Coastal Wetland Status and Trends in the Chesapeake Bay Watershed

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www.ccrm.vims.edu
Coastal Wetlands

**Coastal wetlands**: include saltwater and freshwater wetlands located within coastal watersheds — specifically USGS 8-digit hydrologic unit watersheds which drain into the Atlantic, Pacific, or Gulf of Mexico (EPA definition).

Presently, there are ~40 million acres of coastal wetlands (38% of the estimated total wetland acreage in the US).
Historic changes and evolving views on coastal wetlands

Current status and projected trends – CB coastal wetlands

Primary factors effecting wetlands development & functioning

Conservation planning – importance of landscape perspective

Coastal wetland vulnerability & resiliency

Research needs and Recommendations
Wetlands – historic conditions and losses

Over half of US wetlands were lost from the 1780s to the 1980s (Dahl 1990)
221 million acres – ~ 104 million acres

(≈ 89 million ha – 42 million ha)

A. Wetland Exploitation (1700s – 1954)
B. Moderate Conversion (1954 – 1974)
   - e.g. CWA 1977 slowed conversion/loss
D. No Net Loss (1982 – present)
   - offset loss with creation
Bay streams supported extensive non-tidal wetlands w. relatively organic-rich soils; Low rates of sediment deposition

Extensive deforestation for agriculture – 70-80% of forest cover cleared

Erosion rates increased and large amounts of sediments were transported to the bay and stored in upland areas and stream corridors. Many fluvial wetlands buried by fine upland sediments deposited behind mill dams

Reforestation increased, erosion rates remained high because of remobilization of legacy sediments & urbanization

Baldwin et al. 2012; Walter and Merritts 2008

Variation in wetland structure & function influenced by variable sediment accumulation and erosion rates throughout the bay watershed.

Historical views on wetlands

“...a horrible desert [where] the foul damps ascend without ceasing, corrupt the air and render it unfit for respiration...Never was Rum, that cordial of life, found more necessary than this Dirty Place.”

--Col. William Byrd in describing the ‘Dismal Swamp’ between VA & NC – Early 18th C.

Evolving understanding of wetlands ecosystem

- Shoreline stabilization
- Nutrient transformation
- Groundwater recharge
- Water purification
- Flood protection
- Sediment retention
- Provide habitat for fish & wildlife
**TIDAL FRESHWATER WETLANDS**

State | Total (ha) | Coastal (ha) | %
---|---|---|---
Delaware | 823 | | 
Maryland | 10,345 | | 
Virginia | 16,000 | | 
North Carolina | 1,200 | | 
South Carolina | 26,115 | | 
Georgia | 19,040 | | 

After: Mitsch & Gosselink 2000

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**NON-TIDAL COASTAL WETLANDS**

State | Total (ha) | Coastal (ha) | %
---|---|---|---
VA | 408,371 | 260,627 | 64
MD | 150,976 | 136,558 | 90

Havens, regional assessment

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**TIDAL FRESHWATER WETLANDS**

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After: Mitsch & Gosselink 2000

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**BRACKISH & SALT MARSH**

Chesapeake Bay: 151,095 ha

<table>
<thead>
<tr>
<th>Type</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt Marsh</td>
<td>27,438</td>
</tr>
<tr>
<td>Brackish marsh</td>
<td>113,140</td>
</tr>
<tr>
<td>Intertidal scrub-shrub</td>
<td>10,511</td>
</tr>
</tbody>
</table>

NWI data

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**Total coastal wetlands in Chesapeake Bay**

~~574,625 ha

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A.H. Baldwin from Baldwin et al. 2012

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[Image of map showing coastal wetlands in Chesapeake Bay]

[Image of table showing non-tidal coastal wetlands by state]
Factors effecting the success of coastal wetland protection & restoration

Climate and environmental drivers influencing vertical & horizontal wetland development

Barriers to Migration (human development, topography)

Nutrient Input (eutrophication)

Elevated Atmospheric CO₂

Disturbance (herbivory, fire)

Storms

Invasive spp

Sea-Level Rise

Shallow Subsidence

Deep Subsidence

Cahoon et al. 2009 – Ch. 4 -Coastal Wetland Sustainability of the CCSP Report
Coastal Development
Coastal Development: No net loss is misleading

Corn-soybean field with forested riparian buffer

Great Wicomico River

Cranes Creek

2002
Permitted Erosion Control Structures

A total of 18 Joint Permit Applications received
Hardened shoreline = 3,218 ft

Wetland loss: 1158 ft² vegetated, 5000 ft² non-vegetated

Functional loss is unknown
Must pro-actively plan entire communities
Coastal development: Bay-wide

Chesapeake Bay

18% of tidal shoreline hardened

VA: 11%  MD: 28%

32% riparian land developed

4-5 km² of artificial substrate introduced (intertidal impacted)

On average, **29 km** of VA shoreline continue to be hardened each year

- Bulkhead
- Riprap Revetment

$R^2 = 0.7072$
Coastal Development: Status and Future Trends

Current shoreline hardening – Bulkhead/Riprap

Only ~7% of coastal lands set aside for conservation

Almost 45% of the land expected to be developed

Future shore protection

Map source: D.M. Bilkovic

Map source: Titus et al. 2009
Shoreline hardening: Fish & Benthos

Fish and benthic infauna community integrity reduced near hardened shorelines in Chesapeake Bay

Shoreline hardening: Habitat

Reduced intertidal and subtidal structural habitat along hardened shls

Fringing marsh

Structural benthic habitat

mussel beds, woody debris

SAV - absent at hardened sites

Diversity loss

Assemblage shifts

Bilkovic et al. 2006, Bilkovic & Roggero 2008
Non-linear responses by flora & fauna to riparian development

10-20% riparian development led to changes in communities

Median = 3.0
Median = 2.6
Median = 3.5
Median = 2.9

Estuarine Indicator Research Program -- [http://www.asc.psu.edu](http://www.asc.psu.edu/
Bilkovic et al. 2006; DeLuca et al. 2004, 2008; King et al. 2007)
With the observed negative effects of hardened shorelines, there is a need for alternative erosion protection approaches. **Living shorelines** - designed to control erosion, while simultaneously enhancing estuarine habitats.

**LEGISLATION**

**Maryland** - LS Protection Act (2008)
Requires non-structural shoreline protection practices unless proven infeasible

**Virginia**
Legislation passed in 2011 requiring the development of a general permit for living shorelines. VA’s approach is to streamline permit process for LS.

**NO comprehensive database of created marshes associated with LS**
Climate Change
Climate Change can affect coastal wetlands through multiple ways

**Temperatures** can change plant growth and assemblages

**Storms** can physically remove SAV beds and marsh plants

**Changing weather patterns** can affect local salinity

**Runoff** can add to turbidity and nutrient levels

**Sea level rise** can increase water depth & reduce available habitat

**Shoreline protection** can prevent landward migration
Climate Projections for Chesapeake Bay

**Sea Level Rise**

- SE VA Average Rate is 4.42 mm/yr & accelerating (~3.4 mm/yr baywide)
- We will see at least 1.5 ft rise by 2100

**Surface Water Temperature**

- Both the mean and maximum annual temperatures have increased by more than 1° C (1.8°F) over the past 5-6 decades
- Bay-wide increase ~ 0.3°C per decade
- Seasonal warming occurring ~3 weeks earlier than in the 1960s
- Expected increase of 2 – 6° C by 2100

Geomorphic settings of mid-Atlantic tidal wetlands

Conversion of tidal wetlands to open water

Geomorphic settings have differing hydrodynamics, sediment sources, & vegetative communities

Wetland response to sea level rise expected to vary with geomorphic setting

CCSP 2009: Cahoon et al. 2009; data source: Reed et al., 2008; map source: Titus et al., 2008
Tidal Marshes – SLR & shoreline development

510 km² marsh evaluated

38% (193 km²) of marshes are moderately-highly vulnerable to SLR due to adjacent development.

62% (316 km²) of marshes may have opportunities for landward transgression.

Tidal marshes in the meso-polyhaline reaches at highest risk due to land development & SLR.
Ecogeomorphic feedbacks of climate change:

- Increased temp, CO2, and inundation may increase rates of plant productivity & marsh accretion
  \[ \text{Decay} < \text{OM accumulation} \]

- Accelerated SLR (4.5 mm/yr) could reduce this feedback -
  \[ \text{Decay} > \text{OM accumulation} \]
  Marsh drowns

Lack of positive feedback loop between inundation & plant growth may reduce resiliency of wetlands to SLR
Increased N loads may play a role in degrading salt marshes

Comparison photos of the marshes from the 9-yr ecosystem nutrient-enrichment experiment

- Increase above-ground biomass
- Decrease below-ground biomass of bank-stabilizing roots
- Increase microbial decomposition of organic matter

**Reduced stability = creek-bank collapse**


N effects on plant structure

Under **elevated CO$_2$** conditions:

- Expect shifts from C4 to C3 plants
- Brackish marshes dominated by C3 plants (*Scirpus* spp) may increase root biomass

Under **elevated CO$_2$ & N** conditions:

- N addition may enhance C4 productivity & suppress response of C3 plants to elevated CO$_2$
- Favors plants more sensitive to inundation (*S. patens*)

Langley *et al.* 2013
Langley & Megoncal 2010

Effects of nutrient pollution on marsh vulnerability are complex and unresolved

Nutrient pollution may increase marsh vulnerability to sea level rise
Multiple impacts on tidal marshes – short and long term

- Higher Temperature
- Higher CO$_2$
- Higher Sea level, inundation
- Intensified Storms
- Development Shl hardening

Increased plant productivity
- Decay rates < OM accumulation (near term)
- Decay rates > OM accumulation (long-term)

Fragmentation
Wetland diversity loss
Invasive species

Marsh accretion
Marsh submersion &/or loss of function or resilience
Improved regional models for restoration targeting

To direct wetland restoration/protection, need 1) detailed data on local drivers and processes controlling wetland elevation across geomorphic settings & 2) wetland function assessments that can be integrated into regional models.

Examples of landscape level models integrating site or geomorphic descriptors

**Erosion Vulnerability Assessment – Conceptual 50-year planning window**

- Example Calculation of Potential Erosion Risk Zone
  - 50 yr X ER = 50 yr
  - Risk Zone

**Enhanced NWI-landscape position, landform, and water flow path**

- Historical Shorelines
- Rate of Change Shoreline Transect

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**MD Coastal Atlas**

Tiner 2005 – Nanicoke Watershed
Coastal habitat mosaics

Move towards conservation of ecologically connected network of terrestrial, FW, coastal and marine areas that are likely to be resilient to climate change

Island biogeography --- landscape connectivity

**Structurally connected landscape**

- spatial arrangement of different habitats or elements in the landscape

**Functional component**

- behavioral response of individuals, species, or ecological processes to the physical structure of the landscape

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*Figure: K. McGarigal*

**Structurally connected landscape does not equate to functionally connected for all species**

Tabbs Creek, VA
Importance of landscape setting on coastal wetland ecosystems

The extent to which landscape setting moderates tidal marsh connectivity & estuarine species diversity, composition, and distribution is currently unknown.

- Smaller salt marsh patch sizes in human-dominated landscape settings
- Diversity of estuarine fish lower at natural wetland & riprap shls if surrounding landscape was >20% developed  
  Bilkovic & Roggero 2008
- In the Gulf, infauna & nekton assemblages were less diverse & differed from marshes in less altered reaches  
  Partyka & Peterson 2008

Central to the design and implementation of conservation and restoration initiatives is a better understanding of landscape connectivity effects on wetland ecology.
Most vulnerable coastal wetlands

• **Estuarine marshes** already experiencing submergence & those exposed to development pressures & high RSLR

• **Tidal freshwater marshes**—physically limited resource in the coastal landscape with high ecological value for fisheries; vulnerable to species shifts with salinity intrusion (*Perry et al. 2009*)

• **Freshwater wetlands** that depend primarily on precipitation for their water supply may be more vulnerable to climate change than those that depend on regional groundwater systems (*Winter 2000*)

Most resilient coastal wetlands

• Wetlands within an ecologically connected network of terrestrial, FW, coastal & marine areas

• Wetlands in landscape settings that allow retreat

• Wetlands that receive relatively high sediment loads &/or are experiencing relatively low rates of SLR/subsidence
Uncertainties and Research Needs

- **More detailed data on sediment processes** - Variation in wetland structure & function influenced by variable sediment accumulation & erosion rates

- **Predictions of change in hydrology** caused by both climate and land cover change. For example, hydrologic impacts from rainfall patterns changes will depend on the amount and location of impervious surfaces in the watershed.

- **Determine interactions & feedbacks influencing wetland resilience** - For example, interplay of wetland elevation, CO₂, temp, inundation, nutrients, & soil organic matter accretion in a variety of geomorphic settings.

- **Landscape-level influences on wetland resilience** - Better understanding of the extent that landscape setting moderates wetland fragmentation, connectivity, functionality, and estuarine species diversity, composition, & distribution.

- **Identify thresholds at multiple scales** - Point at which wetlands lose function (not just area) – whole system monitoring and modeling + process studies.

- **A mechanism to fully track the amount and functional loss of wetlands** and buffers throughout the Bay to development, erosion, flooding or sea-level rise.

- **Inventory of marsh creation** associated with living shoreline approaches.
Move from individual property decisions to comprehensive geomorphic-based shoreline protection/restoration planning.

Truly minimize cumulative impacts by encouraging the use of shore protection techniques that preserve/create wetlands & mitigate lost opportunities for wetland migration.

Restoration/conservation targeting that preserves wetland diversity and functions, and coastal habitat connectivity under a changing system.