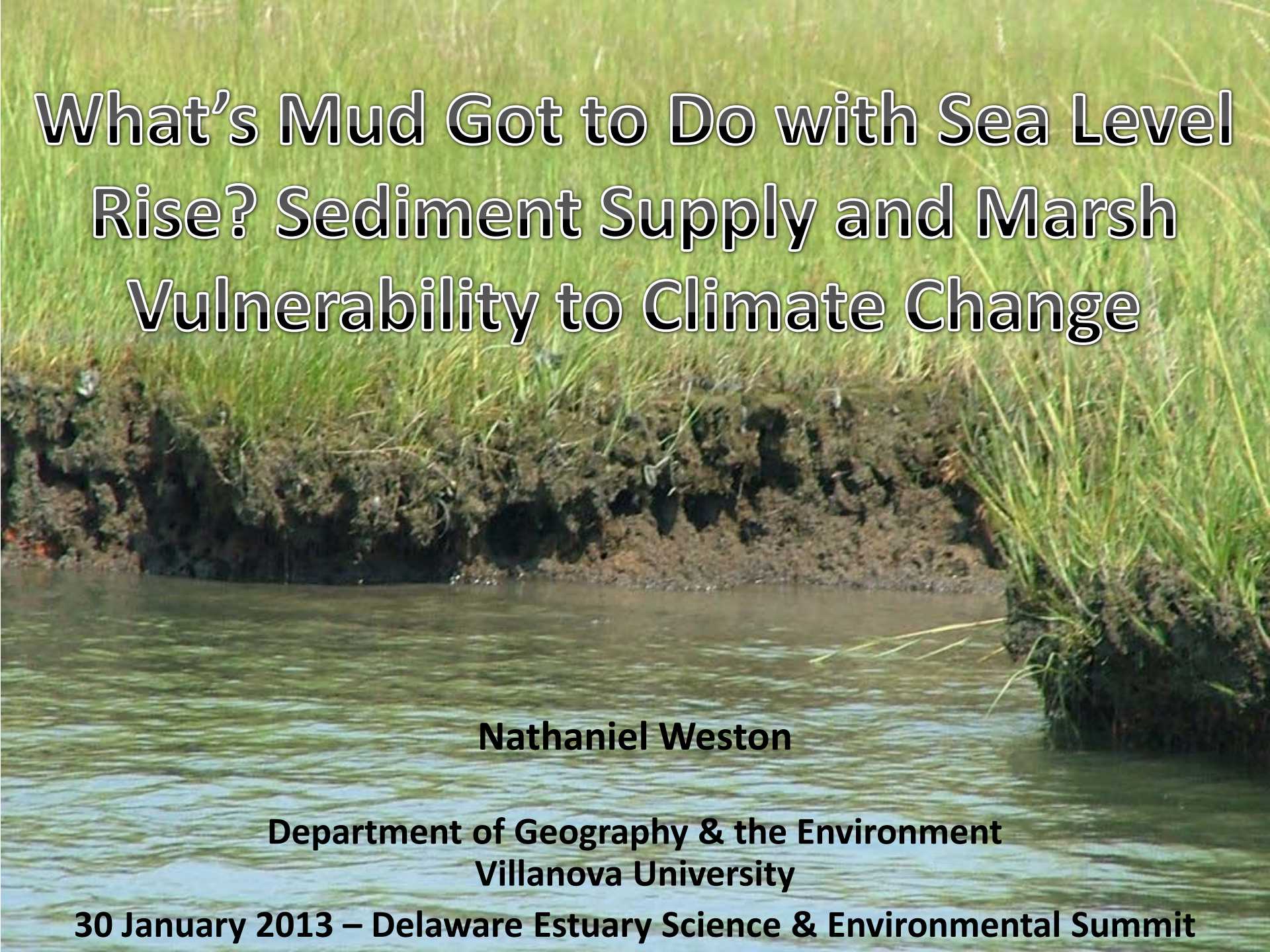
What's Mud Got to Do with Sea Level Rise? Sediment Supply and Marsh Vulnerability to Climate Change



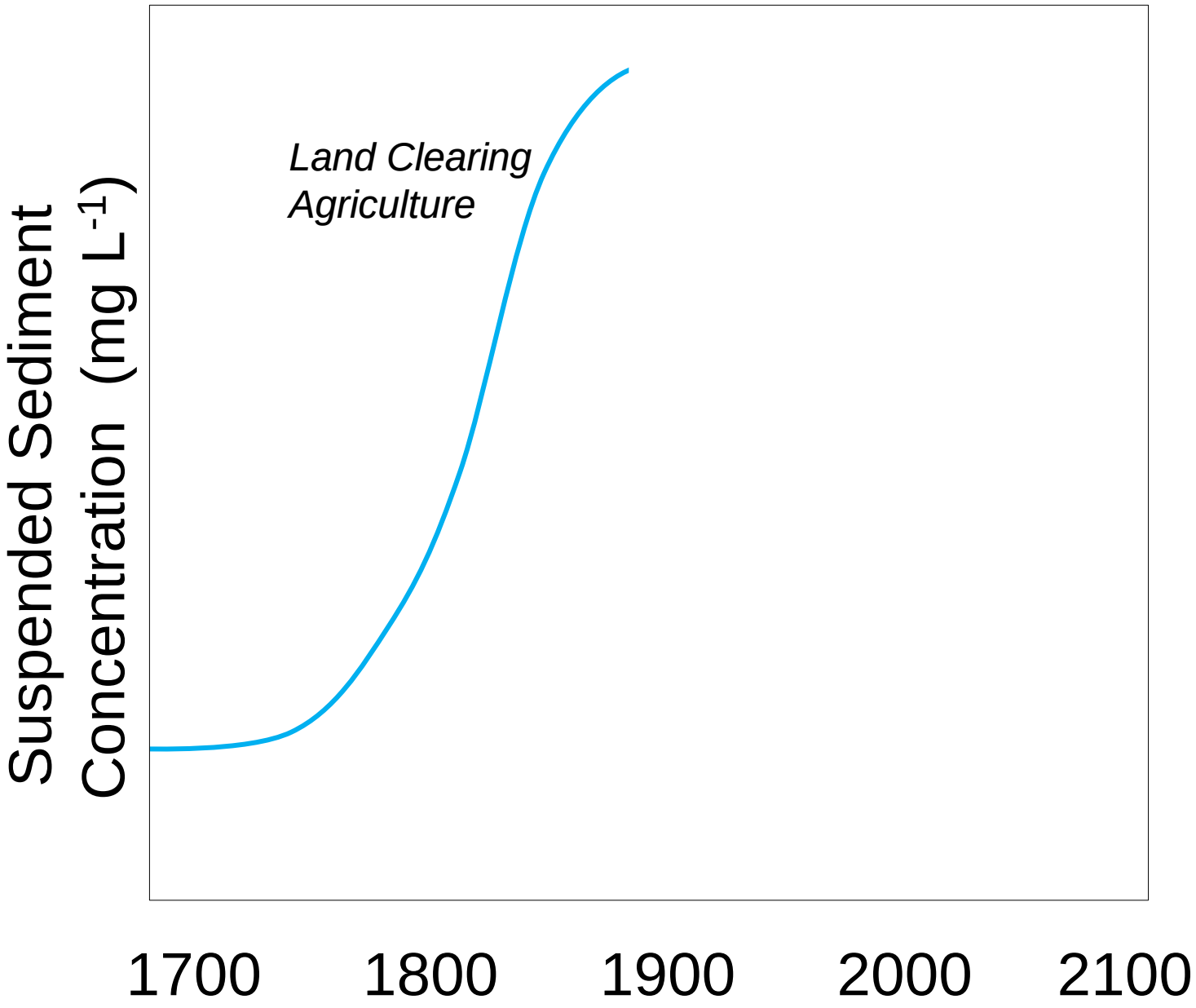
Nathaniel Weston

Department of Geography & the Environment
Villanova University

30 January 2013 – Delaware Estuary Science & Environmental Summit

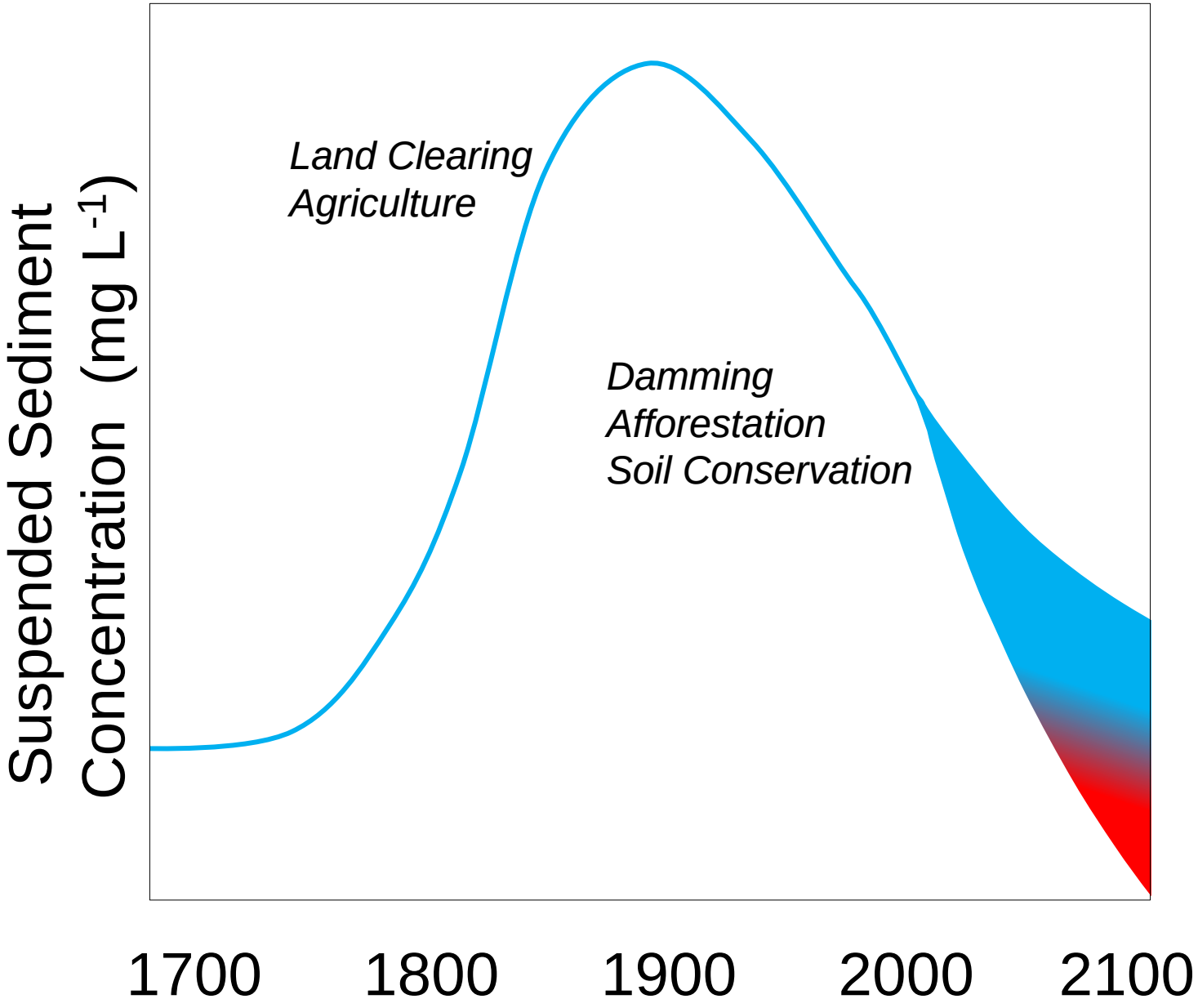
Land Use Change in Colonial Period Through 1900s

Soil Erosion and Sediment Pollution of Waterways

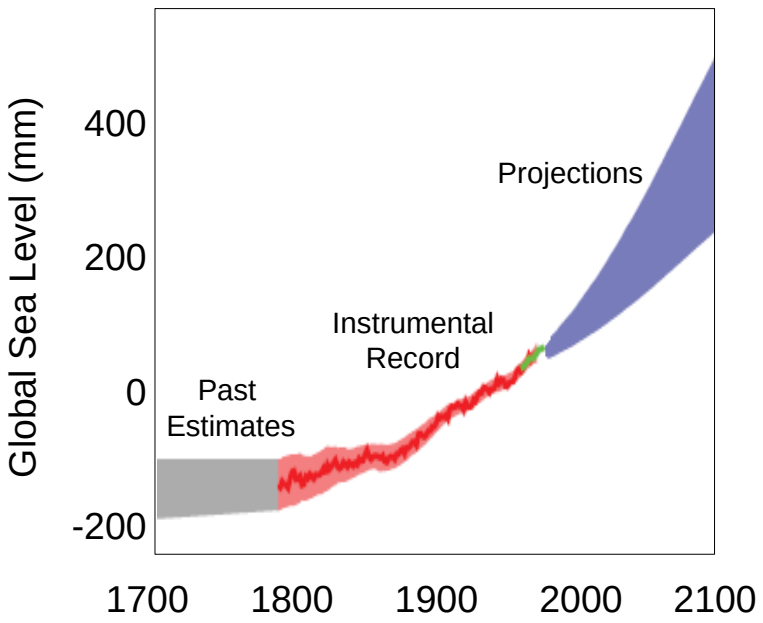

Suspended Sediment Concentration (mg L-1)
Land Clearing
Agriculture
1700
1800
1900
2000
2100

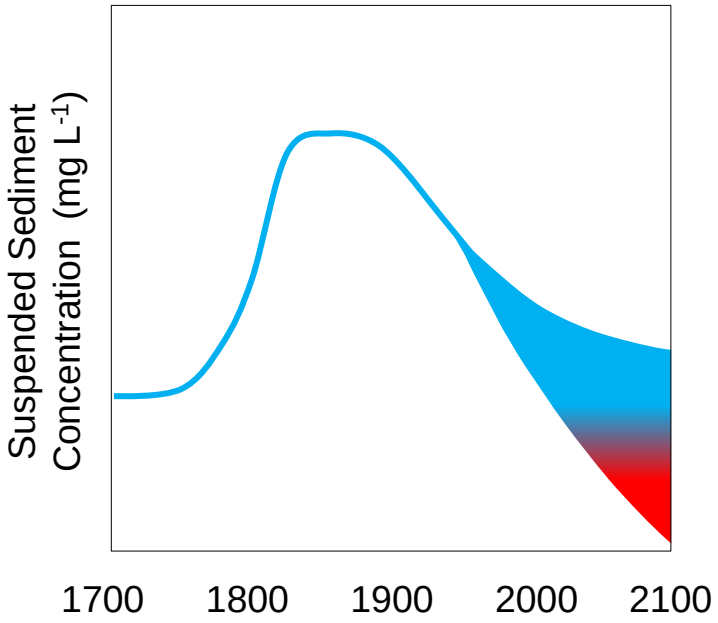
- 1935: Soil Conservation Service (USDA)
  - "The wastage of soil and moisture resources on farm, grazing, and forest lands . . . is a menace to the national welfare"
  - 1994: Natural Resources Conservation Service
- 1972: Clean Water Act

United States Department of Agriculture
NRCS Natural Resources Conservation Service

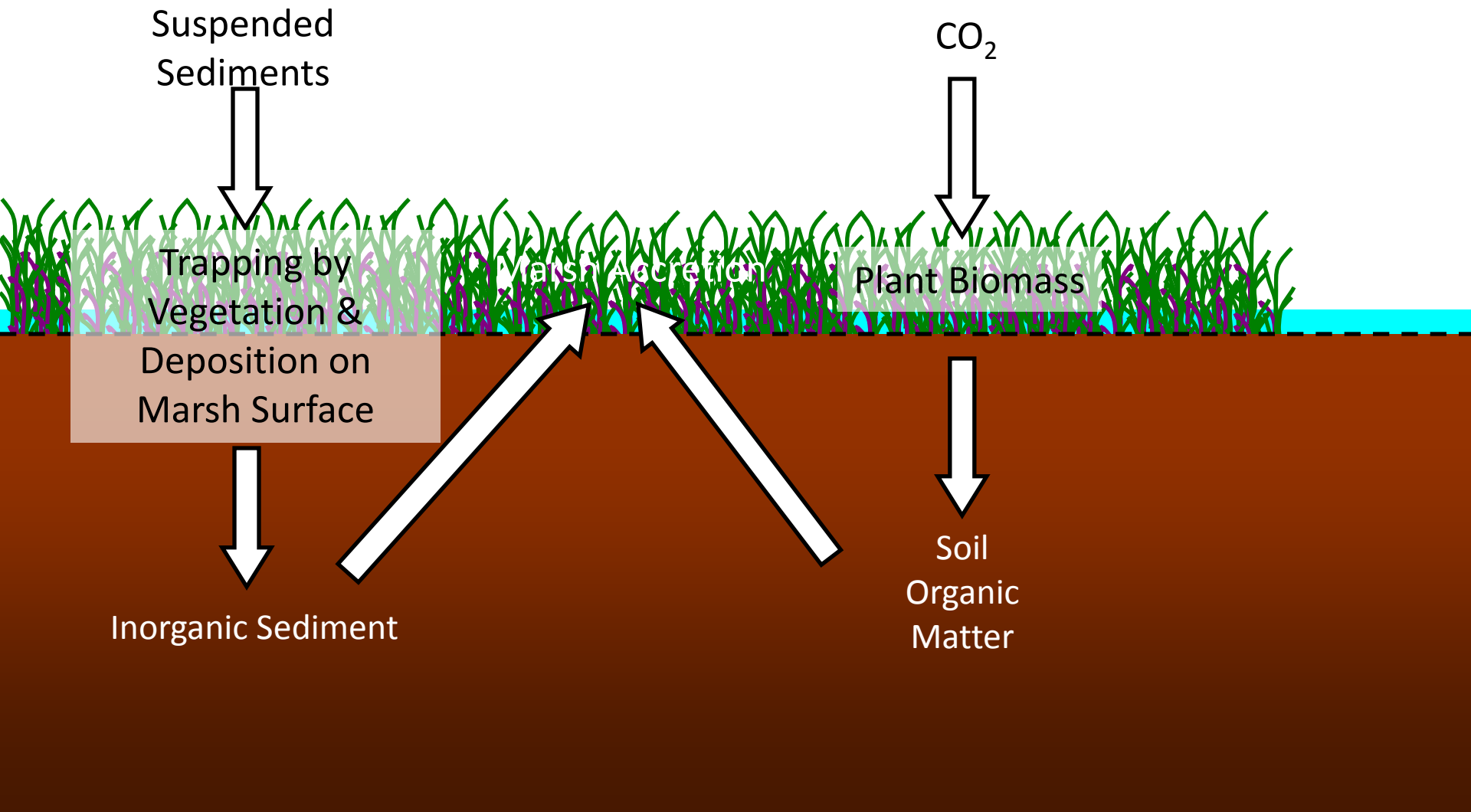

Suspended Sediment Concentration (mg L-1)
Land Clearing
Agriculture
Damming
Afforestation
Soil Conservation
1700
1800
1900
2000
2100

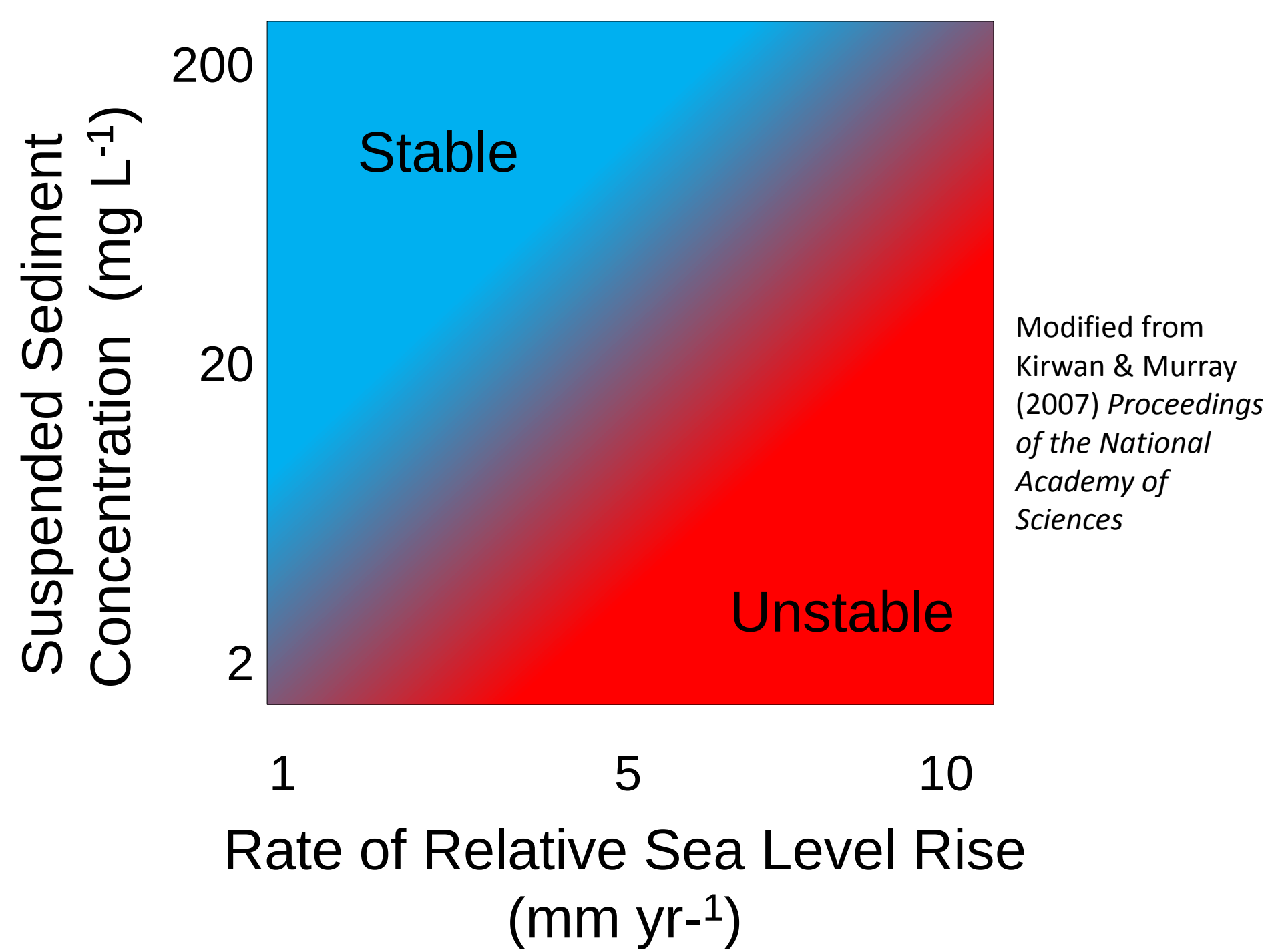
Sea Level Rise & Sediment Availability





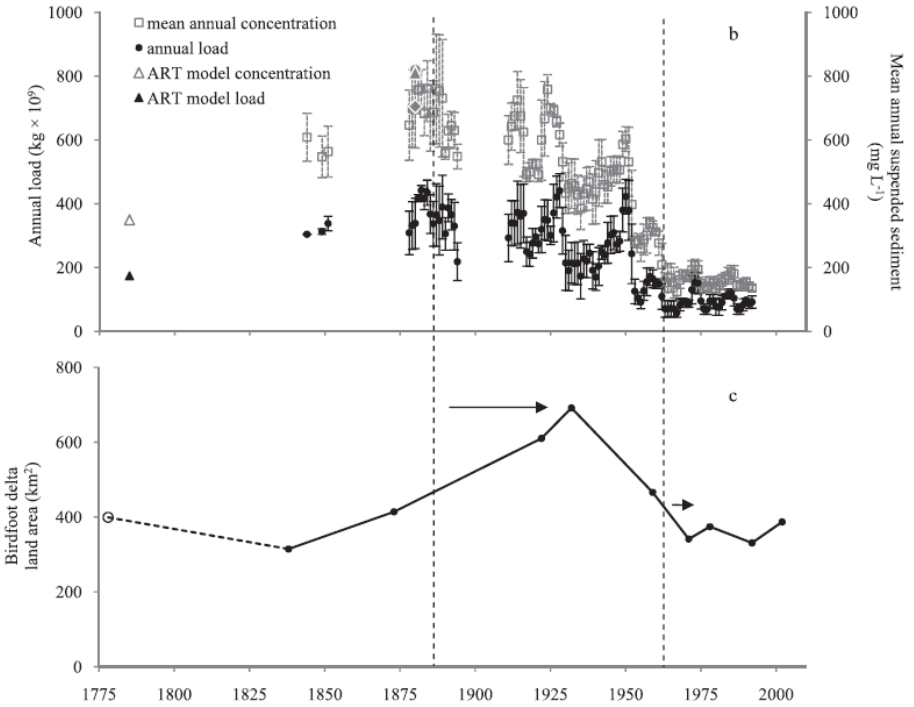
Marsh Accretion



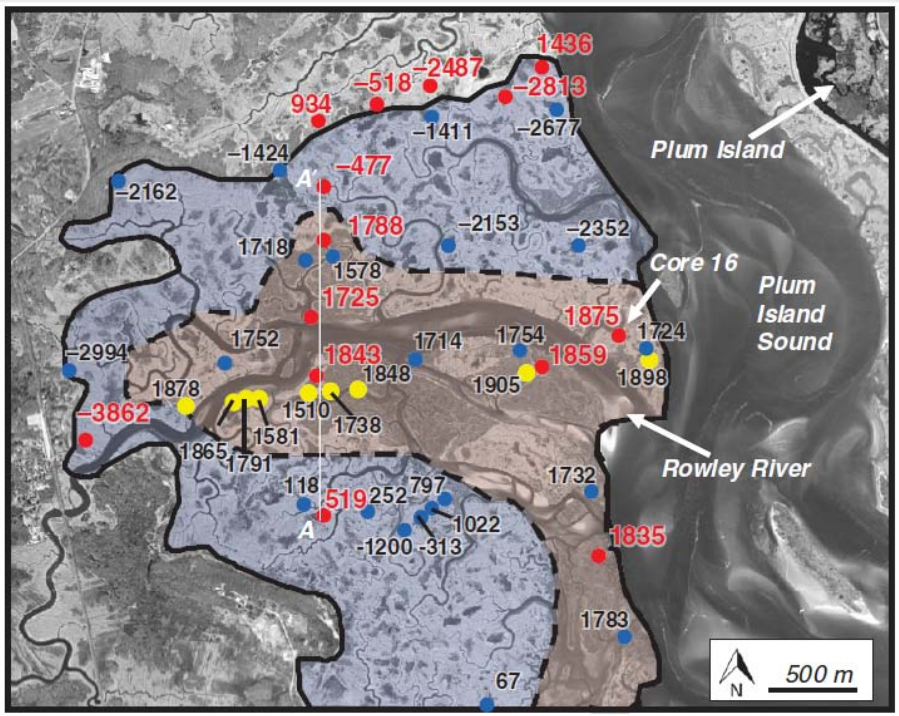


Modified from Kirwan & Murray (2007) *Proceedings of the National Academy of Sciences*

Expansion of Marsh Following Settlement



Tweel & Turner (2012) *Limnology and Oceanography*



Kirwan et al. (2011) *Geology*

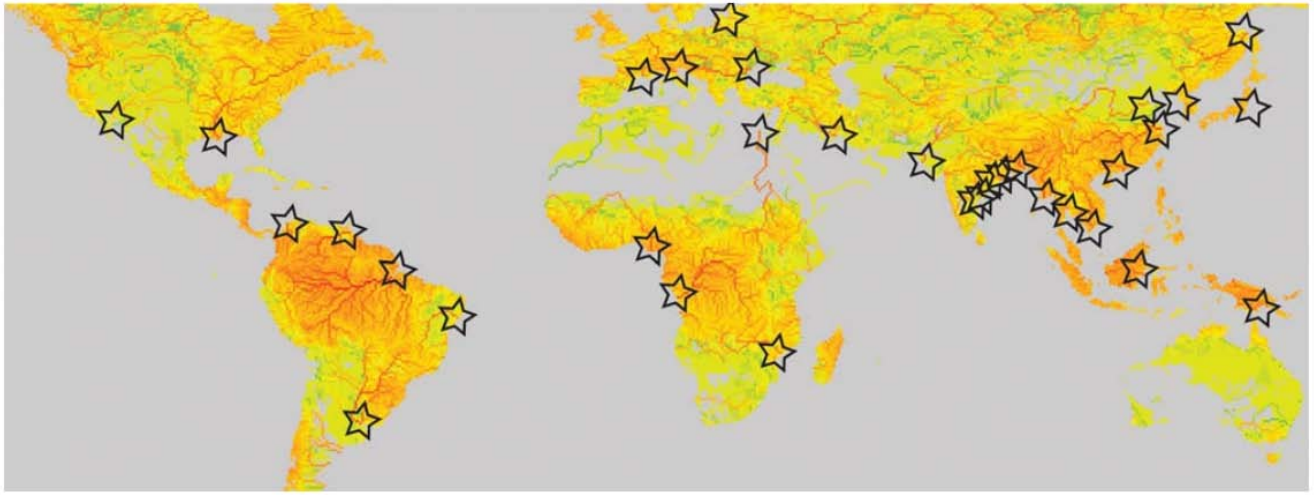
nature geoscience

PROGRESS ARTICLE

PUBLISHED ONLINE: 20 SEPTEMBER 2009 | DOI: 10.1038/NGEO629

Sinking deltas due to human activities

James P. M. Syvitski[1]*, Albert J. Kettner[1], Irina Overeem[1], Eric W. H. Hutton[1], Mark T. Hannon[1], G. Robert Brakenridge[2], John Day[3], Charles Vörösmarty[4], Yoshiki Saito[5], Liviu Giosan[6] and Robert J. Nicholls[7]



Is sediment delivery changing from watersheds to coastal wetlands along the East and Gulf Coasts?

Can these changes be linked to activities in watersheds?

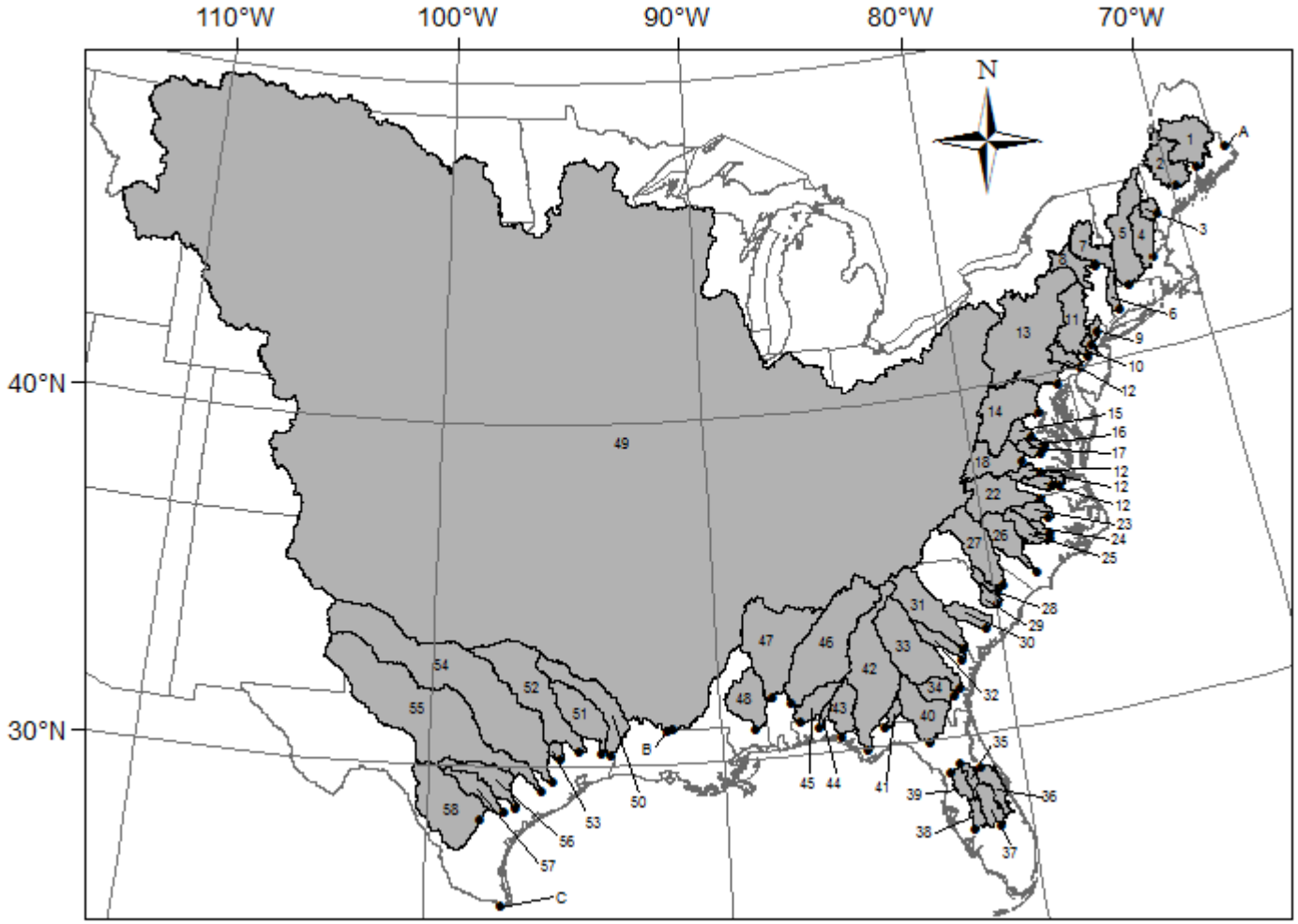
What might these changes mean for tidal marsh vulnerability to climate change?

Analysis of Sediment Concentrations in Rivers Along East and Gulf Coasts

- 58 watersheds
- Average suspended sediment concentration (SSC)
  - United States Geological Survey
- Change in suspended sediment concentrations over time (ΔSSC)

$$SSC = (\Delta SSC_{Date} \times Date) + (\Delta SSC_{Q} \times Discharge)$$

- Watershed characteristics
  - U.S. Department of Agriculture, U.S. Census Bureau, National Land Cover Dataset, National Inventory of Dams, Permanent Service for Mean Sea Level


110°W
100°W
90°W
80°W
70°W
40°N
30°N
N
A
B
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
22
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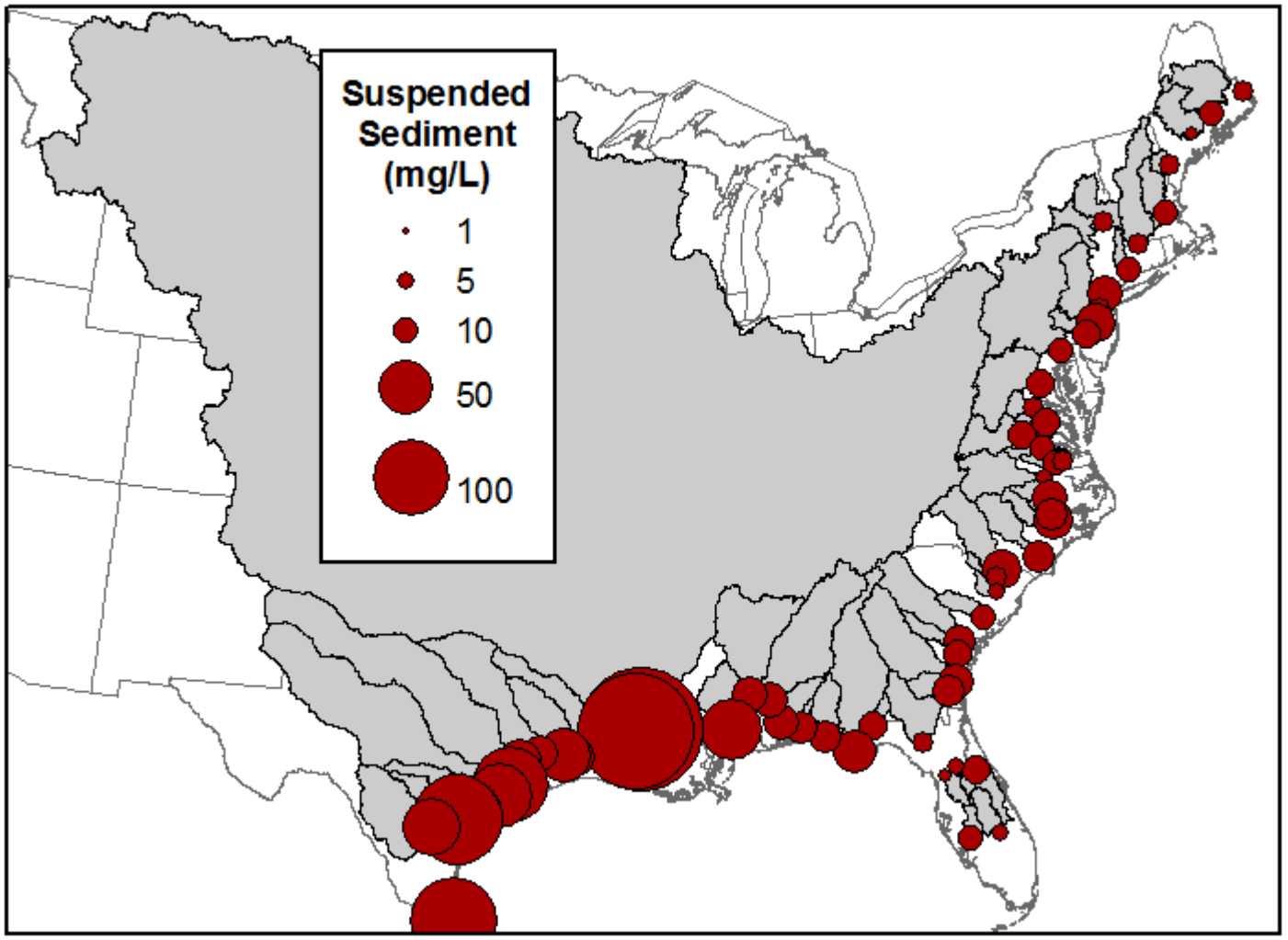
57
58

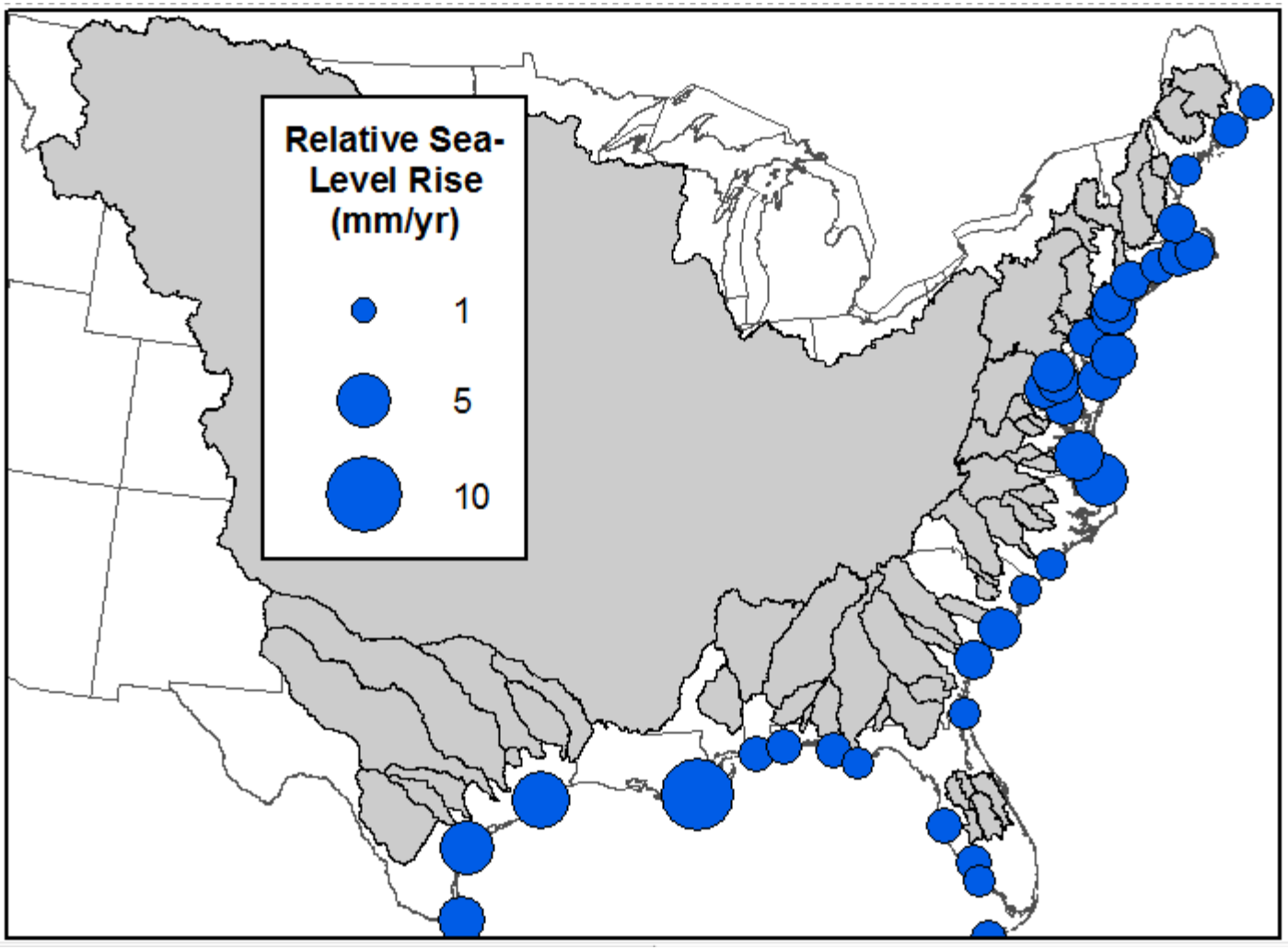
SSC



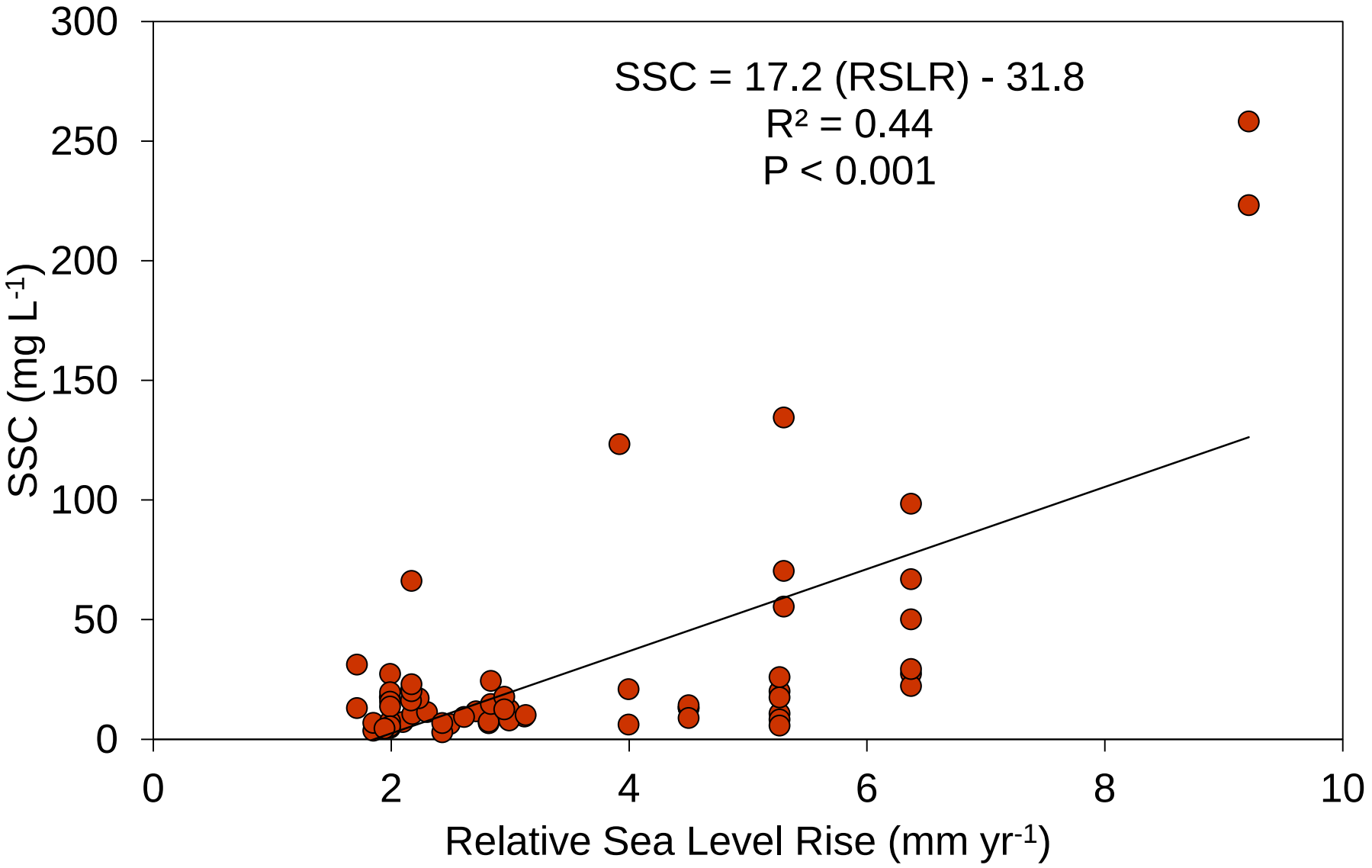
$$FWA\text{-}SSC = 64.8(Area) + 70.8(LU_{Ag}) + 87.2(K_w) - 23.5$$

$$R^2 = 0.80 \; ; \; p < 0.001$$

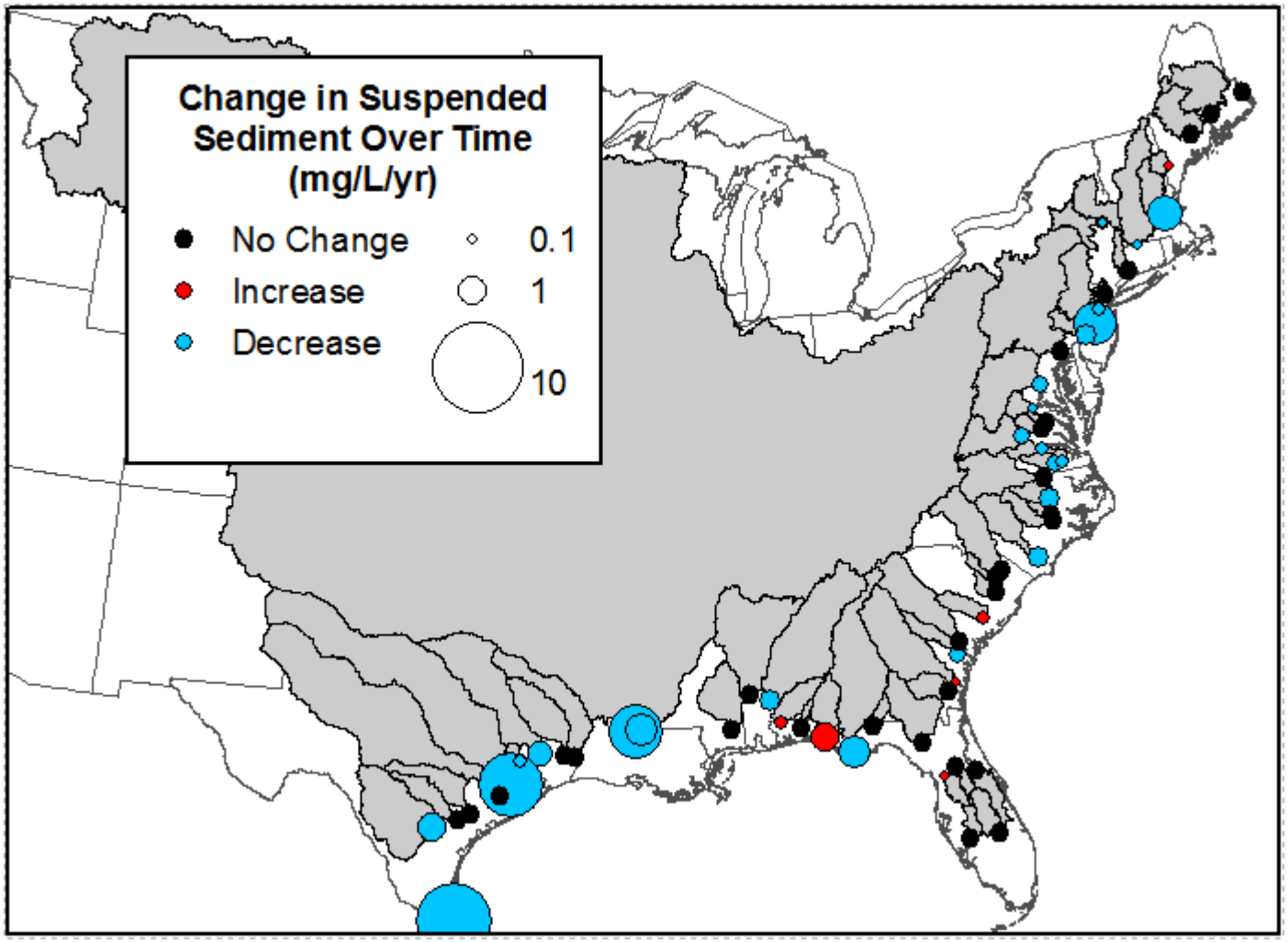
Relative Sea Level Rise



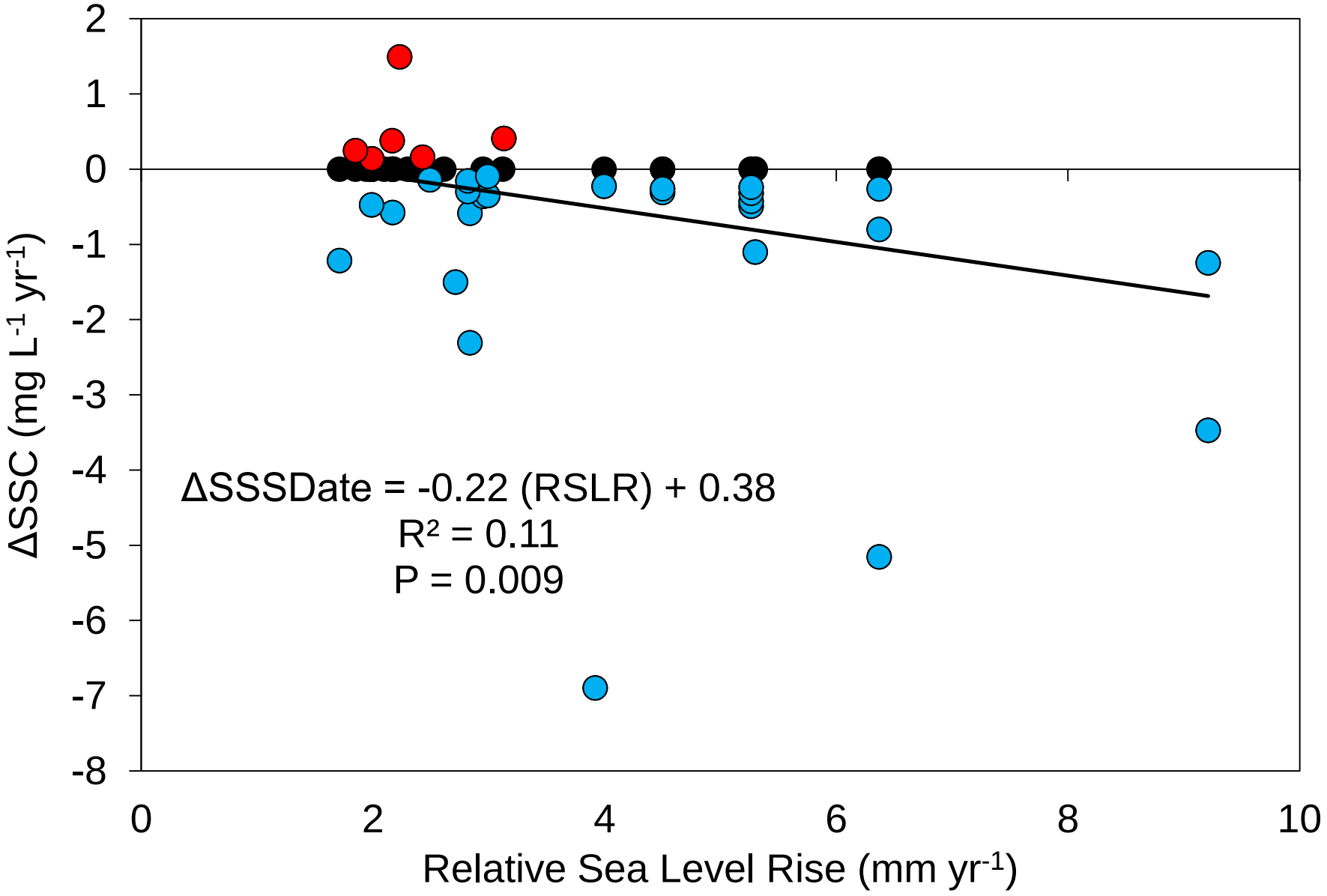
SSC : RSLR

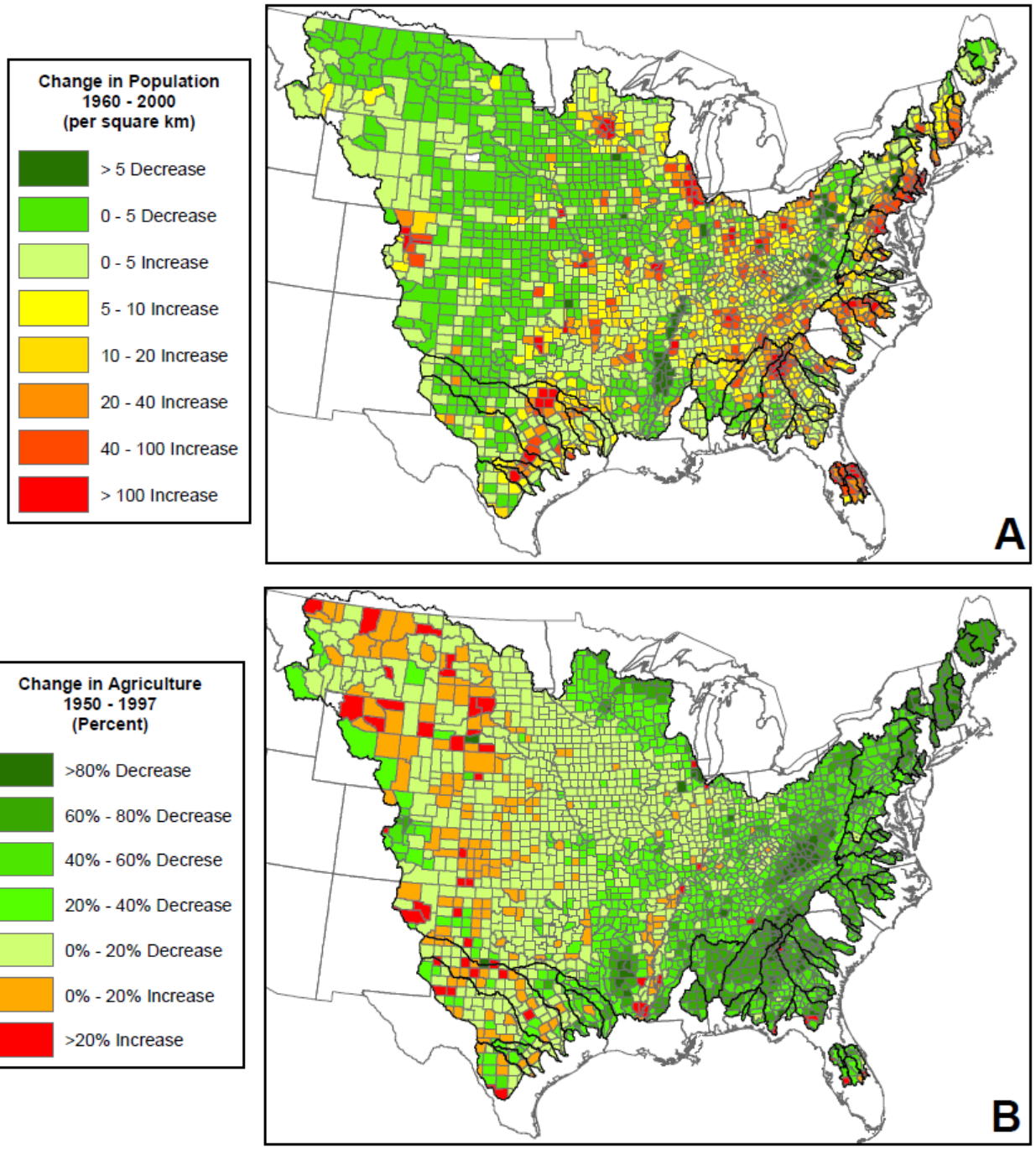

SSC = 17.2 (RSLR) - 31.8
R² = 0.44
P < 0.001
SSC (mg L-1)
300
250
200
150
100
50
0
0
2
4
6
8
10
Relative Sea Level Rise (mm yr-1)

ΔSSC

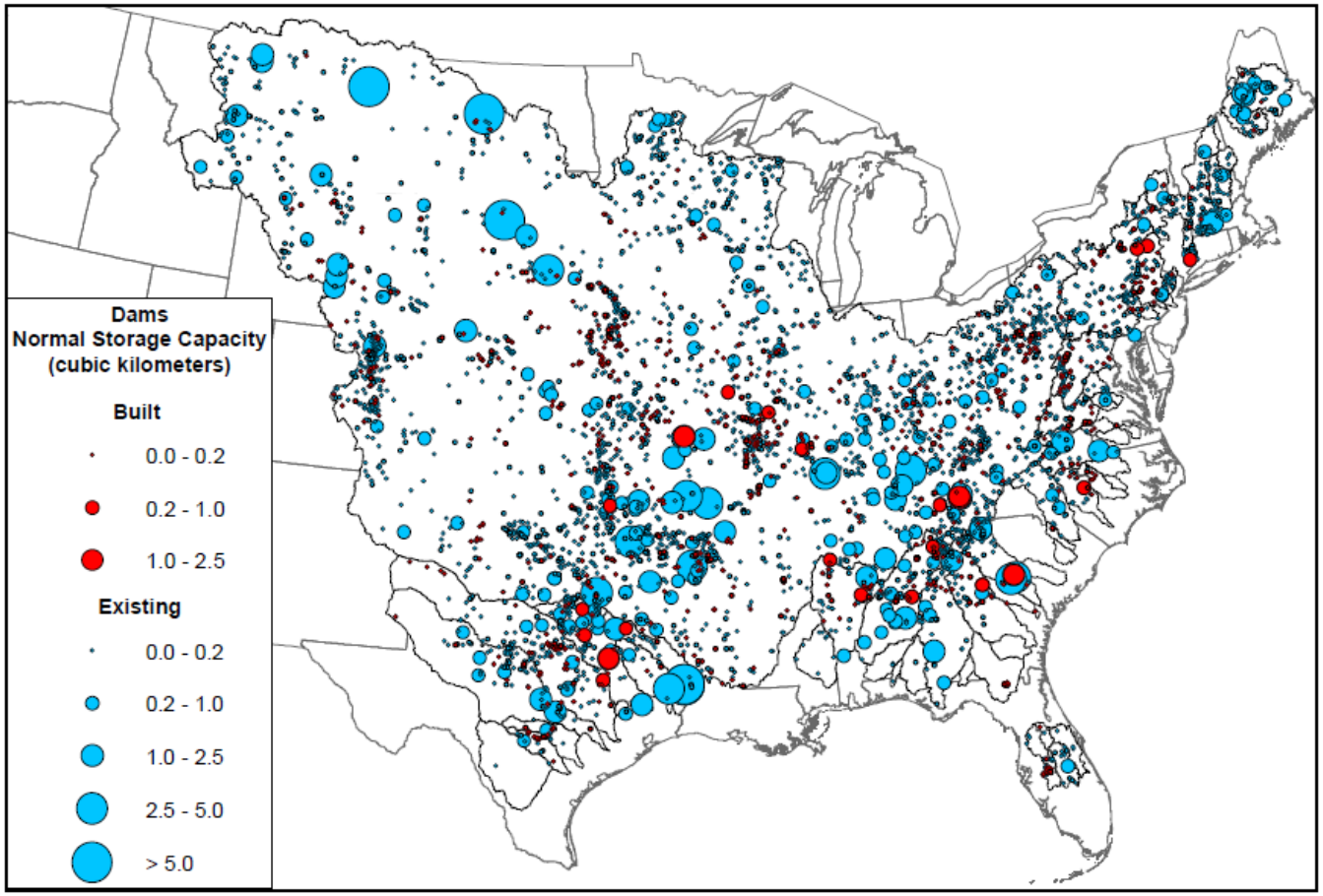

Change in Suspended Sediment Over Time (mg/L/yr)
No Change
Increase
Decrease
0.1
1
10

ΔSSC : RSLR


2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
ΔSSC (mg L-1 yr-1)
ΔSSSDate = -0.22 (RSLR) + 0.38
R² = 0.11
P = 0.009
0
2
4
6
8
10
Relative Sea Level Rise (mm yr-1)

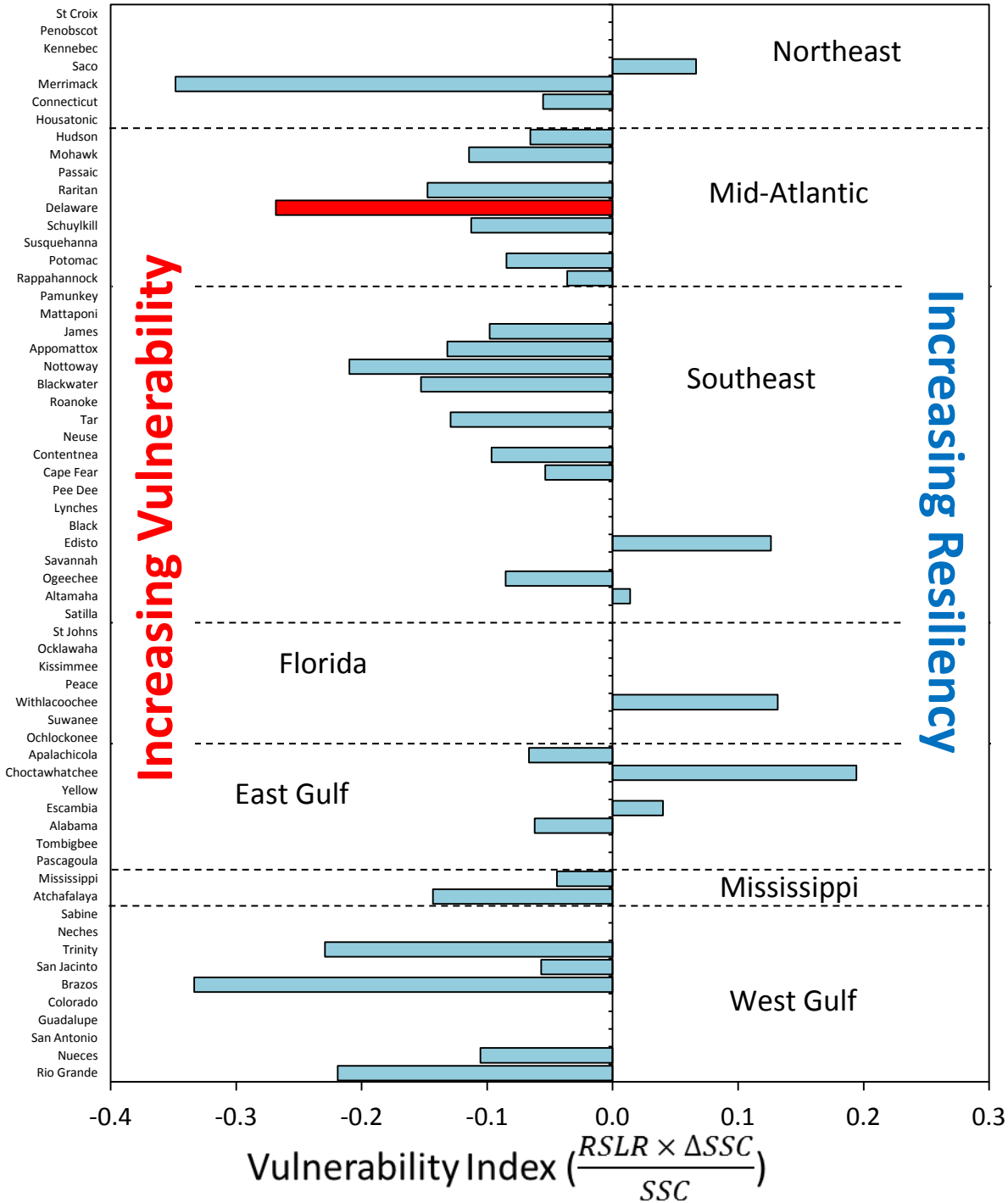

Change in Population
1960 - 2000
(per square km)
> 5 Decrease
0 - 5 Decrease
0 - 5 Increase
5 - 10 Increase
10 - 20 Increase
20 - 40 Increase
40 - 100 Increase
> 100 Increase
A
Change in Agriculture
1950 - 1997
(Percent)
>80% Decrease
60% - 80% Decrease
40% - 60% Decrese
20% - 40% Decrease
0% - 20% Decrease
0% - 20% Increase
>20% Increase
B

Dams

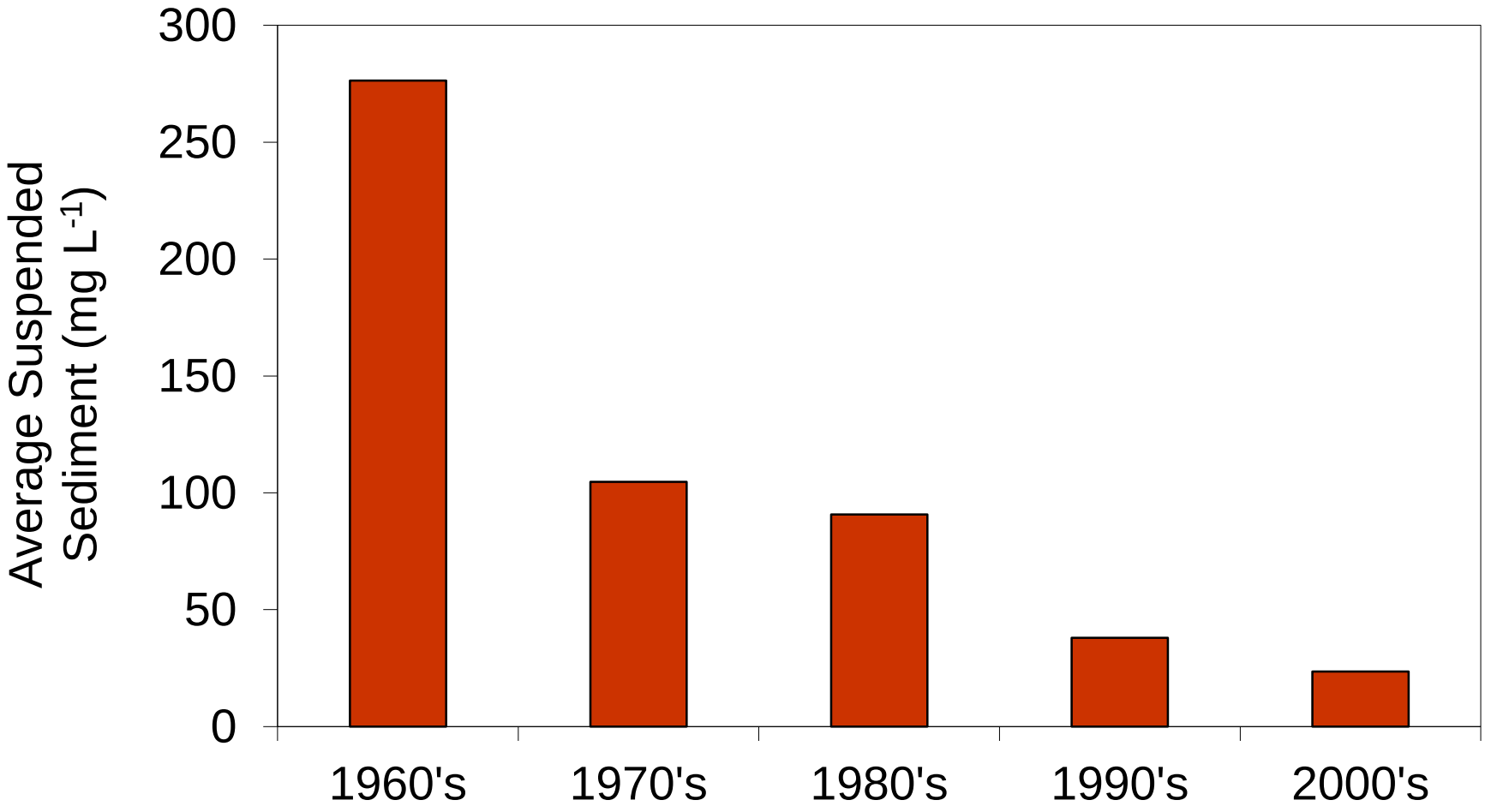


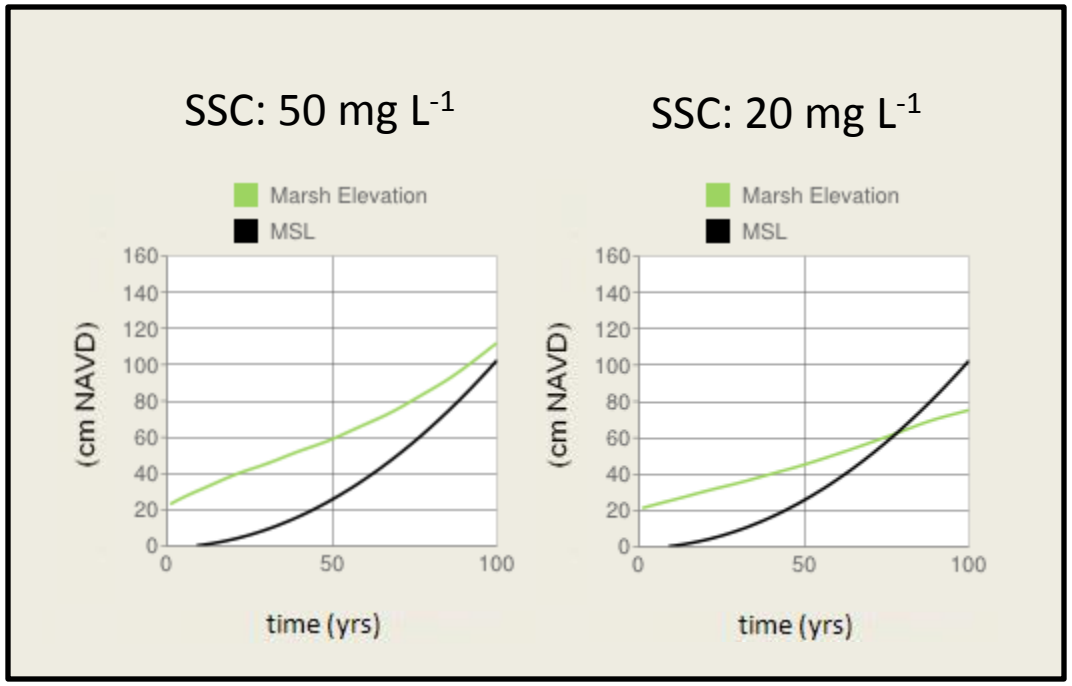
$$\Delta SSC_{Date} = -0.009(\Delta Dam_{RT}) - 0.007(FWA\text{-}SSC) + 0.017$$

$$R^2 = 0.18;\ P = 0.004$$

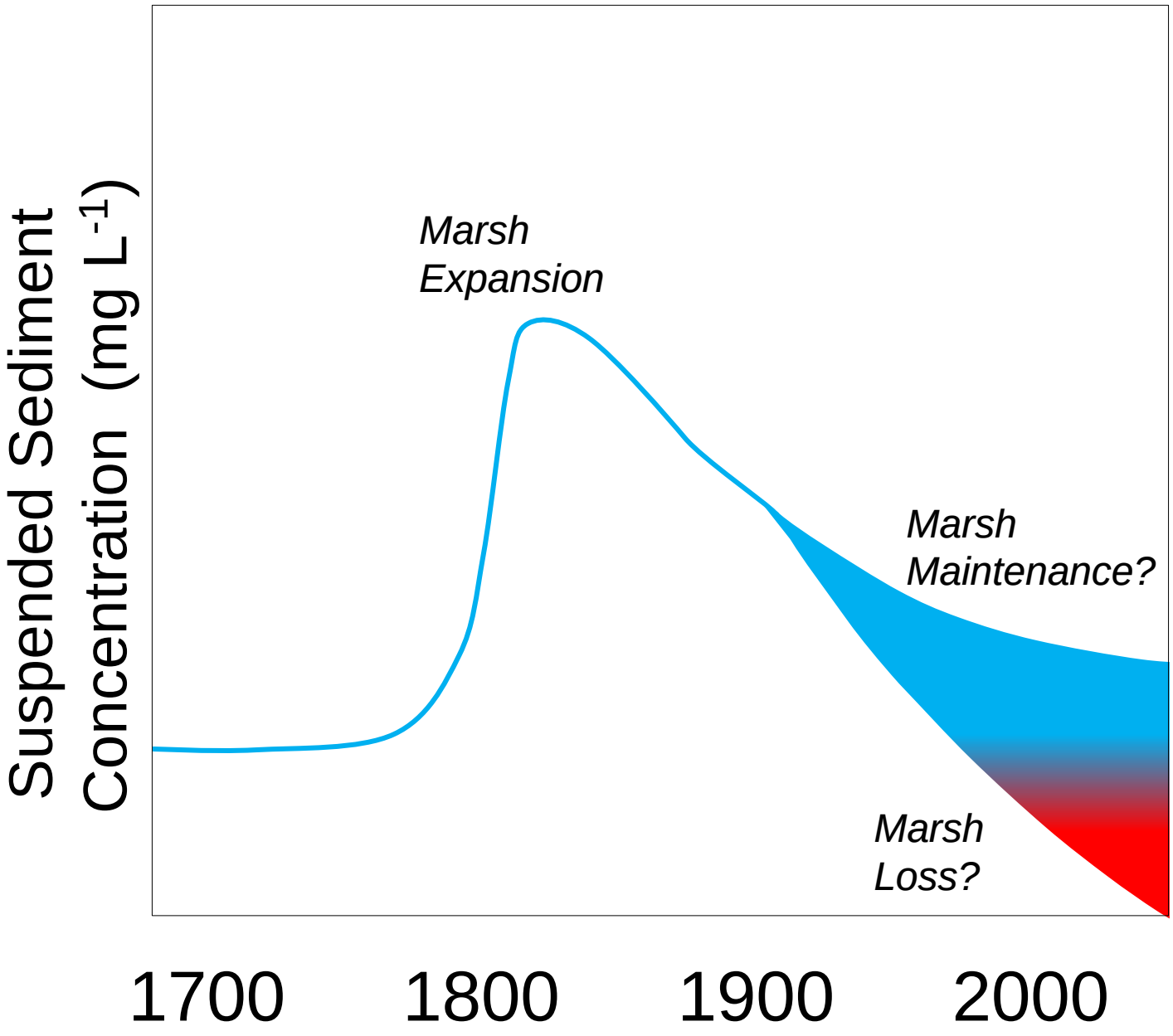

St Croix
Penobscot
Kennebec
Saco
Merrimack
Connecticut
Housatonic
Hudson
Mohawk
Passaic
Raritan
Delaware
Schuylkill
Susquehanna
Potomac
Rappahannock
Pamunkey
Mattaponi
James
Appomattox
Nottoway
Blackwater
Roanoke
Tar
Neuse
Contentnea
Cape Fear
Pee Dee
Lynches
Black
Edisto
Savannah
Ogeechee
Altamaha
Satilla
St Johns
Ocklawaha
Kissimmee
Peace
Withlacoochee
Suwanee
Ochlockonee
Apalachicola
Choctawhatchee
Yellow
Escambia
Alabama
Tombigbee
Pascagoula
Mississippi
Atchafalaya
Sabine
Neches
Trinity
San Jacinto
Brazos
Colorado
Guadalupe
San Antonio
Nueces
Rio Grande
Northeast
Mid-Atlantic
Southeast
Florida
East Gulf
Mississippi
West Gulf
Increasing Vulnerability
Increasing Resiliency
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
Vulnerability Index ($\frac{RSLR \times \Delta SSC}{SSC}$)

Delaware River SSC



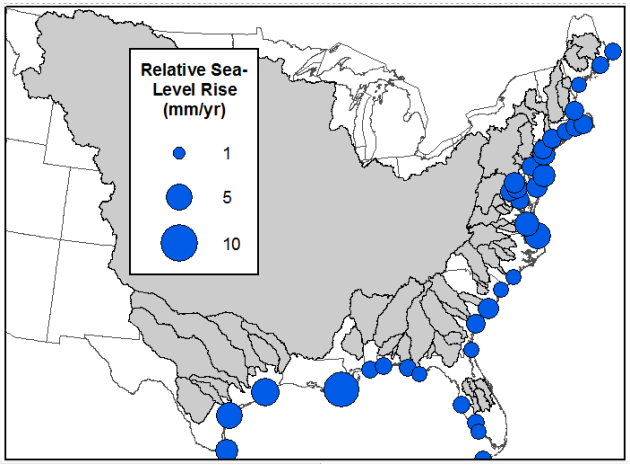


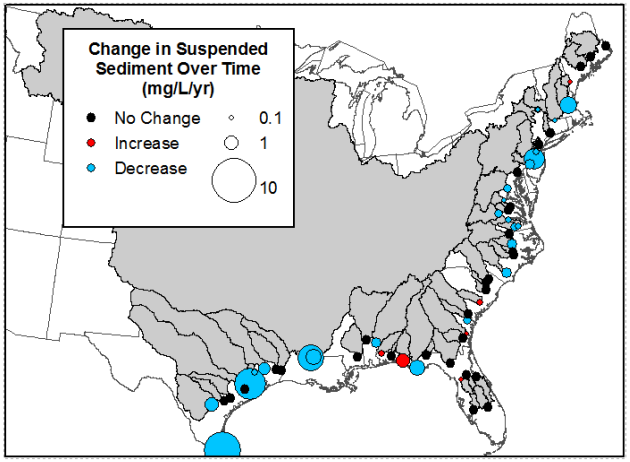
J. Morris; Marsh Equilibration Model

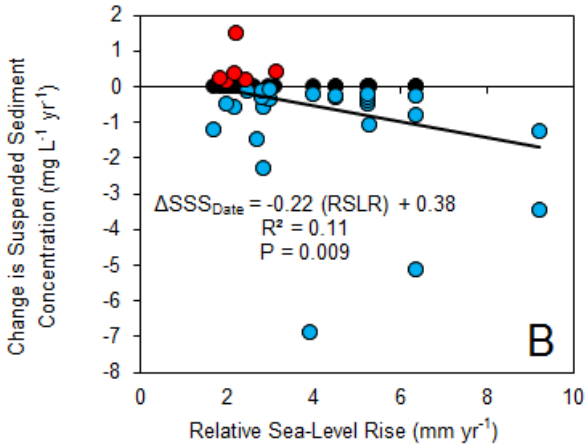

Suspended Sediment Concentration (mg L-1)
Marsh Expansion
Marsh Maintenance?
Marsh Loss?
1700
1800
1900
2000

Conclusions

- Suspended sediment concentrations have declined in many rivers (25 out of 58) along the East and Gulf Coasts
- Decline is most rapid in regions with rapid relative sea-level rise (RSLR)
- Decline in sediment availability together with accelerating RSLR increases marsh vulnerability
  - Regionally, decreased resiliency in Mid-Atlantic (notably Delaware River), Southeast, Mississippi, and Texas Gulf







Acknowledgments

Assistance

- Guillame Turcotte
- Craig Diziki

Funding

- National Science Foundation
- Villanova University

Data Sources

- U.S. Geological Survey
- U.S. Census Bureau
- U.S. Department of Agriculture
- U.S. Army Corps of Engineers
- Permanent Service for Mean Sea Level