Natural capital and ecosystem service valuation as tools to guide restoration and climate adaptation in the Delaware Estuary

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Science Director
Partnership for the Delaware Estuary
To be discussed

The Delaware Estuary

brief orientation

Making our efforts count:

why are NCV & ESV tools needed?

Example: Regional Restoration

goals & approach

restoration matrices

NCV & ESV framework

case studies

Other Applications

climate adaptation

ecological inventories

on the ground projects

Caveat – An Ecological Manhattan Project?
The Watershed

13,611 Square Miles

Delaware River Basin

NEW YORK

PENNSYLVANIA

NEW JERSEY

MARYLAND

ATLANTIC OCEAN

Delaware Bay

Chesapeake Bay
History as a “Working River”

1762 map showing Philadelphia on the Delaware River

Slides adapted from Jonathan Sharp
Also a “Living River”
Delaware Estuary
Making our efforts count

why are NCV & ESV tools needed?

- Large and complex system
- Limited resources
- Broad CCMP
- Urgency

To have Highest Impact, must avoid redundancy, invest strategically

ESV is broadly applicable as an organizing framework for prioritization
Fill Vital Niches: Technical Committees

- Monitoring Advisory Committee
- Toxics Advisory Committee
- Fish & Wildlife Cooperative
- Atlantic States Marine Fisheries Commission
- Atlantic Coast Fish Habitat Partnership*
- Shellfish Stock Assessment Workgroup
- STAC
- DE Estuary Wetland Work Group
- Climate Work Group
- National Water Quality Monitoring Pilot
- Fish Consumption Task Force
- Regional Restoration Workgroup
- Benthic Inventory Workgroup

*Prospective
Working Together

1. Conferences & Workshops
   - Delaware Estuary Science Conference (every 2 years)
Prioritization

1. Conferences & Workshops

2. Science and Technical Committees

3. Watershed–Level Initiatives
   - Science Priority Setting (White Paper)

### Top Ten Technical Needs for the Delaware Estuary

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><strong>Contaminants</strong> (forms, sources, fates &amp; effects for different classes)</td>
</tr>
<tr>
<td>2</td>
<td><strong>Tidal Wetlands</strong> (status, trends and relative importance of different types)</td>
</tr>
<tr>
<td>3</td>
<td><strong>Ecologically Significant Species &amp; Critical Habitats</strong> (benthos, reefs, horseshoe crabs)</td>
</tr>
<tr>
<td>4</td>
<td><strong>Ecological Flows</strong> (effects of base and episodic flows on salt balance &amp; biota)</td>
</tr>
<tr>
<td>5</td>
<td><strong>Physical-Chemical-Biological Linkages</strong> (e.g., sediment budget effects on toxics &amp; biota)</td>
</tr>
<tr>
<td>6</td>
<td><strong>Food Web Dynamics</strong> (key trophic connections among functional dominant biota)</td>
</tr>
<tr>
<td>7</td>
<td><strong>Nutrients</strong> (forms, concentrations and relative balance of macro- and micronutrients)</td>
</tr>
<tr>
<td>8</td>
<td><strong>Ecosystem Functions</strong> (assessment and economic valuation of ecosystem services)</td>
</tr>
<tr>
<td>9</td>
<td><strong>Habitat Restoration and Enhancement</strong> (science &amp; policy)</td>
</tr>
</tbody>
</table>
Prioritization

1. Conferences & Workshops

2. Science and Technical Committees

3. Watershed-Level Initiatives
   - Science Priority Setting (White Paper)
   - Conceptual Framework for System Traits
Prioritization

1. Conferences & Workshops
2. Science and Technical Committees
3. Watershed–Level Initiatives
   - Science Priority Setting (White Paper)
   - Conceptual Framework
   - Monitoring (e.g. NWQMN Pilot)

The Delaware Estuary
Watershed to Ocean
Observing System
(DEWOOS)
Prioritization

1. Conferences & Workshops

2. Science and Technical Committees

3. Watershed–Level Initiatives
   - Science Priority Setting
   - Conceptual Framework
   - Monitoring
   - State of the Estuary
   - Restoration

A Blueprint for a Regional Restoration Initiative in the Delaware Estuary

A Publication of the Partnership for the Delaware Estuary
A National Estuary Program
www.DelawareEstuary.org

February 2008
Restoration

Restore, conserve or otherwise enhance ecosystem structure and function.
...But Smartly

Regional Restoration Initiative

Includes:
• Protection
• Conservation
• Enhancement
• Restoration
Goals:

- Characterize the most ecologically significant natural resources in different watershed regions
- Assess ecological goods and services flowing from these resources
- Use a natural capital valuation approach to identify highest value activities that maximize goods and services from these resources
- Identify, inventory and rank specific projects that conserve, enhance or restore these resources
- Identify high value activities for which we still need projects and work to fill gaps

Principles:

- science-based
- proactive
- timely, responsive
- comprehensive
- multi-jurisdictional

Project Registry
Table 20. A conceptual matrix framework summarizing the principal ecosystem and habitat components of the Delaware Estuary. The cell numbering is arbitrary and meant to give a unique reference point to every cell.

**Number of Cells = 141**

```
<table>
<thead>
<tr>
<th>Aquatic</th>
<th>Nontidal Watershed</th>
<th>Terrestrial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delaware River (above River Mile 133)</td>
<td>Tidal Buffers*</td>
</tr>
<tr>
<td></td>
<td>Other Rivers and Streams (below River Mile 133)</td>
<td>Riparian Buffers**</td>
</tr>
<tr>
<td></td>
<td>Schuylkill River &amp; Its Tributaries</td>
<td>Freshwater</td>
</tr>
<tr>
<td></td>
<td>Christina River &amp; Its Tributaries</td>
<td>(fresh)</td>
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<tr>
<td></td>
<td>Other Tributaries</td>
<td>(brackish)</td>
</tr>
<tr>
<td></td>
<td>Main Channel</td>
<td></td>
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</table>

The Delaware Estuary is a unique and valuable asset to the nation, providing a wide array of ecological services such as wildlife habitat, recreational opportunities, and flood control. However, changes in land use and climate have led to a loss of some of these habitats, and efforts are being made to restore and protect them. The Delaware Estuary is a valuable resource that supports the livelihoods of many people and is an important area for the conservation of biodiversity.
Basic Restoration Matrix

LE-1: Restoration Opportunities Layer

Natural Resources

Restoration Opportunities

Habitats (examples)
- Terrestrial
- Wetland
- Aquatic
  - Forest
  - Meadow
  - Riparian
  - Non-tidal Forested
  - Tidal FW Marsh
  - Tidal Saltmarsh
  - Streambed
  - Mud Flat
  - Hard Bottom
  - Open Water

Living Resources (examples only)
- Birds
- Fish
- Shellfish
- Other

- Shorebirds
- Songbirds
- Raptors
- Diadromous
- Resident
- Oysters
- FW Mussels
- HSC
- Blue Crabs
- Mammals
- Heips
- Macroinsects

Water Quality
Water Quantity/Flow
Land Acquisition
Legal/ESA
Habitat Creation
Augmentation/Improvement/Planning
Function Enhanced
Restored Hydrology
Fish Passage
Stocking
Mgt/Quotas

Each circle will receive a unique cell code for use in the project directory & database. The information shown contains examples only, to be refined in later stages of the RRI.
### Value-Added Restoration Matrix (VARM)

#### Watershed Sub-Region: Lower Estuary 1 (LE1)

<table>
<thead>
<tr>
<th>Conservation/Enhancement/Restoration Activity</th>
<th>Scale</th>
<th>Key</th>
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<tbody>
<tr>
<td>Protect</td>
<td></td>
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<tr>
<td>Water Quality</td>
<td></td>
<td></td>
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<tr>
<td>Water Quantity/Flow</td>
<td></td>
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<tr>
<td>Land Acquisition</td>
<td></td>
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<tr>
<td>Legal</td>
<td></td>
<td></td>
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<tr>
<td>Habitat Restoration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Capital Values</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Considerations*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imporance Score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat Enhancement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(incl/ condition improvement of same acreage)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat Creation</td>
<td></td>
<td></td>
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</tbody>
</table>

#### Habitats (examples)

<table>
<thead>
<tr>
<th>Terrestrial</th>
<th>Wetland</th>
<th>Aquatic</th>
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</thead>
<tbody>
<tr>
<td>hab1</td>
<td>hab2</td>
<td>hab3</td>
</tr>
<tr>
<td>hab4</td>
<td>hab5</td>
<td>hab6</td>
</tr>
<tr>
<td>hab7</td>
<td>hab8</td>
<td>hab9</td>
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<td>hab10</td>
<td>hab11</td>
<td>hab12</td>
</tr>
<tr>
<td>hab13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Notes:
- Cells are shaded grey if not appropriate for subregion or other factors.
- Everything in this spreadsheet is a prototype example to provide framework for considering structure.

#### Key:
- Forest
- Meadow
- Forested Wetland
- Nontidal Herbaceous Wetland
- Tidal Freshwater Wetland
- Tidal Brackish and Salt Marsh
- Other Wetlands
- Streambed
- Shoreline
- Oyster Reef
- Open Water

#### Score:
- 0-10: lo
- 11-20: med
- 21-30: hi

- Cell Code: 2a
- Projects Exist?: GAP, high need
- Ecoservice Value: 0-10
- Extractive Value (Trust): 0-10
- Functional Dominance: 0-5
- Critical Imperiled: 0-5
- Signature Type: 0-3
- Lack of Opportunity: 0-3
- Other Considerations**: 0-3
- Imporance Score: na, 1-7, 21-25

**NOTES:**
- Extra Credit for RUF, Buffer value, single large over several small.
- Have way to flag high need areas with no projects.

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**Conecting**

**continguousness, special circumstances**
# Value-Added Restoration Matrix

<table>
<thead>
<tr>
<th>Restoration Activity</th>
<th>Scale</th>
<th>Key</th>
<th>Terrestrial</th>
<th>Wetland</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>hab1</td>
<td>hab2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Forest</td>
<td>Meadow</td>
</tr>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Habitat Restoration</th>
<th>Natural Capital Values</th>
<th>Cell Code</th>
<th>Projects Exist?</th>
<th>Ecoservice Value</th>
<th>Extractive Value (Trust)</th>
<th>Functional Dominance</th>
<th>Critical Imperiled</th>
<th>Signature Type</th>
<th>Lack of Opportunity</th>
<th>Other Considerations**</th>
<th>Importance Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

- High need

---

Scale: 1 - 2 (low to high)

Key:
- lo: low
- med: medium
- hi: high

Importance Score:
- hab1: 7
- hab2: 21
- hab3: 25

GAP
Regional Restoration Initiative

ID Key Resources

Ecological Valuation

N.C. Outcomes from Activities

Project Registry & Gaps

Case Studies

Tidal Marshes

Bivalve Shellfish

Headwater Streams

Urban Waterfront
Oysters and Other Bivalve Shellfish

From Rutgers HSRL
Others?

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
Oyster Landing Data
Loss of Biodiversity & Population Abundance
<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Scientific Name</th>
<th>DE</th>
<th>NJ</th>
<th>PA</th>
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<td>ALASMIDONTA HETERODON</td>
<td>DWARF WEDGEMUSSEL</td>
<td>Endangered</td>
<td>Endangered</td>
<td>Critically Imperiled</td>
</tr>
<tr>
<td>ALASMIDONTA UNDULATA</td>
<td>TRIANGLE FLOATER</td>
<td>Extirpated ?</td>
<td>Threatened</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>ALASMIDONTA VARICOSA</td>
<td>BROOK FLOATER</td>
<td>Endangered</td>
<td>Endangered</td>
<td>Imperiled</td>
</tr>
<tr>
<td>ANODONTA IMPLICATA</td>
<td>ALEWIFE FLOATER</td>
<td>Extremely Rare</td>
<td>no data</td>
<td>Extirpated ?</td>
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<tr>
<td>ELLIPTIO COMPLANATA</td>
<td>EASTERN ELLIPTIO</td>
<td>common</td>
<td>common</td>
<td>Secure</td>
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<tr>
<td>LAMPSILIS CARIOSA</td>
<td>YELLOW LAMPMUSSEL</td>
<td>Endangered</td>
<td>Threatened</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>LAMPSILIS RADIATA</td>
<td>EASTERN LAMPMUSSEL</td>
<td>Endangered</td>
<td>Threatened</td>
<td>Imperiled</td>
</tr>
<tr>
<td>LASMIGONA SUBVIRIDIS</td>
<td>GREEN FLOATER</td>
<td>no data</td>
<td>Endangered</td>
<td>Imperiled</td>
</tr>
<tr>
<td>LEPTODEA OCHRACEA</td>
<td>TIDEWATER MUCKET</td>
<td>Endangered</td>
<td>Threatened</td>
<td>Extirpated ?</td>
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<tr>
<td>LIGUMIA NASUTA</td>
<td>EASTERN PONDMUSSEL</td>
<td>Endangered</td>
<td>Threatened</td>
<td>Critically Imperiled</td>
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<tr>
<td>MARGARITIFERA MARGARITIFERA</td>
<td>EASTERN PEARLSHELL</td>
<td>no data</td>
<td>no data</td>
<td>Imperiled</td>
</tr>
<tr>
<td>PYGANODON CATARACTA</td>
<td>EASTERN FLOATER</td>
<td>no data</td>
<td>no data</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>STROPHITUS UNDULATUS</td>
<td>SQUAWFOOT</td>
<td>Extremely Rare</td>
<td>Species of Concern</td>
<td>Apparently Secure</td>
</tr>
</tbody>
</table>
Conservation Status of United States Taxa

Source: The Nature Conservancy, 1997
Ecosystem Services

1. Structure
   - Habitat Complexity
   - Binding of Bottom
   - Bottom Turbulence

2. Function
   - Suspended Particulates
   - Particulate N, P
   - Light
   - Sediment Enrichment
   - Recycle Dissolved Nutrients
Clean Water

Start

- No mussels
- 8 adult mussels

Slide from Catherine Gatenby, USFWS
Later

Biofiltration Potential

No mussels  8 adult mussels

Slide from Catherine Gatenby, USFWS
Brandywine River, PA

Delaware Estuary Marshes

Delaware Bay Oysters

Elliptio complanata

Geukensia demissa

Crassostrea virginica

Susquehanna

Delaware River Basin
Estimate of Water Processing Potential

4.3 Billion *Elliptio*

= 2.9 Million Kilos Dry Tissue Weight

= 9.8 Billion Liters per Hour
Salt Marshes

Geukensia demissa

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

= 59.0 Billion Liters per Hour
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

What do we get back if we rebuild lost populations?

If we have to choose, which activities yield greatest outcomes?

Space and time considerations are important

Elliptio complanata
Geukensia demissa
Crassostrea virginica
Oyster Disease and Salinity

From DRBC

Oyster Disease

From Rutgers HSRL

Salt Line Location

www.livingclassrooms.org/lbo/dermo/oyster2.jpg

Oyster Management

Can they maintain (or be maintained) until they might see more optimal conditions?

Longer Growing Season

2 Recruitment Events

Intertidal Niche Expansion?

Point of No Return

Today 2030 2060

No Help
With Help

Oyster Spat Mean Oyster Mean Spat

Year

Number per Bushel

1758
Oyster Reef Revitalization
# Importance of Bivalves to the Delaware Estuary Watershed

<table>
<thead>
<tr>
<th>Natural Capital Value</th>
<th>Commercial</th>
<th>Dockside Product + Secondary Value</th>
<th>Oysters: <em>Crassostrea virginica</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Capital Value</td>
<td>Commercial</td>
<td>Dockside Product + Secondary Value</td>
<td>Oysters</td>
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<tr>
<td></td>
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<td><img src="#" alt="Checkmarks" /></td>
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</tr>
<tr>
<td>Ecosystem Services</td>
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<td>Structural Habitat</td>
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<td>biological hot spots</td>
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<tr>
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<td>Biofiltration</td>
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<td>top-down grazing, TSS removal, light)</td>
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<tr>
<td>Biogeochemistry</td>
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<tr>
<td>enrichment/turnover, benthic production</td>
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</tr>
<tr>
<td>Shoreline Protection</td>
<td><img src="#" alt="Checkmarks" /></td>
<td><img src="#" alt="Checkmarks" /></td>
<td></td>
</tr>
<tr>
<td>- nearshore reefs</td>
<td><img src="#" alt="Checkmarks" /></td>
<td><img src="#" alt="Checkmarks" /></td>
<td></td>
</tr>
<tr>
<td>Shoreline Stabilization</td>
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<tr>
<td>- living edges</td>
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## Importance of Shellfish to the Delaware Estuary Watershed

<table>
<thead>
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<th>Commercial</th>
<th>Ecosystem Services</th>
<th>Cultural-Historical</th>
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<tbody>
<tr>
<td></td>
<td>Dockside Product + Secondary Value</td>
<td>Structural Habitat</td>
<td>Waterman Lifestyle, Ecotourism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>biological hot spots, bottom-binding</td>
<td>Native American - dietary staple</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Prey</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biofiltration</td>
<td></td>
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<td></td>
<td>top-down grazing, TSS removal, light)</td>
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<td>Biogeochemistry</td>
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<td>enrichment/turnover, benthic production</td>
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<tr>
<td></td>
<td></td>
<td>Shoreline Protection - nearshore reefs</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Shoreline Stabilization - living edges</td>
<td></td>
</tr>
</tbody>
</table>

### Oysters (Crassostrea virginica)

- **Dockside Product + Secondary Value**: Yes
- **Structural Habitat**: Yes
- **Prey**: No
- **Biofiltration**: Yes
- **Biogeochemistry**: Yes
- **Shoreline Protection - nearshore reefs**: Yes
- **Shoreline Stabilization - living edges**: Yes
- **Waterman Lifestyle, Ecotourism**: Yes
- **Native American - dietary staple**: Yes
### Importance of Shellfish to the Delaware Estuary Watershed

<table>
<thead>
<tr>
<th>Natural Capital Value</th>
<th>Commercial</th>
<th>Dockside Product + Secondary Value</th>
<th>Oysters</th>
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<tr>
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# Importance of Shellfish to the Delaware Estuary Watershed

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<th>Natural Capital Value</th>
<th>Commercial</th>
<th>Dockside Product + Secondary Value</th>
<th>Oysters (Crassostrea virginica)</th>
<th>Marsh Mussels (Geukensia demissa)</th>
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*FW* mussels are most critically impaired biota.

---

**Note:** The table indicates the presence or absence of specific ecosystem services provided by oysters, marsh mussels, and FW mussels in the Delaware Estuary Watershed. Symbols represent the presence of services: ![ ]( ) indicates presence, ![ ]( ) indicates absence.
ESV Applications

Watershed-Level Activities
- Science Priority Setting
- Conceptual Framework
- Monitoring
- State of the Estuary
- Regional Restoration Initiative

Project Registry

LE-1: Restoration Opportunities Layer

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<tr>
<th>Natural Resources</th>
<th>Restoration Opportunities</th>
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| Le-1 Restoration Opportunities Layer | No Opportunity | Project with Opportunity | Opportunity but No Project |

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<thead>
<tr>
<th>LE-1 Restoration Opportunities Layer</th>
<th>Habitat (examples)</th>
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<td>Non-estuarine</td>
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<td>Tidal</td>
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Applications

Watershed-Level Activities
• Science Priority Setting (White Paper)
• Conceptual Framework
• Monitoring
• State of the Estuary
• Regional Restoration Initiative

Ecological Inventories
– Natural Vegetation Classification System
– Delaware Estuary Benthic Inventory
Applications

Watershed–Level Activities
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Science & Restoration Projects
• Freshwater Mussel Recovery Program
Propagation and Reintroduction

Hatchery
Propagation and Reintroduction

Propagated Juveniles

Photos, R. Neves, VA Tech
Freshwater Mussel Recovery Program

Goals are Being Set Based on Ecosystem Services

- Not including progeny

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<th>Years After Planting</th>
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Ecological Inventories
- Natural Vegetation Classification System
- Delaware Estuary Benthic Inventory

Science & Restoration Projects
- Freshwater Mussel Recovery Program
- Delaware Estuary Living Shorelines
Reduce wave energy
Trap silt
Reduce bank erosion
Protect salt marsh
Living Shorelines
Applications

Watershed–Level Activities
• Science Priority Setting (White Paper)
• Conceptual Framework
• Monitoring
• State of the Estuary
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Ecological Inventories
• Natural Vegetation Classification System
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Science & Restoration Projects
• Freshwater Mussel Recovery Program
• Living Shorelines

Climate Adaptation Planning
• Ready Estuaries Pilot
PDE Climate Ready Approach

Vulnerability Assessment
Natural Capital Valuation
Management & Adaptation Options

Drinking Water
Tidal Wetlands
Bivalve Shellfish

Adaptive Adaptation

Case Study Subgroups

Climate Workgroup

Vulnerability Assessment → Natural Capital Valuation

Management and Policy
Adaptation Plan

Outreach, Education, Messaging

Prioritization
Ecosystem Services in PDE Science

Regional Restoration Initiative

Climate Adaptation

Targeted On-the-Ground Projects

ESV
Summary

Ecosystem Services Valuation represents a powerful tool to ensure that functional processes are studied, monitored and used to prioritize CCMP activities in the same way as structural aspects (e.g., acres).

ESV can provide uniform units/currency for quantifying and comparing natural resource benefits across time and space.

ESV, together with other natural capital values, can help put natural resources on a more even footing with developed assets.

Caveat

ESV may be an Ecological Manhattan Project. Care must be taken not to excuse the loss of low condition, lower value resources that might otherwise be protected or restored.