Coastal Wetland Status and Trends in the Chesapeake Bay Watershed

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Designing Sustainable Coastal Habitats
16-17 April 2013

Virginia Institute of Marine Science
www.ccrm.vims.edu

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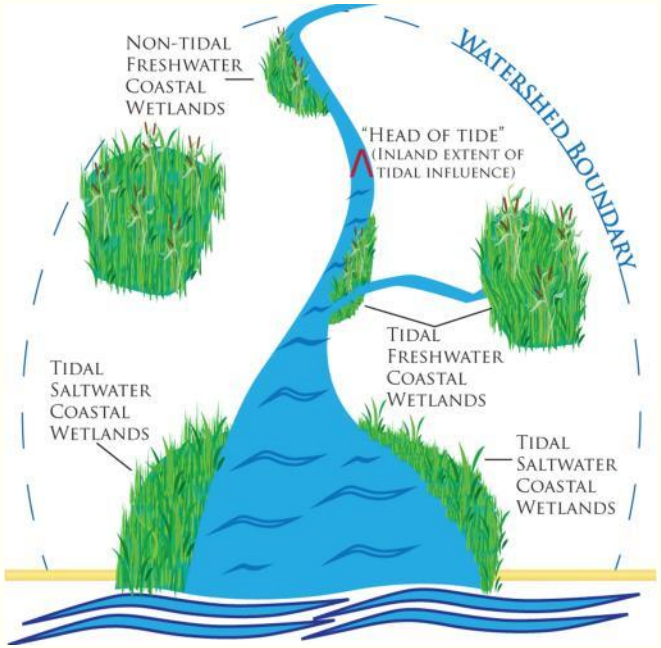
Coastal Wetlands

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)



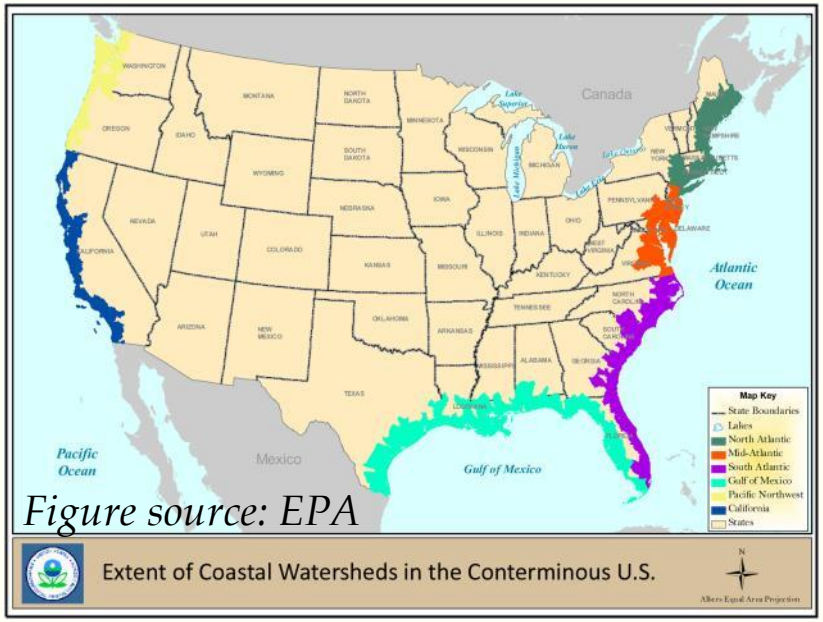


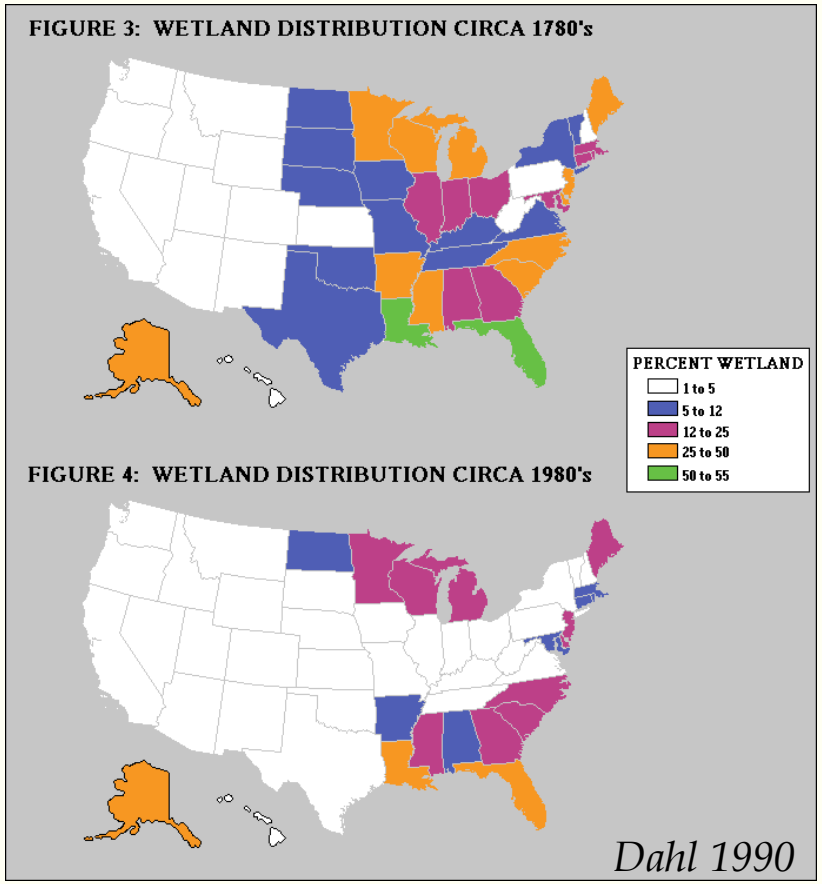
Figure source: EPA

Presently, there are ~40 million acres of coastal wetlands (38% of the estimated total wetland acreage in the US)

Outline

- 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



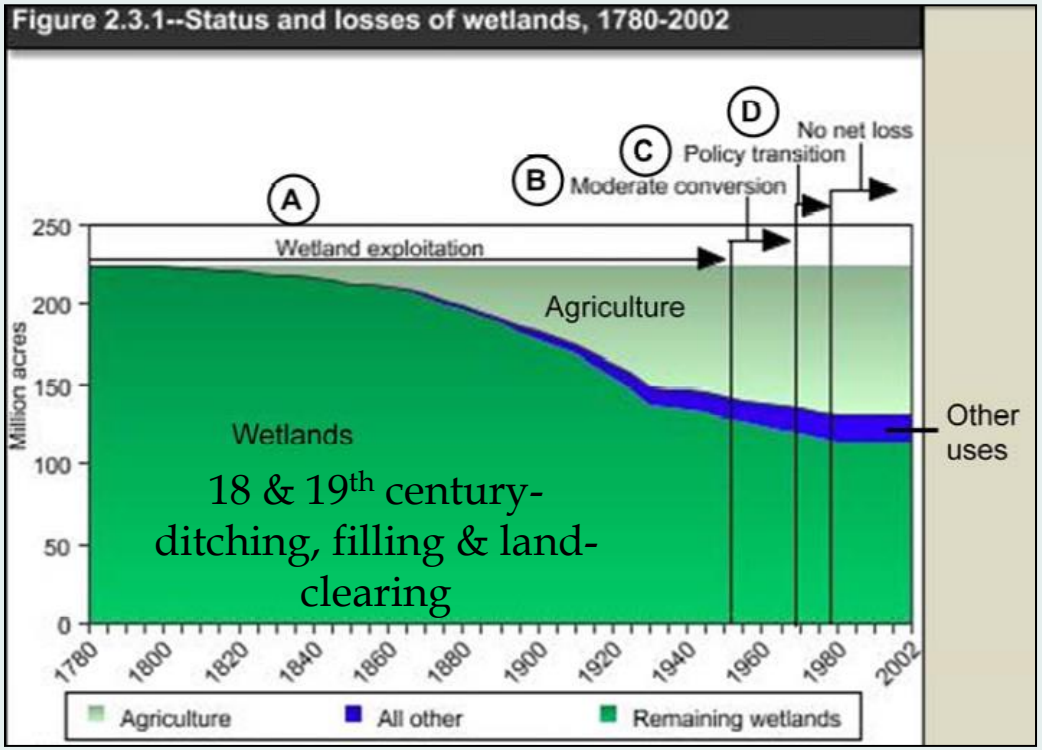


Image credit: U.S. Department of Agriculture Economic Research Service

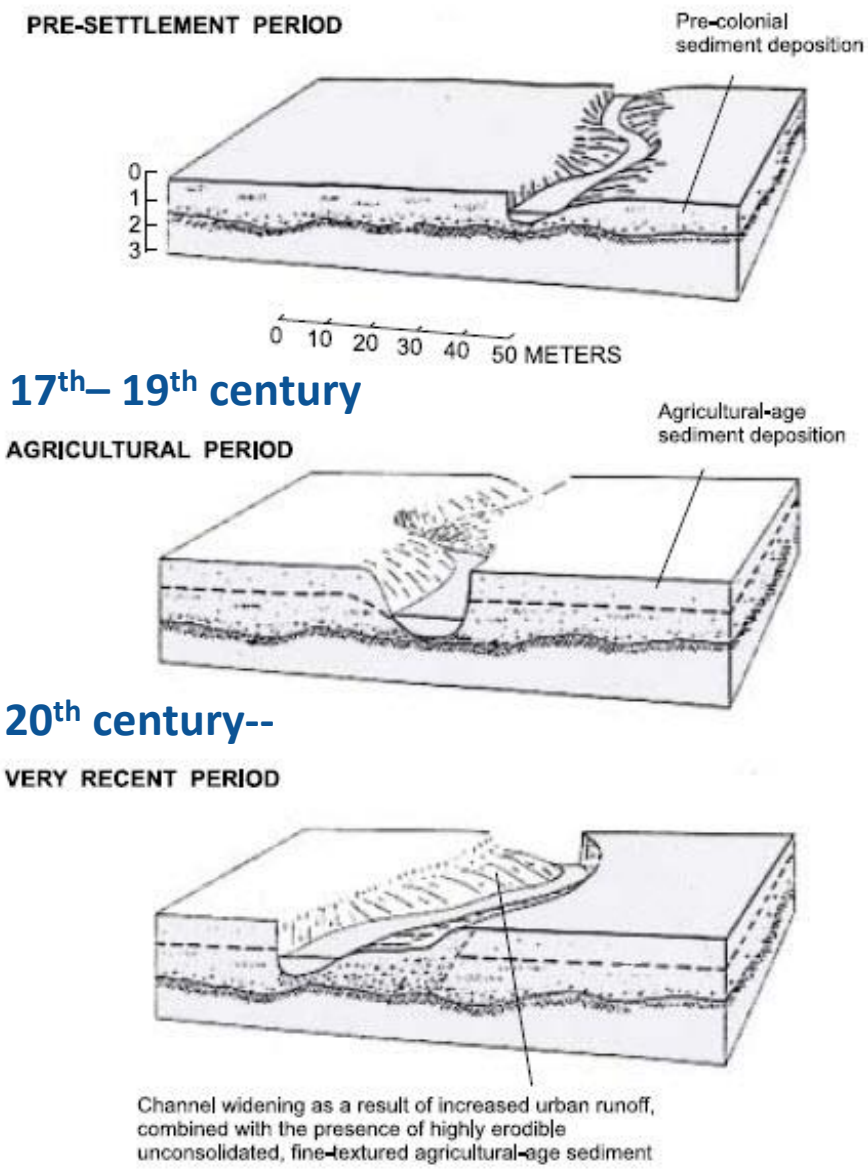
<u>Over half of US wetlands were lost from the 1780s to the 1980s</u> (*Dahl 1990*)

221 million acres – ~ 104 million acres

(~ 89 million ha – 42 million ha)

A. Wetland Exploitation (1700s – 1954)
B. Moderate Conversion (1954 – 1974)
C. Wetlands Protection Regulations (1974-1982)
   -e.g. CWA 1977 slowed conversion/loss
D. No Net Loss (1982 – present)
   -offset loss with creation

Historic changes to Chesapeake Bay sediment deposition patterns and rates



3 defining periods of sedimentation (*USGS 2003 – Sediment Processes…,Modified from Jacobsen & Coleman, 1986*).

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

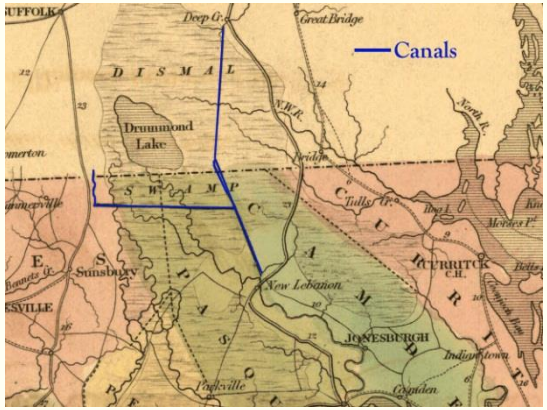
Erosion rates increased and large amounts of sediments were transported to the bay and stored in upland areas and stream corridors. Many fluvial wetlands buried by fine upland sediments deposited behind mill dams

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 <u>variable sediment accumulation and erosion rates throughout the bay watershed</u>.

Function and Values of Wetlands – evolution of understanding



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

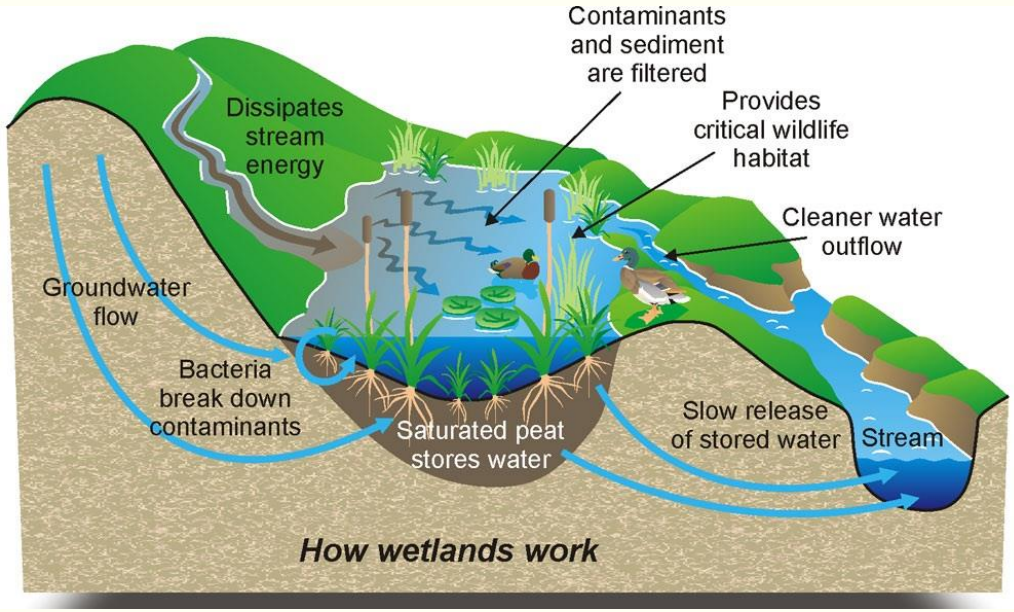
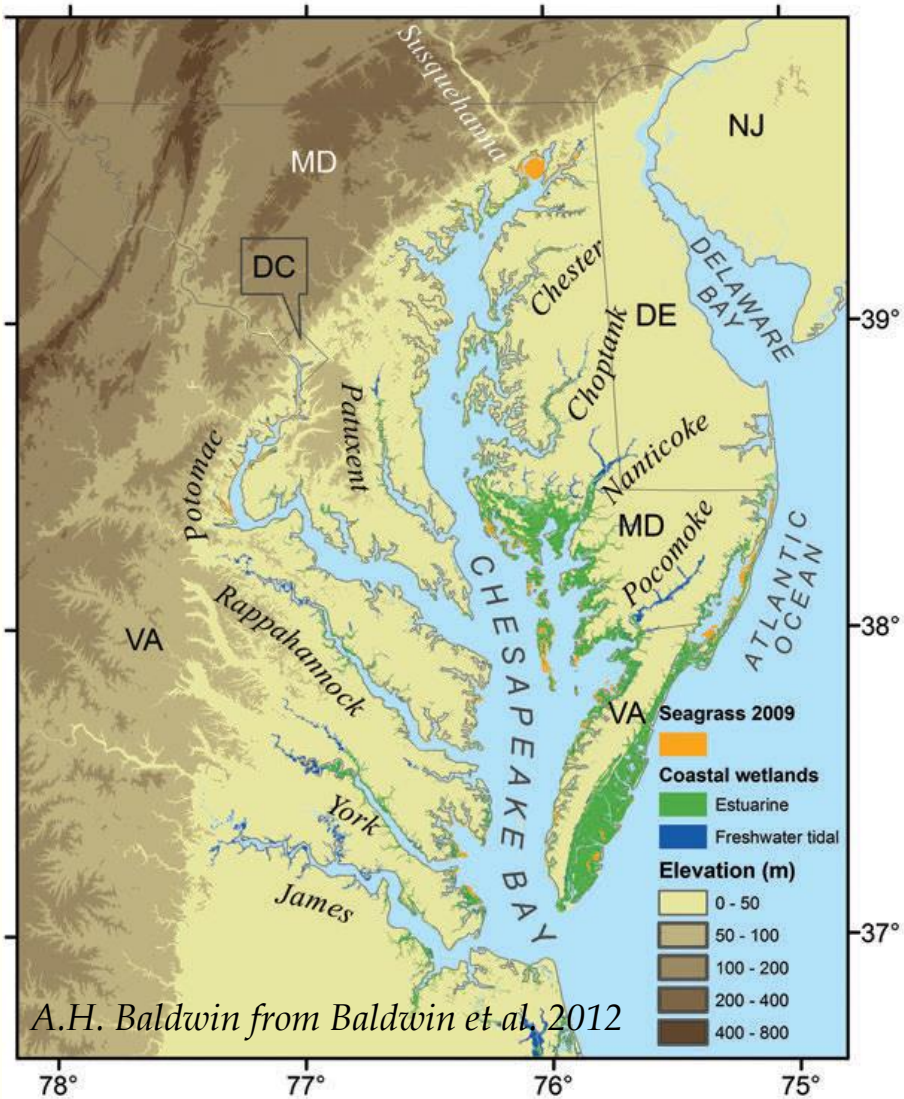


Image: Natural resources Canada

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

Existing coastal wetlands – Chesapeake Bay



A.H. Baldwin from Baldwin et al. 2012

Total coastal wetlands in Chesapeake Bay ~~574,625 ha

NON-TIDAL COASTAL WETLANDS

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

Havens, regional assessment

TIDAL FRESHWATER WETLANDS

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

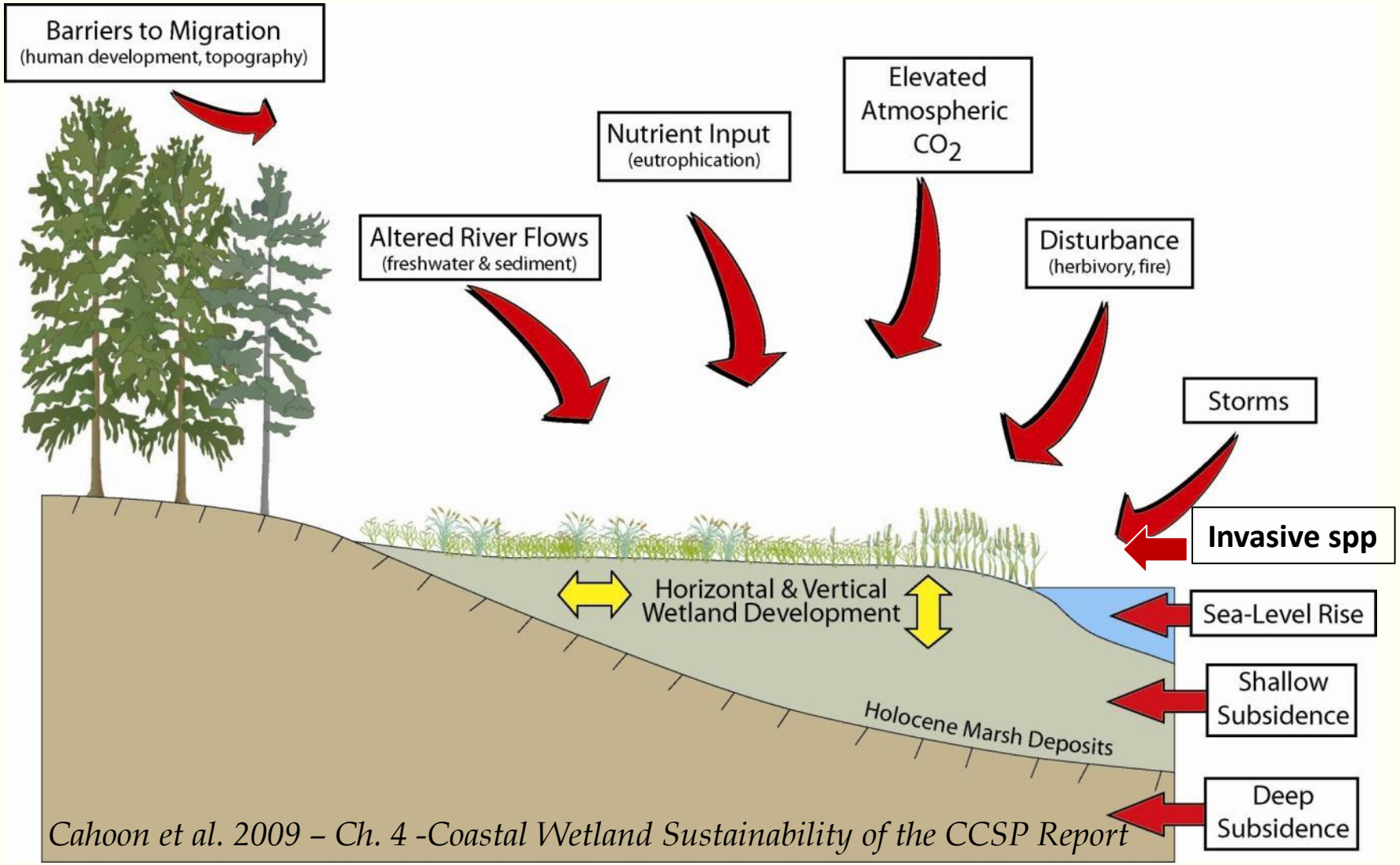
After: Mitsch & Gosselink 2000

BRACKISH & SALT MARSH

Chesapeake Bay:	151,095 ha
Salt Marsh	27,438
Brackish marsh	113,140
Intertidal scrub-shrub	10,511

NWI data

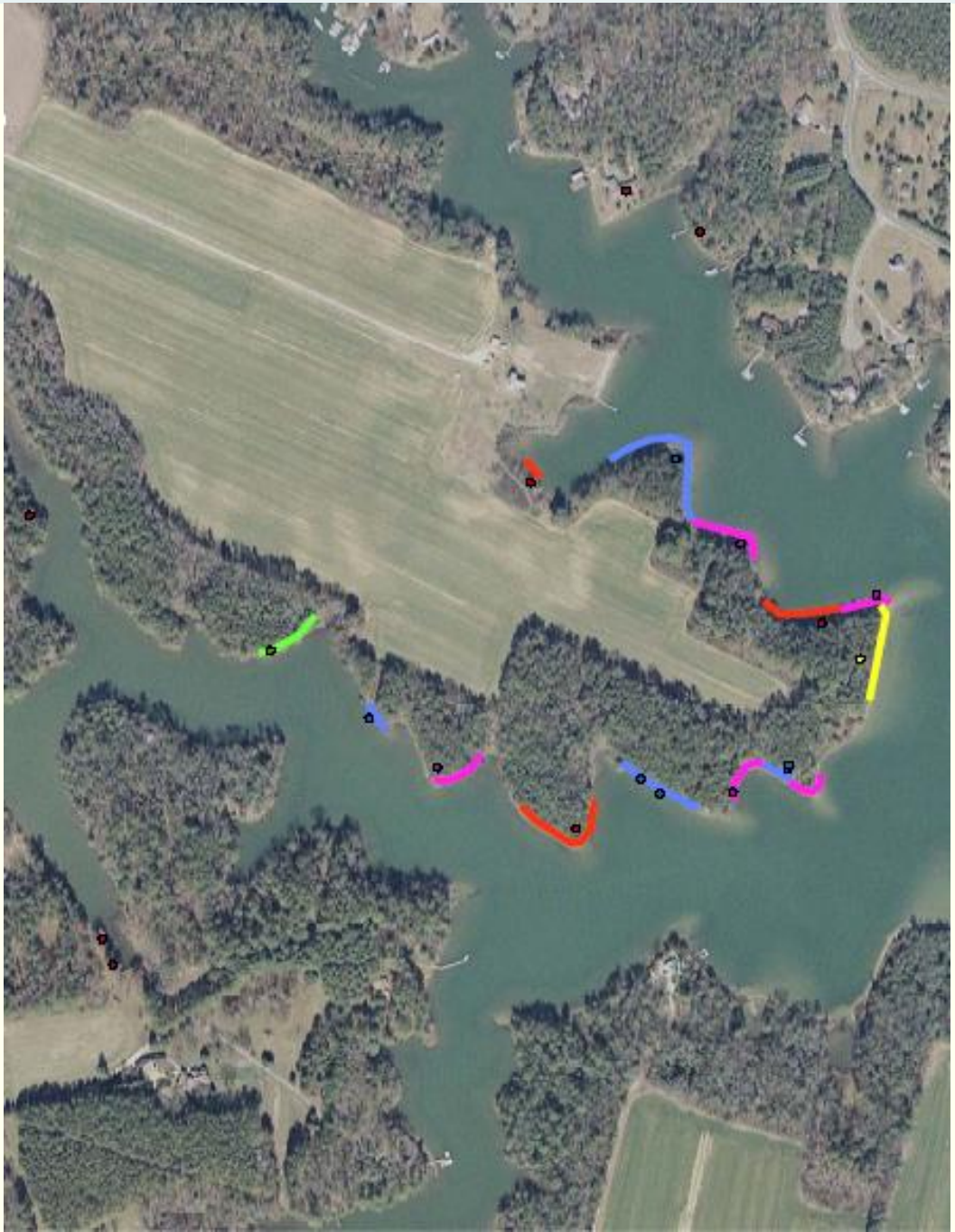
Climate and environmental drivers influencing vertical & horizontal wetland development



Cahoon et al. 2009 – Ch. 4 -Coastal Wetland Sustainability of the CCSP Report

Coastal Development

Coastal Development: No net loss is misleading



Permitted Erosion Control Structures

- 2003
- 2004
- 2005
- 2006
- 2007

A total of 18 Joint Permit Applications received

Cumulative habitat loss

Upland Improvements & Clearing

Revetments

Installed

Proposed

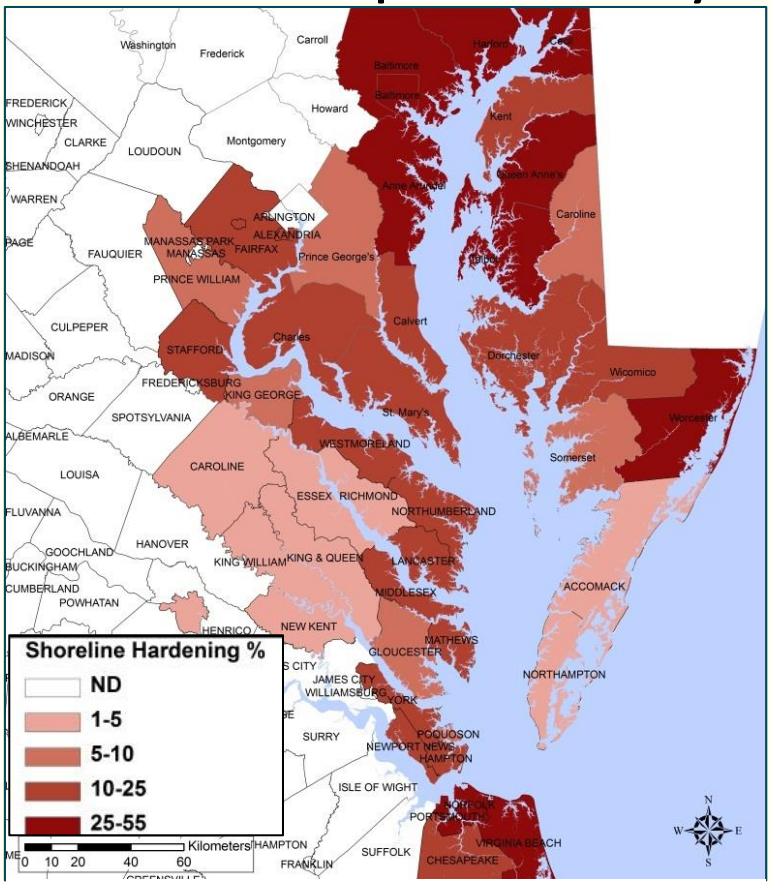
Hardened shoreline = 3,218 ft

Wetland loss: 1158 ft^2 vegetated, 5000 ft^2 non-vegetated

Functional loss is unknown

Must pro-actively plan entire communities

Coastal development: Bay-wide



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

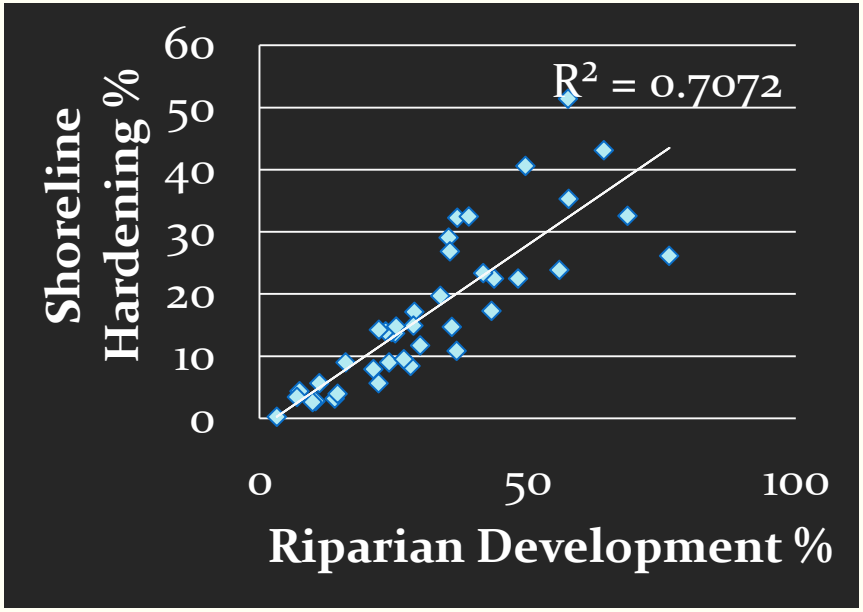
Chesapeake Bay

18% of tidal shoreline hardened

***VA**: 11%* ***MD**: 28%*

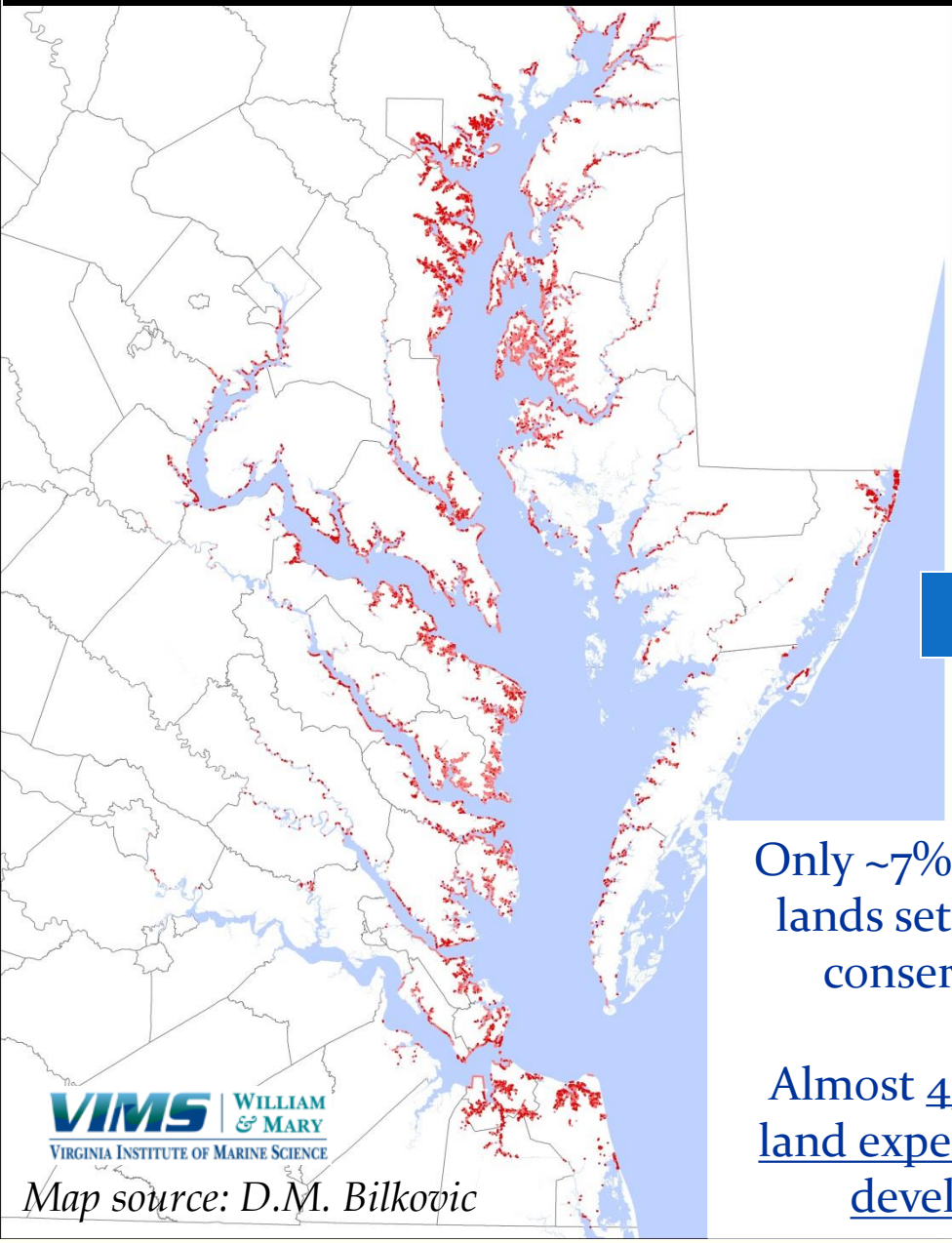
32% riparian land developed

4-5 km^2 of artificial substrate introduced (*intertidal impacted*)



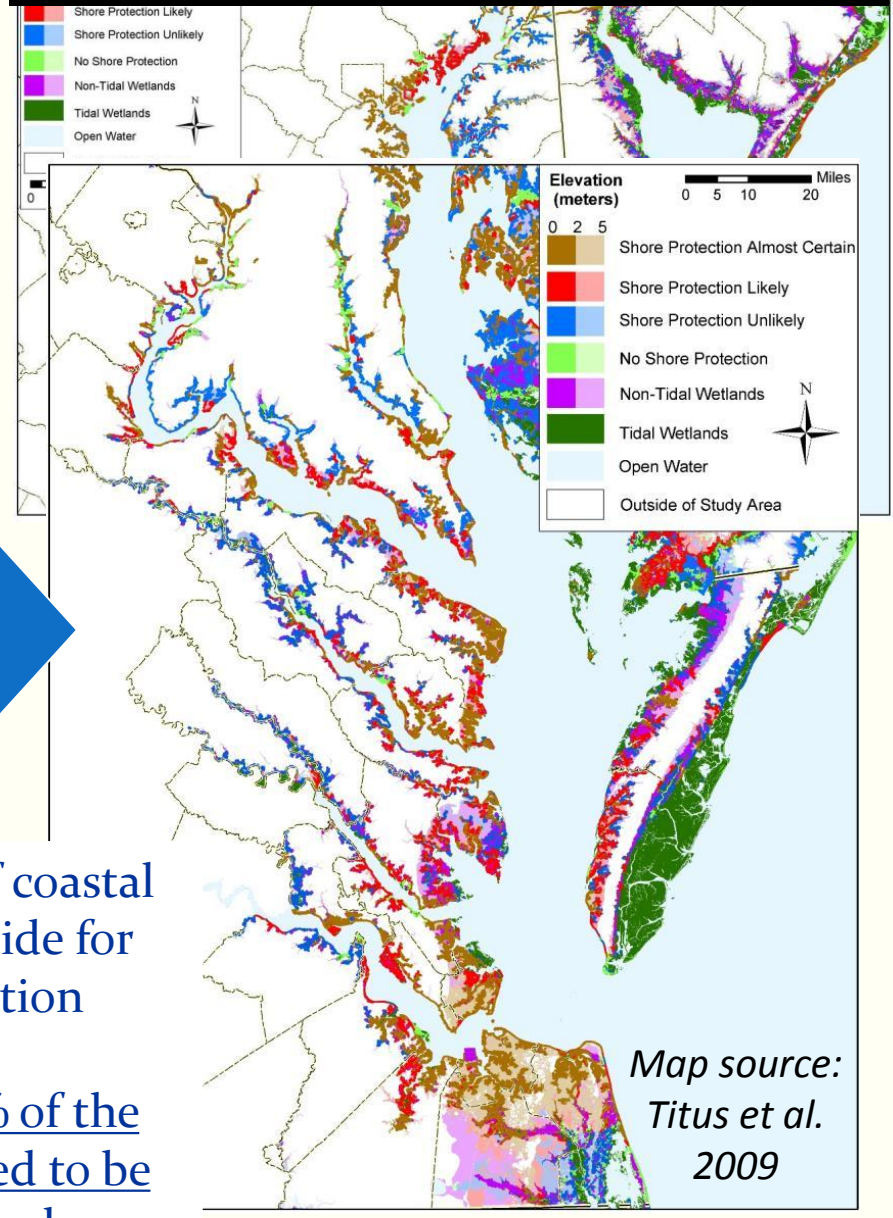
Coastal Development: Status and Future Trends

Current shoreline hardening – Bulkhead/Riprap



Map source: D.M. Bilkovic

Future shore protection



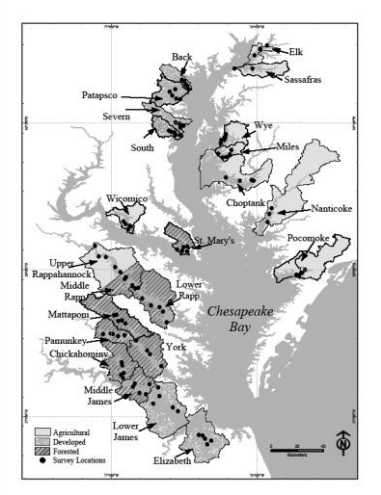
Map source: Titus et al. 2009

Only ~7% of coastal lands set aside for conservation

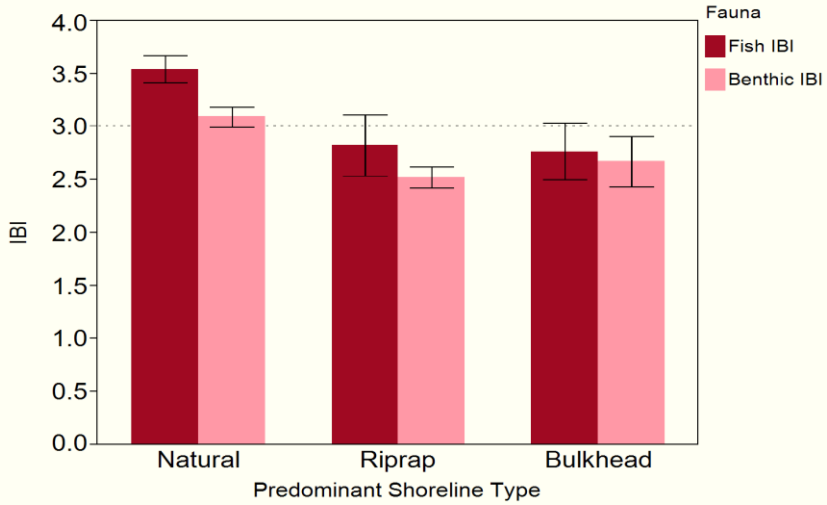
Almost 45% of the land expected to be developed

Habitat & species diversity lower adjacent to hardened shorelines

Shoreline hardening: Fish & Benthos



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



Diversity loss

Assemblage shifts

Shoreline hardening: Habitat

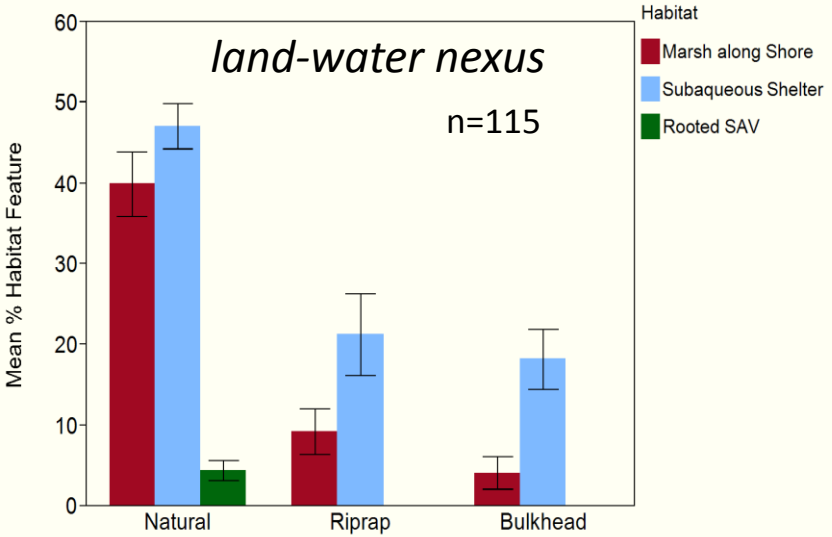
Reduced intertidal and subtidal structural habitat along hardened shls

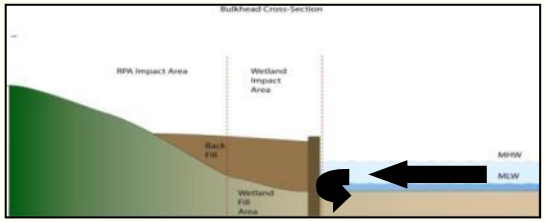
Fringing marsh

Structural benthic habitat

mussel beds, woody debris

SAV - *absent at hardened sites*





Bilkovic et al. 2006, Bilkovic & Roggero 2008

Non-linear responses by flora & fauna to riparian development

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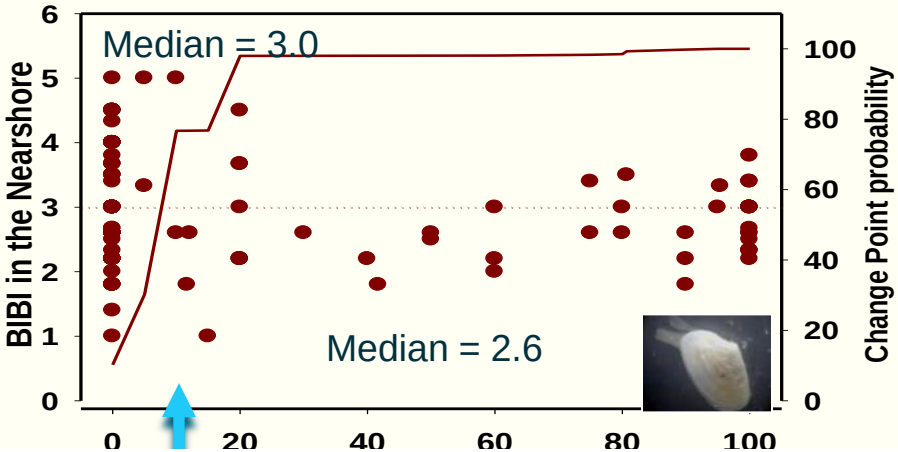
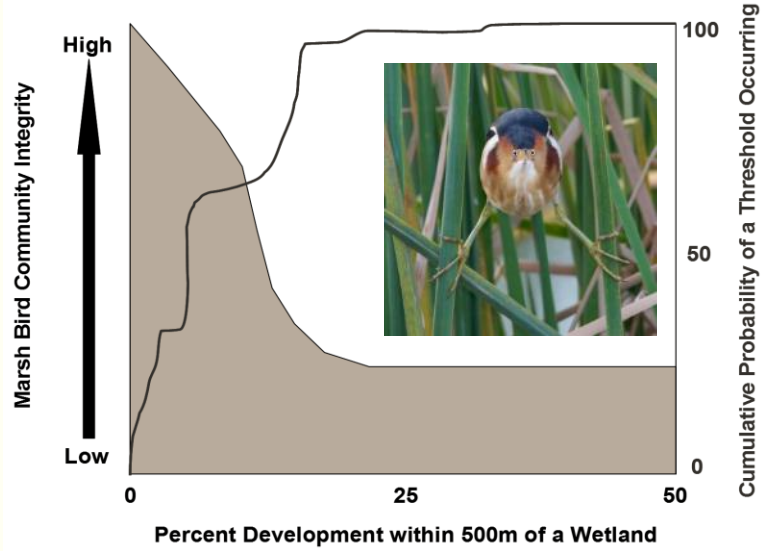
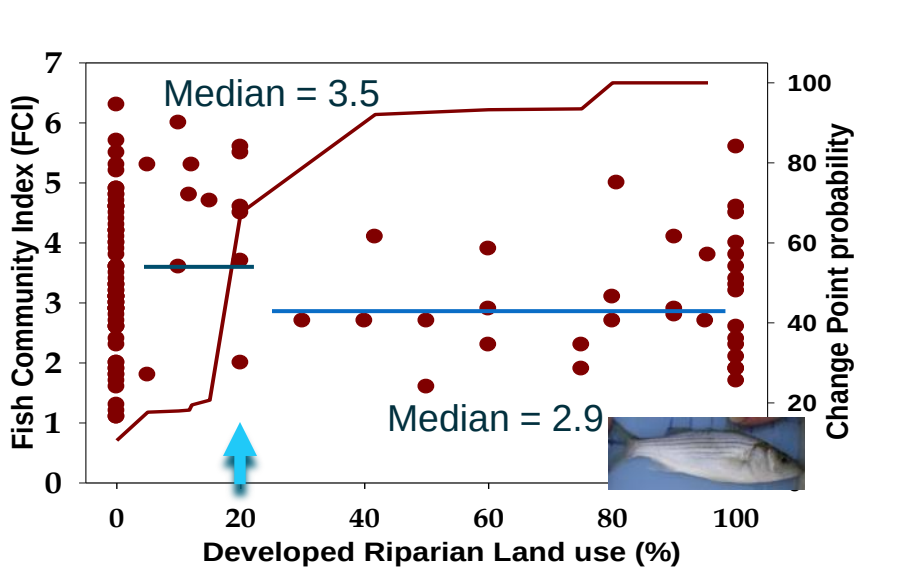
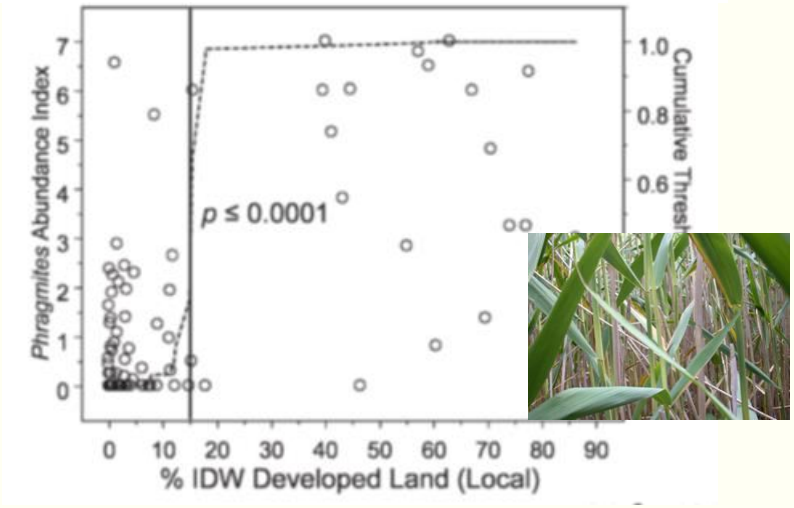
10-20% riparian development led to changes in communities









Estuarine Indicator Research Program -- *http://www.asc.psu.edu/*

Bilkovic et al. 2006; DeLuca et al. 2004, 2008; King et al. 2007

Ecosystem service approach to shoreline protection

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

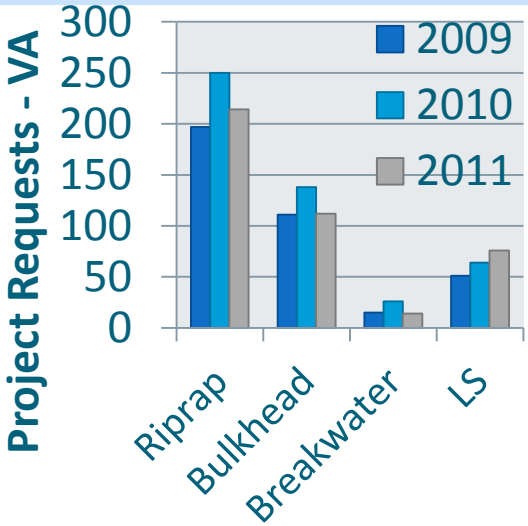
Soft (non-structural)

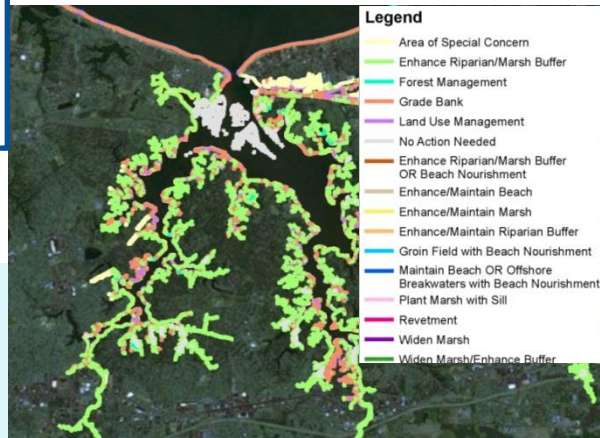
Hybrid- structure used to support plant growth

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 stream-line permit process for LS





**NO comprehensive database of created marshes associated with LS

Climate Change

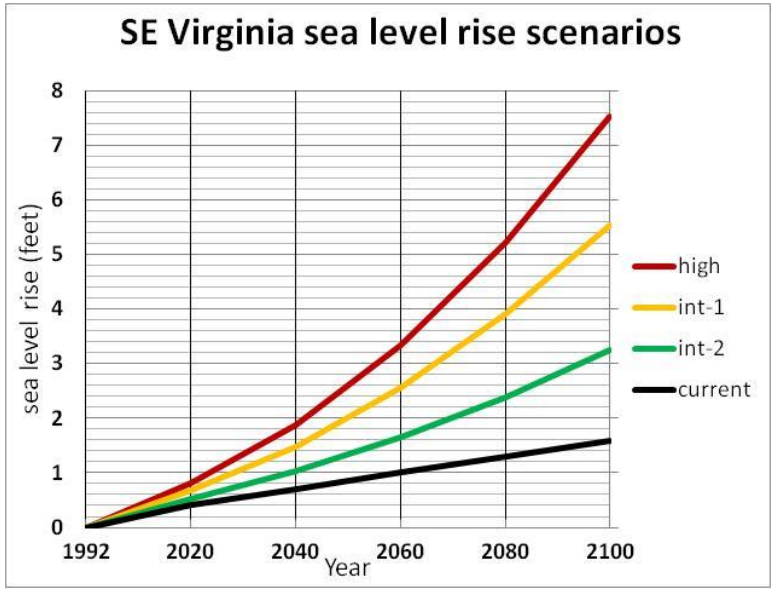
Climate Change can affect coastal wetlands through multiple ways

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

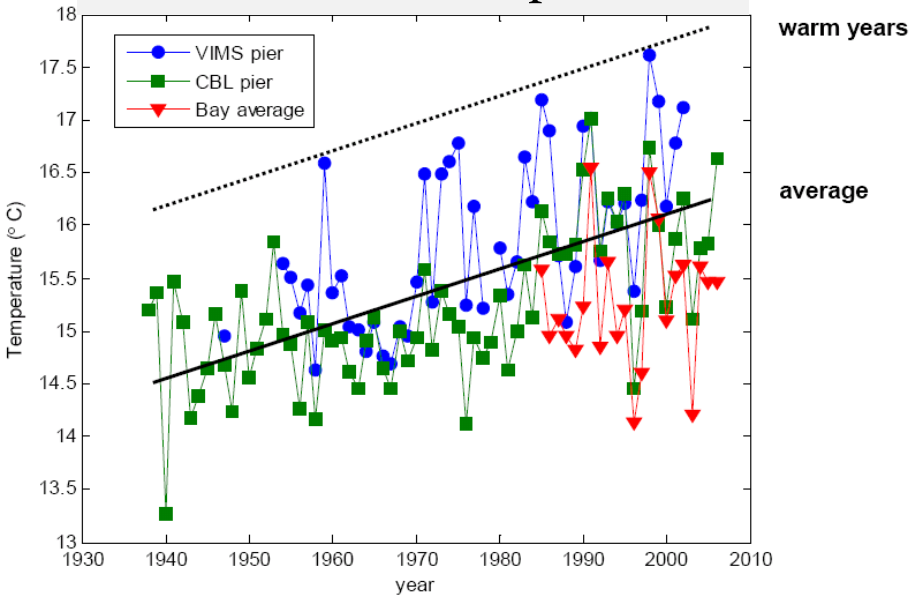
Climate Projections for Chesapeake Bay

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

Sources: *Pyke et al. 2008. Climate change and the Chesapeake Bay. Chesapeake Bay Program STAC Report. & From Austin (2002) American Fisheries Society Symposium, 32, 155-170*

Sea Level Rise – Regional models

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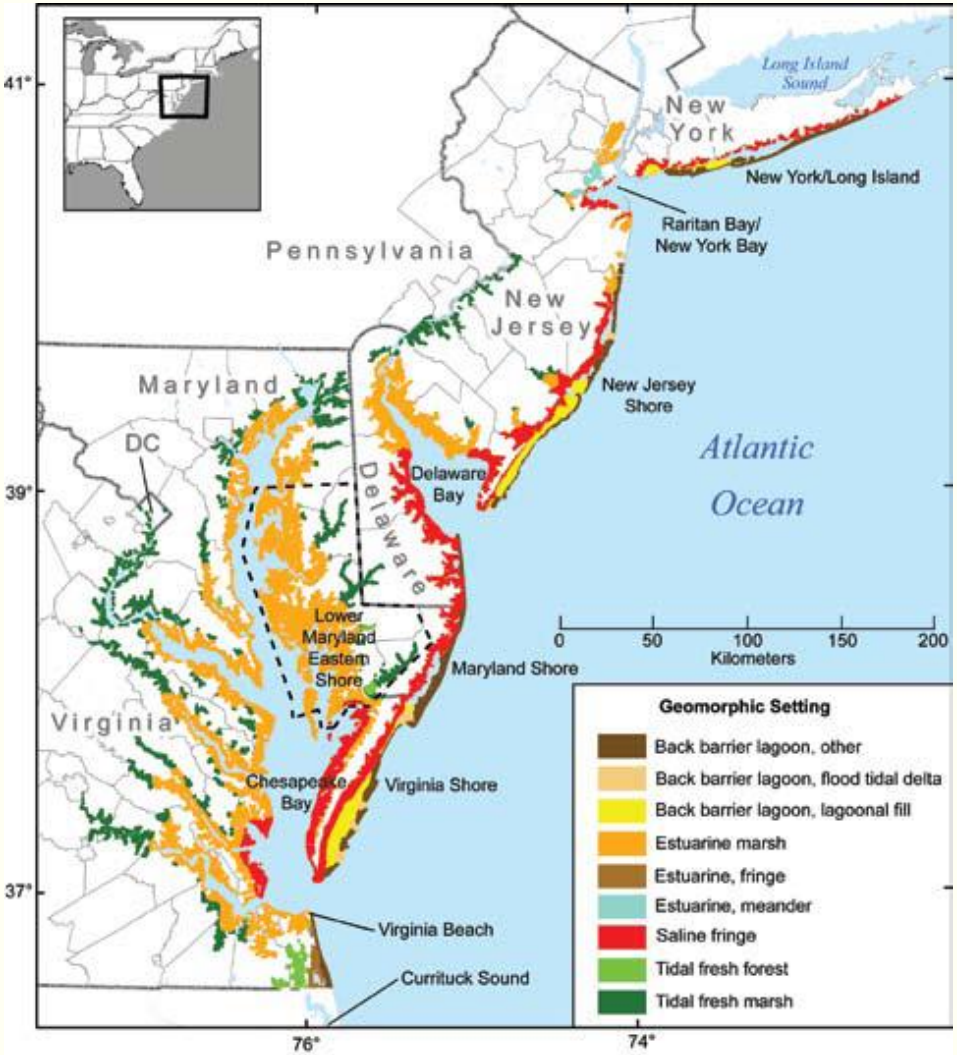
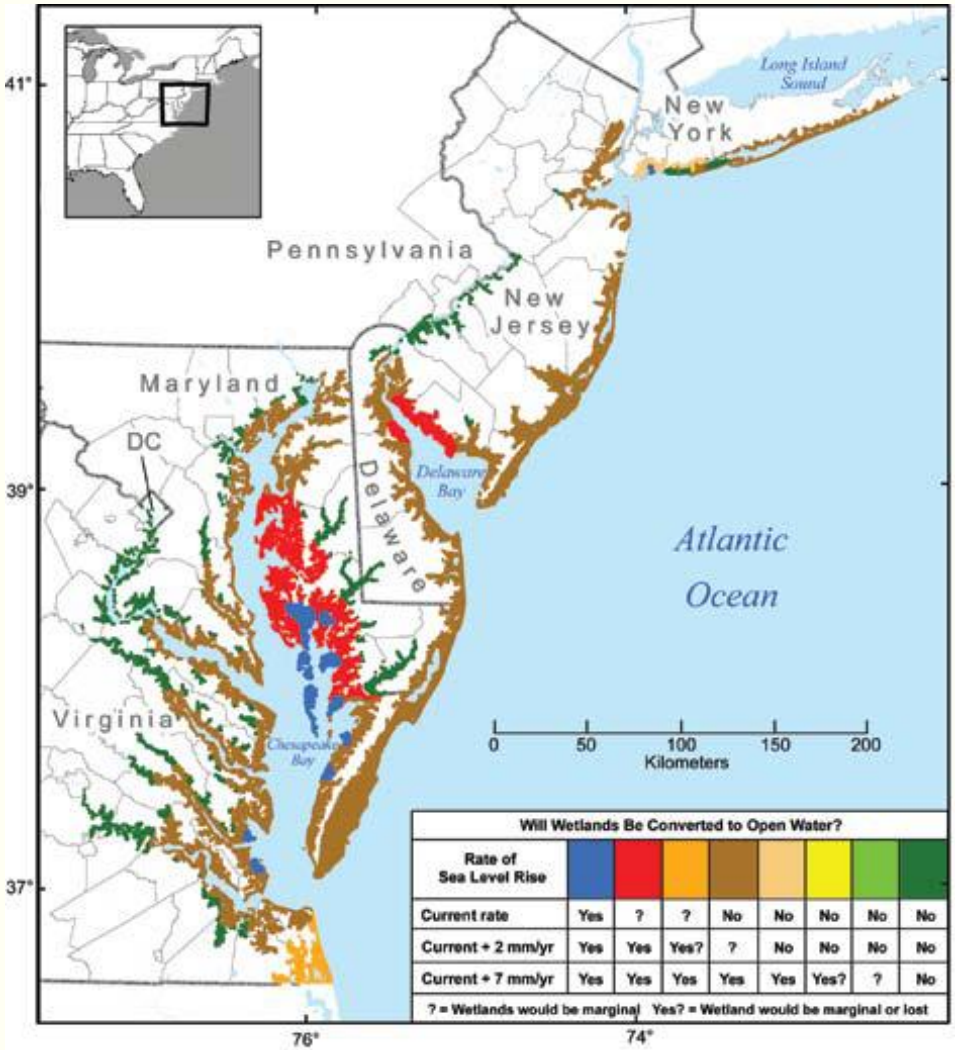
Geomorphic settings of mid-Atlantic tidal wetlands



Conversion of tidal wetlands to open water



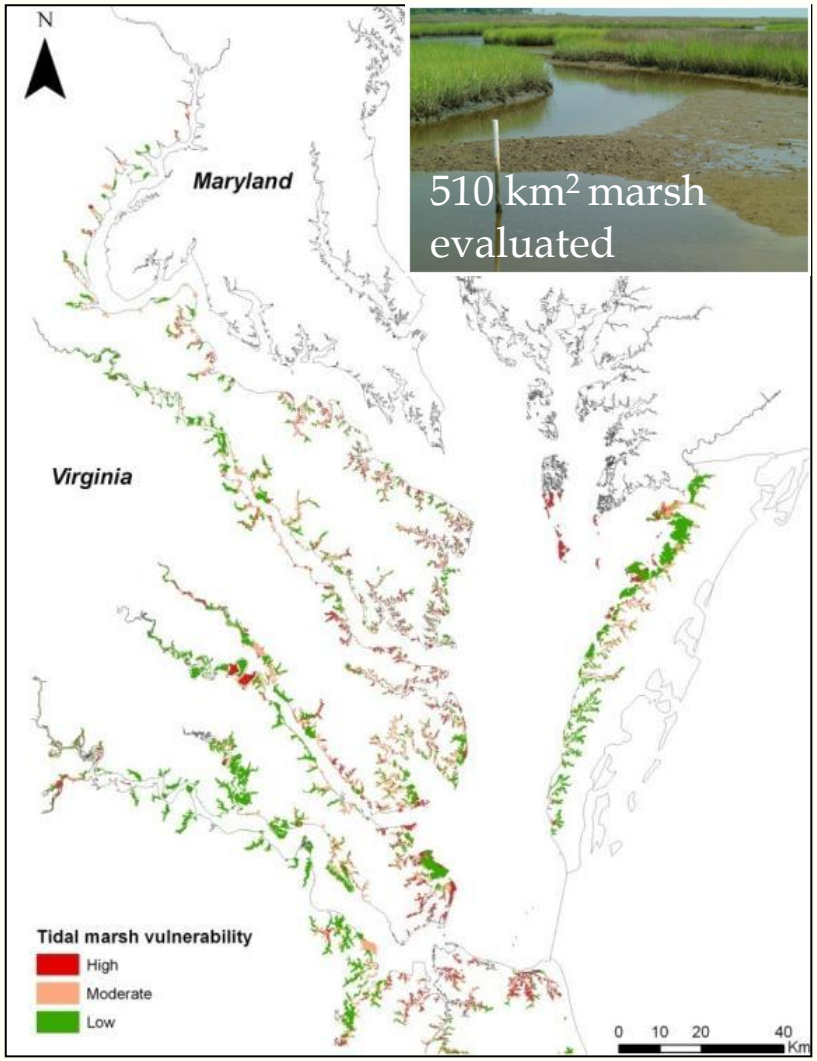
Rate of Sea Level Rise								
Current rate	Yes	?	?	No	No	No	No	No
Current + 2 mm/yr	Yes	Yes	Yes?	?	No	No	No	No
Current + 7 mm/yr	Yes	Yes	Yes	Yes	Yes	Yes?	?	No

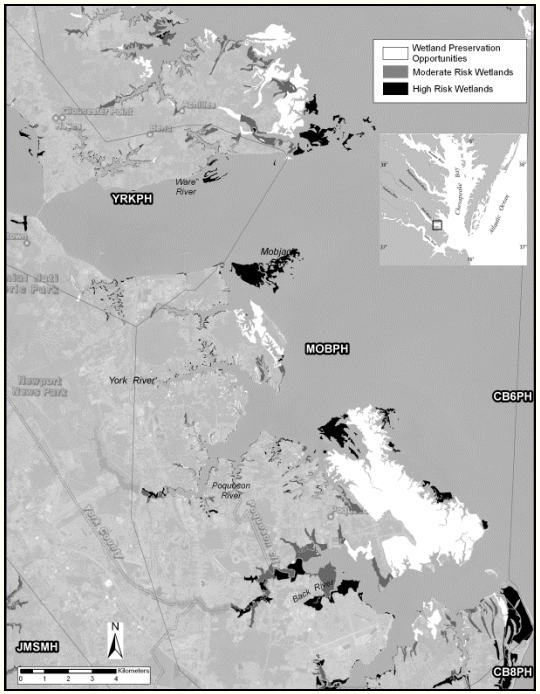
Geomorphic settings have differing hydrodynamics, sediment sources, & vegetative communities

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





Tidal marshes in the meso-polyhaline reaches at highest risk due to land development & SLR

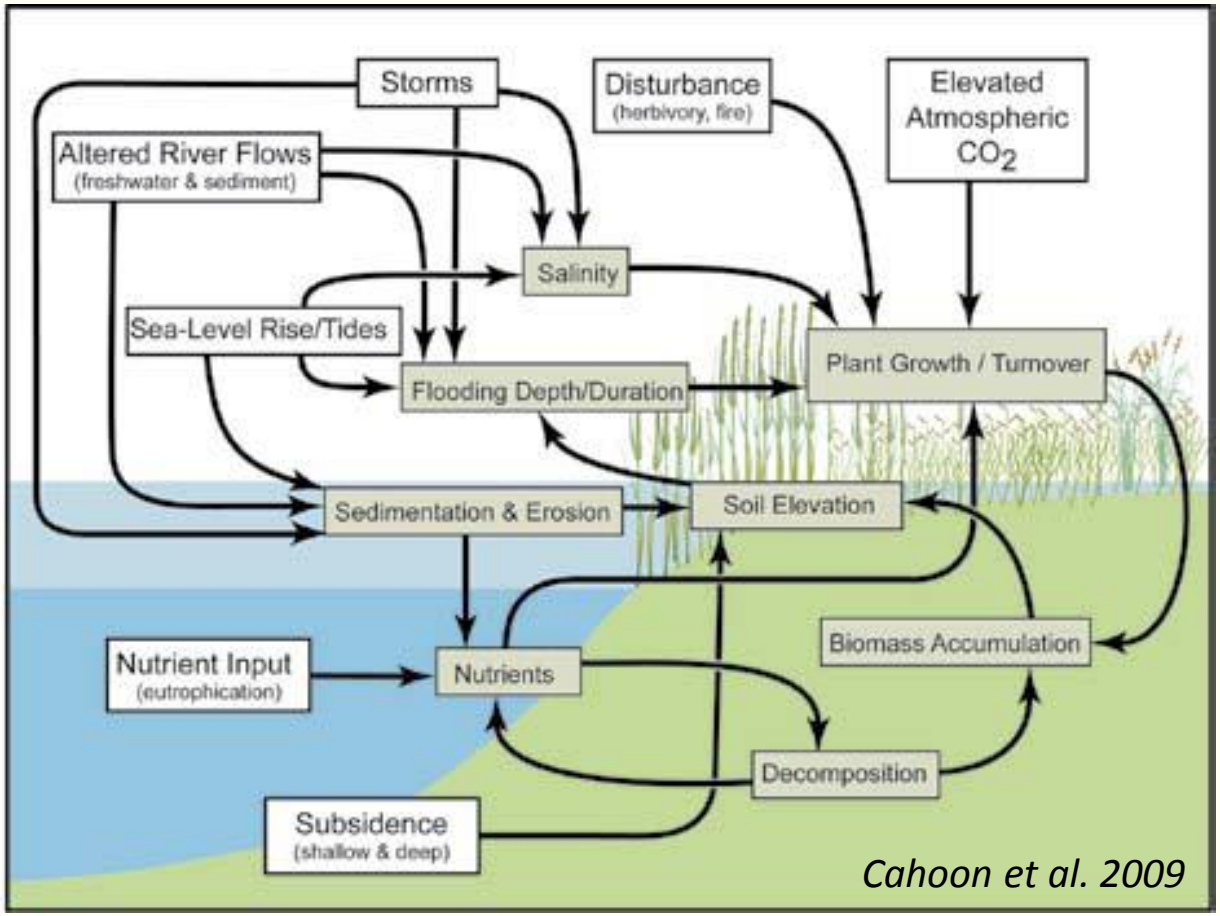
38% (193 km²) of marshes are moderately-highly vulnerable to SLR due to adjacent development

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

High Risk Marsh

Low Risk Marsh

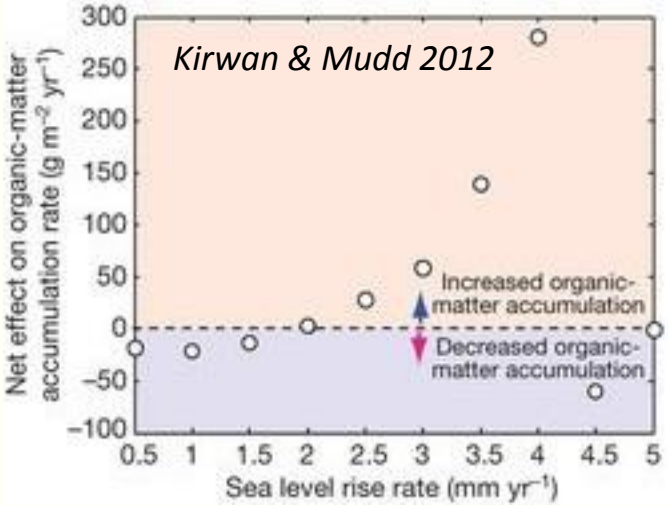
Local Models-Drivers & processes influencing wetland vertical development



Ecogeomorphic feedbacks of climate change:

- **Increased temp, CO2, and inundation** may increase rates of plant productivity & marsh accretion
  Decay < OM accumulation

- Accelerated SLR (4.5 mm/yr) could reduce this feedback -
  Decay >> OM accumulation
  Marsh drowns



Lack of positive feedback loop between inundation & plant growth may reduce resiliency of wetlands to SLR

Effects of nutrient pollution on marsh vulnerability are complex and unresolved

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

*LA Deegan et al. Nature **490**, 388-392 (2012)*

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

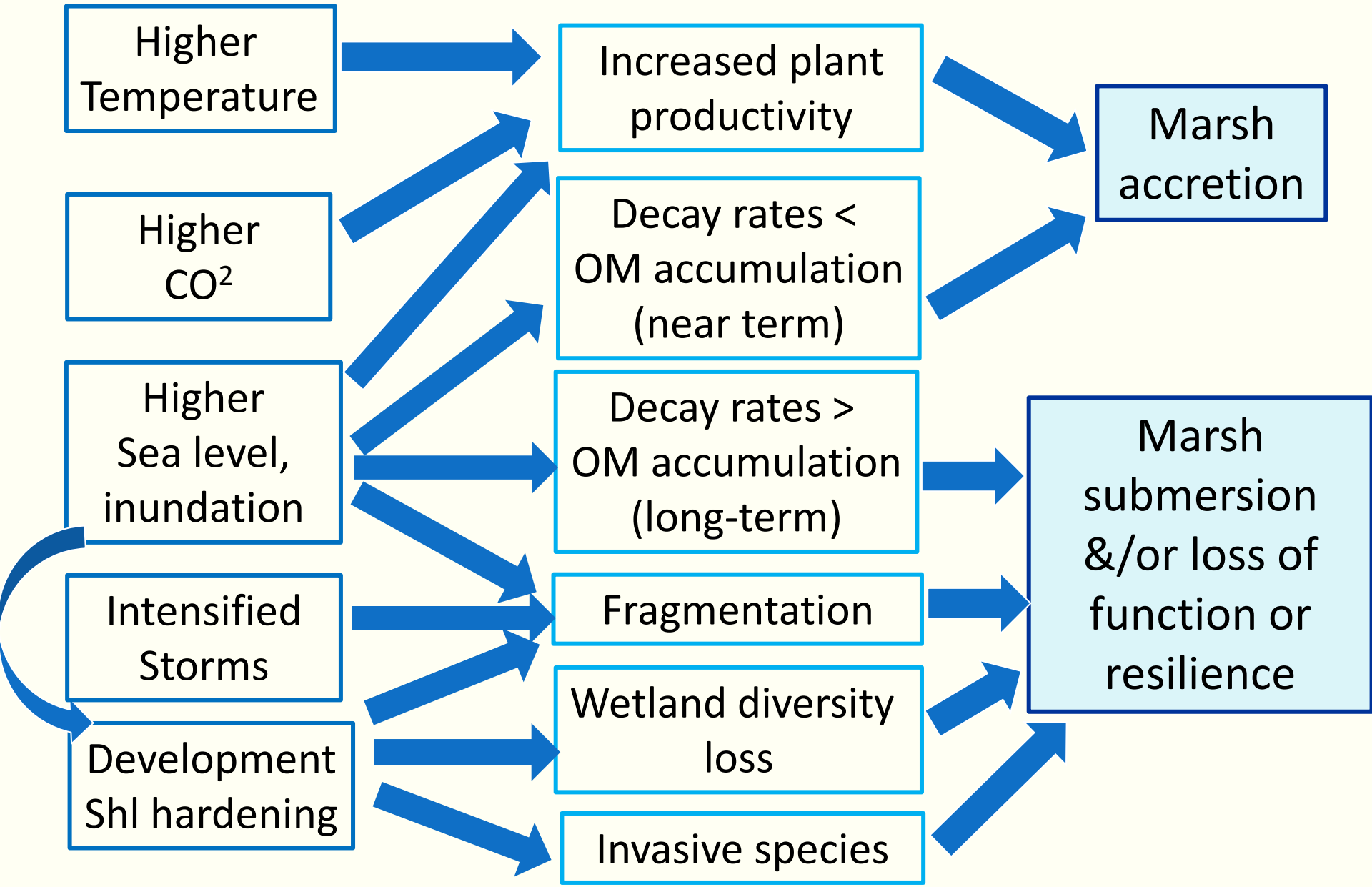
Under **elevated CO_2 & N** conditions:

- 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 & Megonical 2010

Nutrient pollution may increase marsh vulnerability to sea level rise

Multiple impacts on tidal marshes – short and long term

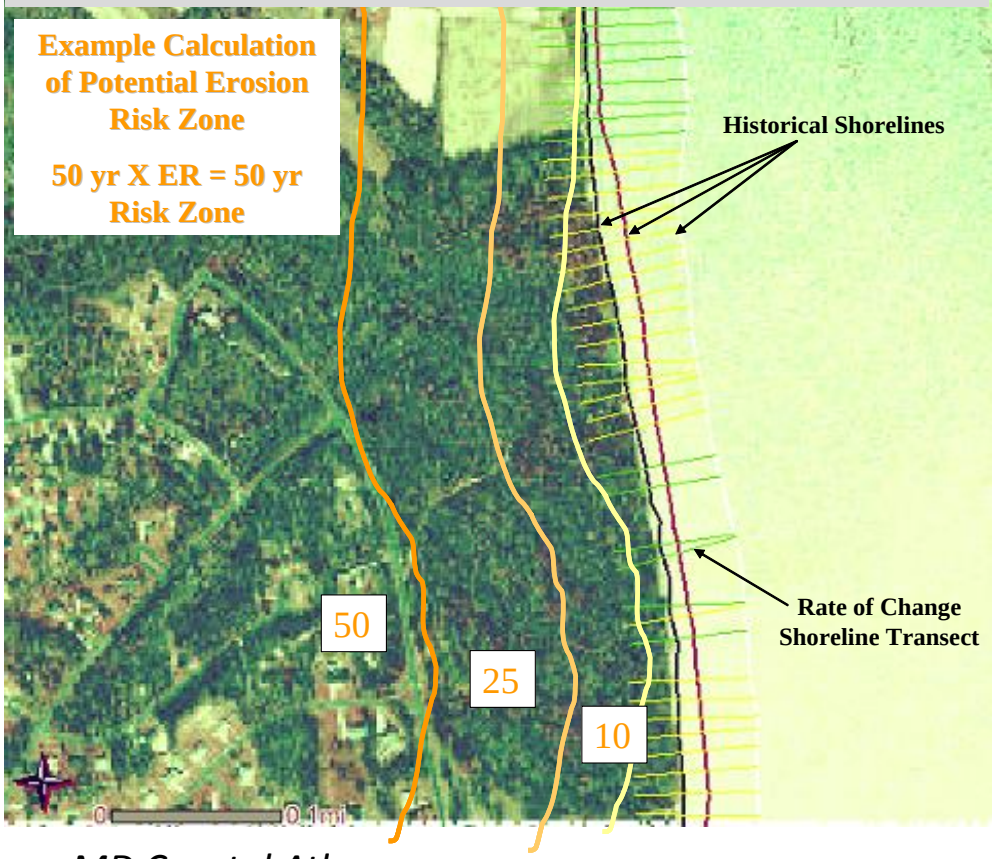


Improved regional models for restoration targeting

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

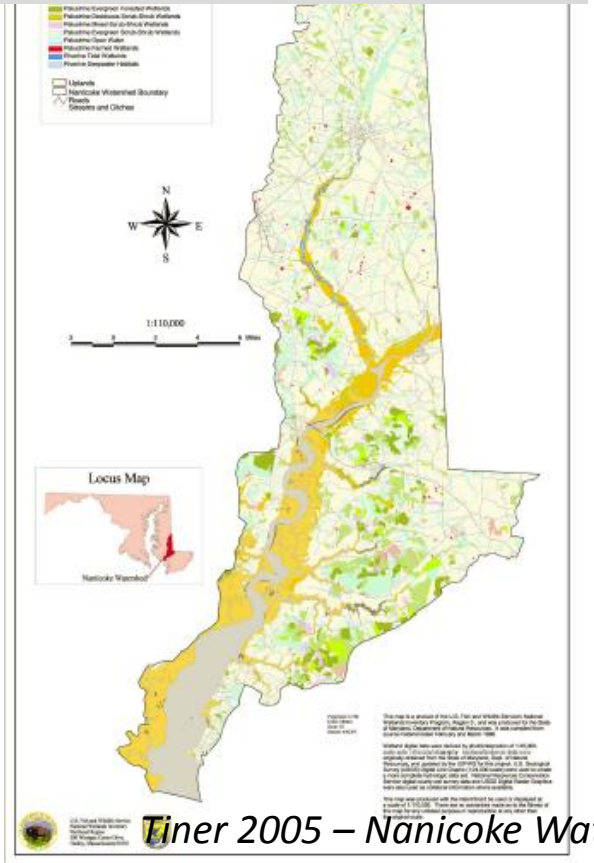
Examples of landscape level models integrating site or geomorphic descriptors

Erosion Vulnerability Assessment – Conceptual 50-year planning window



MD Coastal Atlas

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



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

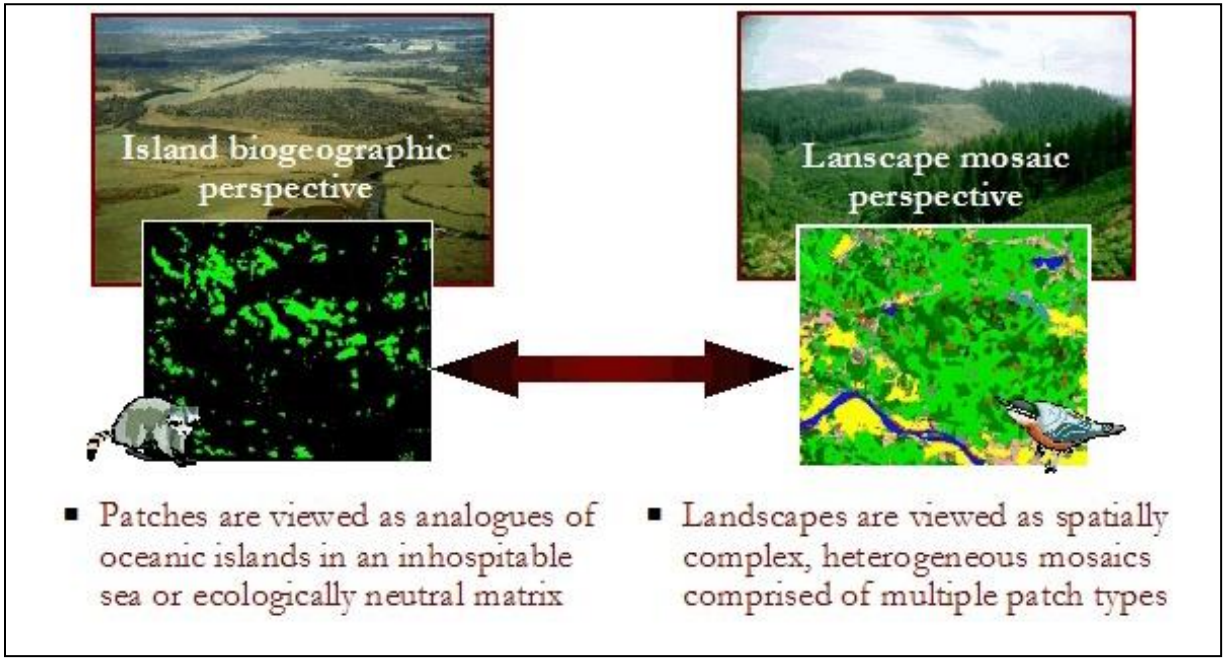


Figure: K. McGarigal

Structural component
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

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

Importance of landscape setting on coastal wetland ecosystems

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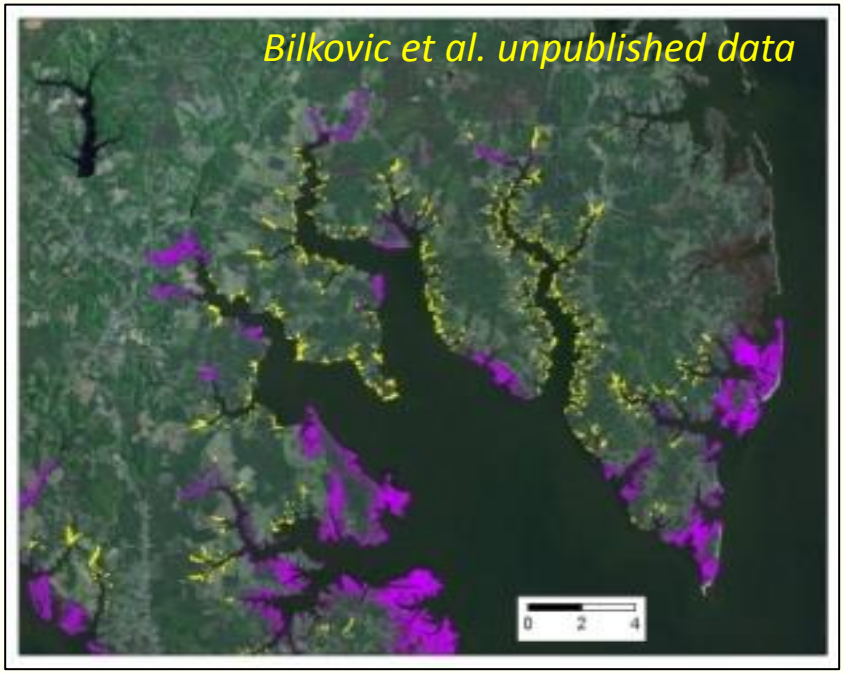
The extent to which landscape setting moderates tidal marsh connectivity & estuarine species diversity, composition, and distribution is currently unknown

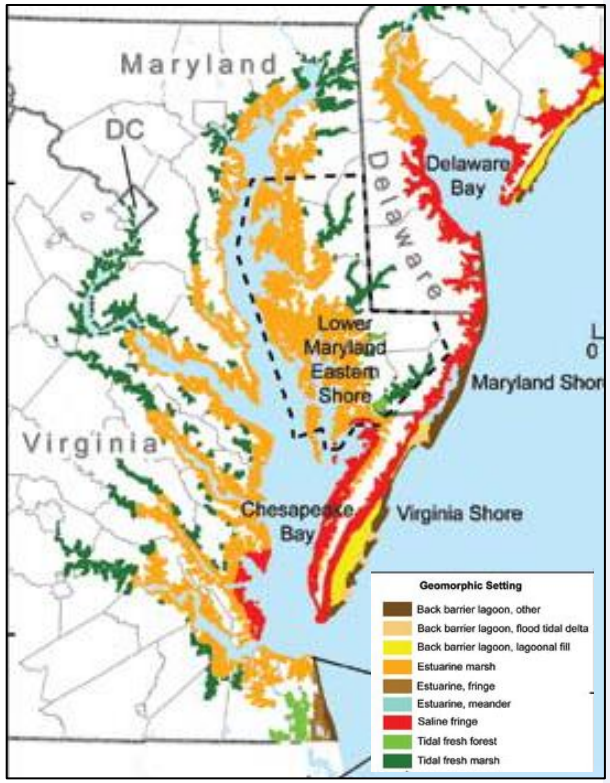


Clustering (fragmentation) patterns of marshes
Dispersed wetlands (yellow) tend to occur in areas of developed land use

- 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

Resiliency and Vulnerability



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.
  e.g., 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***
  e.g., interplay of wetland elevation, CO_2, 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 <u>the amount and functional loss</u> of wetlands*** and buffers throughout the Bay to development, erosion, flooding or sea-level rise

- ***Inventory of marsh creation*** associated with living shoreline approaches

Future Challenges & Strategies

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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