Climate Adaptation in the Delaware Estuary: Risks, Opportunities and Tough Choices

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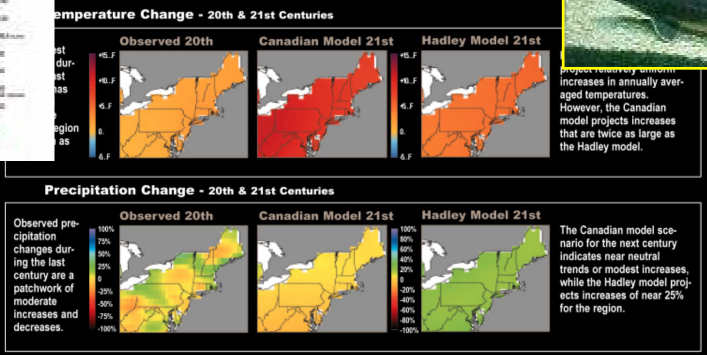
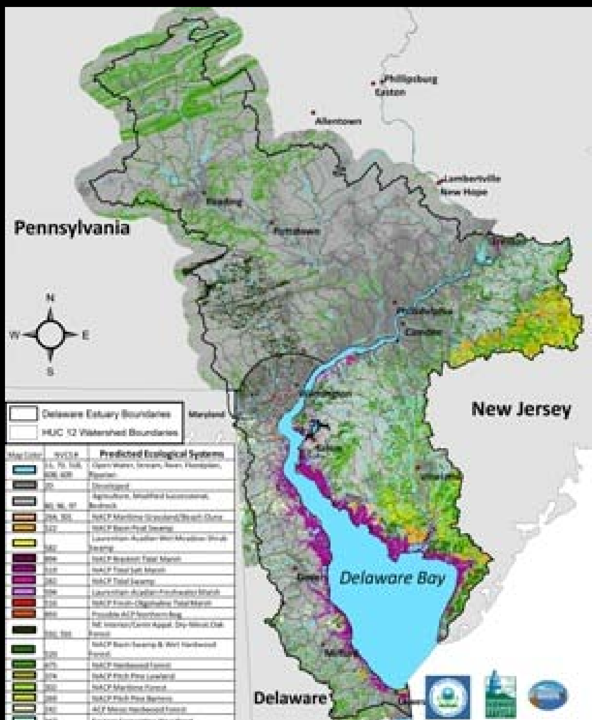


Climate Change in a Complex Landscape



The Working River

- 4th largest US urban center
- world's largest freshwater port
- 70% of east coast oil
- past and present industrial center

The Living Estuary

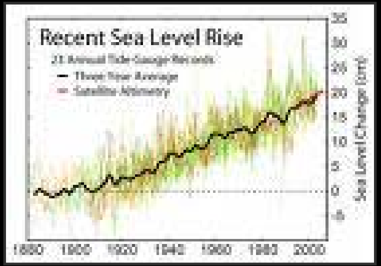
- Water fowl, finfish, shellfish
- Horseshoe crab population
- Extensive tidal marshes

Climate Change in the Delaware Estuary

1. Likely Physical Changes

Temp

Salinity



Sea Level Rise

Storms

2. Example Effects on Resources

Drinking Water

Marshes

Bivalves

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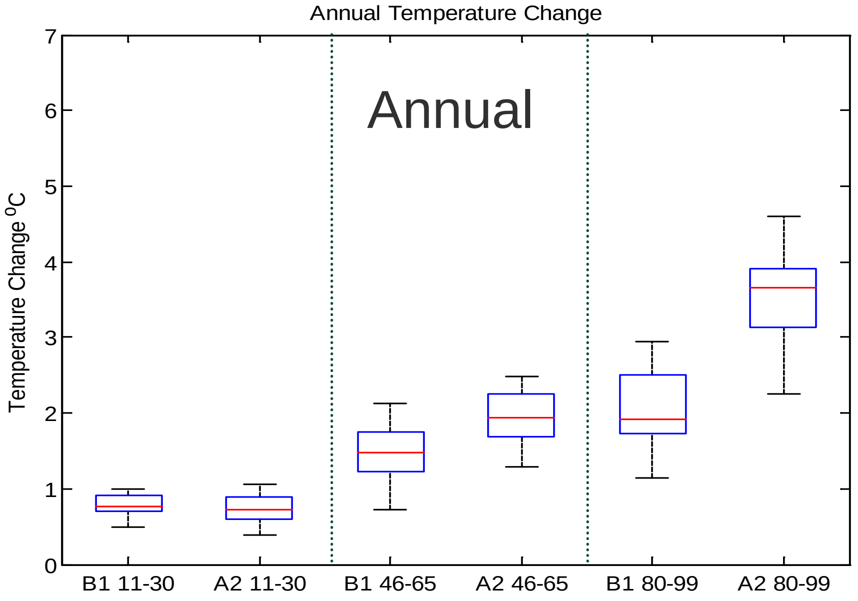
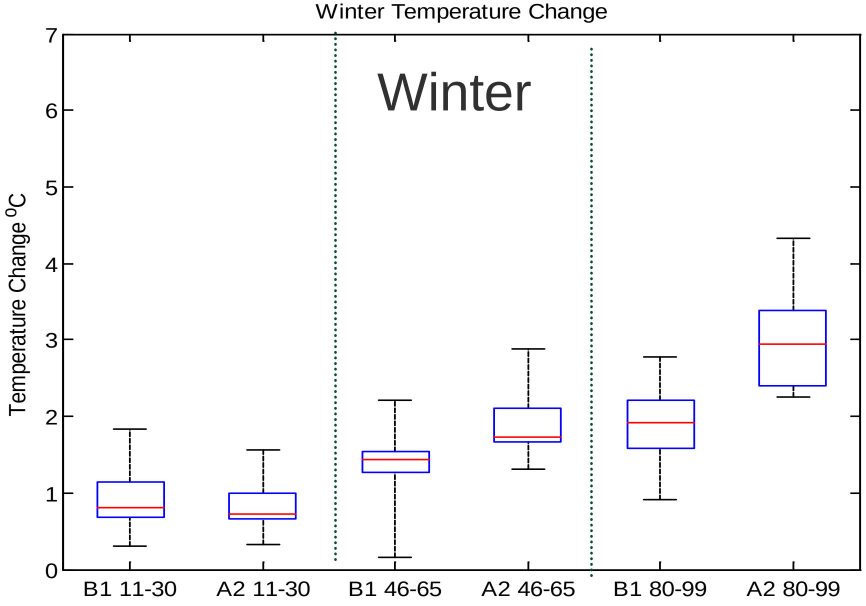
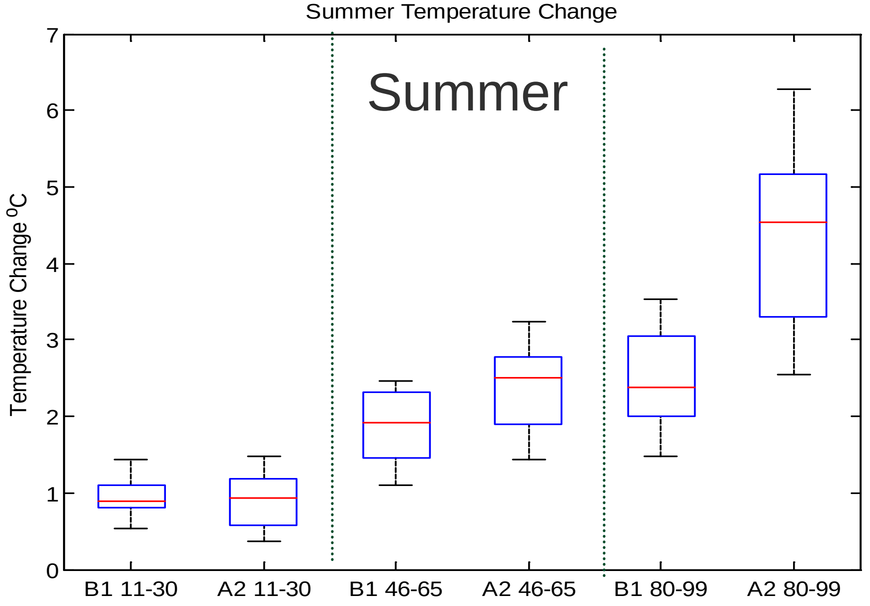
Temperature

- More warming in summer than winter
- Scenario differences minor until late century







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R. Najjar, PSU

Case Studies

Climate Ready Pilot Adaptation Planning

ID Vulnerabilities

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Ecological Valuation

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Adaptation Options

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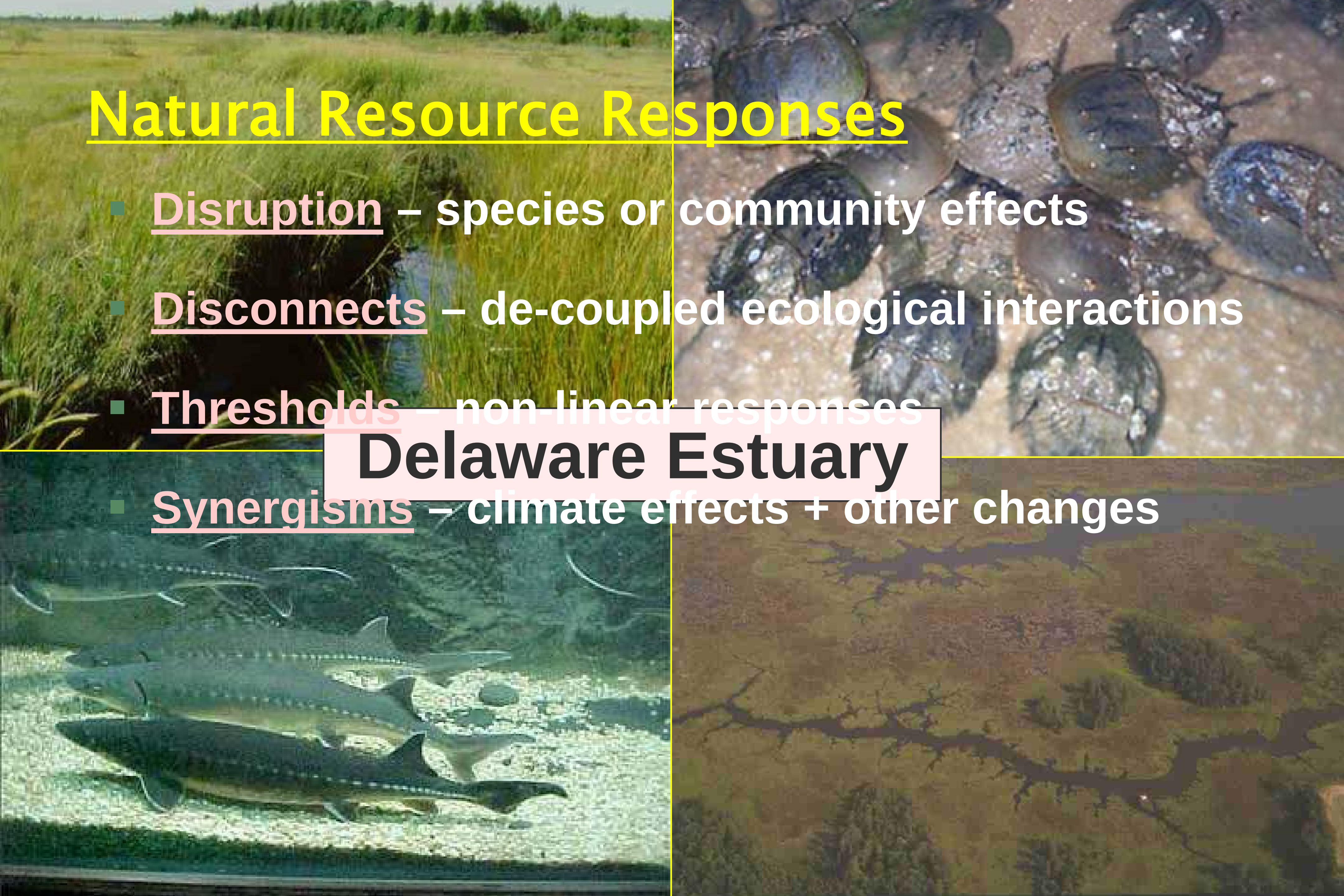
Recommendations and Reporting

Tidal Marshes

Bivalve Shellfish

Drinking Water



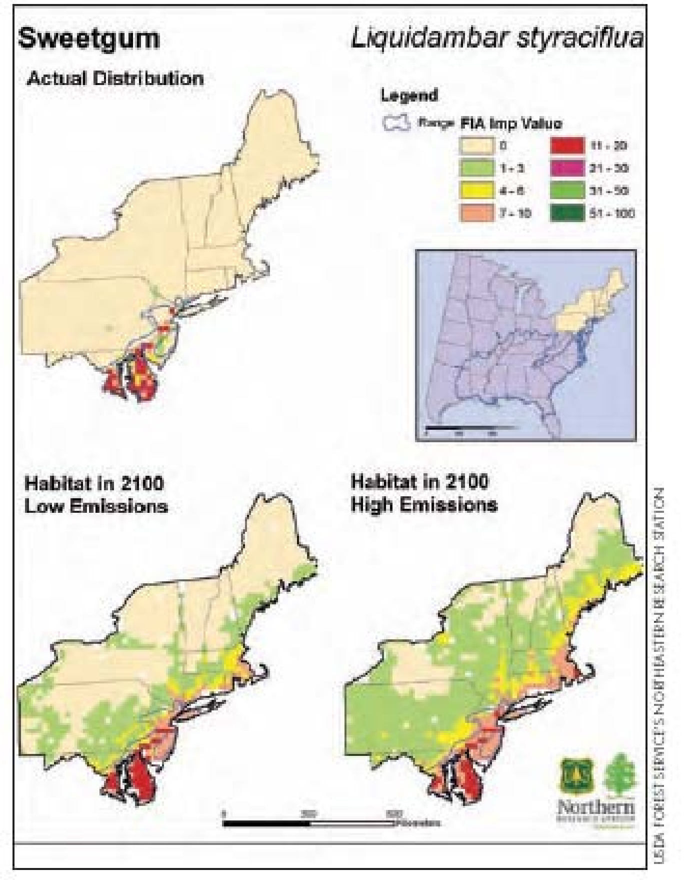
Natural Resource Responses

- **Disruption** – species or community effects
- **Disconnects** – de-coupled ecological interactions
- **Thresholds** – non-linear responses
- **Synergisms** – climate effects + other changes

Delaware Estuary

Disruption

Example: Species Range Shifts



Freshwater Mussels

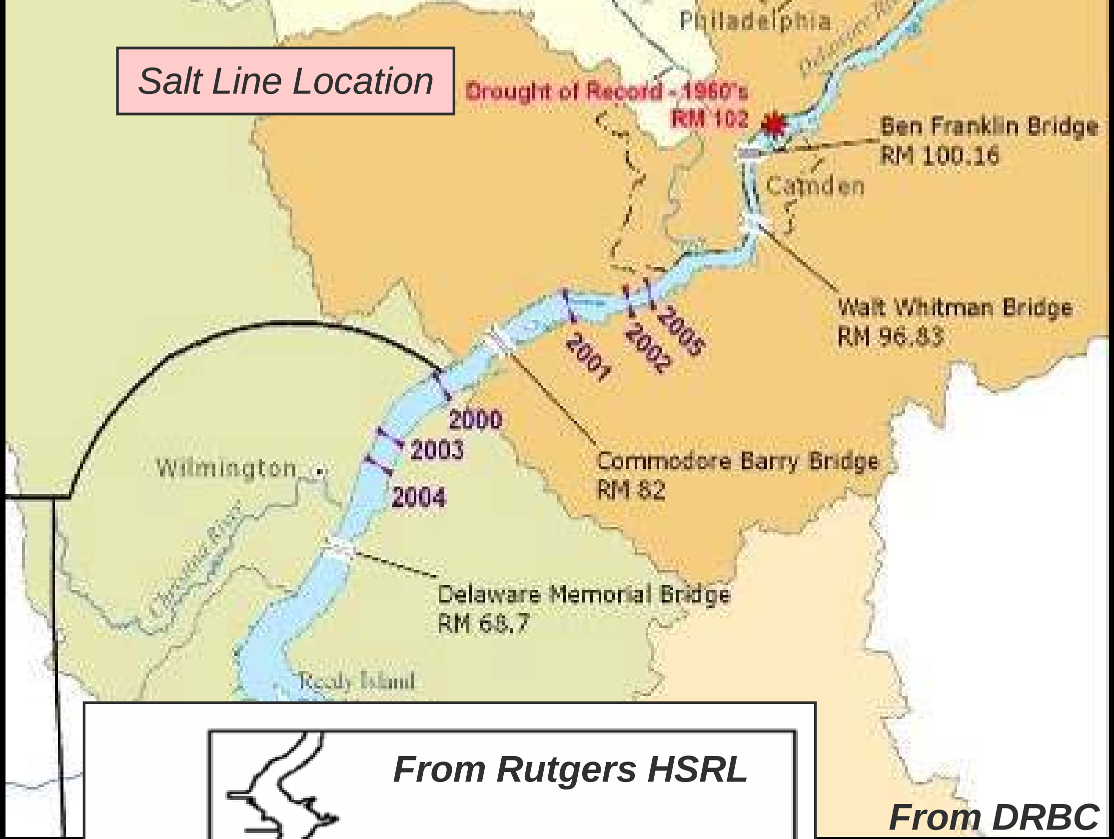
Patchy, Impaired	Rare	Extirpated
		
Elliptio complanata	*Strophitus undulatus*	*Alasmidonta heterodon*

		State Conservation Status		
Scientific Name	**Scientific Name**	**DE**	**NJ**	**PA**
ALASMIDONTA HETERODON	DWARF WEDGEMUSSEL	Endangered	Endangered	Critically Imperiled
ALASMIDONTA UNDULATA	TRIANGLE FLOATER	Extirpated ?	Threatened	Vulnerable
ALASMIDONTA VARICOSA	BROOK FLOATER	Endangered	Endangered	Imperiled
ANODONTA IMPLICATA	ALEWIFE FLOATER	Extremely Rare	no data	Extirpated ?
ELLIPTIO COMPLANATA	EASTERN ELLIPTIO	common	common	Secure
LAMPSILIS CARIOSA	YELLOW LAMPMUSSEL	Endangered	Threatened	Vulnerable
LAMPSILIS RADIATA	EASTERN LAMPMUSSEL	Endangered	Threatened	Imperiled
LASMIGONA SUBVIRIDIS	GREEN FLOATER	no data	Endangered	Imperiled
LEPTODEA OCHRACEA	TIDEWATER MUCKET	Endangered	Threatened	Extirpated ?
LIGUMIA NASUTA	EASTERN PONDMUSSEL	Endangered	Threatened	Critically Imperiled
MARGARITIFERA MARGARITIFERA	EASTERN PEARLSHELL	no data	no data	Imperiled
PYGANODON CATARACTA	EASTERN FLOATER	no data	no data	Vulnerable
STROPHITUS UNDULATUS	SQUAWFOOT	Extremely Rare	Species of Concern	Apparently Secure

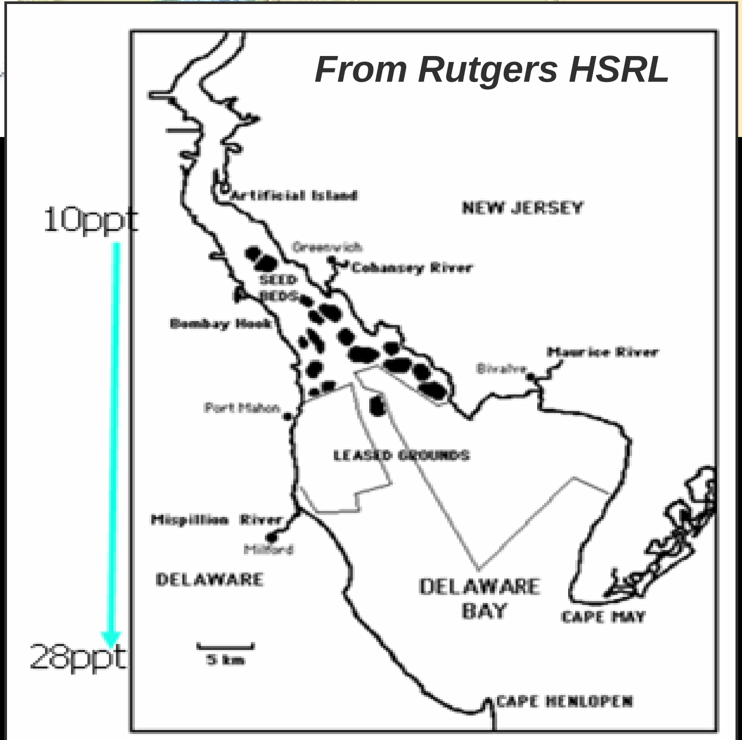
Disruption

Oyster Disease and Salinity

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



From DRBC

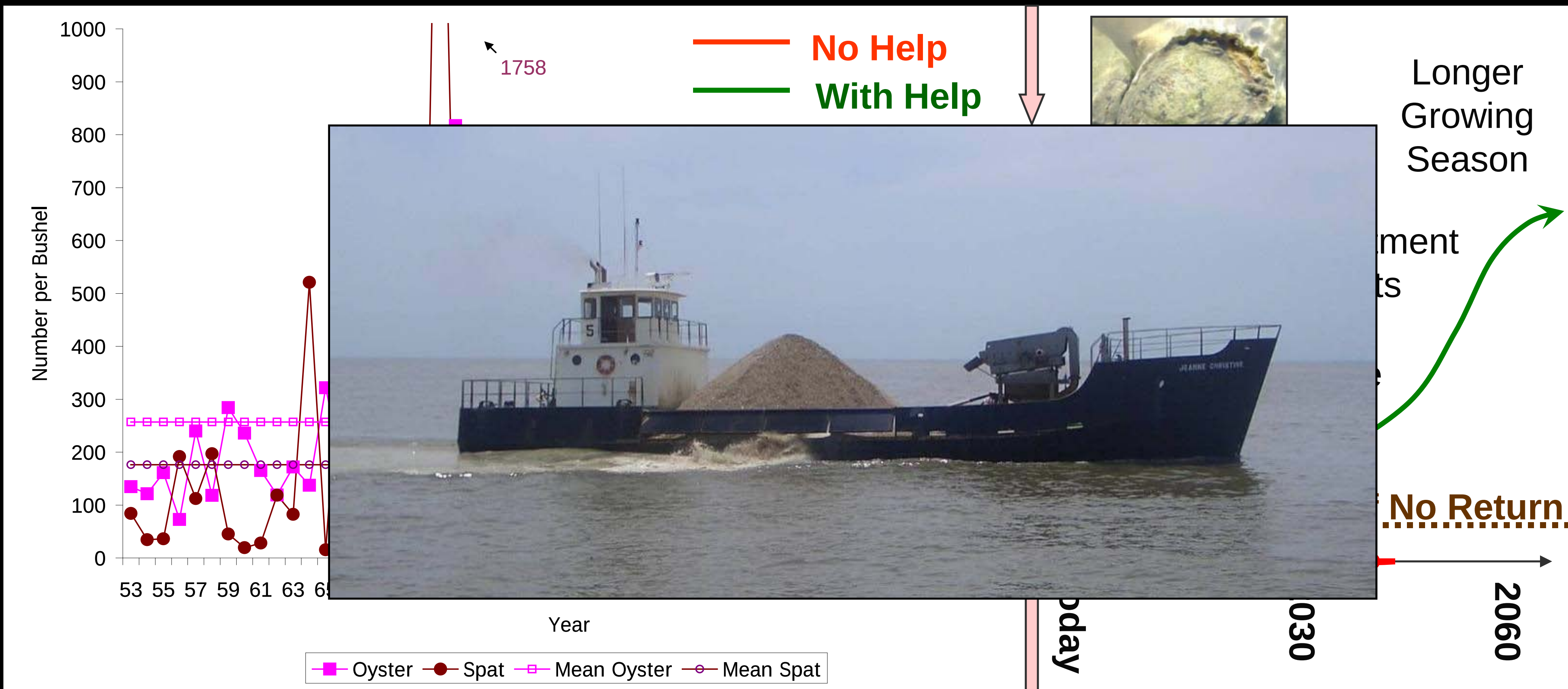


From Rutgers HSRL

Oyster Management

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

DK 10



Historical data from Rutgers Haskin Shellfish Laboratory

Elliptio complanata

Geukensia demissa

Crassostrea virginica

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Bivalve Vulnerability?

Oyster Reefs

- Salinity Driven Disease Epizootics
- Others: Food, pH

Salt marsh Mussel Beds

- Loss and Degradation of Wetland Habitat
- Others: Food, PH

Freshwater Mussel Beds

- Range Shifts with No Dispersal
- Habitat Degradation (T, salinity, pH, fish hosts)

Mussels Are Habitat INITIATIVE
Restoring Our Nation's Water Quality

Clean Water

Slide from R. Neves, VA Tech

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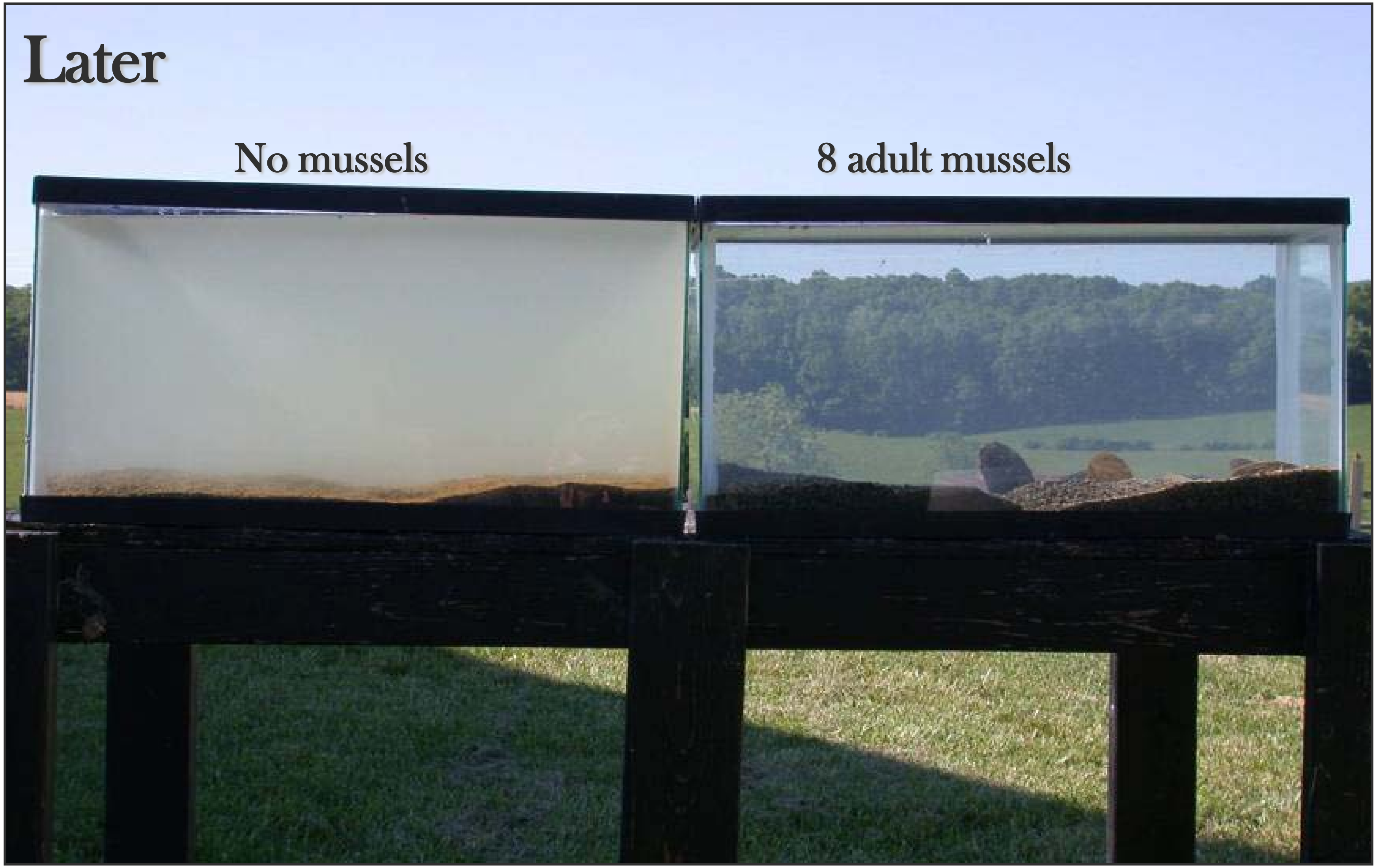
Biofiltration Potential



Slide from R. Neves, VA Tech

Ecosystem Engineers

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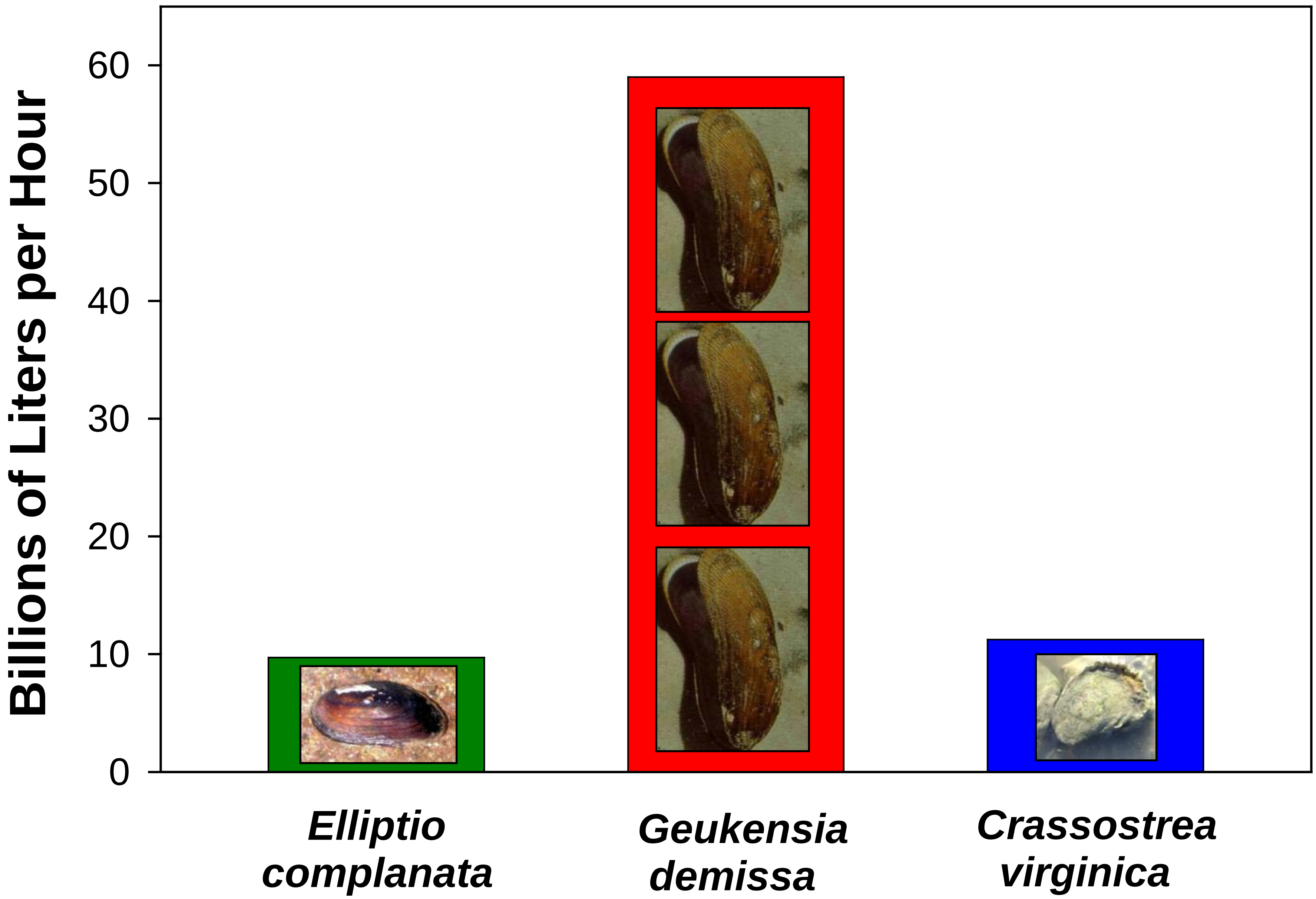
Population-Level Water Processing



Bivalve Natural Capital		Oysters	Marsh Mussels	FW Mussels
Millennium Ecosystem Assessment Categories	***Specific Services/Values***	***Relative Importance Scores***		
Provisioning: Food & Fiber	***Dockside Product***	✓✓✓		✓
Regulating	***Shoreline & Bottom Protection***	✓✓		
	Shoreline Stabilization	✓✓	✓✓✓	✓✓
Supporting	[illegible]	[illegible]	[illegible]	[illegible]
Cultural/ Spiritual/ Historical/ Human Well Being	***Waterman Lifestyle, Ecotourism***	✓✓		
	Native American	✓✓		✓✓✓
	Watershed Indicator	✓✓✓	✓✓	✓✓✓
	Bio-Assessment	✓✓✓	✓✓	✓✓✓

Shellfish Tough Decisions

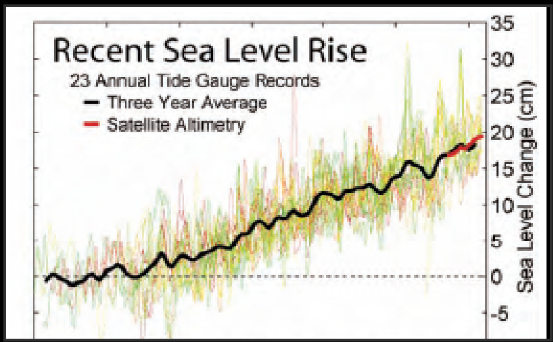
- Which species and associated ecosystem services can be sustained?
- Which should we invest in? (since funding will always be too limited)

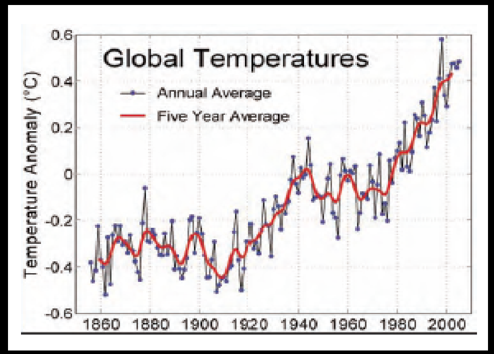
Disconnects *(Hypothetical Example)*

Decoupling of Horseshoe Crab Spawning and Shorebird Migration

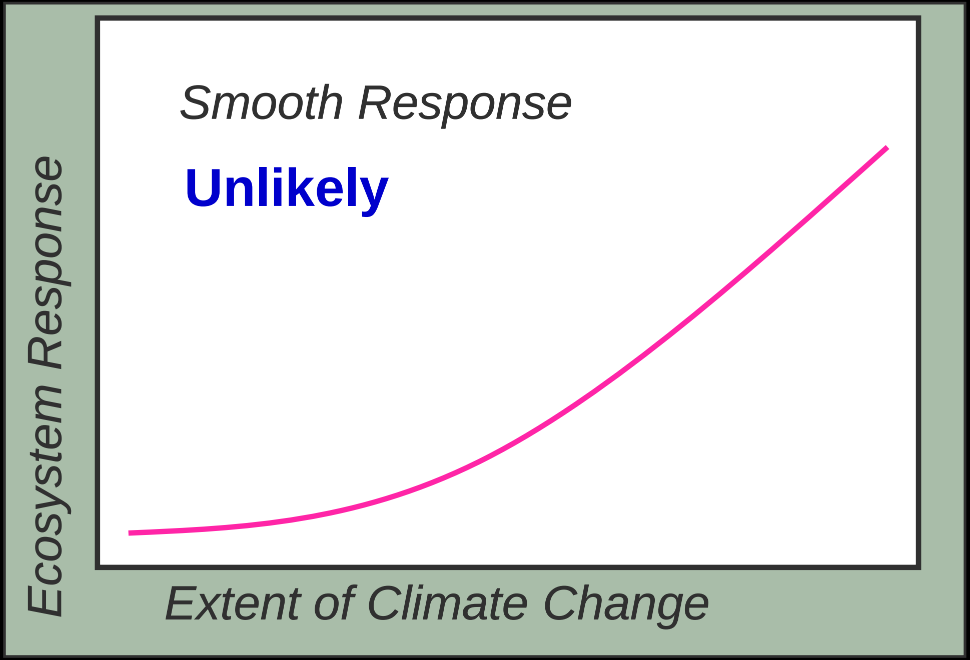
Website slides are from the Delaware Shorebird Project and the Horseshoe Crab Conservation Network

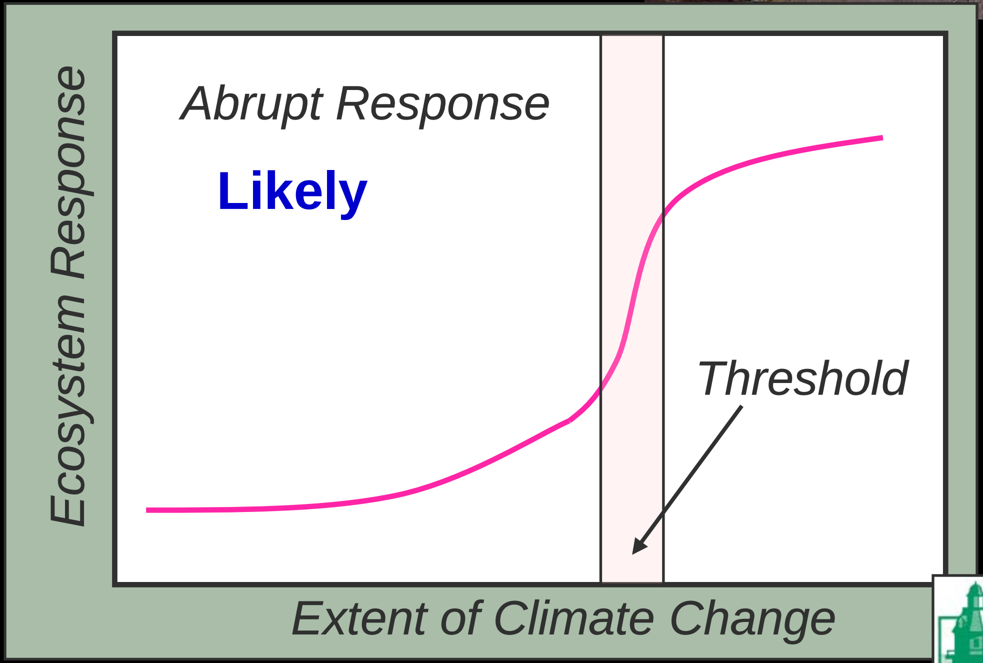
Thresholds (Non-linear Responses)





Tolerance Limits Breached





Slide adapted from Carlos Duarte

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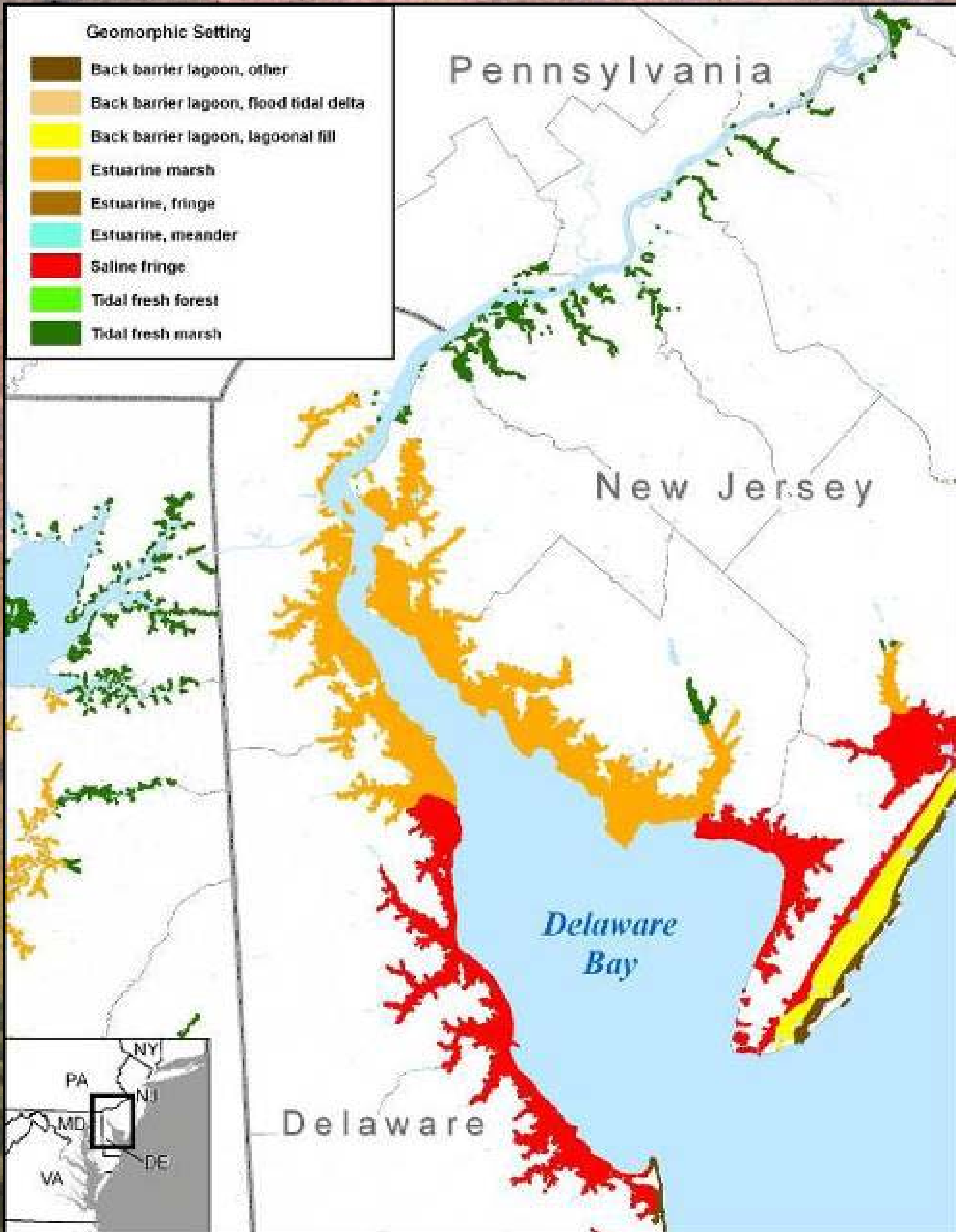
Tidal Wetlands



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Tidal Wetlands

A Signature Trait of System

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

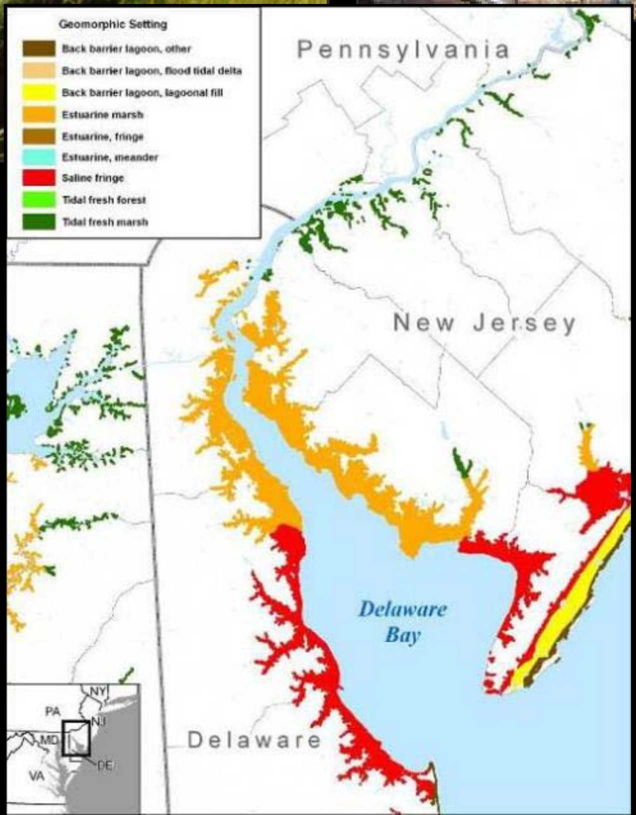
<u>Ecological Values</u>:

Structural

biodiversity
habitat for fish and wildlife
nurseries for imperiled taxa

Functional

food web
water quality
flood protection



Wetland Ecosystem Services

Milenium Ecosystem Assessment 1º Service	2º Service	3º Service	4º Service
Provisioning	Food	Fisheries Support	
		Algae and invertebrate production	
	Genetic Materials	Phragmites control research	
	Biochemical Products	Research in Antifungal Agents	
	Fiber and Fuel	Cellulose stock	
Regulating	Sequestration	Carbon	Carbon Caps, mitigation
	Sediment Stabilization	Erosion control	Meet TMDLs for sediment
	Storm Protection/ Wave Attenuation/ Flood Protection	Protect Property Values and infrastructure	
	Gas Regulation	Carbon Sequestration	
		Oxygen production	
	Water Quality	Sequestration, Filtering	TMDLs: Nutrients, Pollutants
Cultural/ Spiritual Human Well Being	Recreation	Bird watching, hunting, boating	
	Spiritual and Inspirational	Native American Uses	
	Educational	University reasearch & school projects/trips	
	Aesthetic Value	Landscape pictures, paintings, open space	
Supporting	Habitat	Wildlife, shellfish, insects	
	Biodiversity	Maintain Plant Communities	
	Production	Primary Production	
	Water Cycling/Hydrologic Regime		
	Nutrient Cycling/Biogeochemical Processes	Maintain trophic cycles, soil building	

Tidal Wetlands

Concerns:

Degradation

Conversion and Loss

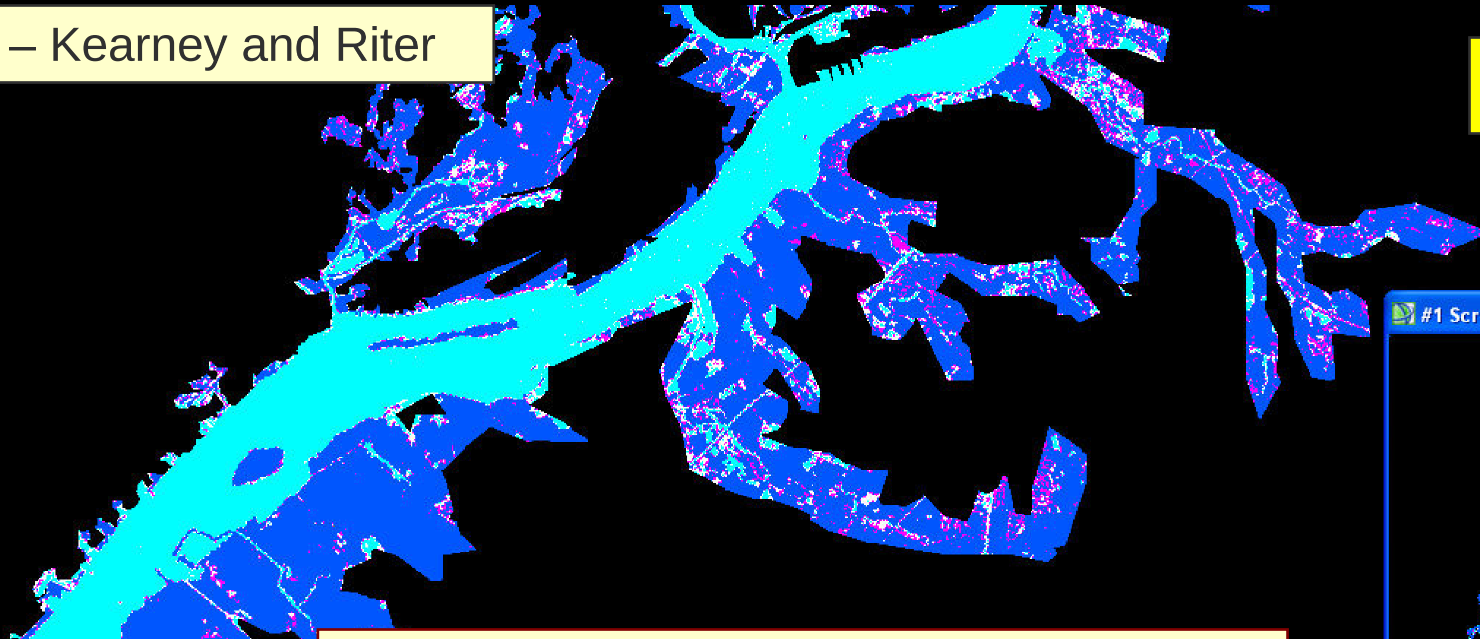
Sea Level & Salinity

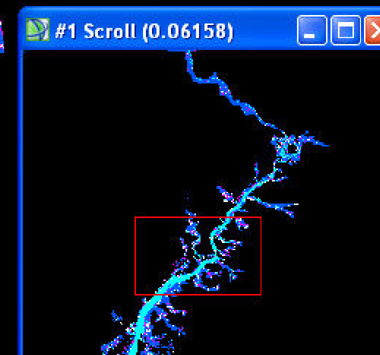
Storms

Sediment budget

Satellite Data – Kearney and Riter

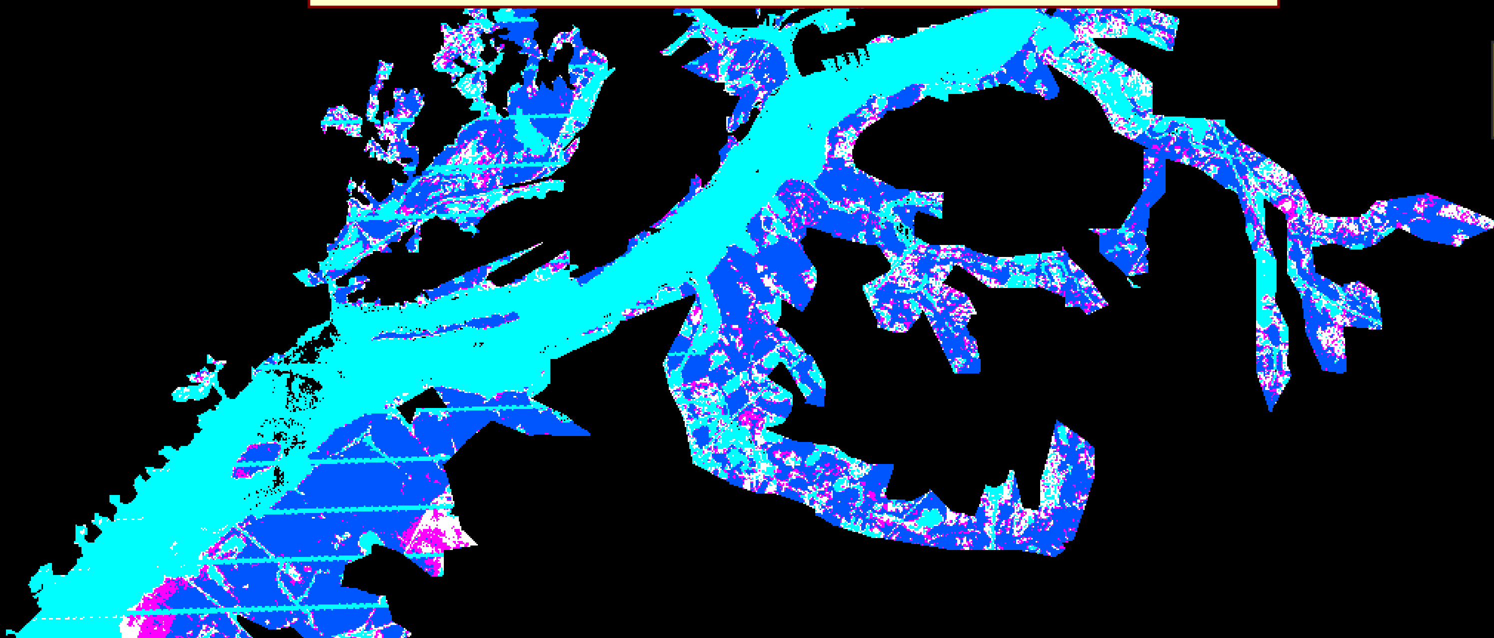
1993

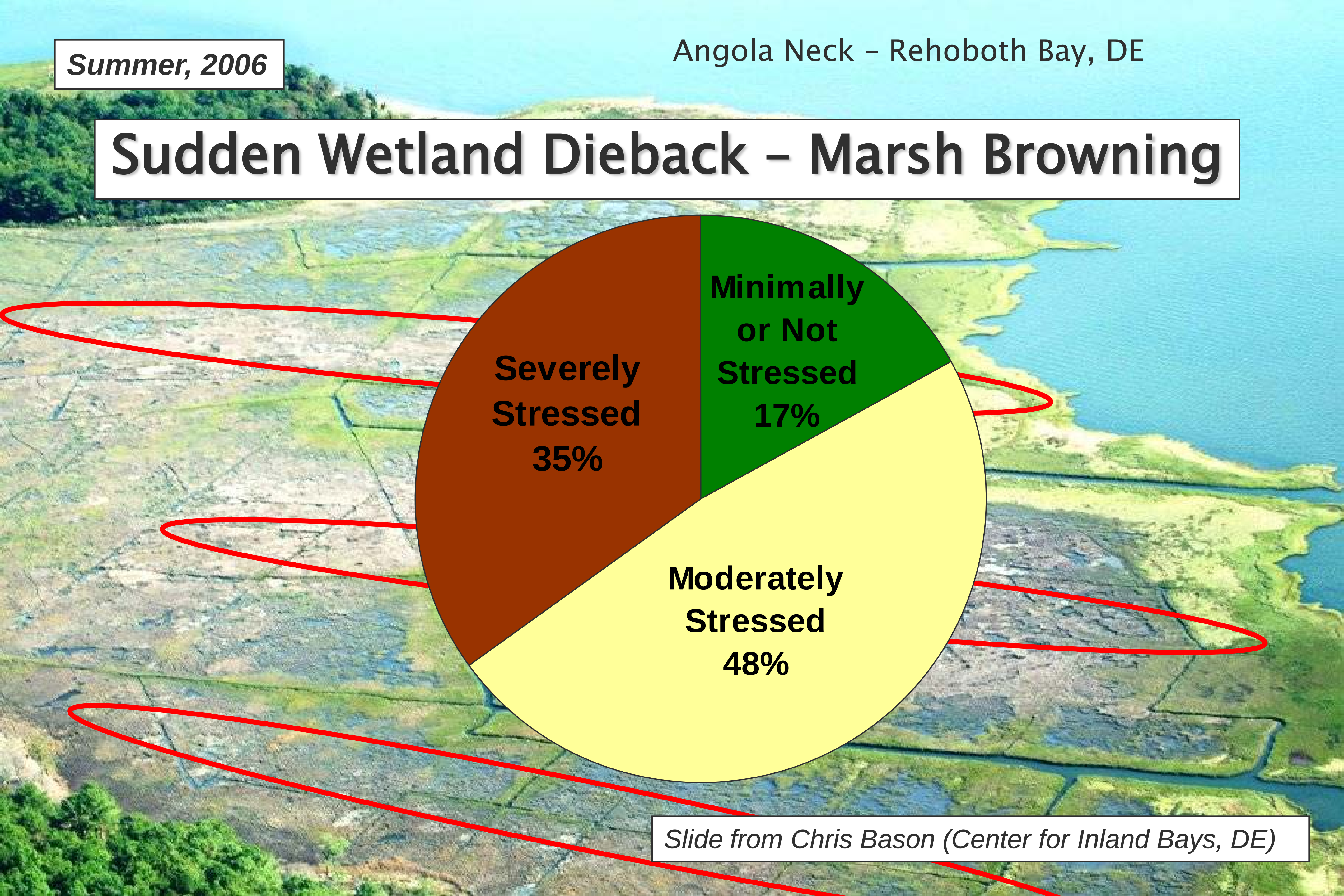




Percent vegetation near Philadelphia airport

2006





Summer, 2006
Angola Neck – Rehoboth Bay, DE
Sudden Wetland Dieback – Marsh Browning
Minimally or Not Stressed 17%
Severely Stressed 35%
Moderately Stressed 48%
Slide from Chris Bason (Center for Inland Bays, DE)

Tidal Wetland Vulnerability?

Freshwater Tidal Marshes

- Salinity Rise Causes Conversion to Brackish
- Barriers to Landward Migration
- Others: Tidal Range, Seasonal Drying/Wetting

Salt Marshes

- Sea Level Rise, Subsidence and Sediment Deficits Lead to Drowning
- Storms and Wind Wave Erosion
- Barriers to Landward Migration
- Others: Seasonal Wetting/Drying, Invasives

Tidal marshes need to move:

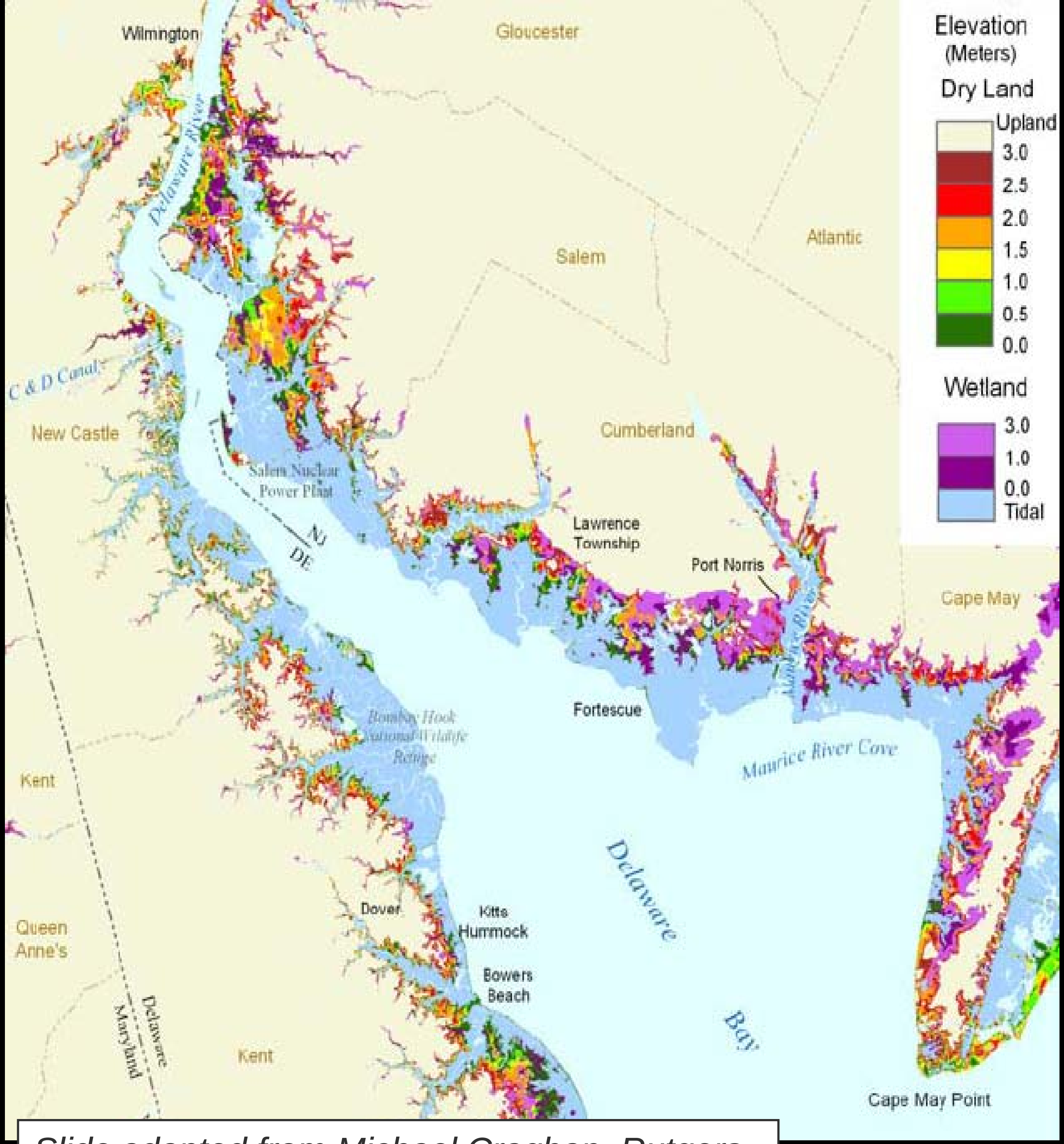
1) <u>horizontally</u>
(landward)

and/or

2) <u>vertically</u>
(to keep pace)

Can they do it?

Where?



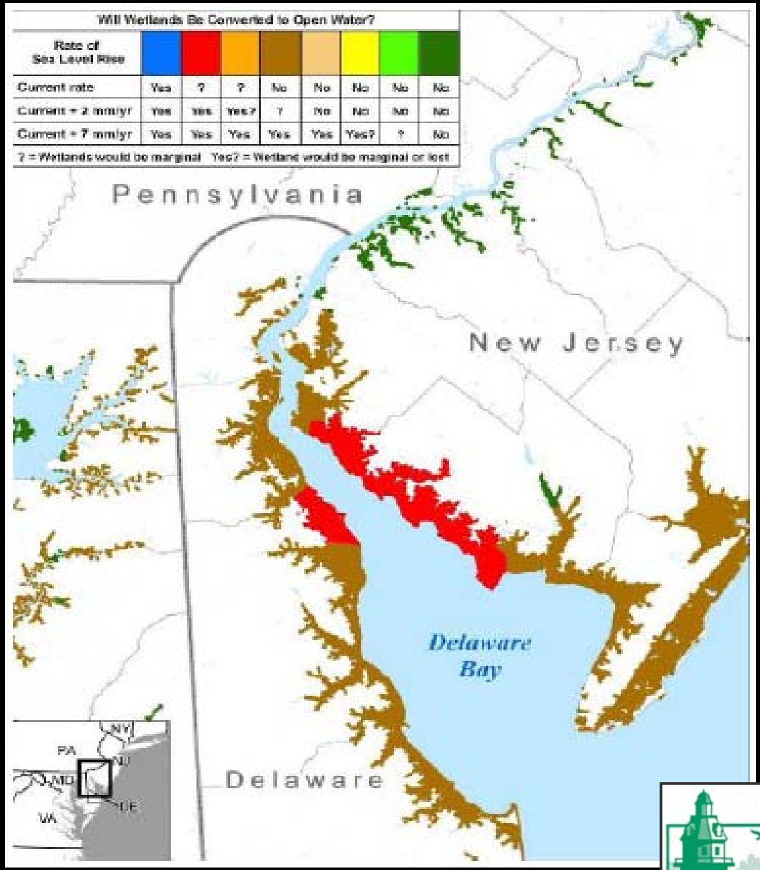
Slide adapted from Michael Craghan, Rutgers

Tidal Wetlands Adaptation Planning

__Goal__: Maximize long-term ecosystem health and resiliency

Will Wetlands Be Converted to Open Water?								
Rate of Sea Level Rise	(blue)	(red)	(orange)	(brown)	(tan)	(yellow)	(light green)	(dark green)
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

? = Wetlands would be marginal   Yes? = Wetland would be marginal or lost



__Wetland Tough Choices__

- Where will wetlands will be converted to open water?
- Where can we save them ?
- Where is strategic retreat the best option?

Synergisms – Climate & Other Changes Together

THE ROYAL SOCIETY

Received 24 July 2002
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Climate change and habitat destruction: a deadly anthropogenic cocktail

J. M. J. Travis

"… The interaction between climate change and habitat loss might be disastrous. During climate change, the habitat threshold occurs sooner. Similarly, species suffer more from climate change in a fragmented habitat."

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Drinking Water Vulnerabilities to Climate Change

Climate Change Will Bring:	Resultant Effects	These Effects will Impact Water Systems Through:	
Warmer Temperatures & Weather Fluctuations	increased precipitation *(rainfall expected to increase mainly in the Northern and Eastern parts of the country)*	increased river discharge and stream flow	1, 2, 6
		increased runoff	1, 2, 6
		increased groundwater levels	1, 2, 6
		extreme flooding	1, 2, 4, 6, 10
		changes in watershed vegetation and forest cover	1, 6
	decreased precipitation *(rainfall expected to decrease mainly in the Southwest, but could be short-term periods in the East)*	decreased river discharge and stream flow	3, 6, 7, 9
		decreased groundwater levels	3, 6, 7, 9
		increased frequency of short-term drought	3, 6, 8, 9
		increased number and intensity of wild fires	1, 6, 9, 10
		changes in watershed vegetation and forest cover	1, 6
	increased frequency and magnitude of storms	lightning and electrical disturbances	5, 10
		storm surge	1, 2, 4, 5, 6, 8, 9, 10
	warmer water temperatures	disruptions to aquatic ecosystems (including wetlands)	6, 7, 8
		sea level rise	1, 4, 5, 6, 7, 8
	thawing permafrost, reduced ice cover and snow pack, and reduction in freezing season	flooding	1, 2, 4, 6, 10
		sea level rise	1, 4, 5, 6, 7, 8
		decreased river discharge and stream flow (spring and summer)	3, 6, 7, 9
		changes in watershed vegetation and forest cover	1, 6

Leading to Issues with the Drinking Water Supply:	
1	erosion of infrastructure
2	overflowing reservoir capacity
3	decreased supply in reservoirs
4	flooding of treatment plants and pump stations
5	inoperable treatment plants
6	degraded water quality of source water and finished water (turbidity, dissolved oxygen, dissolved organic carbon, taste and odor compounds, dbp formation etc.)
7	upward salt line movement
8	saltwater intrusion in coastal aquifers and freshwater habitats
9	increased demand for supply
10	power outages and issues with customer supply

Added Complexity

- Ecological Flows
- Land Use Change
- Dredging
- Spills, NRDA
- Withdrawals
- Wind Farms
- Inunc
- Deve
- Emer

Drinking Water Tough Questions

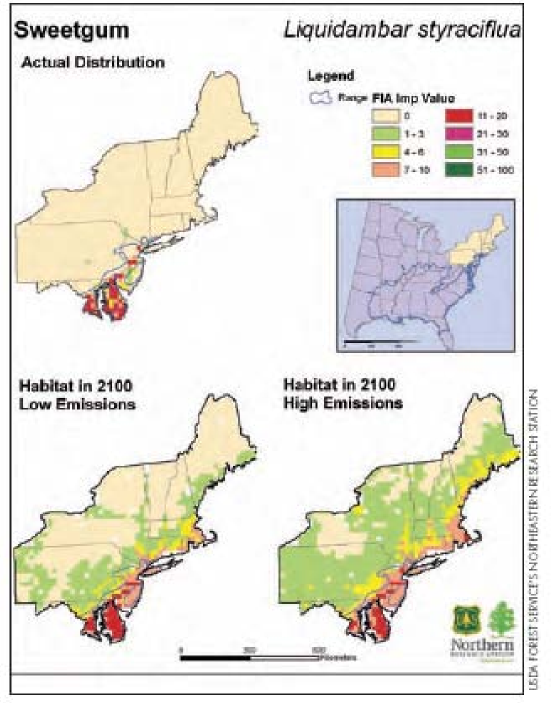
- How can we maintain low salinity in the upper estuary?
- Will more reservoirs be needed, which have their own issues?
- Where should infrastructure be protected from SLR versus strategic retreat?

2004

Principle: "Restore" for the Future

DK 32

- *Forecast future sustainable states*
- *Smart "restoration" = climate adaptation*



- *Shift policy and management paradigms*

Next Steps?

1. Science

Strengthen adaptation plan with more rigorous monitoring and predictive modeling for likely consequences

2. Local Relevance

Develop high resolution geospatial–based planning tools that guide local actions, nested within a watershed-basis

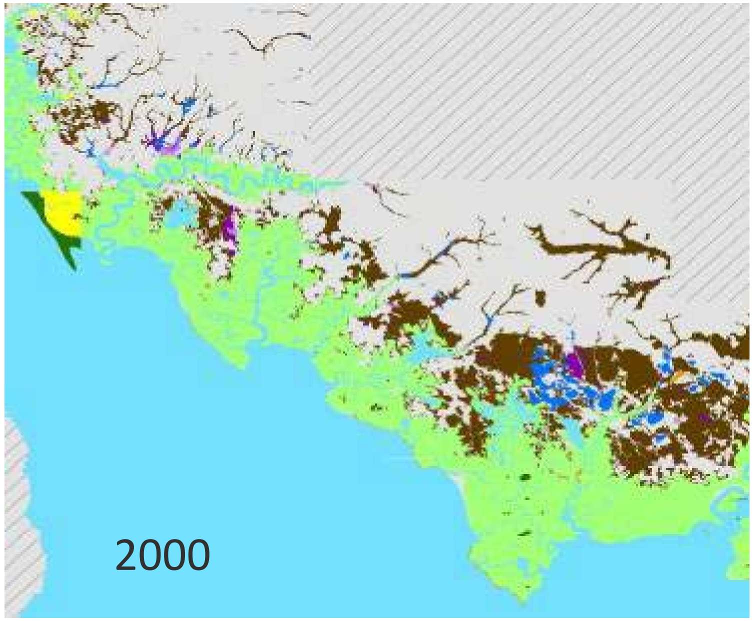
3. Natural Capital

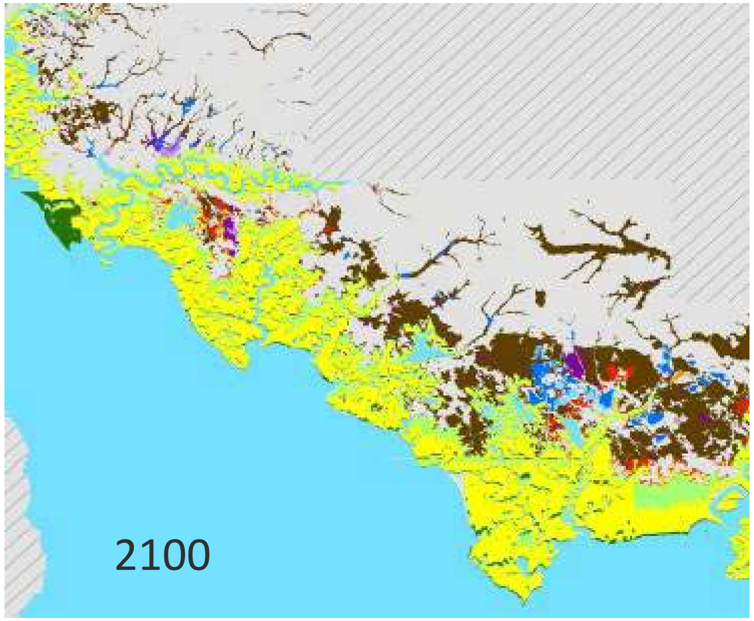
Enhance decision tools with “bang for the buck” estimates of environmental uplift outcomes for various adaptation tactics

4. Collaboration

Implement a coordinated strategy for advancing science, policy and on-the-ground actions

Projecting the Fate of Tidal Wetlands and Their Ecosystem Services Using SLAMM Modeling - *Industrial Economics*





<u>Areas for Model Improvement</u>

- Erosion/Accretion Rates
- Better Vegetation Classifications
- Marsh Drowning Mechanisms

– End –

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Climate Adaptation Planning

ID Vulnerabilities

↓

Ecological Valuation

↓

Adaptation Options

↓

Recommendations and Reporting

Work Groups

Climate Adaptation Work Group (CAWG)

STAC-affiliated; Co-Chairs: Najjar & Kreeger

Tidal Wetland Sub-group

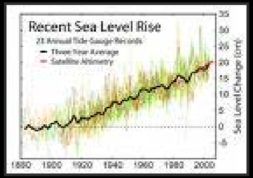
Velinsky & Kreeger

Shellfish Sub-group

Kraeuter & Kreeger

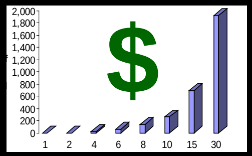
Drinking Water Sub-group

Connolly



Predications & Modeling Team

Najjar



Natural Capital Team

Cole

Climate Adaptation Planning

PDE:	**Climate Ready Pilot**
DRBC:	**Flooding, Inundation, Salinity**
PWD:	**Drinking Water**
PA:	**Energy, Forests**
NJ:	**Carbon Sequestration, Air**
DE:	**Sea Level Rise, Inundation**

DE Estuary Climate Summit?

Ecosystem Services in PDE Science