Building Resilient Urban Coastal Environments Through Science Based Eco-engineering

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Climate Change Drives Coastal Hardening World-Wide
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Coastal population and shoreline degradation

Population living within 100 km of the coast
- None
- Less than 30%
- 30 to 70%
- More than 70%

Source: Adapted from UNEP 2002b, based on Burke and others 2001, Harrison and Pearce 2001
Coastal waters support the richest most diverse ecosystems
Coastal Infrastructure replace reefs with low diversity, non-productive urban environments...
A Concrete Problem...

- Coastlines house > 50% of the world's population\(^1\)
- 70% of coastal infrastructure are concrete based\(^2\)
- Concrete infrastructure poor substrates for biological recruitment
  - Vertical relief
  - Low complexity
  - Surface chemistry
- Commonly associated with nuisance and invasive species
Urban Nature - Restoring / Enhancing Ecosystem Services
Urban Marine Ecology

Cities do not end at the Waterline...

Coastal & Marine Infrastructure - Not Surrogates for Natural Habitats
Ecological Sustainability: Engineering Change

http://nebula.rowan.edu/

http://www.t-book.unina.it/

http://www.ecoshape.nl/files/paginas/ECOSHAPE_BwN_WEB.pdf


http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/newyork/ucr-infographic.pdf

http://nebula.rowan.edu/
Design solutions

www.barangaroo.com
Design solutions

Seattle Waterfront 2015 - in progress

- Light penetration
- Vertical Habitats
- Sloping Habitats

http://waterfrontseattle.org/
**Design solutions**

THESEUS - coastal risk assessment and mitigation funded by the European Commission. [http://www.theseusproject.eu](http://www.theseusproject.eu)

(Firth et al., 2014)
Environmentally Sensitive Technologies

Composition

Surface Texture

Macro Design

Bringing Concrete to Life

- Rich and Diverse Marine Life
- Enhanced Ecosystem Services
- Improved Structural Performance
- Low Carbon Solution
- Cost Effective
- Aesthetic
Biogenic Buildup

- **Inorganic matter:** significant differences
  - Site: Med > Red
  - Months post deployment: 6M < 12M
  - Concrete composition: M1,4,5 > M2,3, Portland

- **Organic matter:** no specific trend

Maximal values:
- Med Sea 1 kg/m²
- Red Sea 0.5 kg/m²

(Perkol-Finkel & Sella, 2014)
**Enhanced Biogenic Buildup → Bioprotection**

**Structural advantages:**
- Strength and durability
- Reduced chloride penetration
- Absorption of wave energy
- Reduce maintenance

**Biological advantages:**
- Biological niches
- Ecosystem services
- Water quality (filter feeders)
- Reduce ratio NIS/native species
- Esthetics

Concrete strengthens with time as oyster growth develops (Risinger, 2012)

Concrete Flexural strength

![Concrete Flexural strength chart](chart.png)
Polinom Case Study

Antifer Armor Defense Units (Haifa, Israel, East Mediterranean)
Polinom Case Study: Environmentally Sensitive Breakwater

Key Findings:
- Ecological Enhancement of Fish & Invertebrates: x 2 Richness & Biodiversity
- Greater Similarity to Typical Rocky Reef Communities
- Reduced Dominance of Invasive Species

Control Antiflers

ECOncrete® Antiflers
Polinom Case Study: Environmentally Sensitive Breakwater

**INVERTEBRATES**

<table>
<thead>
<tr>
<th>Species Count</th>
<th>ECOcrete</th>
<th>Portland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Invasive</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Cryptogenic</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>36</strong></td>
<td><strong>15</strong></td>
</tr>
<tr>
<td><strong>Ratio Invasive/Native</strong></td>
<td><strong>0.57</strong></td>
<td><strong>2.00</strong></td>
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</table>

**FISH 24M**

<table>
<thead>
<tr>
<th>Species Count</th>
<th>ECOcrete</th>
<th>Portland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Invasive</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>16</strong></td>
<td><strong>10</strong></td>
</tr>
<tr>
<td><strong>Ratio Invasive/Native</strong></td>
<td><strong>0.14</strong></td>
<td><strong>0.43</strong></td>
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</table>
Working Together to Build a More Resilient Region

Secretary Donovan announces the winners of Rebuild by Design.

Since June 2013, ten interdisciplinary design teams have been working with a diverse range of stakeholders throughout the Sandy-affected region to develop innovative solutions to rebuild. On June 2nd, Secretary Shaun Donovan of HUD announced the winning proposals. Read More about the final designs.

Winning Proposals

- **LIVING BREAKWATERS**
  - SCAPE / Landscape Architecture
  - Staten Island, New York

- **Hunts Point Lifelines**
  - PennDesign/CLIN
  - Bronx, New York

- **Resist, Delay, Store, Discharge: A Comprehensive Strategy for Hoboken**
  - OMA
  - Hoboken, New Jersey

- **New Meadowlands: Productive City + Regional Park**
  - MIT CAU + ZUS + URBANISTEN
  - The Meadowlands, New Jersey

- **Living with the Bay: A Comprehensive Regional Resiliency Plan for Nassau County’s South Shore**
  - Interboro Team
  - Long Island, New York

- **BIG U**

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REBUILD BY DESIGN
LIVING BREAKWATERS
STATEN ISLAND + RARITAN BAY
HUD REBUILD BY DESIGN

SCAPE / LANDSCAPE ARCHITECTURE PLLC
PARSONS BRINCKERHOFF
STEVENS INSTITUTE OF TECHNOLOGY
OCEAN AND COASTAL CONSULTANTS
SEARC CONSULTING
THE NEW YORK HARBOR SCHOOL
LOT-EK
MTWTF
PAUL GREENBERG
DESIGN FOR HABITAT

TYPICAL BREAKWATER

MODIFY FORM TO AVOID CRITICAL HABITAT
ECOLOGICAL VALUE - HIGH

REEF STREETS

SHELTER IN STRUCTURE
FEED IN THE "STREET"
CREATE NICHEs

LIVING BREAKWATERS & TOTTENVILLE SHORELINE PROTECTION

WHO ARE WE DESIGNING FOR: TARGET FUNCTIONAL GROUPS

- Hard Forming Species
- Motile Benthic Invertebrates
- Structure Oriented Reef Fish
- Structure Oriented Forage Fish
- Transient Recreational and Commercial Fishing
- Vegetation

- Blue Crab
- Atlantic Menhaden
- Atlantic Herring
- Bluefin Tuna
- Atlantic Cod
LIVING BREAKWATERS DESIGN
TYPE A BREAKWATERS

BREAKWATER PLAN

BREAKWATER REEF RIDGE
Max 20:1 Slope from -1 MHW

BREAKWATER REEF STREET
17.7' Width, Approx Length 64'7";
Aligned with toplines

Emerged:
MHW to breakwater crest

Breakwater Saddle
-2 MHW

Breakwater Crest
Elevation = 3 NAVD88

Seafloor
Elevation = 0 NAVD88

HLL to Seafloor

MLW
Elevation = -2.5 NAVD88

MHW
Elevation = +1 NAVD88

Type A Breakwater Axon and Plan
LIVING BREAKWATERS DESIGN
TYPE B BREAKWATERS

BREAKWATER REEF RIDGE
- Max. 1:2 slope from -2 MLW
- Angled 15 degrees

BREAKWATER REEF STREET
- 22 ft. wide, epicentral length, 54 ft
- Angled 15 degrees

BREAKWATER CREST
- Elevation +14 NAVD88

SEAFLOOR
- Elevation -2 MLW

Intertidal
- MLW to Intertidal

MLW
- Elevation -2.62 NAVD88

MHW
- Elevation +2.08 NAVD88

LIVING BREAKWATERS & TOTTENVILLE SHORELINE PROTECTION

Breakwater Axon at MLW

TYPE B BREAKWATER AXON AND PLAN
BREAWATER MATERIALS

LIVING BREAKWATERS & TOTTENVILLE SHORELINE PROTECTION

NAVIGATION AID

REEF RIDGES
REEF STREETS
BIO-ENHANCED CONCRETE UNIT

VALUE

INTERNAL REEF RIDGE RIP RAP STONE #2: D50= 36”, 24”, 15”
INTERNAL REEF RIDGE RIP RAP STONE #1: D50= 40”
TOE ARMOR STONE: D50= 48”
MARINE MATTRESS: D50= 12”

INTERNAL CORE STONE D50= 4”
MARINE MATTRESS HT= 12”
INTERNAL REEF RIDGE RIP RAP STONE #1 D50= 30”
REEF RIDGE CREST RIP RAP STONE #2 D50= 36”, 24”, 15”
STONE ARMOR UNIT D50= 40”
STONE TOE ARMOR UNIT D50: 48”
BIO ENHANCING CONCRETE TOE ARMOR UNIT Dimension: 48”x 48”
BIO ENHANCING CONCRETE TIDE POOLS Dimensions vary with placement
BIO-ENHANCED CONCRETE UNITS
Breakwater Cross-section: Habitat Potential

**CORE / LEESIDE**
- Higher likelihood of fine grain sediment build up
- Habitat for Hard Clams and Flounder
- Eelgrass habitat creation

**CORE / WAVESIDE**
- Habitat for predatory fish and other larger animals
- Likely to have low amounts of sedimentation

**REEF FINGER / STREET**
- High diversity of niche ranges & varied habitat
- Habitat for juvenile fish and crustaceans
- Sediment halo provides enhancement to soft-bottom
- Increased water circulation through streets

**EMERGENT**
- Provides habitat for marine mammals (seals) and birds
Importance of integrating ecological considerations into planning, design, and implementation of future hard coastal infrastructure and management schemes in light of global climate change and population growth

Ecological enhancement of coastal and marine infrastructure is a feasible, scalable and effective means for reducing the ecological footprint of coastal infrastructure, by enhancing ecosystem services and essential habitats
Building Resilient Urban Coastal Environments Through Science Based Eco-engineering

- Harnessing biological processes can increase both ecological and structural performance
- Increased resilience through biomimicry - biogenic buildup and bioprotection (longer life span, reduced maintenance)
- Need clear regulations & incentives to facilitate implementation of ecological engineering
Blue is the new Green

Need for established incentives/regulations

While “green” building standards such as the LEED system are applied globally, “blue” standards for coastal infrastructure are only now spurring (Envision™, WEDG) calling for further R&D of innovative environmentally sensitive technologies.

Waterfront Edge Design Guidelines (WEDG)

"A well-designed edge is one where waterfront access, resilience, and ecological benefits are all incorporated into an integrated design."

www.waterfrontalliance.org/WEDG
Blue is the new Green