr>
<td><strong>Beach characterization (width, elevation, volume, shoreline position and change over time)</strong></td>
<td>Shoreline position, RTK surveys; Grain size analysis; 2x annually</td>
</tr>
<tr>
<td><strong>Horseshoe Crab spawning/egg abundance</strong></td>
<td>Transects and 3 meter quadrants, 3x weekly (May) 50 -100m sections, minimum 5 transects/beach Shallow and deep sampling 1x week (May)</td>
</tr>
<tr>
<td><strong>Shorebirds – body condition and population estimates</strong></td>
<td>Cannon nets, spotting scopes Weight 50 m beach segments, Surveys 3x/week (May) Counts by species and behavior (roosting vs. feeding)</td>
</tr>
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Aquatic Connectivity

- Restore fish passage
- Restore riparian habitat, reconnect the floodplain
- Remove unsafe and obsolete dams
- Reduce community flood risk
- Protect roads and infrastructure

Photos: USFWS
Aquatic connectivity and flood resilience

To what extent have dam removal and culvert replacement projects lead to improved ecological and social resilience outcomes?

Pond Lily Dam Removal, Woodbridge, CT
## Ecological Monitoring

### Core Aquatic Connectivity Metrics

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| **Fish Migration Rate, Assemblage and Abundance** | Video monitoring and iSpy software, Fyke nets, PIT tag arrays, cameras, back pack electrofishing unit, 50 foot bag seine  
  Frequency: Often weekly in spring migration for 5 years |
| **Flooding Depth, Extent and Inundation Pattern** | HEC-RAS model of water surface elevations; previously modeled flood maps                  |
| **River Flow/Depth**                        | River morphology survey, USGS gage, cross sections, LIDAR                                  |
| **Habitat Availability**                    | ArcGIS spatial analysis, physical habitat variables, macroinvertebrate surveys, EPA Visual Habitat Assessment tool, Wolman pebble counts, stream profile and sediment deposition assessment techniques |
| **Sediment composition and contaminants**   | Bathymetric survey and sediment samples, DREAM sediment transport model, LIDAR             |
| **Water Quality**                           | Bacteria, dissolved oxygen, salinity, pH, conductivity, water temperature, chlorophyll a, total phosphorus, orthophosphate, ammonia, nitrate, total nitrogen, TSS, turbidity  
  Frequency: Some parameters continuously |
| **Riparian composition**                    | Transects and plots, georeferenced photos  
  Frequency: Growing season annually          |
The refuge is:

• 4,423 acre tract of tidal marsh
• Located at the northern end of Smith Island
• 12 miles offshore
• Supports largest concentration of wintering waterfowl
• Important habitat for fisheries and non-game wildlife, two large and diverse wading bird nesting colonies

Typical shoreline near low tide

- Subtidal bottom
- Peat Scarp
- Exposed Peat terrace
- Sandy berm
- High marsh
The Issue

- Broad fetch on northern and western shorelines
- Shoreline retreat - 10 to 15 feet/year
- Loss of nearly 3.3 acres of habitat annually

Actions taken to:

- Protect Habitat - wetlands and SAV beds
- Provide community protection
- Protect commercial crabbing grounds (soft shell crabs)
Erosion Control

- Stabilize ~ 21,000 linear feet of shoreline
  - Headland control structures
  - Sand nourishment
  - Wetland plantings
- Construction completed summer 2016

Cost: $9 million
Living Shoreline Project
Fog Point, Martin NWR
Smith Island, MD

- Plantings completed Fall 2016
- Implement ecological and socio-economic metrics, 2017-2023
Living Shoreline Project
Gandy’s Beach, NJ

• Partnership project with TNC
• Nature Conservancy Preserve
• NJ shoreline on Delaware Bay
• Habitat for species like horseshoe crabs and red knots
The Issue:

- Shoreline increasingly vulnerable to erosion
- Shoreline has shrunk by nearly 500 feet since 1930
- Significantly impacted by storm surge from Hurricane Sandy
- Continued marsh loss will result in increased flood risk to community
- Loss of habitat
Living Shoreline Project
Gandy’s Beach, NJ

Erosion Control  Cost: $880,000

- Use living shorelines
  - bagged shell and oyster castles
- Stabilize 3,000 feet of beach and tidal marsh shoreline
- Restore 337 acres of salt marsh and adjacent uplands.

Putting Oyster Castles Together
Credit: Mary Conti/TNC
Living Shoreline Project
Gandy’s Beach, NJ

Bagged Shell in Action

- Collected as part of a shell recycling program
- Bagged oyster shells created by local schools
- Volunteers move shell bags across beach

Credit: Project PORTS
Credit: Project PORTS
Living Shoreline Project
Gandy’s Beach, NJ

Project Benefits

• Reduce erosion rates
• Improve ecosystem connectivity
• Provide community protection from flooding
• Restores and enhances habitat
• Improves near-shore water quality
• Provides suitable oyster habitat to promote the growth of oyster reefs

Partners

New Jersey Department of Environmental Protection, Bureau of Coastal Engineering, The Nature Conservancy, Downe Township, Cumberland County, American Littoral Society, The Partnership for the Delaware Estuary, Rutgers University, Haskin Shellfish Research Lab
## Ecological Monitoring: Living Shoreline Core Metrics

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<tr>
<td>• Shoreline Position</td>
<td>• Annual RTK survey of shoreline profiles in treated and untreated areas before and after construction (BACI)</td>
</tr>
<tr>
<td>• Vertical Accretion</td>
<td>• Annual RTK survey of elevation plots in treated and untreated areas before and after construction (BACI)</td>
</tr>
</tbody>
</table>
| • Vegetation Cover and Structure            | • Intertidal vegetation plots read annually in treated and untreated areas before and after construction (BACI)  
|                                             | • Submerged aquatic vegetation transects surveyed 2x/yr                  |
| • Oyster coverage and population            | • Stratified Biological Plot Sampling                                   |
| • Oyster length frequency                   | • Site level sampling within select plots                               |
| • Water temperature and salinity            | • YSI logger                                                           |
| • Nekton abundance and species richness     | • Seine and block net sampling                                         |
| • Wave height, frequency, duration          | • Wave gauge                                                          |
“If resilience is built through a project, and no perfect resilience metric is around to measure it, does it have an impact?”

Anonymous, National Adaptation Forum, St. Louis, MO 2015