A Tidal Water Model for the Assessment of 2035 Climate Change Risk to the Chesapeake TMDL

Goal Team Chairs and Leadership Quarterly Meeting

June 30, 2021

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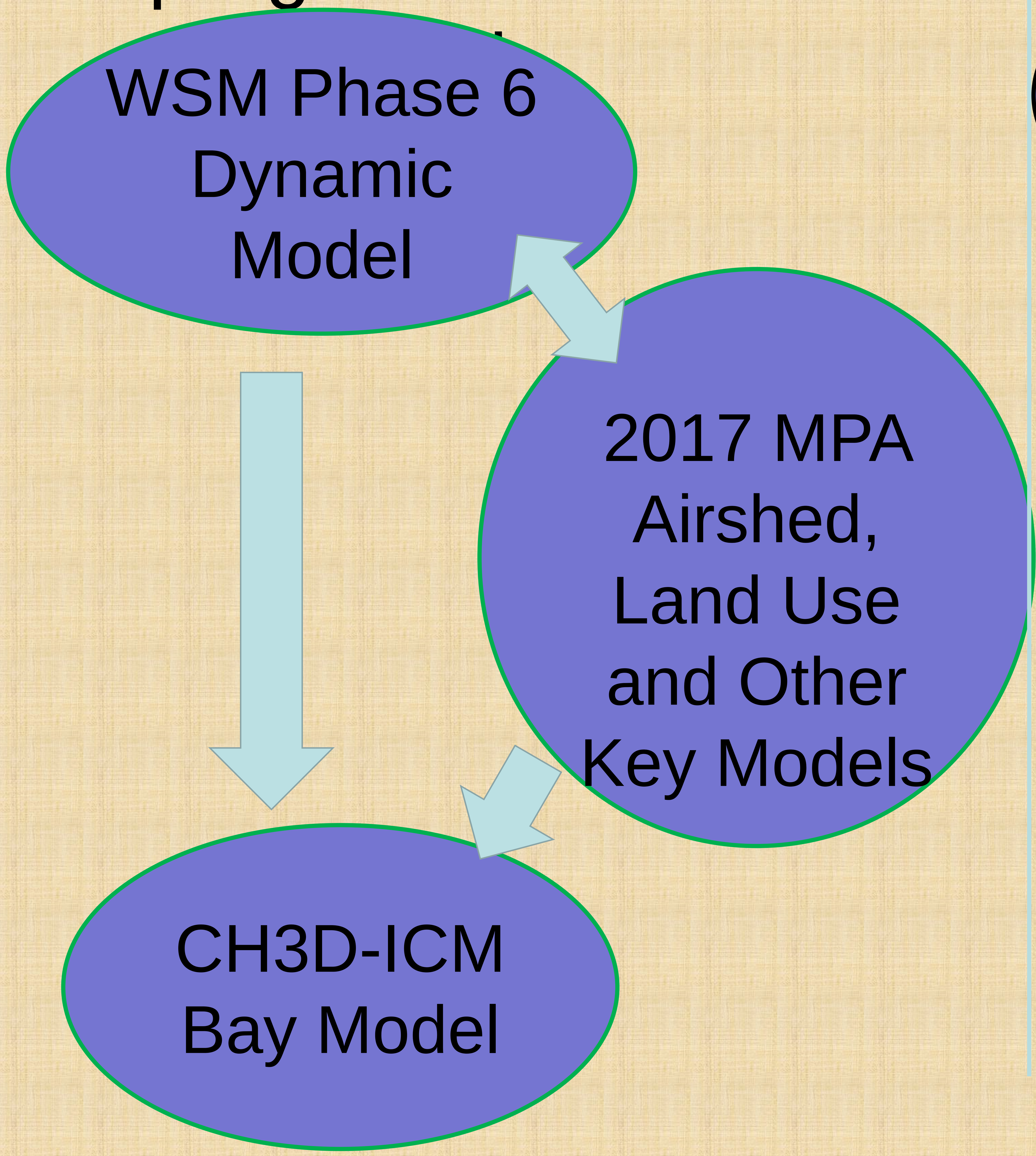
Chesapeake Bay Program
Science, Restoration, Partnership

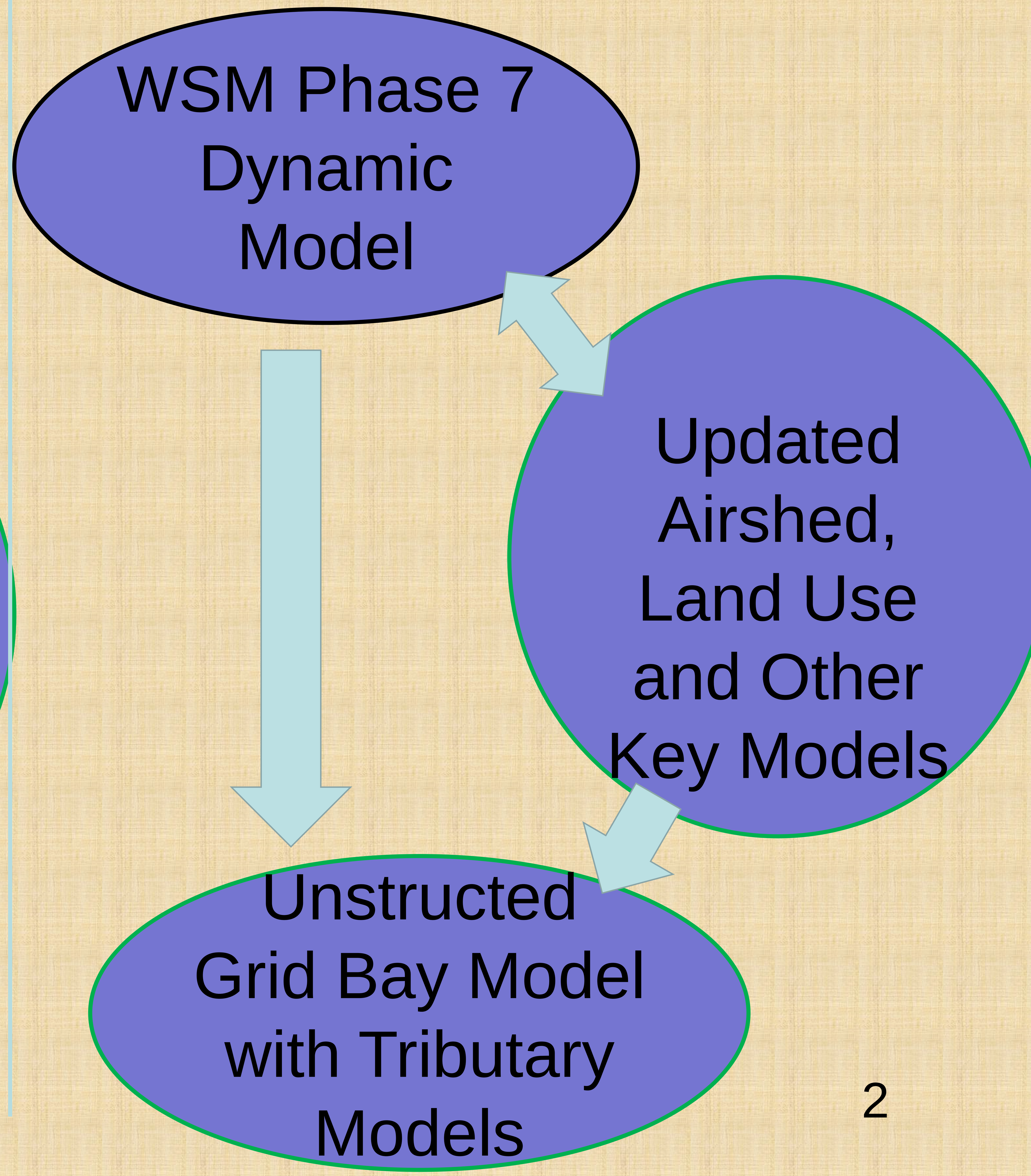
CBP Bay Model Products

Bay Model for 1) allowable estuarine loading and carrying capacity for Bay TMDL, 2) ancillary Bay model studies, 3) ancillary model tools (N-P exchanges), and 4) information/ collaboration with CBP research community.

CBP Phase 6 model application from 2017 Midpoint Assessment (MPA) to 2025 assessment of progress with 2025

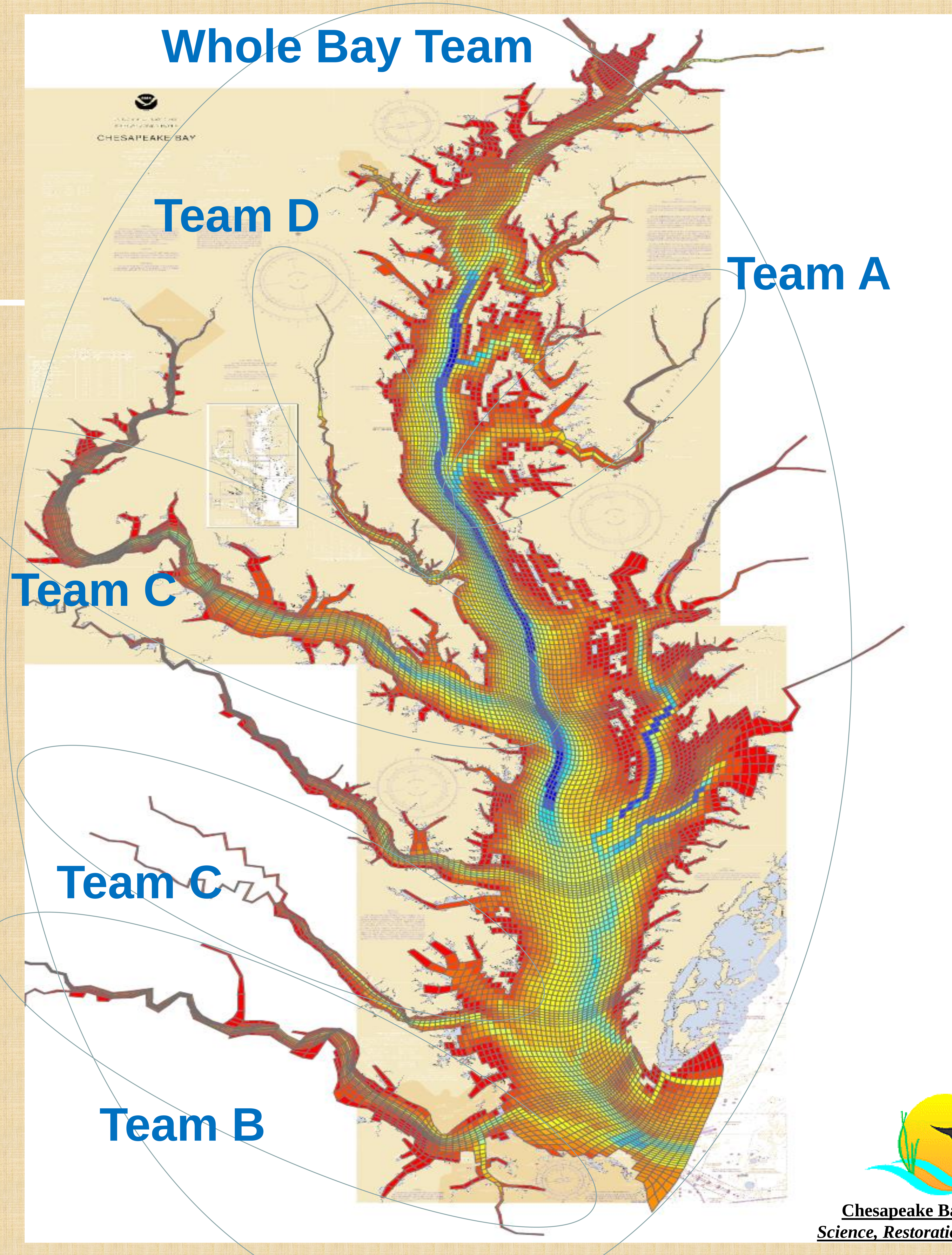


Application of Phase 7 in 2025 for 2035 Climate Change Risk Assessment to CB water quality standards and TMDL.



How an Unstructured Grid Model in the Chesapeake with Multiple Model Teams Would Work

- Main Bay Model (MBM) of all tidal waters used for integration of tributary model findings and for management scenarios.
- Multiple Tributary Model (MTM) teams working in tributaries and collaboratively sharing information with all model teams on a regular basis.
- Similar to CMAQ multiple model approach.



Chesapeake Bay Program
Science, Restoration, Partnersh

Timeline: 2021 to 2022

2021
RFA Completed for Main Bay Model (MBM). MBM Team begins work.

- Get initial CBP Main Bay Model (MBM) structure in place with Main Bay Model *Request for Assistance* (RFA).
- Initial work begins on shallow water DO, clarity, and chlorophyll simulation.

2022
RFA Completed for Multiple Tributary Models (MTMs). MTM Teams begin work. Link MBM and TMT model development.

- 2022 RFA for MTMs complete. Main and Tributary model structure and boundaries determined.
- Decision rules for regulatory model calibration established.
- Begin Multiple Tributary Model (MTM) work on shallow water DO, clarity, and chlorophyll simulation.
- Semiannual MBM and MTM PI meetings begin.
- Examine use of linked watershed to tidal water hydrology inputs from Phase 7.

Timeline: 2023 to 2024

2023
Refine shallow water DO, clarity/SAV, chlorophyll for WQ standard assessment

- Use Phase 7 WSM inputs of hydrology, sediment, and nutrients. (Phase 7 Model complete and fully operational in December 2023).
- Continue semiannual MBM and MTM PI meetings.
- Demonstrate improved simulation of shallow water DO, clarity/SAV, chlorophyll with unstructured grid MBM and MTMs.
- Demonstrate sea level rise and tidal wetland simulation. capability.

2024
Unstructured Grid Bay Model fully operational December 2024

- Adjust for input load changes from hydrology, sediment, and nutrients due to final reviewed version of Phase 7 model.
- Continue MTMs and semiannual Trib Model PI meetings.
- Complete shallow water DO, clarity/SAV, chlorophyll refinements
- Unstructed grid Bay Model (MBM and MTMs) fully operational December 2024.

Timeline: 2025 to 2026

2025
Apply Unstructured Grid Bay Model to 2035 climate change risk to Chesapeake water quality standards

- Apply the 2025 MBM & MTMs to 2035 climate change risk.
- Determine the carrying capacity the Bay has for nutrient loads under conditions of 2035, 2045, 2055 and beyond.
- Examine in detail Open Water DO, clarity/SAV, and chlorophyll water quality standards under scenario conditions for Bay and tidal tributaries.
- Develop nitrogen/phosphorus tradeoffs for tidal waters.

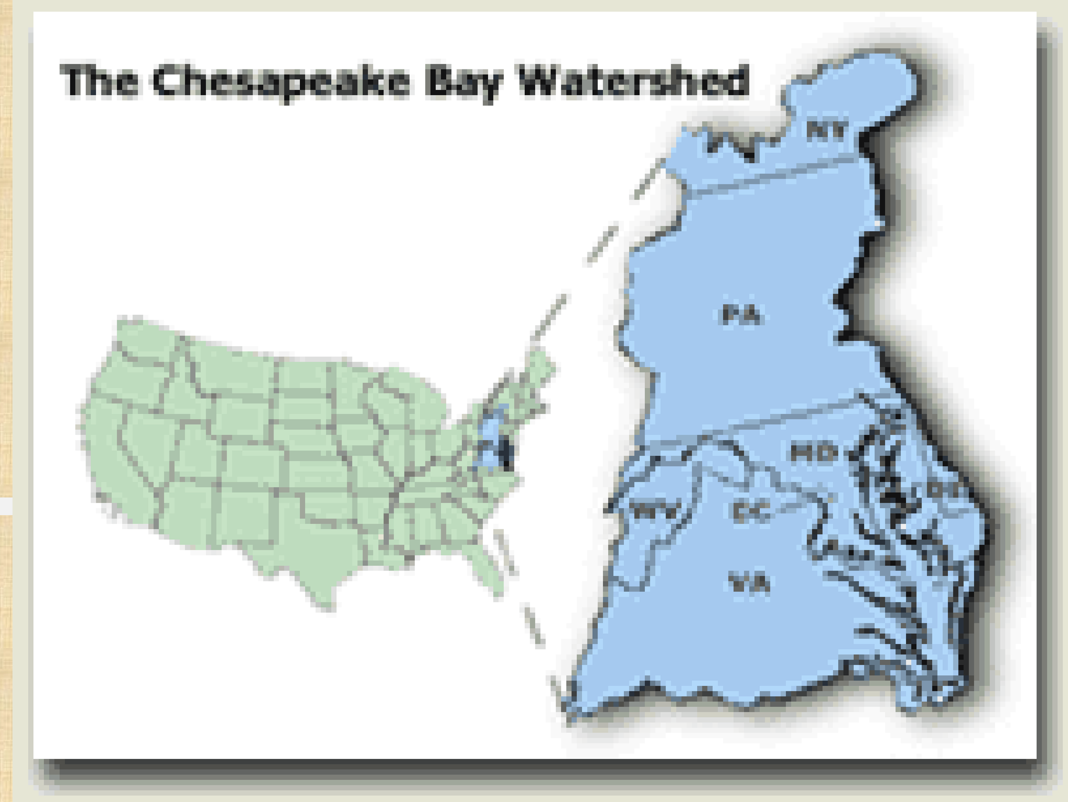
2026
Confirm and support CBP decision makers with 2035 climate change risk assessment

- Develop tributary and local tidal water assessments as requested by CBP Partners.
- Update local tidal water TMDLs, e.g., James Chlorophyll TMDL as requested by CBP.
- Main Bay Model “frozen” until 2035 but continue MTMs and semiannual Trib Model PI meetings through 2025 and 2026.

Next Steps

- By June the RFA was completed and reviewed by CBPO and sent to EPA Region 3 Grant Offices. The RFA Evaluation Team was formed.
- In the third quarter of 2021 the RFA will be released.
- The period of RFA response, review of proposals, selection of Main Bay Model team, RFA documentation, selection review, and approval of selection will cover the third and fourth quarter of 2021. Also, writing of MTM RFA begins.

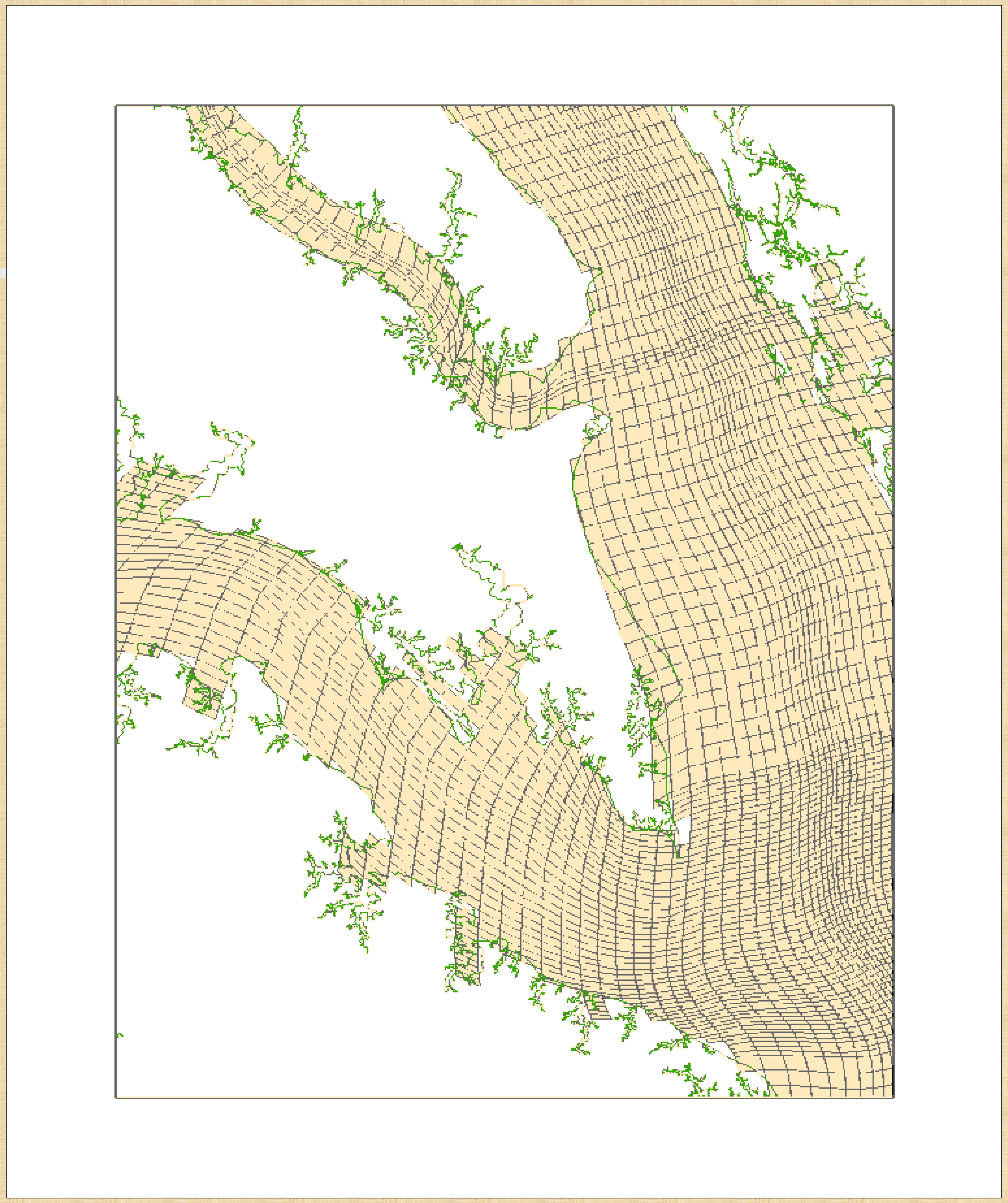
Overview/Key Points:



- Submerged Aquatic Vegetation (SAV) simulation requiring a refined Water Quality and Sediment Transport Model Simulation of shallow water, shoreline erosion & resuspension (with bed model giving boundary conditions).
- Oyster, menhaden, & other filter feeder simulations successful.

Estuarine Water Quality Model

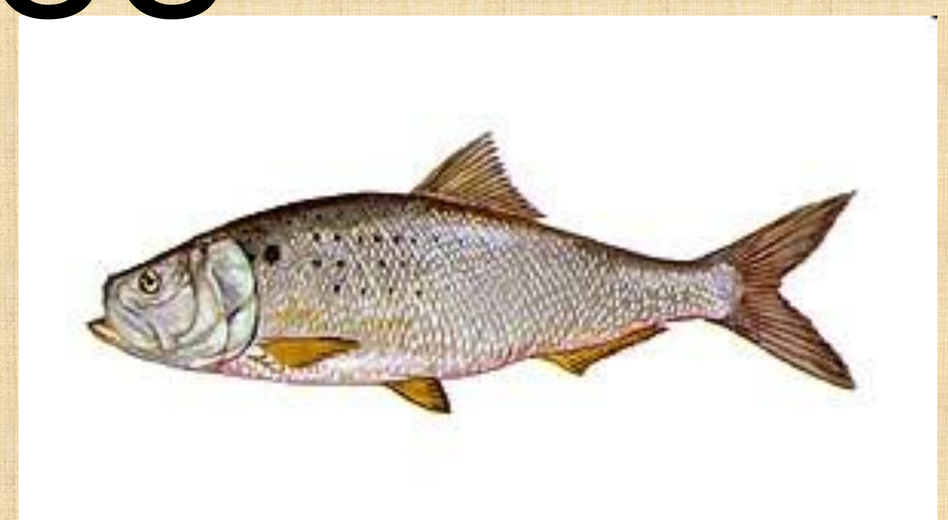
• Model allows assessment of dissolved oxygen., clarity, and chlorophyll water quality standards.



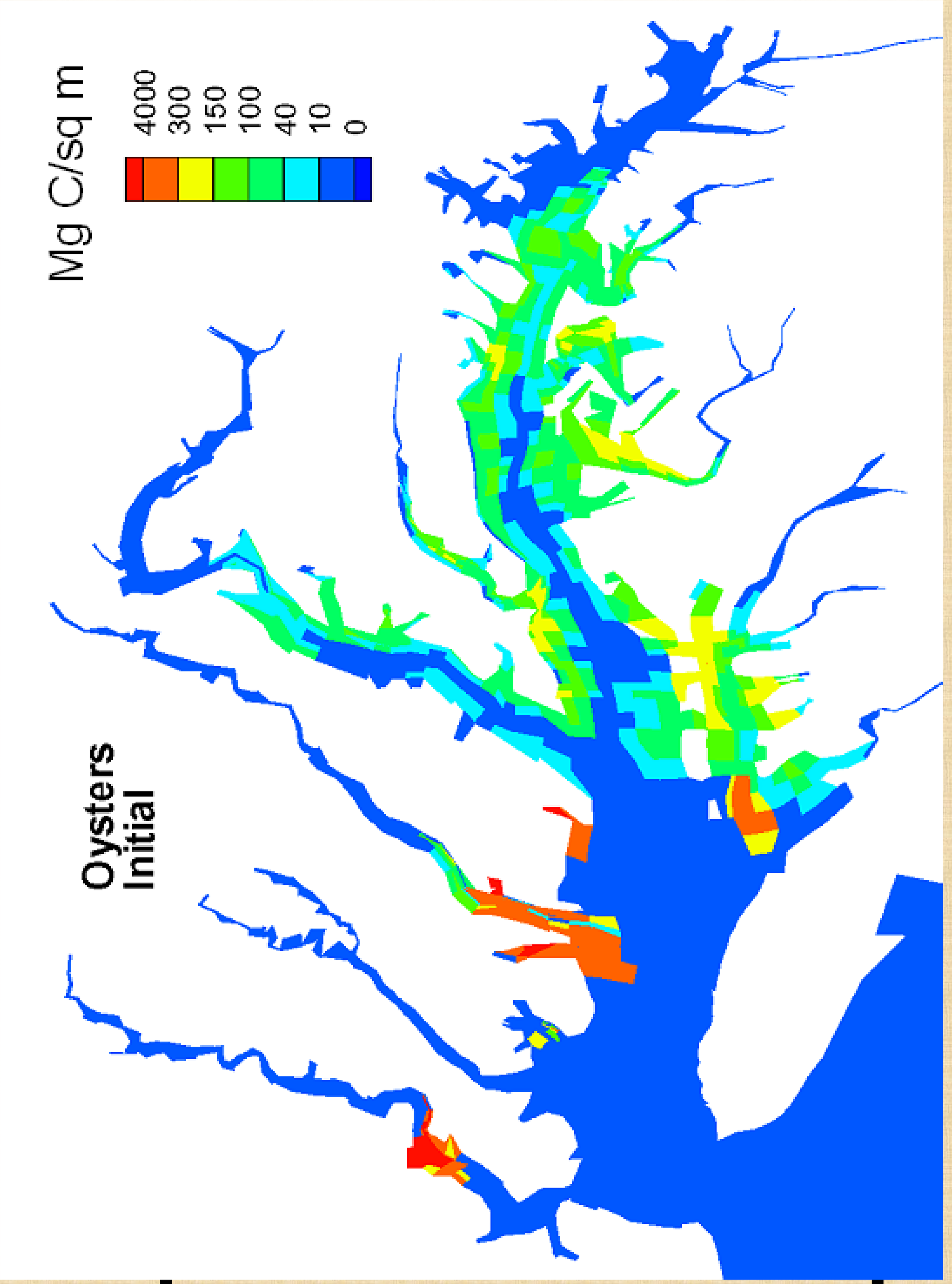
• Because of tight coupling of processes, several of the integrated LR models are coupled to the Water Quality Model, i.e., interacting at every model timestep. The coupled models are the SAV, oyster, and menhaden models.

Filter Feeders: Oysters & Menhaden

- We have oysters in the model fully coupled with water quality and sediment transport.
- We have provided separate estimates of harvest and disease mortality.
- Simulation of key menhaden filter feeder effect on water quality supported by three years of studies of menhaden populations, distribution, and feeding.



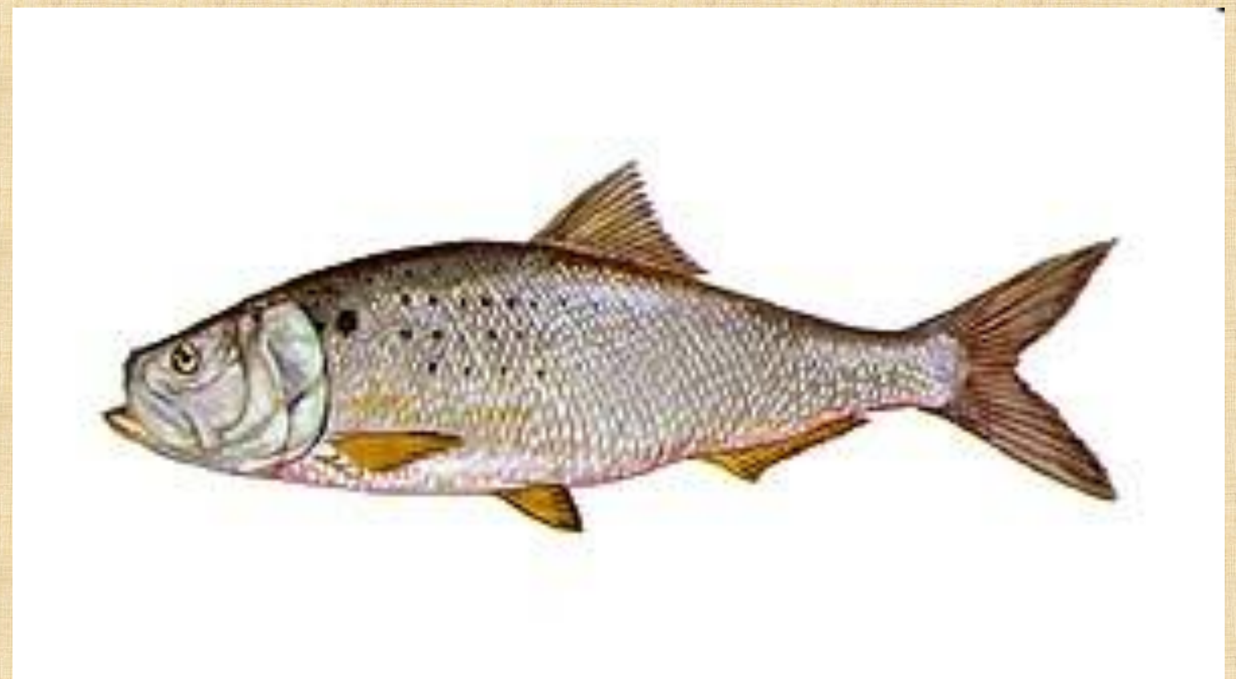
Coupled Living Resource Models



- The clarity/SAV WQS is for the restoration of SAV, yet increased SAV biomass has positive feedbacks on the improving clarity.

- For more than a decade oysters have been demonstrated to improve water clarity, particularly in shallow water - habitat for both oysters and SAV.

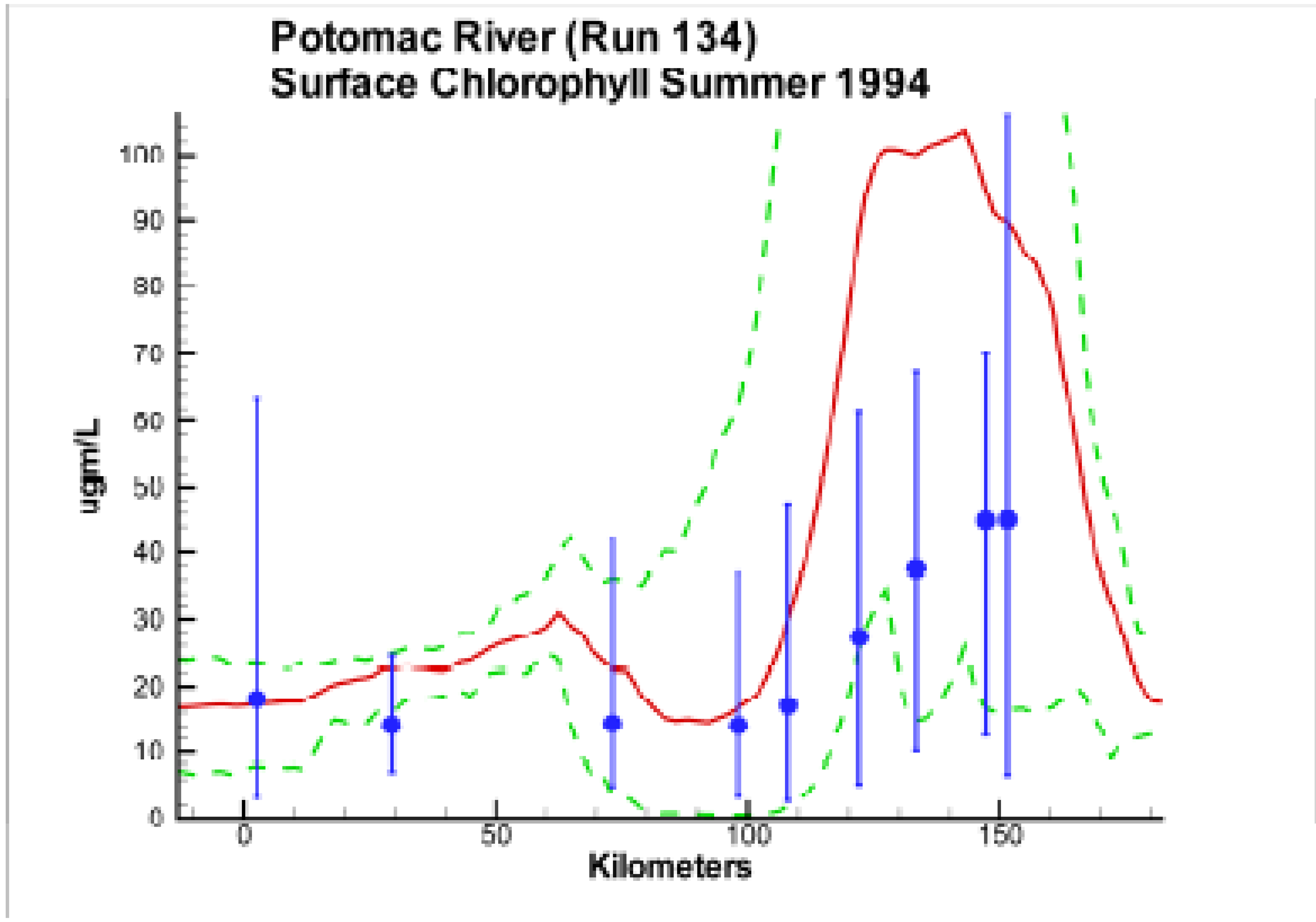
- The influence of menhaden on water clarity has been demonstrated.



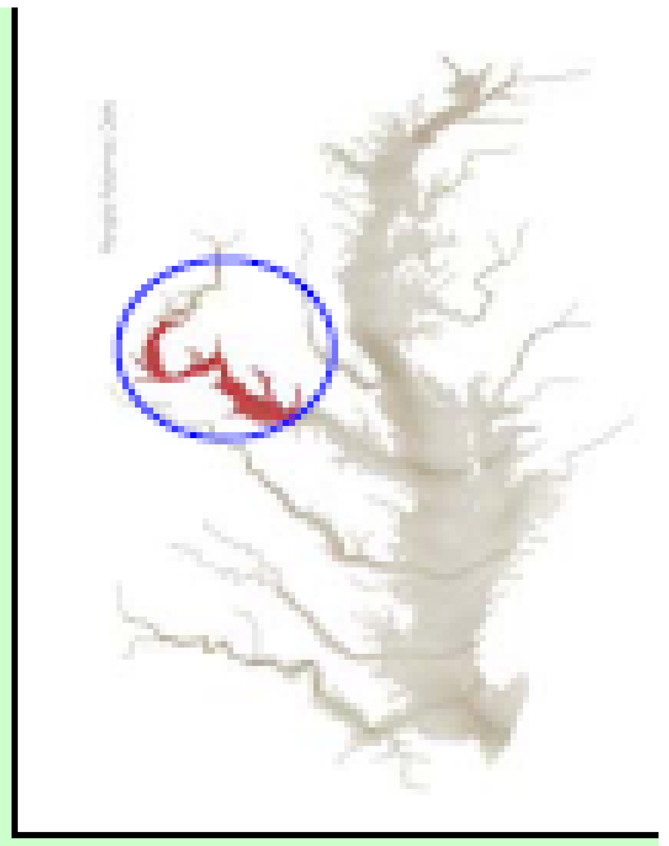
Fundamental Equation

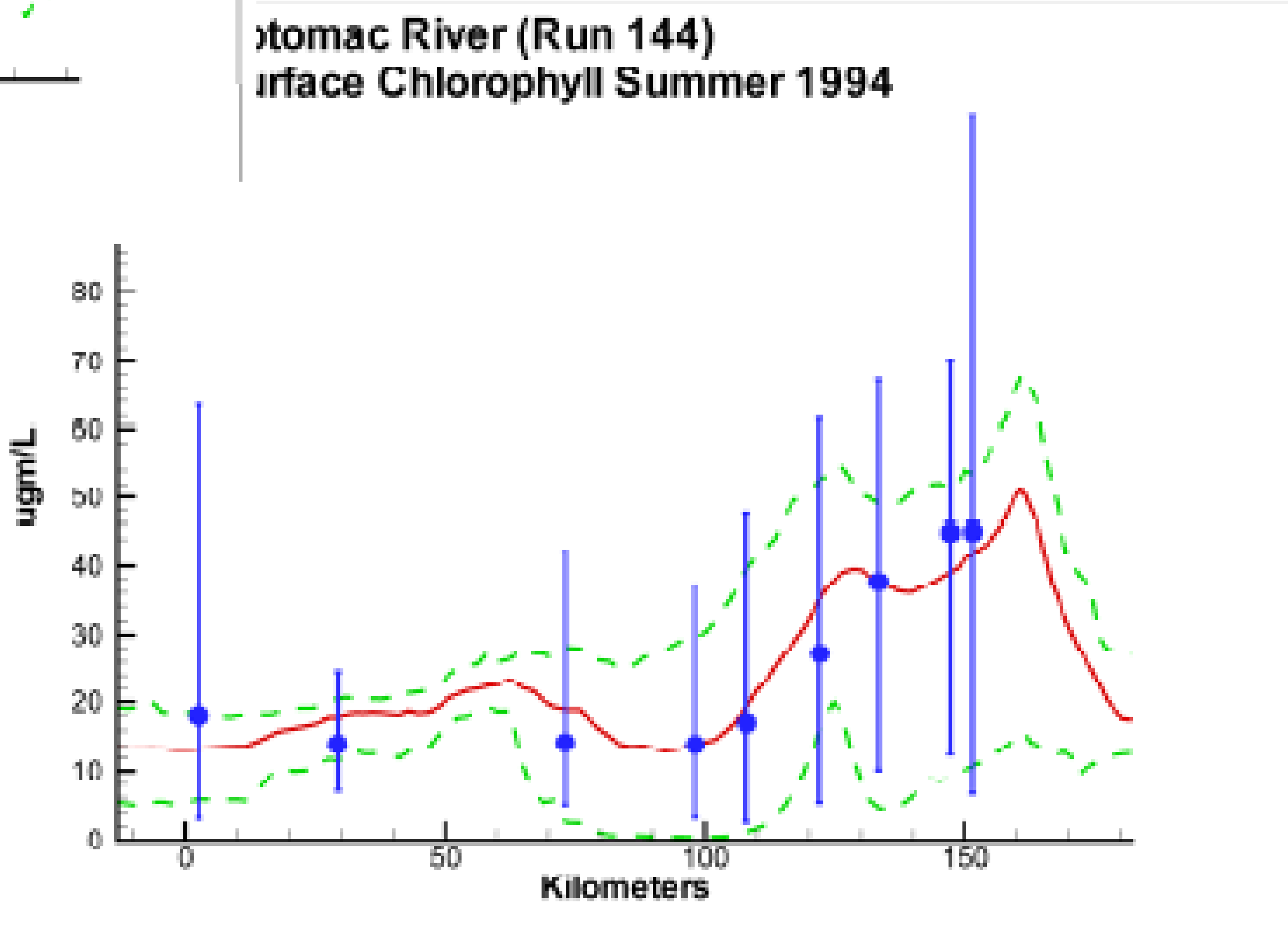
$$\frac{dFF}{dt} = \alpha \cdot Fr \cdot POC \cdot FF - r \cdot FF - \beta \cdot FF^2 - hmr \cdot FF$$

FF = filter feeder biomass (mg C m^{-2})
α = assimilation efficiency ($0 < \alpha < 1$)
Fr = filtration rate (m^3 mg^{-1} filter feeder carbon d^{-1})
POC = particulate organic carbon in overlying water (mg m^{-3})
r = specific respiration rate (d^{-1})
β = predation rate (m^2 mg^{-1} filter feeder C d^{-1})
hmr = mortality rate due to hypoxia (d^{-1})
t = time (d)



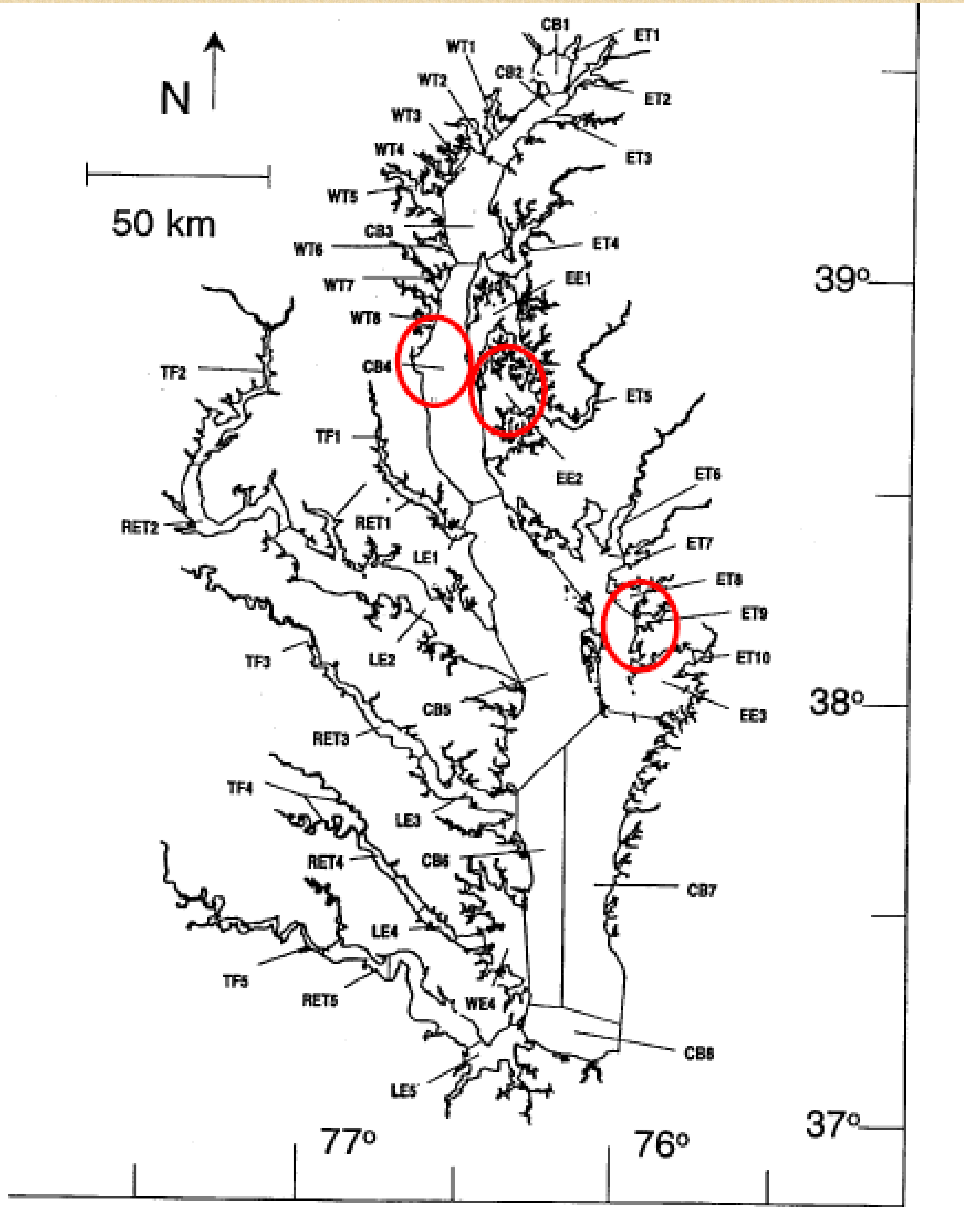
No Suspension
Feeders





With Suspension
Feeders

Filter feeder dynamics are important in water quality and we have that in our simulation.

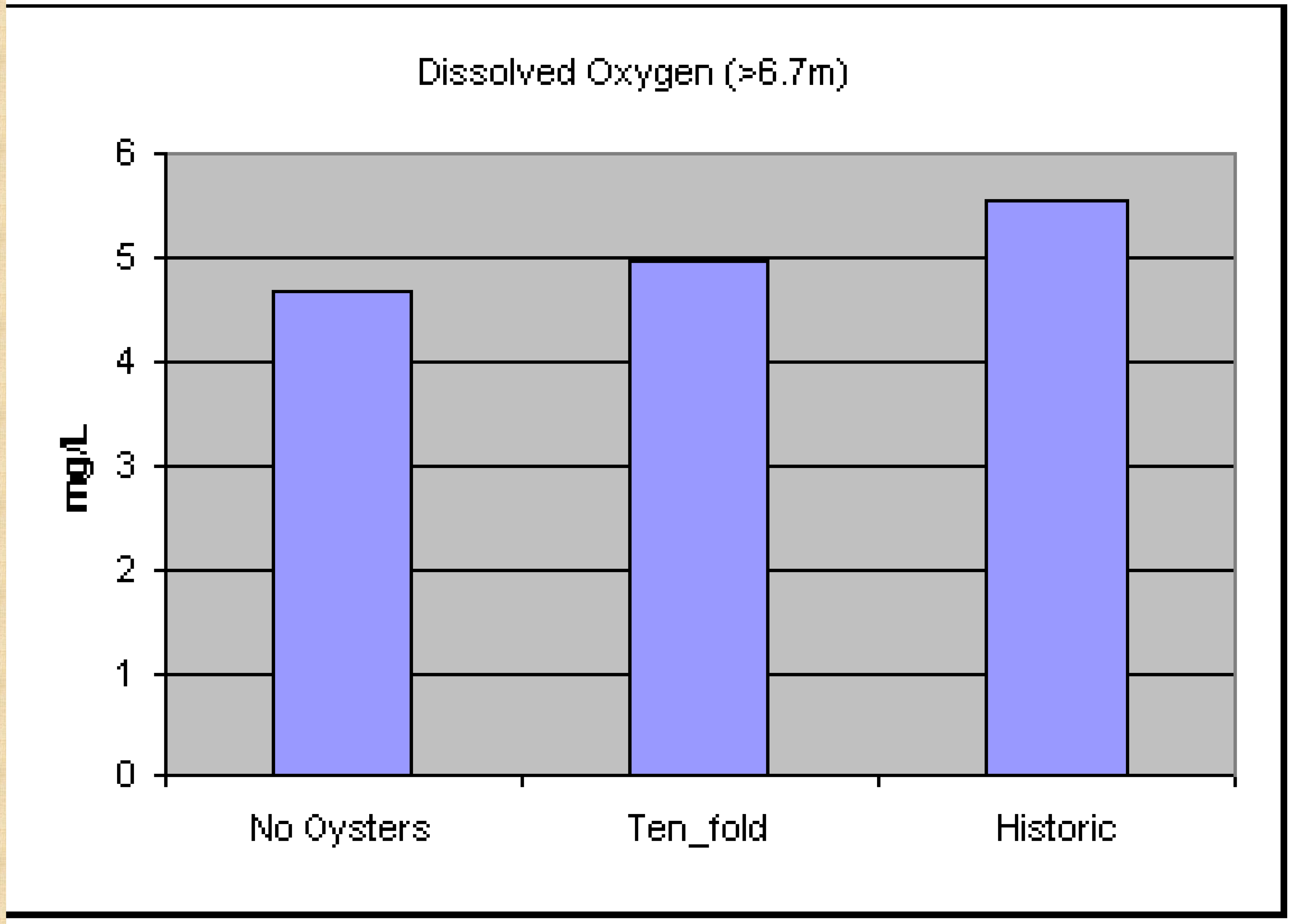


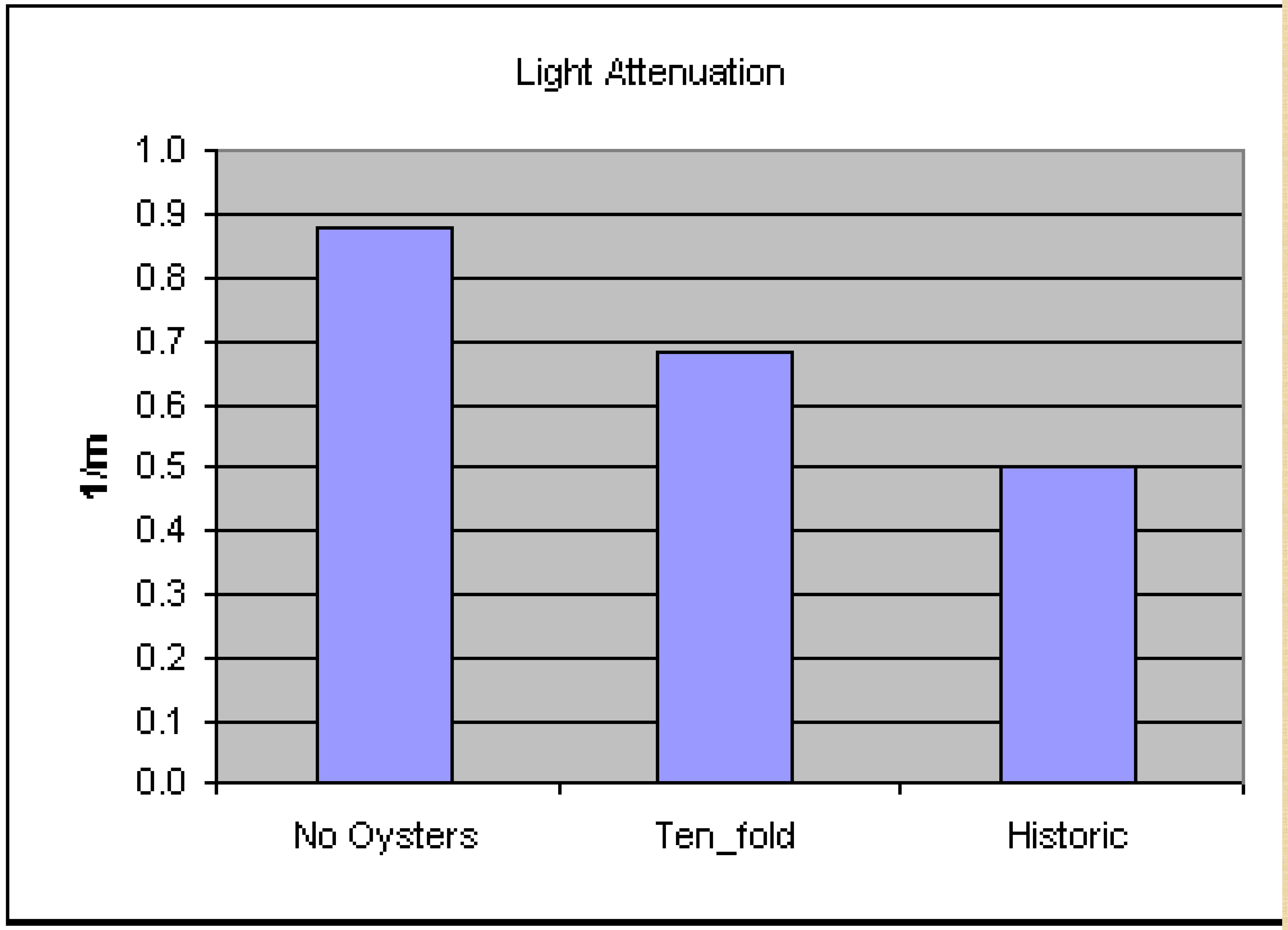
N
50 km
CB1
ET1
WT1
CB2
WT2
ET2
WT3
ET3
WT4
WT5
CB3
ET4
WT6
WT7
EE1
39°
WT8
TF2
CB4
ET5
TF1
EE2
ET6
RET2
RET1
ET7
LE1
ET8
ET9
TF3
LE2
ET10
38°
CB5
EE3
RET3
TF4
LE3
RET4
CB6
CB7
LE4
TF5
RET5
WE4
CB8
LE5
77°
76°
37°

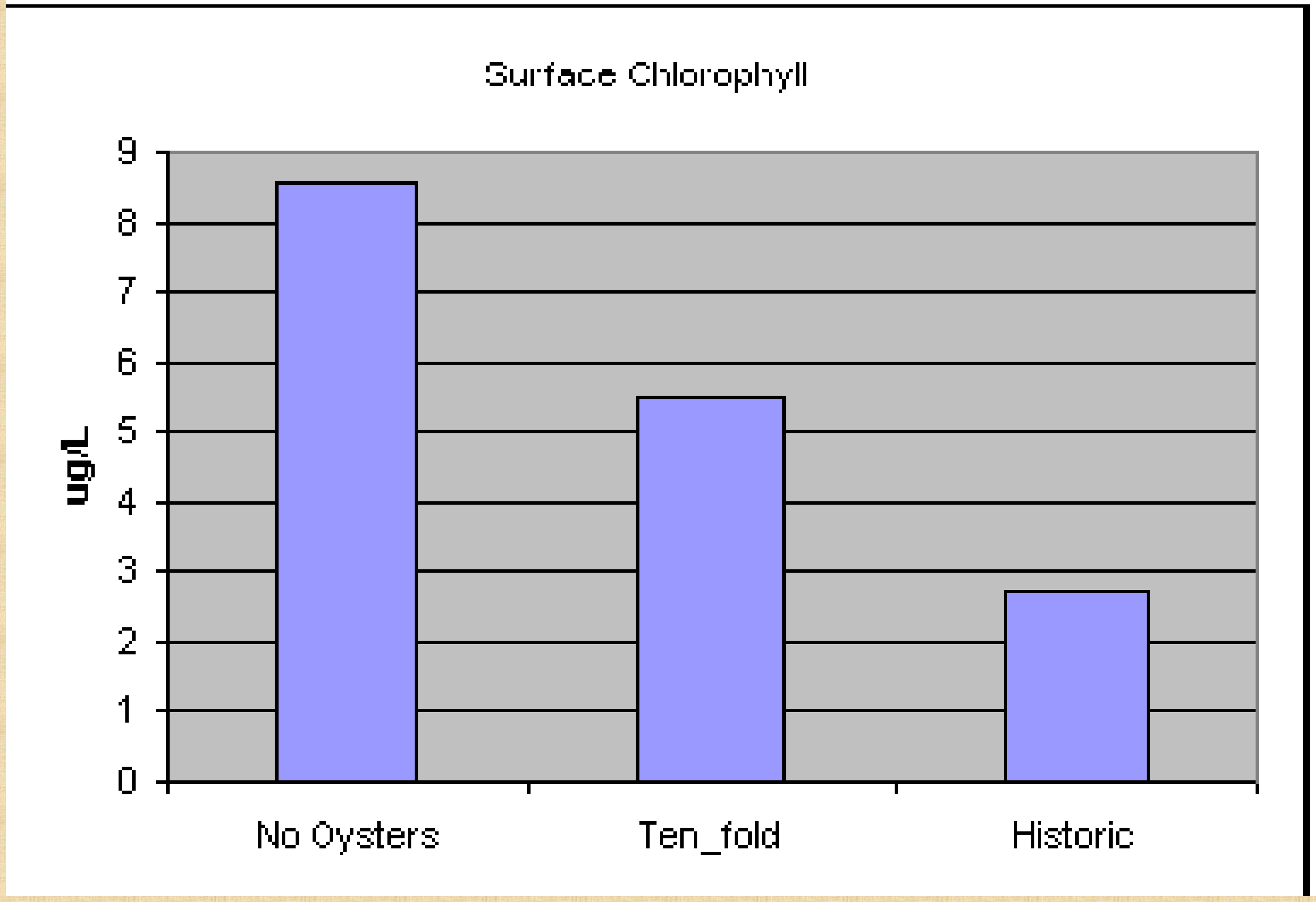
CB4

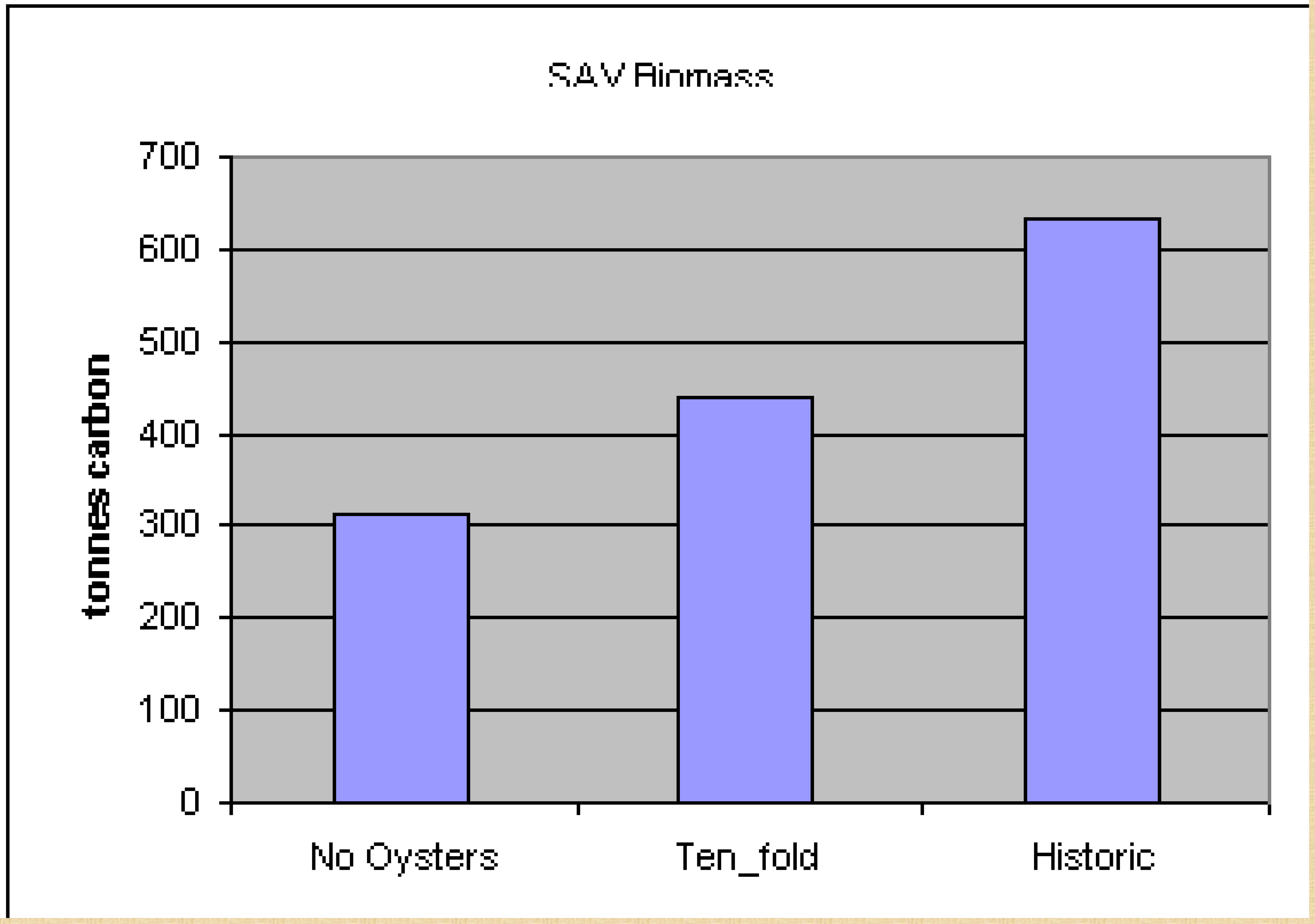
Dissolved Oxygen (>12.8m)
mg/L
2.5
2.0
1.5
1.0
0.5
0.0
No Oysters
Ten_fold
Historic
Light Attenuation
1/m
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
No Oysters
Ten_fold
Historic
Surface Chlorophyll
ug/L
10
9
8
7
6
5
4
3
2
1
0
No Oysters
Ten_fold
Historic
SAV Biomass
tonnes carbon
200
180
160
140
120
100
80
60
40
20
0
No Oysters
Ten_fold
Historic

EE2

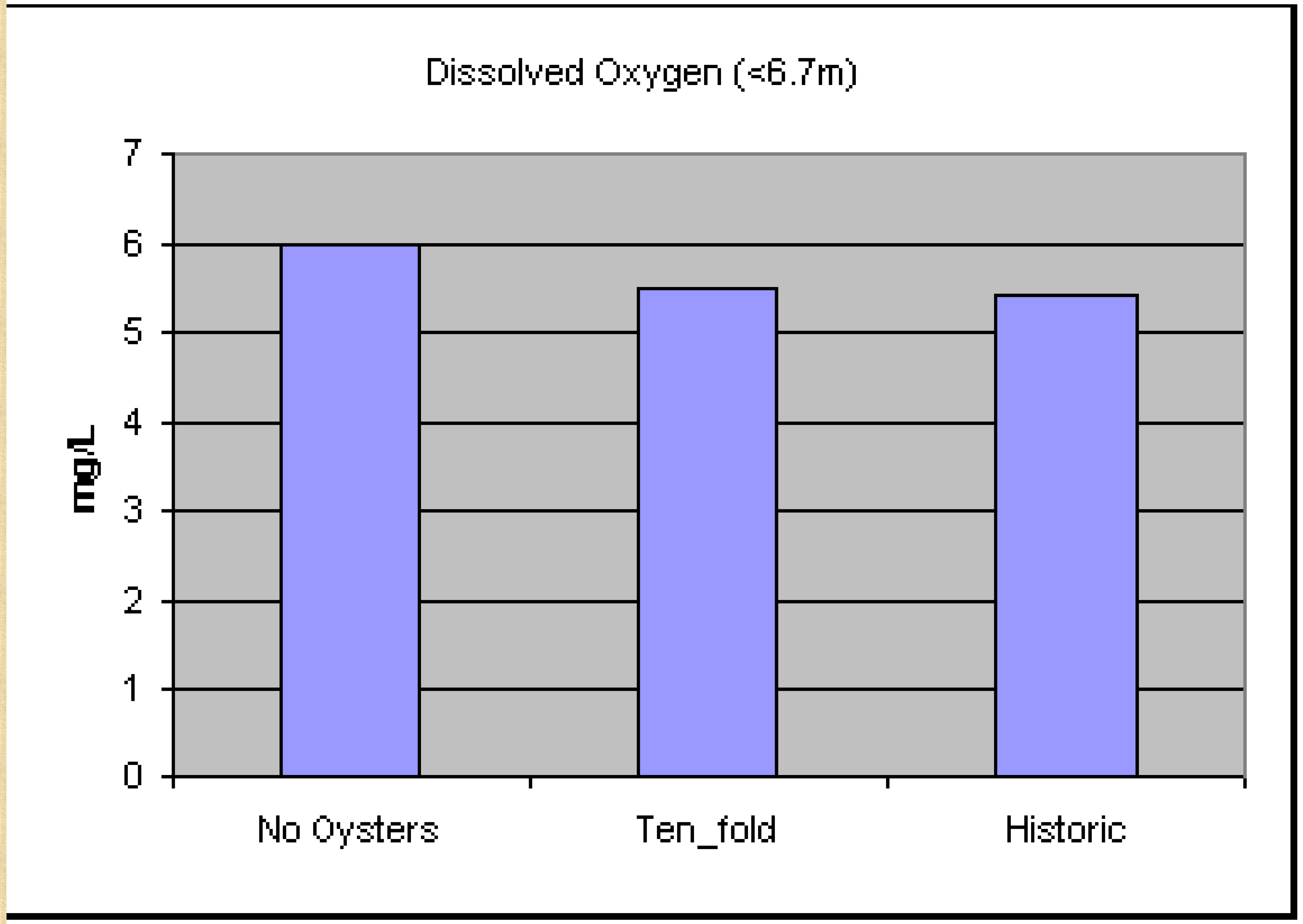

Dissolved Oxygen (>6.7m)
mg/L
0
1
2
3
4
5
6
No Oysters
Ten_fold
Historic

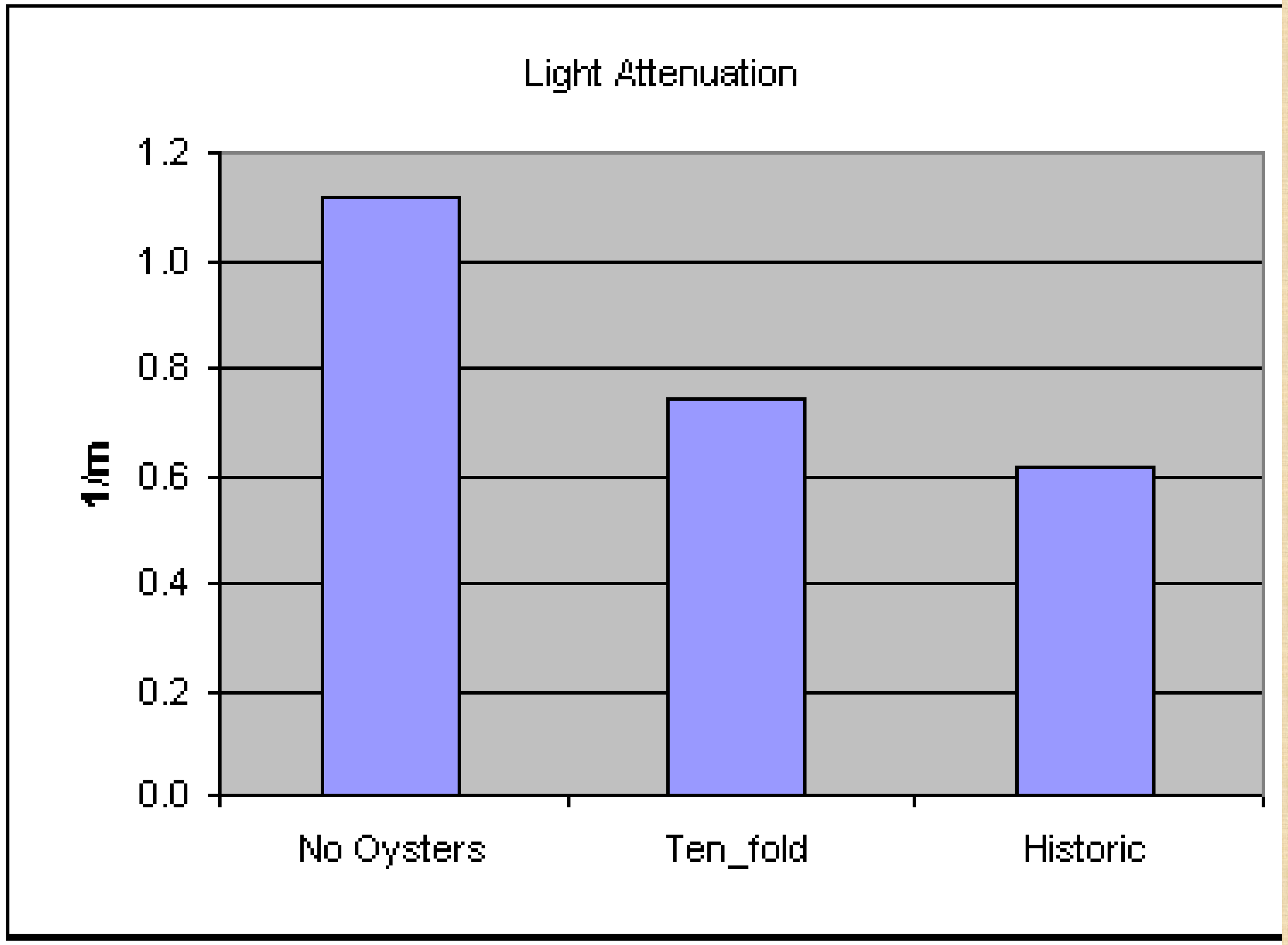

Light Attenuation
1/m
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
No Oysters
Ten_fold
Historic

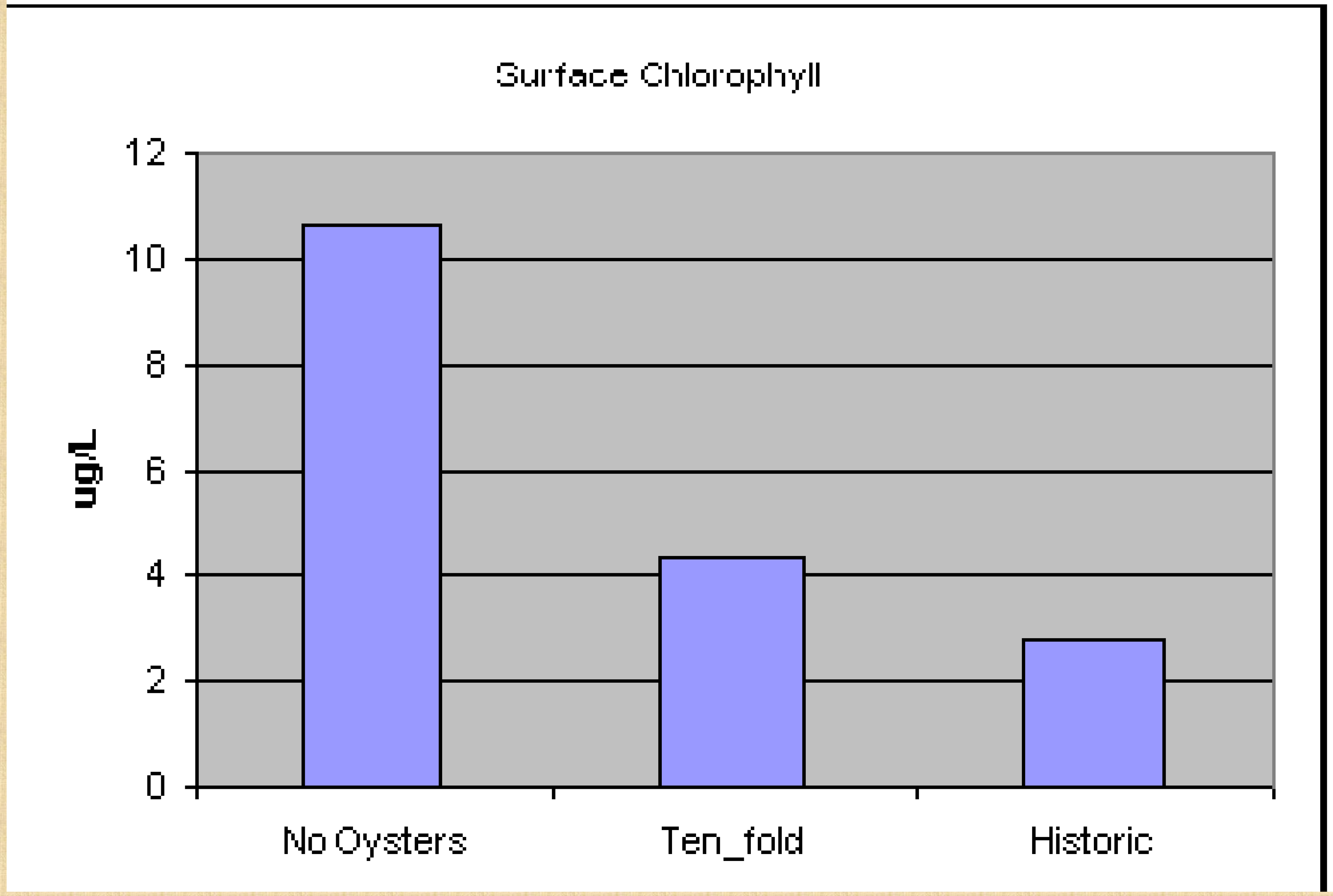

Surface Chlorophyll
ug/L
0
1
2
3
4
5
6
7
8
9
No Oysters
Ten_fold
Historic

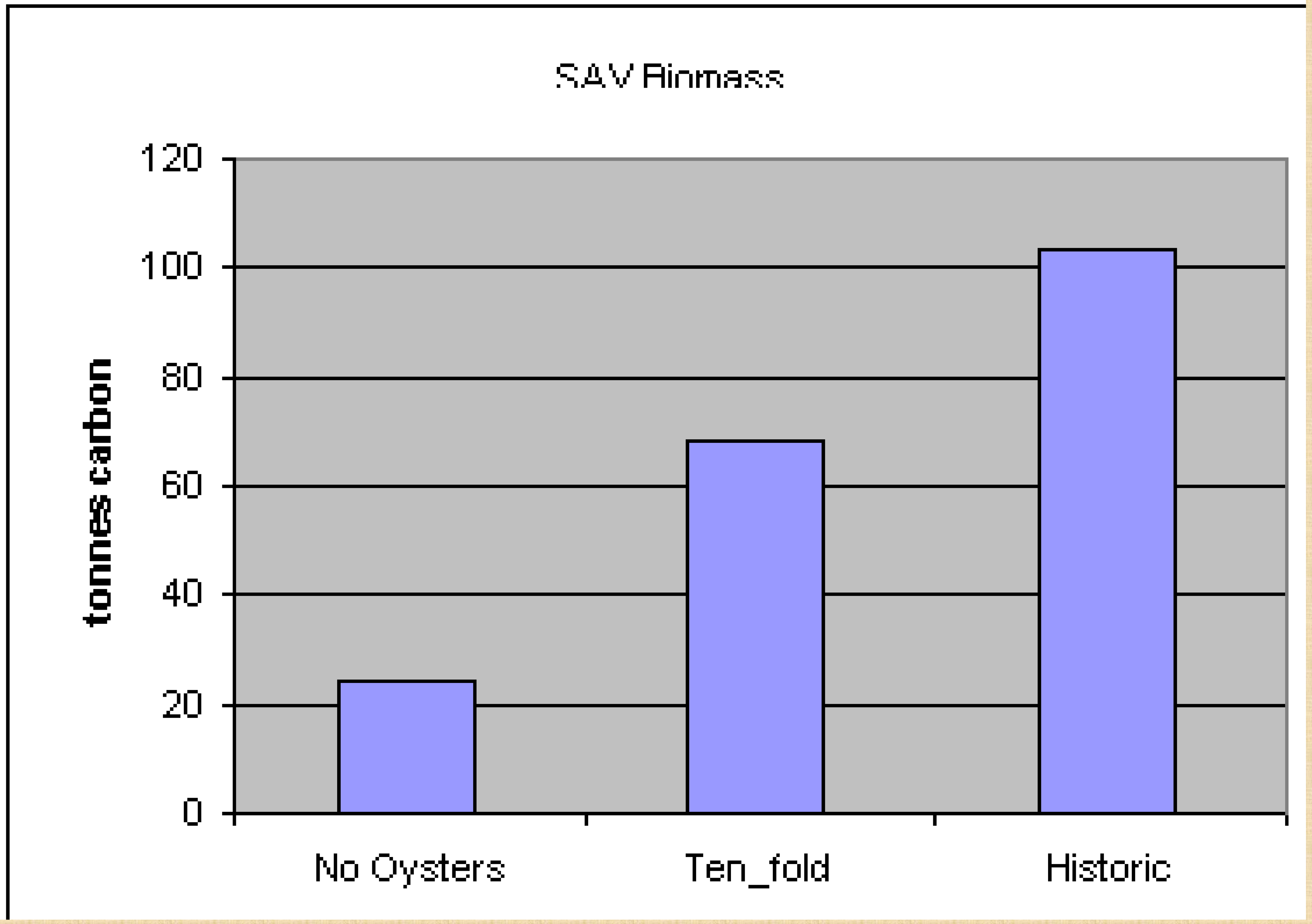

SAV Biomass
tonnes carbon
0
100
200
300
400
500
600
700
No Oysters
Ten_fold
Historic

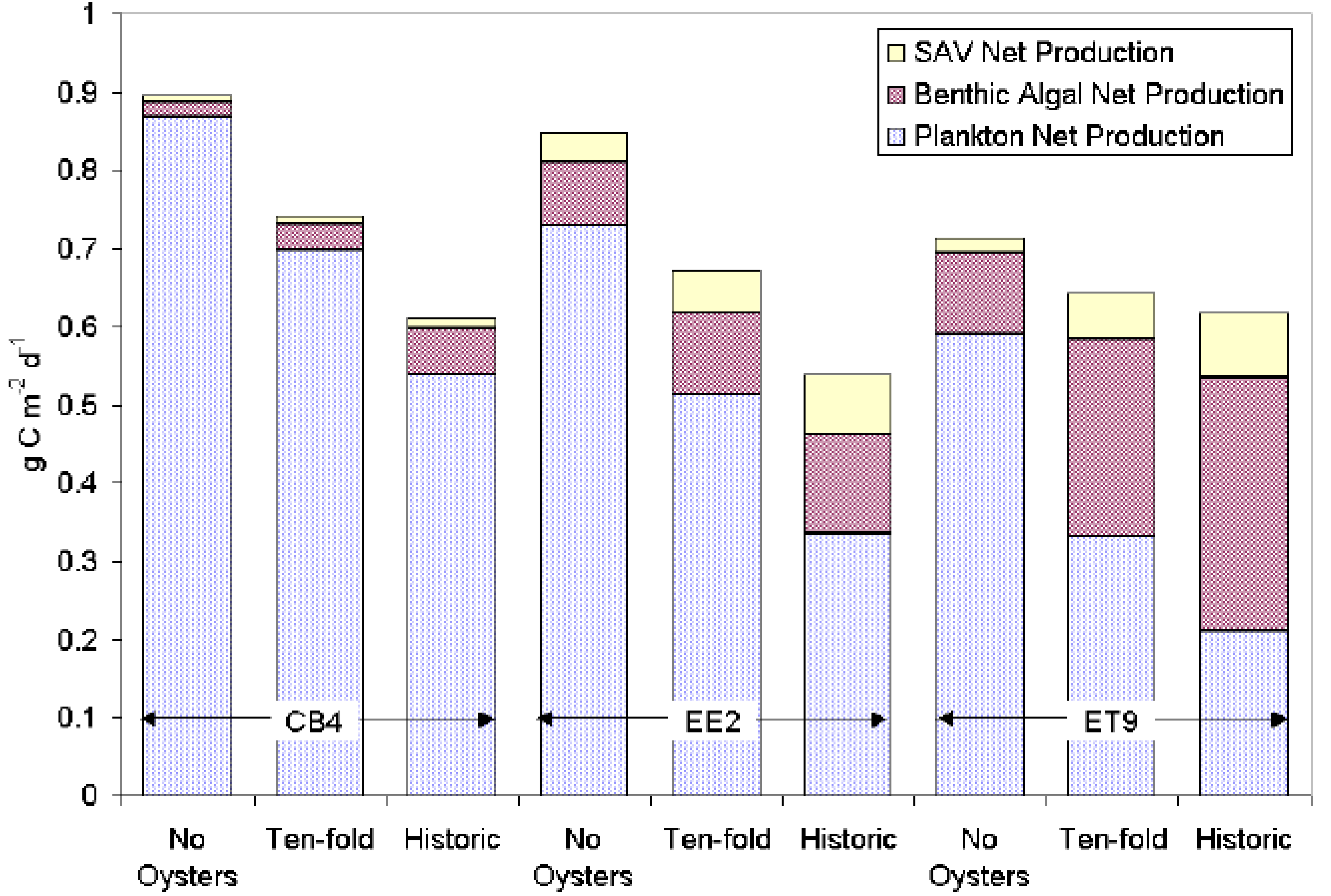
ET9


Dissolved Oxygen (<6.7m)
mg/L
0
1
2
3
4
5
6
7
No Oysters
Ten_fold
Historic


Light Attenuation
1/m
0.0
0.2
0.4
0.6
0.8
1.0
1.2
No Oysters
Ten_fold
Historic

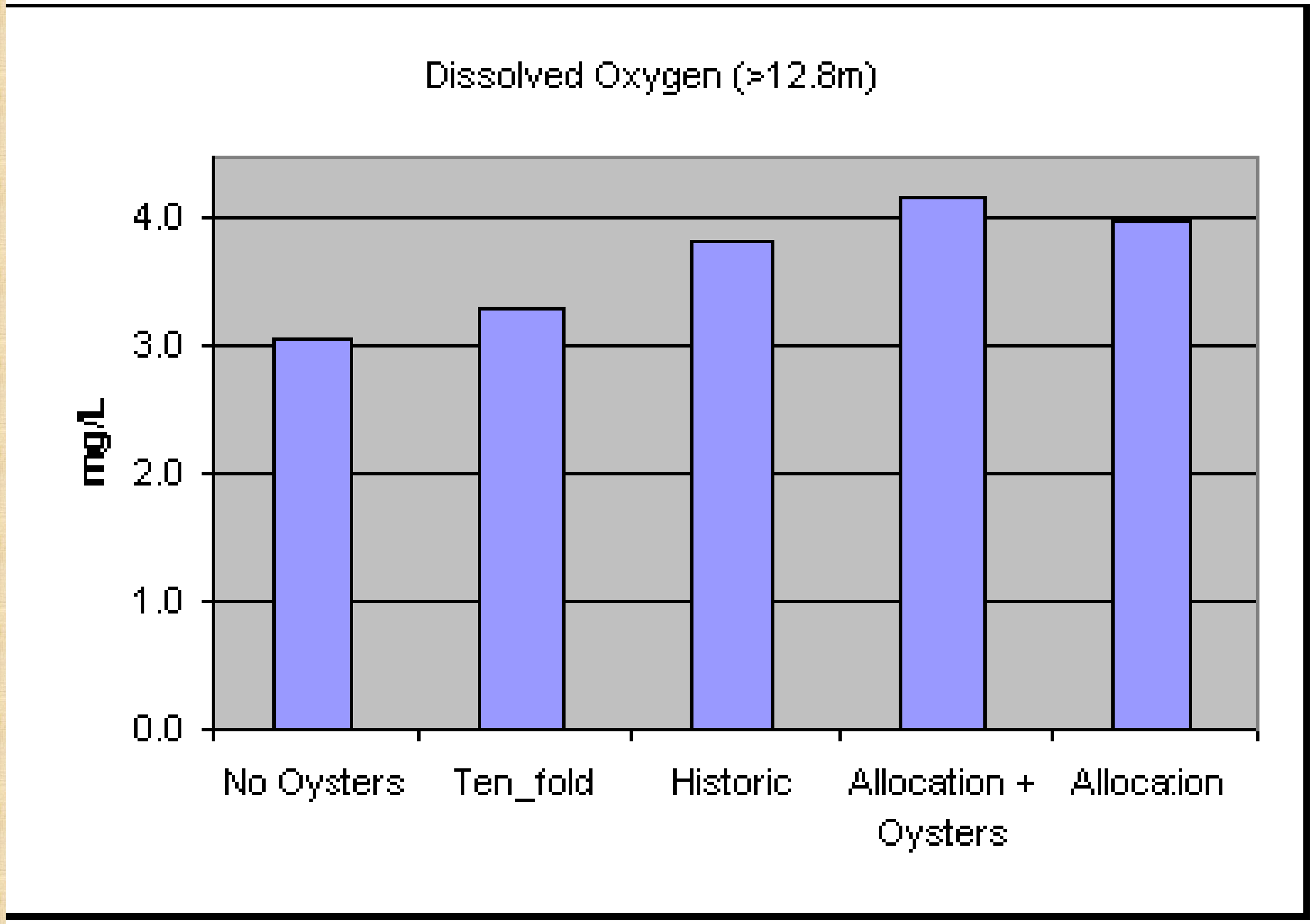

Surface Chlorophyll
ug/L
0
2
4
6
8
10
12
No Oysters
Ten_fold
Historic

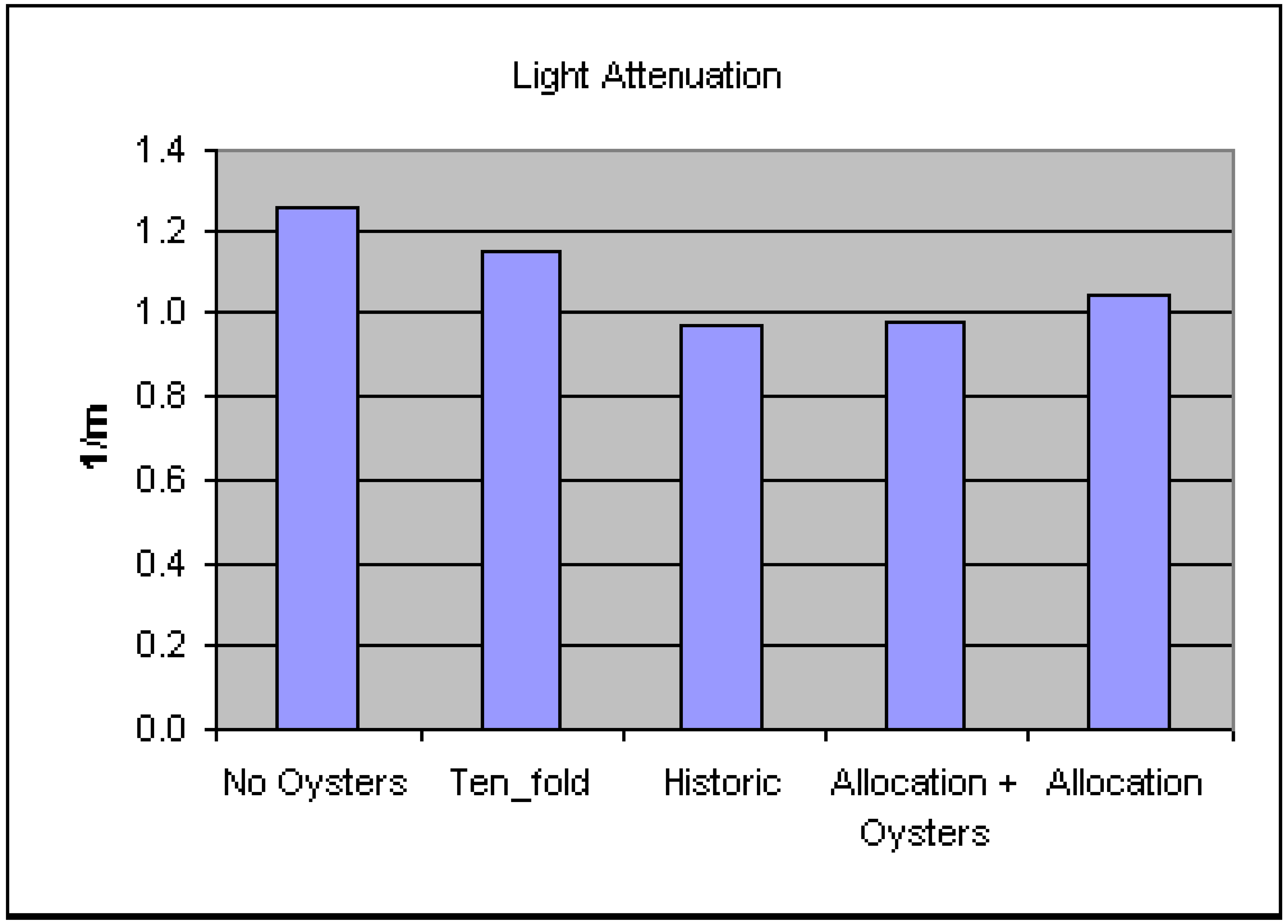

SAV Biomass
tonnes carbon
0
20
40
60
80
100
120
No Oysters
Ten_fold
Historic

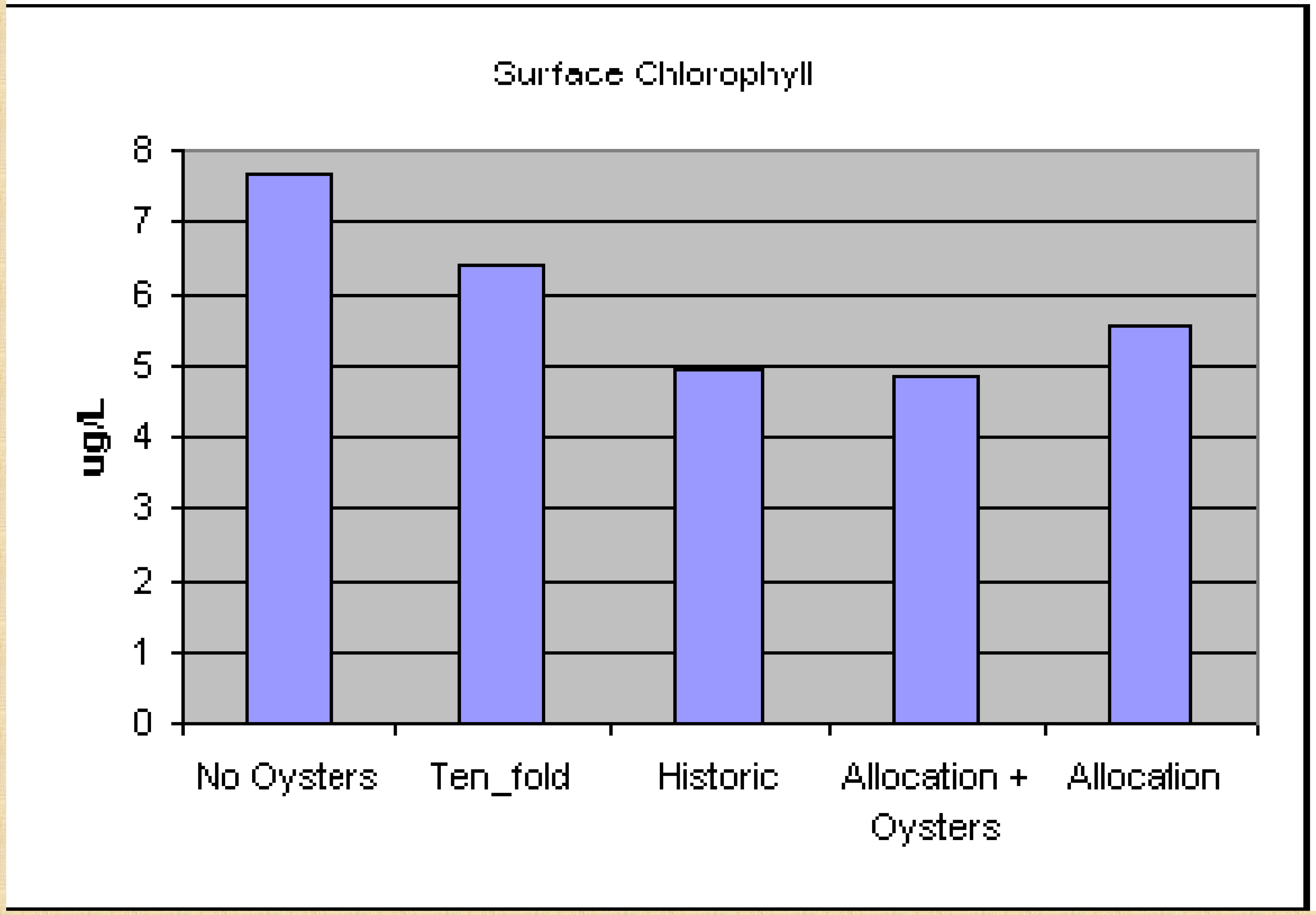


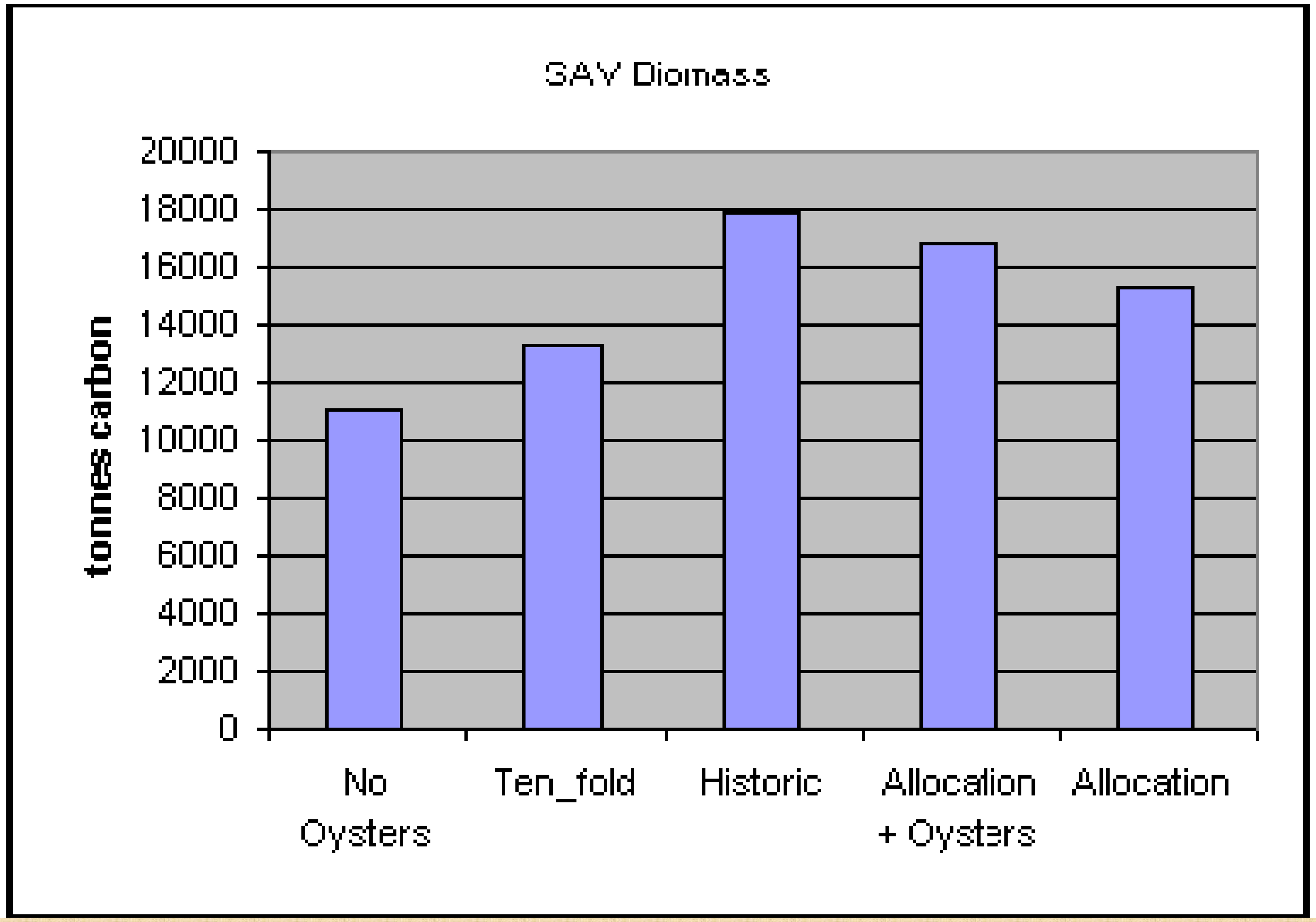
SAV Net Production
Benthic Algal Net Production
Plankton Net Production
g C m-2 d-1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CB4
EE2
ET9
No Oysters
Ten-fold
Historic
No Oysters
Ten-fold
Historic
No Oysters
Ten-fold
Historic

System-Wide Summary

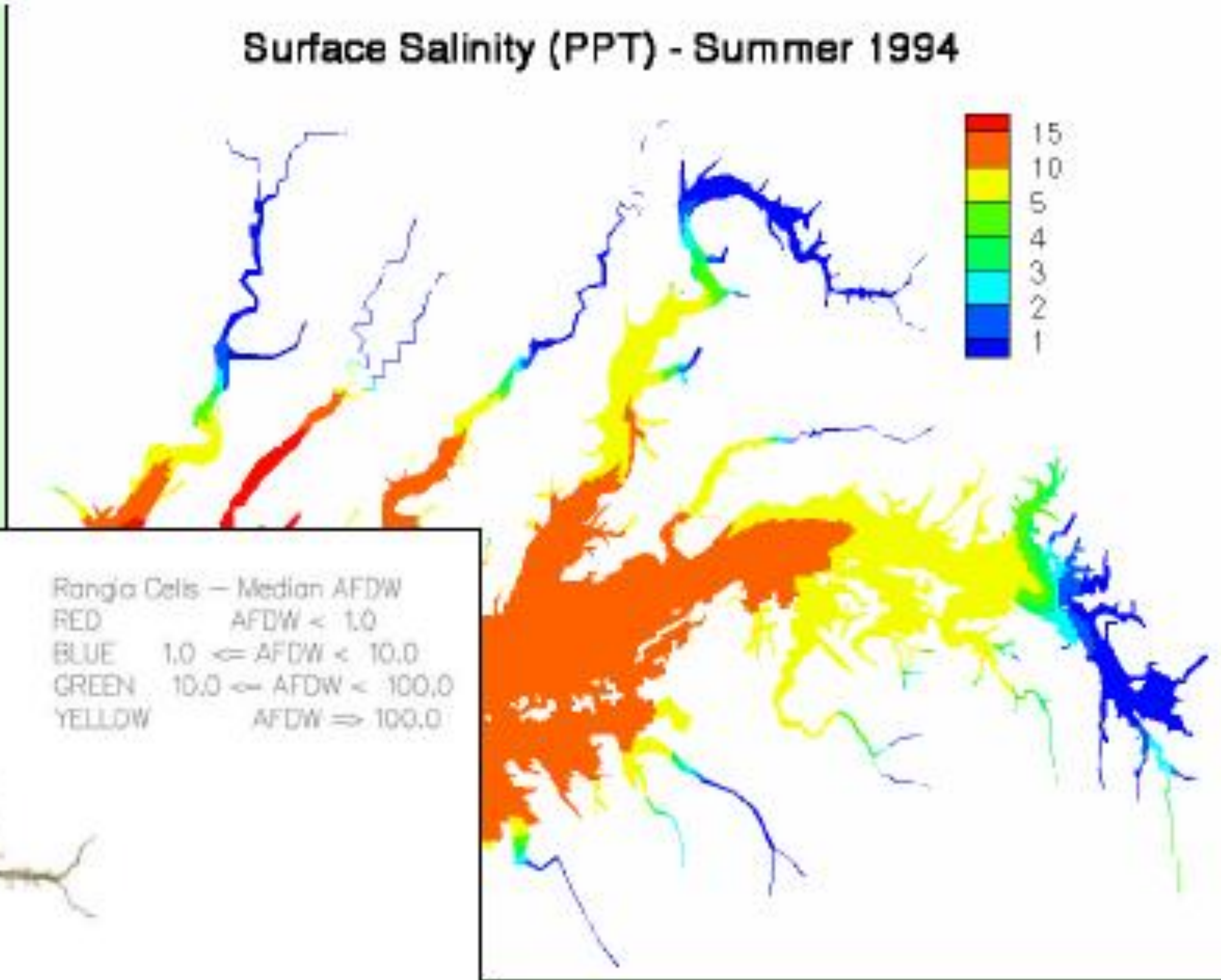


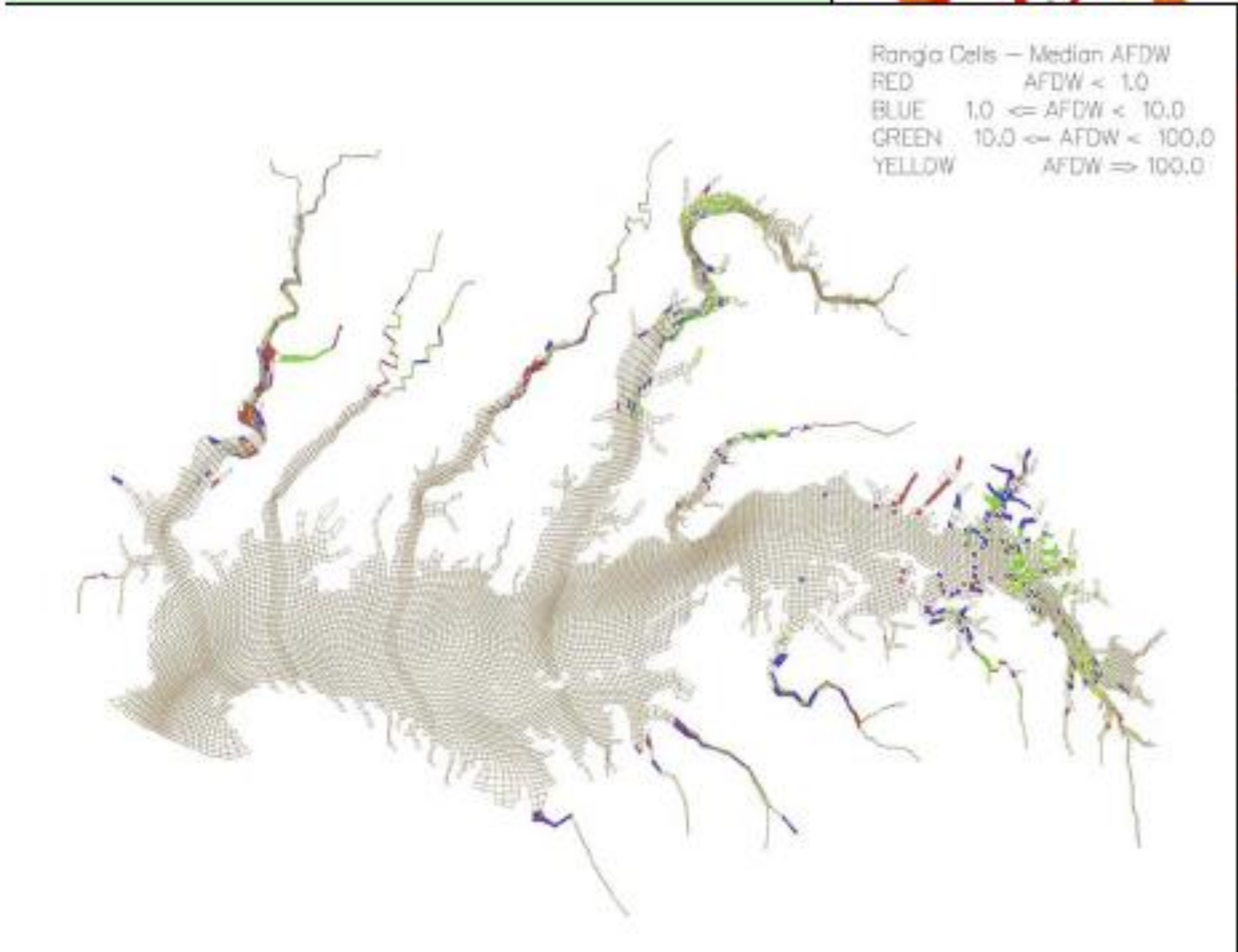






Rangia – Observed Distribution





Corbicula – Observed Distribution