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

Danielle Kreeger
Science Director

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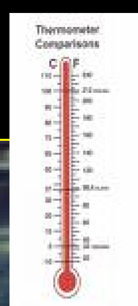

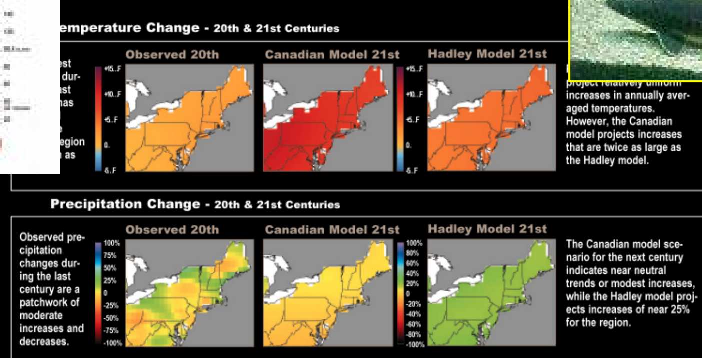

The Partnership for the Delaware Estuary

One of 28 EPA NEPs

Tri-state, NGO

Coordination, Education, Restoration and Science Advancement

Third Party Science and Technical Oversight and Gap-Filling, multi-sector STAC

PARTNERSHIP FOR THE DELAWARE ESTUARY, INC

Along the Christina River Wilmington, DE

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ESTUARY NEWS

NEWSLETTER OF THE PARTNERSHIP FOR THE DELAWARE ESTUARY: A NATIONAL ESTUARY PROGRAM

Climate Change Hits Home

By Kathy Klein, Executive Director, Partnership for the Delaware Estuary

As I was driving to work one recent morning, thinking about writing this article and listening to National Public Radio, I learned that the Bulletin of Atomic Scientists has concluded that the threat posed by climate change is second only to that posed by nuclear weapons. Although I am actually relieved that climate change is finally getting the attention it deserves, I am also keenly aware that time continues to tick away as world leaders and other policymakers explore ways to address global warming and its environmental impacts.

Being the visual person that I am, I can't seem to forget the recent image in the media of a lone polar bear floating on a piece of ice that had broken off the Arctic icecap as a result of melting. What most people do not realize, however, is you do not have to go to the Arctic to see the results of global warming. For many years, scientists in the Delaware Estuary have noted the dieback of upland

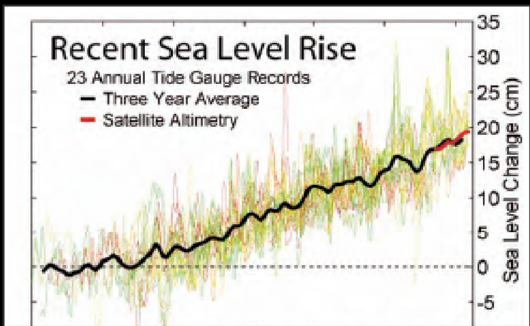
tant to realize, however, that there are small steps each one of us can take in our daily lives that, when multiplied, can make a meaningful impact.

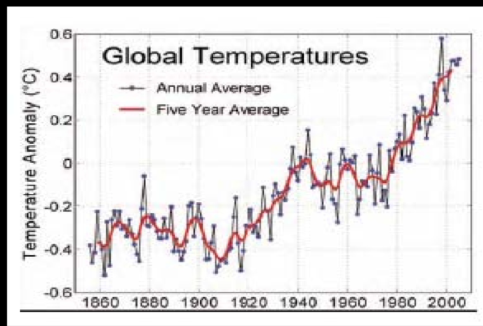
One of these small steps is the use of compact florescent light bulbs (CFLs). CFLs use up to 75 percent less energy than regular incandescent light bulbs while lasting approximately eight times longer, and this results in less production of greenhouse gas emissions, air pollution, and toxic waste. The average CFL will save its owner at least $55 in energy costs over its lifetime. If every U.S. household replaced one bulb with a CFL, it would have the same impact as removing 1.3 million cars from the road.

I love a challenge and I hope you do too. Therefore, I would like to challenge the readers of "Estuary News" to make the switch at home, in at least one light fixture, from an incandescent light bulb to a CFL. If you already use CFLs in your home, why not make the

Ecological Responses

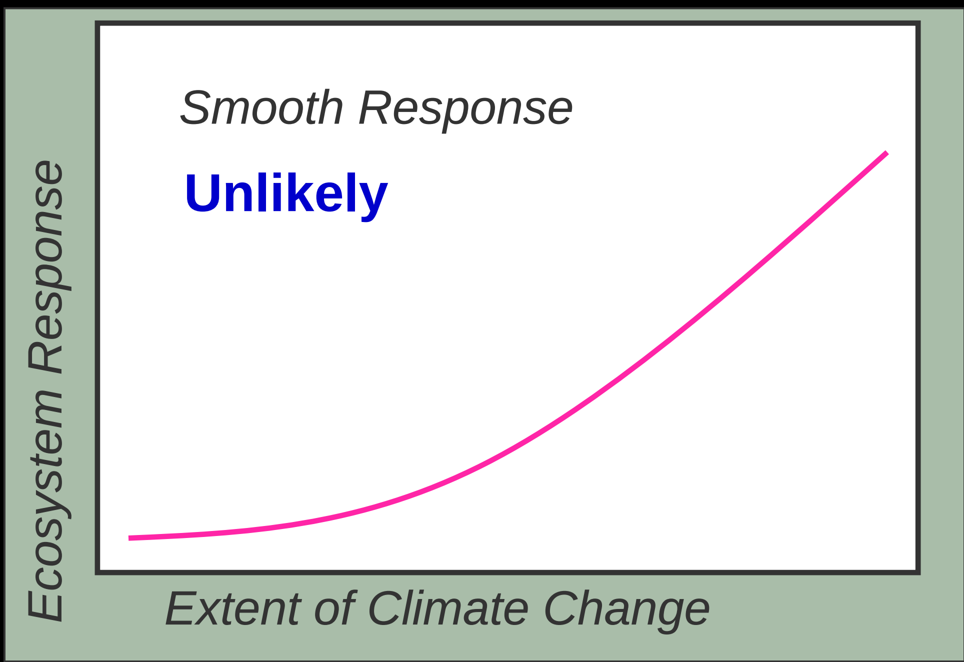
Thresholds, Disconnects, Shifts

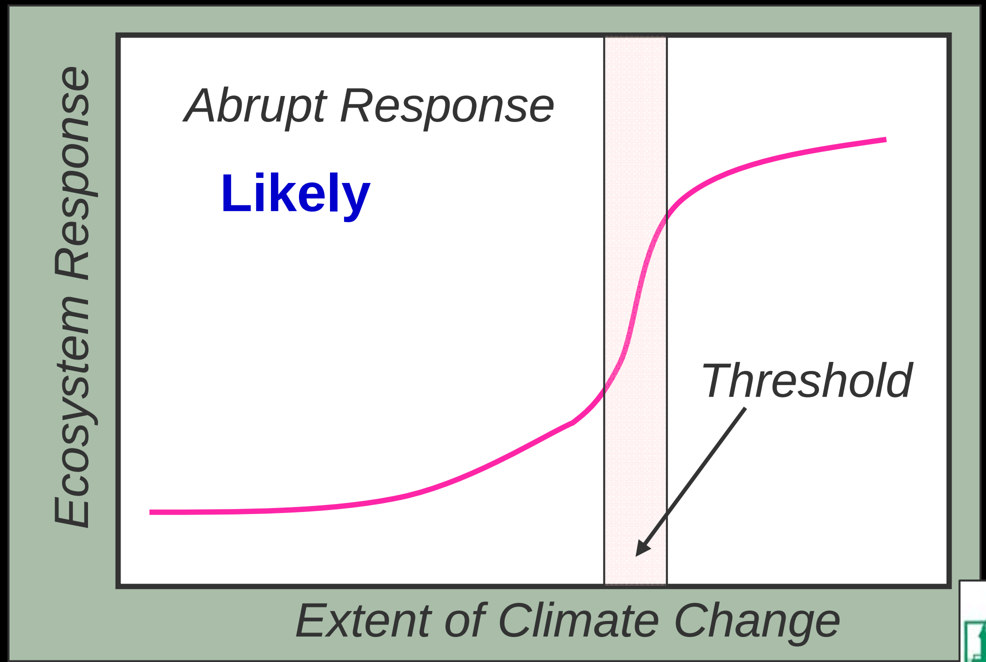




Example

Breached Tolerance Limits





Slide adapted from Carlos Duarte

Case Studies

Climate Ready Pilot Adaptation Planning

ID Vulnerabilities

↓

Nature's Benefits

↓

Adaptation Options

↓

Recommendations

Tidal Marshes

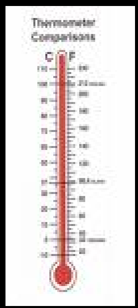
Bivalve Shellfish

Drinking Water

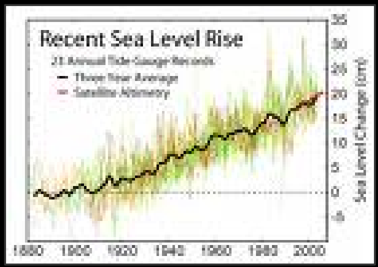
Climate Change in the Delaware Estuary

1. Likely Physical Changes

Temp



Salinity



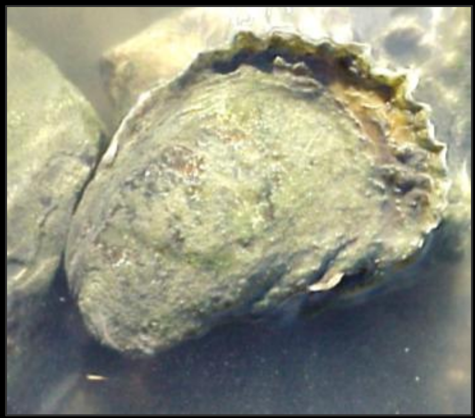
Sea Level Rise

Storms

2. Example Effects on Key Resources

Water

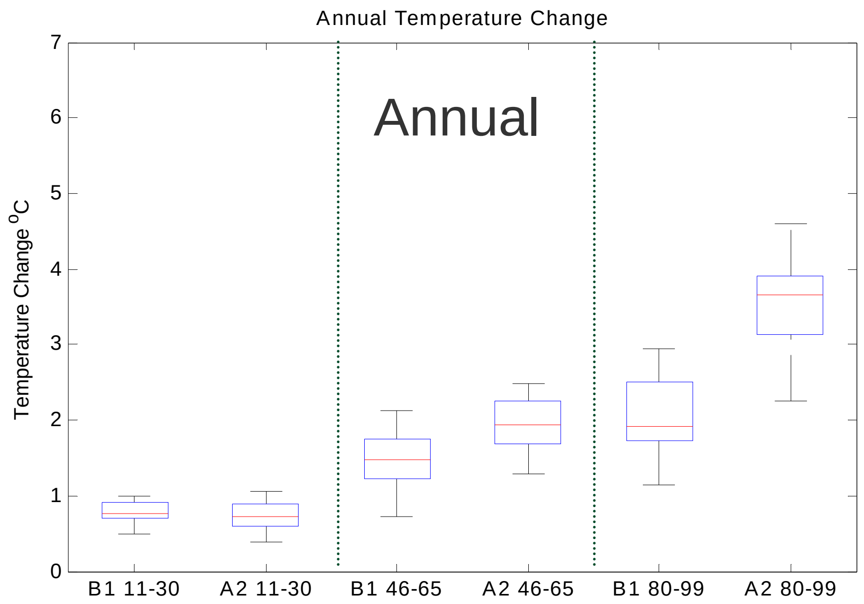
Wetlands

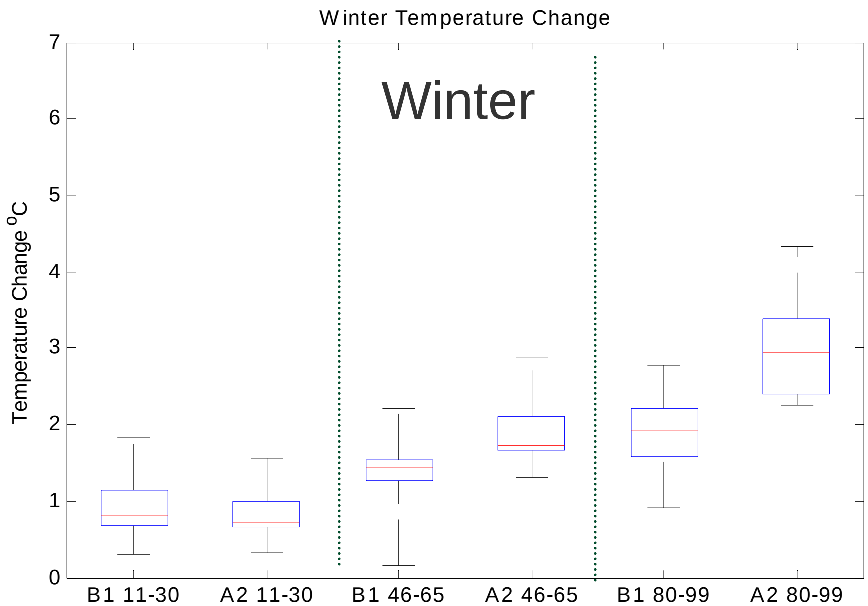


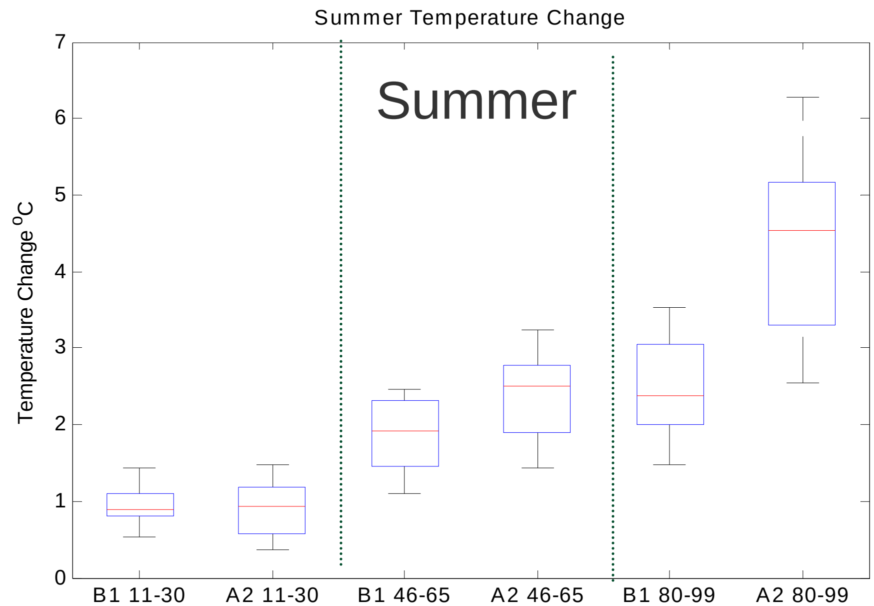
Fish & Wildlife

Temperature

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



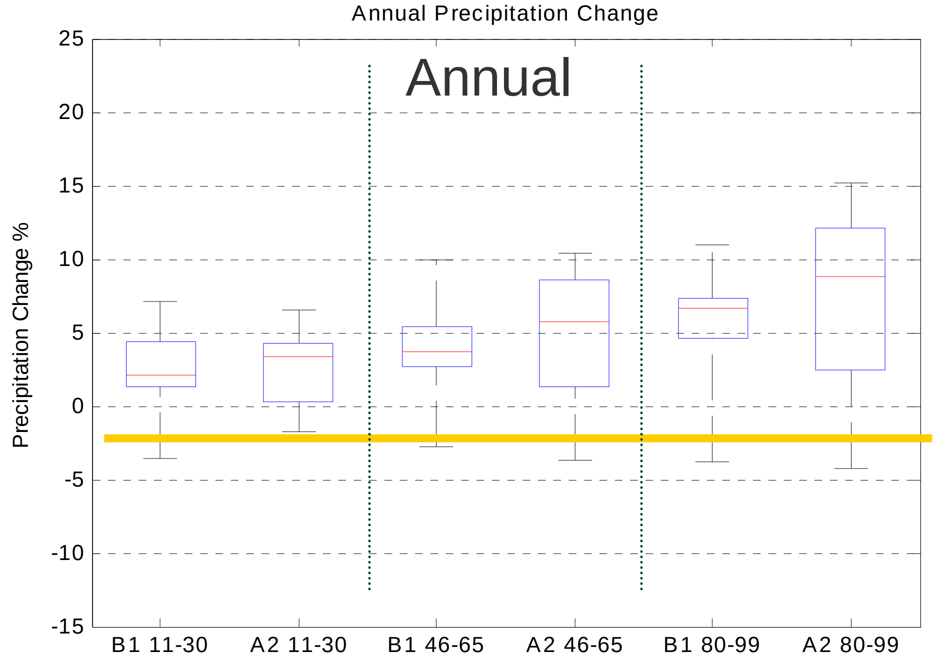


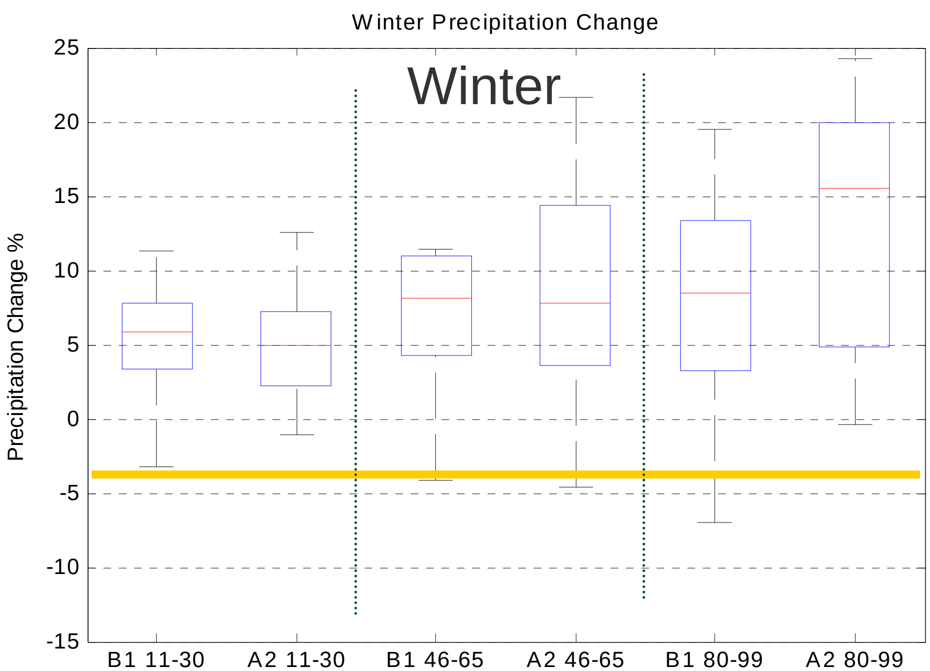


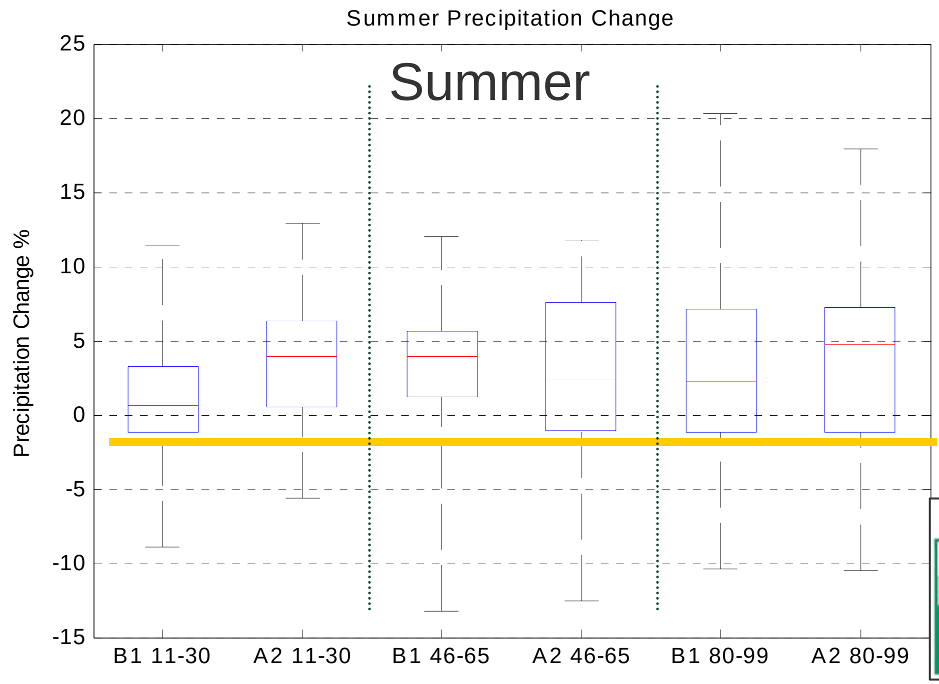
R. Najjar, PSU *– Draft not for distribution*

Precipitation

- **Annual precipitation increase**
- **Greater increase and agreement among models in winter than summer**
- **Less agreement among models for precipitation than temperature**







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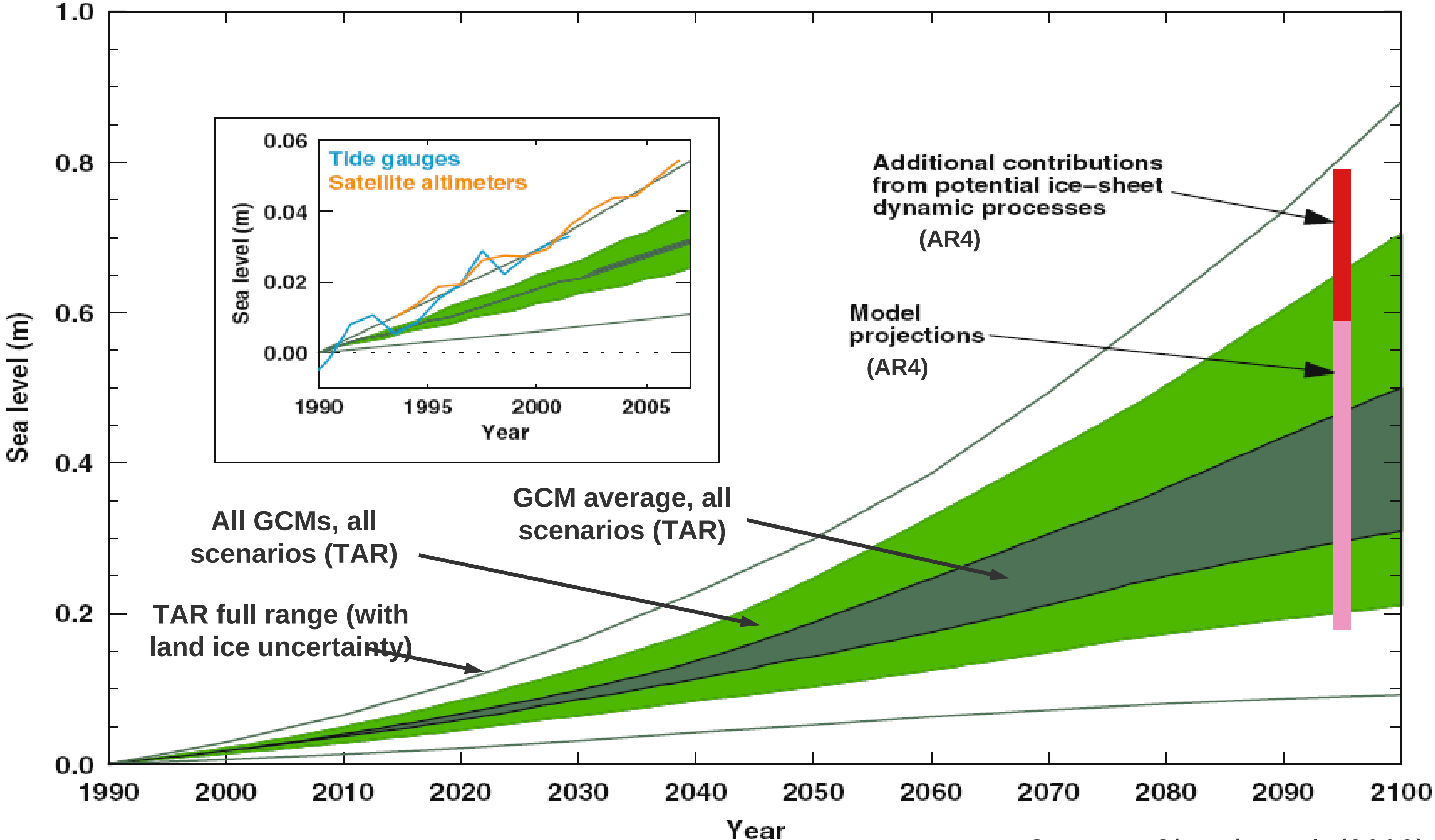
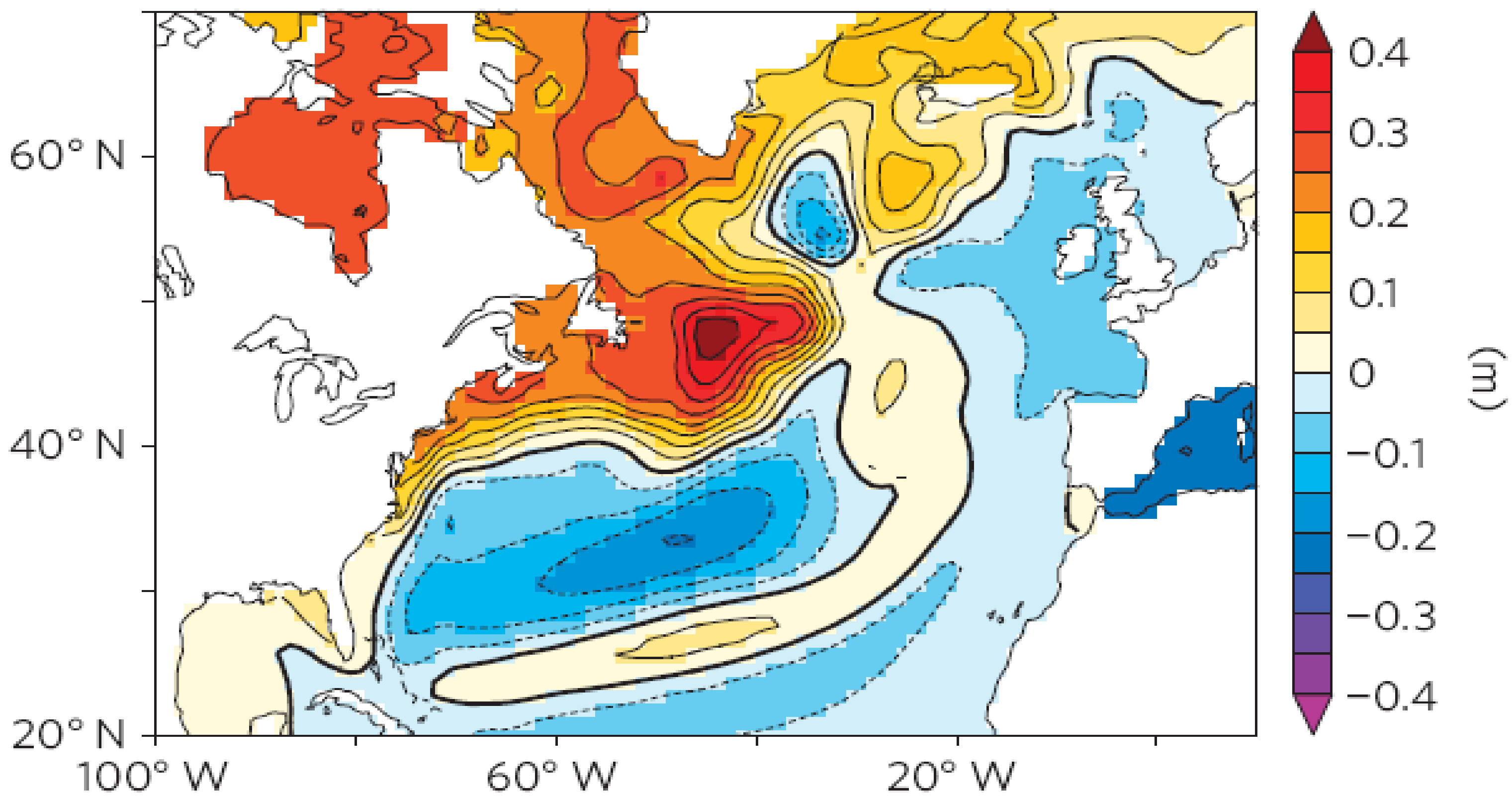
Global SLR —future



Source: Church et al. (2008)

SLR in Mid-Atlantic due to changing ocean currents

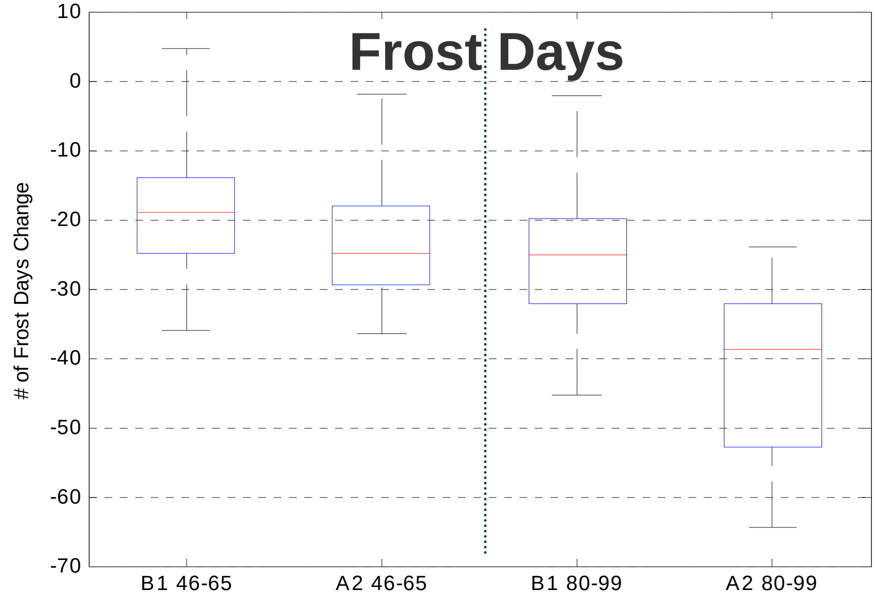
Projected 21st century change in dynamic sea level from the GFDL CM2.1 model (A2 scenario)

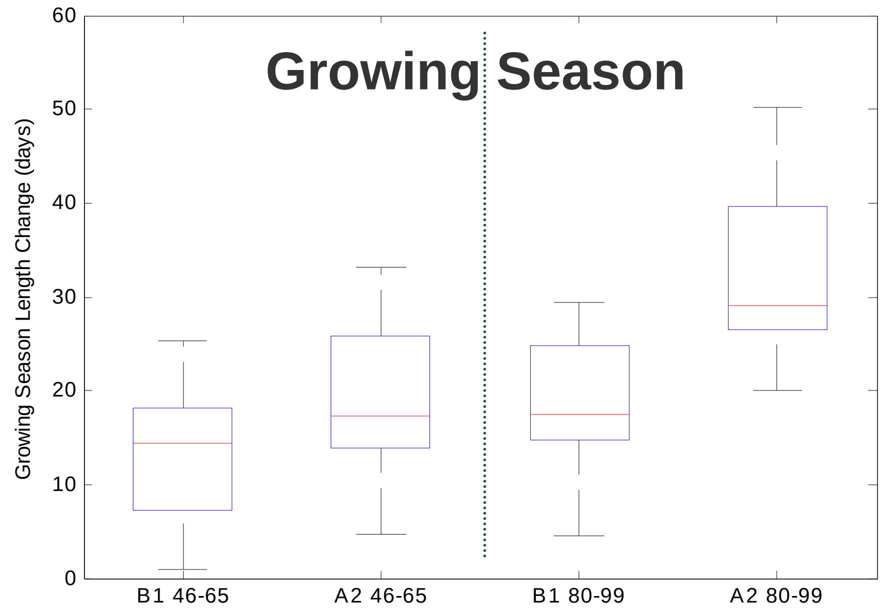


Source: Yin et al. (2009)

Annual frost days and growing season length changes

- Warmer spring and fall means fewer frost days and longer growing seasons





R. Najjar, PSU *– Draft not for distribution*

Case Studies

Climate Ready Pilot Adaptation Planning

ID Vulnerabilities
↓
Loss of Nature's Benefits
↓
Adaptation Options
↓
Recommendations

Tidal Marshes

Bivalve Shellfish

Drinking Water

Tidal Wetlands

A Signature Trait of System

Near Contiguous Band

Diverse: ***Freshwater Tidal Marshes***
Brackish Marshes
Salt Marshes

<u>Nature's Benefits</u>

Flood Protection
Water Quality
Fish and Wildlife
Natural Areas
Carbon Sequestration

Wetland Benefits (Ecosystem Services)

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

Tidal Wetlands

Long-standing Concerns

Degradation

Conversion and Loss

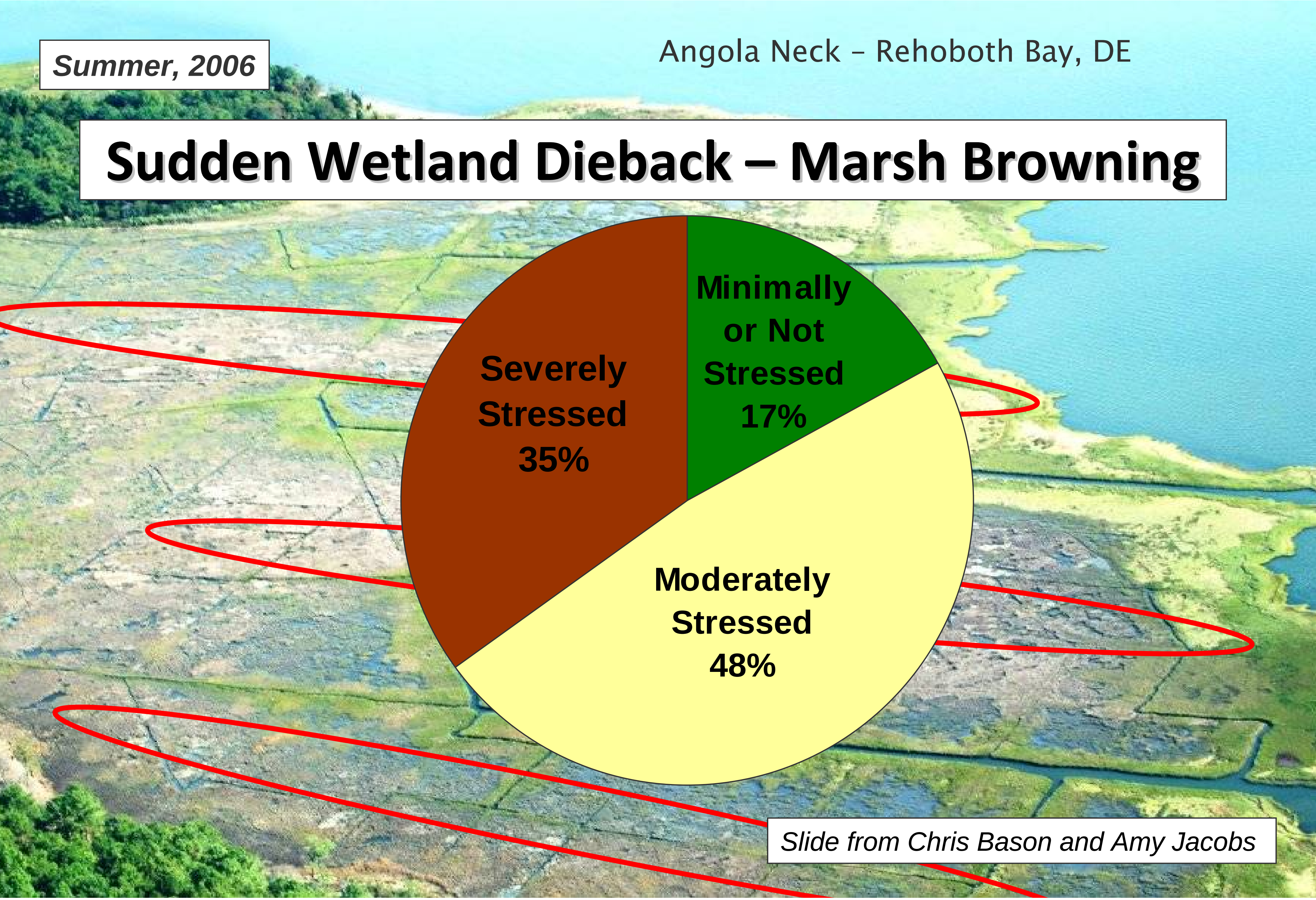
Growing Concerns

Sea Level & Salinity Ris

Storms

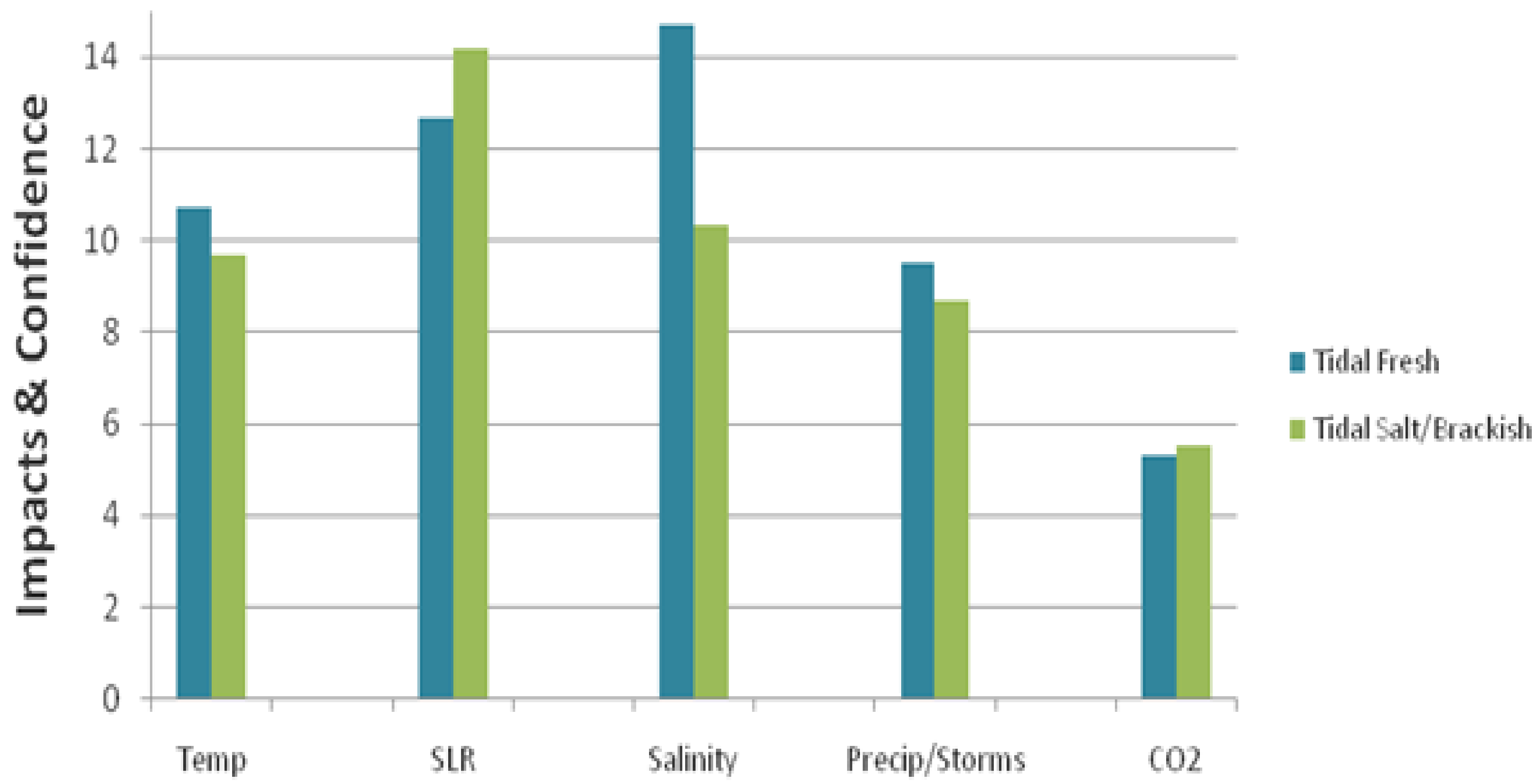
Sediment budget

Tidal Wetlands and Ecosystem Services - *Industrial Economics*


Summer, 2006
Angola Neck – Rehoboth Bay, DE
Sudden Wetland Dieback – Marsh Browning
Severely Stressed 35%
Minimally or Not Stressed 17%
Moderately Stressed 48%
Slide from Chris Bason and Amy Jacobs

Shifts in Community Composition:

Relative Vulnerabilities of Fresh & Salt Wetlands from Climate Drivers



Tidal Wetland Vulnerability

	Tidal Fresh Marsh	Salt Marsh
		
	Sea Level Rise	
Shifts in Community Species Composition	High	Highest
Ability of Accretion Rate to Equal RSLR Rate	Med-High	Highest
Ability for Landward Migration	High	Highest
Change of Marsh Area	High	Highest
Increased Tidal Range (Upper River)	Med-High	High
Ratio of shoreline edge to marsh area	Med-High	High
Rate of Channel Scour	Med-High	Med-High
Storm surge susceptibility	High	Highest
Seaward edge erosion	High	Highest
	Salinity Range Increase	
Shifts in Community Species Composition	Highest	Med-High
Salt Water Intrusion to Fresh Water Habitats	Highest	Med-High
Salt exposure/stress event	High	Med-Low
Change in Habitat Support	Highest	Med-Low
Productivity	Med-High	Med-Low
Invasive Species	Med-Low	Med-Low

Low
MED-LOW
MED-HIGH
HIGH
HIGHEST

Tidal Wetland Vulnerability

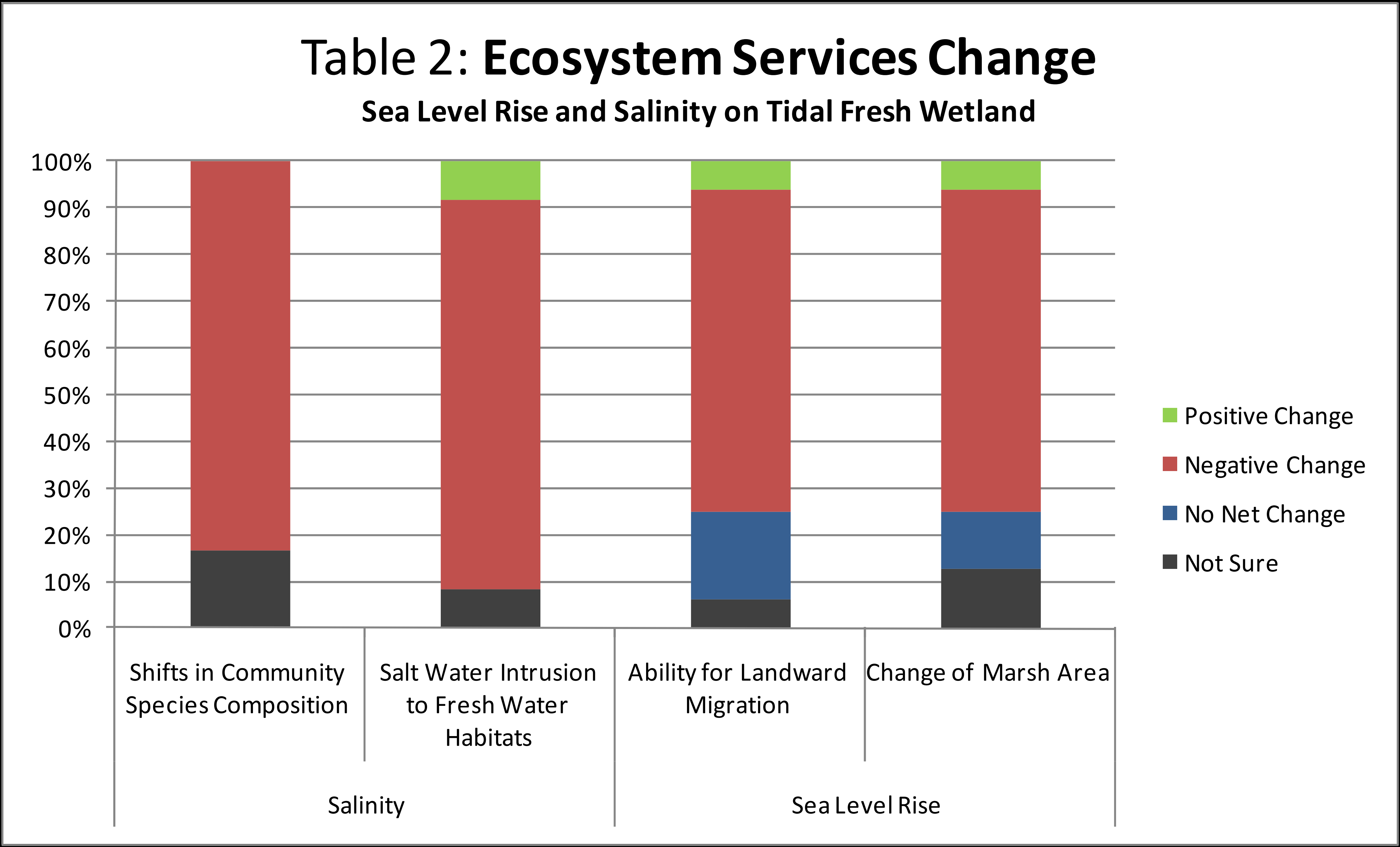
Freshwater Tidal Marshes

- 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

More Losers than Winners

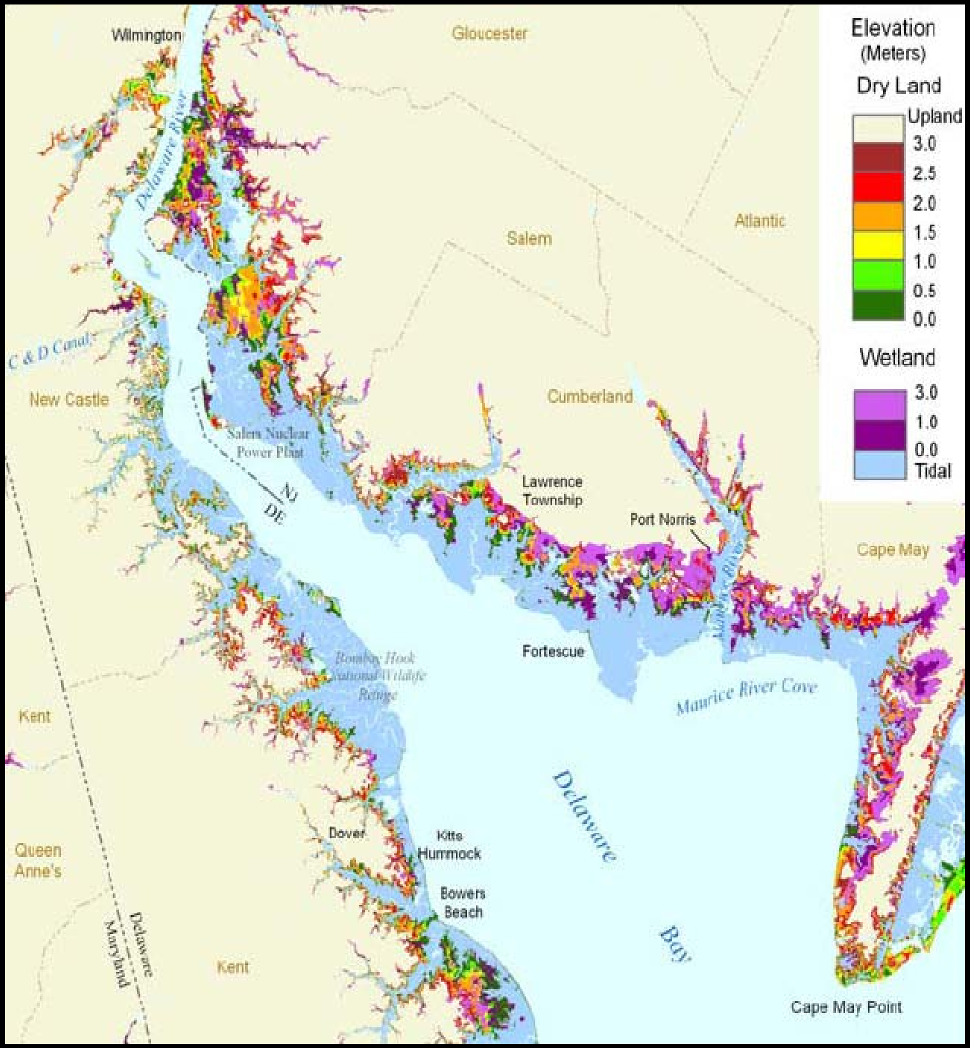


Tidal Wetlands Adaptation Planning

DK 22

Wetland Tough Choices

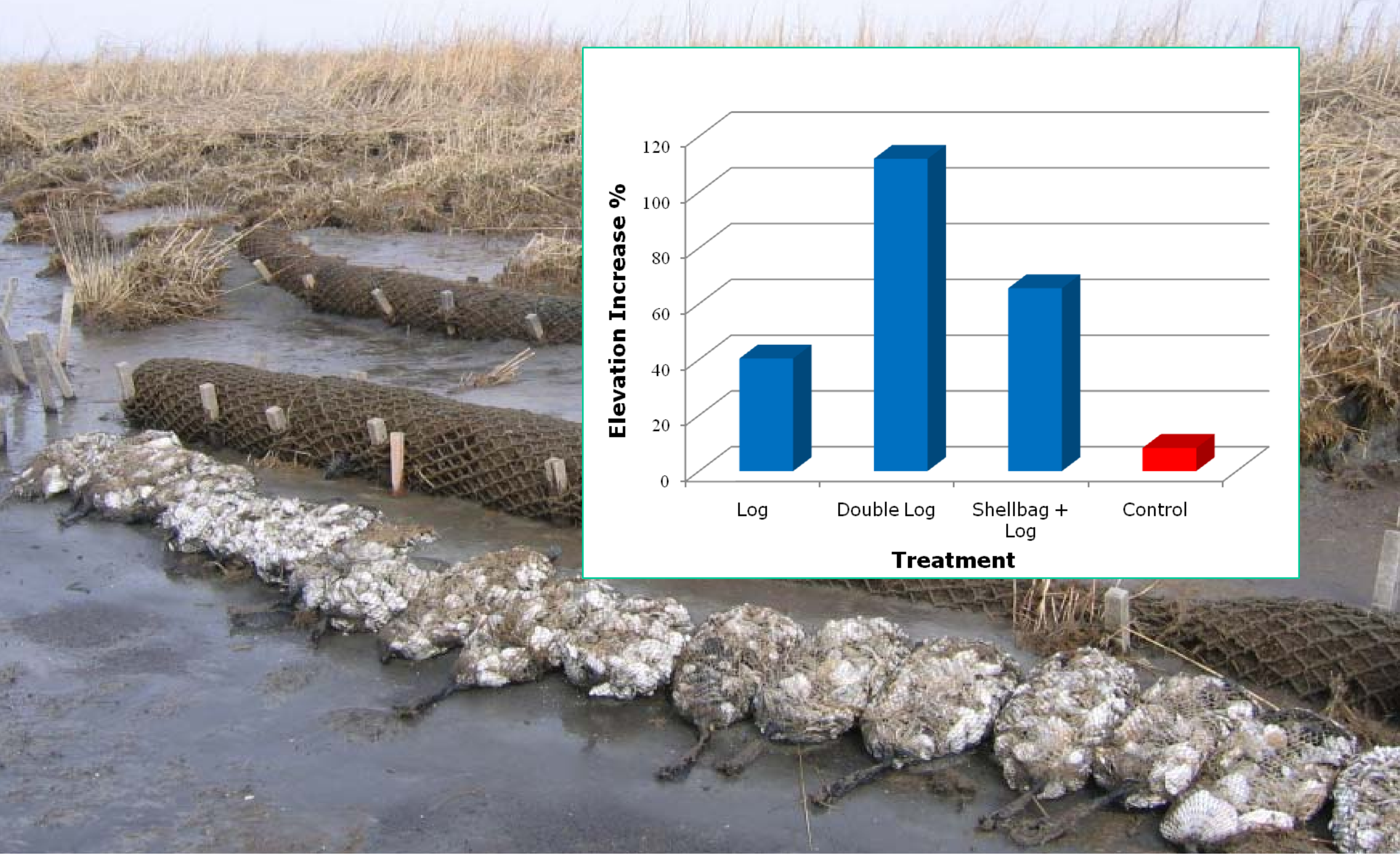
- Where will wetlands will be converted to open water?
- Where can we save them ?
- Where is strategic retreat the best option?



Adaptation Tactics?

e.g., Living Shorelines

Delaware Estuary Living Shorelines



Tidal Wetland Adaptation Options

Tidal Fresh Marsh	Salt Marsh
	

Low
MED-LOW
MED-HIGH
HIGH
HIGHEST

Adaptation Options

	Tidal Fresh	Tidal Salt/Brackish
	Sea Level Rise	
Beach/marsh nourishment	Med-High	Med-Low
Elevating homes/structures	Med-Low	Med-Low
Dikes, Bulkheads, and Tide Gates	Med-High	Med-High
Structure Setbacks	High	Med-High
Rebuilding infrastructure	Med-High	Med-High
Strategic Retreat	Highest	Highest
Creation of Buffer Lands	Highest	High
Living Shorelines	High	High
	Salinity Range Increase	
Watershed flow management	High	Med-High

CLIMATE READY ESTUARIES
EPA

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ID Vulnerabilities

↓

Loss of Nature's Benefits

↓

Adaptation Options

↓

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Bivalves of the Delaware

Elliptio complanata

Geukensia demissa

Crassostrea virginica

11 Other Species of Freshwater Unionid Mussels

Corbicula fluminea

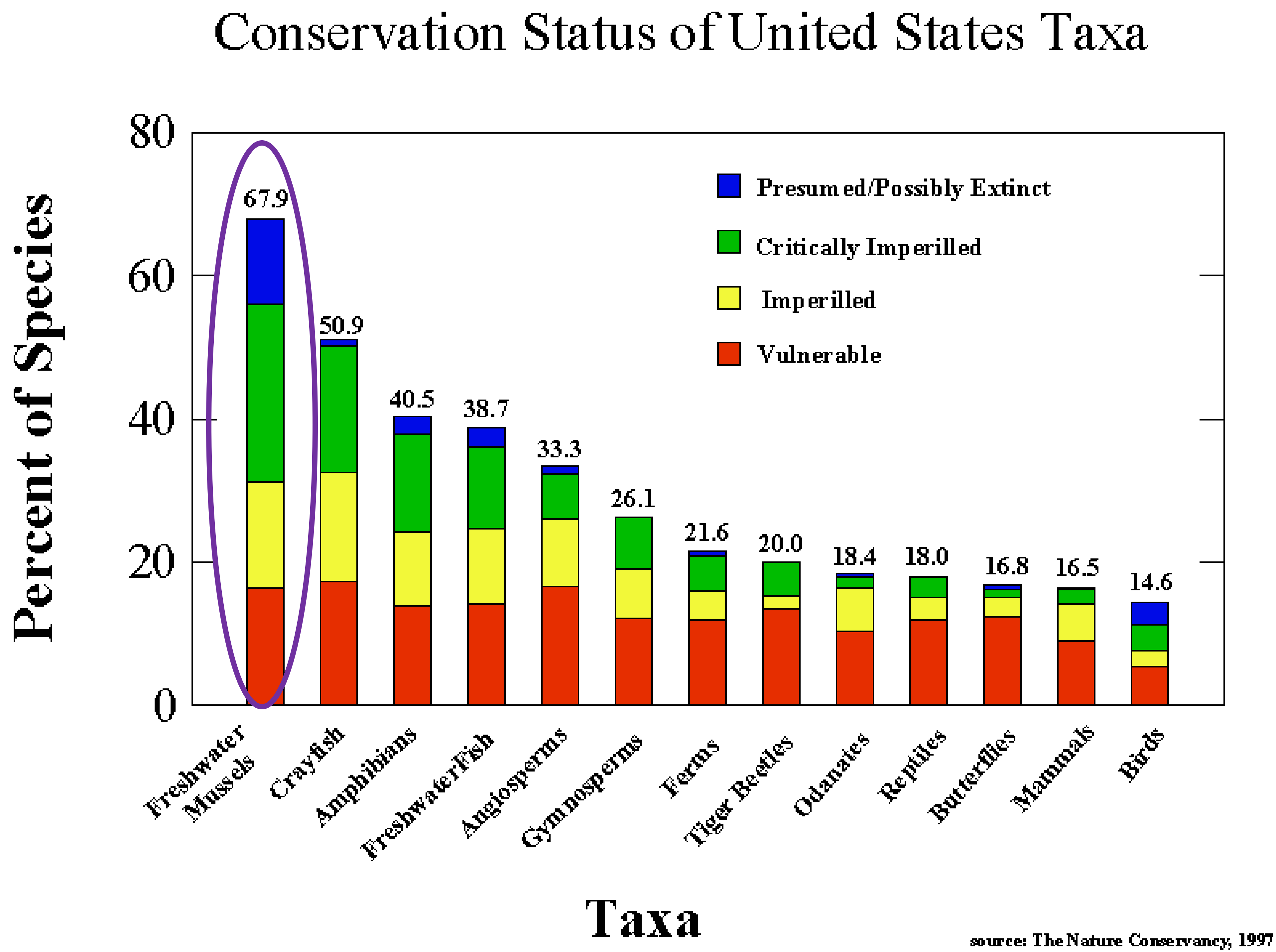
Rangia cuneata

Mya arenaria

Mytilus edulis

Ensis directus

Mercenaria mercenaria



Conservation Status of United States Taxa
Percent of Species
80
60
40
20
0
Presumed/Possibly Extinct
Critically Imperilled
Imperilled
Vulnerable
67.9
50.9
40.5
38.7
33.3
26.1
21.6
20.0
18.4
18.0
16.8
16.5
14.6
Freshwater Mussels
Crayfish
Amphibians
Freshwater Fish
Angiosperms
Gymnosperms
Ferns
Tiger Beetles
Odanates
Reptiles
Butterflies
Mammals
Birds
Taxa
source: The Nature Conservancy, 1997

Shifts in Species Ranges of 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

Nature's Benefits

Bivalve Shellfish are "Ecosystem Engineers"

CTUIR Freshwater Mussel Project

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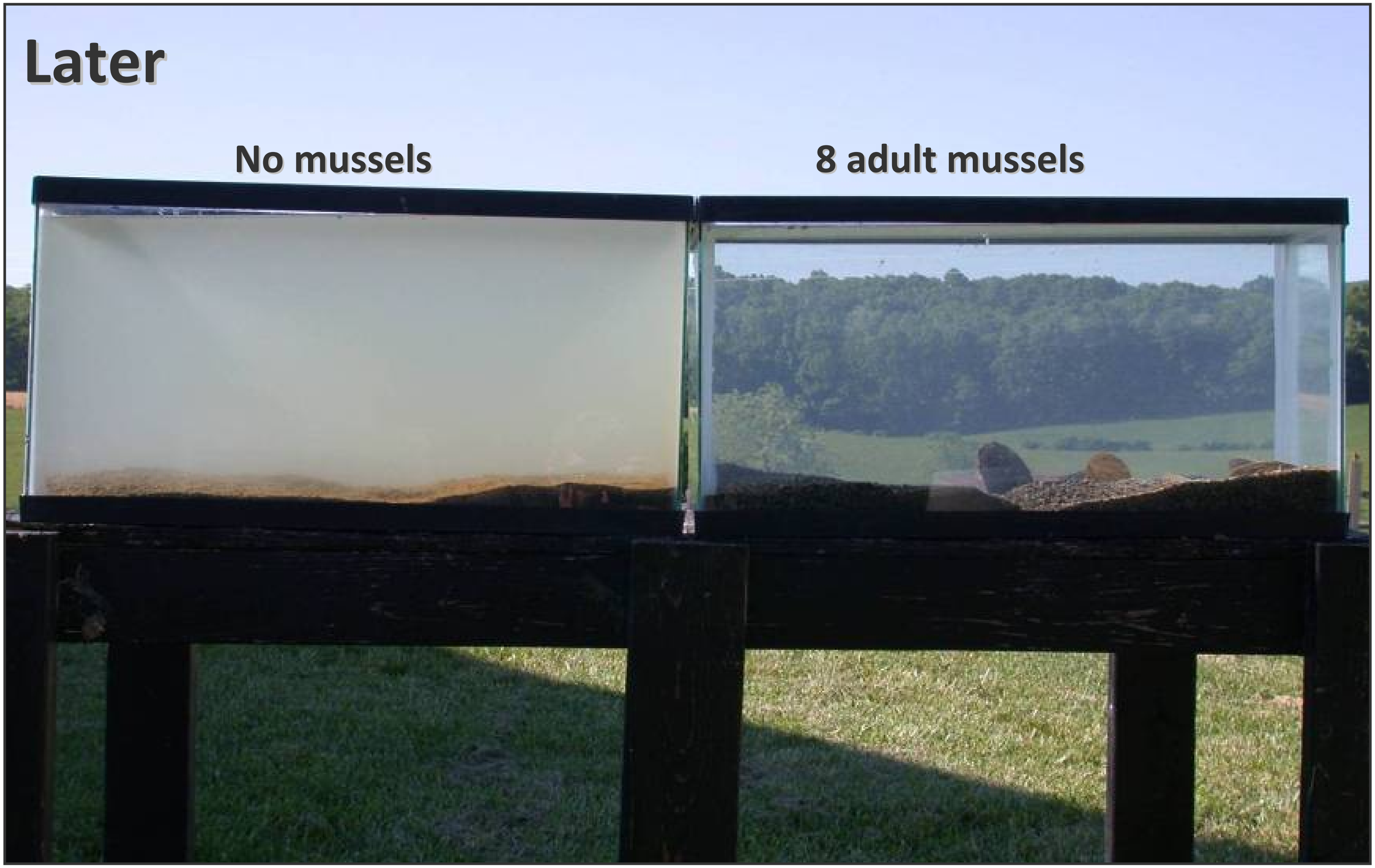
Water Filtration Benefits

Slide from R. Neves, VA Tech

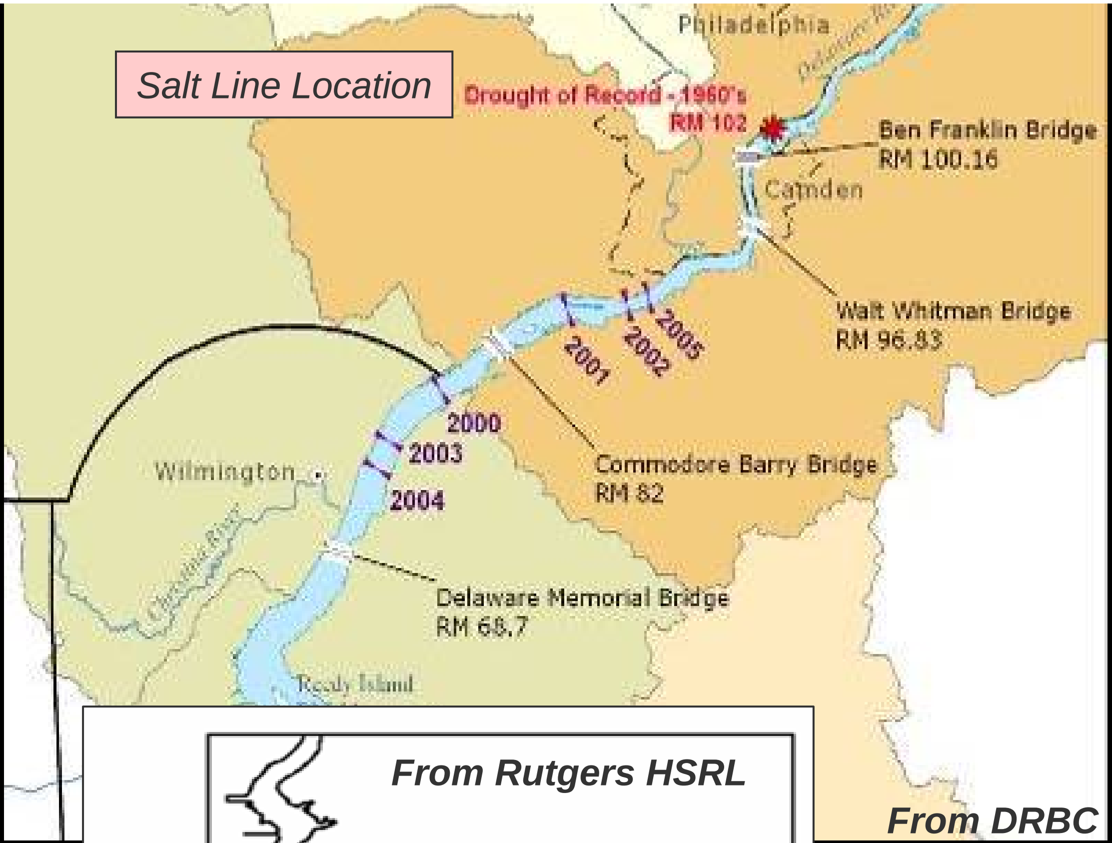
Water Filtration Benefits



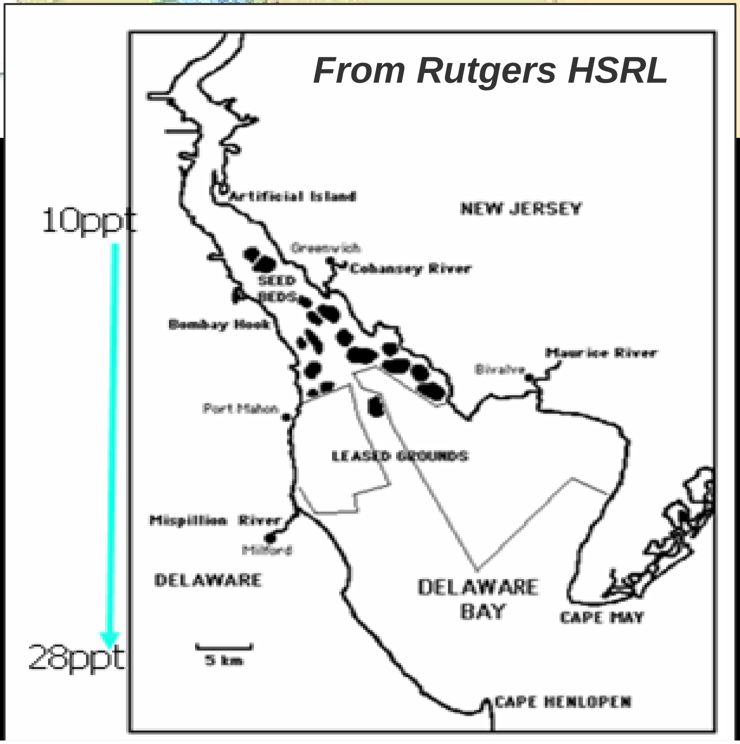
Slide from R. Neves, VA Tech

Oyster Disease and Salinity

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



From DRBC



From Rutgers HSRL

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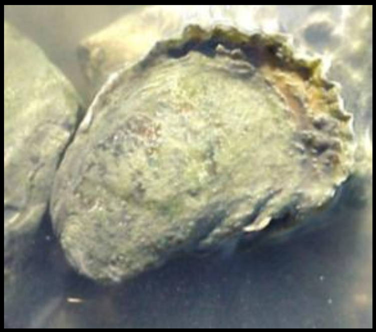
Oyster Management

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

Historical data from Rutgers Haskin Shellfish Laboratory

Elliptio complanata

Geukensia demissa



Crassostrea virginica

Bivalve Vulnerability?

Oyster Reefs

- Salinity Driven Disease Epizootics
- Others: Food, pH

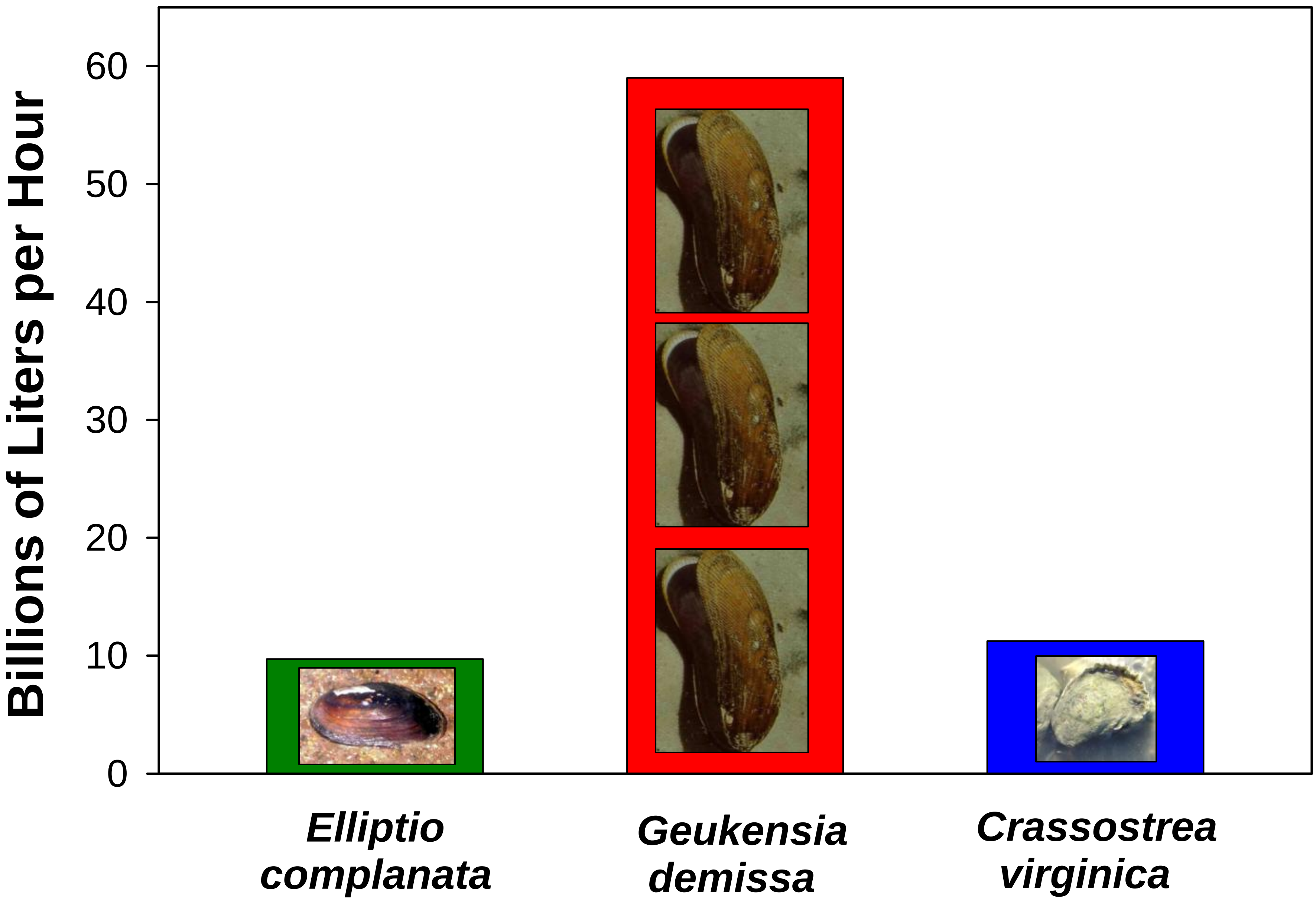
Salt marsh Mussel Beds

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

Freshwater Mussel Beds

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

Water Filtration Benefits



Nature’s Benefits (Natural Capital)

Shellfish Tough Decisions

Which species and associated benefits can be sustained?

Which should we invest in? (since funding will always be limited)

Millennium Ecosystem Assessment Categories	Specific Services/Values	Oysters	Marsh Mussels	FW Mussels
Provisioning: Food & Fiber				✓
Regulating				
				✓✓
Supporting				✓✓
				✓✓✓
	Bio-filtration Health	✓✓✓	✓✓✓	✓✓✓
	Biogeochemistry	✓✓	✓✓	✓✓
	Prey	✓	✓✓	✓
Cultural/ Spiritual/ Historical/ Human Well Being	Waterman Lifes Ecotourism Livelihoods	✓✓		
	Native American	✓✓		✓✓✓
	Watershed Indicator	✓✓✓	✓✓	✓✓✓
	Bio-Assessment Health	✓✓✓	✓✓	✓✓✓

Relative Importance Scores

CLIMATE READY ESTUARIES EPA

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↓

Loss of Nature's Benefits

↓

Adaptation Options

↓

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Drinking Water

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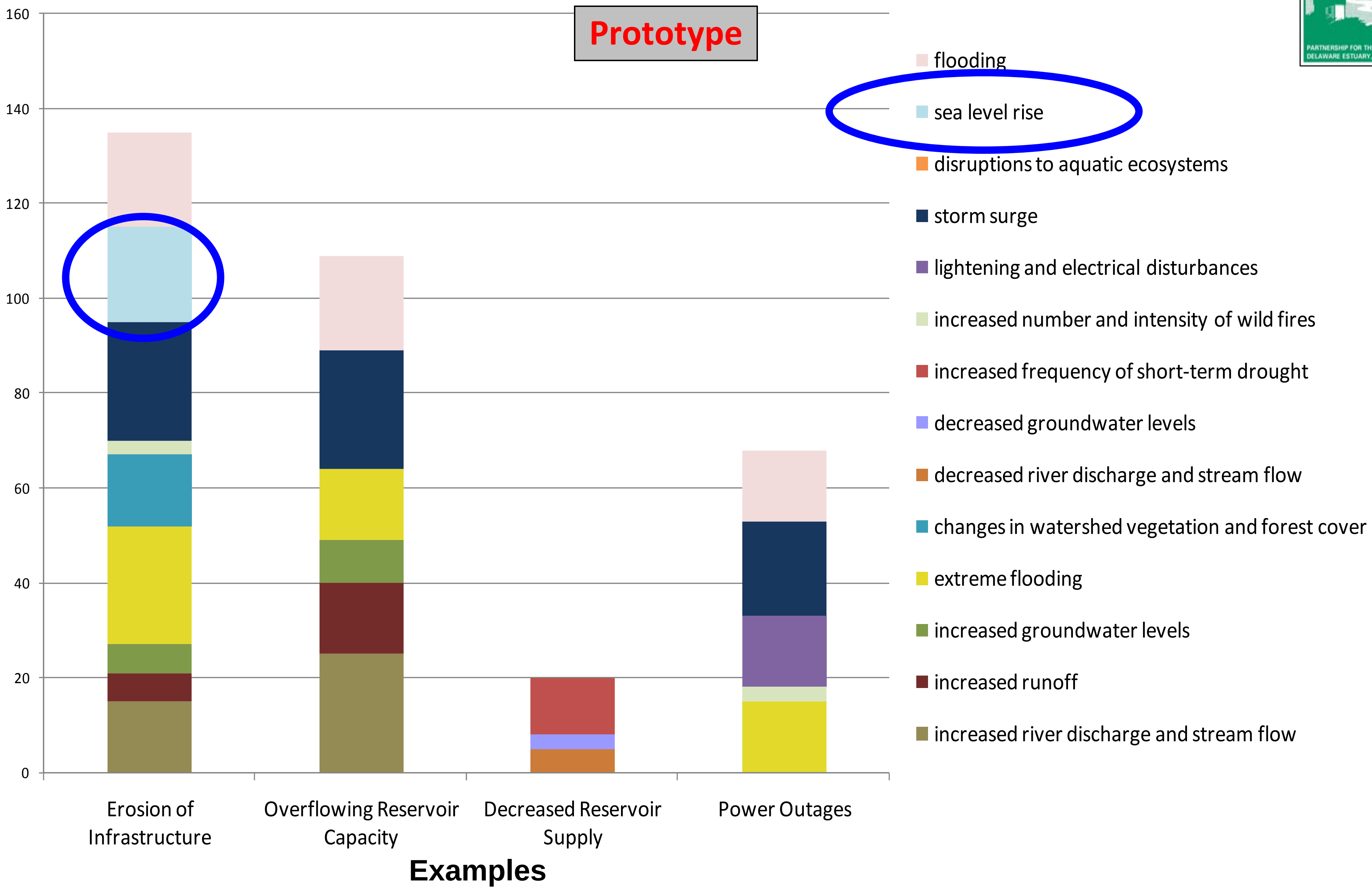
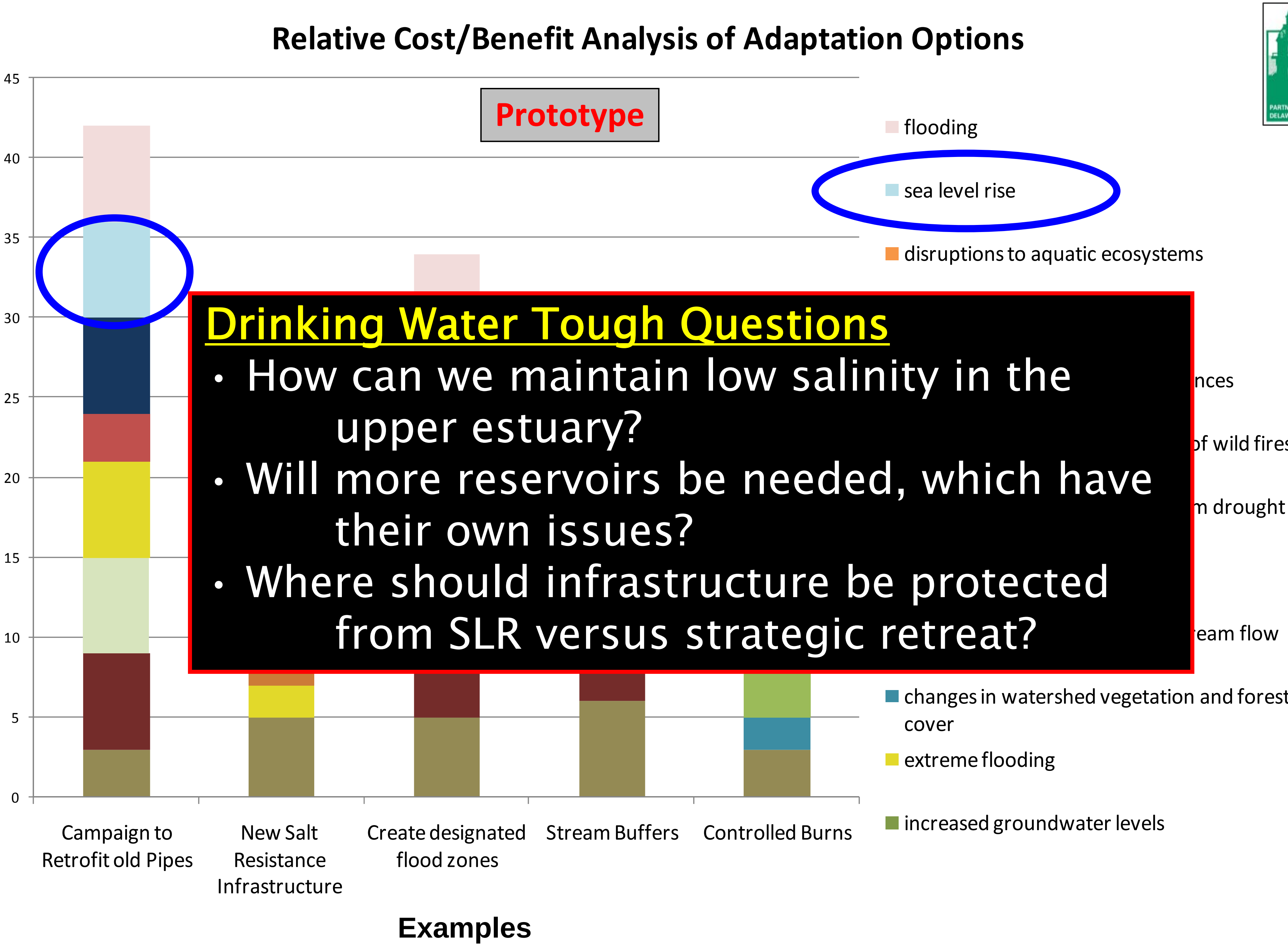
Climate Impacts on Drinking Water Supply



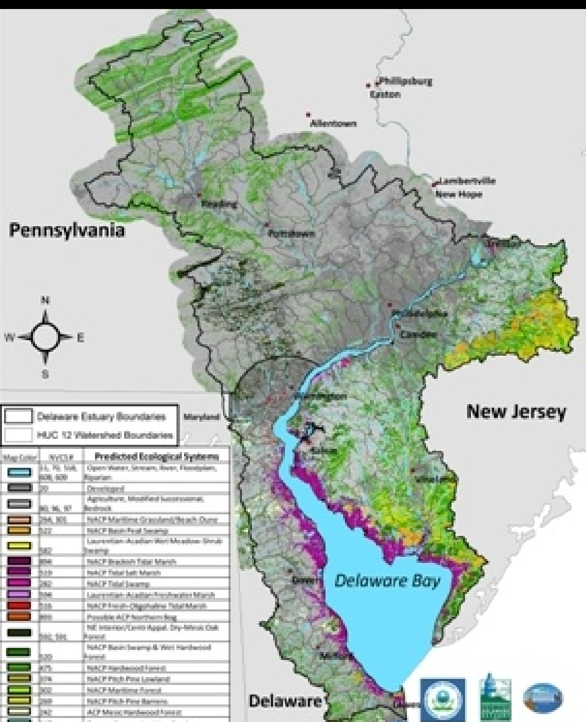


Drinking Water Tough Questions

- 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?

Climate Change in a Complex Landscape


DK 42



<u>**The Living Estuary**</u>

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

<u>**The Working River**</u>

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



Climate Change +Other Changes

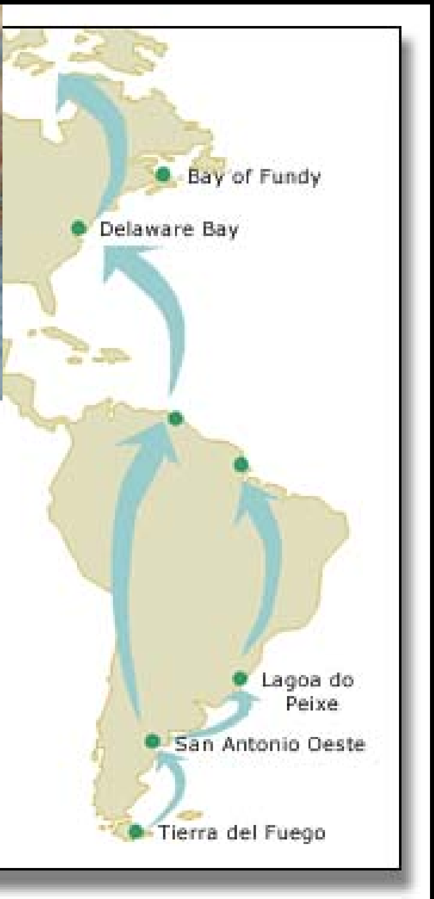
DK 43

- Marcellus Shale
- Dredg… NRDA
- Withdrawals
- Wind Farms
- Land Use Change
- Development
- Emerging Pollutants
- Ecological Flows

Added Complexity

Many Other Issues

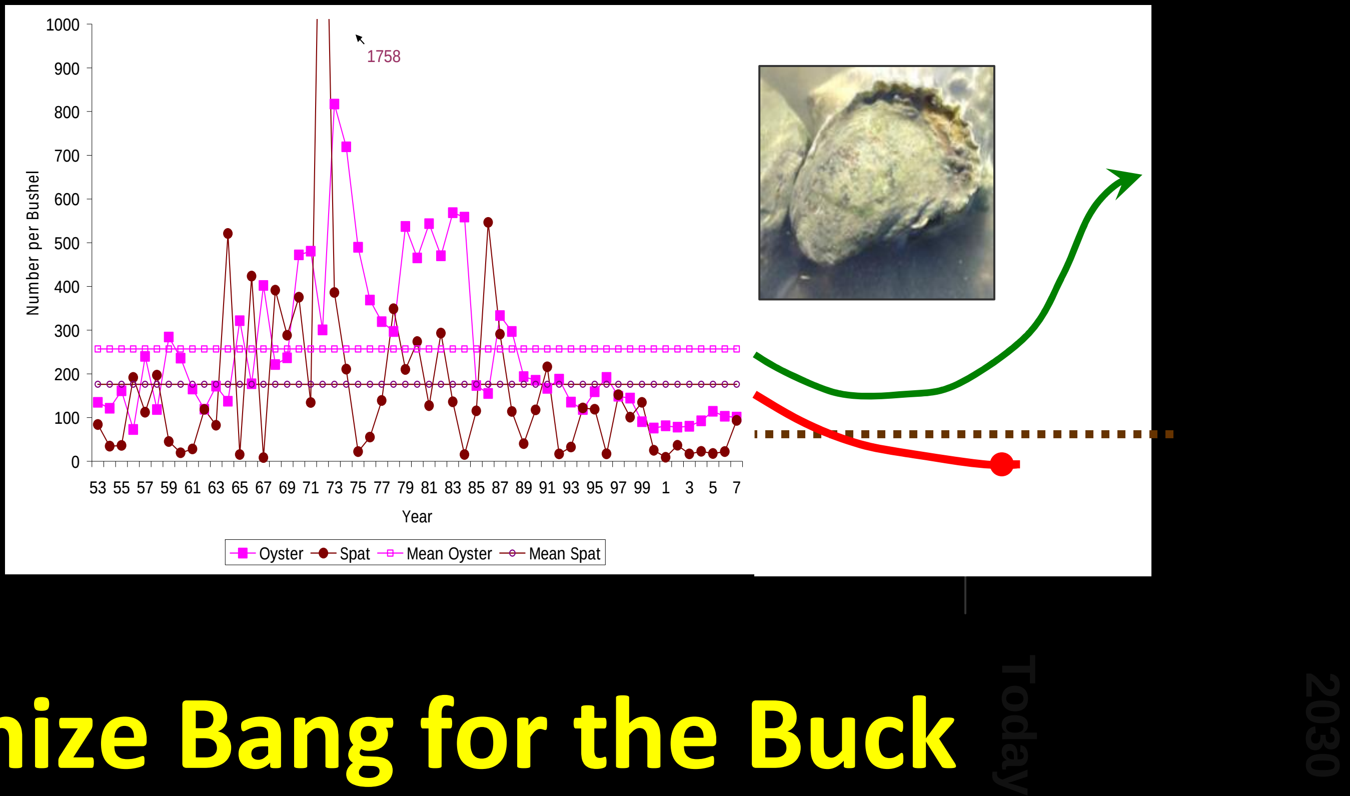
Timing of Shorebird Migration and Horseshoe Crab Spawning



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

"Restore" for the Future

- *Forecast future sustainable states (winners and losers)*
- *Smart "restoration" = climate adaptation*
- *Shift policy and management paradigms*



Maximize Bang for the Buck

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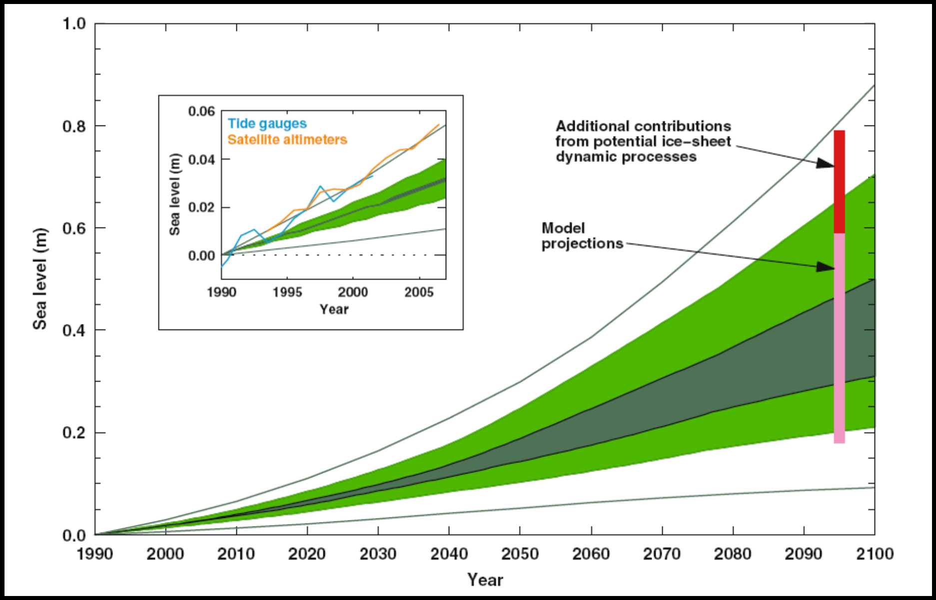
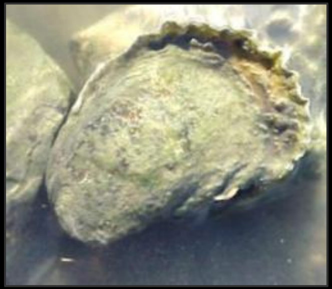
– End –





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. Nature's Benefits

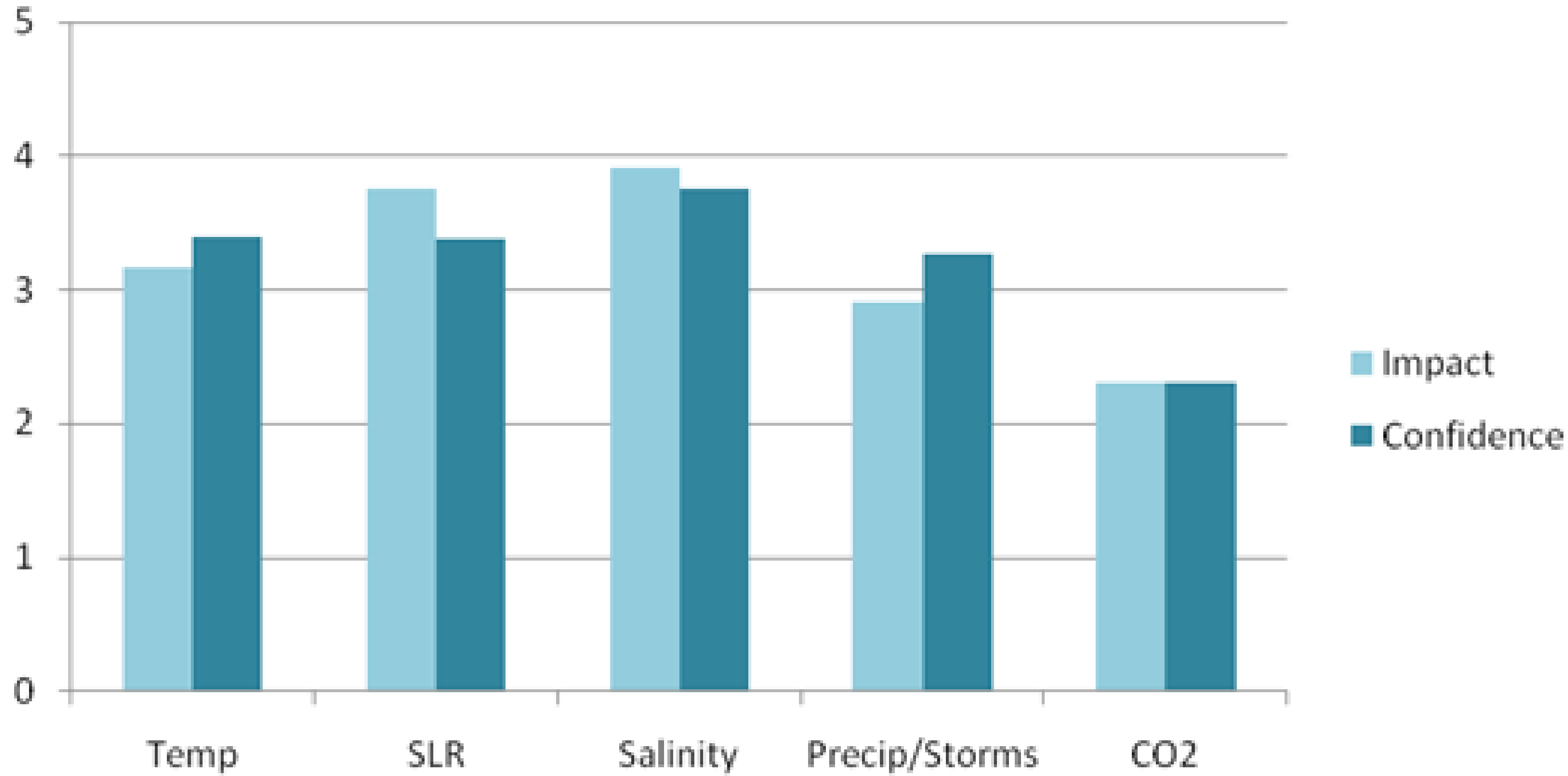
Develop and use decision tools with "bang for the buck" estimates of environmental outcomes for various adaptation tactics

4. Collaboration

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

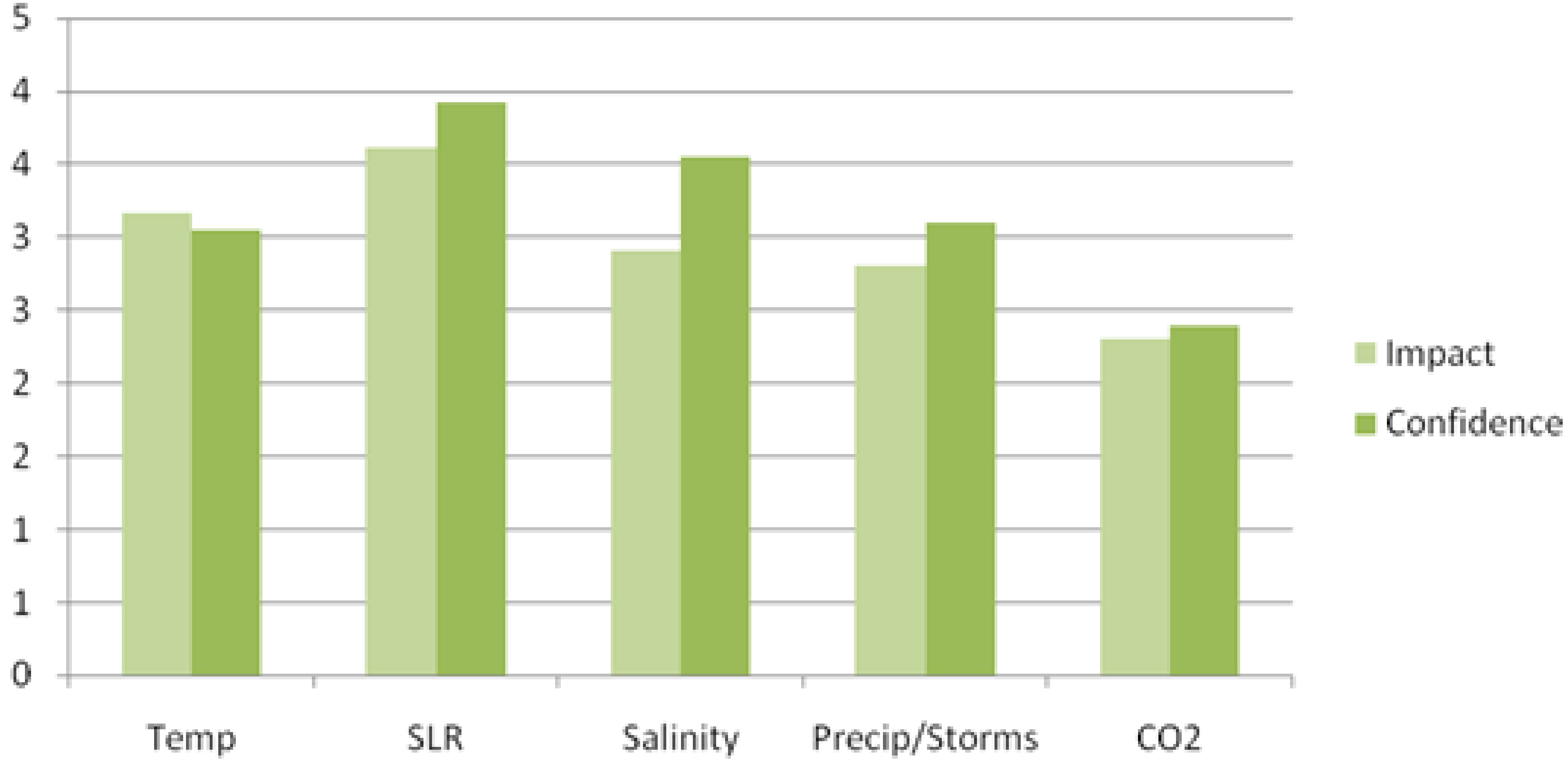
Shifts in Community Composition:

Tidal Fresh Wetland Impacts v. Confidence Levels



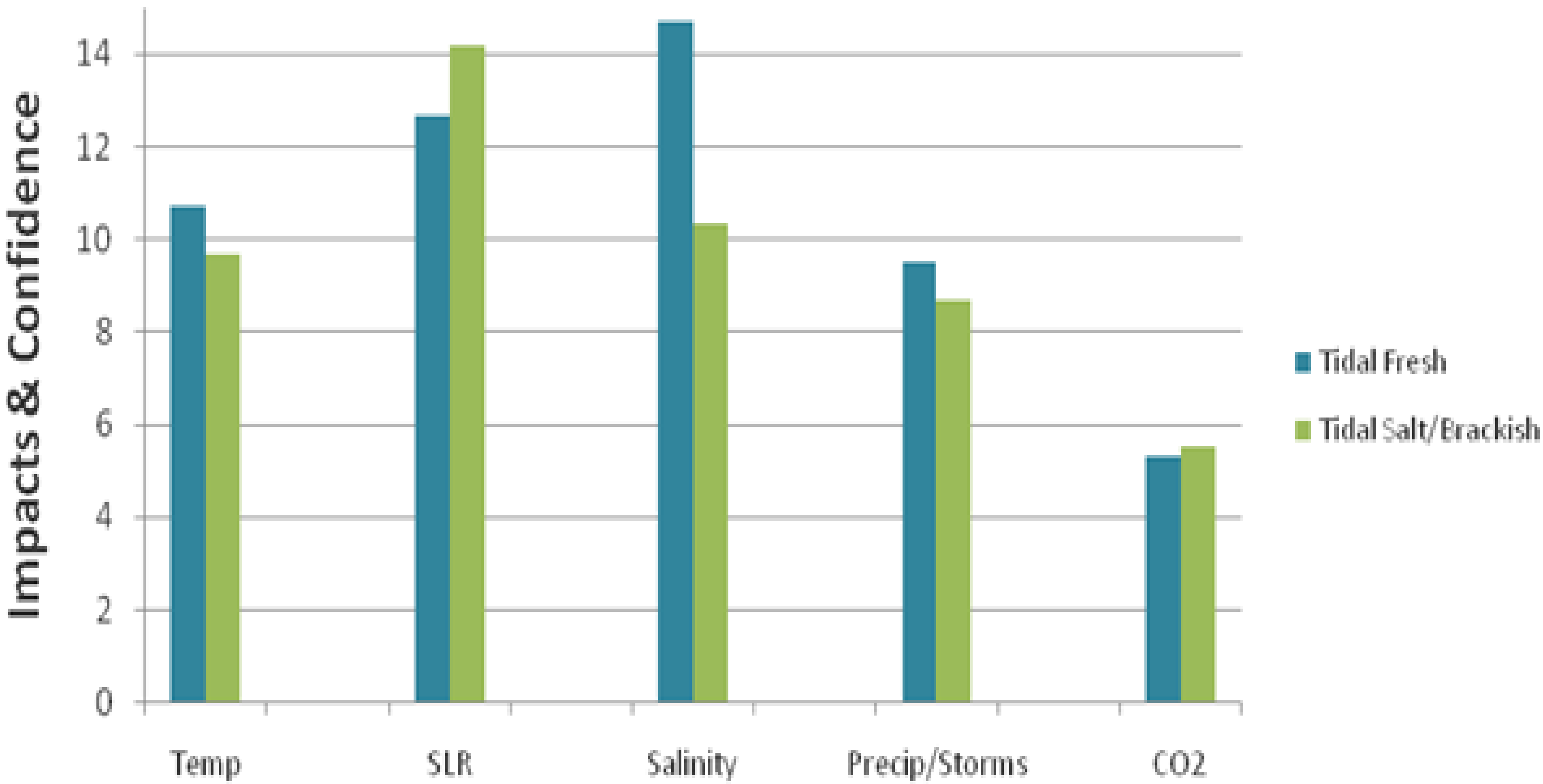
Shifts in Community Composition:

Salt/Brackish Wetlands Impacts v. Confidence Levels

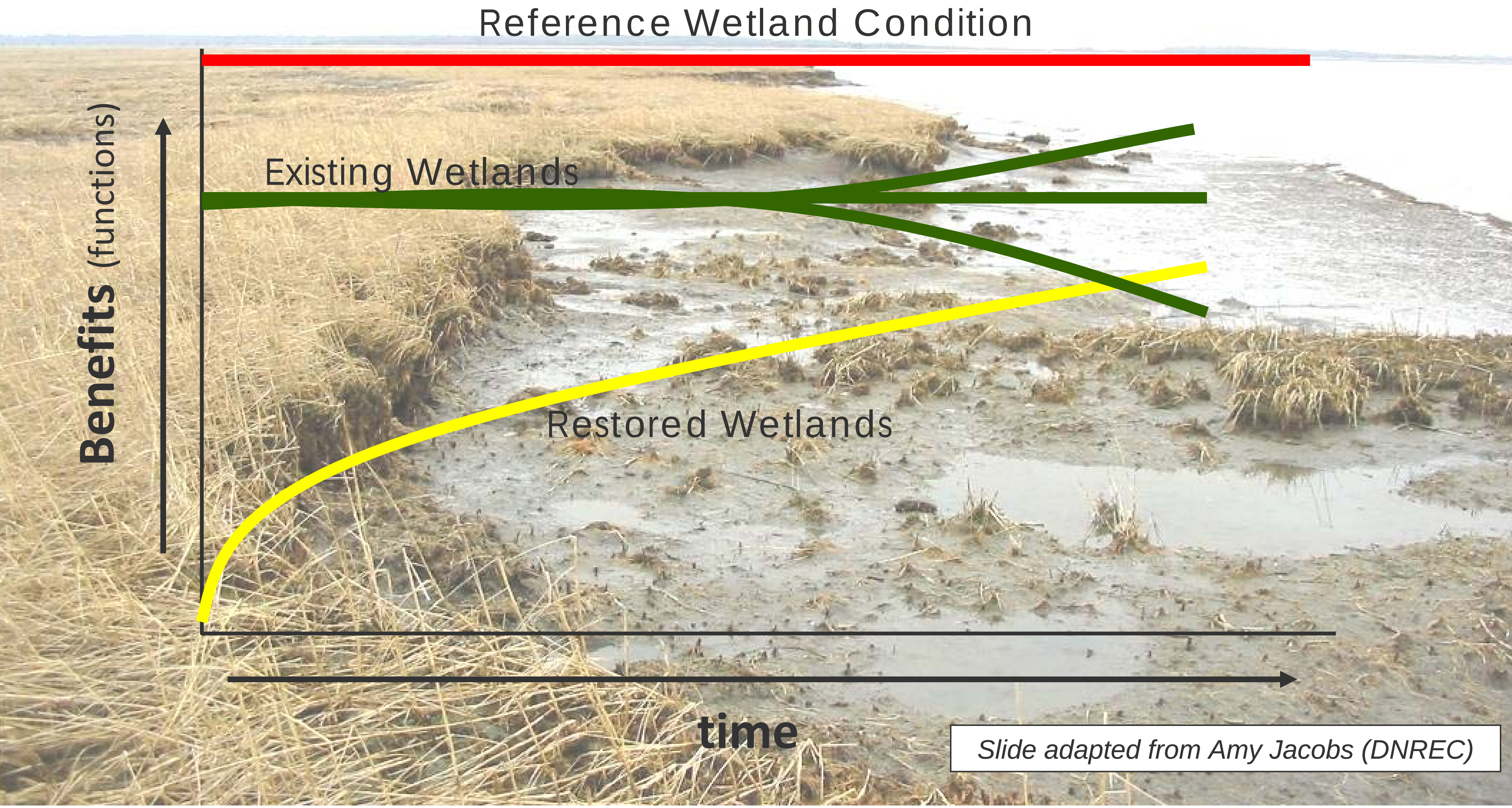


Shifts in Community Composition:

Relative Vulnerabilities of Fresh & Salt Wetlands from Climate Drivers



Changes in Wetland Function
Natural versus Restored



Slide adapted from Amy Jacobs (DNREC)