Monitoring and Assessment of Coastal Wetlands in Representative Estuaries of the Mid-Atlantic

Danielle Kreeger, PhD.
Martha Maxwell Doyle
Tidal Wetlands

A Hallmark of the Delaware Estuary

Near Contiguous Band
Diverse: *Freshwater Tidal Marshes*  
*Brackish Marshes*  
*Salt Marshes*

Nature’s Benefits
- Flood Protection
- Fish and Wildlife
- Natural Areas
- Carbon Sequestration
- Water Quality
Barnegat Bay

mainly salt marshes

High Salt Marsh
Low Salt Marsh
Coastal wetland monitoring and assessment: Why it is important for your state or organization?

Coastal wetlands are:

- a hallmark feature of the Delaware and Barnegat Estuaries
- critical for sustaining fish and wildlife, preserving water quality, and protecting against flooding (especially post-Sandy!)
- one of the most degraded habitats due to past land use practices and degradation
- increasingly threatened by increasing sea level, salinity, storms

Tracking and understanding the health and acreage of coastal wetlands is a top priority for the National Estuary Programs and coastal managers.
We were seeing declines but significant data gaps

**Acreage?**
no recent, consistent, high resolution data across the estuary

**Condition?**
no data
Response: The Mid-Atlantic Coastal Wetland Assessment:
Integrated Monitoring of Tidal Wetlands for Water Quality/Habitat Management and Climate/Restoration Planning
Response: Wetland Case Study in Climate Planning

Climate Change and the Delaware Estuary

Executive Summary

A Publication of the Partnership for the Delaware Estuary
A National Estuary Program

June 2010

Climate Predictions
Resources Vulnerability
Predicted Resource Changes
Adaptation Options
Adaptation Strategy

http://delawareestuary.org/climate-change
Tidal Wetland Projections

by 2100:
• loss of 50,236 acres of uplands and non-tidal wetlands
• gain of 106,529 acres of open water and tidal flats
• 26% net loss of 42,558 acres of tidal wetlands
• net loss of >60,000 metric tons/year of primary production
Emerging Threats

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

Derecho
6/29/12

Hurricane
8/30/11

Hurricane Sandy
10/29/12
(lowest BP ever recorded)
2012 State of the Estuary Report

Rapid loss of acreage and degraded wetland health

Losing an acre per day (1996-2006)

Most tidal wetlands are moderately or severely stressed

Future scenarios are worrisome

http://delawareestuary.org/technical-report-delaware-estuary-basin
Example Questions from Managers

Are wetlands keeping pace with sea level rise?

How are wetlands responding to stressors, such as pollution?

Are wetlands as healthy and productive as they can be?

Where will wetlands likely survive in the future?

What actions or tactics will work best to sustain the greatest functional wetland acreage in the future?
What are the unique aspects of coastal wetland monitoring?

Coastal wetlands are:

- Situated at land-sea interface, filled and confined by development
  - near head of tide where early settlers established ports
  - 50% of US population now lives in coastal zone

- Affected by system manipulation and changes
  - altered sediment budgets
  - increased nutrients, altered stoichiometry
  - diking and tidal restrictions for farming and waterfowl
  - ditching for mosquito control
  - insufficient enforcement of wetland protections

- Increasingly vulnerable to climate changes
  - sea level rise, tidal range
  - salinity rise
  - storm intensity and frequency
Many Tidal Marshes Cannot Survive When Sea Levels Rise >1 cm Per Year
Will Tidal Wetlands Keep Pace with SLR?

Diagram showing the factors affecting tidal wetlands:

- Sediment Supply
- Energy, Erosion
- Elevation
- Capitol
- Sea Level
- Nutrients
- Primary Productivity
Response: The Mid-Atlantic Coastal Wetland Assessment: Integrated Monitoring of Tidal Wetlands for Water Quality/Habitat Management and Climate/Restoration Planning
## MACWA Design:

### Tier 1

**Remotely sensed data on acreage, some condition**

- Wetland Extent
- Wetland Buffer Condition
- Wetland Contiguosity
- Historic Change
- Wetland Morphology
- Plant Community Integrity
- Shoreline Condition
- Anthropogenic Alterations

### Tier 2

**On-the-ground data on condition, stressors**

<table>
<thead>
<tr>
<th>Design Component</th>
<th>Example Indicators</th>
<th>Example Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetland Extent</td>
<td>wetland acreage (hectares) per subpopulation and NWI attribute type</td>
<td></td>
</tr>
<tr>
<td>Wetland Buffer Condition</td>
<td>adjacent land use (e.g., % natural vs. developed in 100m band)</td>
<td></td>
</tr>
<tr>
<td>Wetland Contiguosity</td>
<td>connectivity (inter/intra); patch sizes and fragmentation</td>
<td></td>
</tr>
<tr>
<td>Historic Change</td>
<td>loss or gain in acreage for different subpopulations &amp; attributes</td>
<td></td>
</tr>
<tr>
<td>Wetland Morphology</td>
<td>percent open water; edge to area ratios</td>
<td></td>
</tr>
<tr>
<td>Plant Community Integrity</td>
<td>vegetation community/type (e.g., <em>Phragmites</em> vs. <em>Spartina</em>, high marsh vs. low marsh, bare soil, open water)</td>
<td></td>
</tr>
<tr>
<td>Shoreline Condition</td>
<td>edge status (e.g., hardening, erosion)</td>
<td></td>
</tr>
<tr>
<td>Anthropogenic Alterations</td>
<td>channel straightening, ditching, tide gates, groundwater withdrawals</td>
<td></td>
</tr>
<tr>
<td>Plant Community Integrity</td>
<td>vegetation community type (description of species assemblage)</td>
<td></td>
</tr>
<tr>
<td>Primary Production</td>
<td>invasive species (percent cover of <em>Phragmites</em>)</td>
<td></td>
</tr>
<tr>
<td>Wetland Morphology</td>
<td>species list (floristic quality assessment index)</td>
<td></td>
</tr>
<tr>
<td>Invertebrate Community Integrity (sessile species)</td>
<td>vegetation structure board</td>
<td></td>
</tr>
<tr>
<td>Wildlife Habitat Integrity (mobile species)</td>
<td>below and above ground biomass</td>
<td></td>
</tr>
<tr>
<td>Hydrological and Shoreline Integrity</td>
<td>percent open water; edge to area ratios</td>
<td></td>
</tr>
<tr>
<td>Substrate Integrity</td>
<td>presence and relative abundance of functional dominant and bioindicator species</td>
<td></td>
</tr>
<tr>
<td>Elevation and Sediment Budget</td>
<td>evidence of fish and mobile shellfish; avian IBI</td>
<td></td>
</tr>
<tr>
<td>Water Quality</td>
<td>evidence of hydrological alterations or impairment (e.g. depressions, dikes, rip rap)</td>
<td></td>
</tr>
<tr>
<td>Biogeochemical Cycling</td>
<td>percent organic matter and sediment description</td>
<td></td>
</tr>
<tr>
<td>Carbon Storage</td>
<td>relative elevation, evidence of accretion or subsidence, wrack accumulation</td>
<td></td>
</tr>
<tr>
<td>Elevation and Sediment Budget</td>
<td>fixed monitoring stations in second order tidal creek (temperature, specific conductivity, pH, turbidity, DO, water level)</td>
<td></td>
</tr>
<tr>
<td>Plant Community Integrity</td>
<td>grab samples in tidal creek for dissolved nutrients and seston quantity &amp; quality, ebb &amp; flood tides (TSS, chlorophyll, proximate biochemistry and stoichiometry)</td>
<td></td>
</tr>
<tr>
<td>Anthropogenic Alterations</td>
<td>sediment porewater nutrient concentrations, forms, stoichiometric ratios; denitrification rates</td>
<td></td>
</tr>
<tr>
<td>Plant Community Integrity</td>
<td>carbon sequestration in belowground biomass; litter accumulation</td>
<td></td>
</tr>
<tr>
<td>Functional Dominant Fauna Integrity</td>
<td>Sediment Elevation Table (SET), elevation relative to sea level (in addition to Tier 2 metrics)</td>
<td></td>
</tr>
</tbody>
</table>

### Tiers 3 and 4

**Intensive studies and monitoring data on condition, function**

- Water Quality
- Biogeochemical Cycling
- Carbon Storage
- Plant Community Integrity
- Functional Dominant Fauna Integrity
**Tier 2**

**Mid-Atlantic Tidal Rapid Assessment Method (Mid-TRAM v.3)**

- Buffer Integrity
- Hydrologic Integrity
- Habitat/Bio Integrity
- Shoreline Integrity

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Metric</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buffer/Landscape</td>
<td>Percent of AA Perimeter with 5m-Buffer</td>
<td>Percent of AA perimeter that has at least 5m of natural or semi-natural land cover</td>
</tr>
<tr>
<td>Buffer/Landscape</td>
<td>Average Buffer Width</td>
<td>The average buffer width surrounding the AA that is in natural or semi-natural condition</td>
</tr>
<tr>
<td>Buffer/Landscape</td>
<td>Surrounding Development</td>
<td>Percent of developed land within 250m from the edge of the AA</td>
</tr>
<tr>
<td>Buffer/Landscape</td>
<td>250m Landscape Condition</td>
<td>Landscape condition within 250m surrounding the AA based on vegetation, disturbance to substrate and extent of human visitation</td>
</tr>
<tr>
<td>Buffer/Landscape</td>
<td>Barriers to Landward Migration</td>
<td>Percent of landward perimeter of wetland within 250m that has physical barriers preventing wetland migration inland</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Ditching &amp; Draining</td>
<td>The presence of ditches in the AA</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Fill &amp; Fragmentation</td>
<td>The presence of fill or wetland fragmentation from anthropogenic sources in the AA</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Wetland Diking / Tidal Restriction</td>
<td>The presence of dikes or other tidal flow restrictions</td>
</tr>
<tr>
<td>Hydrology</td>
<td>Point Sources</td>
<td>The presence of localized sources of pollution</td>
</tr>
<tr>
<td>Habitat</td>
<td>Bearing Capacity</td>
<td>Soil resistance using a slide hammer</td>
</tr>
<tr>
<td>Habitat</td>
<td>Vegetative Obstruction</td>
<td>Visual obstruction by vegetation &lt;1m measured with a cover board.</td>
</tr>
<tr>
<td>Habitat</td>
<td>Number of Plant Layers</td>
<td>Number of plant layers in the AA based on plant height</td>
</tr>
<tr>
<td>Habitat</td>
<td>Percent Co-dominant Invasive Species</td>
<td>Percent of co-dominant invasive species in the AA</td>
</tr>
<tr>
<td>Habitat</td>
<td>Percent Invasive</td>
<td>Percent cover of invasive species in the AA</td>
</tr>
</tbody>
</table>
Step 1. GIS Analysis

e.g. Barriers to Landward Migration, Development

Open water is not counted

~30% is road or development
Step 2. Field Assessment

Figure 3: Location of Subplots in a circular assessment area.
Bearing Capacity  Percent Invasive
Shoreline Integrity

Shoreline Alterations

Shoreline Erosion

Configuration of the assessment area (red circle) buffer area (yellow circle,) and shoreline transects (green lines) for each random wetland sample point.
PA Tidal Wetlands – Condition Summary

Maurice Tidal Wetlands – Condition Summary
Overall RAM Scores Across Watersheds

206 Sites
Most interesting RAM results are in the weeds

Watershed data shows the main local issues

Comparative analyses among watersheds highlight variations

Main attribute means in Maurice

Lower bearing capacity = firmer substrate
Shoreline Condition

Compared among representative watersheds

>100 Sites

Lower scores mainly due to higher erosion

Dozens of other metrics
Tier 4 - Site-Specific Intensive Monitoring (SSIM)

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

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>State</th>
<th>Estuary</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tinicum NWR</td>
<td>PA</td>
<td>Delaware</td>
<td>Oligohaline, freshwater tidal marsh</td>
</tr>
<tr>
<td>2</td>
<td>Christina River</td>
<td>DE</td>
<td>Delaware</td>
<td>Mesohaline, brackish tidal marsh</td>
</tr>
<tr>
<td>3</td>
<td>Crosswicks Cr</td>
<td>NJ</td>
<td>Delaware</td>
<td>Oligohaline, freshwater tidal marsh</td>
</tr>
<tr>
<td>4</td>
<td>Dennis Creek</td>
<td>NJ</td>
<td>Delaware</td>
<td>Euryhaline, <em>Spartina</em> salt marsh</td>
</tr>
<tr>
<td>5</td>
<td>Maurice River</td>
<td>NJ</td>
<td>Delaware</td>
<td>Euryhaline, <em>Spartina</em> salt marsh</td>
</tr>
<tr>
<td>6</td>
<td>Dividing Creek</td>
<td>NJ</td>
<td>Delaware</td>
<td>Mesohaline, brackish tidal marsh</td>
</tr>
<tr>
<td>7</td>
<td>Reedy</td>
<td>NJ</td>
<td>Barnegat</td>
<td>Euryhaline, <em>Spartina</em> salt marsh</td>
</tr>
<tr>
<td>8</td>
<td>Island Beach</td>
<td>NJ</td>
<td>Barnegat</td>
<td>Euryhaline, <em>Spartina</em> salt marsh</td>
</tr>
<tr>
<td>9</td>
<td>West Creek</td>
<td>NJ</td>
<td>Barnegat</td>
<td>Euryhaline, <em>Spartina</em> salt marsh</td>
</tr>
<tr>
<td>Proposed</td>
<td>Broadkill River</td>
<td>DE</td>
<td>Delaware</td>
<td>Euryhaline, <em>Spartina</em> salt marsh</td>
</tr>
</tbody>
</table>
**Methods**

- **Elevation and Accretion**
- **Plant Biomass**
- **Algal Biomass**
- **Soil and Water Chemistry**
- **Plant Community**

*Slide credit: Dr. Tracy Quirk*
Measures of Elevation, accretion and subsidence

Slide credit: Dr. Bob Christian
Elevation

Surface elevation change (NAVD88, cm)

Date
3/1/11  5/1/11  7/1/11  9/1/11  11/1/11  1/1/12  3/1/12  5/1/12  7/1/12  9/1/12  11/1/12

Crosswicks
Tinicum
Christina

Slide credit: Dr. Tracy Quirk
Surface elevation change

Crosswicks: 24 ± 2 mm/yr
Tinicum: 16 ± 9 mm/yr
Christina: 14 ± 10 mm/yr

Not significantly different from zero

Date
3/1/11  5/1/11  7/1/11  9/1/11  11/1/11  1/1/12  3/1/12  5/1/12  7/1/12  9/1/12  11/1/12

Surface elevation change (mm)

16 ± 9 mm/yr
14 ± 10 mm/yr
24 ± 2 mm/yr

Slide credit: Dr. Tracy Quirk
## Species Inventories

Table 11. Time, location, elevation and dominant plant species along line transects in Christina River, Delaware Estuary, DE.

<table>
<thead>
<tr>
<th>Date/Time</th>
<th>Transect</th>
<th>Date/Time</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Ortho Ht (m)</th>
<th>Dom Spp</th>
<th>Subdom Spp</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/13/2011 12:08</td>
<td>1</td>
<td>7/13/2011 12:08</td>
<td>39° 43' 18.81131&quot; N</td>
<td>75° 33' 55.31529&quot; W</td>
<td>0.6896</td>
<td><em>Peltandra virginica</em></td>
<td><em>Typha angustifolia</em></td>
</tr>
<tr>
<td>7/13/2011 12:11</td>
<td>1</td>
<td>7/13/2011 12:11</td>
<td>39° 43' 19.20260&quot; N</td>
<td>75° 33' 56.08426&quot; W</td>
<td>0.6912</td>
<td><em>Typha angustifolia</em></td>
<td><em>Peltandra virginica</em></td>
</tr>
<tr>
<td>7/13/2011 12:13</td>
<td>1</td>
<td>7/13/2011 12:13</td>
<td>39° 43' 19.27854&quot; N</td>
<td>75° 33' 56.61466&quot; W</td>
<td>0.571</td>
<td><em>Typha angustifolia</em></td>
<td><em>mix P. virginica/A. cannabinus</em></td>
</tr>
<tr>
<td>7/13/2011 12:26</td>
<td>1</td>
<td>7/13/2011 12:26</td>
<td>39° 43' 18.48583&quot; N</td>
<td>75° 33' 54.12005&quot; W</td>
<td>0.6224</td>
<td><em>Peltandra virginica</em></td>
<td><em>Typha angustifolia</em></td>
</tr>
<tr>
<td>7/13/2011 12:26</td>
<td>1</td>
<td>7/13/2011 12:26</td>
<td>39° 43' 18.45173&quot; N</td>
<td>75° 33' 54.02064&quot; W</td>
<td>0.5419</td>
<td><em>Nuphar lutea</em></td>
<td><em>Peltandra virginica</em></td>
</tr>
<tr>
<td>7/13/2011 12:28</td>
<td>1</td>
<td>7/13/2011 12:28</td>
<td>39° 43' 18.37777&quot; N</td>
<td>75° 33' 53.93586&quot; W</td>
<td>0.5369</td>
<td><em>Typha angustifolia</em></td>
<td><em>Pontederia cordata</em></td>
</tr>
</tbody>
</table>
Floristic Quality Index (FQI) of Each Plot in 2012
Percent Cover of Vascular Plants

Christina Bio Plots

<table>
<thead>
<tr>
<th>PV1</th>
<th>PV2</th>
<th>PV3</th>
<th>PV4</th>
<th>PV5</th>
<th>PV6</th>
<th>PV7</th>
<th>PV8</th>
<th>PV9</th>
<th>RE1</th>
<th>RE2</th>
<th>RE3</th>
<th>RE4</th>
<th>RE5</th>
<th>RE6</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>90</td>
<td>70</td>
<td>60</td>
<td>75</td>
<td>85</td>
<td>90</td>
<td>95</td>
<td>80</td>
<td>60</td>
<td>70</td>
<td>80</td>
<td>90</td>
<td>70</td>
<td>80</td>
</tr>
</tbody>
</table>

2011 vs 2012
Aboveground Biomass

Species richness declines down bay

Biomass highest at Christina

- Crosswicks: 10 species
- Tニック: 3 species
- クリスターナ: 2 species

Slide credit: Dr. Tracy Quirk
Belowground biomass (g/m²)

Crosswicks  Tinicum  Christina

0 - 15 cm depth  Location

Near  Far  Near  Far  Near  Far

Slide credit: Dr. Tracy Quirk
Faunal Communities
Water and soil

Slide credit: Dr. Tracy Quirk
Tidal Creek Nutrients

Nitrate + Nitrite

<table>
<thead>
<tr>
<th>Site</th>
<th>NO₃⁻ + NO₂⁻ concentration (µM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinicum</td>
<td>120</td>
</tr>
<tr>
<td>Christina</td>
<td>140</td>
</tr>
<tr>
<td>Maurice</td>
<td>100</td>
</tr>
<tr>
<td>Dennis</td>
<td>80</td>
</tr>
</tbody>
</table>

Ammonium

<table>
<thead>
<tr>
<th>Site</th>
<th>NH₃-N (µM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tinicum</td>
<td>15</td>
</tr>
<tr>
<td>Christina</td>
<td>10</td>
</tr>
<tr>
<td>Maurice</td>
<td>25</td>
</tr>
<tr>
<td>Dennis</td>
<td>5</td>
</tr>
</tbody>
</table>

Slide credit: Dr. Tracy Quirk
How are we funding MACWA?

Any way we can!

- National Estuary Programs
- EPA Wetland Program Development Grants
  - design and implement RAM and SSIM
  - helping to build state capacity
- Coastal Zone Management Grants (NJ and PA)
  - MACWA-affiliated Intensive studies
- Private Sector Support (DuPont)
- Non-Profits (Christina Conservancy)
- In-Kind Match (Rutgers, Academy of Natural Sciences)
Challenges?

• Funding
  - state budgets and capacity extremely limited (NJ and PA)
  - no federal grants/programs to sustain wetland monitoring
  - remote sensing data out of date or low resolution

• Access
  - coastal wetlands vary greatly in ease of access
  - landowner permission
Summary

- Coastal wetlands are a hallmark feature of the Delaware and Barnegat Estuaries
- They provide diverse benefits that sustain lives and livelihoods
- They are vulnerable to combined watershed and climate stressors, especially post-Sandy
- Monitoring of wetland status and trends will assist in managing and sustaining them
- Regional coordination strengthens scientific outcomes, improves management and leverages more diverse funding

Martha Maxwell Doyle
We Thank the Many People Who Have Assisted in Workshops, Workgroups and in the Field

And We Are Grateful to Our Primary Funders:

EPA Headquarters
EPA Region 2
EPA National Estuary Program
DE Dept. of Natural Resources Environ. Control
NJ Coastal Management Program
PA Coastal Management Program