

DAR Invited Science Presentation

September 23rd, 2026

Title: The “sediment shadow” in Chesapeake Bay’s tidal freshwater rivers has important implications for restoration

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Major Takeaways for DAR:

- Under typical contemporary conditions from 1984-2021, little upstream watershed sediment is delivered past the tidal freshwater zone of the many Chesapeake tributaries (but was in the past)
- More saline (>10 psu) sites at the downstream ends of tidal rivers and the mainstem of the Chesapeake Bay have had a consistent 25% decline in total suspended solids over the past decades, but, less saline sites have had highly variable trends but no consistent change in sediment
- Mega-Storms can transport sediment farther into the estuary (but most is deposited in Upper Chesapeake Bay)
- Many tidal wetlands are not likely to persist with additional sea-level increases (brackish wetlands will persist longer)

Additional Resources:

- Web summary: [The “sediment shadow” in Chesapeake Bay’s tidal freshwater rivers has important implications for restoration | U.S. Geological Survey](#)
- Journal article: <https://doi.org/10.1016/j.ecss.2026.109931>



The “sediment shadow” in Chesapeake Bay’s tidal freshwater rivers has important implications for restoration

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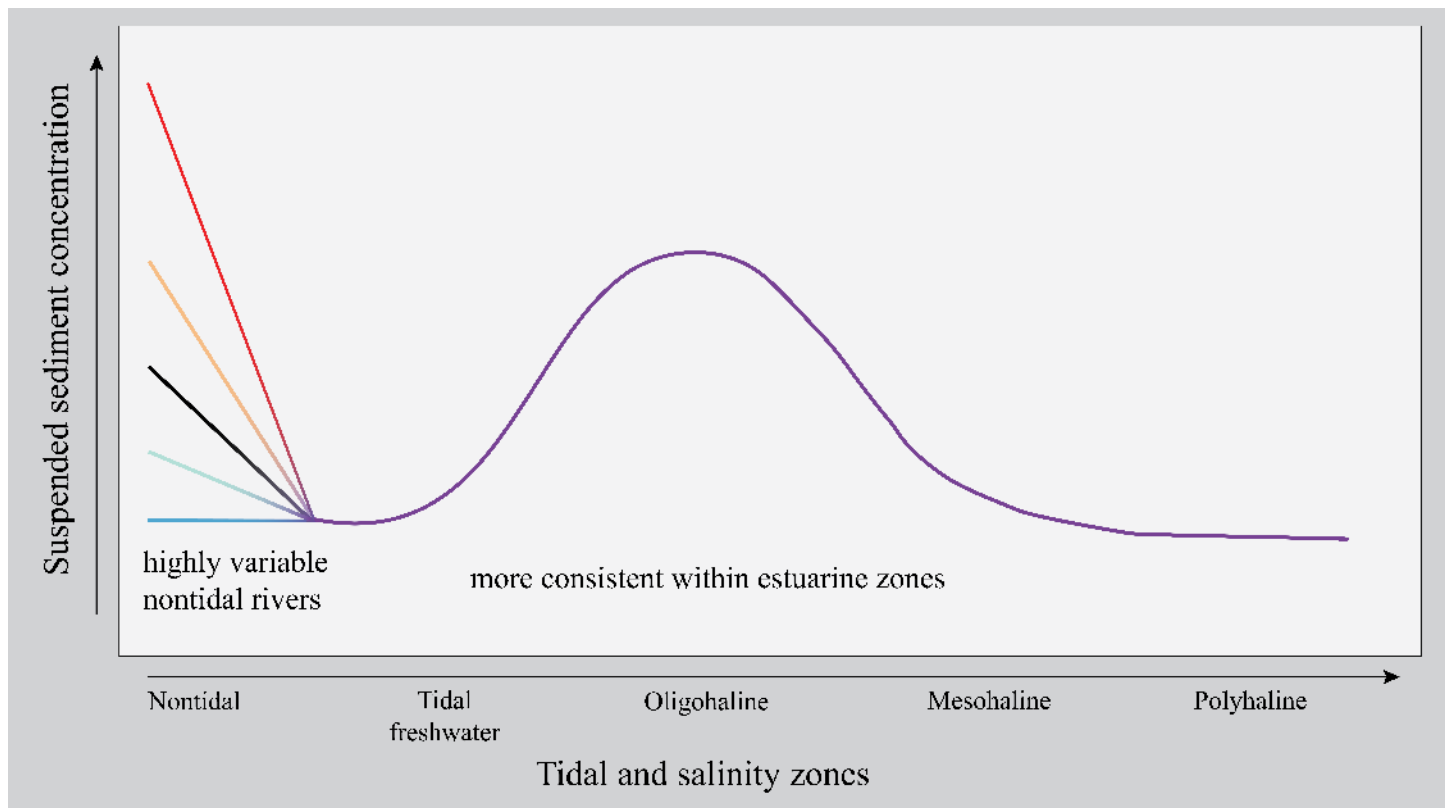
Analyses of long-term suspended sediment concentration data reveals limited delivery of contemporary watershed sediment to the Bay

NASA

The “sediment shadow” in Chesapeake Bay’s tidal freshwater rivers has important implications for restoration | U.S. Geological Survey

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.2026.109931>

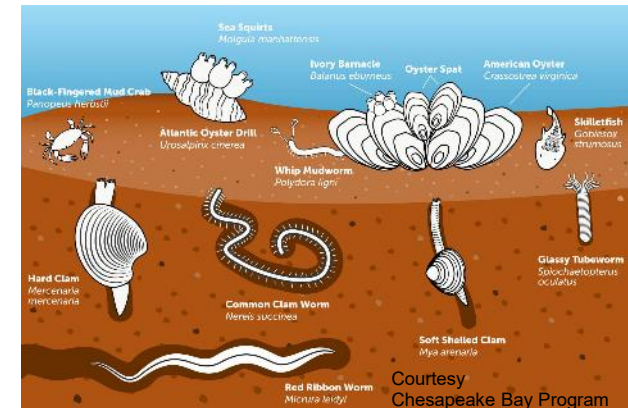
General pattern of river and estuary sediment concentration in the Chesapeake



Why care about sediment in the Chesapeake Bay?

Excess fine sediment:

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



Sediment is a vector for other contaminants

Managing sediment may help with other contaminants

- Phosphorus: **77% of TP load to the Bay is attached to sediment (particulate)** (Zhang et al. 2015)
- Nitrogen: 18% of TN load is attached to sediment (Zhang et al. 2015)
- Metals, pesticides, PCBs, and organic contaminants, for example

How is sediment managed in Chesapeake?

Chesapeake Bay TMDL:

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

... mostly through watershed BMPs

Watershed → *Bay*



and also many local nontidal stream TMDLs

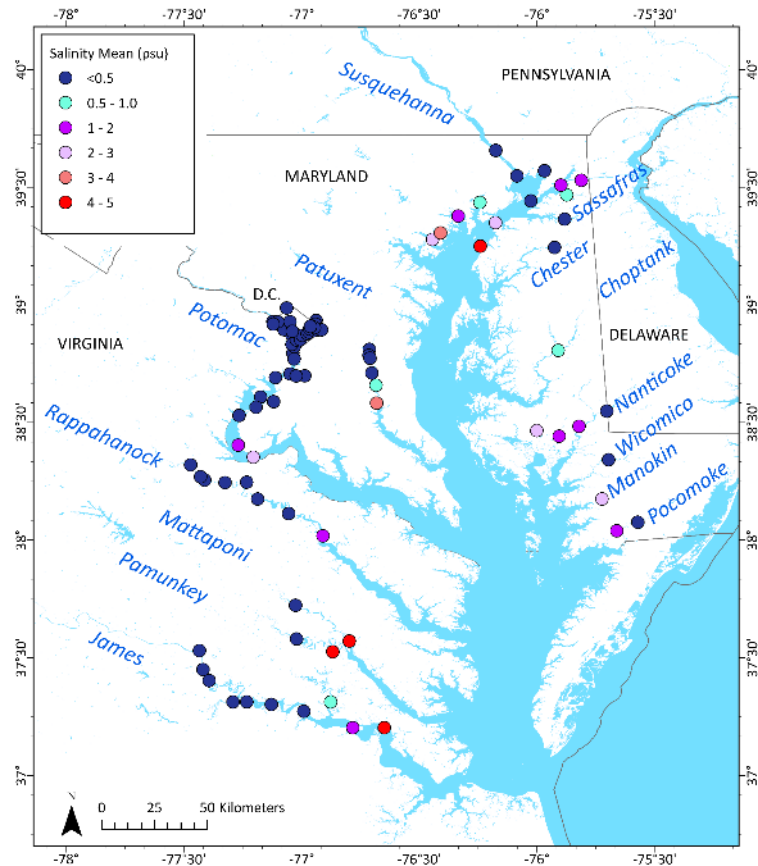
Tidal freshwater rivers

Extensive ecosystem along U.S. Atlantic Coast

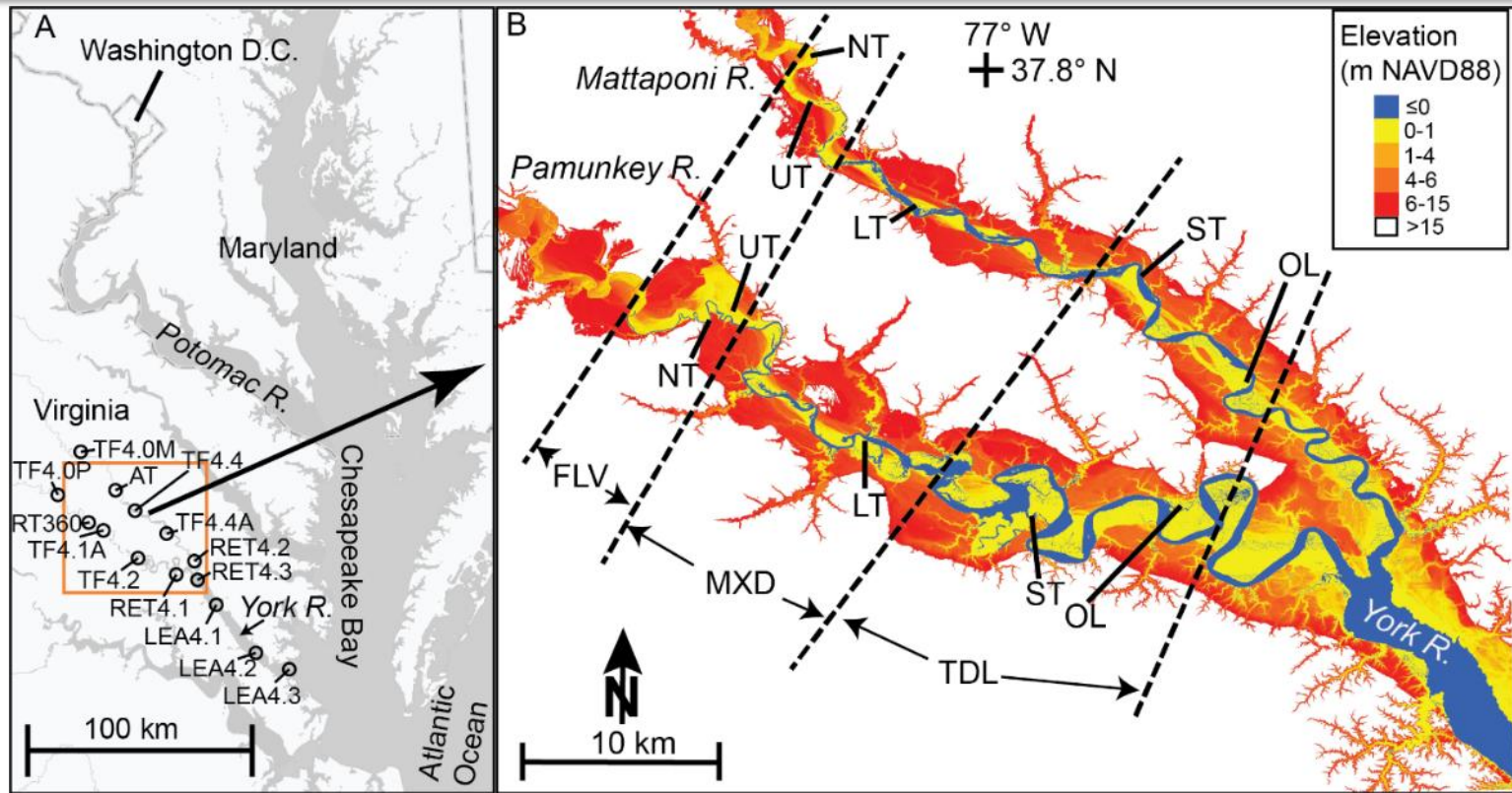
→ ~ 3,000 km

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

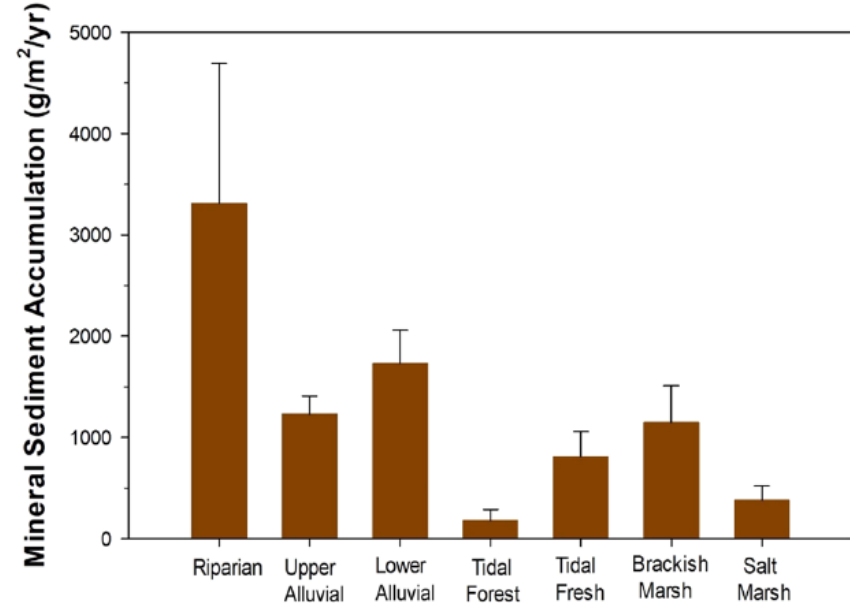
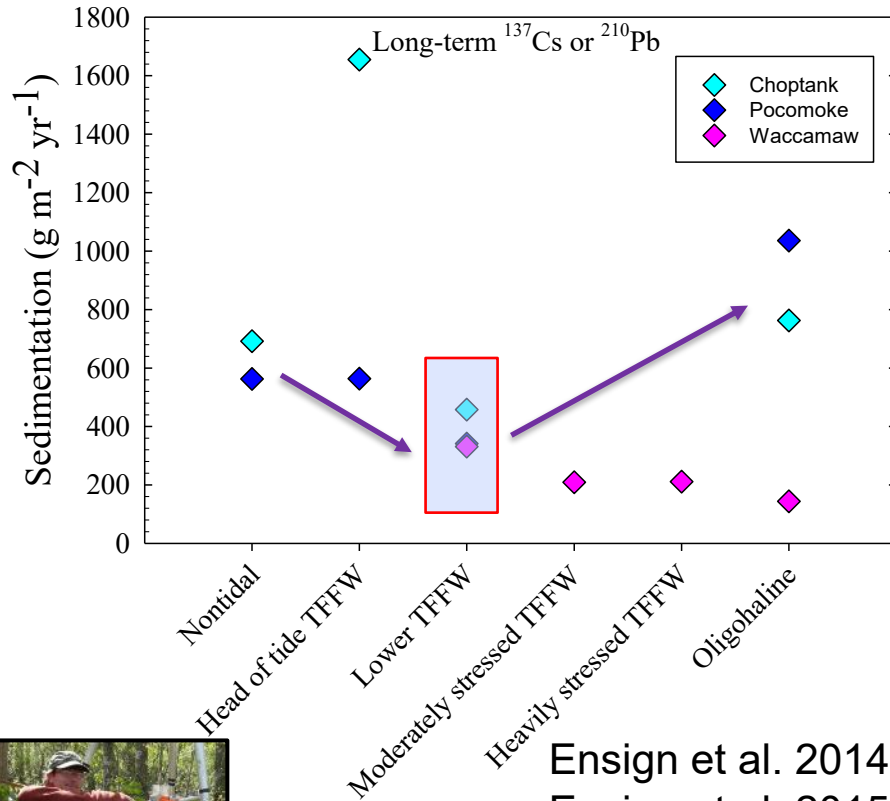
Common around Chesapeake Bay



Tidal Rivers: the dynamic interface of estuaries and watersheds



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 and watershed

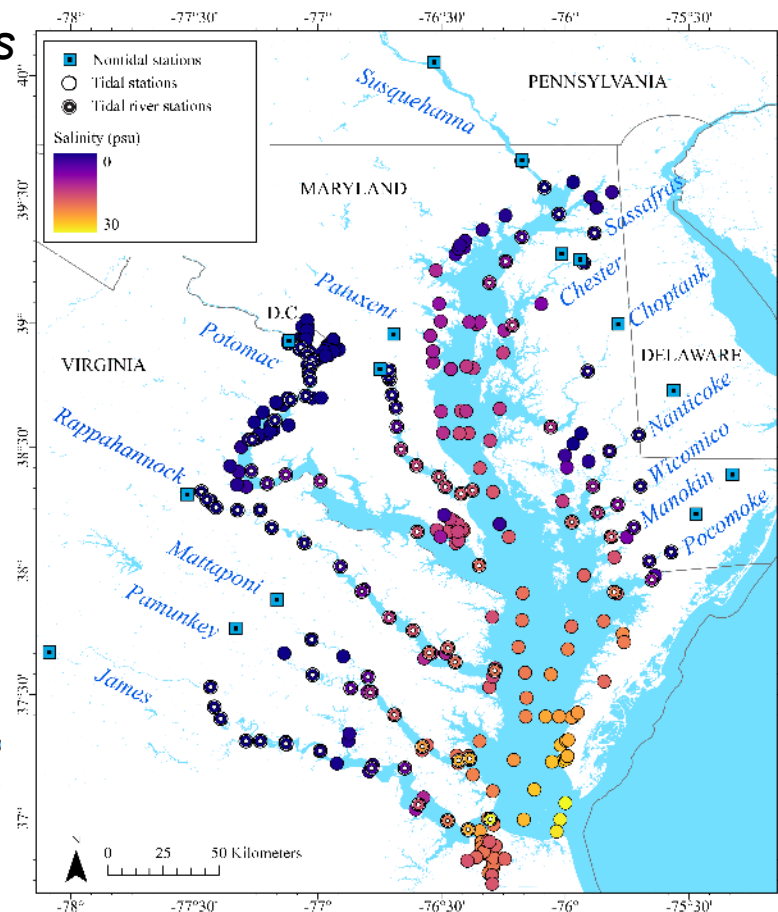
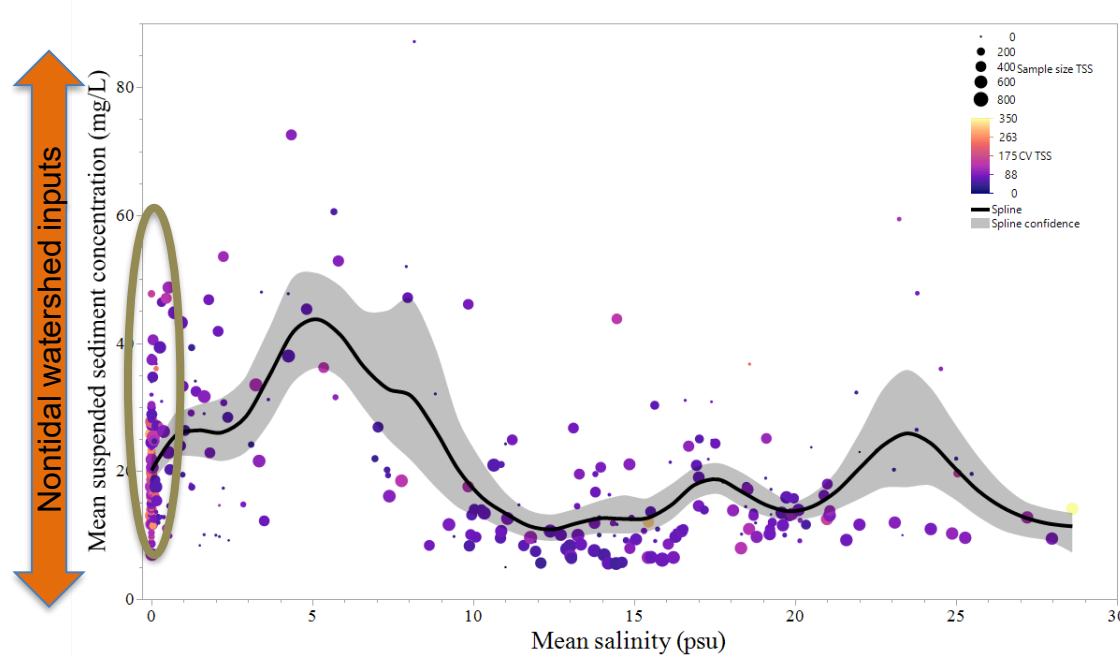
What we did:

Analyze suspended sediment data across all of Chesapeake Bay and adjacent rivers

- Combined analysis of [Chesapeake Bay Tidal Monitoring Program](#) and [Chesapeake Nontidal Water Quality Monitoring Program](#)
- Focus on downriver pattern in suspended sediment
- Can't estimate loads in tidal waters... focus on concentrations

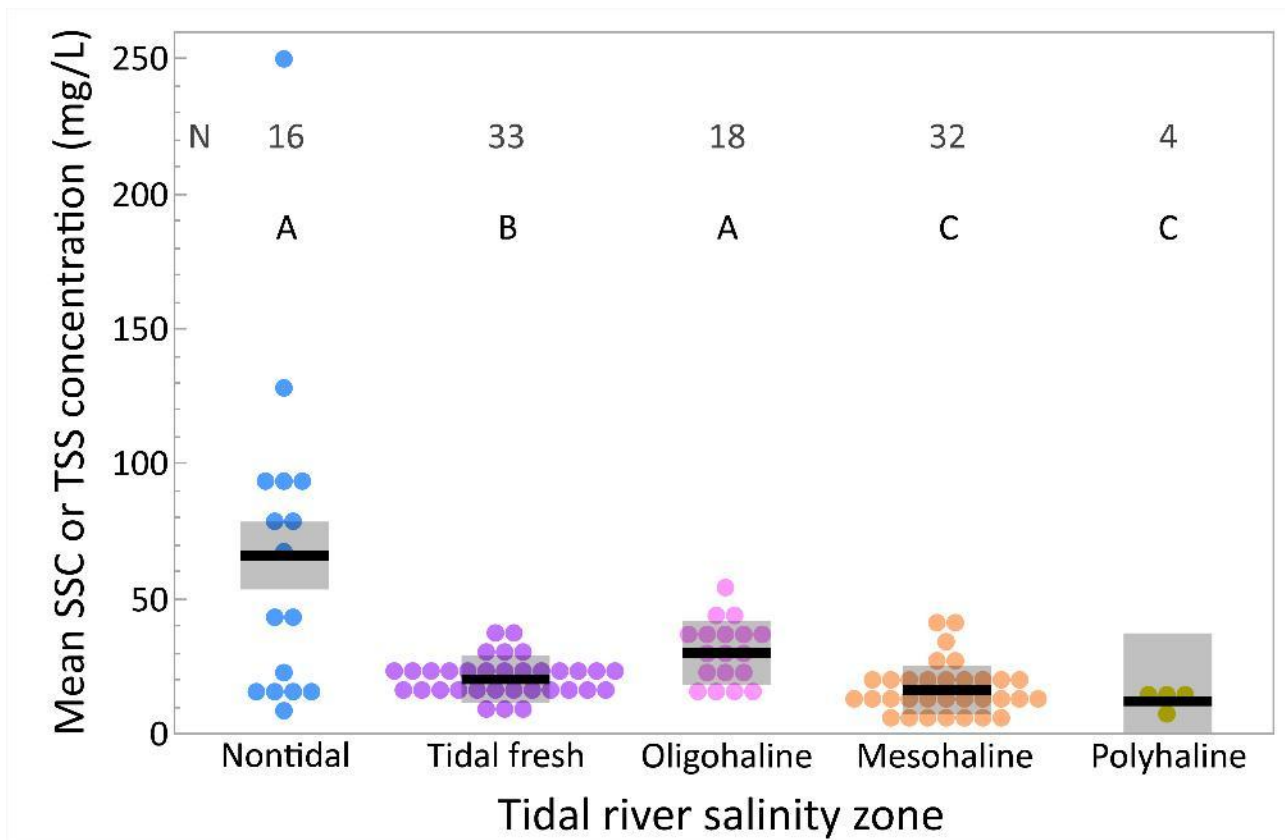
Chesapeake Bay Program (CBP) long-term data (1984-2021)

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

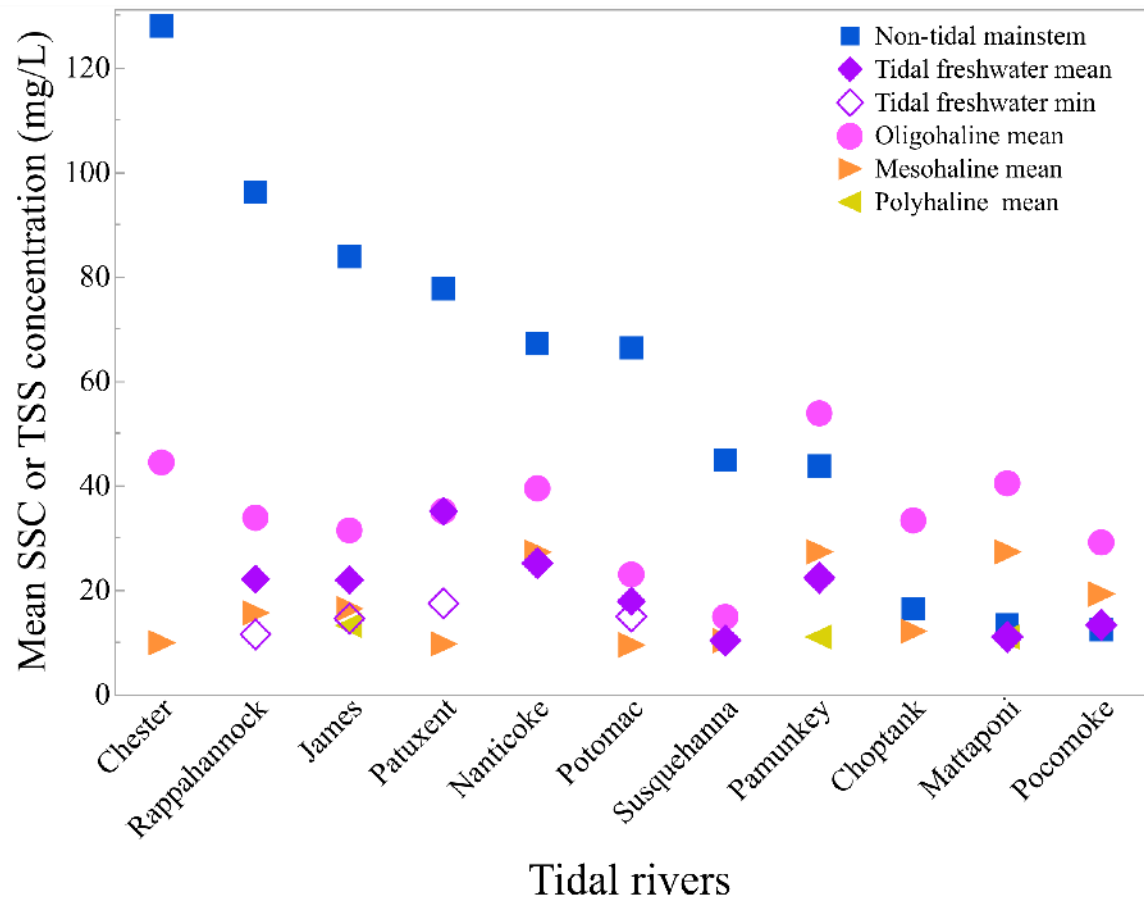


Mean SSC/TSS for each station: by tidal and salinity zone

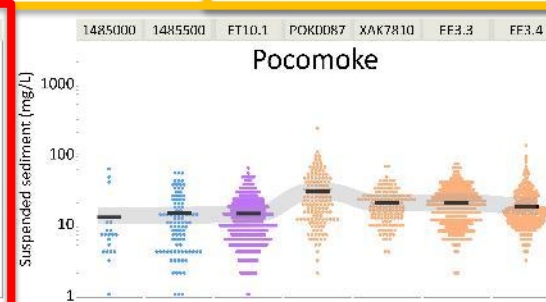
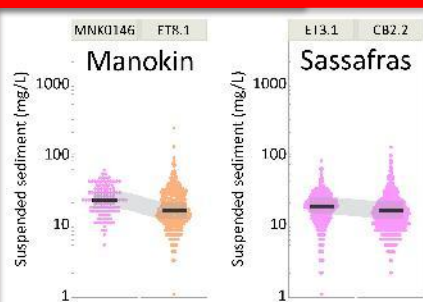
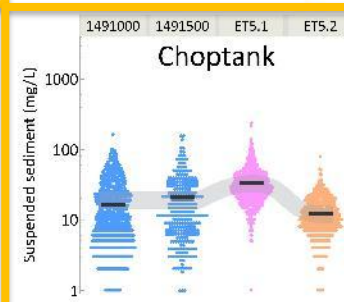
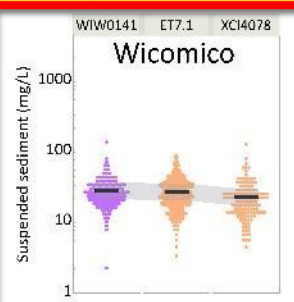
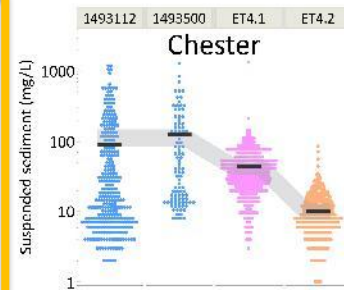
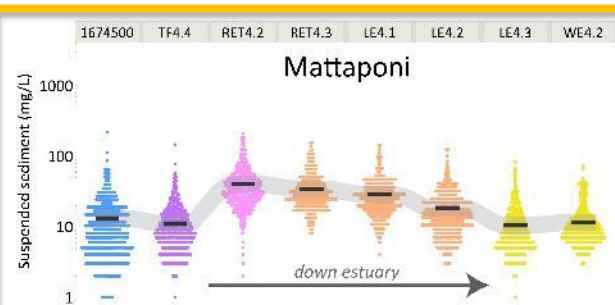
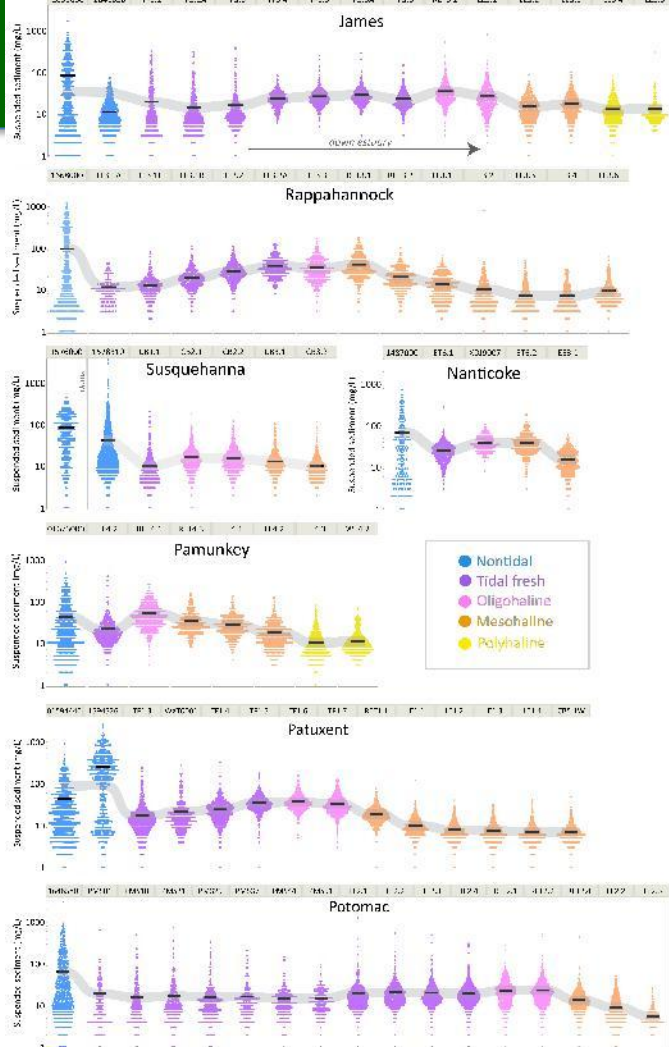
Average: 66 20 30 16 12 mg/L



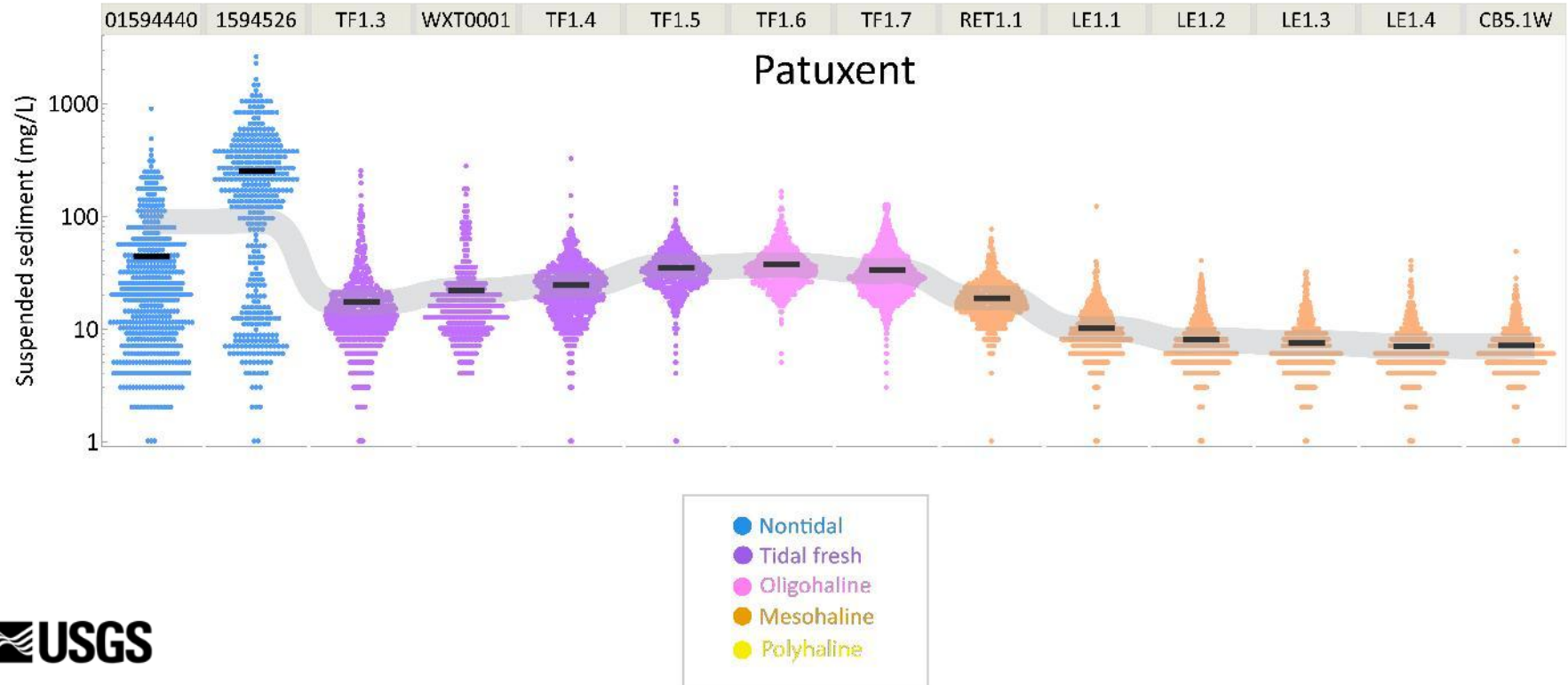
Mean SSC/TSS across stations: by zone in each tidal river



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

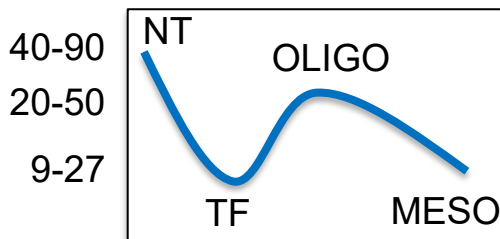


4 classes of downriver trends in SSC/TSS 1984 to 2021



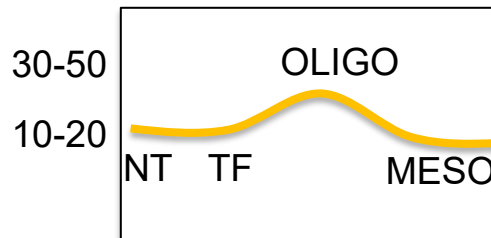
Four different system behaviors of sediment availability changes

Higher watershed sediment



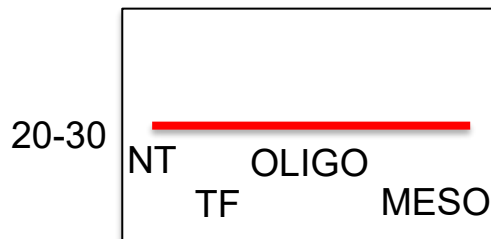
7 rivers
(5 largest)

Moderate watershed sediment

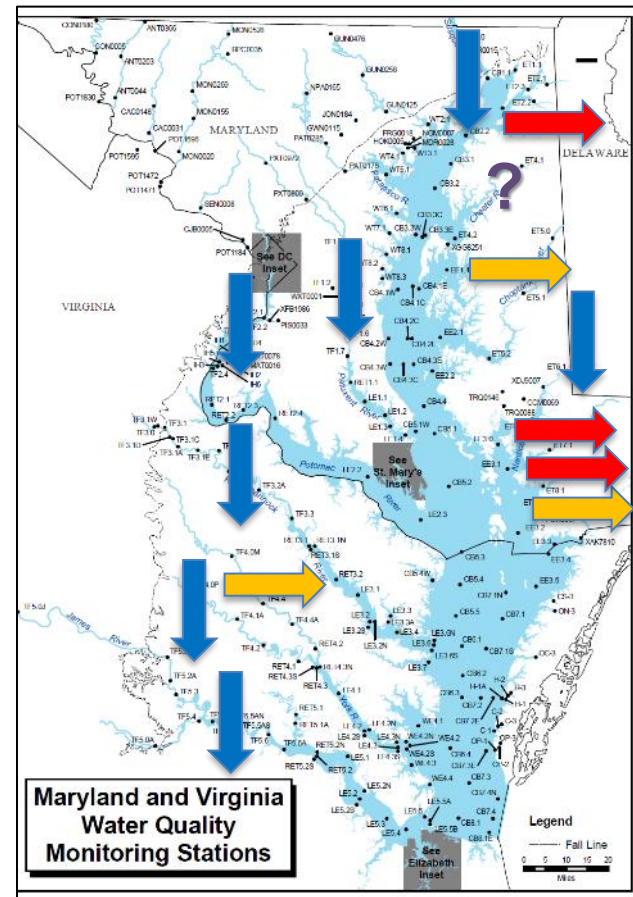


3 rivers

Lower watershed sediment

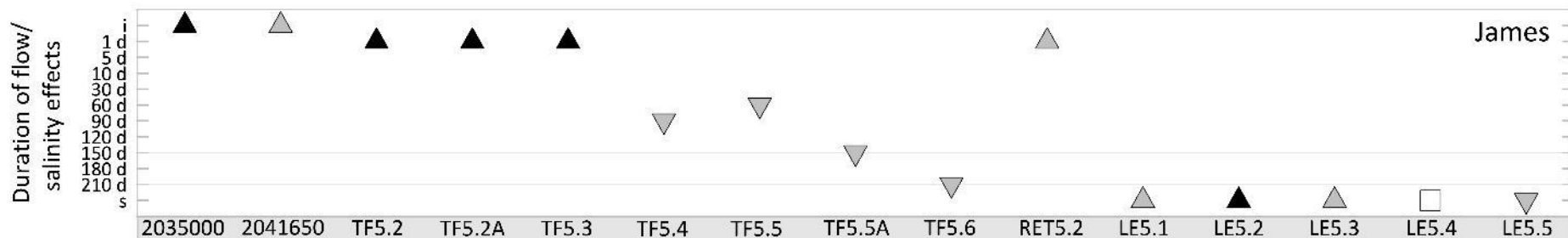


3 rivers

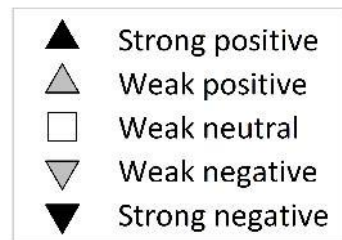


GAM analyses of TSS at tidal stations 1999 to 2022

Fast response to river FW input

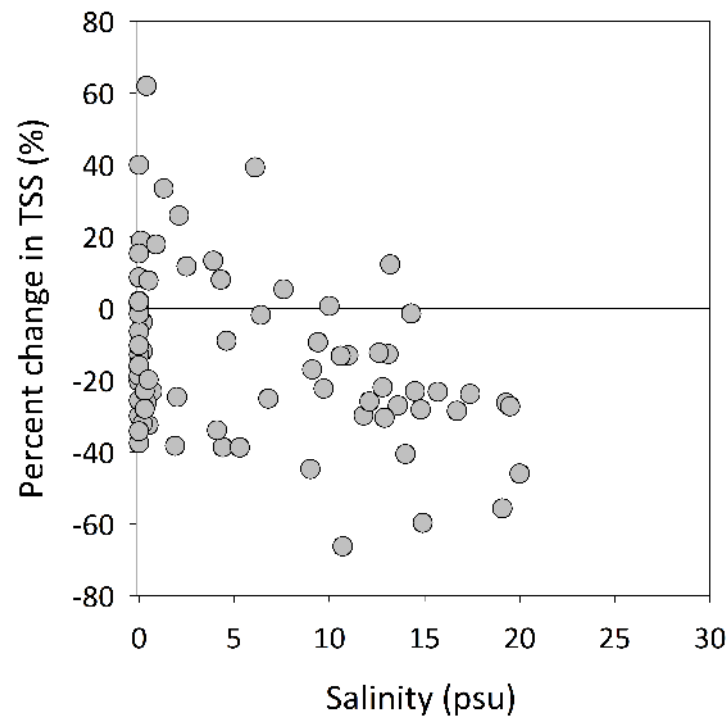
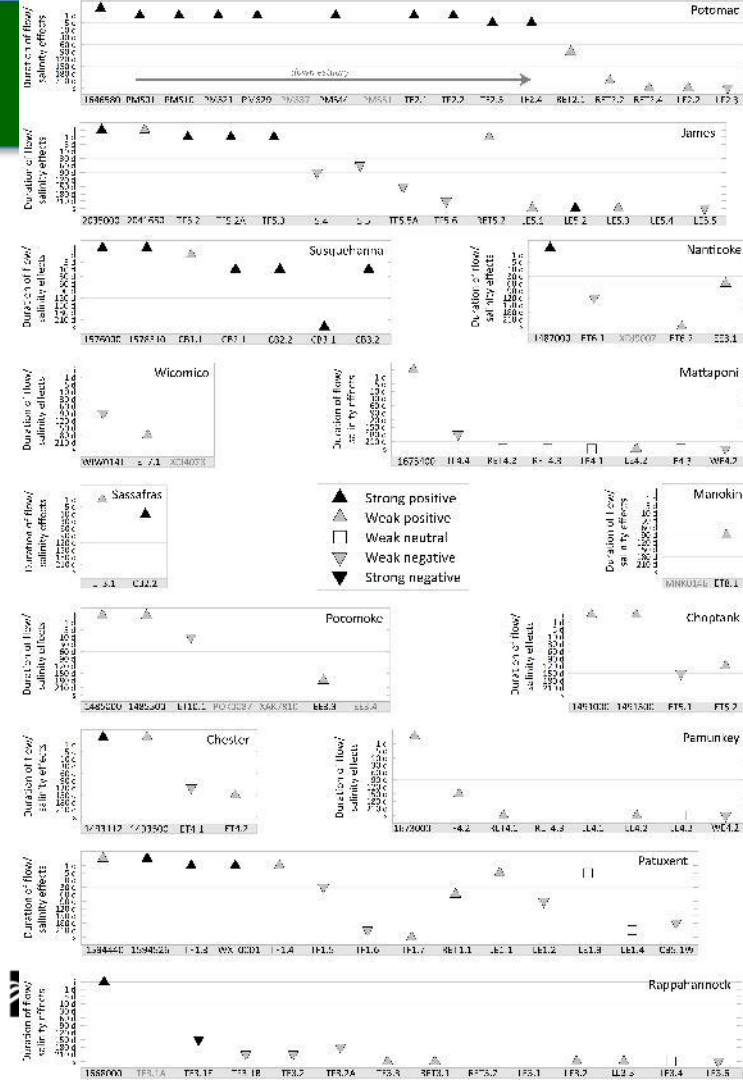


Slow response to river FW input



GAM analyses of TSS at tidal stations 1999 to 2022

Above 10 psu had a 25% reduction in TSS



Caveats and limitations

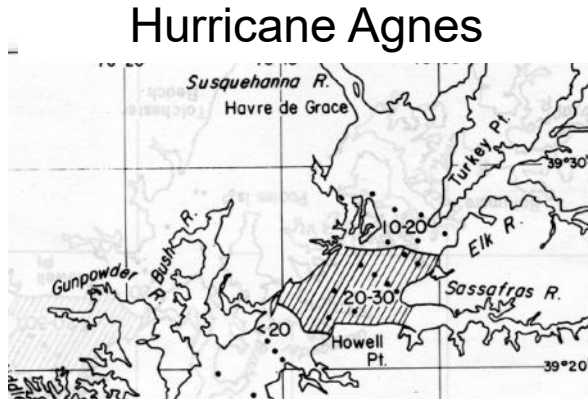
Could sediment bypass surface waters in tidal freshwater zone?

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

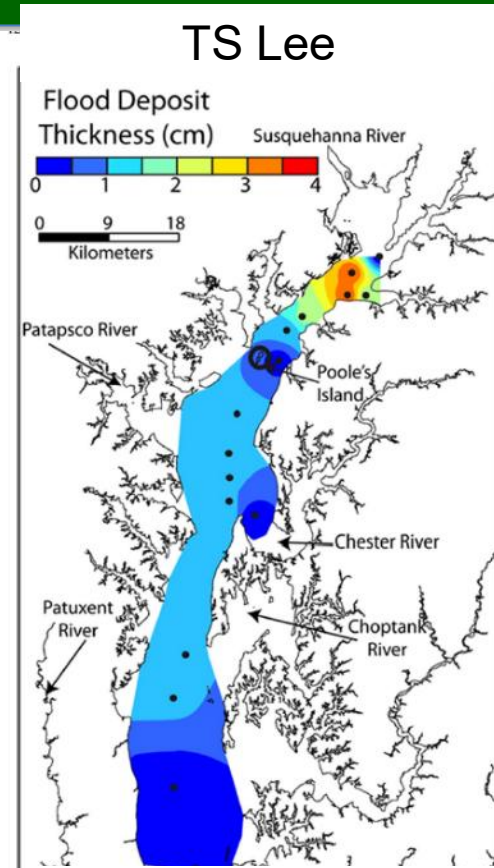
The role of massive floods in recent past

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](#)).



Zabawa and Schubel | 1974



Palinkas et al. | 2014

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 press](#)) and filled river channels around historic colonial port towns ([Gottschalk, 1945](#)).

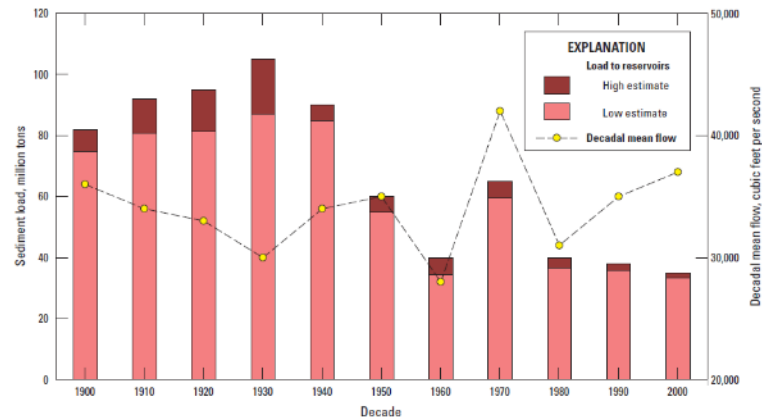
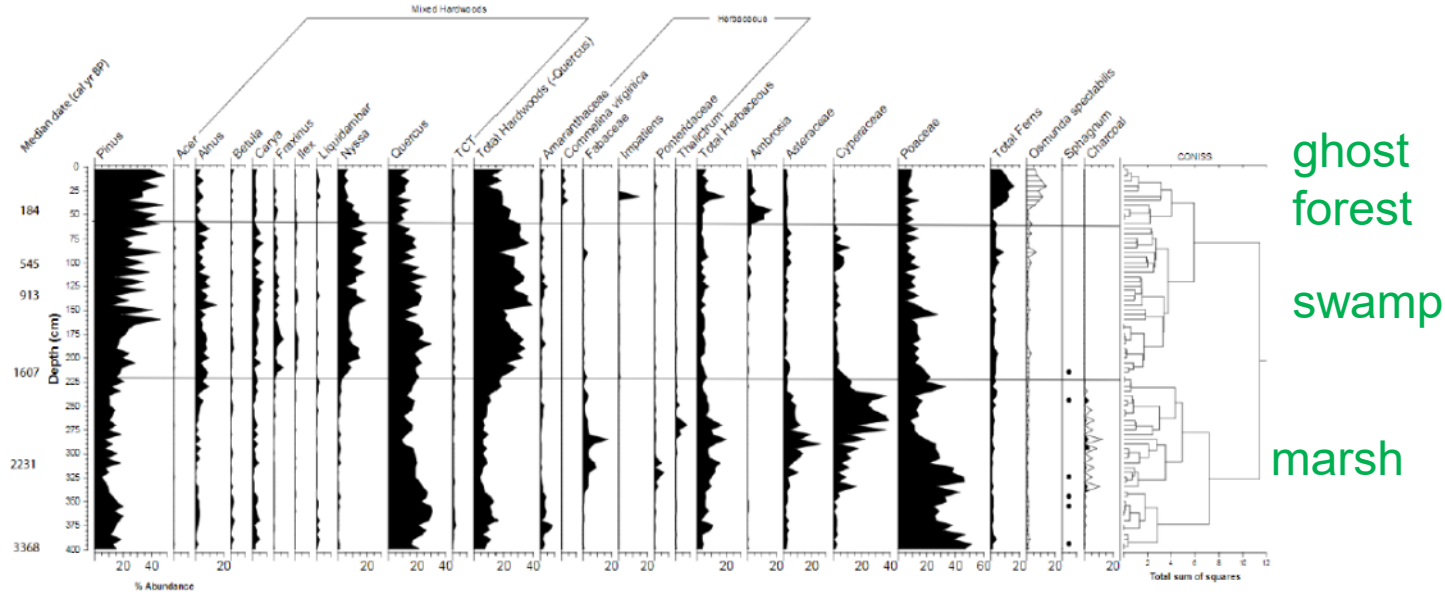


Figure 3. Total estimated sediment transported from the Susquehanna River into three reservoirs in Pennsylvania and Maryland, 1900–2010.

Langland | 2015

Legacy sediment delivery created or changed tidal wetlands

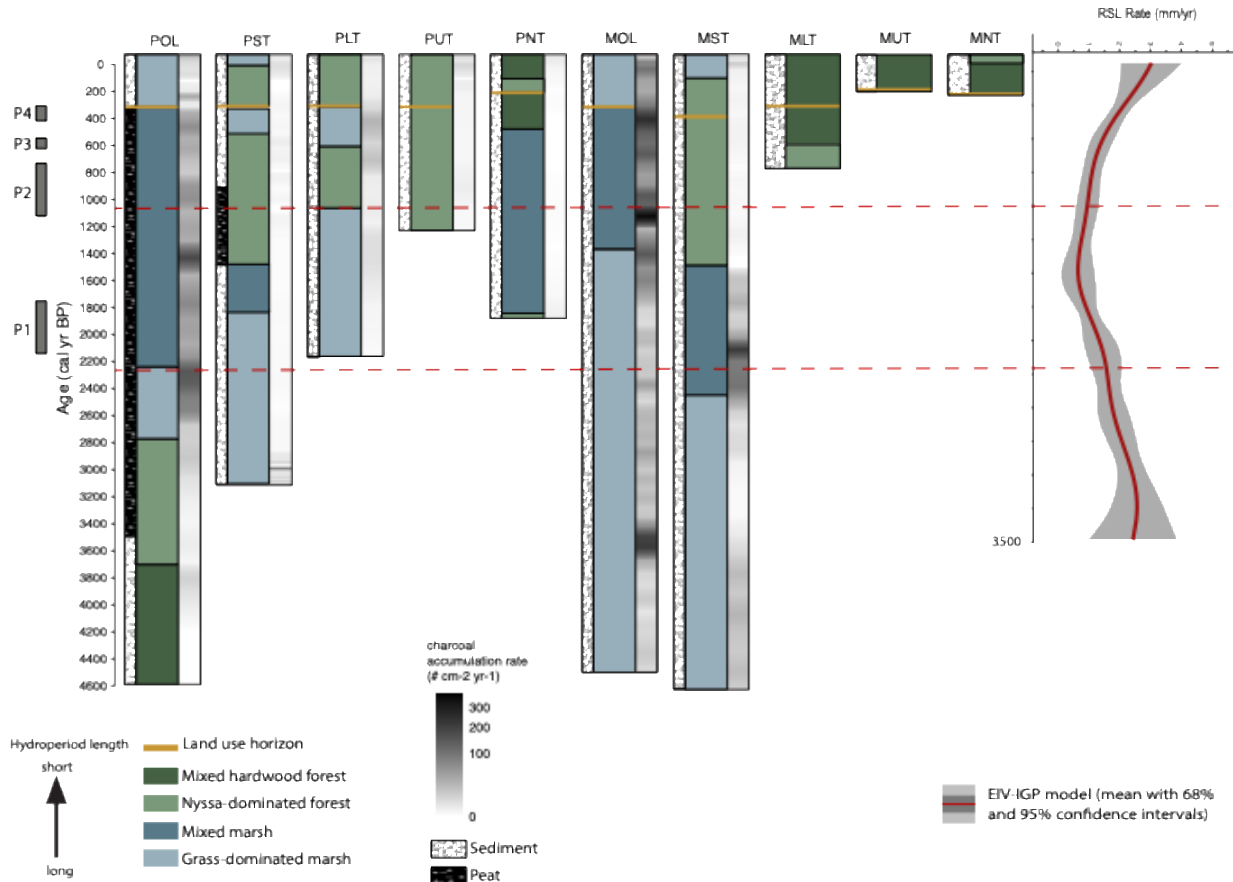


Mattaponi Transitioning Site



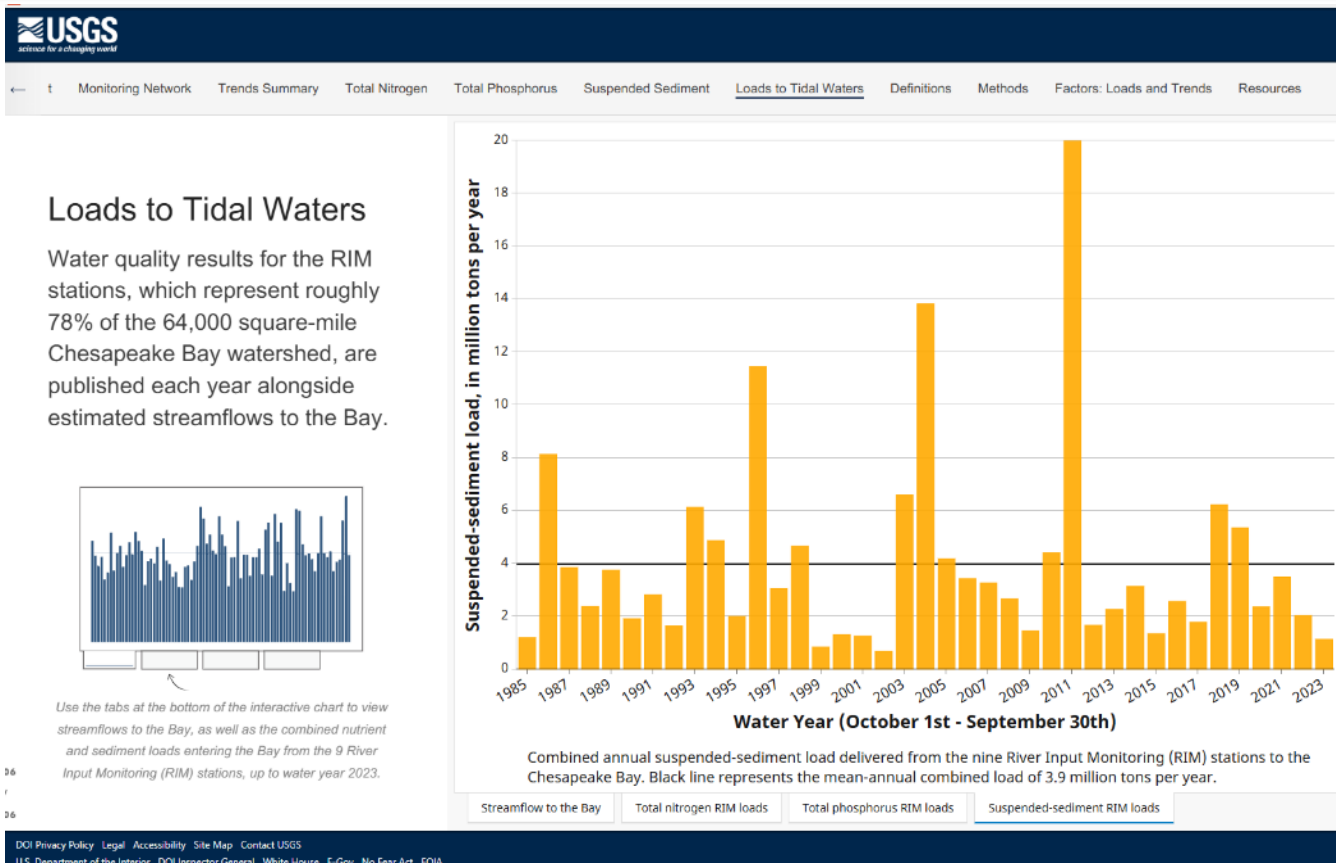
Jones et al. | in press

Legacy sediment delivery created or changed tidal wetlands



Contemporary sediment loads from watershed to tidal waters

*No change over
same time period*

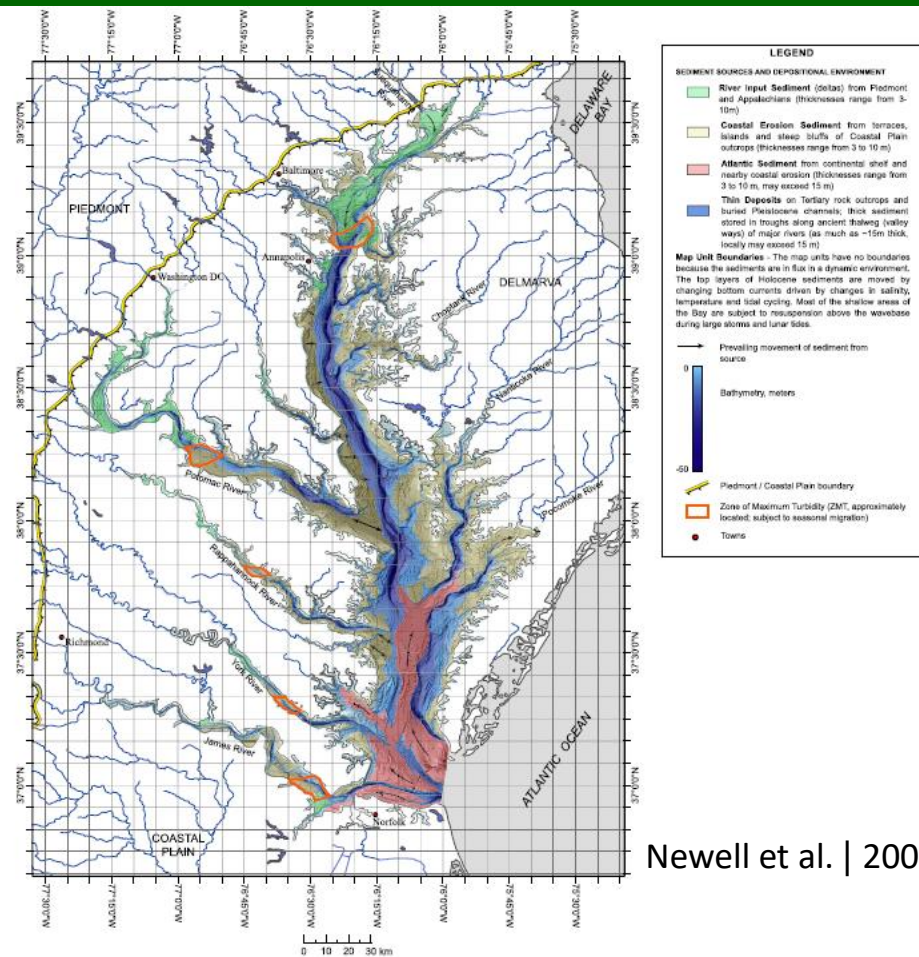


Watershed delivery to the Bay

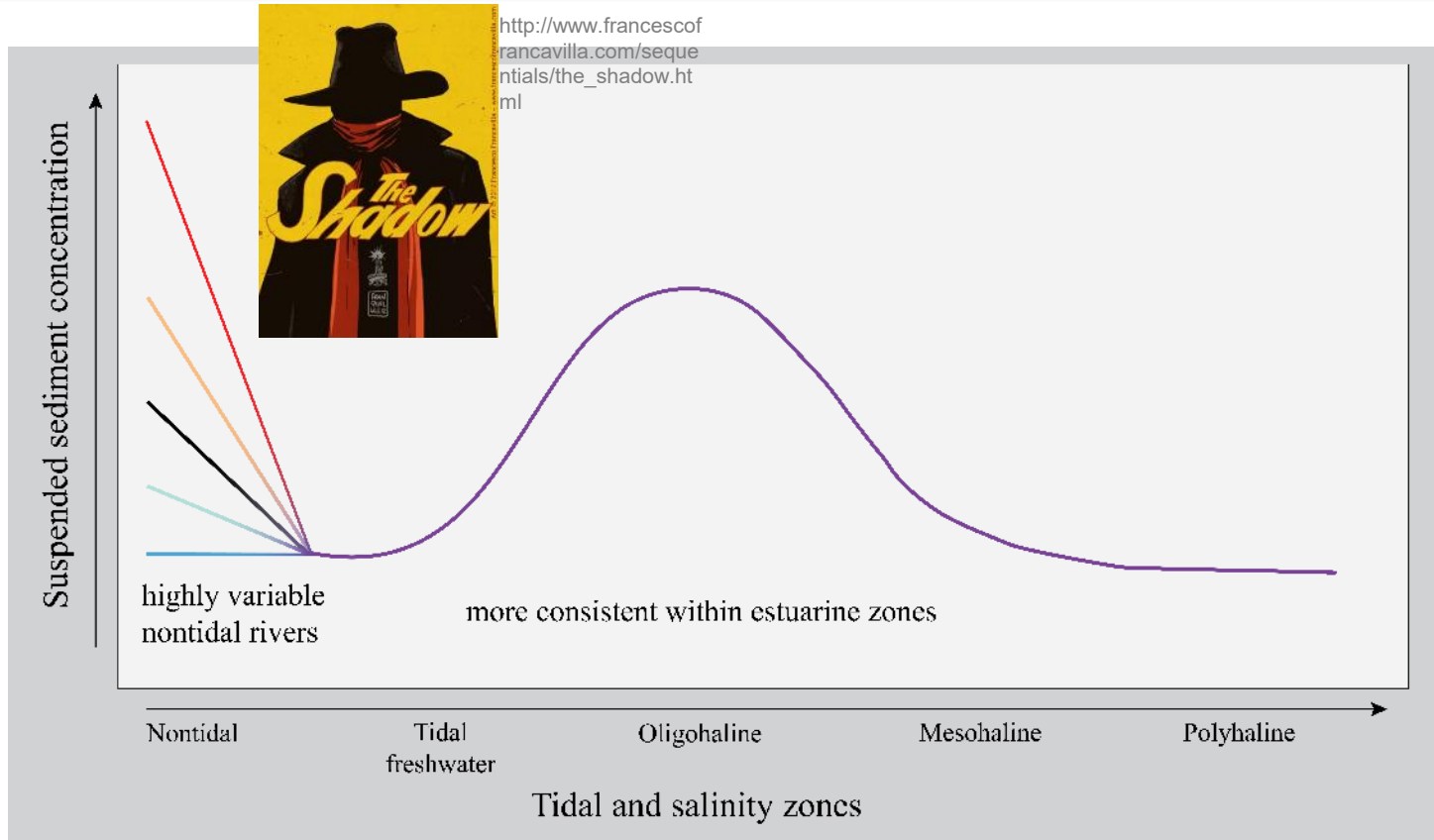
Sources of sediment within the Chesapeake Bay include:

- river inputs
- coastal erosion
- and marine inputs

depending on location



General pattern of river and estuary sediment concentration in the Chesapeake



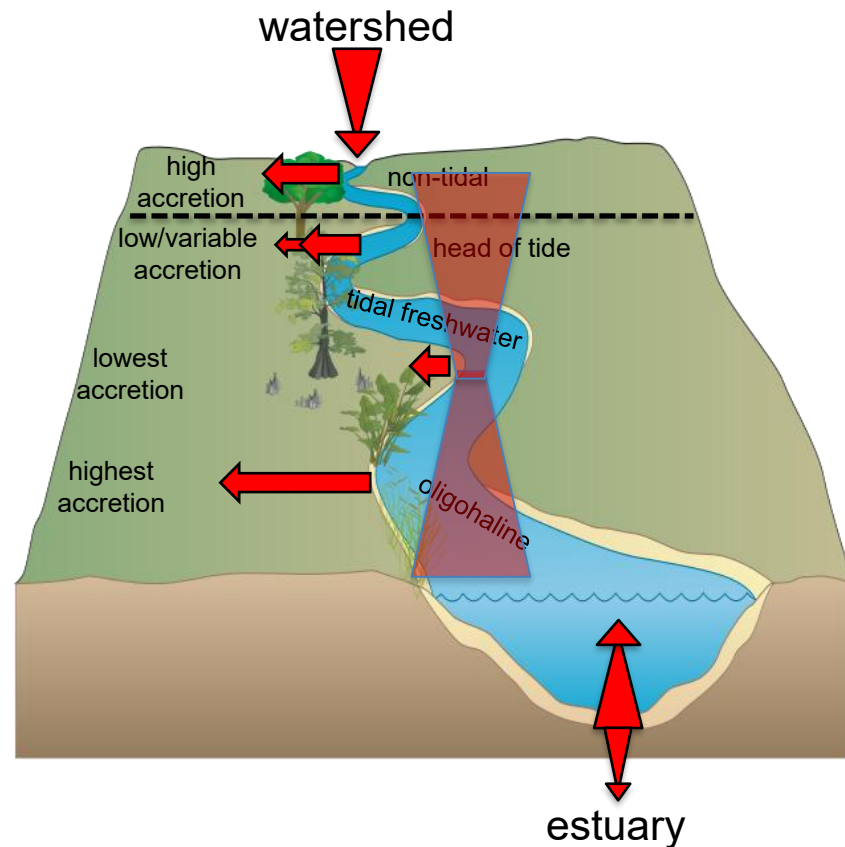
What is the Sediment Shadow?

Minimal sediment availability in
lower tidal freshwater rivers
and wetlands,

either in-channel suspended
sediment concentration or tidal
wetland sedimentation

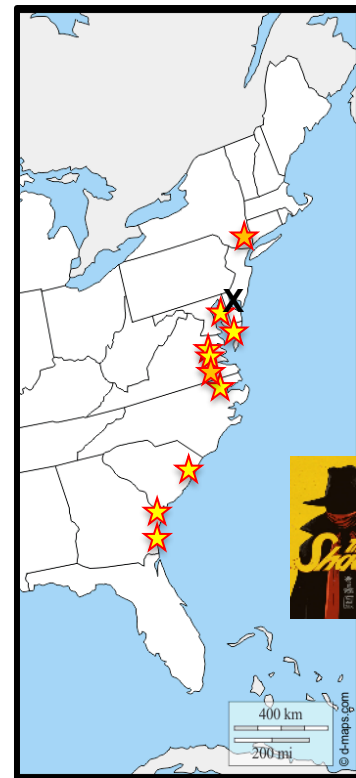


http://www.francescofrancavilla.com/sequentials/the_shadow.html

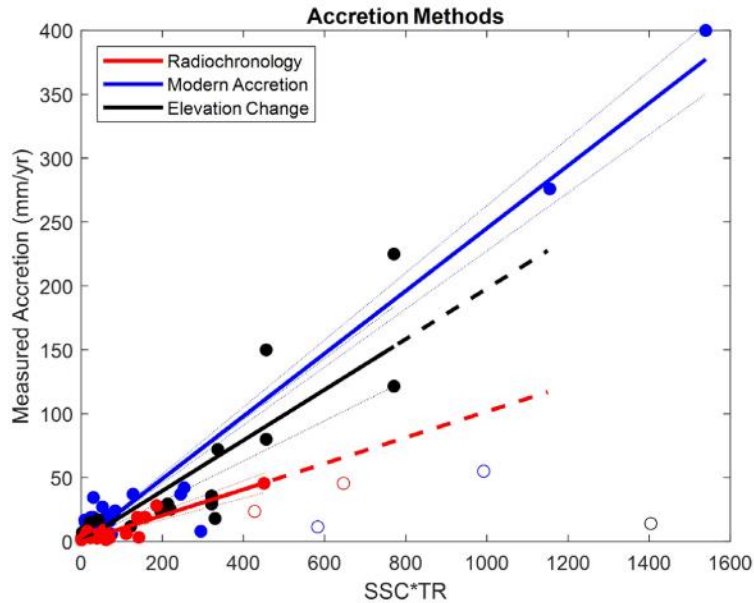


How widespread is the Sediment Shadow?

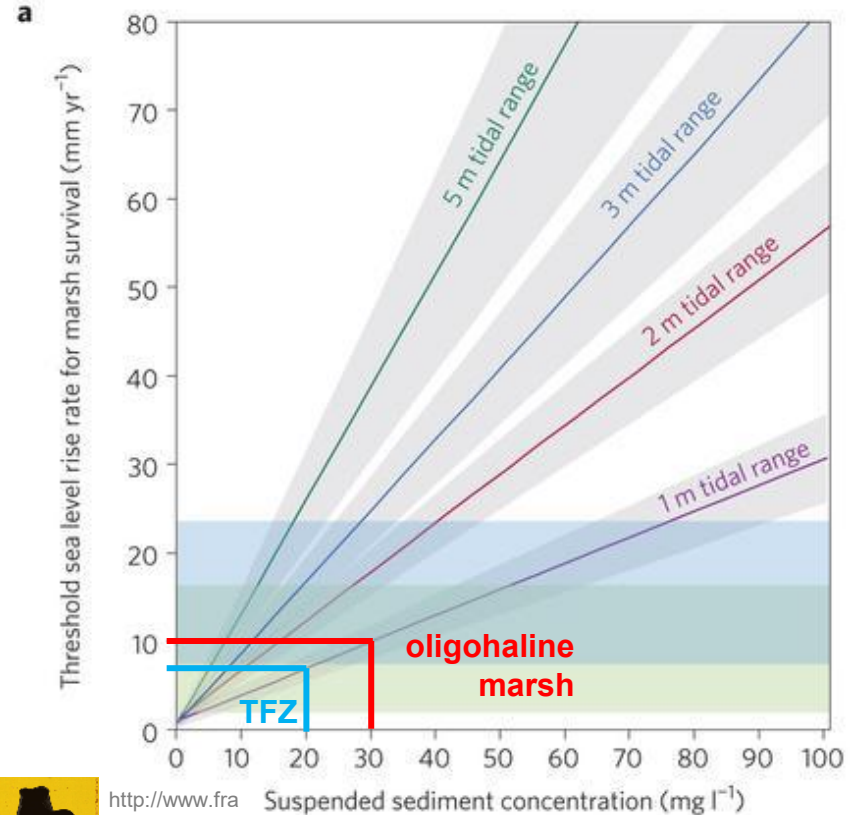
- The Sediment Shadow has been observed over the U.S. Atlantic Coast's tidal freshwater rivers
 - James (Bukaveckas and Isenberg 2013)
 - Choptank (Ensign et al. 2014, Ensign et al. 2015)
 - Pocomoke (Ensign et al. 2014, Ensign et al. 2015)
 - Roanoke (Hupp et al. 2015)
 - Waccamaw/Winyah (Noe et al. 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)”



Consequences for tidal wetland resilience to sea level rise



Coleman et al. 2022



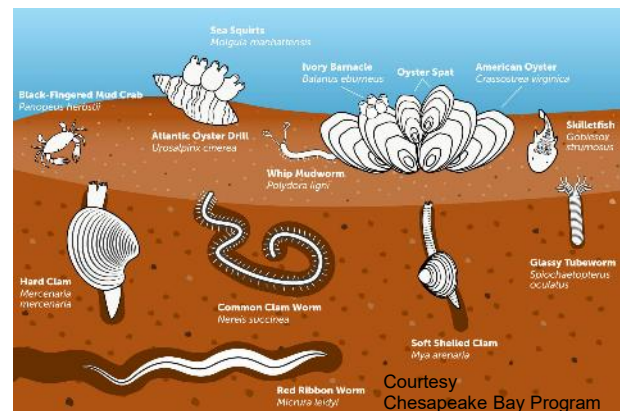
Kirwan et al. 2016

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





Thank you