Assessing oyster aquaculture impact on water quality in Chesapeake Bay

Richard Tian, Carl Cerco, Lewis Linker
Chesapeake Bay Program Office

Modeling Quarterly Review Meeting
04/10/2018
Annapolis

Chesapeake Bay Oyster Aquaculture

- **Oyster aquaculture is rapidly expanding, by 10 folds from 2012 to 2016 in Maryland waters, and better developed on VA portion of the Bay.**
- **By 2025, an estimated 112 millions market size oysters (3 inches) will be harvested in MD and 280 millions will be harvested in VA.**
- **Equivalent to an annual removal of $78x10^3$ lbs nitrogen, and $8.6x10^3$ lbs phosphorus through soft tissue harvest only.**
- **On top of harvest removal, oyster can also remove suspended solids and nutrient through filtration and biogeochemical processes.**

Oyster Basic Equation in Model

$$\frac{dO}{dt} = \propto \cdot Fr \cdot VSS \cdot IF \cdot (1 - RF) \cdot O - BM \cdot O - \beta \cdot O$$

In which:

O = oyster biomass (g C m^{-2})

α = assimilation efficiency (0 < α < 1)

Fr = filtration rate (m^3 g^{-1} C d^{-1})

VSS = Total Organic (Volatile) Suspended Solids (g m^{-3})

IF = ingestion fraction (0 < IF < 1)

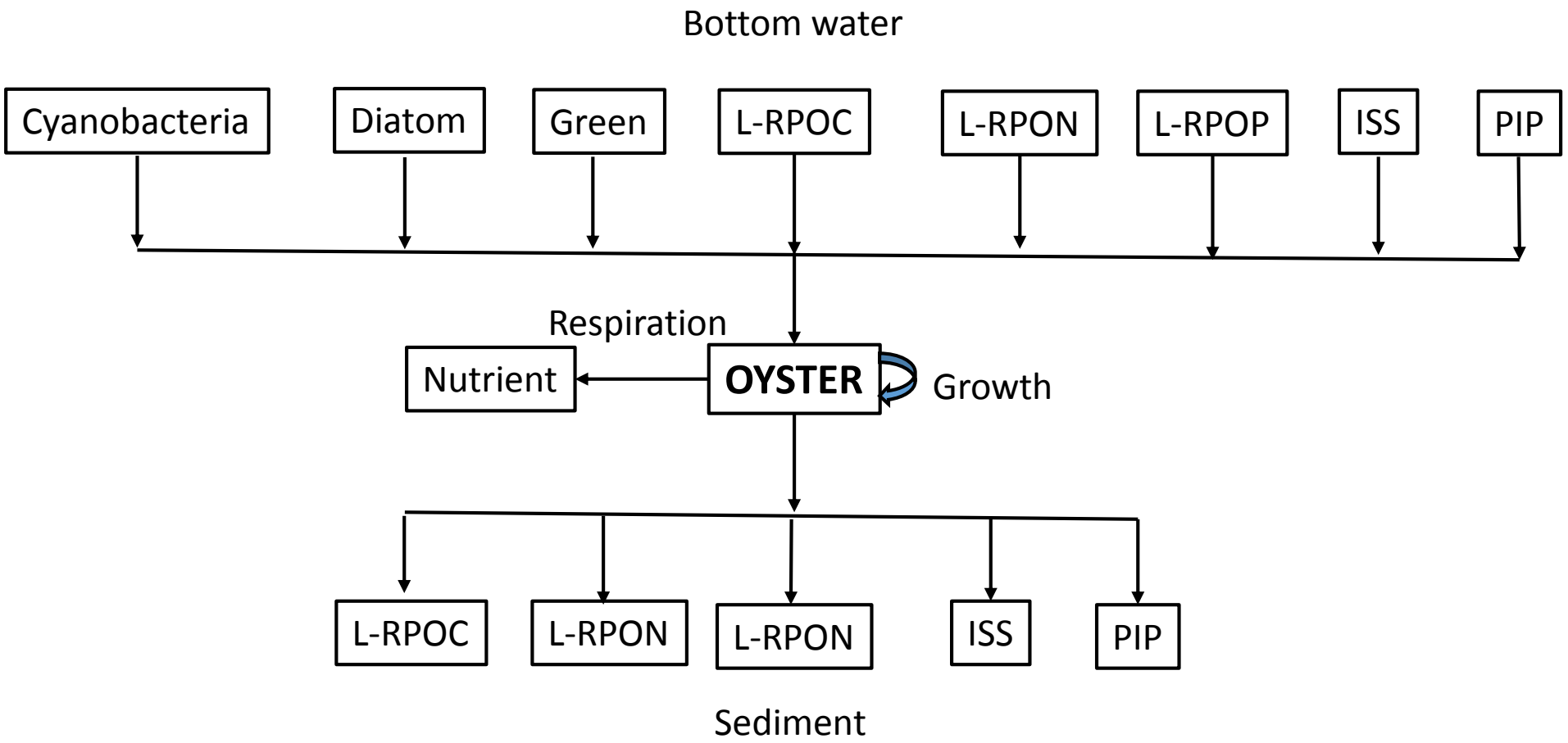
RF = respiration fraction (0 < RF < 1)

BM = basal metabolism (d^{-1})

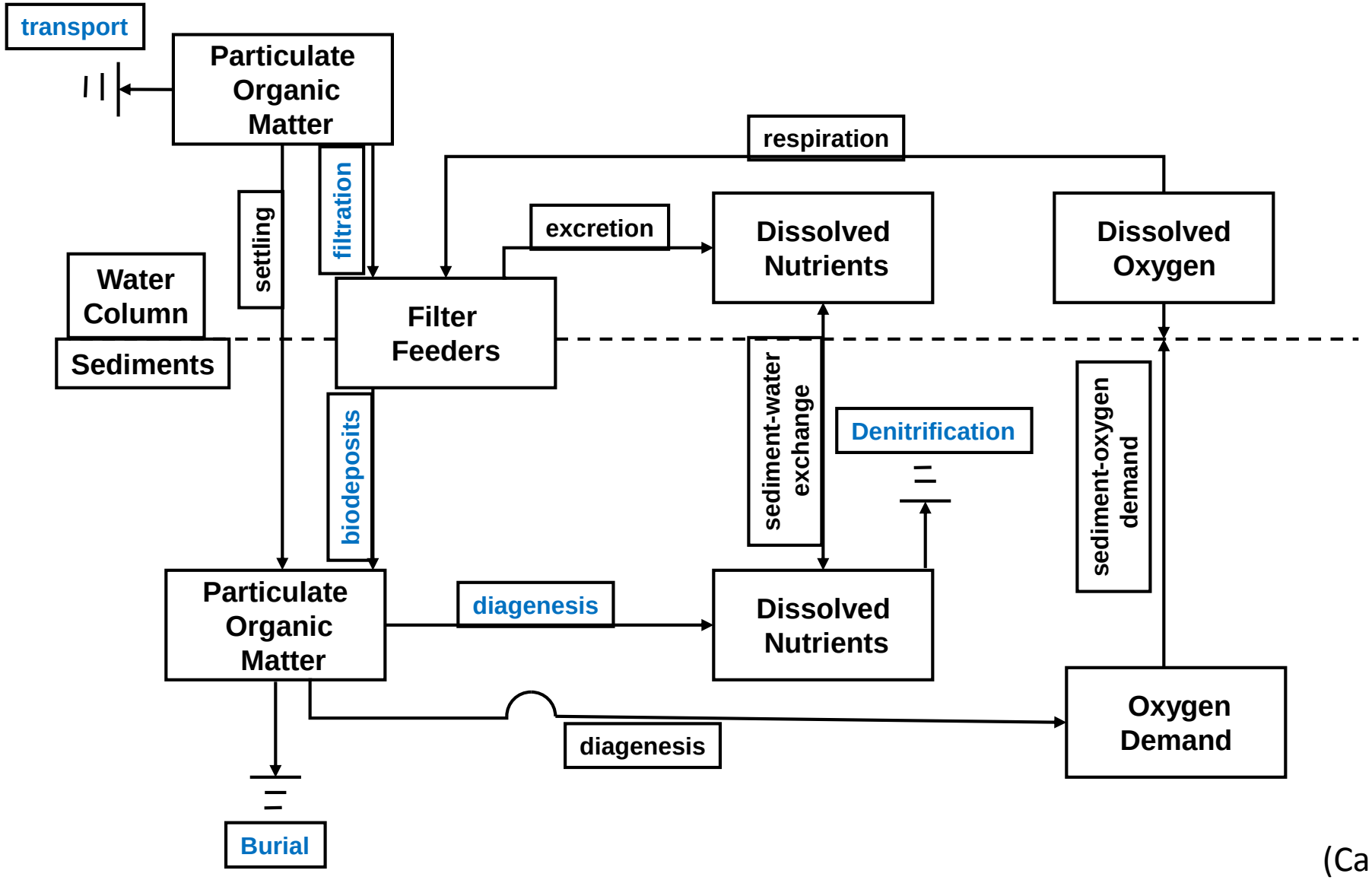
β = mortality (d^{-1})

From Carl Cerco

Fluxes generated by oyster



Diagenesis Model with Benthos



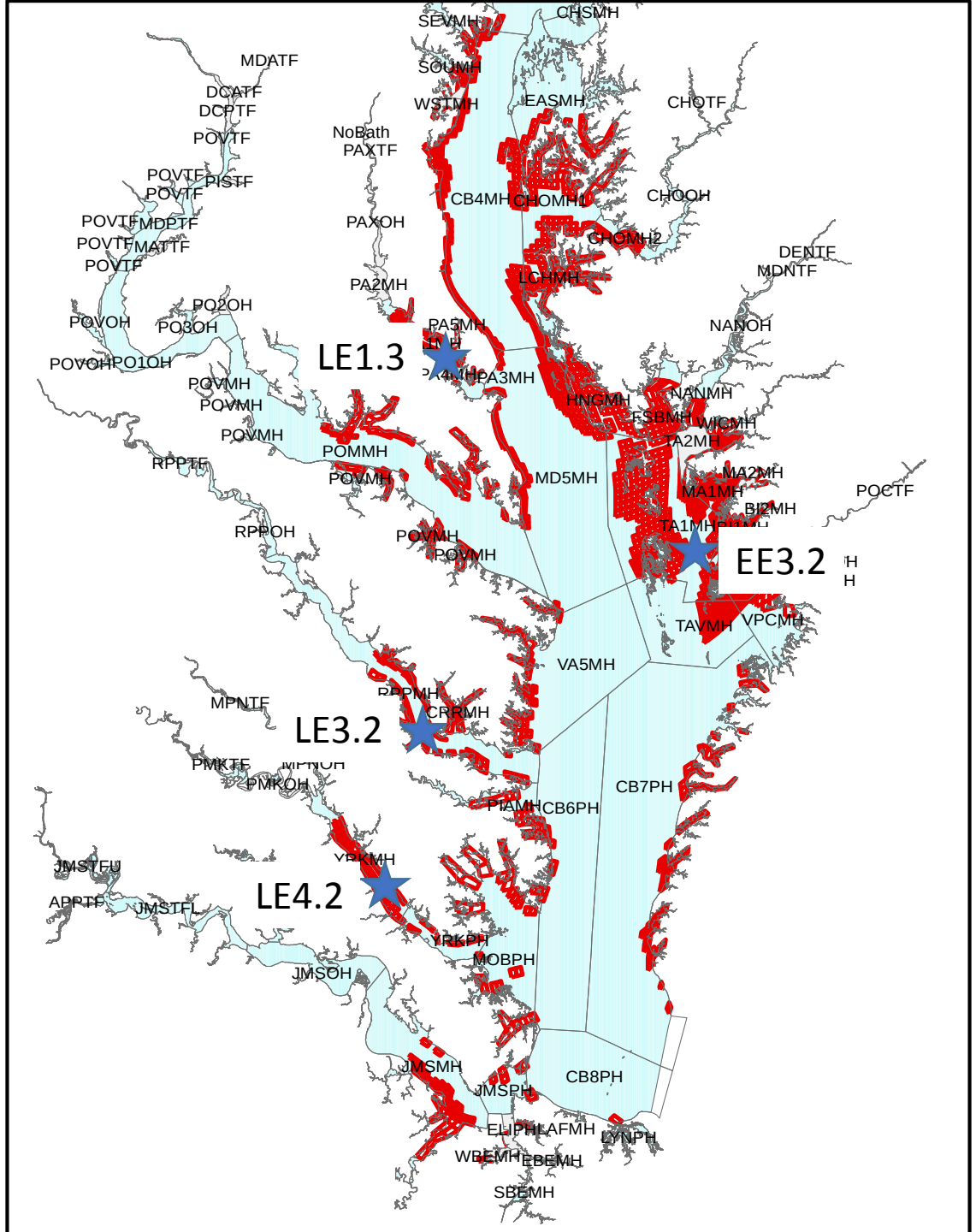
(Carl Cerco; Modified)

Oyster Aquaculture sites

- MD: Salinity ≥7 ppt, depth ≤ 12 ft.
- VA: Lease sites
- Sufficient phytoplankton and suspended solids

Model setup

- 392 million oysters harvest in 2025, equivalent to 468k lbs C in biomass.
- 78k lbs N and 8k lbs P reduction in nutrient loads.
- Oyster biomass in the water column is 1.5 times the annual harvest for aquaculture in cages (20% in MD and 80% in VA).
- Oyster biomass on the bottom is twice the annual harvest for bottom culture (80% in MD and 20% in VA).



Deep channel non-attainment

Scenario	name	Base	Base_Soft tissue removal	Base_soft tissue revoal +biogeochemistry	WIP2	WIP2_soft tissue removal	WIP2_soft tissue removal +biogeochemistry
Nitrogen	loading	325TN	324.92TN	324.92TN	195TN	194.92TN	194.92TN
Phosphorous	loading	21.9TP	21.89TP	21.89TP	13.7TP	13.69TP	13.69TP
CB3MH	MD	7.18%	7.16%	7.00%	0.00%	0.00%	0.00%
CB4MH	MD	45.03%	44.90%	44.41%	6.00%	5.70%	5.24%
CB5MH_MD	MD	20.76%	20.68%	20.23%	0.00%	0.00%	0.00%
CB5MH_VA	VA	4.12%	4.02%	3.60%	0.00%	0.00%	0.00%
POTMH_MD	MD	15.69%	15.64%	15.16%	0.00%	0.00%	0.00%
RPPMH	VA	13.81%	13.27%	12.65%	0.00%	0.00%	0.00%
ELIPH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CHSMH	MD	16.38%	16.38%	16.38%	0.00%	0.00%	0.00%
EASMH	MD	18.04%	18.05%	18.01%	6.26%	6.10%	5.98%

- non-attainment decreased from 6.00 to 5.24% in CH4MH, equivalent to 198 thousand pounds of nitrogen and 2.2 thousand pounds of phosphorus removal from the watershed
- No significant difference between base and WIP scenarios in terms of non-attainment.

Deep water non-attainment

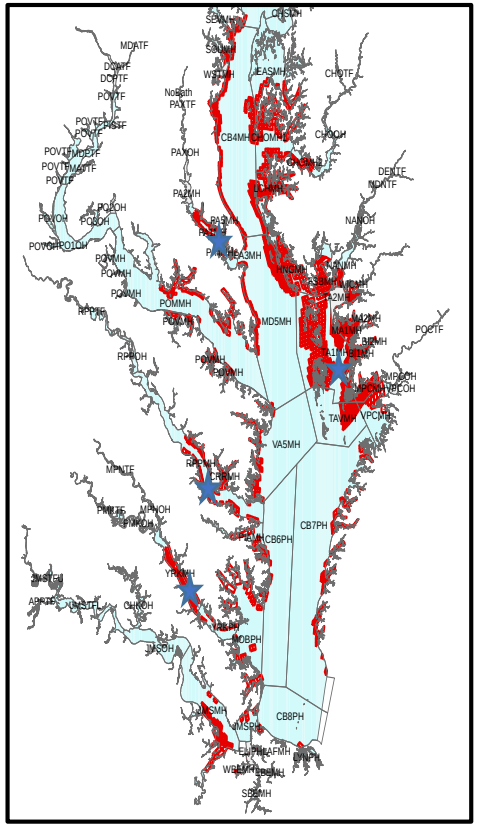
Scenario	name	Base	Base_Soft tissue removal	Base_soft tissue revoal +biogeochemistry	WIP2	WIP2_soft tissue removal	WIP2_soft tissue removal +biogeochemistry
Nitrogen	loading	325TN	324.92TN	324.92TN	195TN	194.92TN	194.92TN
Phosphorous	loading	21.9TP	21.89TP	21.89TP	13.7TP	13.69TP	13.69TP
CB3MH	MD	1.35%	1.34%	1.26%	0.05%	0.05%	0.05%
CB4MH	MD	18.77%	18.69%	18.25%	5.01%	5.00%	4.87%
CB5MH_MD	MD	6.19%	6.17%	6.06%	0.96%	0.89%	0.80%
CB5MH_VA	VA	0.28%	0.26%	0.23%	0.00%	0.00%	0.00%
CB6PH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CB7PH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PATMH	MD	16.64%	16.64%	16.64%	0.67%	0.67%	0.67%
MAGMH	MD	51.01%	51.01%	51.01%	1.21%	1.21%	0.41%
SOUMH	MD	18.59%	18.59%	18.59%	2.96%	2.96%	2.96%
SEVMH	MD	6.13%	6.13%	6.08%	0.00%	0.00%	0.00%
PAXMH	MD	7.55%	7.54%	7.32%	0.00%	0.00%	0.00%
POTMH_MD	MD	4.06%	4.05%	3.95%	0.00%	0.00%	0.00%
RPPMH	VA	5.40%	5.31%	5.00%	0.00%	0.00%	0.00%
YRKPH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ELIPH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SBEMH	VA	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%
CHSMH	MD	3.54%	3.54%	3.54%	0.00%	0.00%	0.00%
EASMH	MD	1.60%	1.60%	1.32%	0.45%	0.45%	0.45%

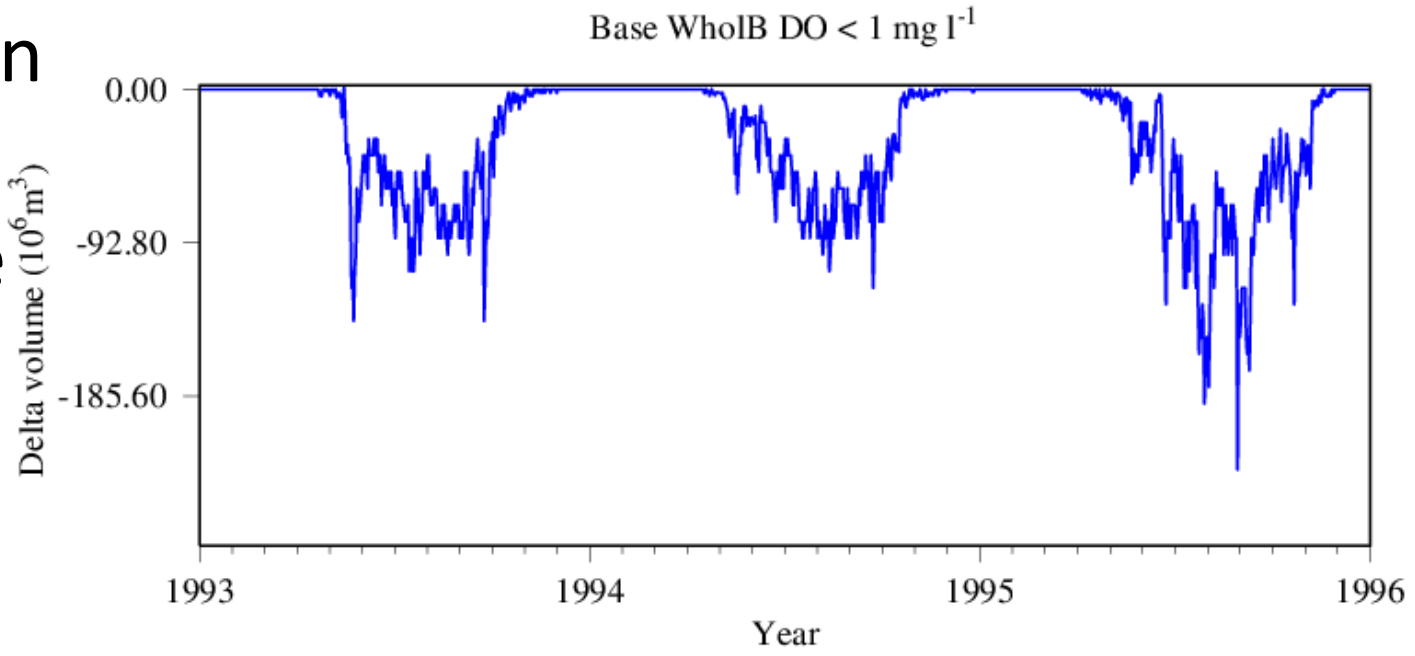
Open water non-attainment

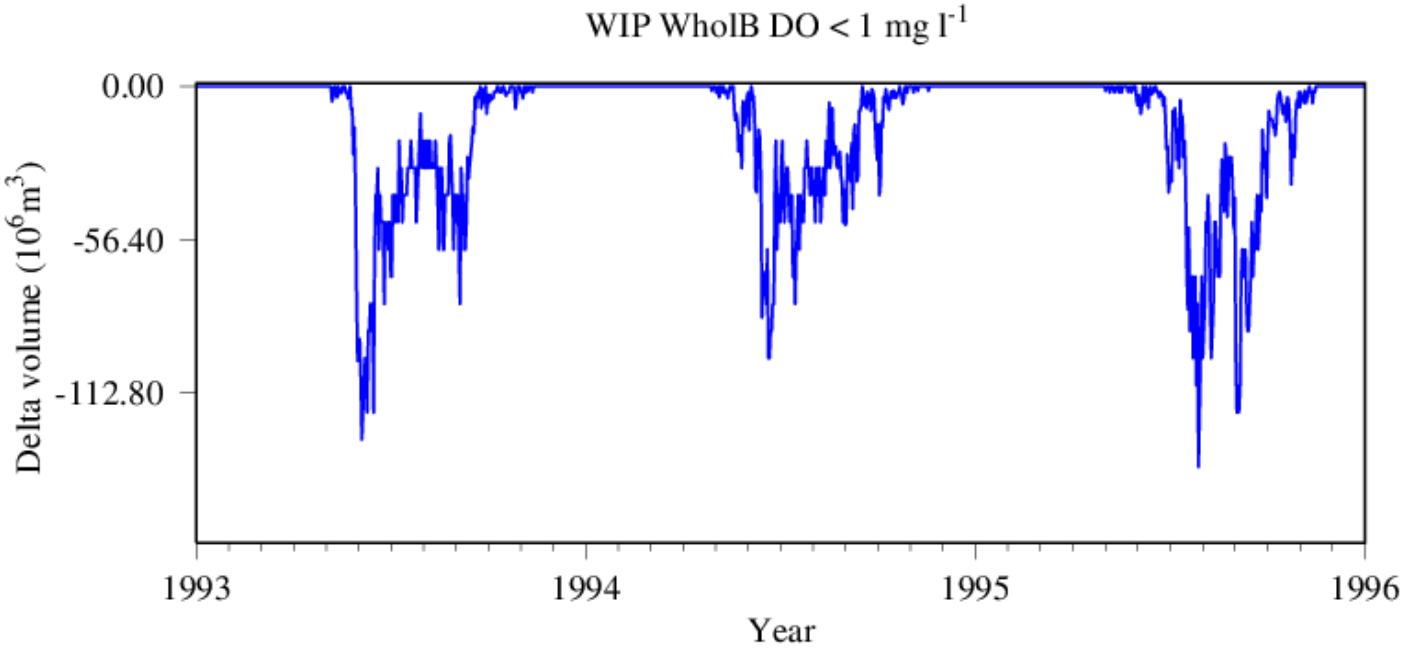
(Segments with oyster aquaculture)

Scenario	name	Base	Base_Soft tissue removal	Base_soft tissue revoal +biogeochemistry	WIP2	WIP2_soft tissue removal	WIP2_soft tissue removal +biogeochemistry
Nitrogen	loading	325TN	324.92TN	324.92TN	195TN	194.92TN	194.92TN
Phosphorous	loading	21.9TP	21.89TP	21.89TP	13.7TP	13.69TP	13.69TP
WSTMH	MD	2.85%	2.85%	2.85%	0.00%	0.00%	0.00%
RPPMH	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
CRRMH	VA	24.53%	24.53%	24.53%	5.21%	5.21%	5.21%
YRKMH	VA	24.15%	23.92%	23.27%	0.82%	0.91%	0.69%
CHOMH2	MD	4.07%	4.02%	3.71%	0.00%	0.00%	0.00%
CHOMH1	MD	1.75%	1.75%	1.71%	0.01%	0.01%	0.01%
LCHMH	MD	0.12%	0.12%	0.01%	0.00%	0.00%	0.00%
MANMH	MD	0.63%	0.63%	0.63%	0.63%	0.63%	0.63%
TANMH_MD	MD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TANMH_VA	VA	2.04%	2.01%	1.77%	0.00%	0.00%	0.00%
POCMH_MD	MD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
POCMH_VA	VA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Difference in Hypoxia volume in the whole Bay (DO< 1 mg/l)
Slightly higher in the base case (upper panel) then in the WIP case

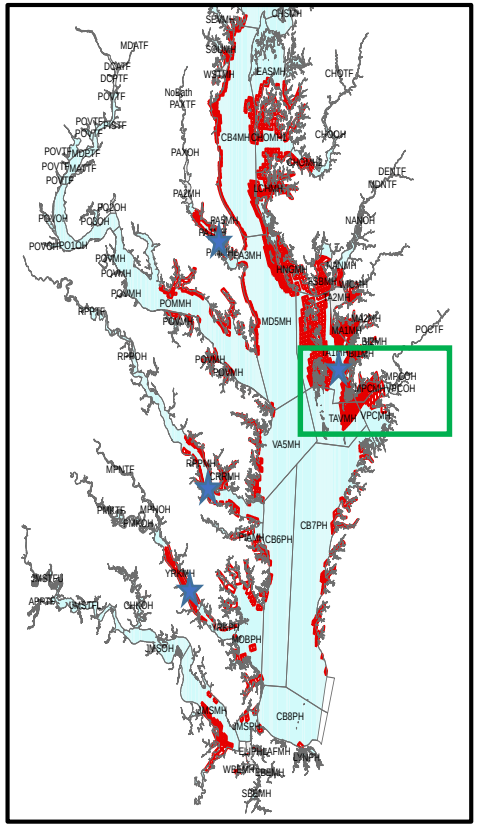


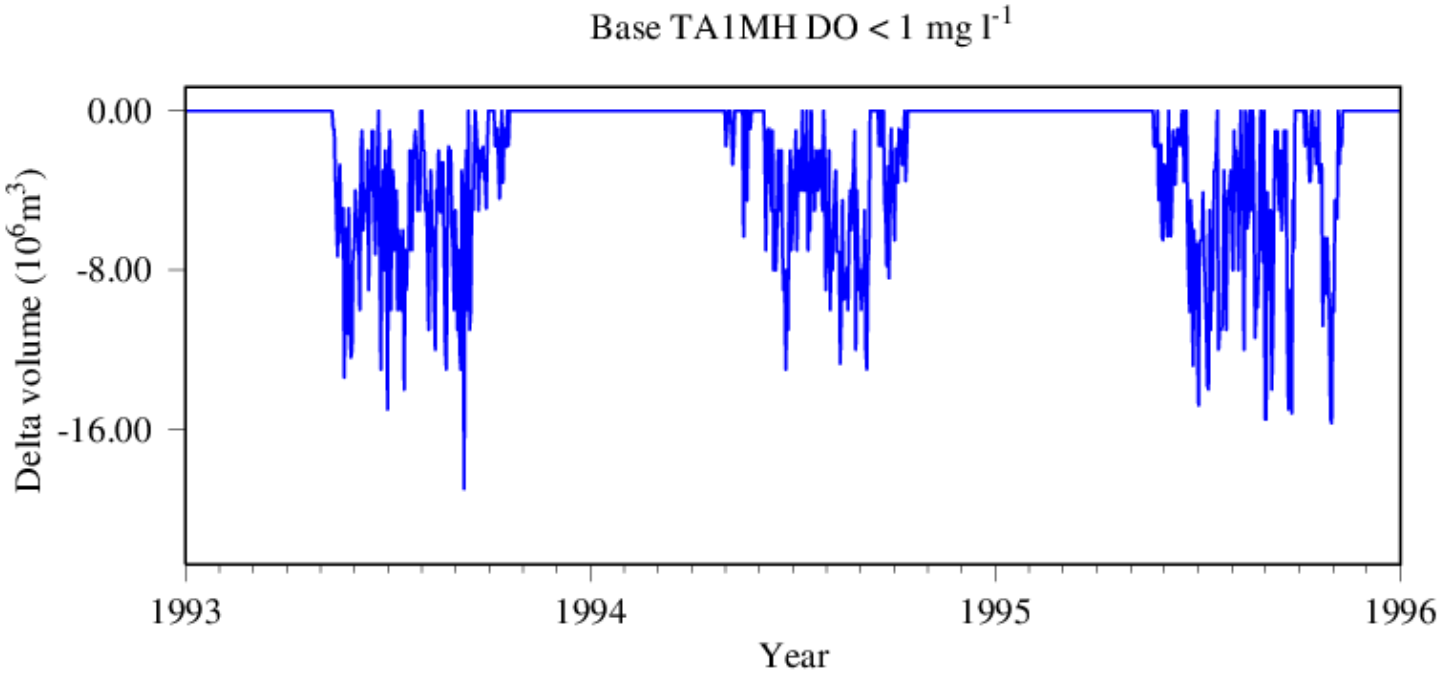


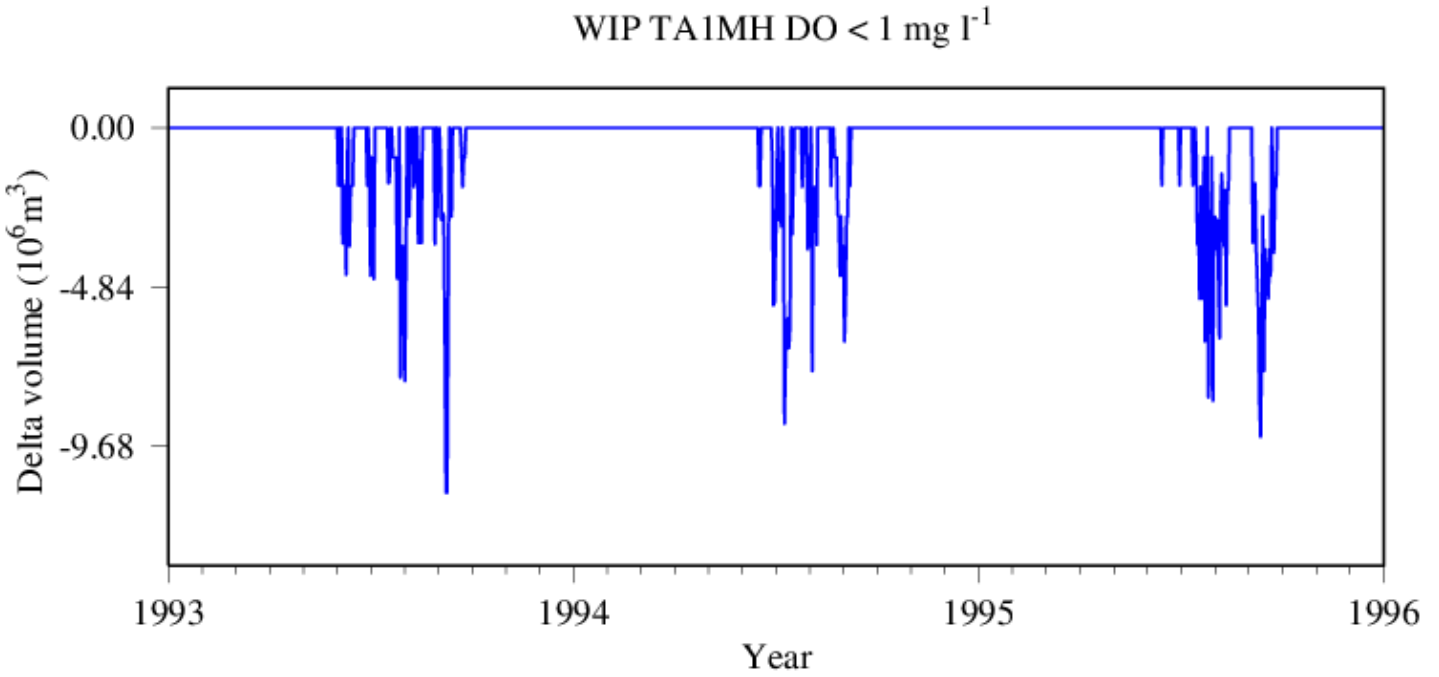


Difference in Hypoxia volume Tangier Sound, an aquaculture segment.

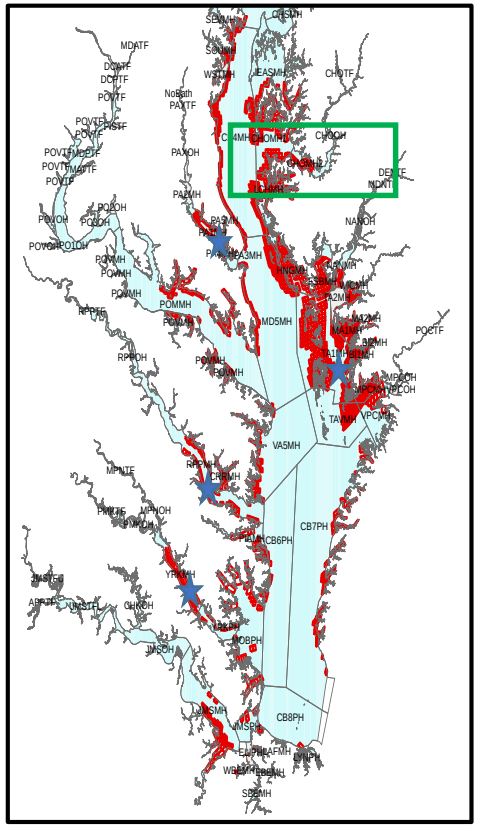
(Slightly higher in the base case (upper panel) then in the WIP case)

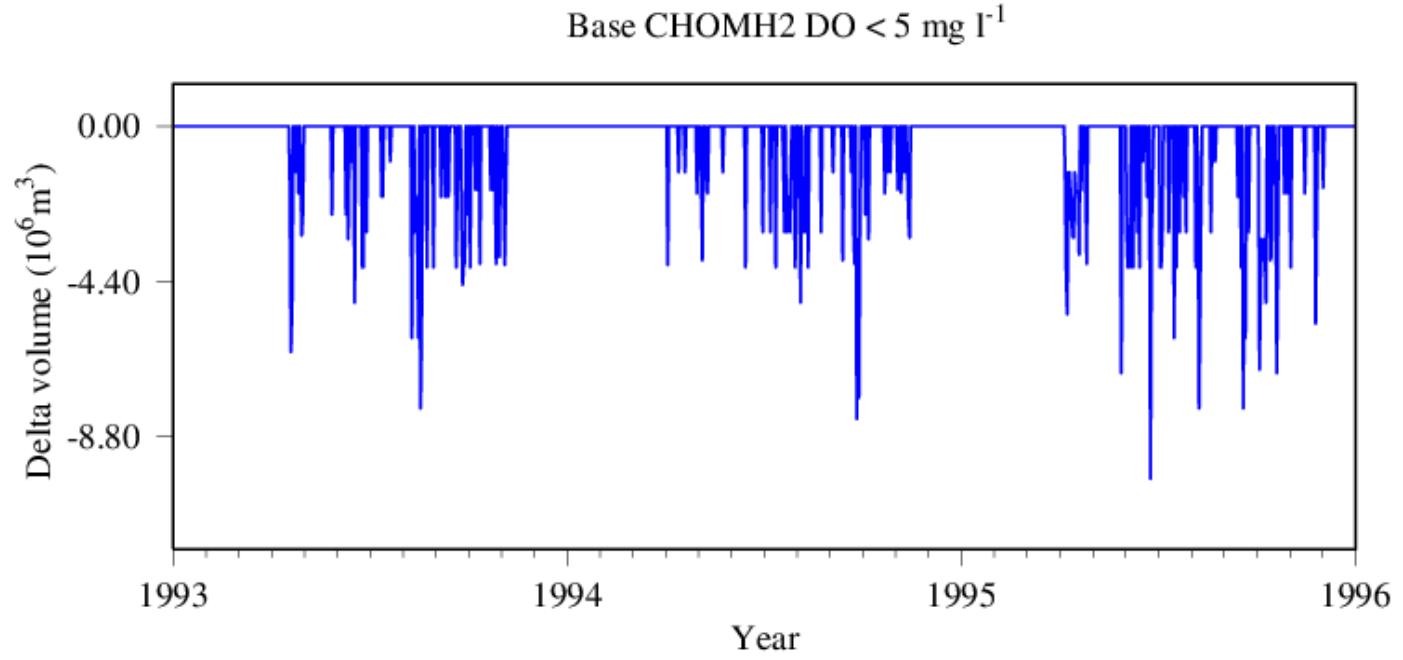


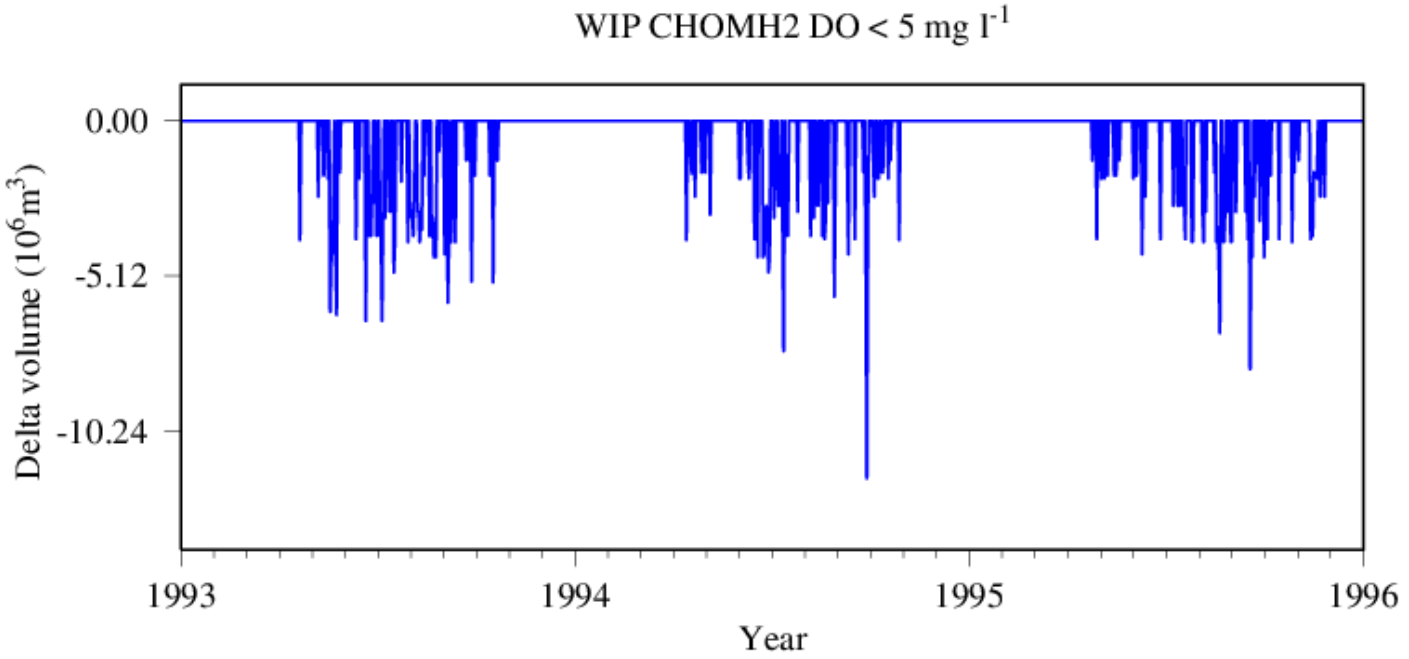




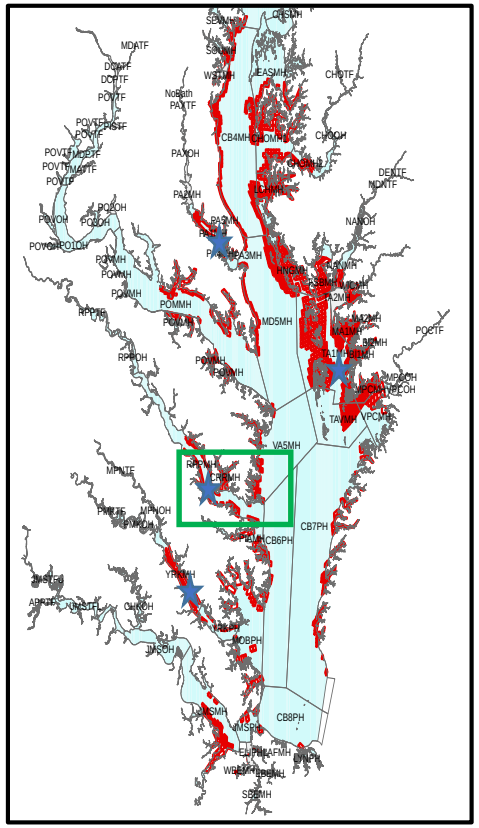
Difference in low-DO volume in Choptank Estuary (High frequency variation)

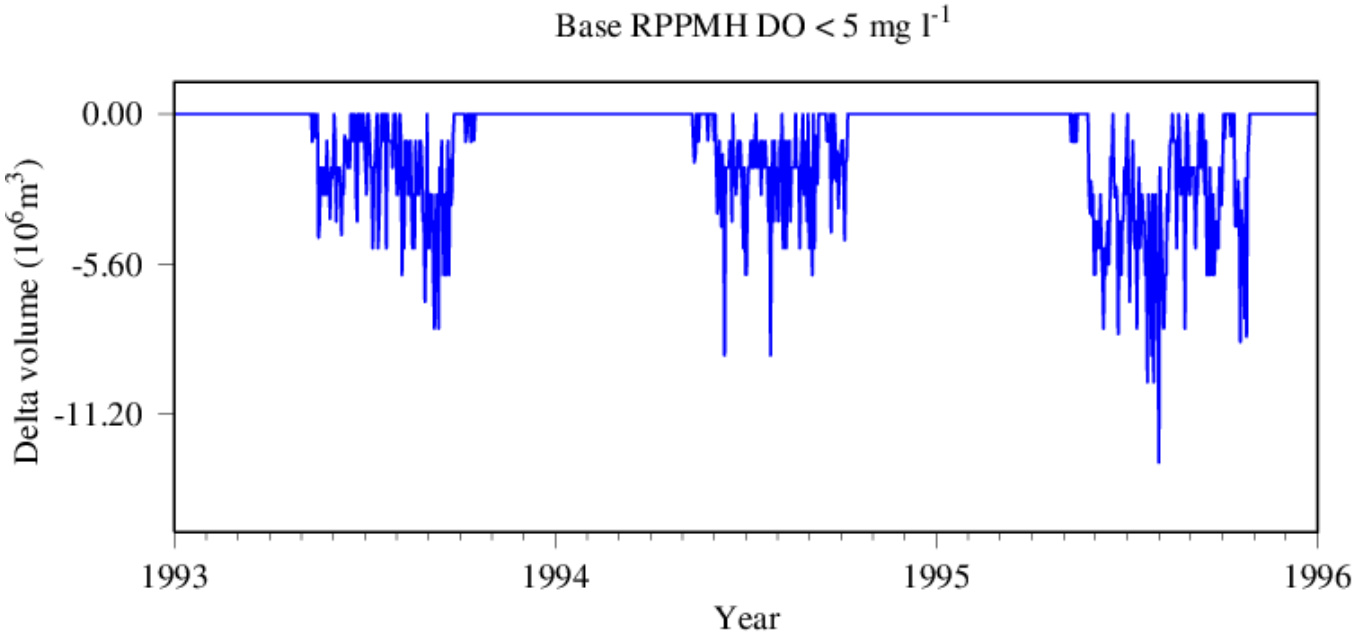


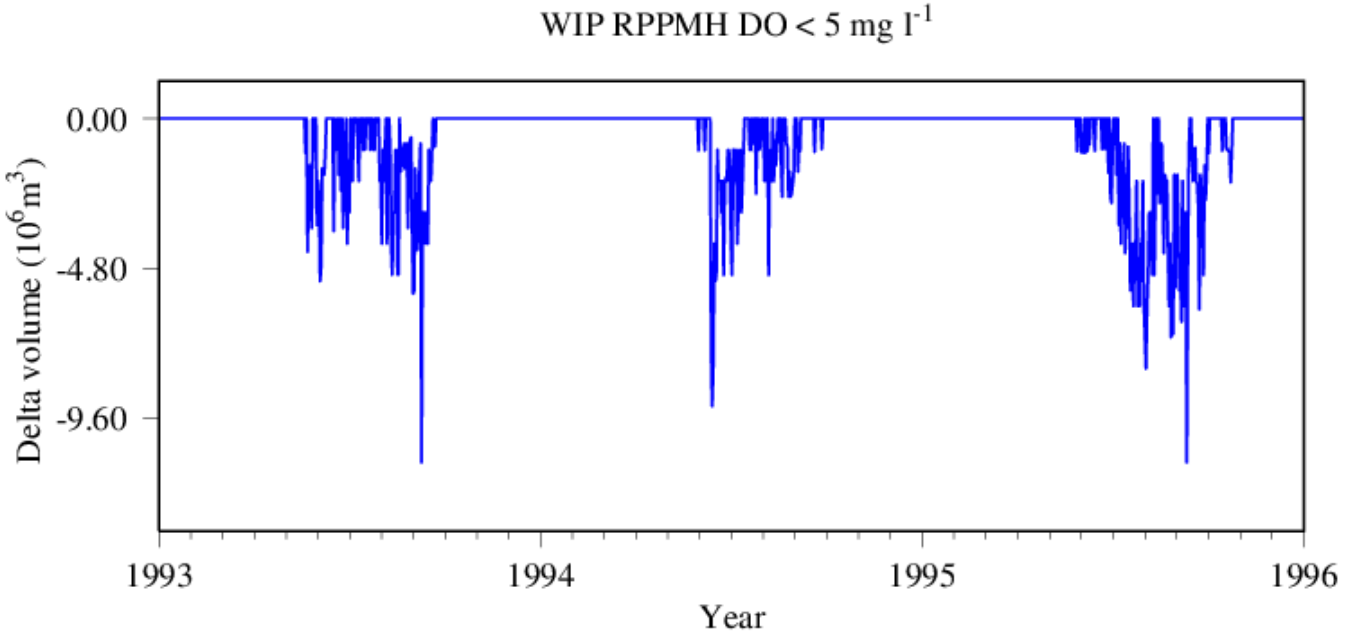




Difference in low-DO volume in Rappahannock Estuary (Slightly higher in the base case (lower panel) then in the WIP case)

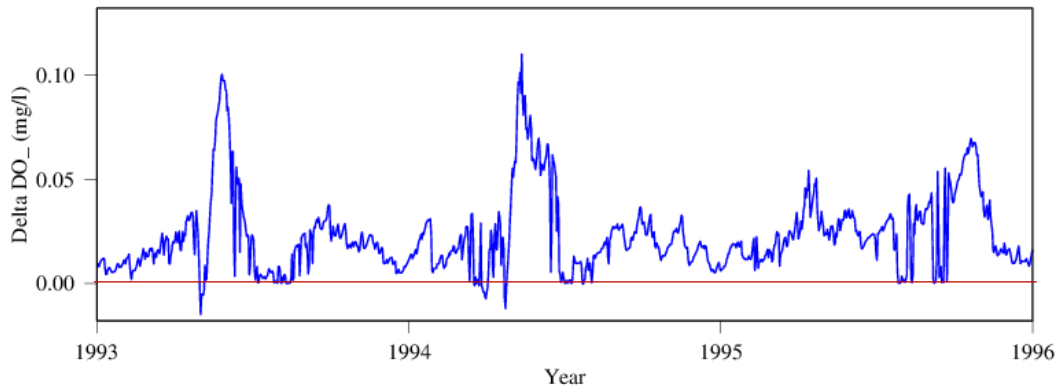




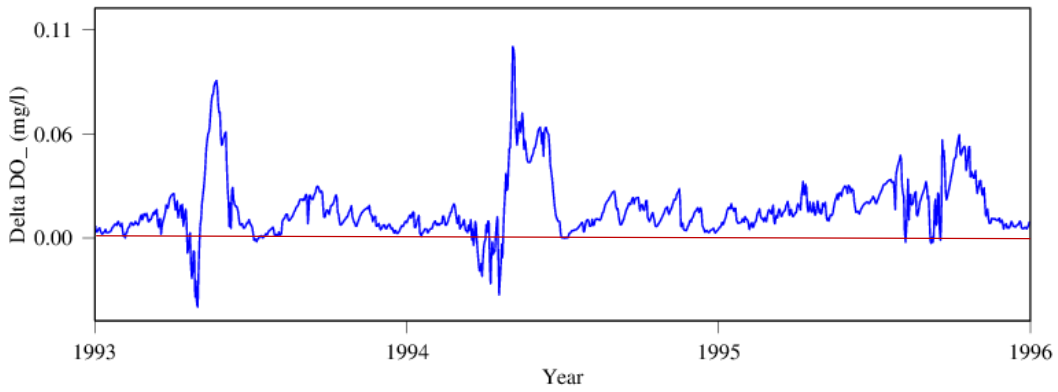


DO improvement across deep channel and local waters with projected oyster aquaculture in 2025 under the WIP condition

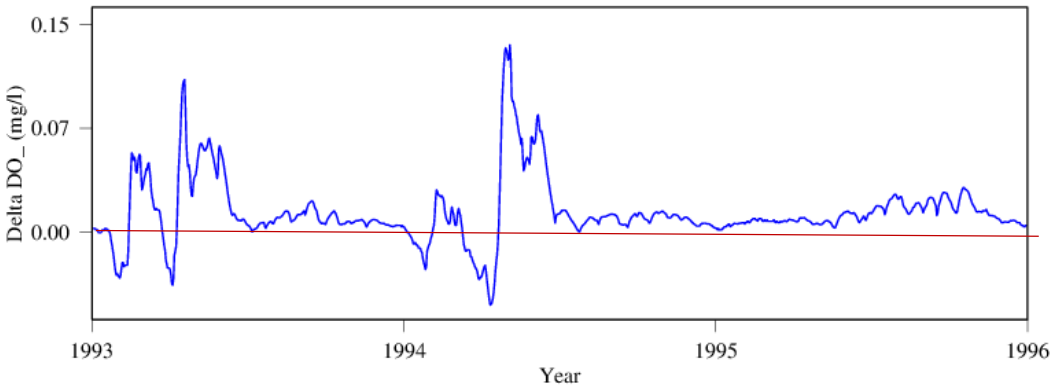
CB4.2C Bottom



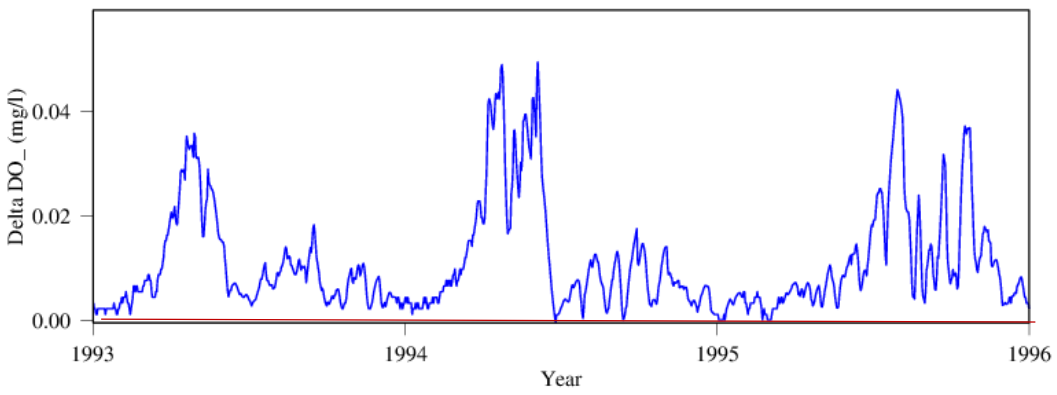
CB5.2 Bottom



EE3.2 (Tangier Sound)

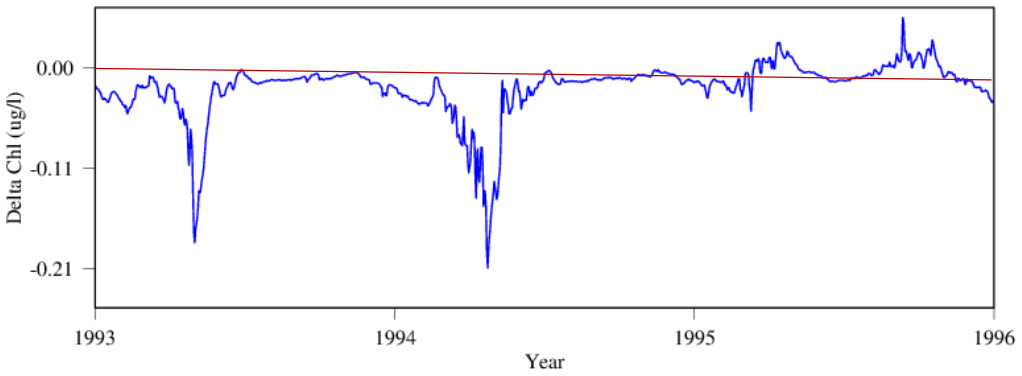


LE4.2 (York River)

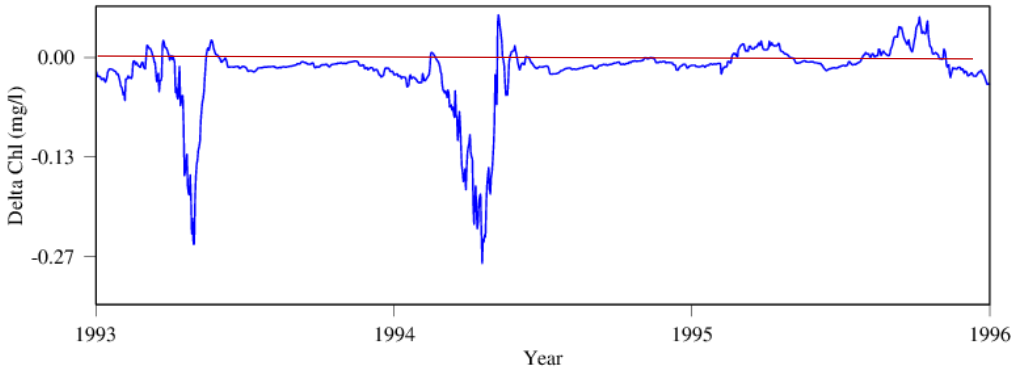


Chl changes with projected oyster aquaculture in 2025 under the WIP condition

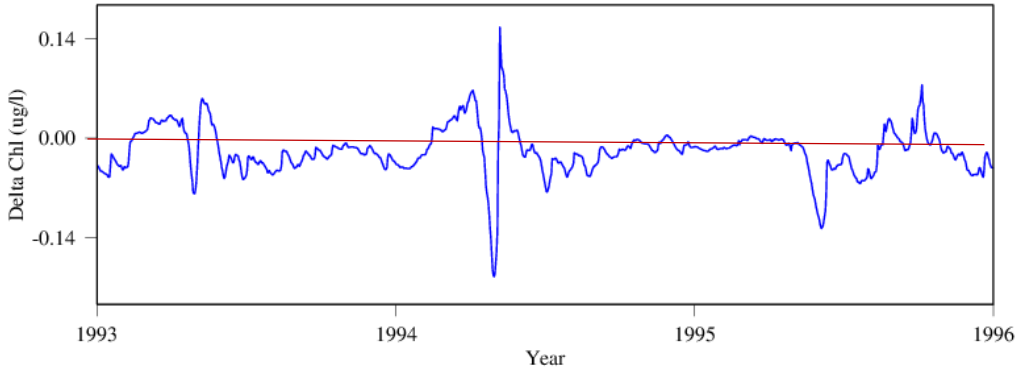
CB4.2C Bottom



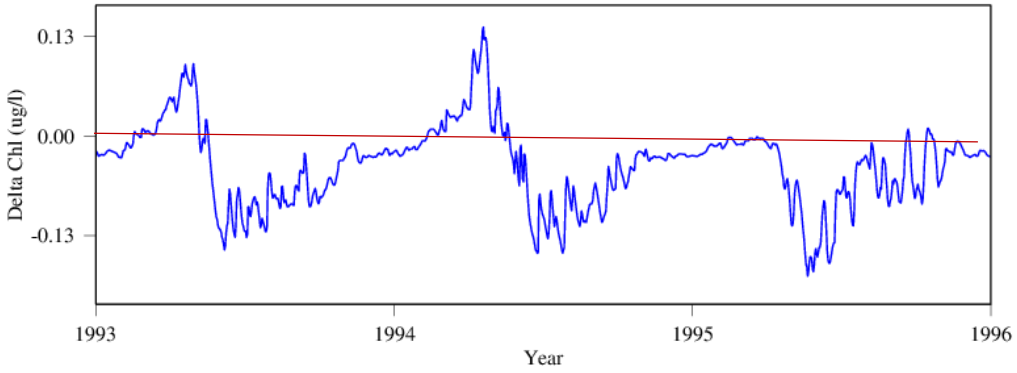
CB5.2 Bottom



EE3.2 (Tangier Sound)

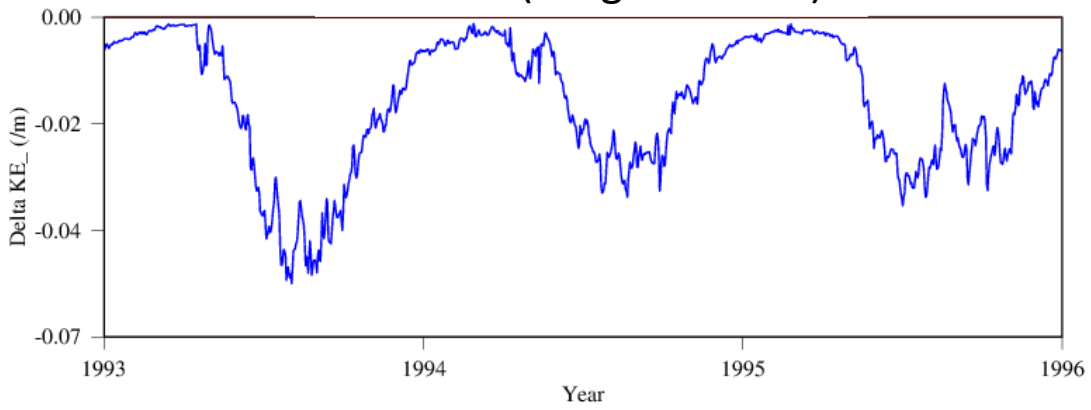


LE4.2 (York River)

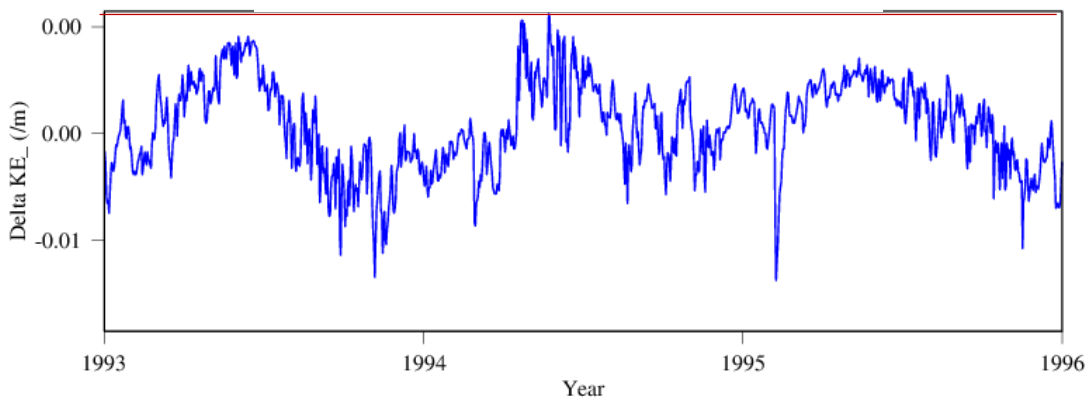


KD improvement with projected oyster aquaculture in 2025 under the WIP condition

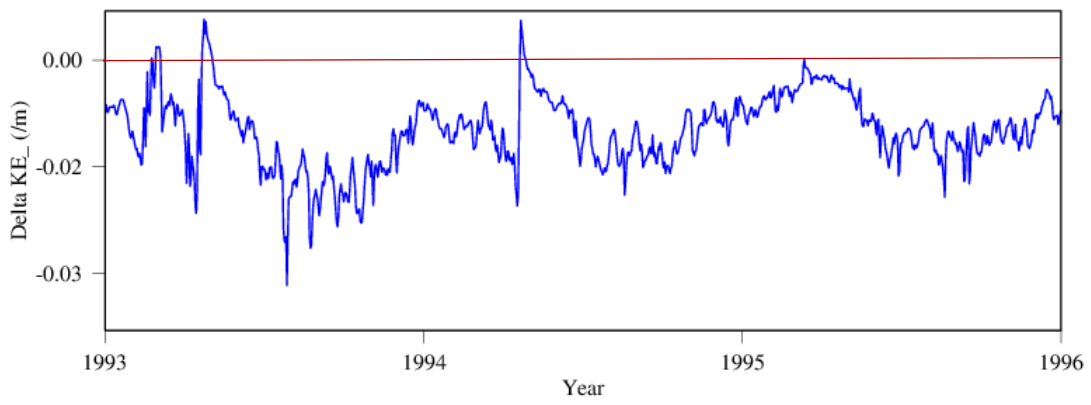
EE3.2 (Tangier Sound)



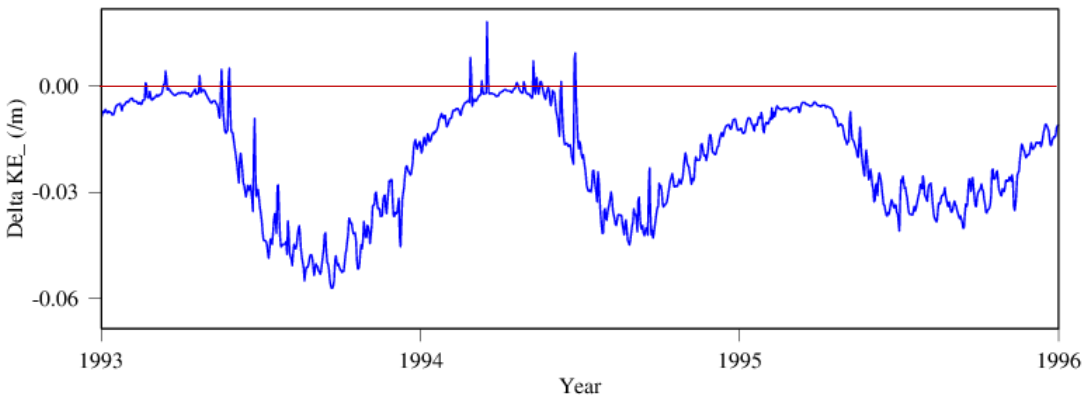
LE1.3 (Patuxent)



LE3.2 (Rappahannock)

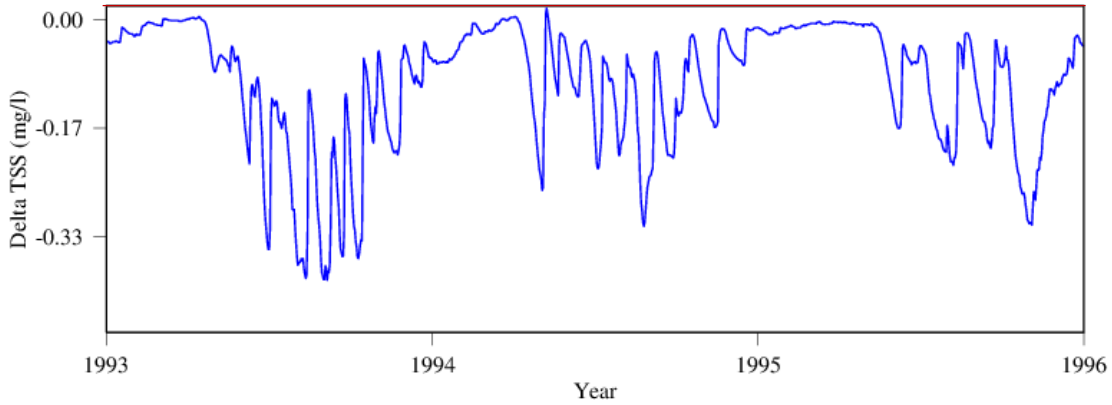


LE4.2 (York River)

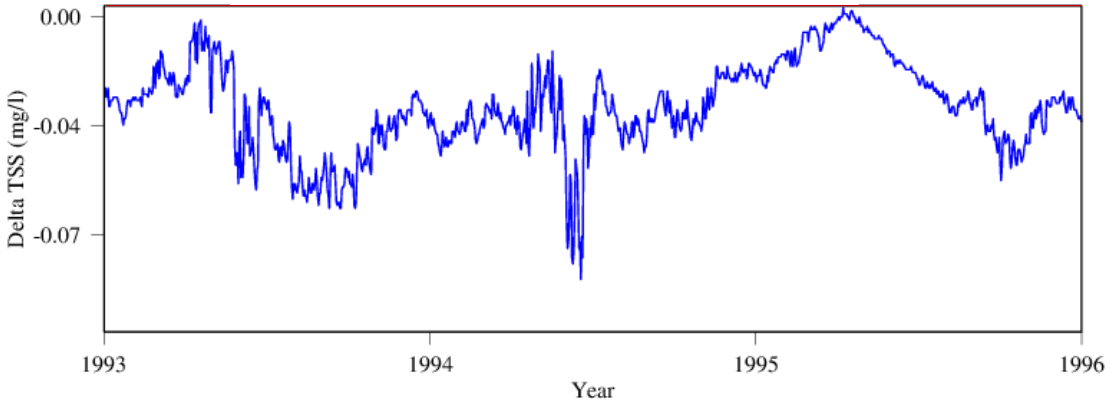


TSS changes with projected oyster aquaculture in 2025 under the WIP condition

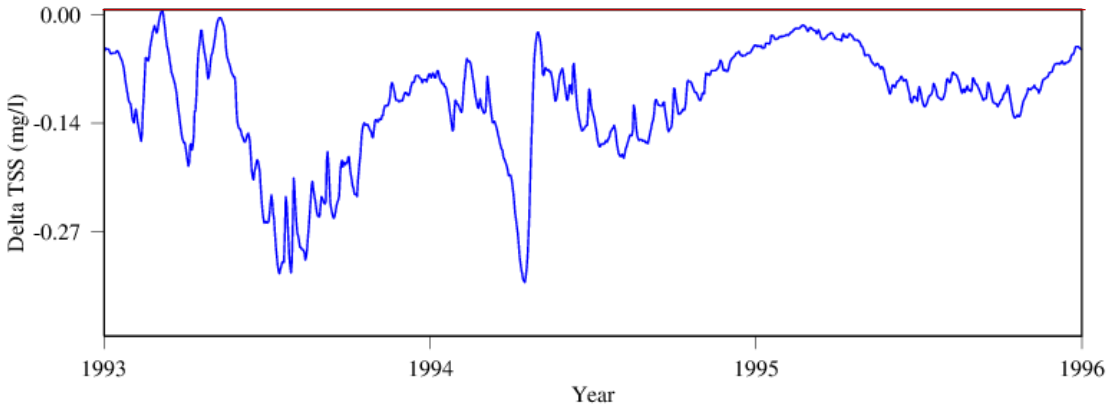
EE3.2 (Tangier Sound)



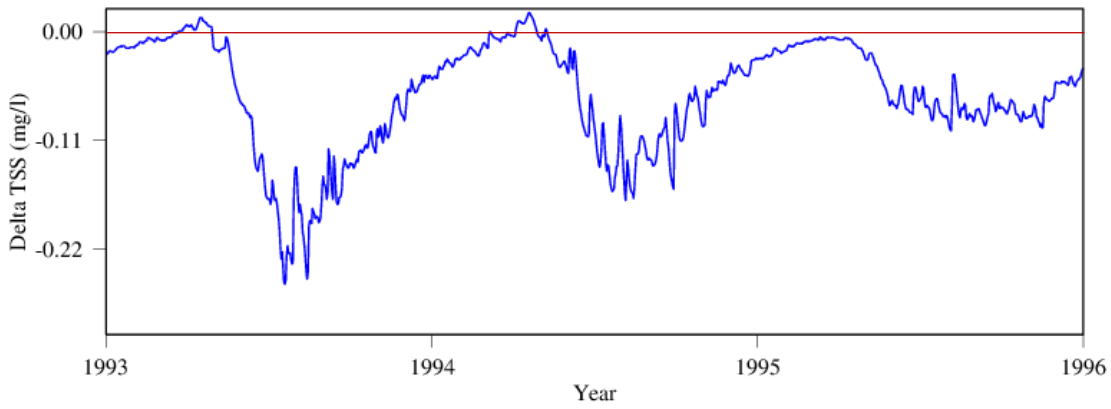
LE1.3 (Patuxent)



LE3.2 (Rappahannock)



LE4.2 (York River)



Summary

- Full oyster aquaculture buildout is estimated to improve water quality attainment both locally and in deep hypoxic water.

- Signal of impact on an array of water quality variables: DO, Chlorophyll, KD, and TSS.

- In the WIP scenario, the simulated biogeochemical nutrient removal are about twice as effective at improving CB4MH Deep Channel DO attainment than nutrient removal from oyster harvesting.

(Soft tissue removal: $78x10^3$ lbs N; Biogeochemical processes: $120x10^3$ lbs nitrogen; Total $198x10^3$ lbs N**)**