Enhancing and Harnessing Nature for Climate Resilience in the Delaware Estuary

Danielle Kreeger
Partnership for the Delaware Estuary

SER Mid-Atlantic
March 29, 2013
Climate Change and the Delaware Estuary

Executive Summary

June 2010

http://www.delawareestuary.org/science_projects_climate_ready_products.asp
Questions

How will climate change here?
How will changes impact resources?
What are our options for making these resources more resilient?
How do we prioritize tactics?
What if we don’t take action?

(since every dollar is precious)
How Will Climate Change? as per Dr. Ray Najjar

Temperatures
More in summer than in winter
Locked in for next 30 years

°C

Graph showing temperatures over different centuries (Early Century, Mid Century, Late Century) with projected changes for B1 and A2 scenarios.
Temp. has warmed by 1°C in the past century, mainly in past 30 yrs.

http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp
How Will Climate Change?

**Temperatures**
More in summer than in winter
Locked in for next 30 years

**Precipitation**
7-9% increase
More in winter than in summer
More heavy events
State of the Estuary 2012

Precip. has increased >10%

Trend over past 30 years > 5 times trend over last 100 years

http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp
How Will Climate Change?

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Sea Level
0.6 - 1.5 m by 2100 (or more)
Local rates >> global

Salinity
How Will Climate Change?

**Temperatures**
- More in summer than in winter
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- 0.6 - 1.5 m by 2100 (or more)
- Local rates >> global

**Salinity**

**Growing Season**
Emerging Threats

Frequent Bigger Storms
Heat Stress
Saltwater and Sea Level Rise
Flooding (amid Droughts)

Hurricane Sandy
10/29/12
(lowest BP ever recorded)

Derecho
6/29/12

Over 800 preliminary thunderstorm wind reports indicated by *
Peak wind gusts 80-100mph. Millions w/o power.

Storm
10/1/10
Predictions > Vulnerability > Adaptation > Action

The Four Regions of the Delaware Estuary Watershed

*The Delaware Estuary is one of 28 National Estuary Programs. The study area for the Partnership for the Delaware Estuary covers the lower 1,827 square miles of the Delaware River Watershed, which includes a central 1,384 square miles below the head of the tide in Trenton.
Coastal Wetlands

Abundant
Diverse

Benefits:
Flood Protection
Water Quality
Fish and Wildlife
Natural Areas
Carbon Capture
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<td>Nutrient Cycling/Biogeochemical Processes</td>
<td>Maintain trophic cycles, soil building</td>
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</table>

**Wetland Benefits** (Ecosystem Services)
Valuation of New Jersey’s Natural Capital and Ecosystem Services

New Jersey Department of Environmental Protection

Slide from Bill Mates, NJDEP
The Mid-Atlantic Coastal Wetland Assessment: Integrated Monitoring of Tidal Wetlands for Water Quality and Habitat Management and Restoration Planning
Maurice River Mouth

Interior Drowning

Edge Retreat

1848

1890

2006

Courtesy, Jeff Gebert ACOE
State of the Estuary Report 2012
Percentage Loss of Emergent Tidal Marsh 1996-2006
Christina Watershed
Tidal Wetland
RAM:

30 Sites in 2011
PA Tidal Wetlands – Condition Summary

Maurice Tidal Wetlands – Condition Summary
Site-Specific Intensive Monitoring (SSIM)

- Tidal Wetlands
- Non-Tidal Wetlands
- SSIM Stations
- SSIM Stations (Pending)
- Villanova Stations
- DNREC Station
Christina Marsh SSIM Station

- PV7
- PV8
- PV9
- PV4
- PV5
- PV6
- PV1
- PV2
- PV3
- RE1
- RE2
- RE3
- RE4
- RE5
- RE6

Line Transects
Surface Elevation Table
Permanent Bio Plots
Random Bio Plots
Tidal Creek Nutrients

Nitrate + Nitrite

Ammonium

Tidal fresh

Slide credit: Dr. Tracy Quirk
2012 State of the Estuary Report

Rapid loss of acreage and degraded wetland health
Most Salt Marshes Cannot Survive When Sea Levels Rise >1 cm Per Year
Coastal Wetlands - Future

>25% Loss of tidal wetlands

- Conversion of >40,000 acres Uplands to Wetlands
- Conversion of >100,000 acres Wetlands to Water
- Loss of Benefits >> Acreage Losses
Will Tidal Wetlands Keep Pace with SLR?

- Storms
- Disturbance (herbivory, fire)
- Elevated Atmospheric CO₂

- Altered River Flows (freshwater & sediment)
- Sea-Level Rise/Tides
- Flooding Depth/Duration
- Sedimentation & Erosion
- Soil Elevation

- Salinity
- Plant Growth / Turnover
- Nutrients
- Biomass Accumulation
- Decomposition

- Nutrient Input (eutrophication)
- Subsidence (shallow & deep)
Coastal Wetland Vulnerability

**Freshwater Tidal Marshes**
- Salinity Rise
- Barriers to Landward Migration
- Tidal Range

**Salt Marshes**
- Sea Level Rise
- Storms and Wind Wave Erosion
- Barriers to Landward Migration
To promote tidal marshes, help them move:

1) **horizontally** (landward)

   and/or

2) **vertically** (to keep pace)

_Titus and Wang, 2008_  
_http://maps.risingsea.net/New_Jersey.html_
Coastal Wetlands – Adaptation Options

- Living shorelines
- Buffers
- Sediment management
- Structure Setbacks
- Strategic Retreat
- Protect river flow to offset saltwater

**Wetland Tough Choices**
- Where will they be converted to open water?
- Where can we save them?
- Where is strategic retreat the best option?
Living Shorelines

• Control Erosion
• Enhance Ecological Conditions
• Not Natural
Living Shoreline R&D

Mussel Powered Living Shorelines for Salt Marsh Erosion Control
May 2010
June 2010
September 2011 (after Hurricane Irene)
November 2012 (after Hurricane Sandy)

DelawareEstuary.org

- Practitioners Guide
- Outreach Products
- Potential Project Inventory (DE, NJ)
Living Shorelines – Many Options
Living Shorelines Planning Project

- Inventory of Types
- GIS Analysis in Areas of Interest
- Selection of Potential Project Sites
- Workshops
- Proposals for Pilots

Estuary Areas of Interest (AOI)
- NJ AOIs- Dodge Grant
- PA AOIs- Sunoco Grant
- DE AOIs- DE Coastal Program Grant
Potential Project Sites

- Marcus Hook, PA
- Gandy’s Beach, NJ
- Fortescue, NJ
- Camden, NJ
- Money Island, NJ
- Money Island, NJ
- Leipsic River, DE
- Blackbird Creek, DE
- Murderkill River, DE
- Leipsic River, DE
Beneficial Use

- Marshes need sediments
- More sediment is removed from the system by dredging than enters via rivers
- Sediment deficits > marsh drowning
- River sediments might follow main channel to sea rather than enter marshes
- Waves from ships exacerbate erosion
- Both *passive* sediment trapping (e.g. living shorelines) and *active* sediment placement can help replace lost elevation due to these factors
Potential Dredged Material Utilization Projects

J.B. Smith, ACOE 2011
Restoration for the Future = Climate Adaptation
Bivalve Shellfish (oysters, mussels, clams)

- 60 Species
- Diverse

Benefits:
- Stabilize Erosion
- Water Quality
- Fish and Wildlife
- Commercial Fishery

Slides from Dick Neves, VA Tech
Bivalves of the Delaware

Elliptio complanata

Geukensia demissa

Crassostrea virginica

11 Other Species of Freshwater Unionid Mussels

Corbicula fluminea

Rangia cuneata

Mya arenaria

Mytilus edulis

Ensis directus

Mercenaria mercenaria
Nature’s Benefits

Bivalve Shellfish are “Ecosystem Engineers”

Mussel Beds

Oyster Reefs
Ecosystem Services - Why are they Important?

1. Structure
   ▲ Habitat Complexity
   ▲ Bind Bottom
   ▲ Stabilize Shorelines
   ▲ Bottom Turbulence

2. Function
   ▼ Suspended Particulates
   ▼ Particulate N, P
   ▲ Light reaching bottom
   ▲ Sediment Enrichment
   ▲ Dissolved Nutrients
Biofiltration Potential

Start

No mussels
8 adult mussels

Slide from Dick Neves, VA Tech
Biofiltration Potential

Later

No mussels

8 adult mussels

Slide from Dick Neves, VA Tech
## Delaware River Basin

### State Conservation Status

<table>
<thead>
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<th>DE</th>
<th>NJ</th>
<th>PA</th>
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### Images

- **Patchy, Impaired**
- **Rare**
- **Extirpated**
Since 1996
One Mussel Bed in a 6 mile reach of the Brandywine River

Filters >25 metric tons dry suspended solids per year

Estimated Removal = 7.1%

Data from Kreeger, 2006

Map from The Brandywine River Conservancy
4.3 Billion *Elliptio* \((DK\ estimate)\)
2.9 Million Kilos Dry Tissue Weight \((DK)\)

\[= 9.8\ Billion\ Liters\ per\ Hour\]
Susquehanna
Delaware Bay Oysters
Crassostrea virginica
Brandywine River, PA
Geukensia demissa
Elliptio complanata
Delaware Estuary Marsh mussels
Delaware Freshwater Mussels
Kreeger
Delaware River Basin
M AR Y L A N D
D E L A W A R E
A T L A N T I C O C E A N
D E L A W A R E
Ribbed Mussels in Salt Marshes

Tidal creeks
Ribbed Mussels in Salt Marshes

208,000 per hectare on average
10.5 Billion *Geukensia*
Clearance Rate = 5.1 L h⁻¹ g⁻¹ (*DK data*)
11.7 Million Kilos Dry Tissue Weight (*DK*)

= 59.0 Billion Liters per Hour
**Oysters**

*Crassostrea virginica*

**Landings Data**

**Rutgers Data** (Powell, 2003)
Oysters on Seed Bed Reefs

2.0 Billion *Crassostrea* *(Powell, 2003 data)*
Mean size = 0.87 g dry tissue weight *(DK data)*
Clearance Rate = 6.5 L h⁻¹ g⁻¹ *(Newell et al 2005)*
= 11.2 Billion Liters per Hour
Population-level Water Processing

Water Processing per Unit Biomass

Summer Clearance Rate (L/h/g) vs. Abundance

- Millions

Population - level Water Processing

Billions of Liters per Hour per

= 80 Billion L/h

Freshwater Mussel

Marsh Mussel

Oyster

Bio-filtration
Considerations

- Total filtration capacity for one fw mussel species (~10 billion L/hr) is >250X freshwater inflow from the Delaware River and other tributaries (not total volume)

- Total filtration capacity of oysters and ribbed mussels in Delaware Bay (~70 billion L/hr) is ~8% of tidal volume per day (100% in 11.5 days)

- Water processing potential is estimated based on current abundances

- We need to estimate carrying capacity for current future bivalves and not just look at the past
Climate Impacts Vary by Species and Location

**Freshwater Mussels**: imperiled, complicated live history, cannot tolerate salinity

**Oysters**: disease and salinity

**Ribbed Mussels**: losing marsh habitat
Bivalve Projections – Oysters
Can they be maintained until they might see better conditions?

Historical data from Rutgers Haskin Shellfish Laboratory
Bivalve Projections – Ribbed Mussels
Losing Marsh Habitat

>25% Loss of Tidal Marsh by 2100
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Options for Making Shellfish More Resilient

Shellplanting for Oysters

Propagate Mussels

Monitoring & Research

Water Quality & Flow Management

Living Shorelines

Fish Passage Restoration

Riparian Restoration
What Actions Are Recommended for Shellfish?

1. Plant Shell for Oysters
2. Propagate all Bivalves and Seed New Reefs/Beds
3. Restore Riparian Buffers for Freshwater Mussels
4. Manage Water Flow to Minimize Effects of Flooding on Freshwater Mussels and Salinity on Oysters and Freshwater Tidal Bivalves
5. Maintain Water Quality for all Bivalves
Surveys

- Determine current mussel population status
- Identify sources for restoration
- Areas with Mussels: Prioritize for Conservation
- Areas without Mussels: Prioritize for Restoration
Stream Suitability Tests

 Ensure recipient streams can support mussels
 Monitor fitness of caged mussels
 Compare candidate restoration streams

Strategic restoration
Reintroduction

- Restock mussels in former range
- Reproductive adults
- Juvenile “seed”
- Track performance with electronic tags
- Inexpensive
Propagation

- Fastest and clearest way to boost stocks
- Technical challenges largely resolved
- Difficult to fund, more expensive
Tidal Delaware River - Quantitative Surveys

Make case for restoration via ecosystem services
Identify habitat needs to guide restoration designs
Site 2

- Six species
- Richness = 3.4 species m⁻²
- Density:
  - range = 0 – 80 mussels m⁻²
  - mean = 30.1 mussels m⁻²
- Co-dominants
  *Pyganodon cataracta* and *Elliptio complanata*
Planned: Mussel Habitat Engineering

- Substrate Needs ID’d
- Incorporate mussel habitat into freshwater tidal living shorelines?
- Promotes bed stability plus water quality
## Physiologically-Based Water Filtration Estimate

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<tr>
<th>Location</th>
<th>Area (m²)</th>
<th>Number</th>
<th>Tissue Weight (g)</th>
<th>Clearance Rate (L/hr g DTW⁻¹)</th>
<th>Bed Clearance (gal day⁻¹)</th>
<th>TSS Filtration (metric tons DW day⁻¹)</th>
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<td>241,151</td>
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<td>Total</td>
<td>38,375</td>
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</table>

>6 million gallons per day
Observations

- Potential filtration of **6.3 mgd** for these 4 beds is:
  - 2.5% of freshwater inflow from the Delaware River
  - 1.6% of drinking water withdrawals for Philadelphia
- More beds exist, especially in New Jersey
- More mussels live deeper
- Sites with low bed stability had few or no mussels; therefore:

*Habitat restoration to increase benthic carrying capacity for mussels could yield measureable water quality benefits (returns on investment)*
Freshwater Mussel Recovery Program

Goals Based on Ecosystem Services

Years After Planting

Not including progeny

Millions of Liters Processed

0 200 400 600 800 1,000 1,200 1,400 1,600 1,800 2,000

1 2 4 6 8 10 15 30
Desired Watershed Condition:
A diverse and robust assemblage of native bivalves living in abundance in all available tidal and non-tidal ecological niches and providing maximum possible natural benefits.
Restoration for the Future = Climate Adaptation

Headwaters to Sea
1. Non-tidal
2. Intertidal
3. Subtidal
Recognize Problem

Assess Vulnerability & Prioritize Solutions

Solutions

2010

Climate Change and the Delaware Estuary
Executive Summary

2011

Weathering Change
Working with Nature to Protect Communities & Clean Waters

2012

Technical Report for the Delaware Estuary & Basin

2013

Translate & Engage

Action Plans

Track Change
Climate Change + Other Changes

- Marcellus Shale
- Dredging
- Withdrawals
- Land Use Change
- Development
- Emerging Pollutants
- Ecological Flows
- Spills

Added Complexity

11/27/2004
Take Home Messages

• Not all changes to natural resources will be damaging, but there will be many *more losers than winners*

• **Need a Paradigm Shift:** Plan and “restore” for the future rather than the past, dynamic rather than static conditions

• Adaptation requires *investment* to protect lives, livelihoods

• Proactive investment today will *save money* in the long term due to compounding of ecosystem services

• Adaptation actions are underway but constrained by funding
Despite Tough Times,…

High Potential for Beneficial Outcomes from Natural Infrastructure Investment

Investment in Delaware Valley Lags

Fig. 8.8. Comparison of US EPA federal spending in FY2010 on environmental management and restoration in nine major water bodies in the United States (from Strackbein and Dawson 2011)

http://delawareestuary.org/science_programs_state_of_the_estuary_treb.asp
www.DelawareEstuary.org