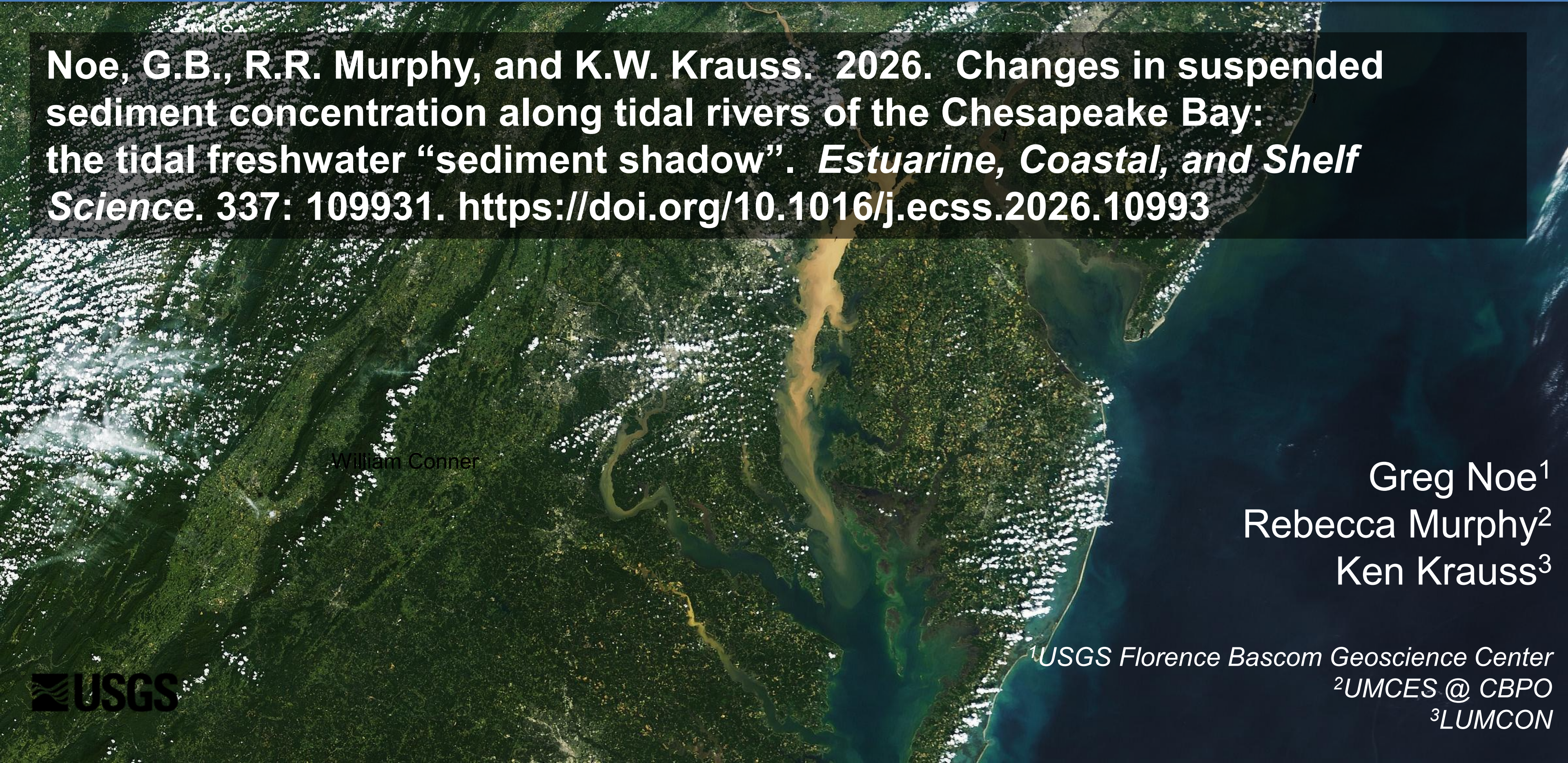
Analyses of long-term suspended sediment concentration data reveals limited delivery of contemporary watershed sediment to the Bay

Noe, G.B., R.R. Murphy, and K.W. Krauss. 2026. Changes in suspended sediment concentration along tidal rivers of the Chesapeake Bay: the tidal freshwater "sediment shadow". *Estuarine, Coastal, and Shelf Science*. 337: 109931. https://doi.org/10.1016/j.ecss.2026.10993



William Conner

Greg Noe[1]
Rebecca Murphy[2]
Ken Krauss[3]

[1]USGS Florence Bascom Geoscience Center
[2]UMCES @ CBPO
[3]LUMCON

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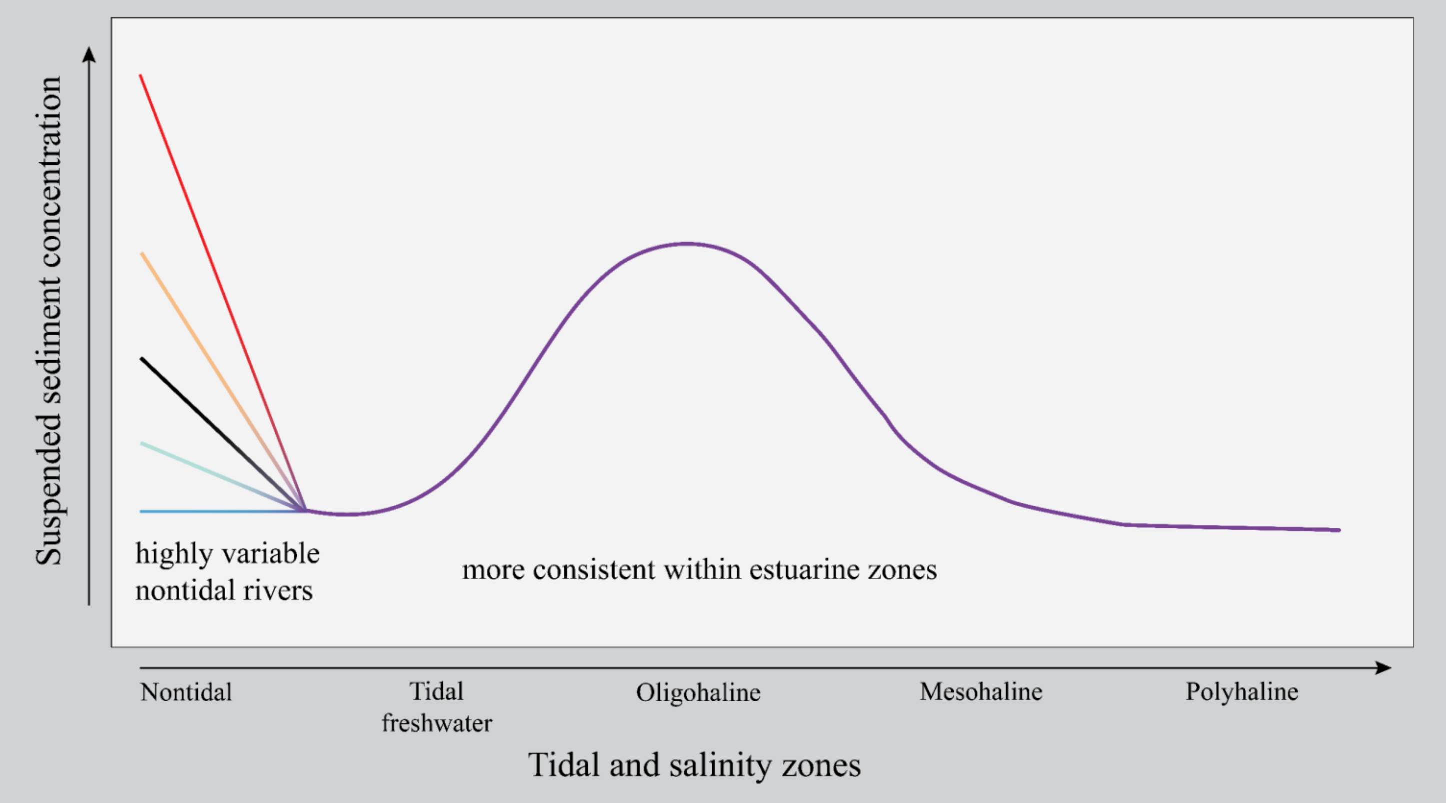
General pattern of river and estuary sediment concentration in the Chesapeake

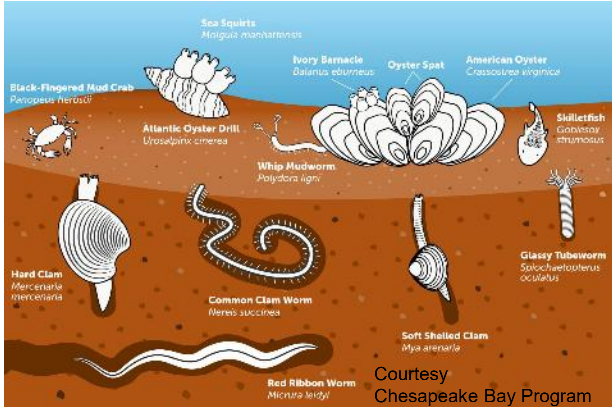


Noe, Murphy, Krauss 2020 | *Estuarine, Coastal and Shelf Science*

Why care about sediment in the Chesapeake Bay?

<u>Excess fine sediment</u>:

1. Impairs habitat through clarity and benthic deposition
2. Transports attached and constituent pollutants (esp. Phosphorus)
3. Provides resilience to sea-level rise for tidal wetlands



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Noe et al. 2020 | *Wiley Interdisciplinary Reviews: Water*

How is sedimentation managed in Chesapeake?

Chesapeake Bay TMDL:

implementing management actions that would reduce downstream sediment loading by 20%

… mostly through watershed BMPs

USGS

Tidal freshwater rivers

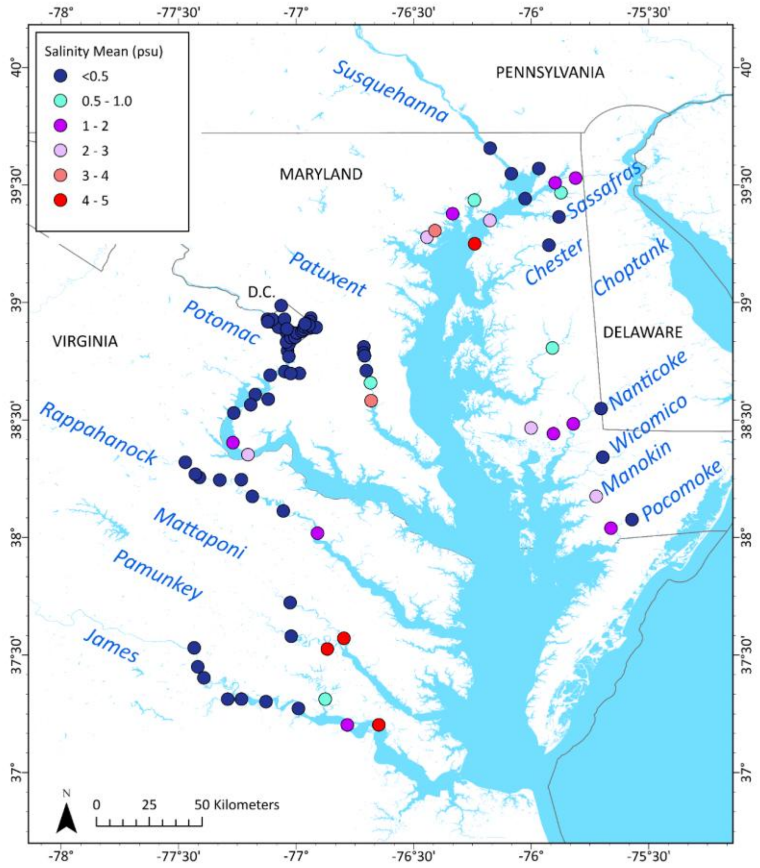
Length of tidal river scales with watershed drainage area, depending on geology,

And adds up to an extensive ecosystem along

U.S. Atlantic Coast

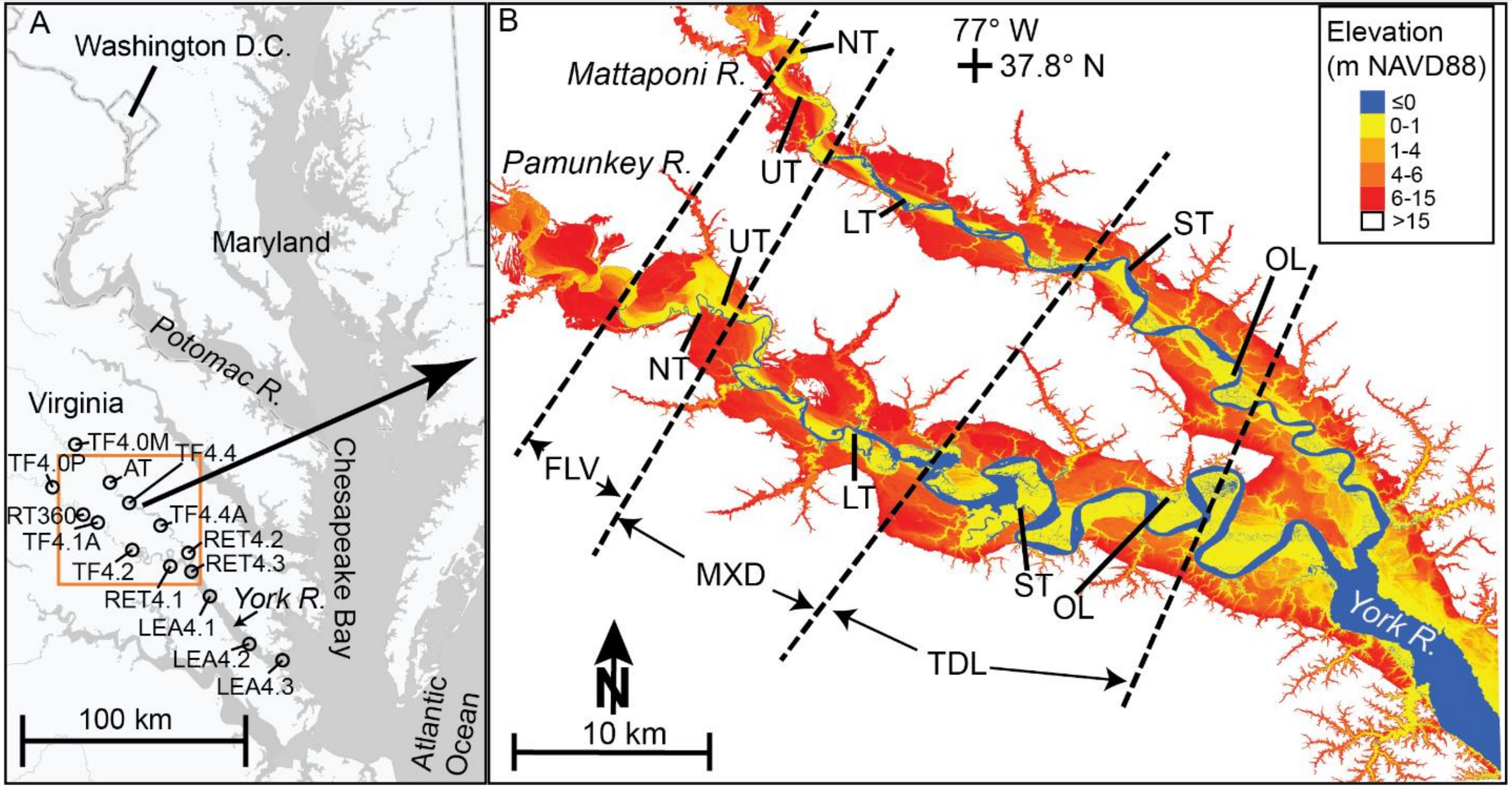
→ ~ 3,000 km

Ensign and Noe 2018 | *Frontiers Ecology & Env.*



USGS

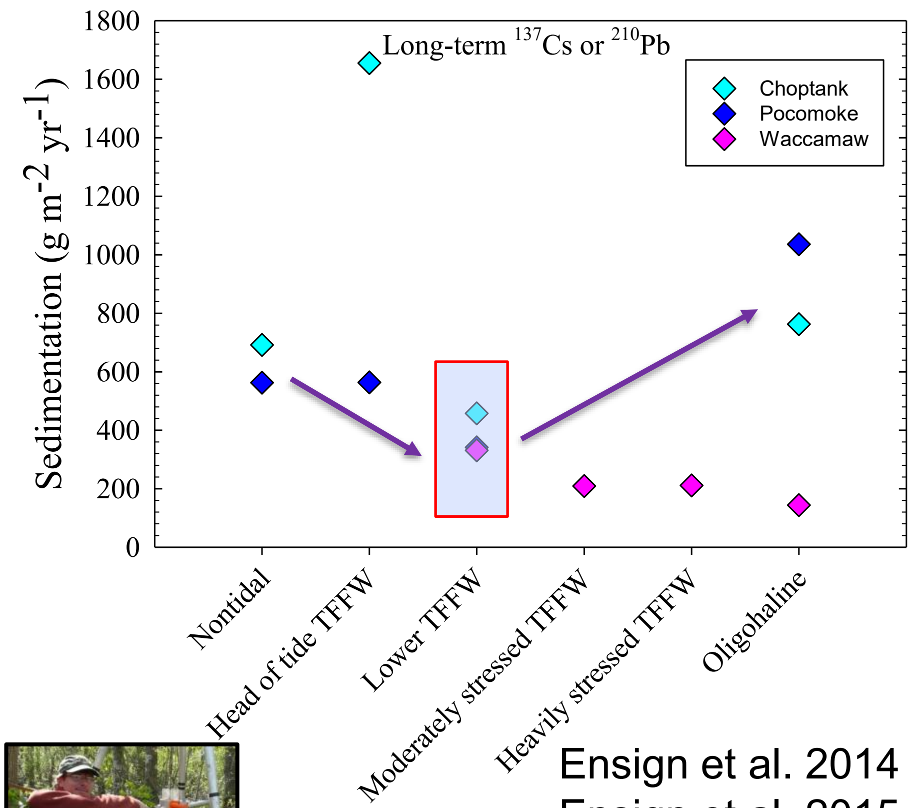
Tidal Rivers: the dynamic interface of estuaries and watersheds

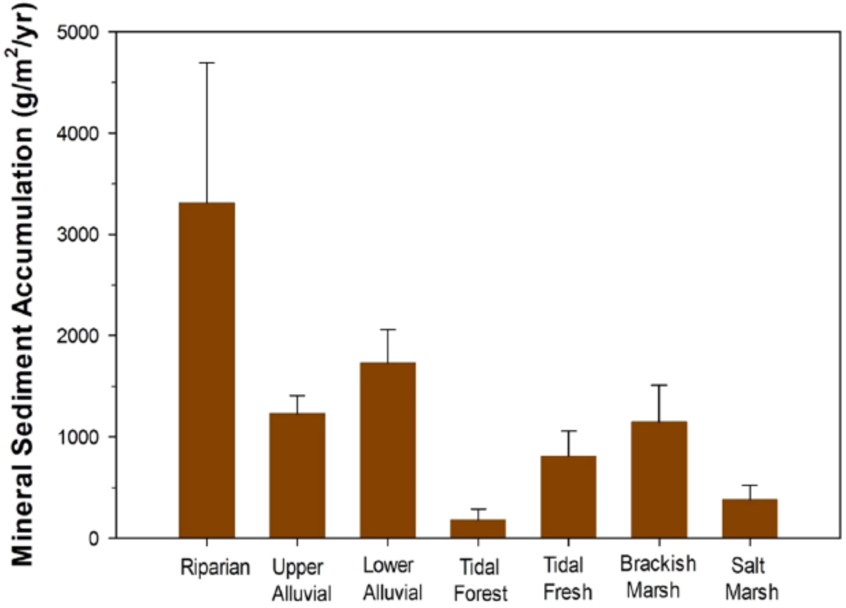


USGS

Kroes et al. 2023 | *Estuaries & Coasts*

Wetland sedimentation rates minimal in TFFW



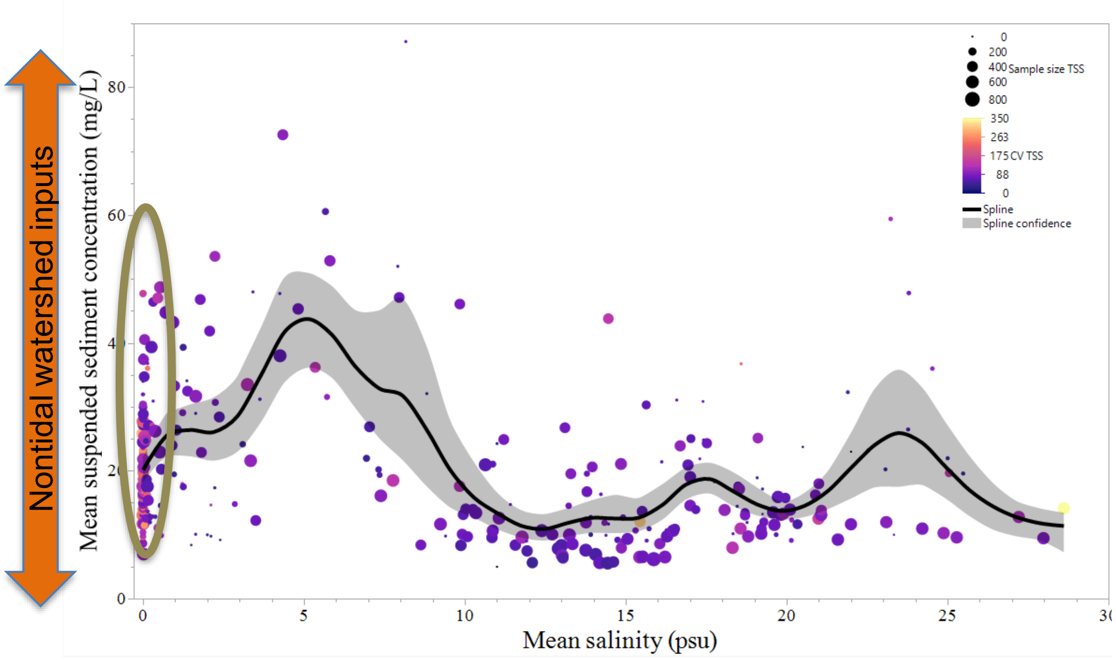


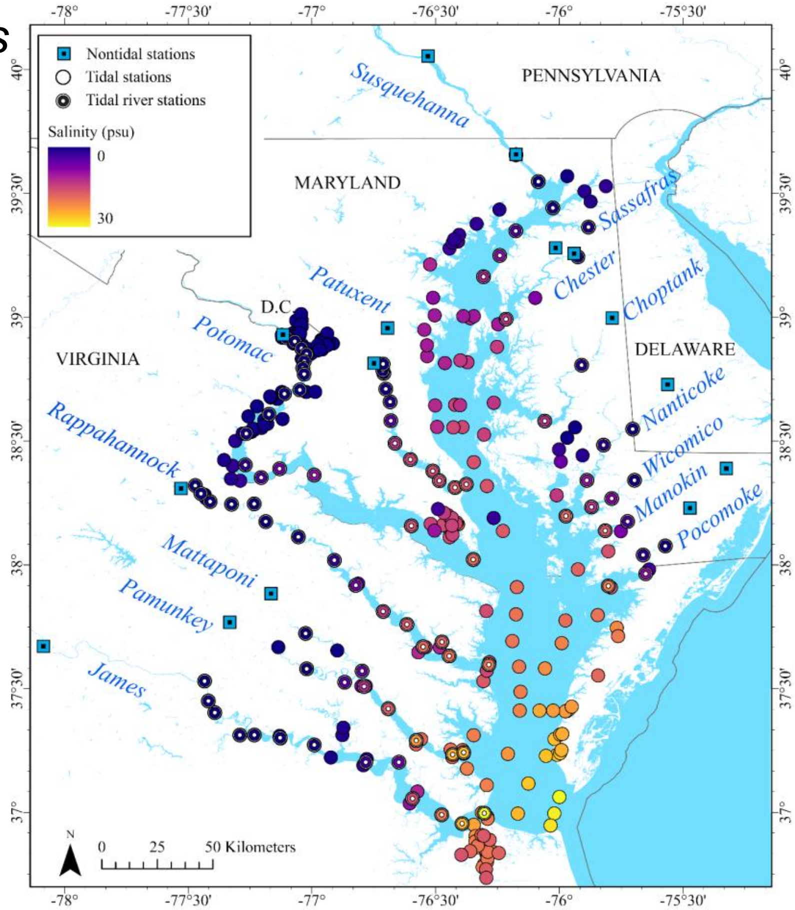
Craft et al. 2022 | *Rivers*

Ensign et al. 2014 | *JGR-ES*
Ensign et al. 2015 | *GRL*
Noe et al. 2016 | *Estuaries & Coasts*

Chesapeake Bay Program (CBP) long-term data (1984-2021)

Surficial samples: top of water column in tidal waters (typically 1 m deep below water surface)





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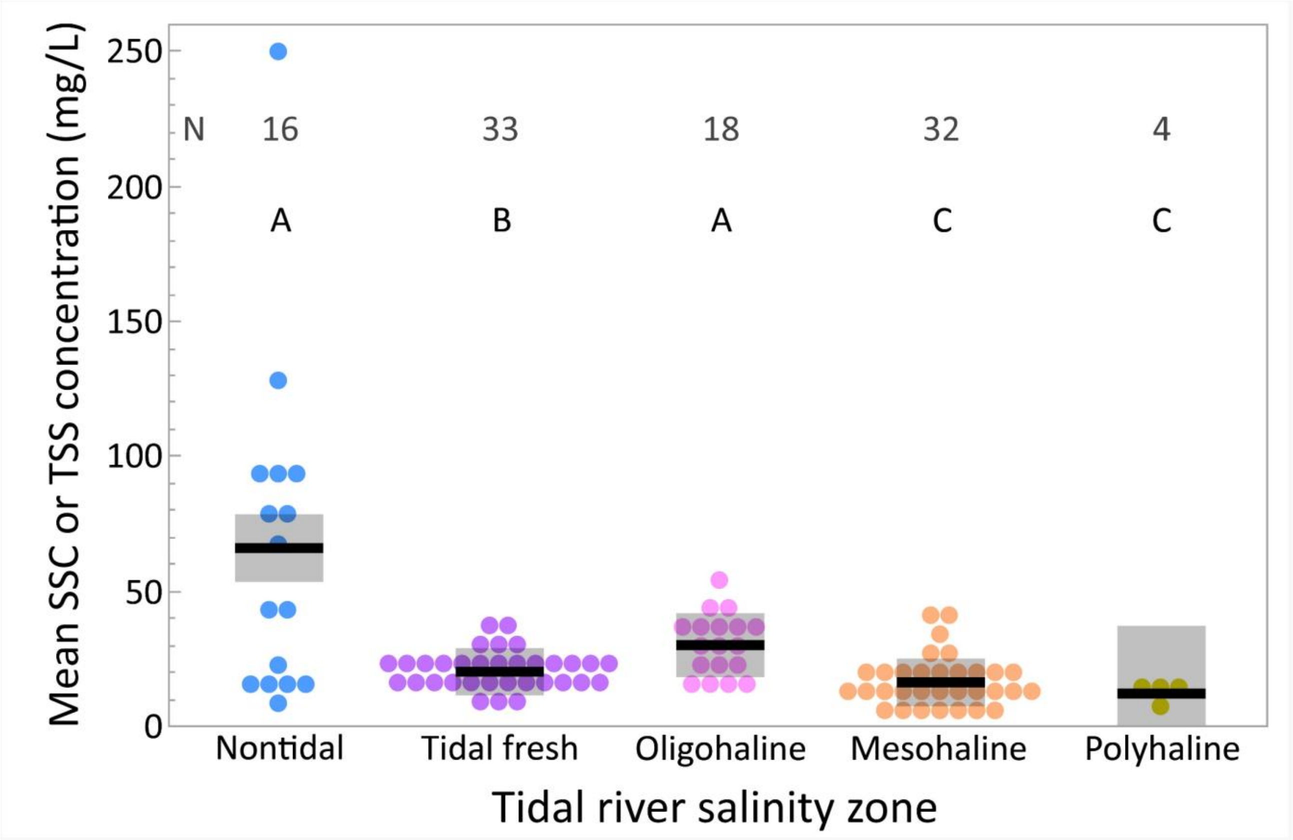
Mean SSC/TSS for each station: by tidal and salinity zone



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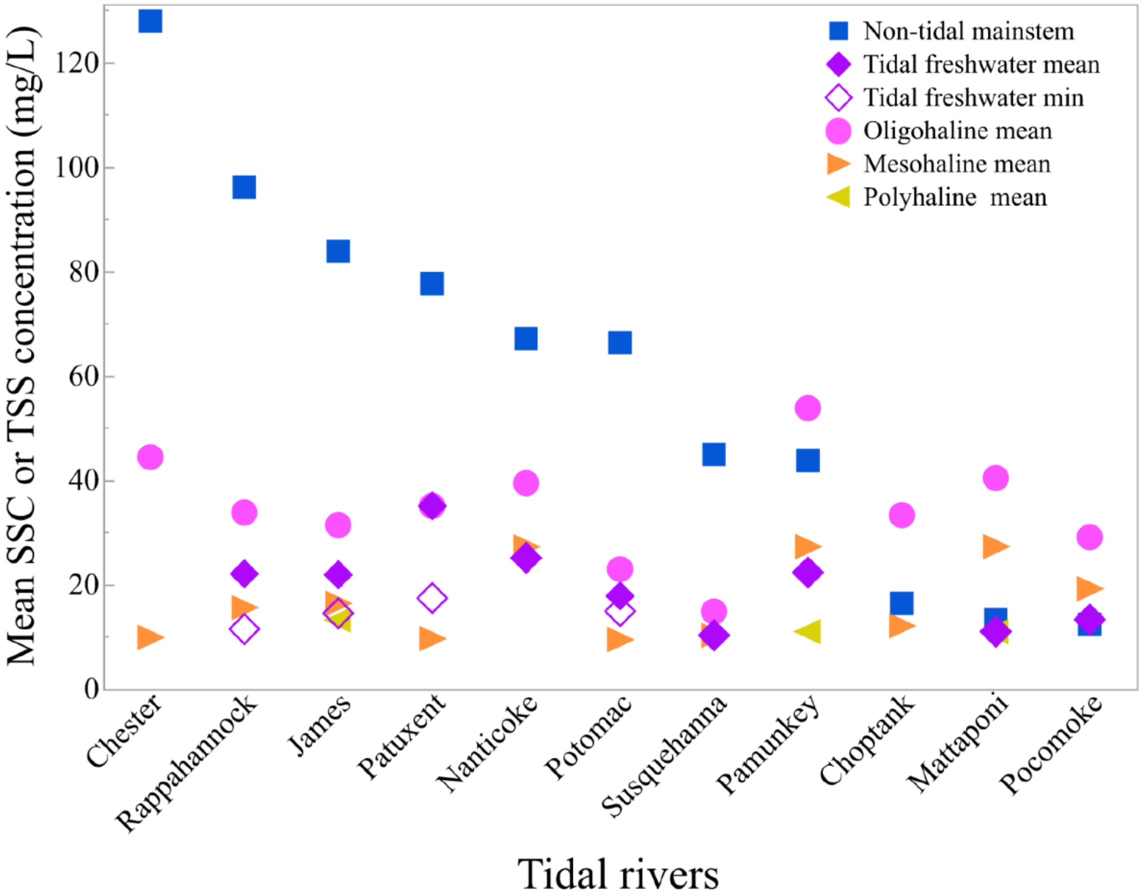
Mean SSC/TSS across stations: by zone in each tidal river



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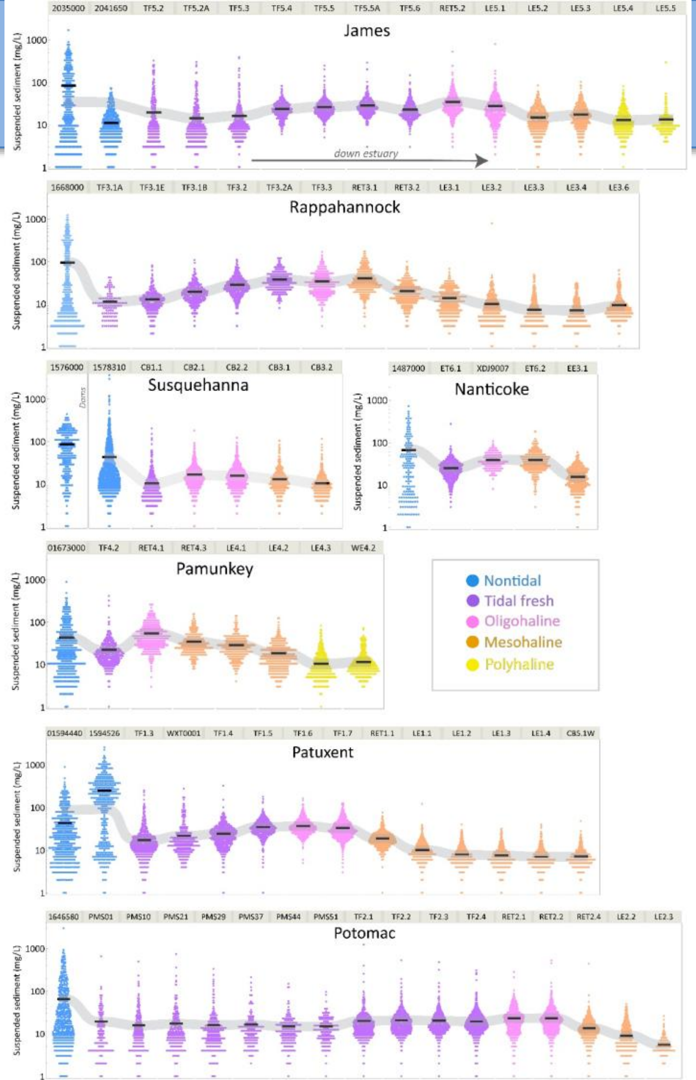
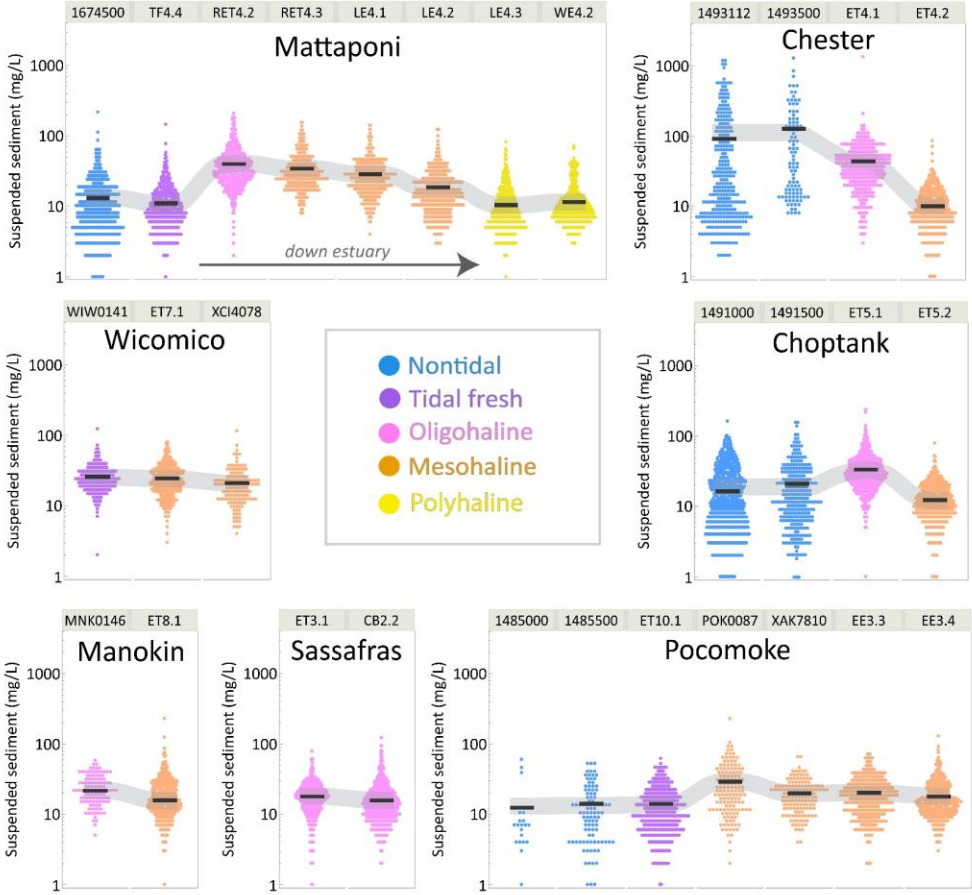
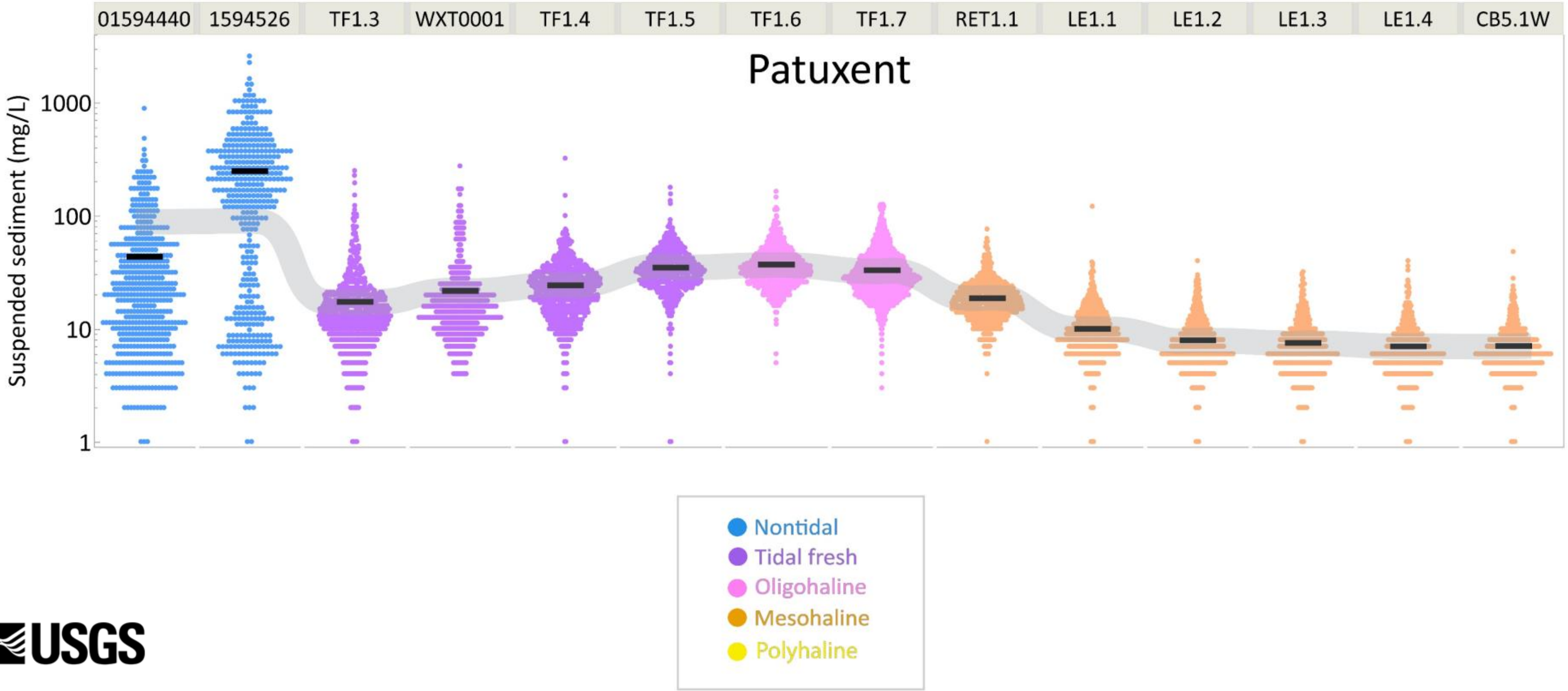
4 classes of downriver trends in SSC/TSS 1984 to 2021





4 classes of downriver trends in SSC/TSS 1984 to 2021



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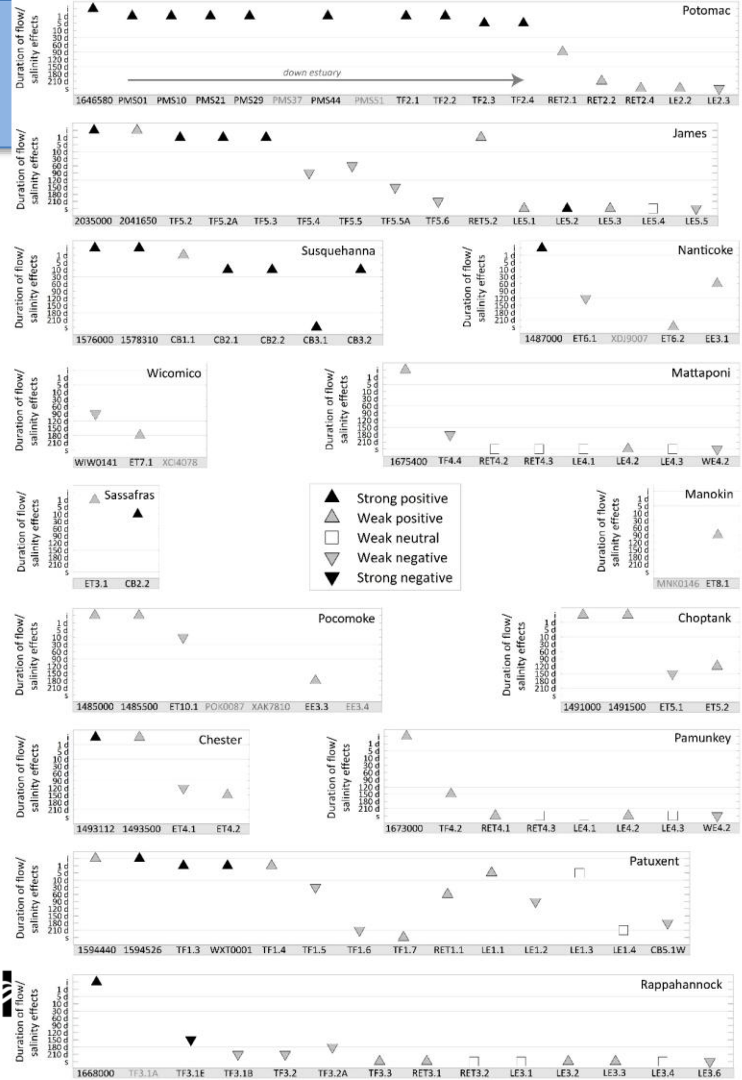
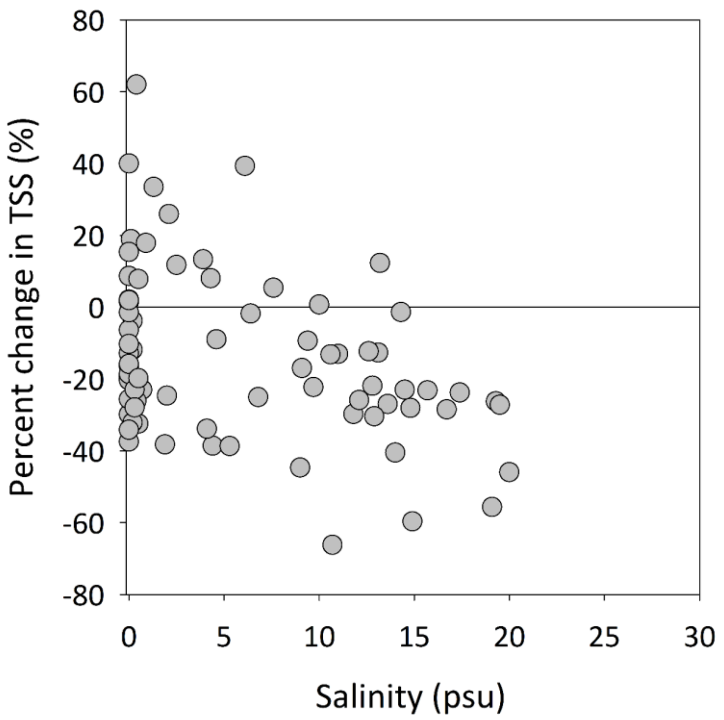
GAM analyses of TSS at tidal stations 1999 to 2022

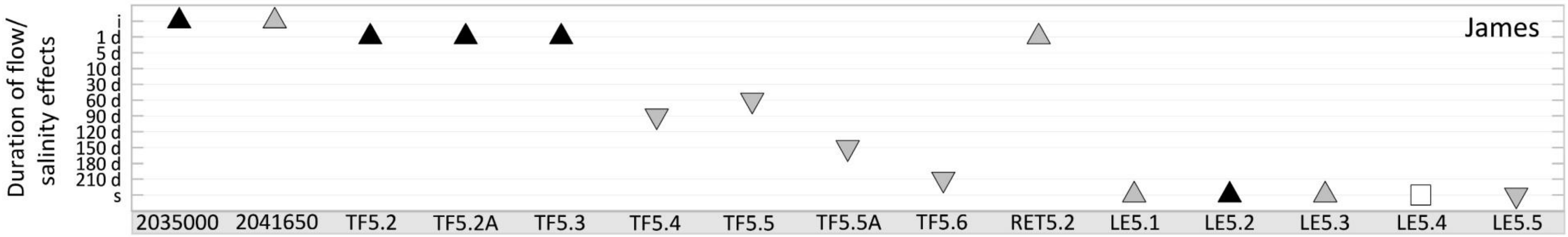


Above 10 psu had a 25% reduction in TSS

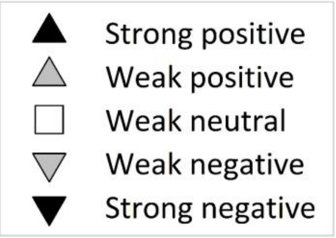


GAM analyses of TSS at tidal stations 1999 to 2022

Fast response to river FW input



Slow response to river FW input



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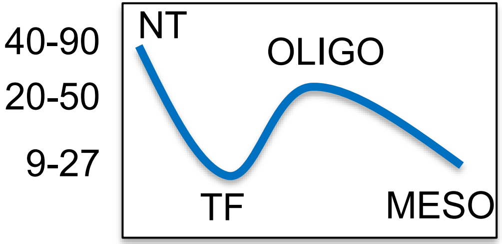
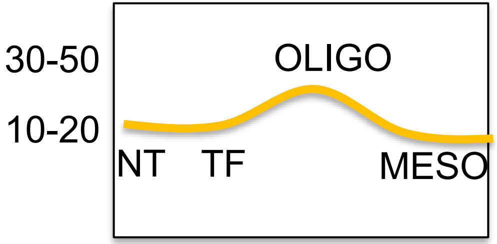
Four different system behaviors of sediment availability changes

Higher watershed sediment



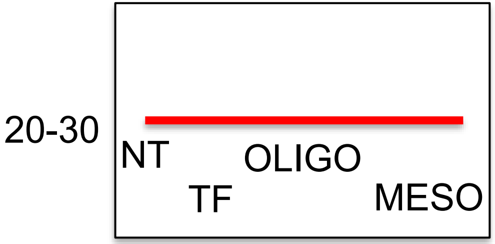
7 rivers (5 largest)

Moderate watershed sediment

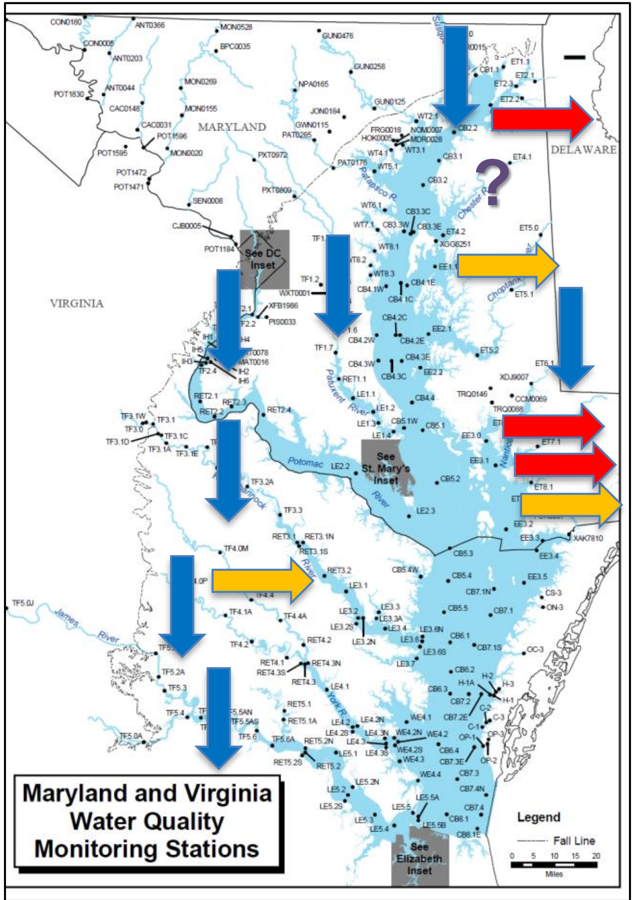


3 rivers

Lower watershed sediment



3 rivers



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Caveats and limitations

Could sediment bypass surface waters in tidal freshwater zone?

- Bottom layer of uppermost TFZ sites had 33% greater SS concentration than the surface layer.
- Bedload transport possible, but also goes upstream towards ETM

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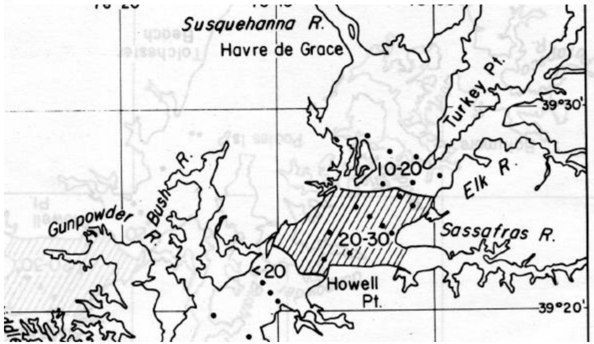
The role of massive floods in recent past

Patterns of sediment deposition around the Chesapeake Bay indicate that the upper estuary traps nearly all watershed sediment delivered (Donoghue et al., 1989; Marcus and Kearney, 1991; Sanford et al., 2001).

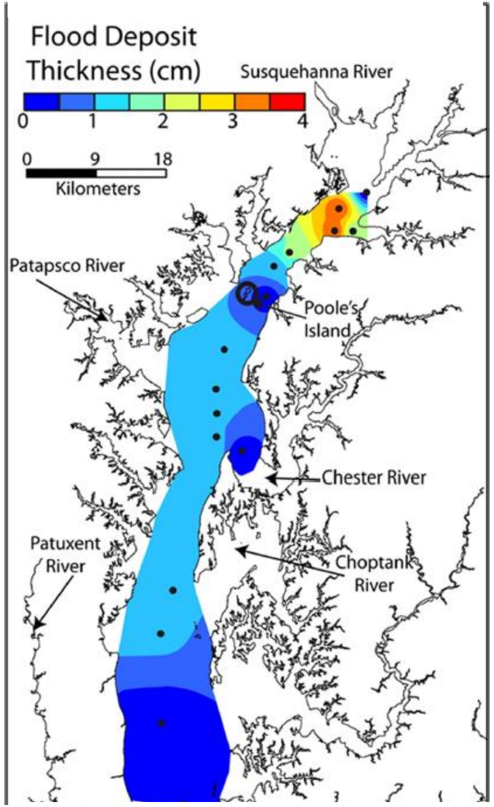
Most of the sediment delivered from the Choptank River following the flood of record after Hurricane Irene (2014) was trapped in the upper tidal freshwater zone (Ensign et al., 2015).

Hurricane Agnes



Zabawa and Schubel | 1974

TS Lee



Palinkas et al. | 2014

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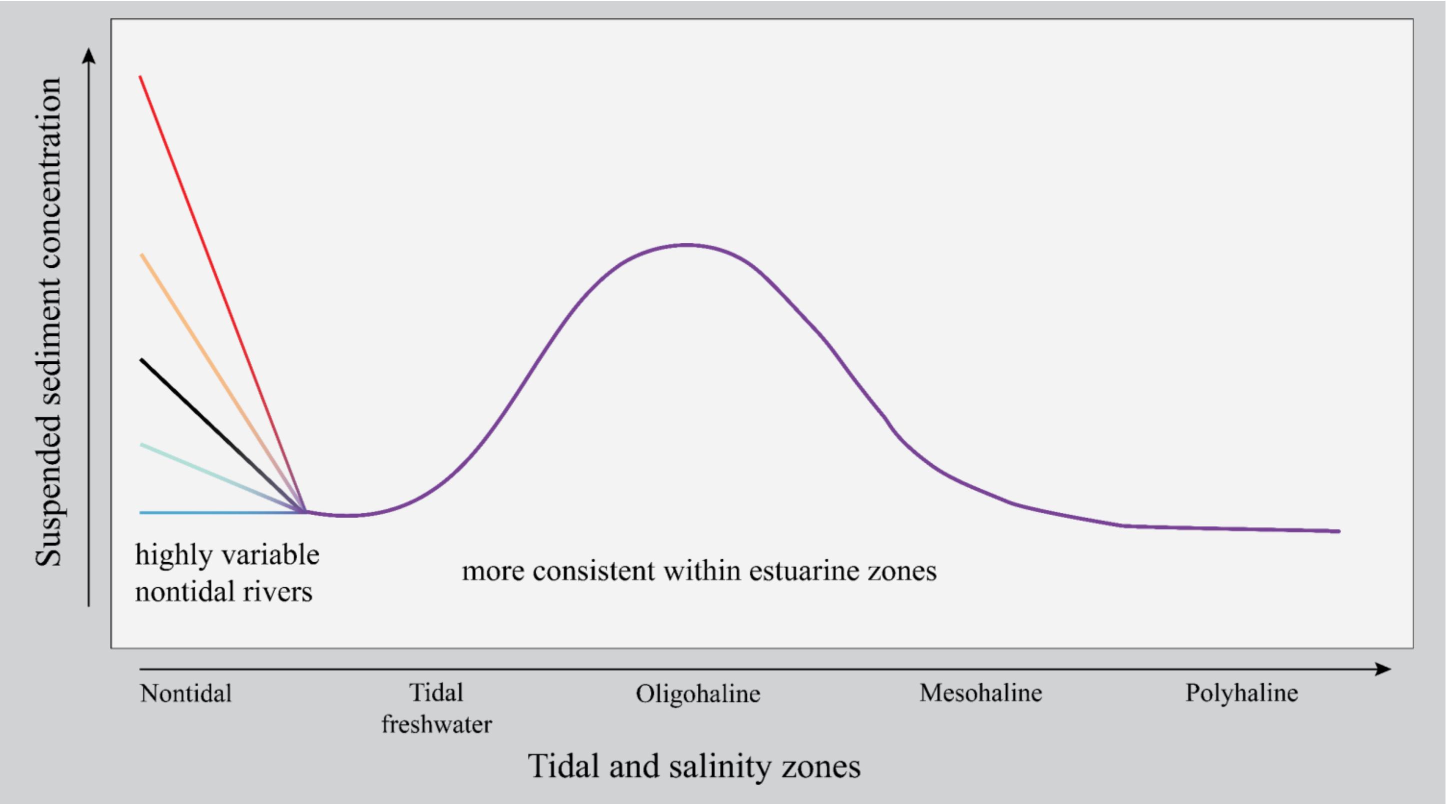
General pattern of river and estuary sediment concentration in the Chesapeake



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Sediment delivery in the past

Nontidal river sediment loads were much higher in past centuries due to deforestation and intensification of agriculture after European colonization (James, 2018; Noe et al., 2022).

These historically high rates of sediment delivery led to deposition in tidal rivers that formed extensive new wetlands near the heads-of-tide (Pasternack, 2007; Jones et al. in prep.) and filled river channels around historic colonial port towns (Gottschalk, 1945).

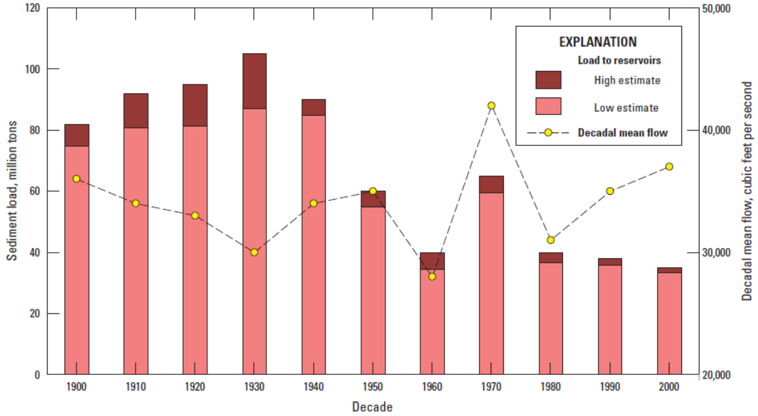


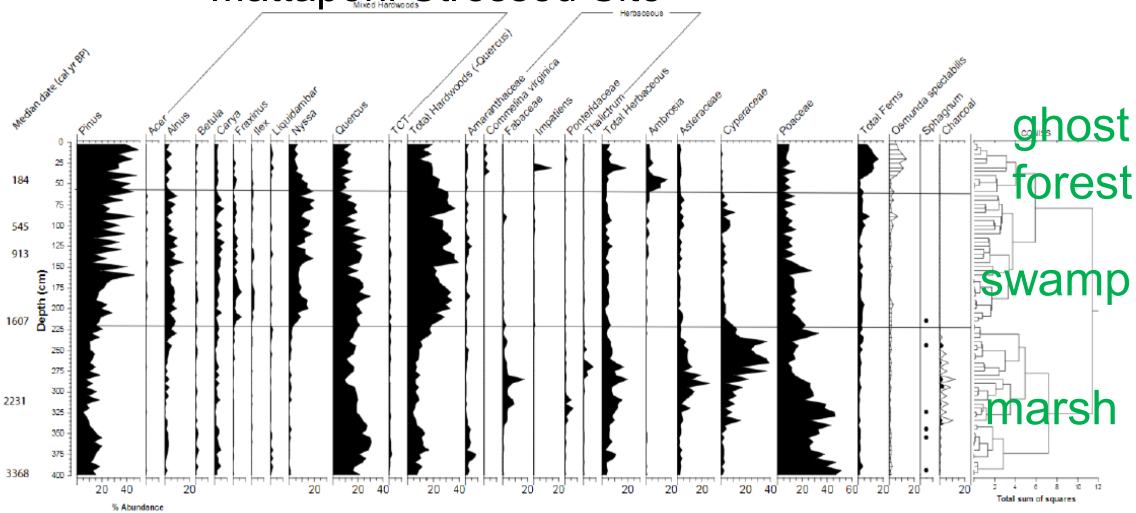
Figure 3. Total estimated sediment transported from the Susquehanna River into three reservoirs in Pennsylvania and Maryland, 1900–2010.

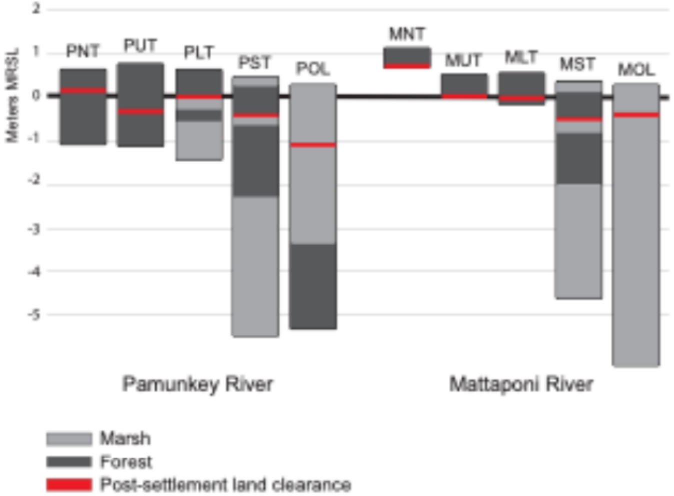
Langland | 2015

USGS

Legacy sediment delivery created or changed tidal wetlands

Mattaponi Stressed Site





These data are preliminary and are subject to revision. They are being provided to meet the need for timely 'best science' information. The assessment is provided on the condition that neither the U.S. Geological Survey nor the United States Government may be held liable for any damages resulting from the authorized or unauthorized use of the assessment.

USGS

Jones et al. in prep.

Contemporary sediment loads from watershed to tidal waters

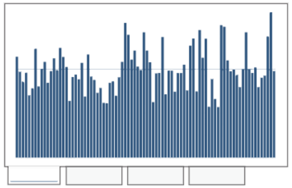
No change over same time period

USGS science for a changing world

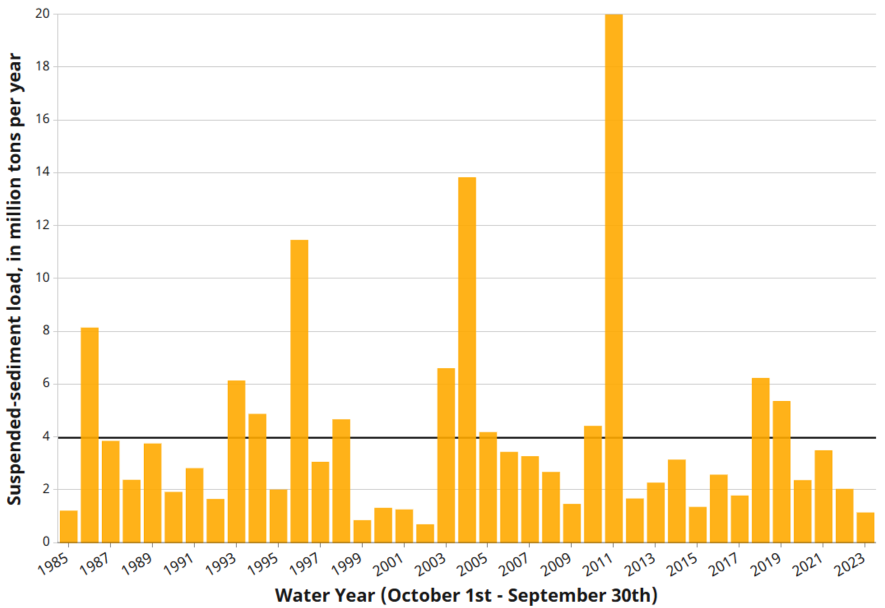
← t Monitoring Network | Trends Summary | Total Nitrogen | Total Phosphorus | Suspended Sediment | Loads to Tidal Waters | Definitions | Methods | Factors: Loads and Trends | Resources

Loads to Tidal Waters

Water quality results for the RIM stations, which represent roughly 78% of the 64,000 square-mile Chesapeake Bay watershed, are published each year alongside estimated streamflows to the Bay.



Use the tabs at the bottom of the interactive chart to view streamflows to the Bay, as well as the combined nutrient and sediment loads entering the Bay from the 9 River Input Monitoring (RIM) stations, up to water year 2023.



Combined annual suspended-sediment load delivered from the nine River Input Monitoring (RIM) stations to the Chesapeake Bay. Black line represents the mean-annual combined load of 3.9 million tons per year.

Streamflow to the Bay | Total nitrogen RIM loads | Total phosphorus RIM loads | Suspended-sediment RIM loads

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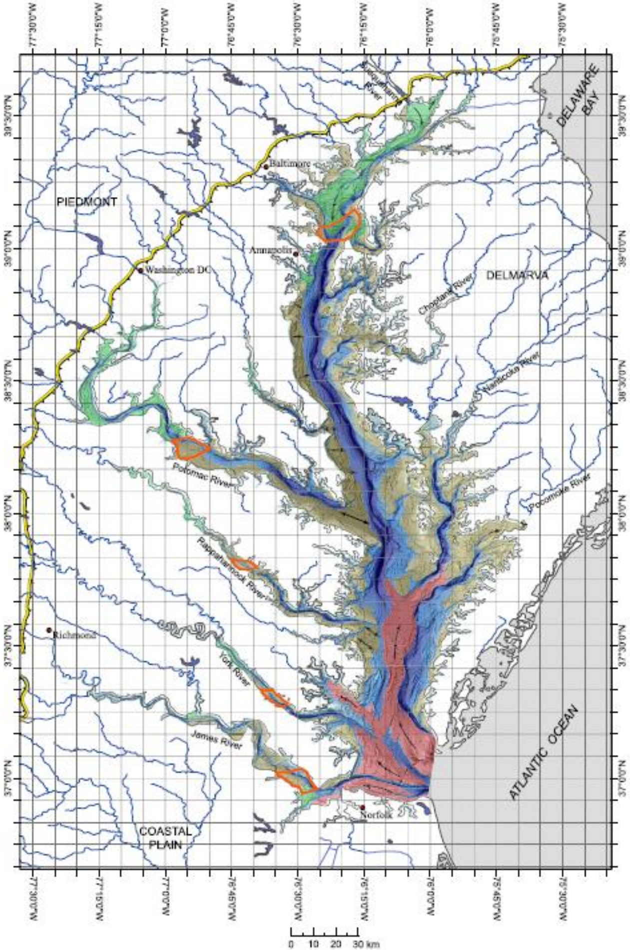
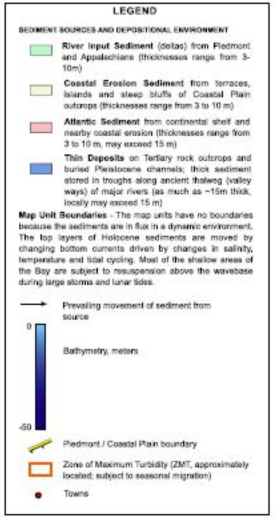
https://va.water.usgs.gov/geonarratives/ntn/

Watershed delivery to the Bay

Sources of sediment within the Chesapeake Bay include river inputs, coastal erosion, and marine inputs, depending on location





Newell et al. 2004

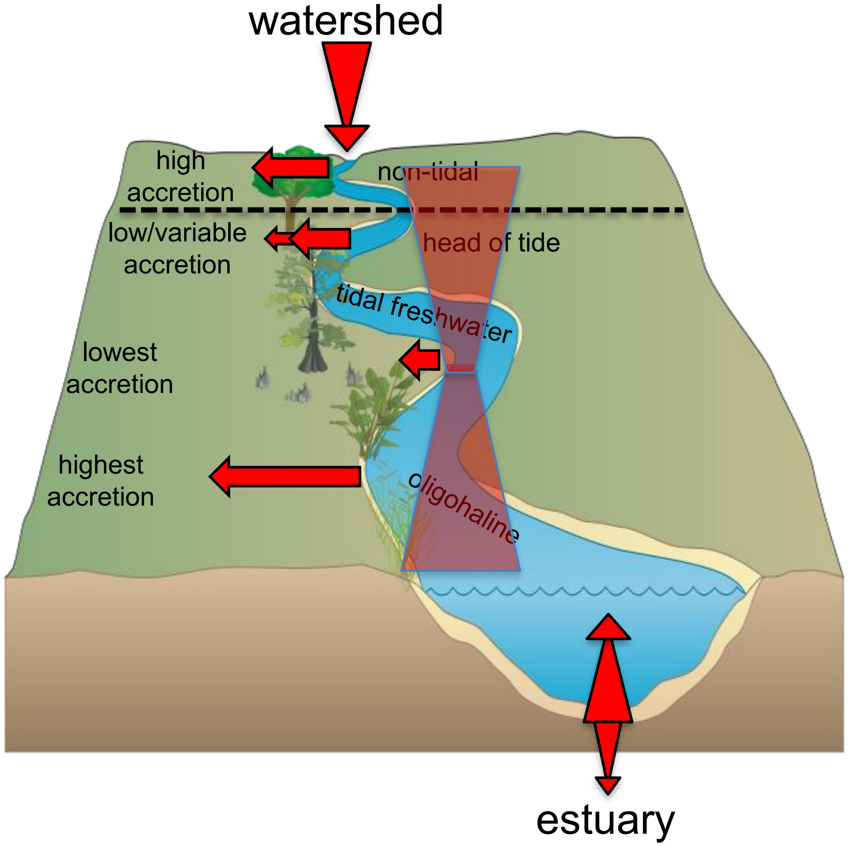
USGS *Delivery to Bay*

What is the Sediment Shadow?

Minimal sediment availability in lower tidal freshwater rivers and wetlands,

either in-channel suspended sediment concentration or tidal wetland sedimentation

http://www.francescofrancavilla.com/sequentials/the_shadow.html

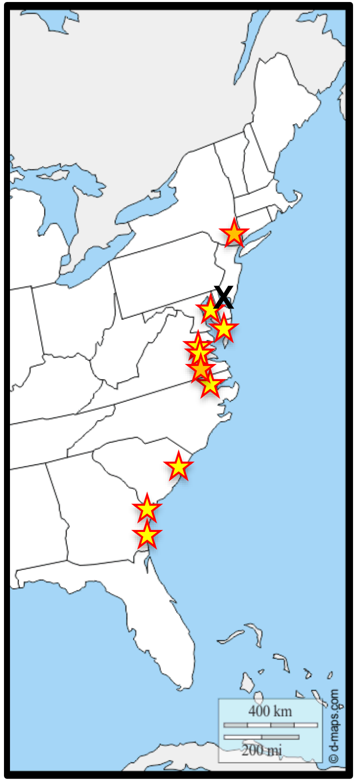


How widespread is the Sediment Shadow?

- The Sediment Shadow has been observed over the U.S. Atlantic Coast's tidal freshwater rivers
  - James (Bukaveckas and Isenberg 2013)
  - Choptank (Ensign et al. 2014, Ensign et al. 2015)
  - Pocomoke (Ensign et al. 2014, Ensign et al. 2015)
  - Roanoke (Hupp et al. 2015)
  - Waccamaw/Winyah (Noe et al. 2016)
  - Savannah (Noe et al. 2016)
  - Hudson (Ralston and Geyer 2017)
  - Altamaha (Craft et al. 2022)
  - Mattaponi (Kroes et al. 2023, Darke and Megonigal 2003)
  - Pamunkey (Kroes et al. 2023)

  - NOT Delaware River (Haaf et al. 2022)

- "Less than 5% of the sediment from rivers of the Atlantic drainage ever reaches the continental shelf or the deep sea (Meade 1982)



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Potential consequences for Chesapeake Bay restoration

Contemporary sediment availability is minimal in tidal freshwater zone

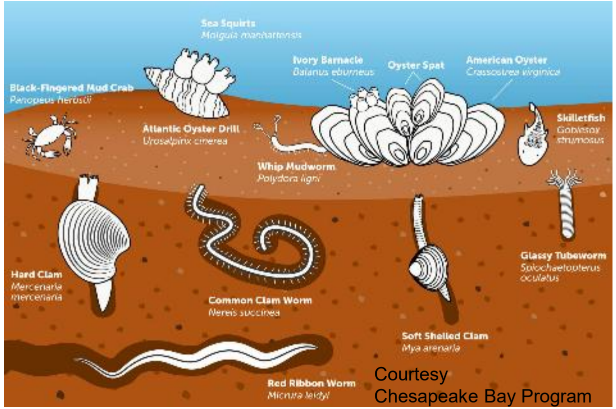
→ Impact response to rSLR and watershed restorations

- Historic sediment loads used to be higher and did get delivered farther into Bay

- Contemporary sediment sources:
  - TFZ is watershed sediment
  - ETM seems likely to be sediment delivered to the estuary long ago that is being reworked into suspension
  - Mid-Bay source is coastal erosion
  - Lower Bay source is Atlantic

- Agrees with findings of controls on Secchi depth by Testa et al. 2019


JJ Orth



Courtesy
Chesapeake Bay Program

USGS


Thank you