Chesapeake Bay estuary topics
10 Mar 2020

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- L Sanford
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- B Benham
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Estuarine science gaps

What are the ‘tipping points’ for estuarine processes?

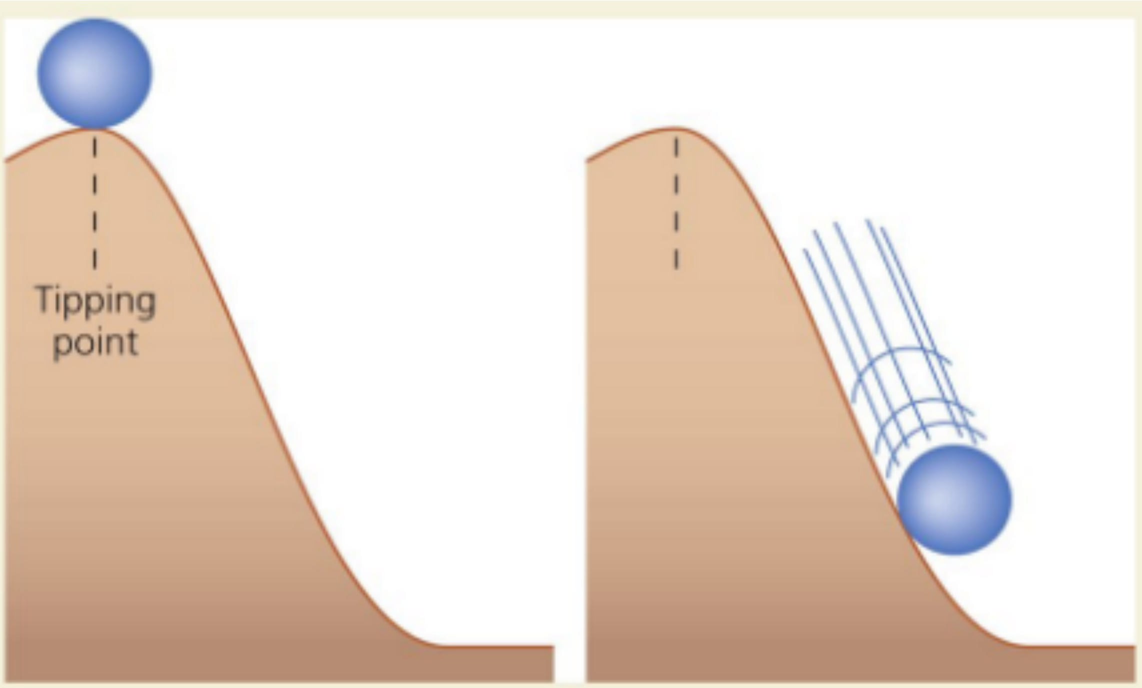
What are the ramifications of climate change in Chesapeake Bay responses?

Can we better understand the processes that occur at the land-sea interface?

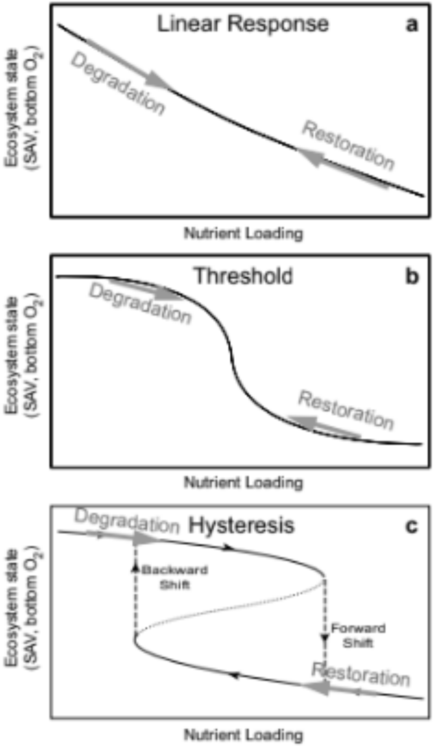
Tipping points

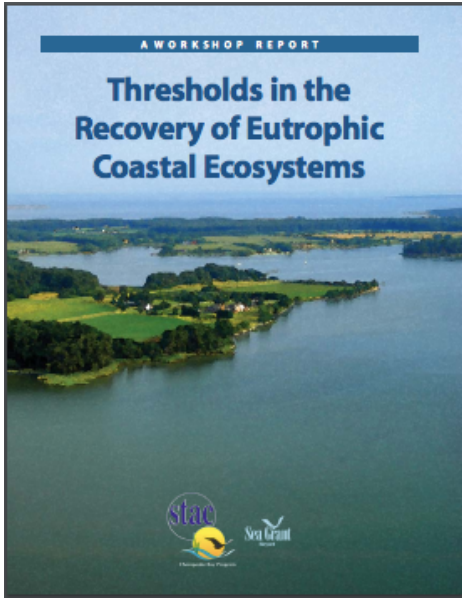
- Water clarity tipping point
- Dissolved oxygen tipping point
- SAV tipping point
- Tipping points affecting Bay health metrics
- Scientific response to tipping points; monitoring, modeling and research

Ecological "tipping points"



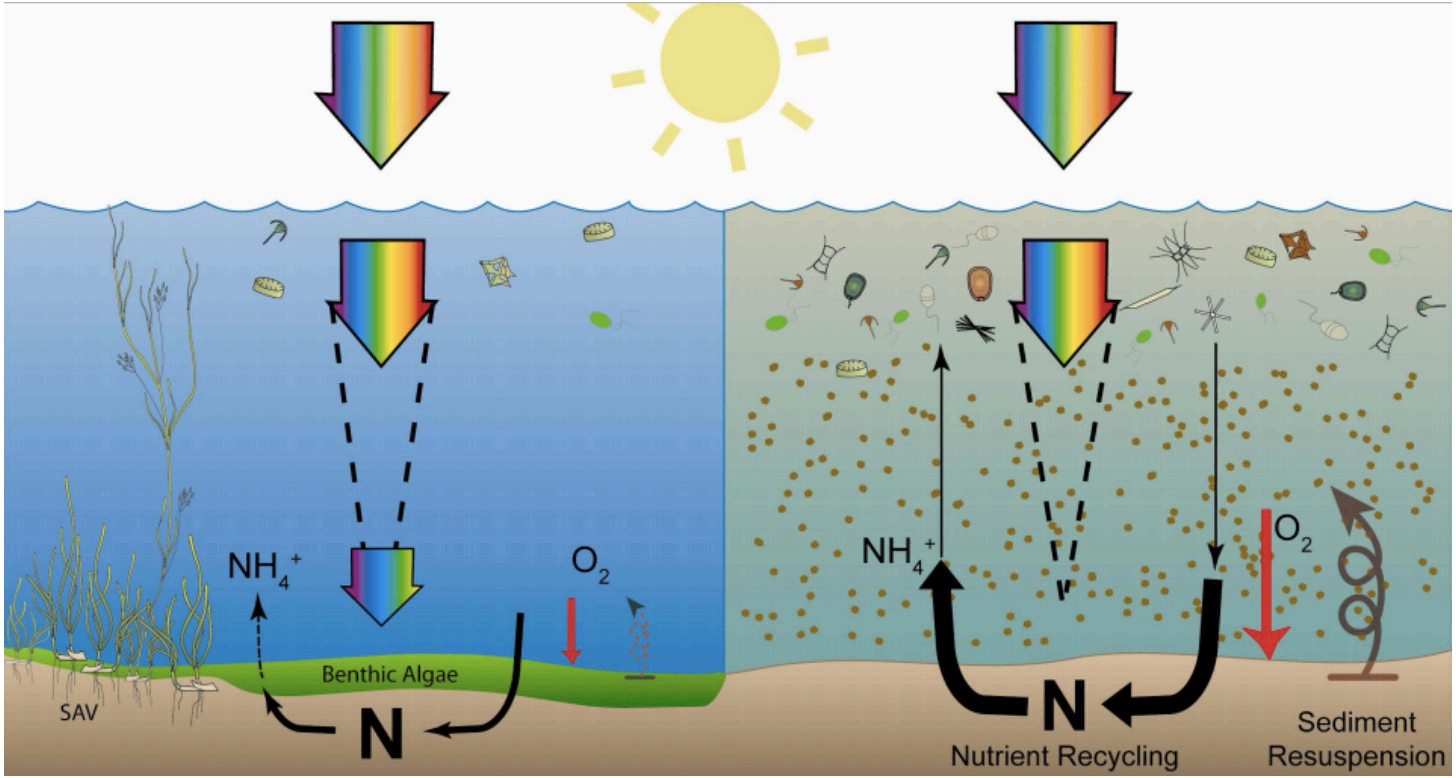
Threshold response = "tipping point"





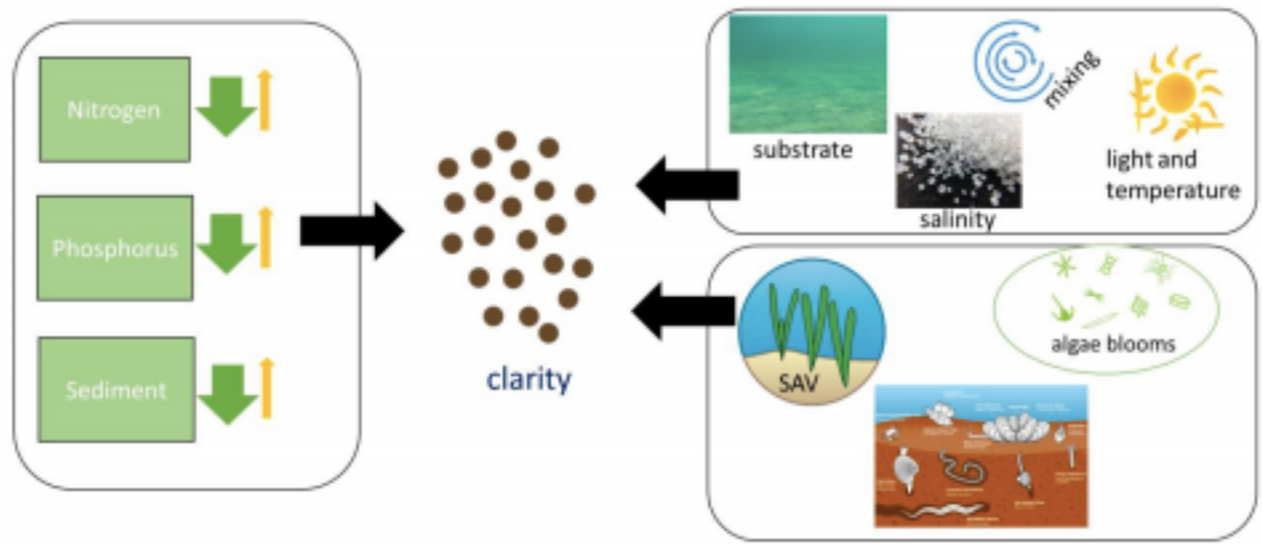
Kemp and Goldman, 2008

Water clarity tipping point



Boynton et al., 2009

Understanding and Explaining 30 Years of Water Clarity Trends in the Chesapeake Bay's Tidal Waters



Keisman et al., 2019

Water clarity report summary

Why did long-term Secchi depth trends decline from the mid-1980s to present day, despite reductions in both point- and nonpoint- source nutrient loads from the watershed? SMALL ORGANIC PARTICLES

Why have we seen a different story with light attenuation trends (i.e., water clarity as Kd, measured with radiometers)? SMALL ORGANIC PARTICLES

Why have mainstem Secchi depth trends begun to improve in the last decade? DON'T KNOW

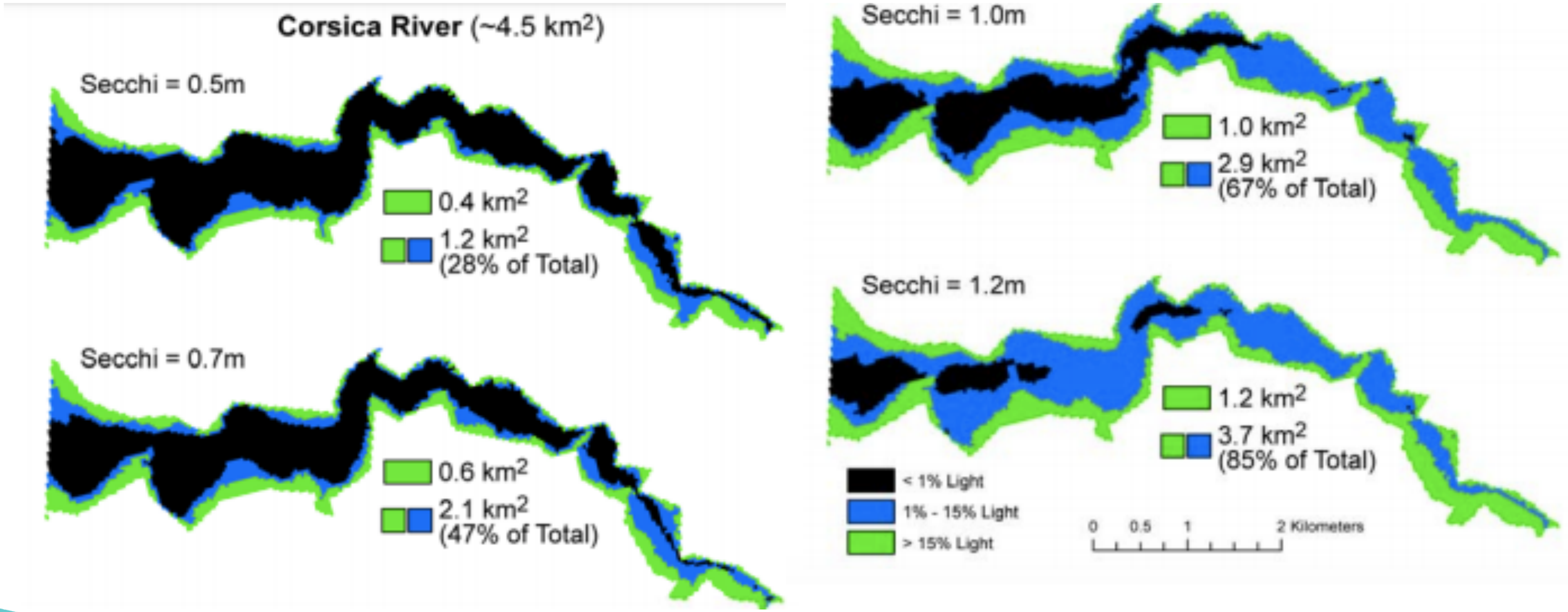
What has more impact on trends in water clarity: internal resuspension of particulate matter, or sediment inputs from the watershed and local shoreline? IT DEPENDS

What about biology? REALLY IMPORTANT, BUT MAY BE INDIRECT

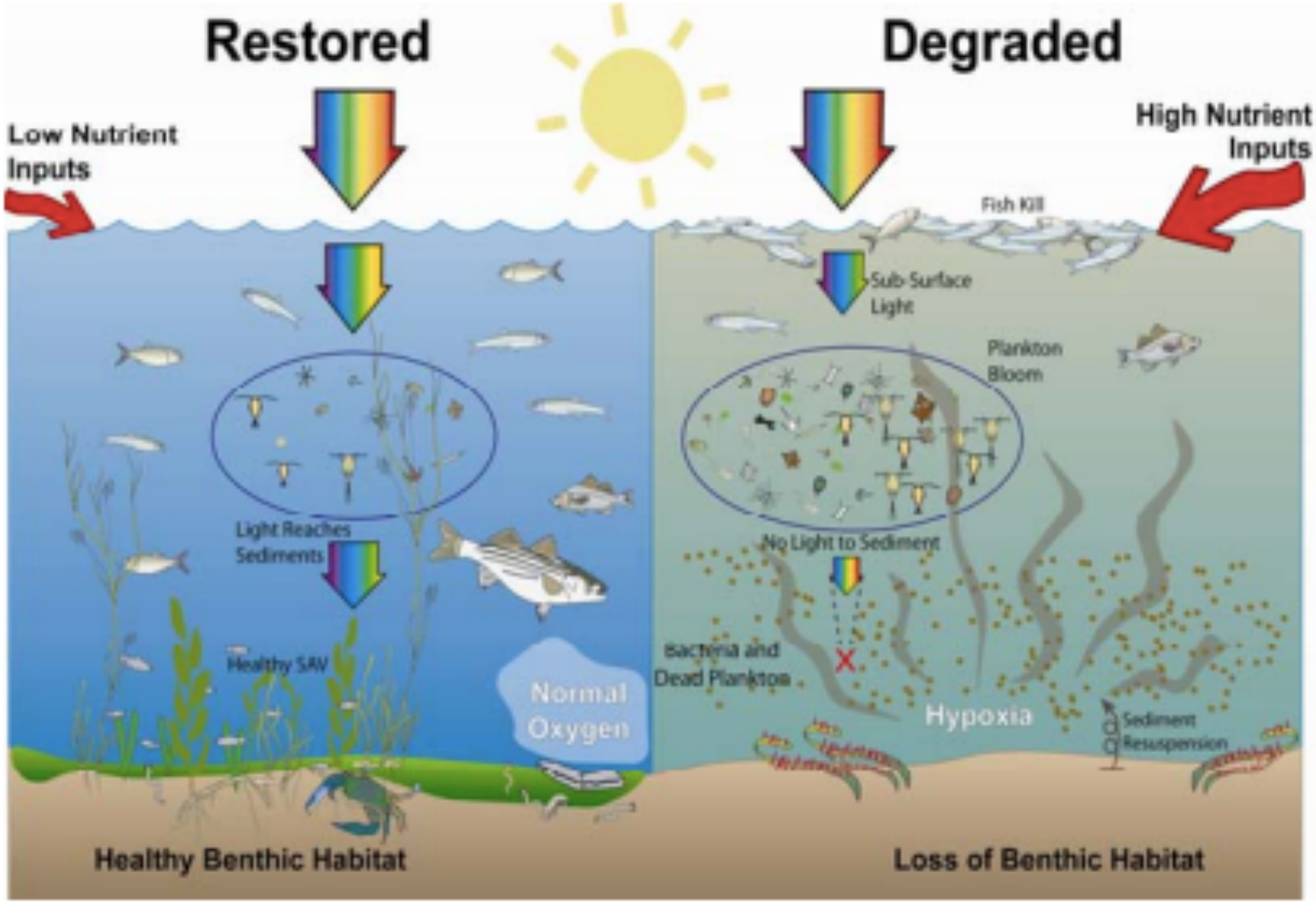
Current management strategies aim to improve Chesapeake Bay water quality (including water clarity) by reducing nitrogen, phosphorus, and sediment inputs to tidal waters (Chesapeake Bay Program 2019). Does this approach target the appropriate drivers of poor water clarity? YES, BUT MORE TARGETED RESEARCH NEEDED

Keisman et al., 2019

Benthic lighted area sensitive to water clarity

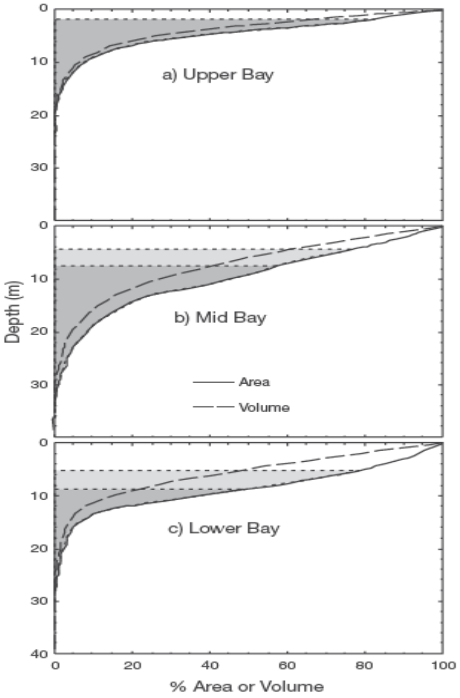


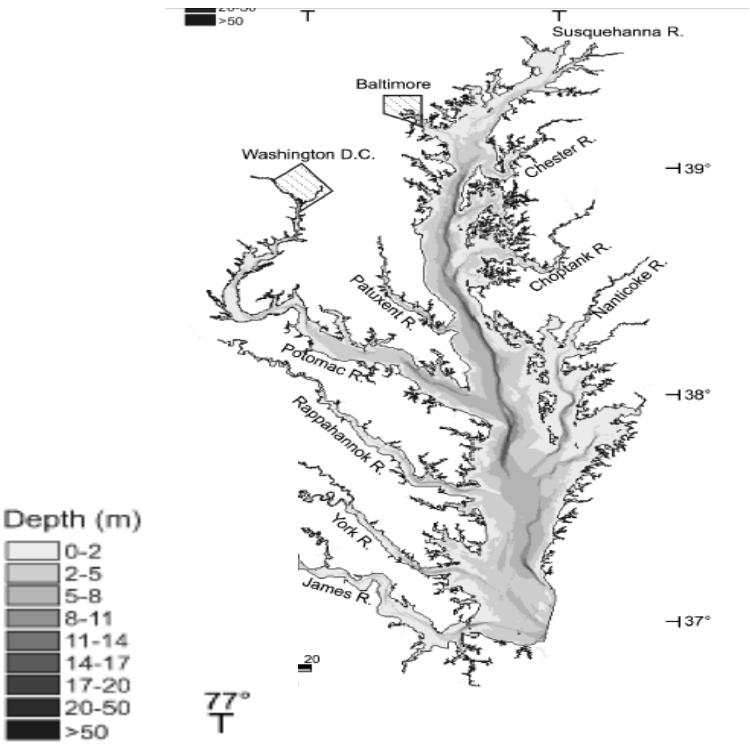
Boynton et al., 2009



Restored
Degraded
Low Nutrient Inputs
High Nutrient Inputs
Fish Kill
Sub-Surface Light
Plankton Bloom
Light Reaches Sediments
No Light to Sediment
Healthy SAV
Normal Oxygen
Bacteria and Dead Plankton
Hypoxia
Sediment Resuspension
Healthy Benthic Habitat
Loss of Benthic Habitat

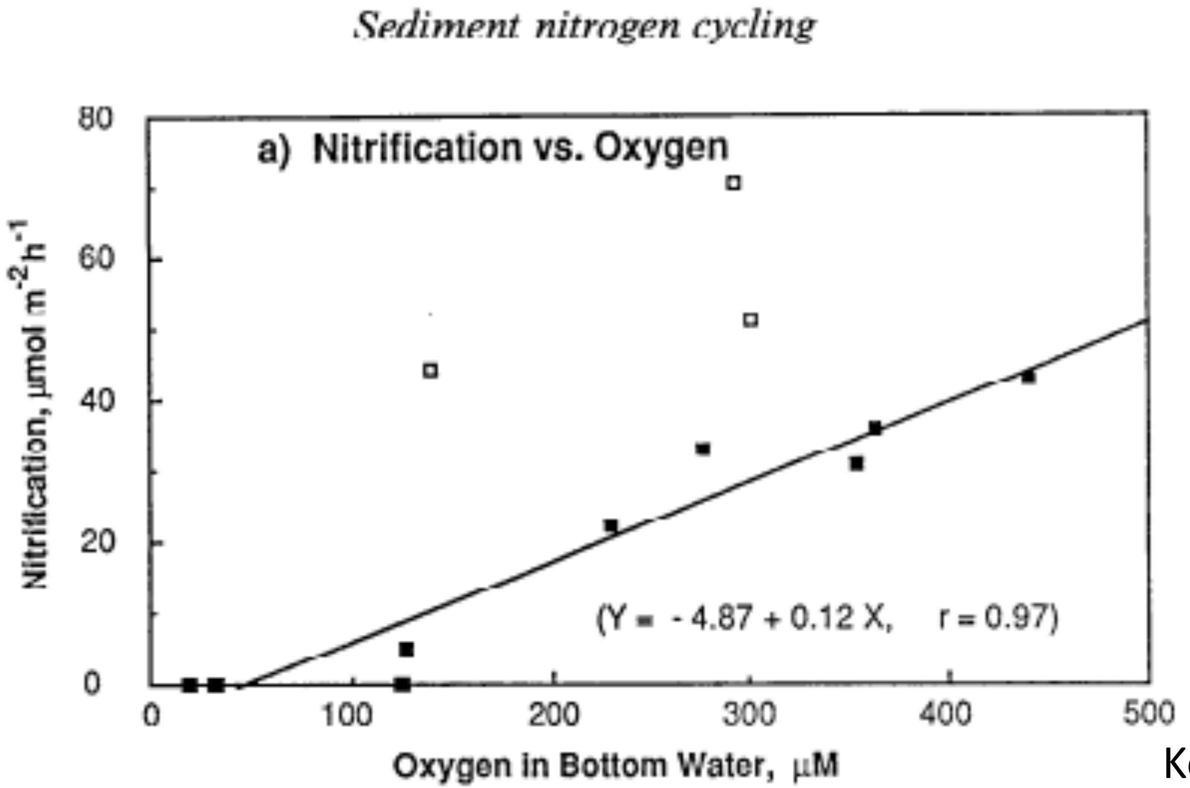
Chesapeake Bay bathymetry means that small changes in water clarity will have major impacts





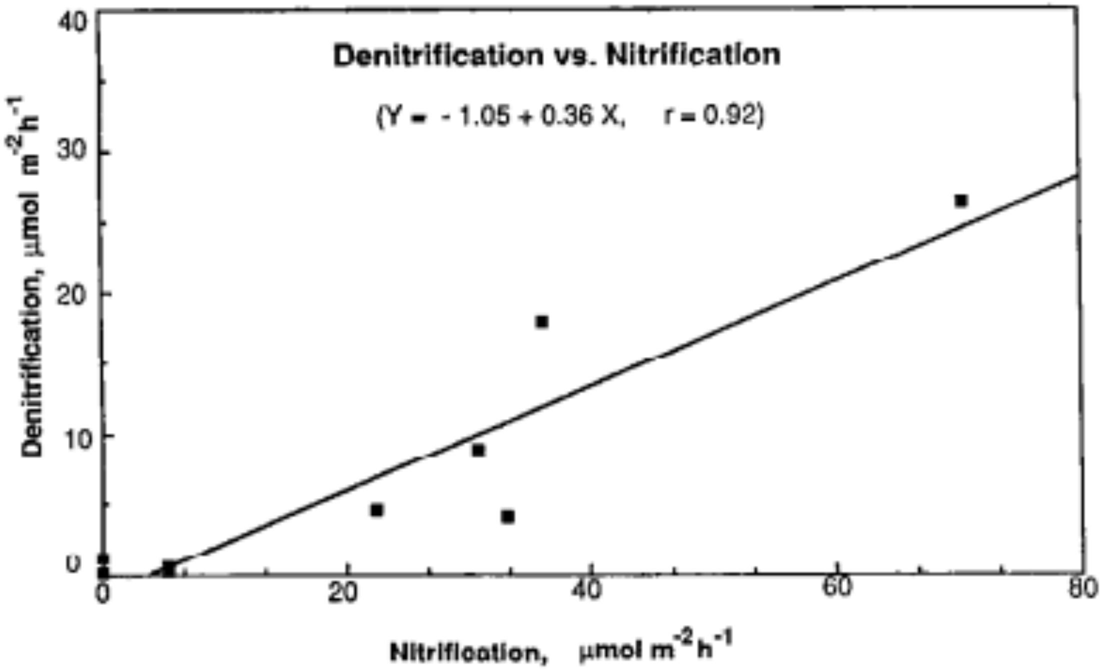
Kemp et al., 2005

Dissolved oxygen tipping point



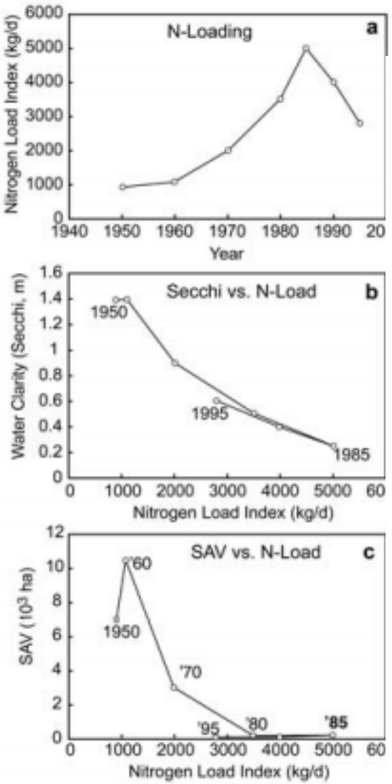
Kemp et al., 1990

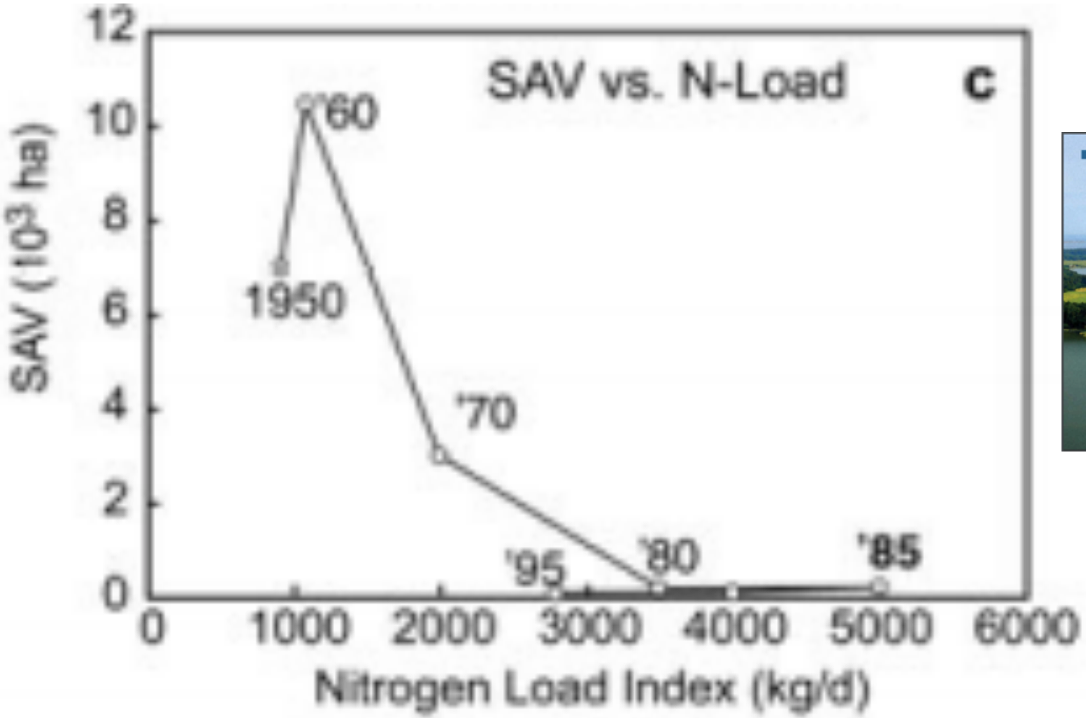
Bottom water oxygen controls denitrification

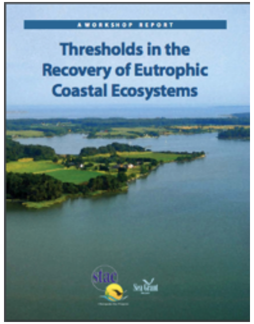


Kemp et al., 1990

SAV tipping point: Hysteresis in SAV recovery

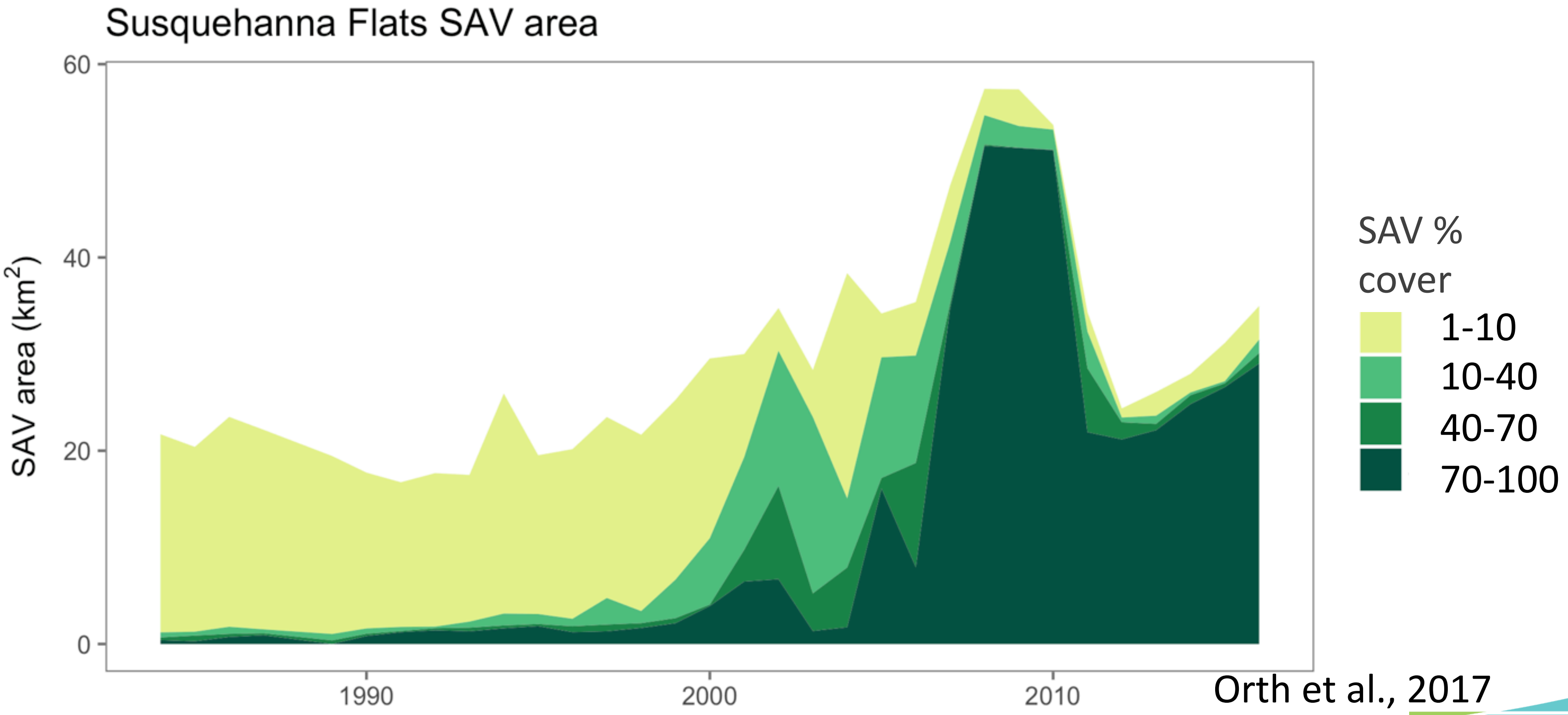






Kemp and Goldman, 2008

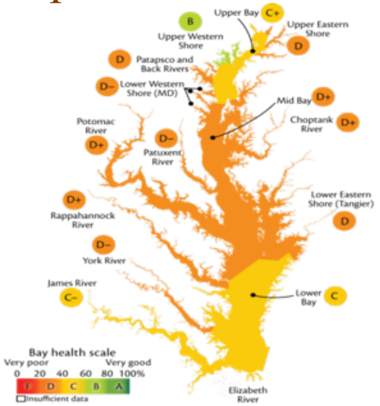
SAV recovery in the upper Chesapeake Bay

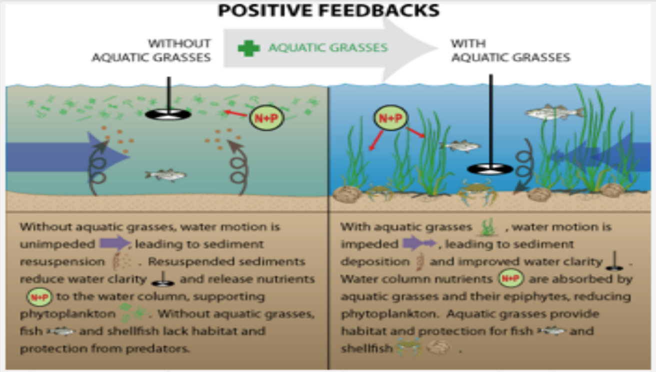


Orth et al., 2017

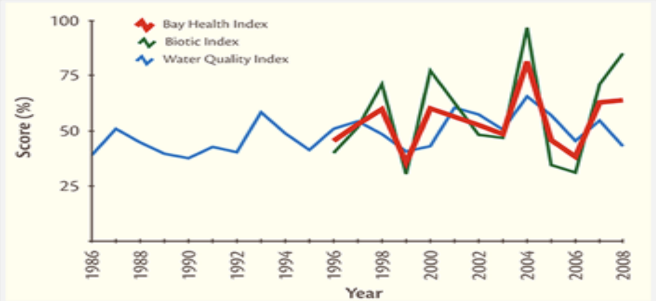
Nonlinear ecosystem transformations

Chesapeake Bay report card

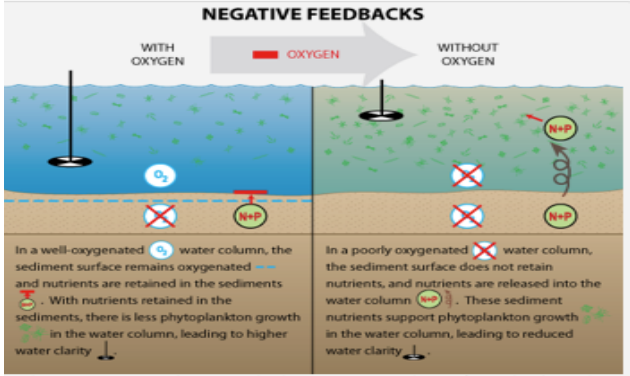




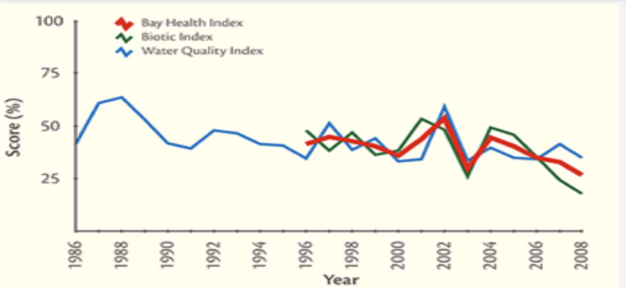
The resurgence of aquatic grasses in the Upper Bay results in the positive feedbacks to water quality.



Positive ecological feedbacks resulting in improving water quality trajectories.

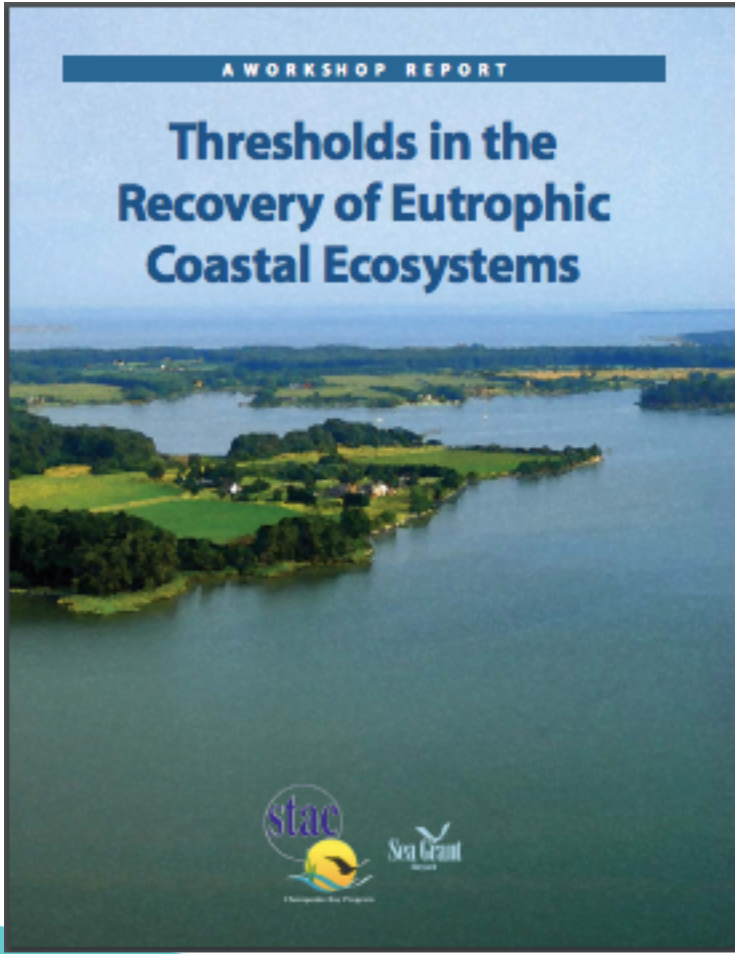


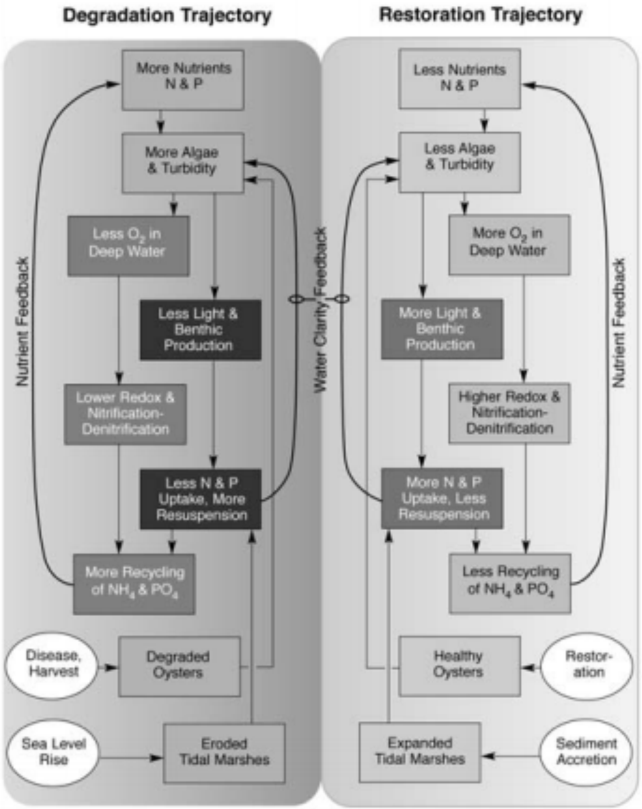
Declining oxygen conditions in the lower Western Shore of Maryland results in degrading water quality.



Negative ecological feedbacks resulting in degrading water quality trajectories.

www.ecoreportcard.org/Chesapeake-Bay





Kemp and Goldman, 2008

Scientific response to tipping points

Monitoring: Careful observations to establish tipping points for both degradation and restoration trajectories, Frequent water clarity measurements, Continued bottom water dissolved oxygen levels and annual SAV surveys

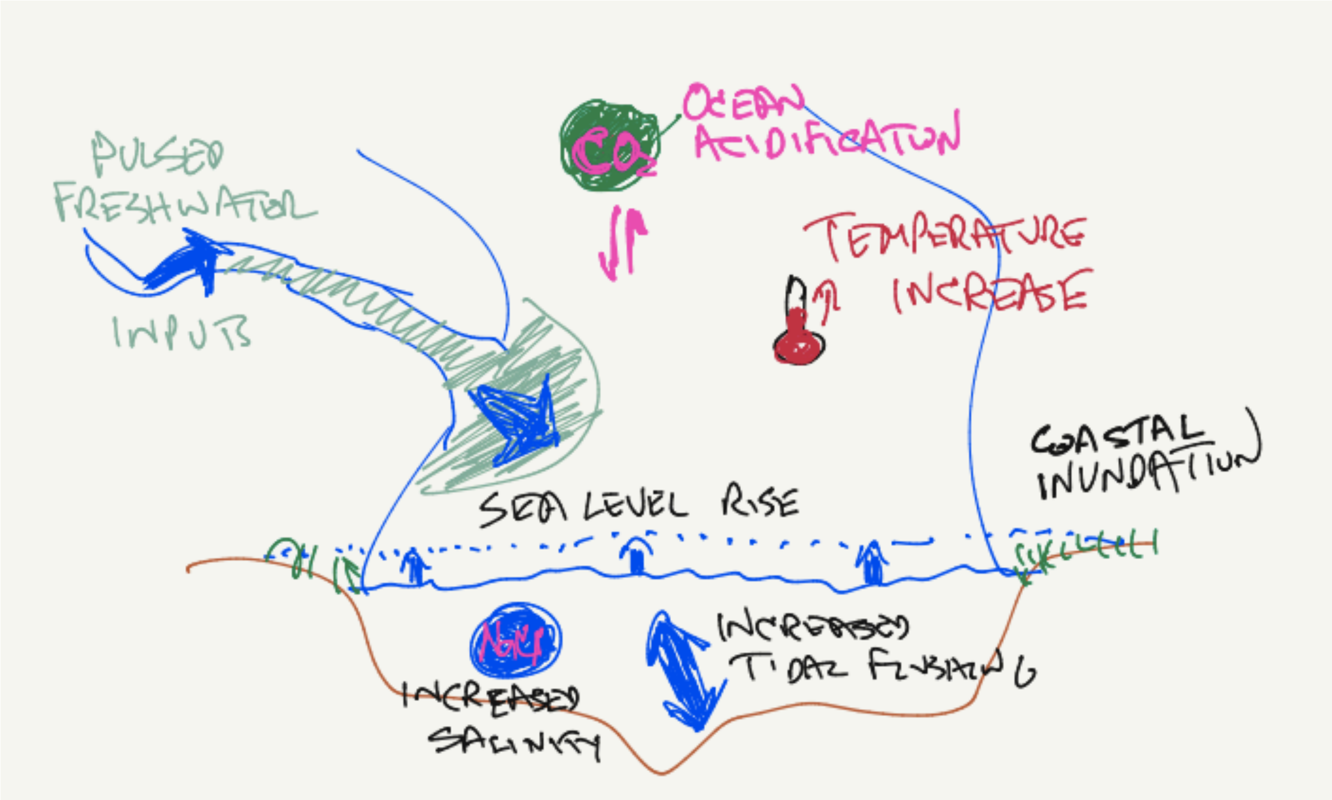
Modeling: Incorporate ecological feedbacks into models, Extrapolate specific site measurements to Bay-wide forecasting, model continued nutrient reductions needed to reverse degradation or enhance restoration

Research: Investigate feedback mechanisms, Test out tipping points in different salinity regimes, Spatial variability of nitrification/denitrification, Shift to restoration ecology

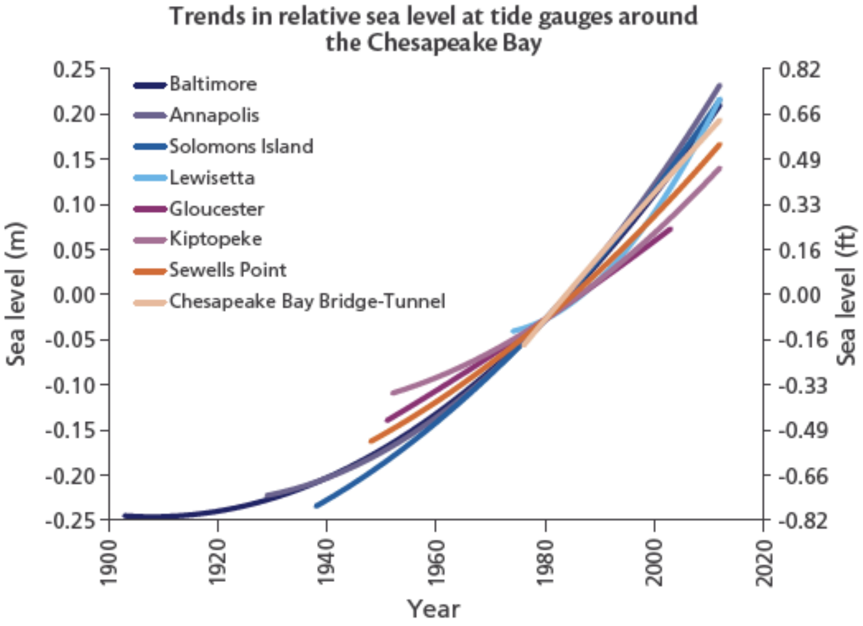
Climate change

- Observed changes
  - Sea level
  - Temperature
  - Salinity
- Anticipated changes
  - Dissolved inorganic carbon
  - Precipitation patterns
  - Tropical storm frequency & intensity
- Scientific response to climate change; monitoring, modeling and research

Climate change



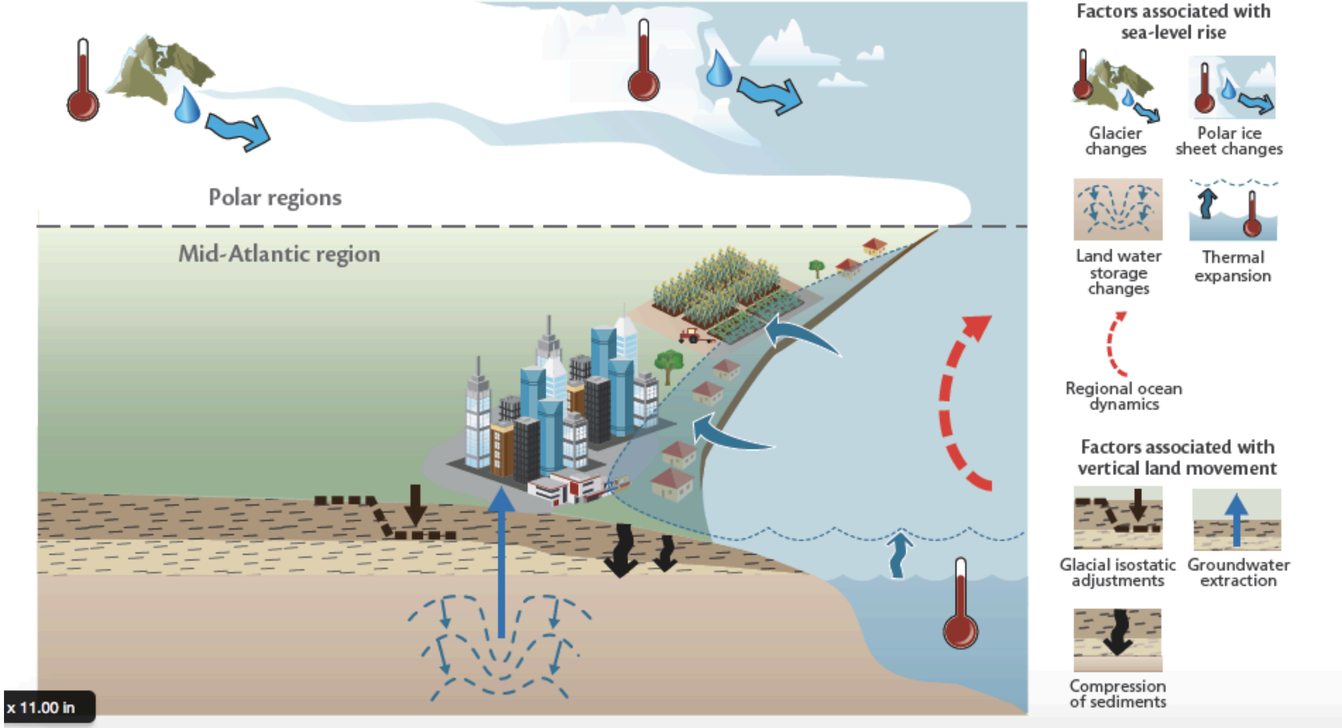
Observed changes: Sea level rise



Relative sea-level rise over the past century from analysis of tide gauge records from the Chesapeake Bay; sea level is relative to 1980.[23] The mathematical analysis applied removes oscillating modes to depict the underlying trends.

Boesch et al., 2013

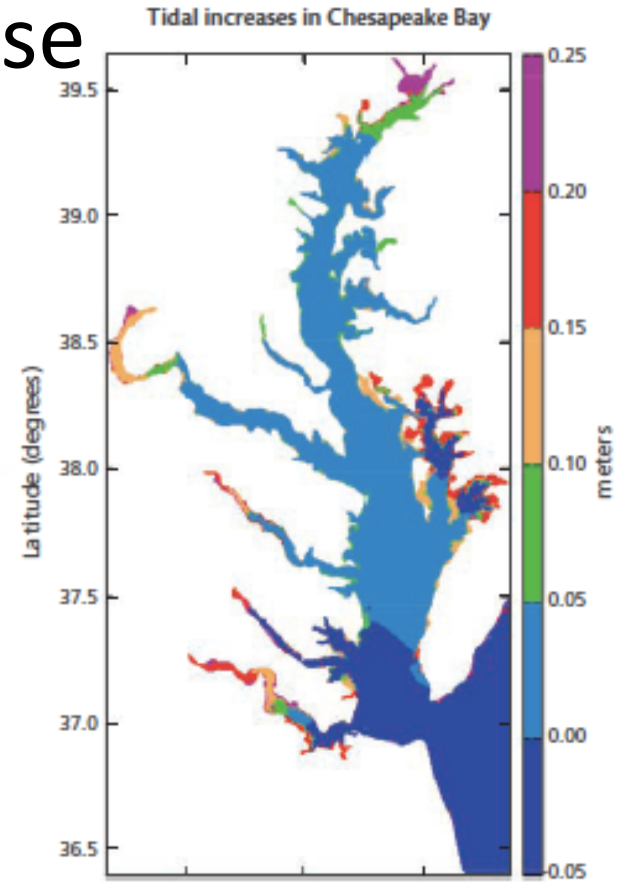
Observed changes: Sea level rise



Boesch et al., 2013

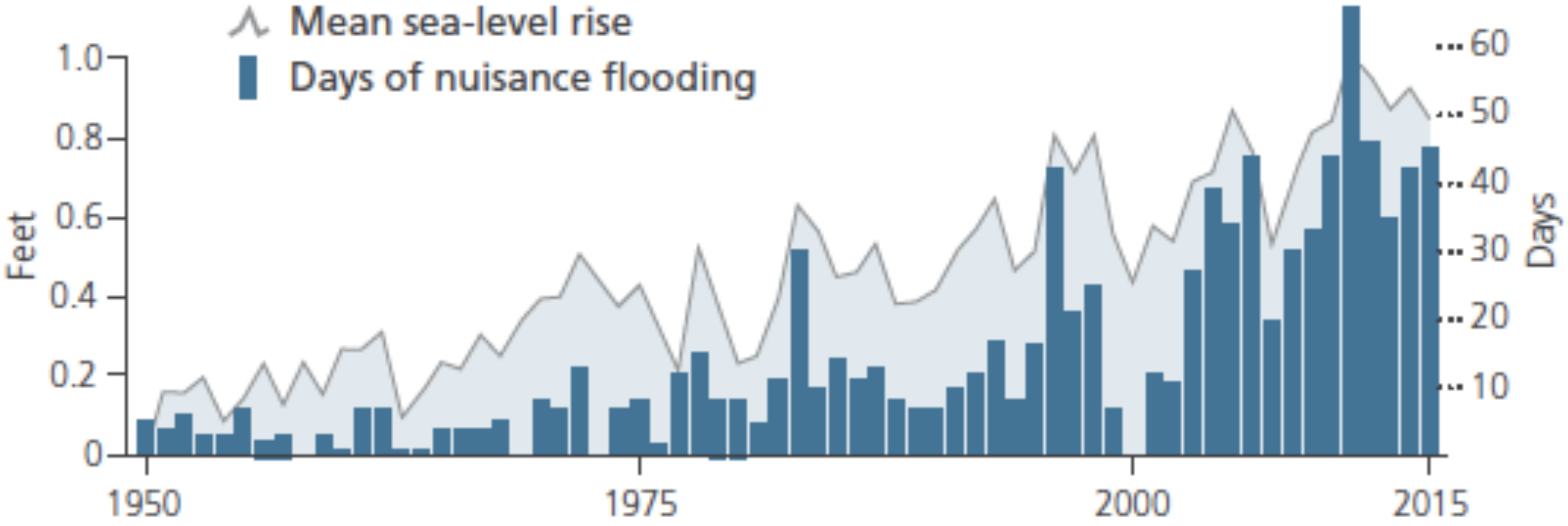
Observed changes: Sea level rise

A one-meter rise in sea level will shift the resonance response of the Chesapeake Bay toward 24 hours, thus increasing tidal range in the upper Bay.[28]



Boesch et al., 2013

Observed changes: Sea level rise



Boesch et al., 2018

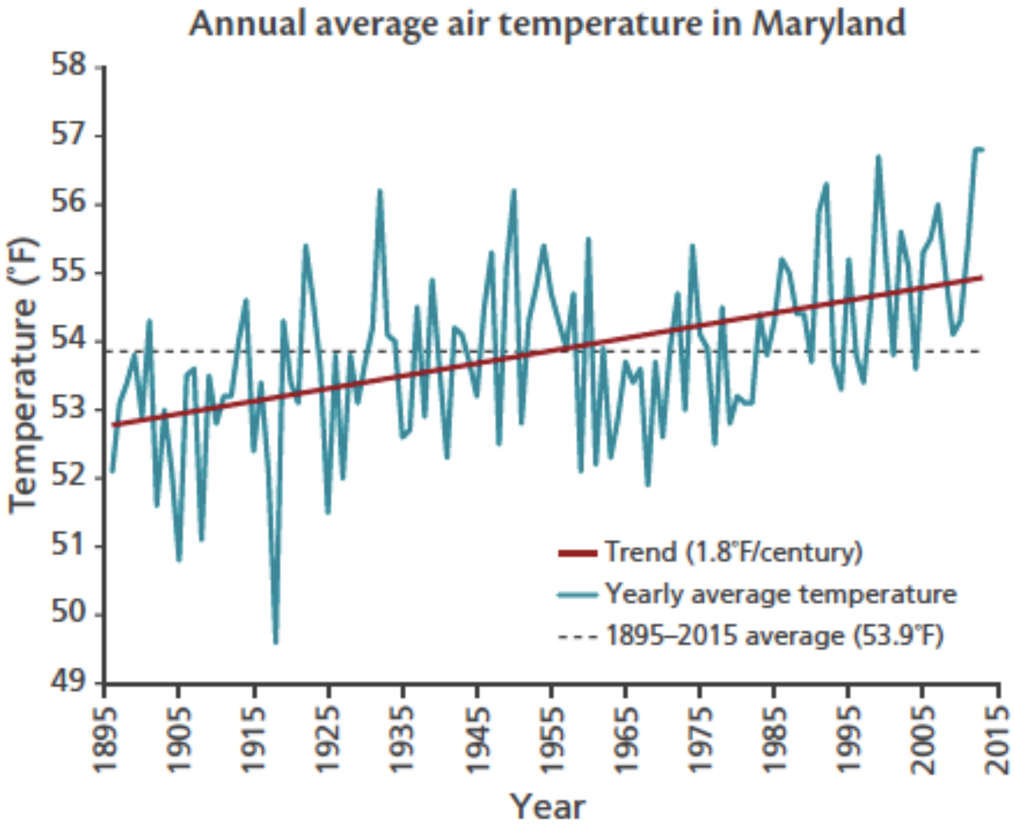
Observed changes: Sea level rise

Table 1. Individual contributions to global mean sea-level rise in mm/yr.

	1993-2015	2005-2015
Thermal expansion	1.30	1.30
Glaciers	0.65	0.74
Greenland	0.48	0.76
Antarctic	0.25	0.42
Residual	0.37	0.28
Total	**3.05**	**3.50**

Boesch et al., 2018

Observed changes: Temperature



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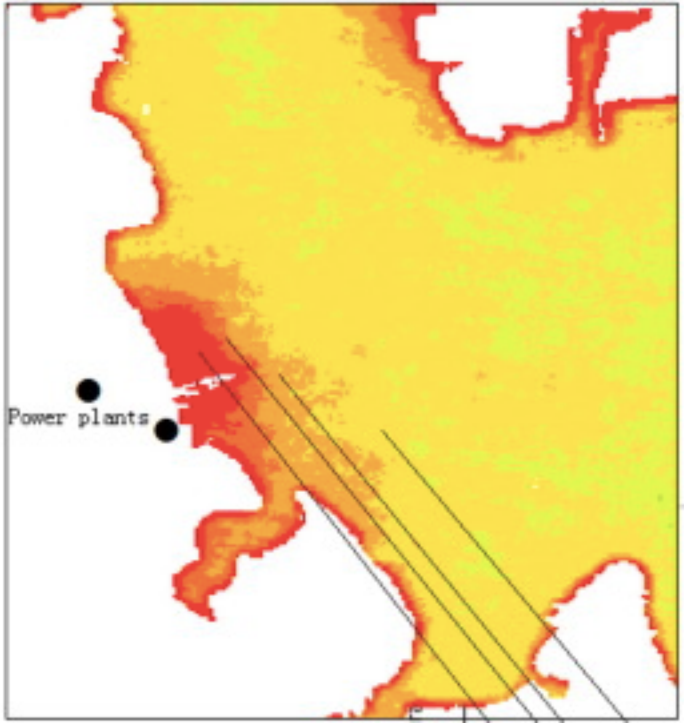
Observed changes: Temperature

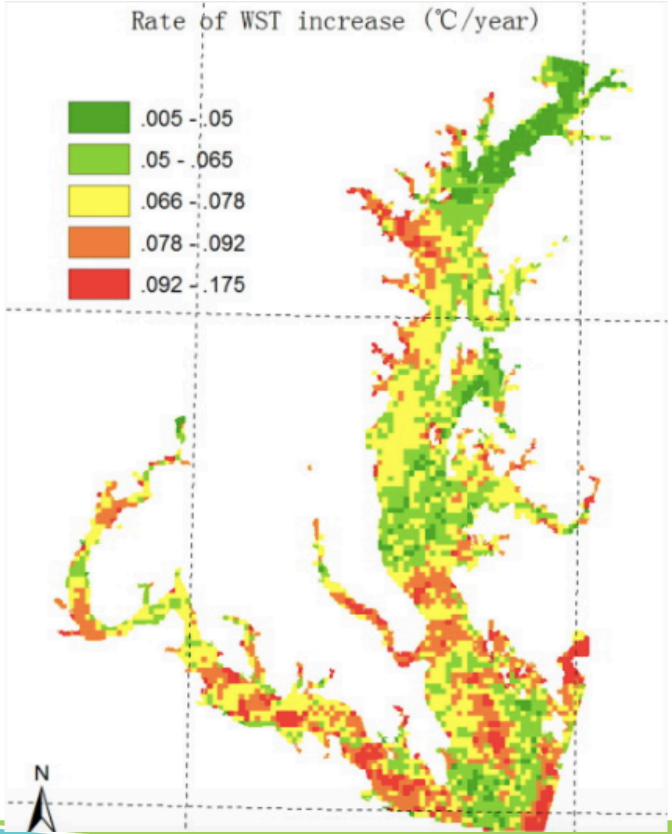


Calvert Cliffs thermal plume

Ding and Elmore, 2015

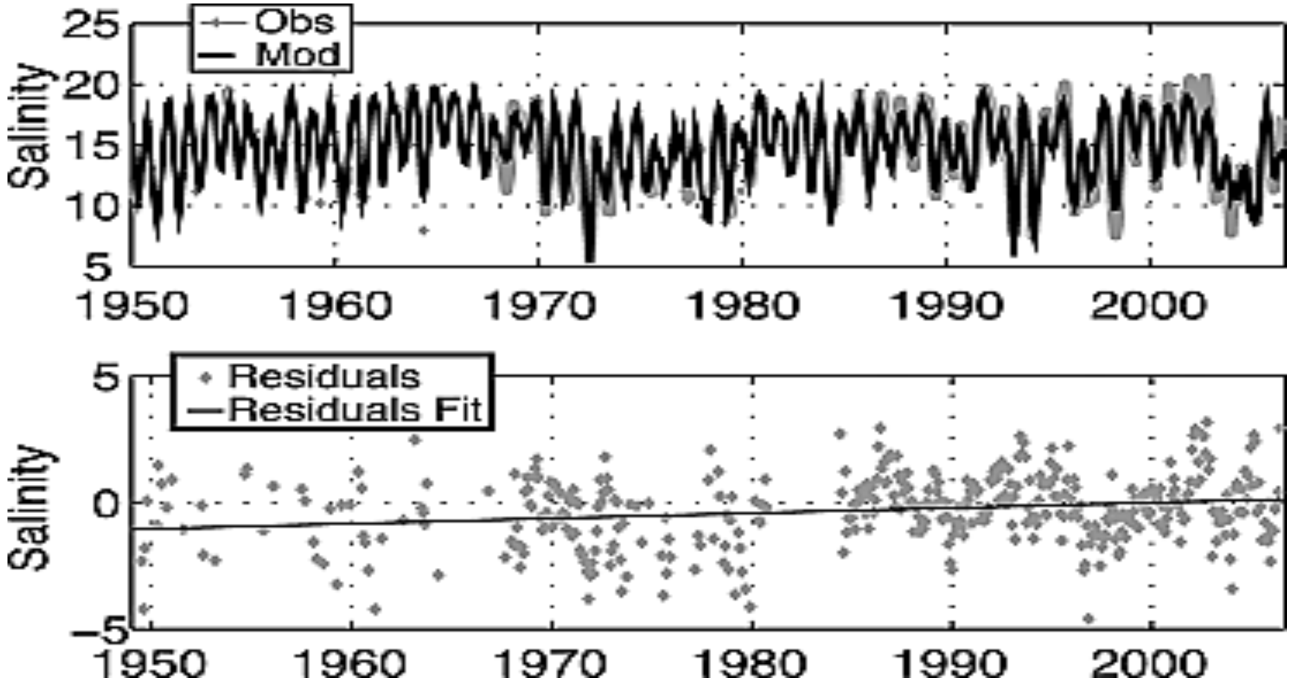
Observed changes: Temperature

Stormwater water runoff is warm



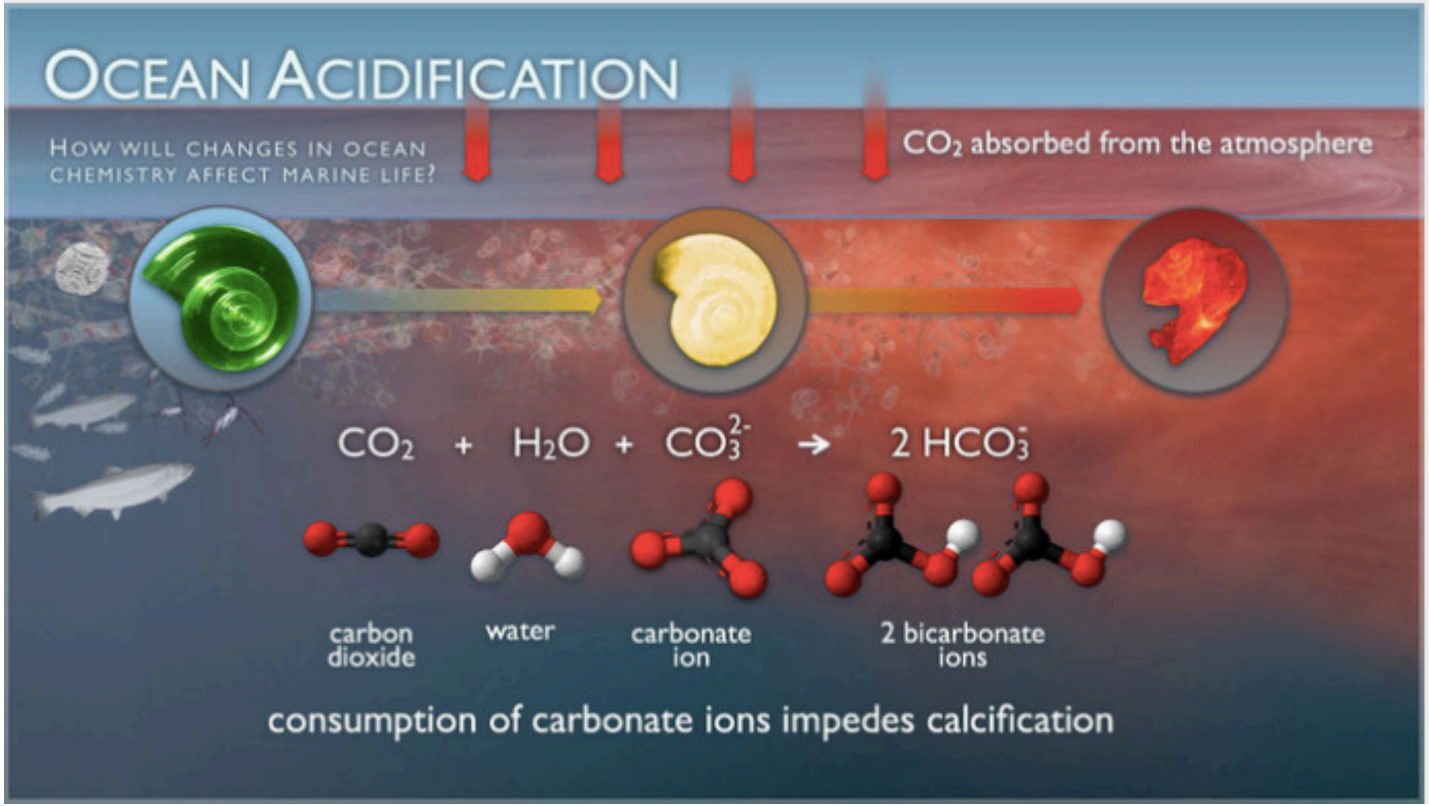
Ding and Elmore, 2015

Observed changes: Salinity



Journal of Geophysical Research: Oceans, Volume: 113, Issue: C9, First published: 03 September 2008, DOI: (10.1029/2007JC004247)

Anticipated changes: DIC



Anticipated changes: DIC

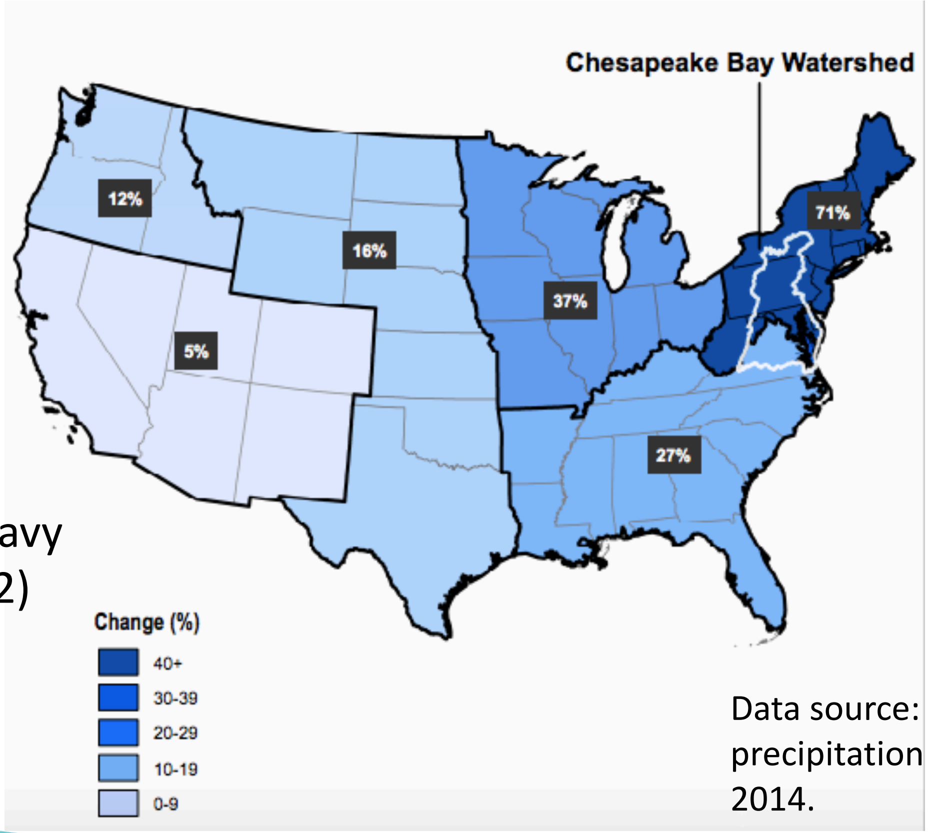
Front. Mar. Sci., 06 March 2019 | https://doi.org/10.3389/fmars.2019.00099

Chesapeake Bay Inorganic Carbon: Spatial Distribution and Seasonal Variability

Jean R. Brodeur[1], Baoshan Chen[1], Jianzhong Su[1,2], Yuan-Yuan Xu[1], Najid Hussain[1], K. Michael Scaboo[1], Yafeng Zhang[3], Jeremy M. Testa[4] and Wei-Jun Cai[1]*

“[These results] underline the importance of large estuarine systems for mitigating acidification in coastal ecosystems, since riverine chemistry is substantially modified within the estuary.”

Anticipated changes: Precipitation patterns



Observed changes in heavy precipitation (1958-2012)

Data source: Observed change in precipitation adopted from Melillo et al., 2014.

Anticipated changes: Precipitation patterns

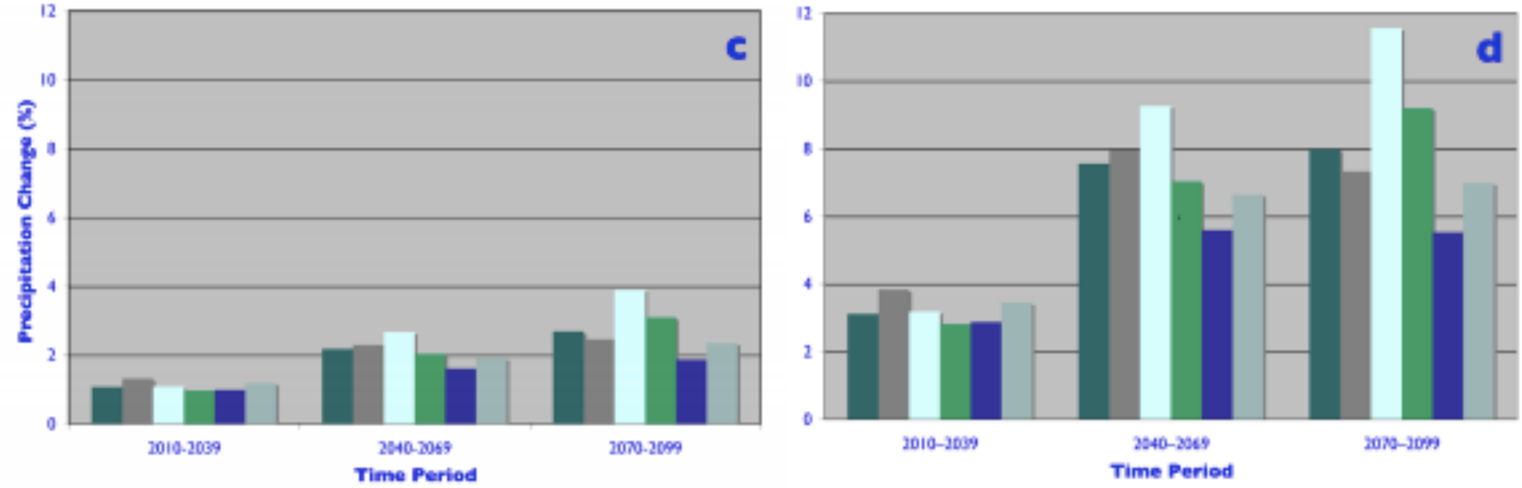
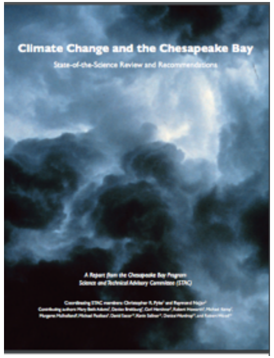
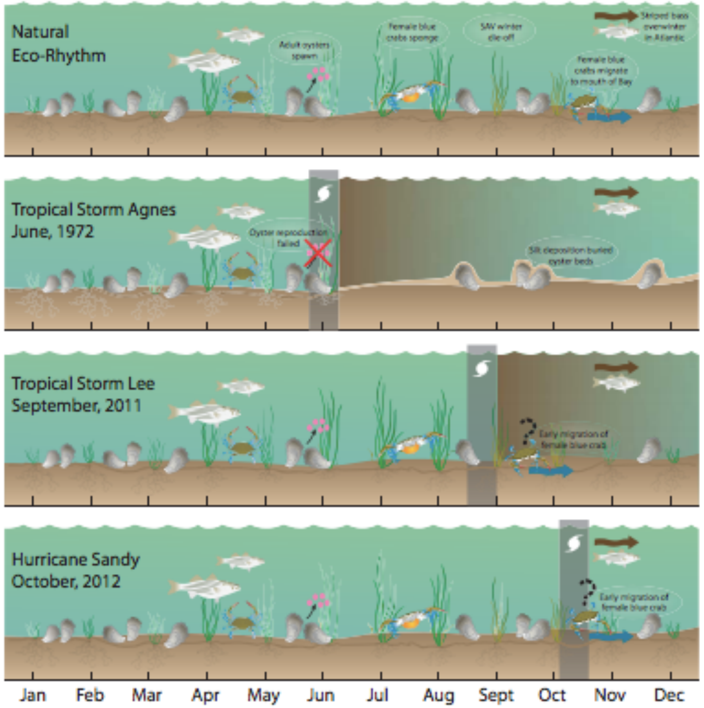


Figure 4. *Projected change in the annual mean temperature (a and b) and precipitation (c and d) of the Chesapeake Bay watershed for six IPCC scenarios (see Figure 1) averaged over seven climate models (a and c) and the four highest ranked (b and d). From Najjar et al. [2008].*



Anticipated changes: Tropical storm frequency and intensity

Tropical Storm Lee



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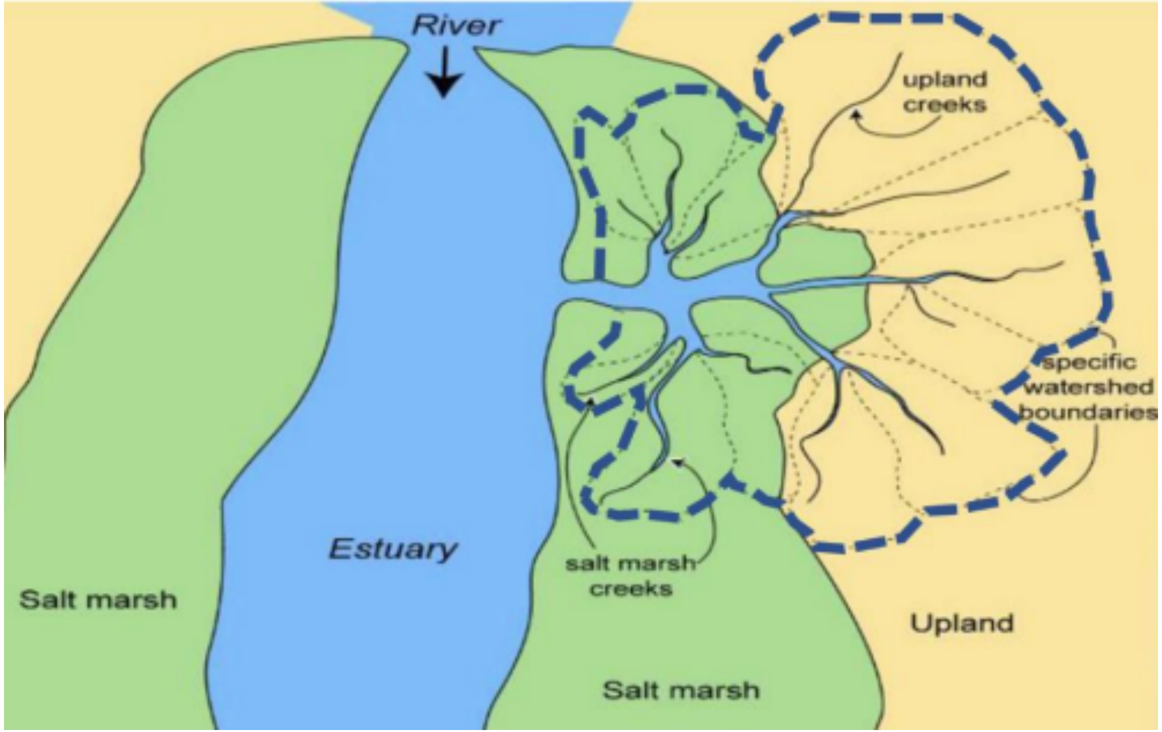
Land sea interface

- Triblets
- Processes
- Scientific response to tipping points; monitoring, modeling and research

Land sea interface: Triblets



Boomer et al., 2019

Land sea interface: Triblets

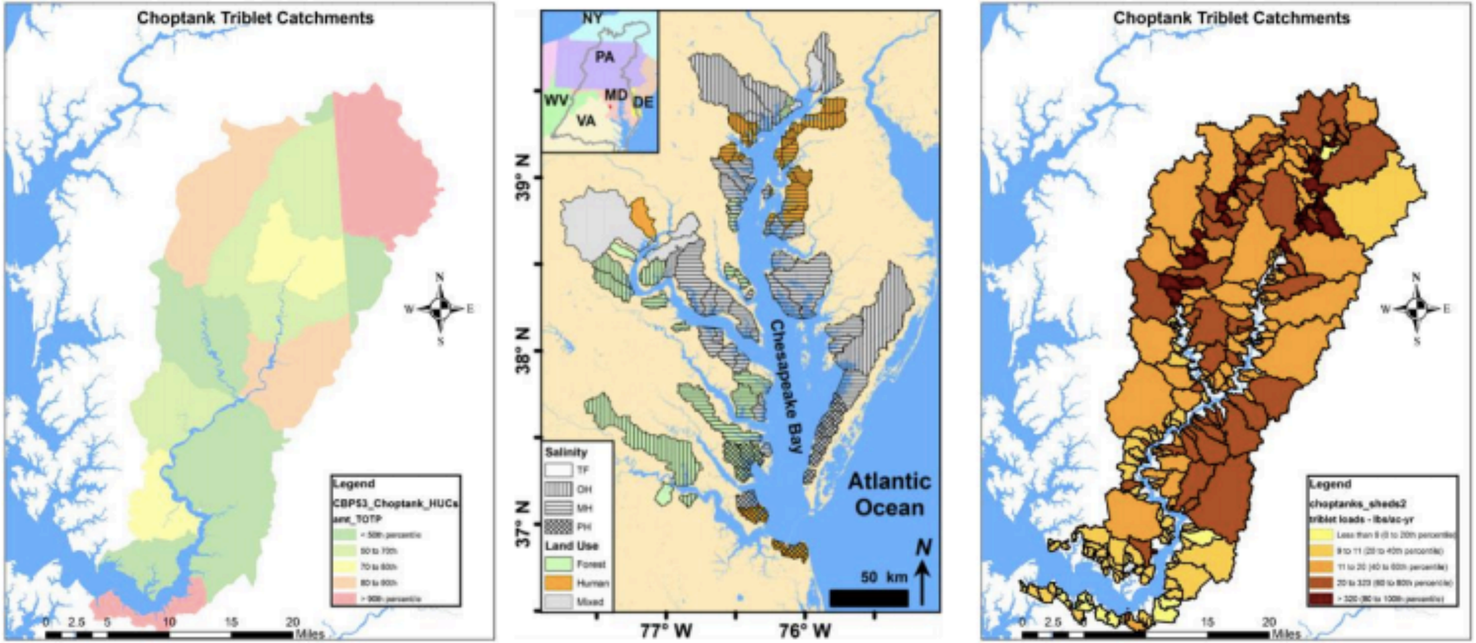
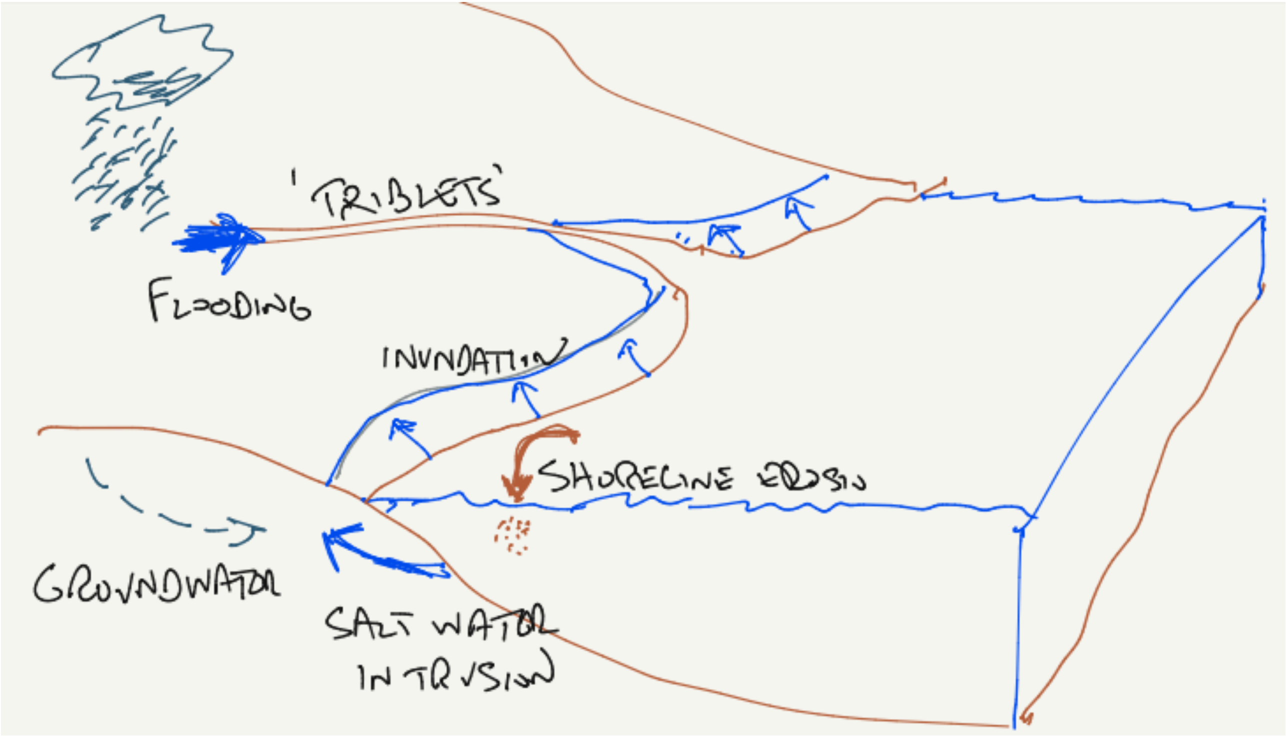


***Figure 3:** Current Chesapeake Bay Program's land-river model segments of the Choptank River in contrast to potential triblet-based model segmentation strategies, including land areas draining to small estuaries (middle) or based on channelized waterways connecting uplands to the estuary (right). Note the middle figure maps examples of triblet catchments across the Chesapeake Bay watershed (Weller and Jordan), in addition to the Choptank River subsystems (left and right panels).*

Boomer et al., 2019

Land sea interface: Triblets



Scientific response to land sea interface

Monitoring: Develop a practical way to monitor in difficult land sea interfaces

Modeling: Develop simple estuarine characterizations, good triblet models will require extensive expertise and time

Research: Develop methodology to establish high priority triblets for management interventions, field research to determine responses of triblets to management (natural science) and stakeholder perceptions (social science)