Challenges and Opportunities for Modeling Shallow Water Ecosystems in Chesapeake Bay

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Once we dive into shallow waters….

Challenges are also Opportunities

(1) The land-water interface becomes more complex, and more resolved data needed
- but resolving fine-scale inputs might lead to better characterization

(2) Primary producers occupy the sediments
- if modeled, these effects can allow us to understand feedbacks, biological responses

(3) Marsh-estuary exchange may be more relevant
- marshes can take up nutrients, export carbon(consume oxygen), respond to SLR

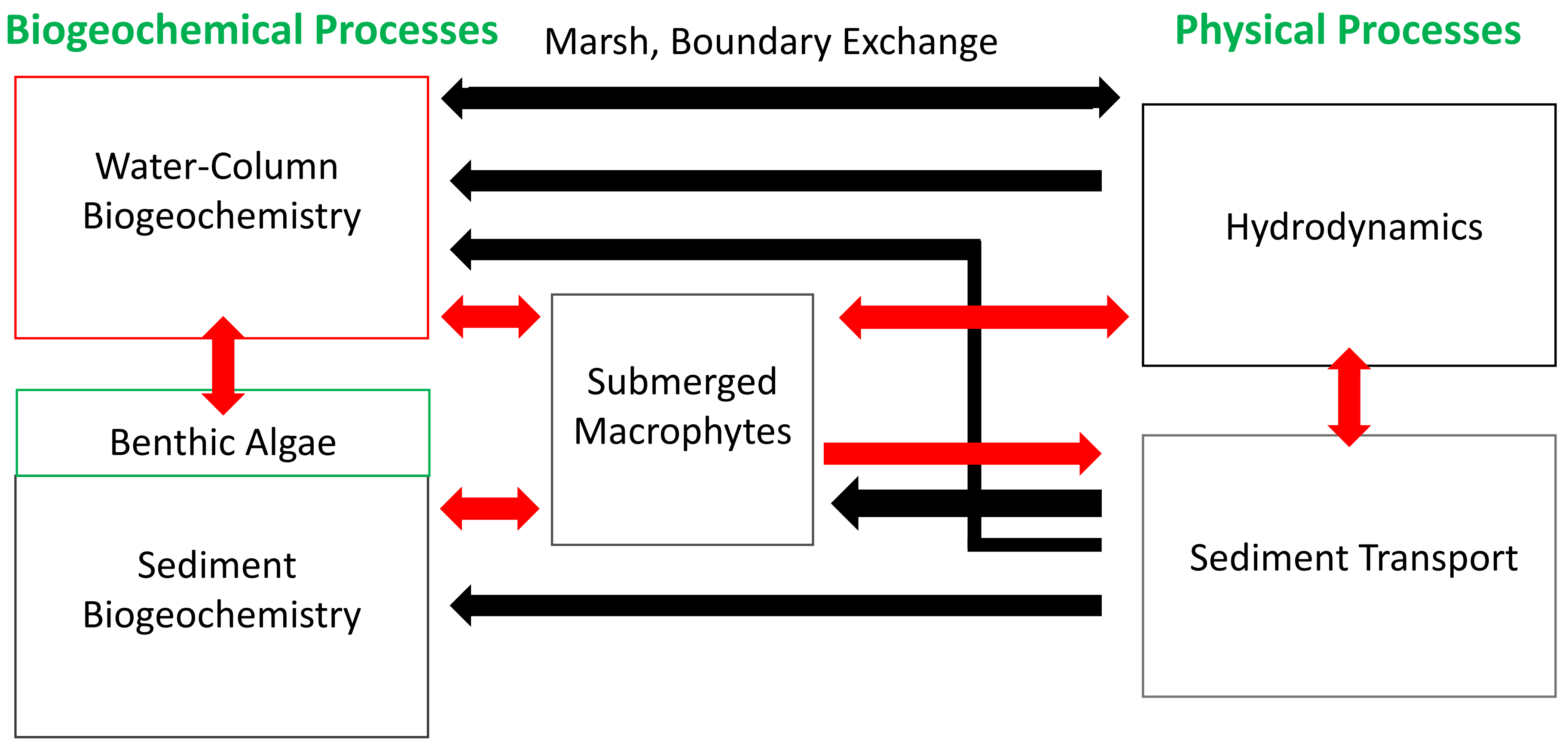
(4) High-frequency variability can be common
- quantifying this variability allows better assessment of DO and chl-a criteria

(5) Shallow-waters can get HOT

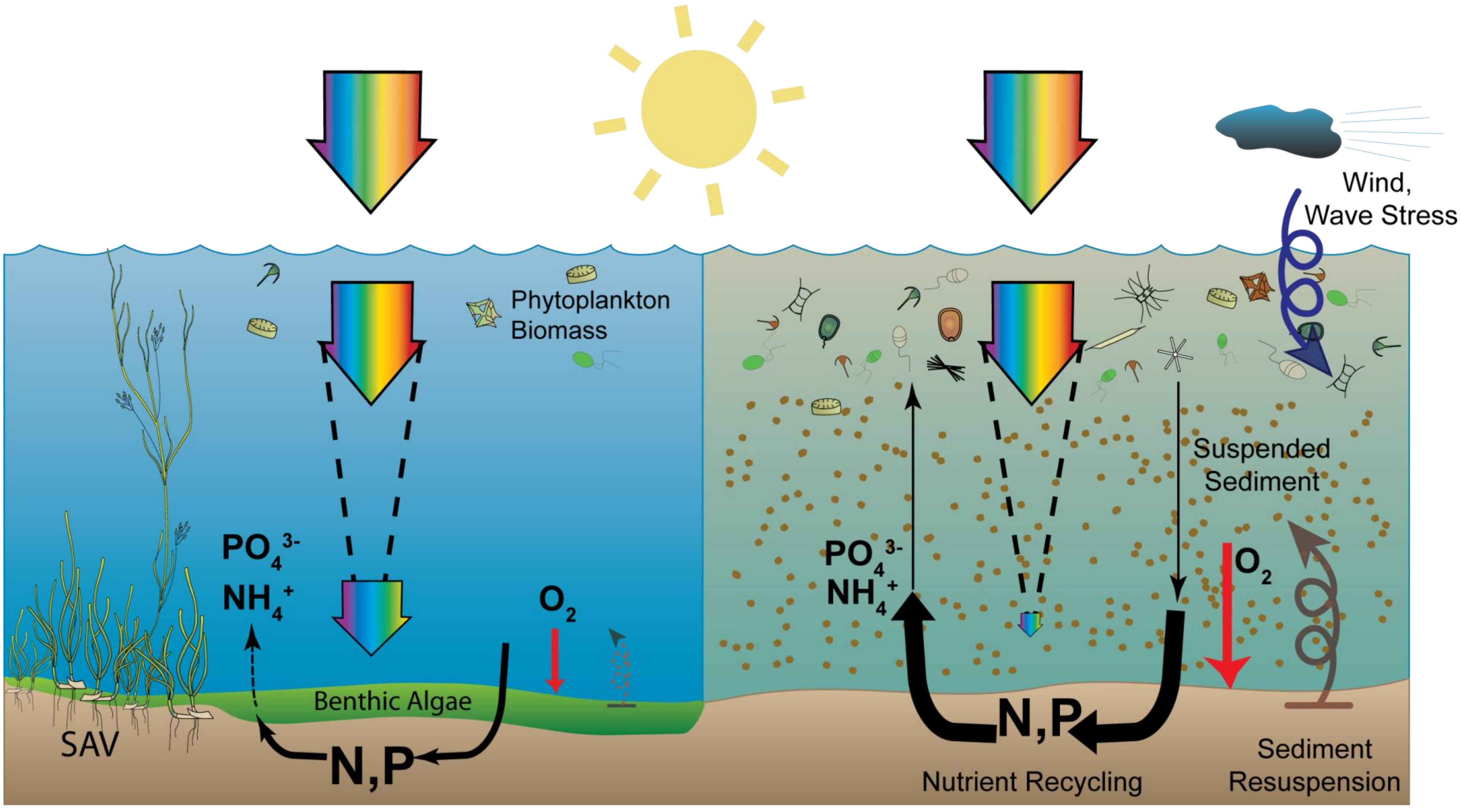
(6) New shallow-water models require new observations – linked modeling-monitoring

Some Key Processes in Shallow Waters

(1) Sediment-water interactions are important
(2) Influence of submerged macrophytes
(3) Sediment resuspension
(4) Benthic algal growth
(5) Diel cycling hypoxia
(6) Marsh-estuary exchange
(7) Tributary-Mainstem Exchange



Key Processes and Feedbacks in Shallow Habitats

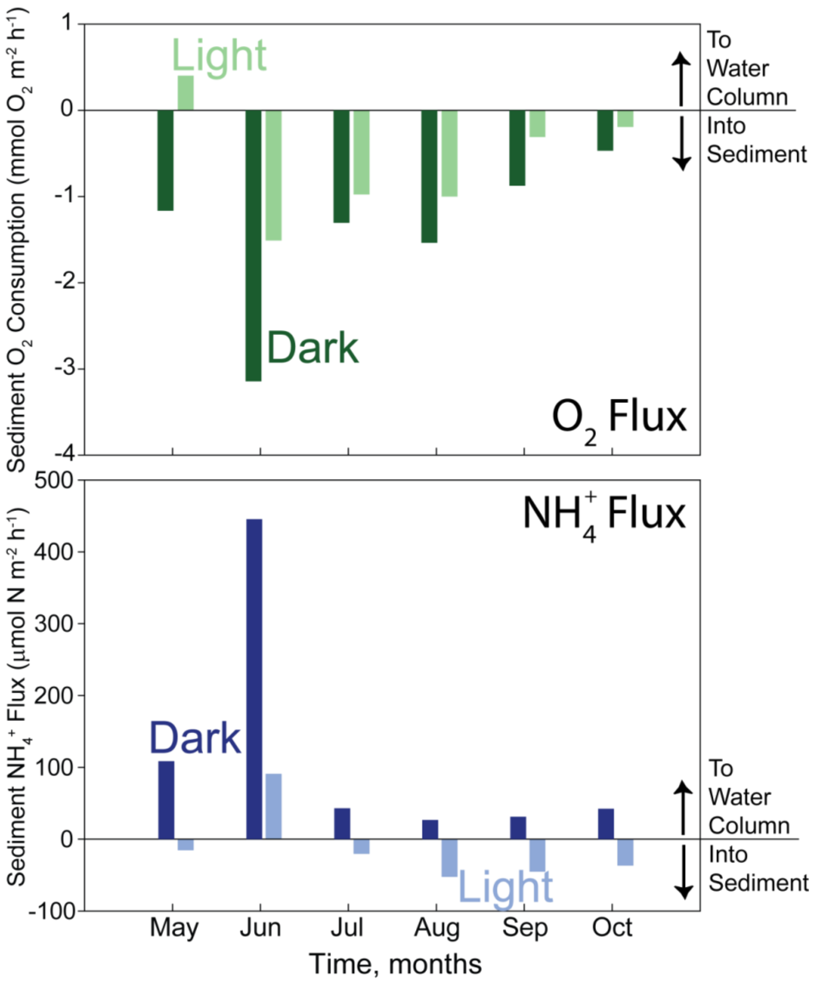


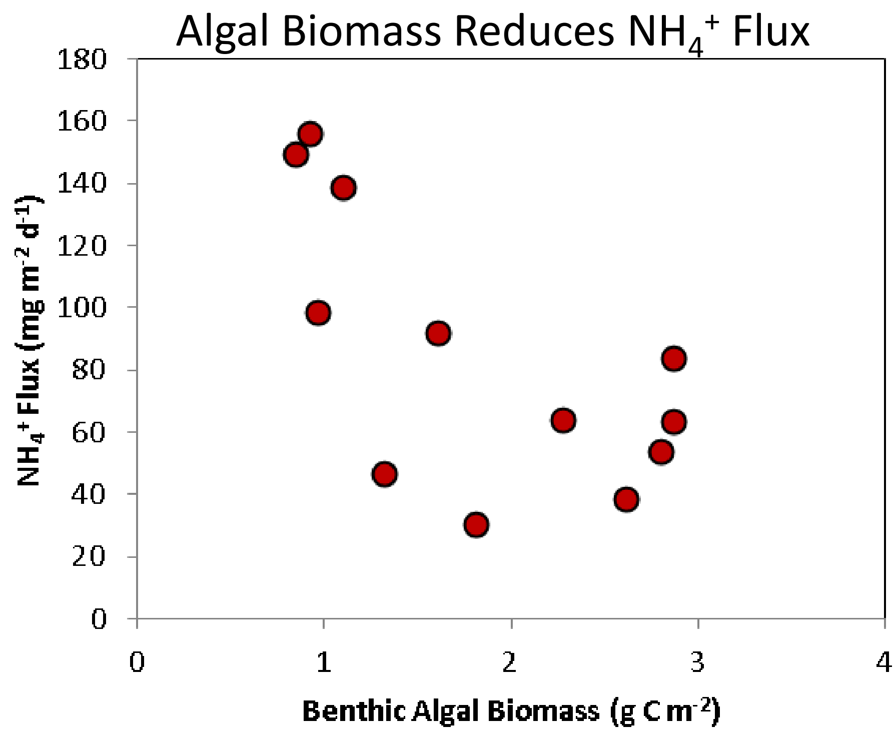
“Healthy” Ecosystem

Degraded Ecosystem

(Boynton et al. 2009)

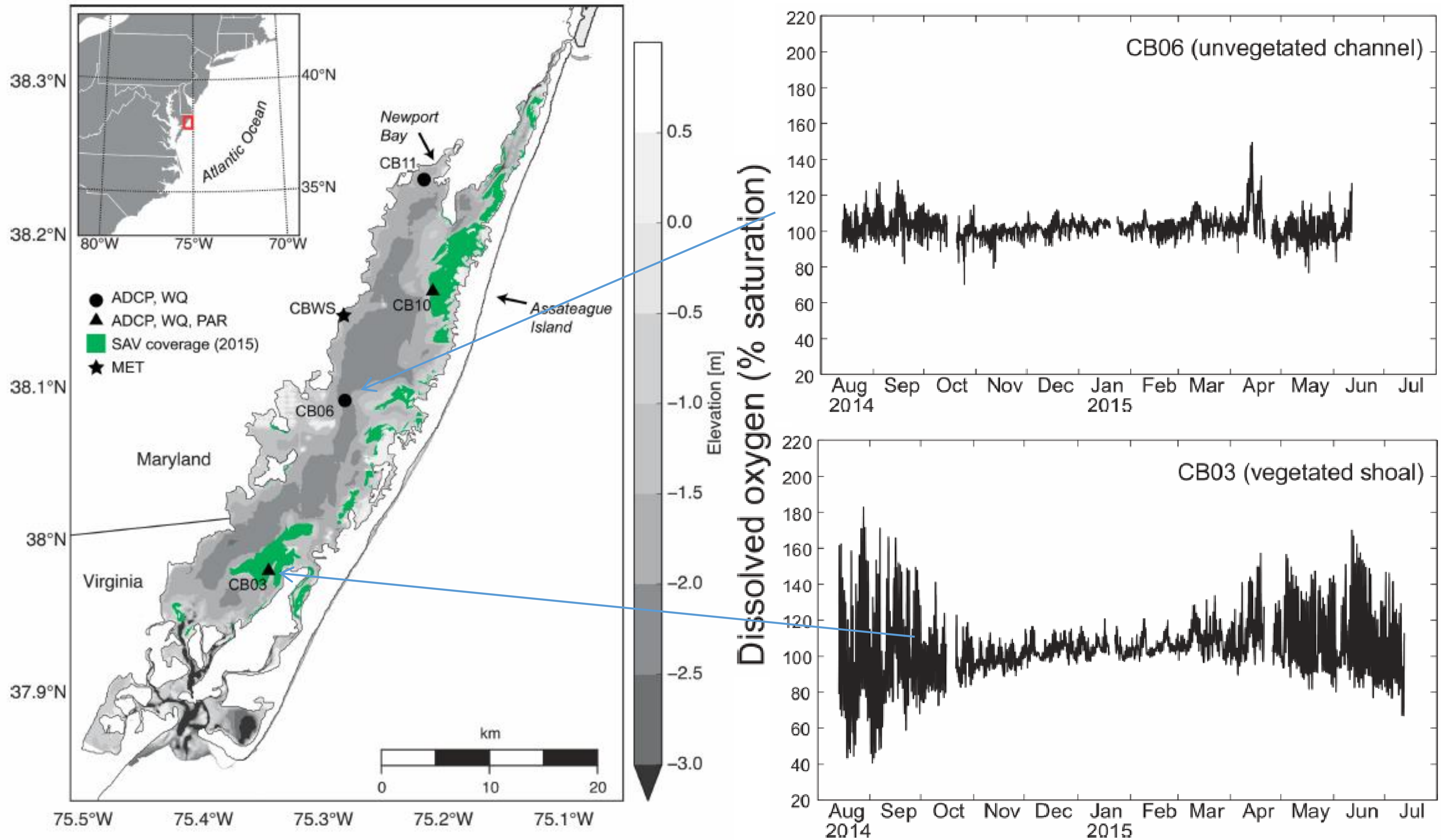
Light, Benthic Algae, and Nutrient Flux





(Cornwell and Owens, Unpubl.)

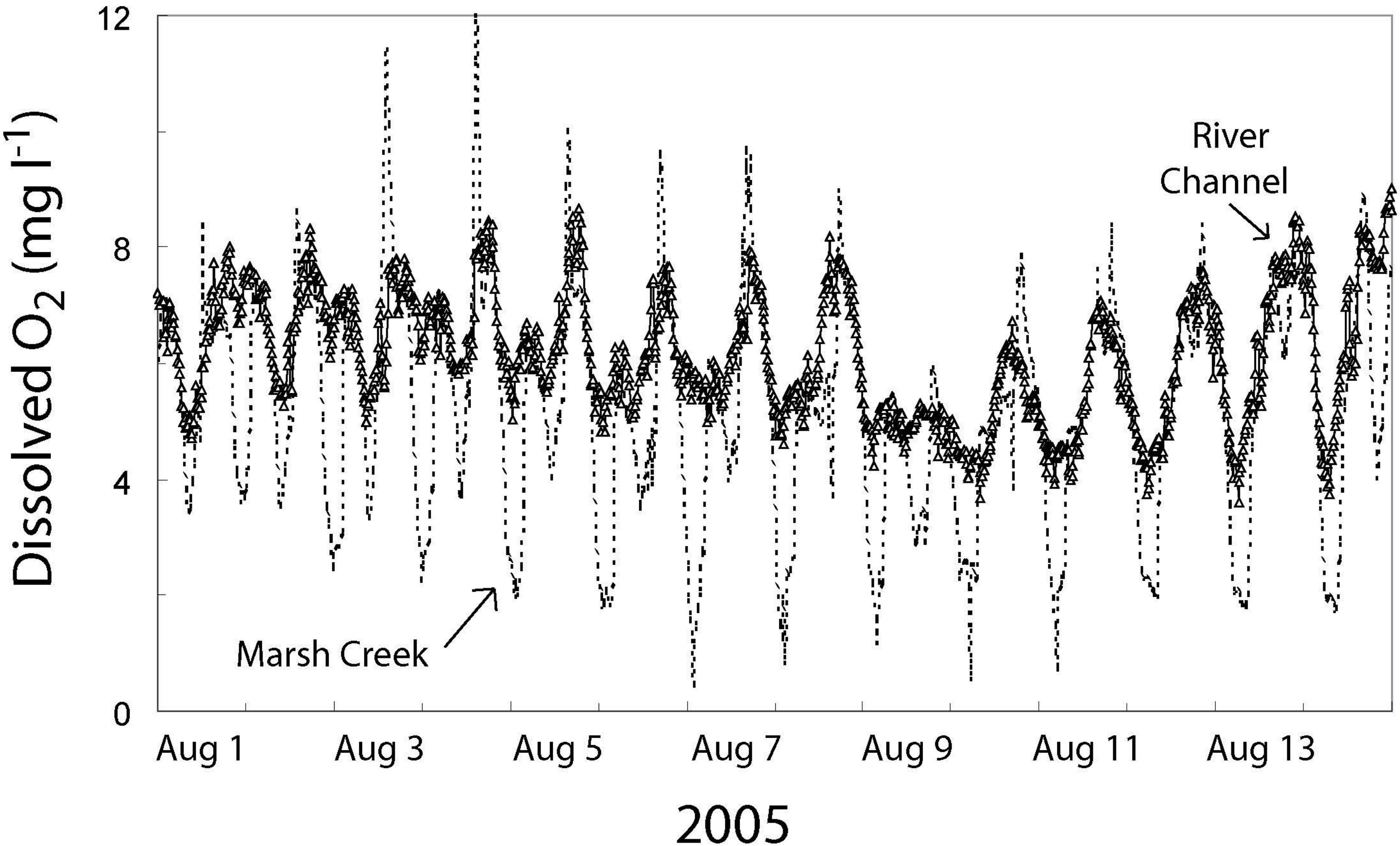
Oxygen Variability Higher in Vegetated Regions



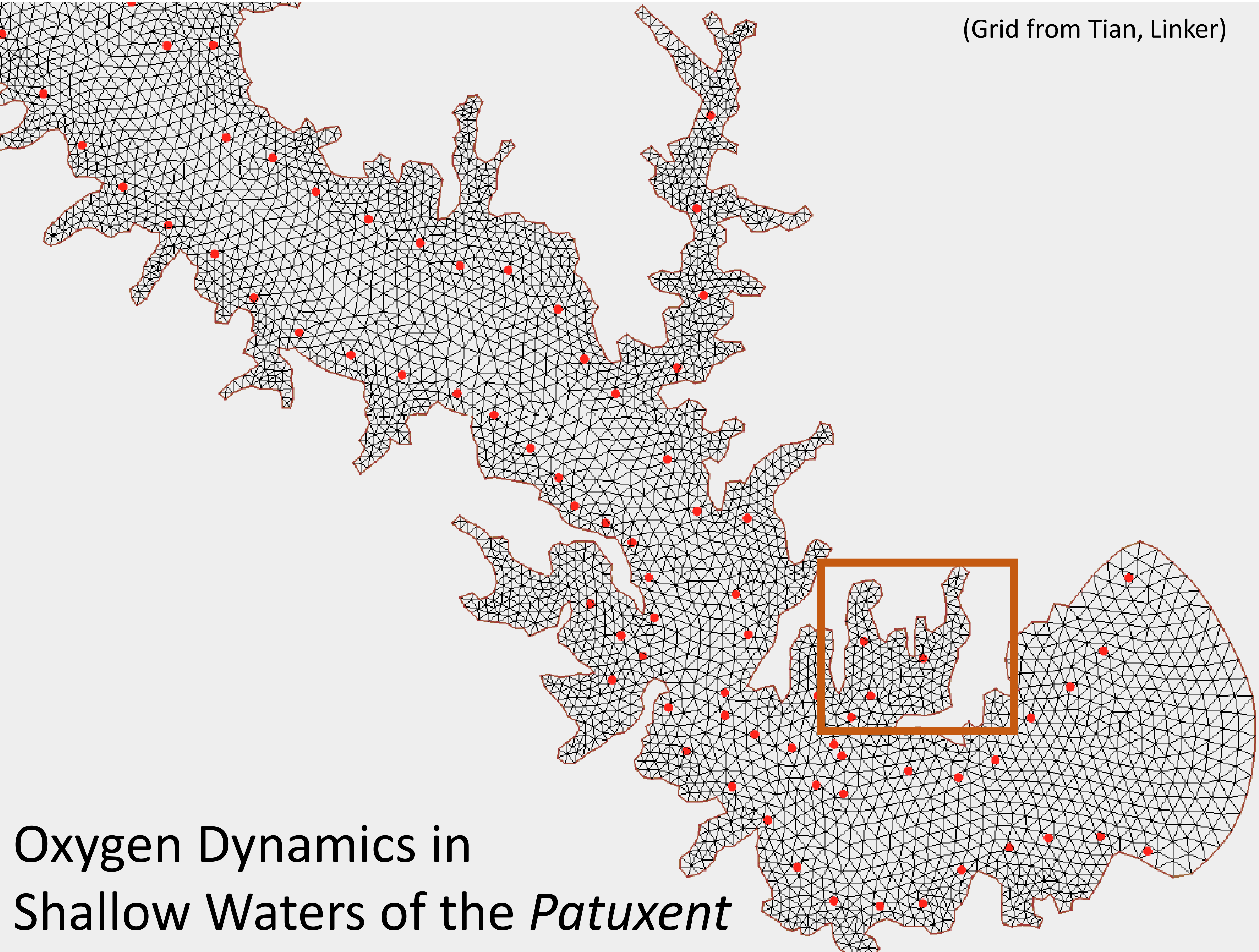
(Ganju et al. 2020.)

Marsh Estuary Exchange and Oxygen Variability
Upper Patuxent

Marsh Estuary Exchange and Oxygen Variability
Upper Patuxent

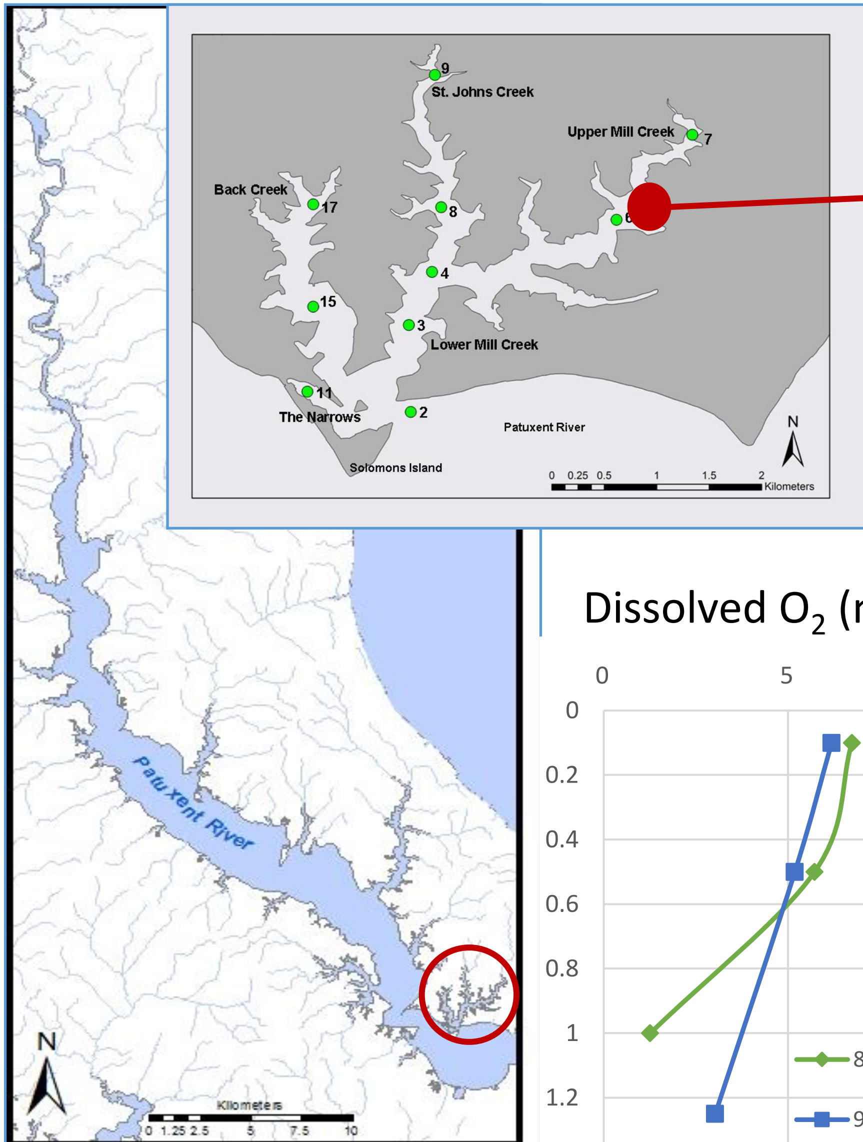


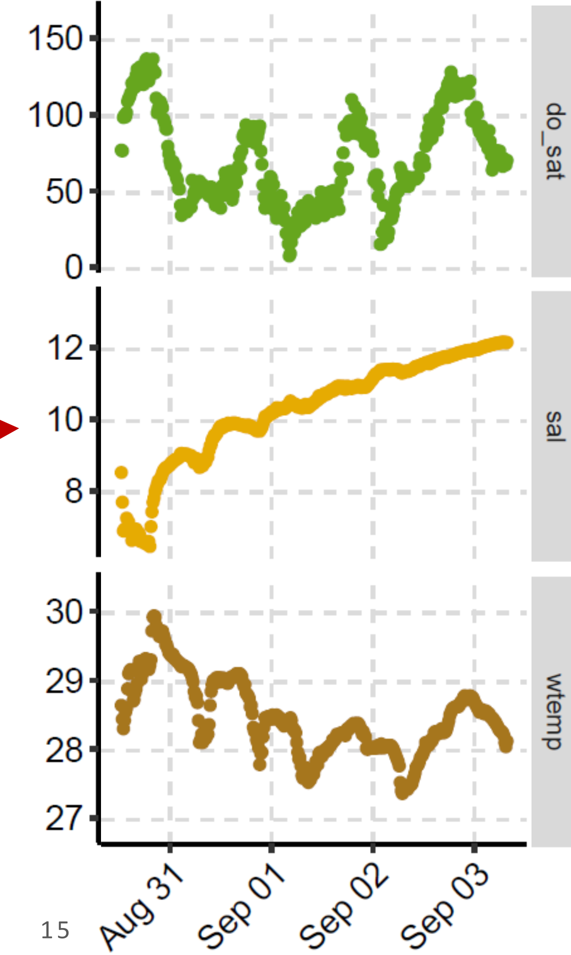
(Testa, Unpubl.)

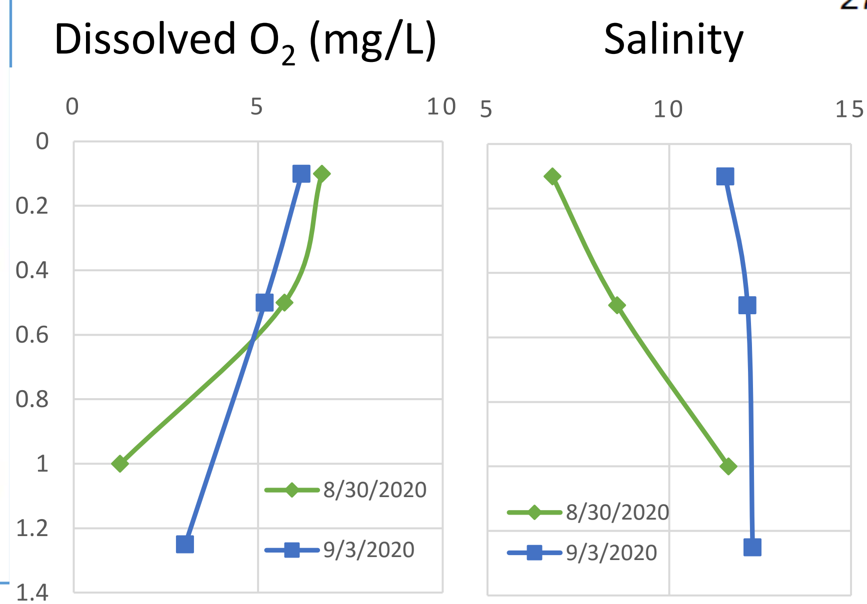


Oxygen Dynamics in Shallow Waters of the *Patuxent*

Episodic Low Oxygen in Shallow Creeks

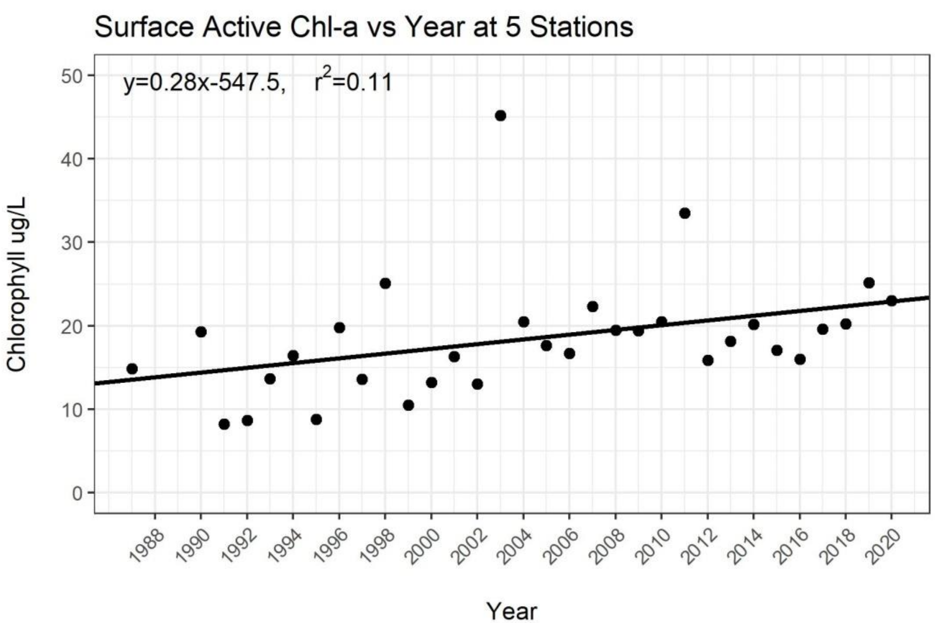


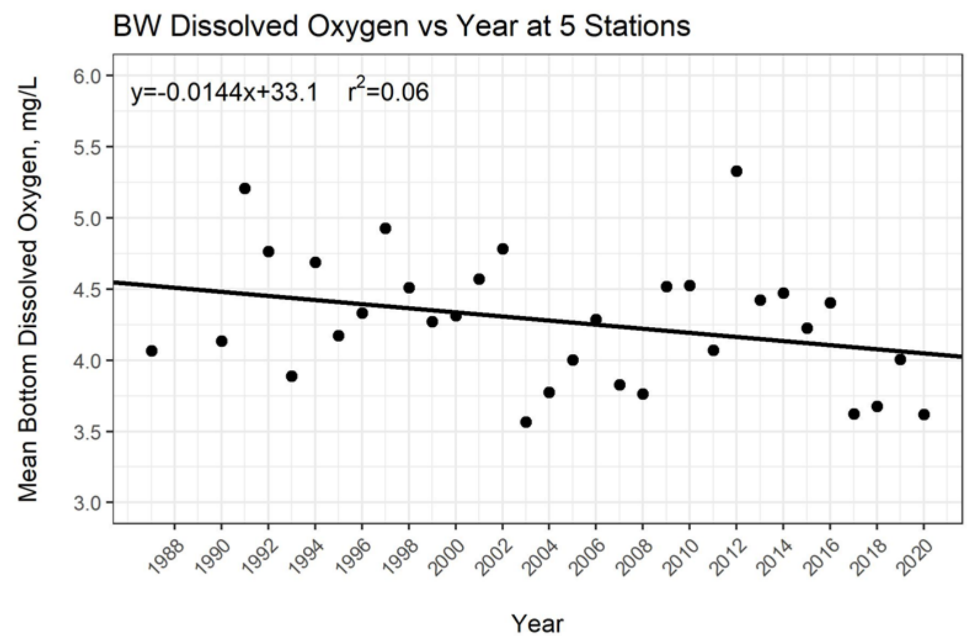




(Testa, Unpubl.)

Looking Ahead: How do we Approach ‘Shallow’ Waters?





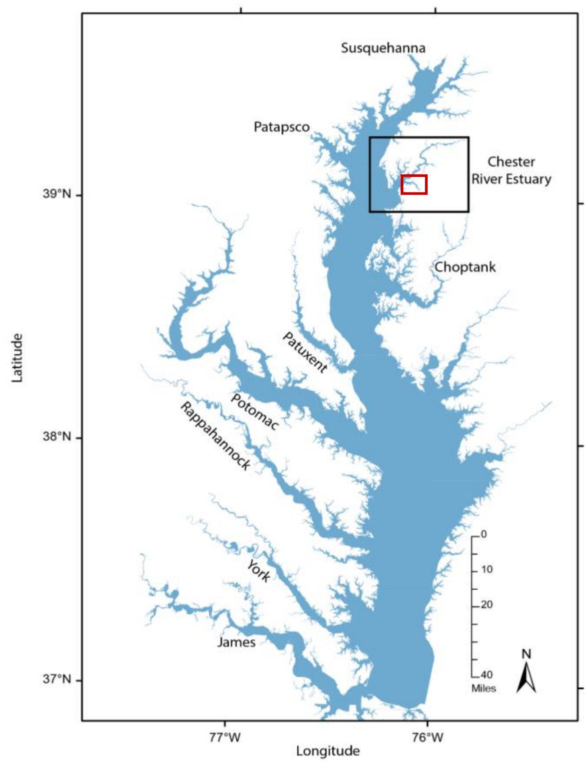
These are long-term patterns, with apparent trends, measured in the deepest part of a ‘shallow’ system

Would a ConMon program have measured this?

(Data from Ehrich et al. 2021.)

Case Study: Numerical Model of a Shallow Water Estuary

Richard Tian, Lewis Linker,
Damian Brady, Jeremy Testa



Why the Corsica River?

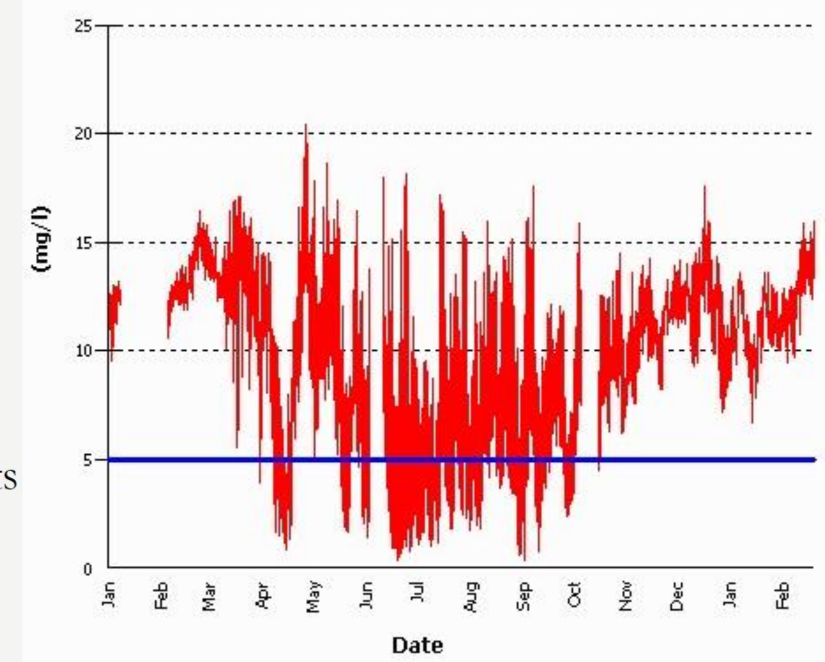
Hypoxia, Fish Kills,
Targeted for Restoration

Photo courtesy of Cal Gray III

CORSICA RIVER TARGETED INITIATIVE

PROGRESS REPORT: 2005-2011

The Corsica River Initiative is nationally recognized for its Watershed Plan and restoration effort that continues to receive attention for its outstanding contributions in research, monitoring and implementation.



Why the Corsica River?

Nutrient Load Declines

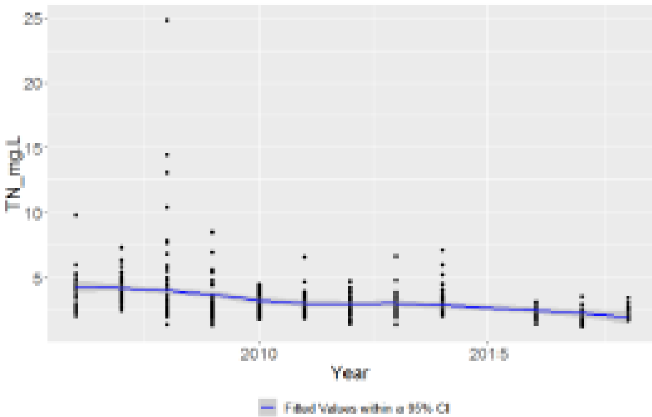


Figure 10. LOESS curve fitted to composite samples of total nitrogen (TN) concentration in Gravel Run (GVL).

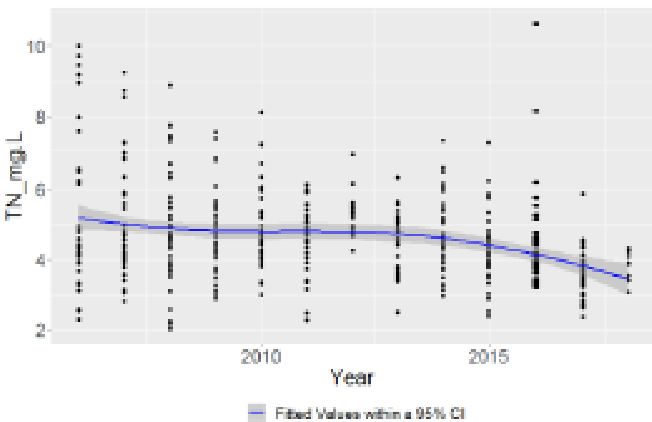


Figure 11. LOESS curve fitted to composite samples of total nitrogen (TN) concentration in Old Mill Stream (OMS).

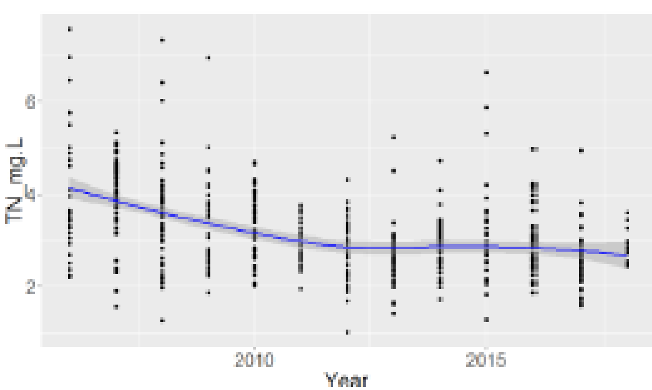


Figure 12. LOESS curve fitted to composite samples of total nitrogen (TN) concentration in Three Bridges Branch (TBB).

(Wallace 2019)

Why the Corsica River?

Nutrient Load Declines

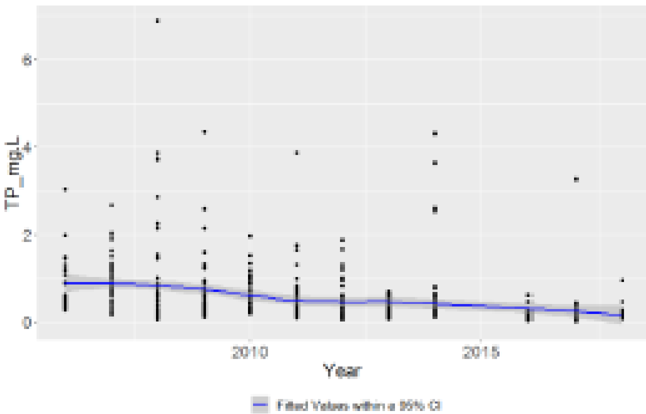


Figure 17. LOESS curve fitted to composite samples of total phosphorus (TP) concentration in Gravel Run (GVL) for the period 2006 to 2018.

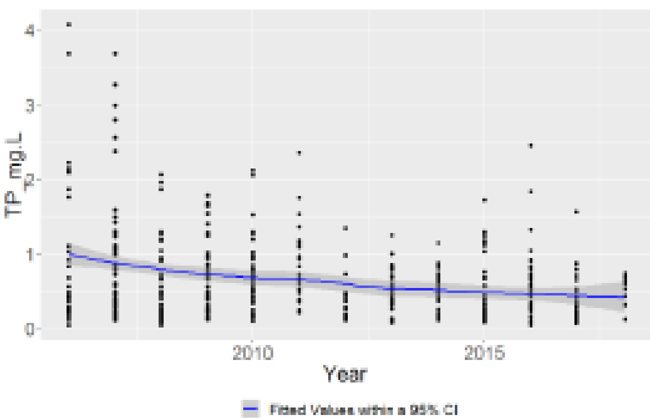


Figure 18. LOESS curve fitted to composite samples of total phosphorus (TP) concentration in Old Mill Stream (OMS) for the period 2006 to 2018.

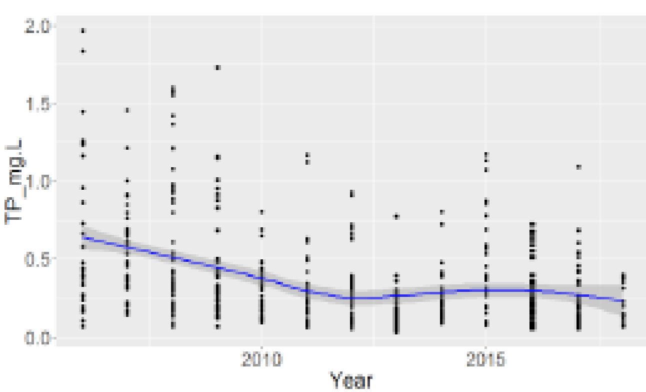
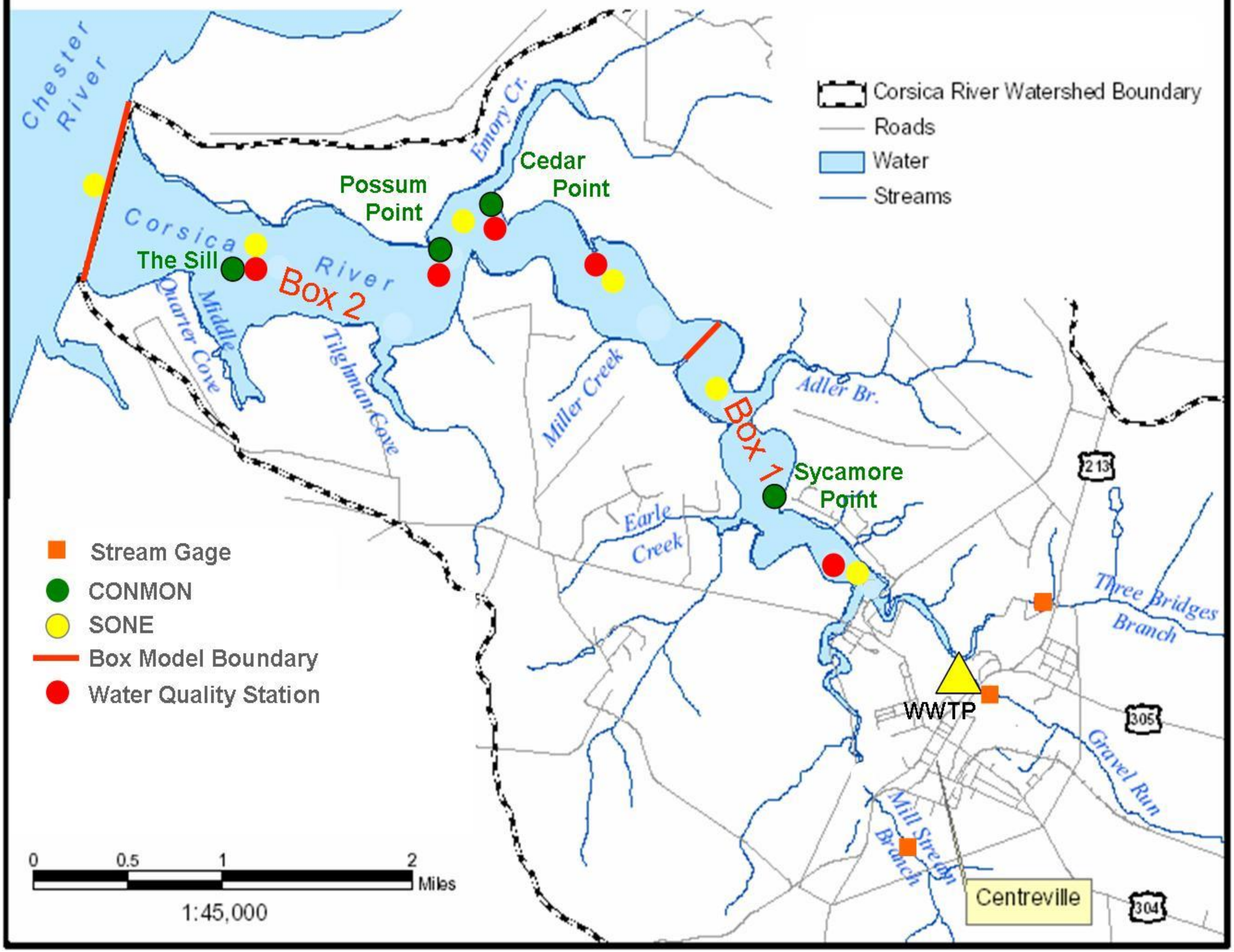


Figure 19. LOESS curve fitted to composite samples of total phosphorus (TP) concentration in Three Bridges Branch (TBB) for the period 2006 to 2018.

(Wallace 2019)

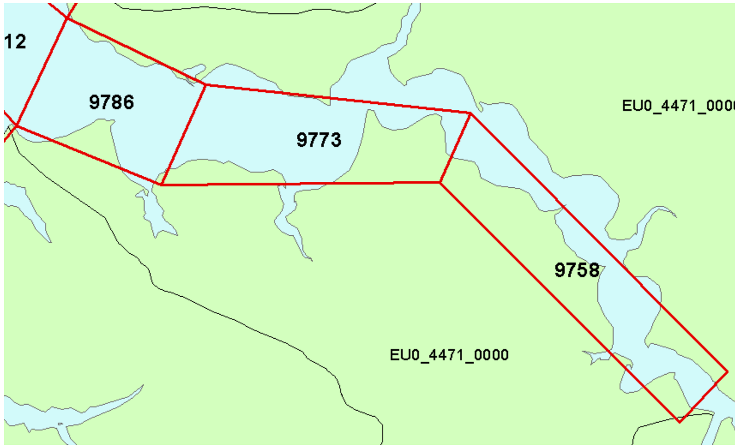
Corsica River and Key Features (map courtesy DNR)



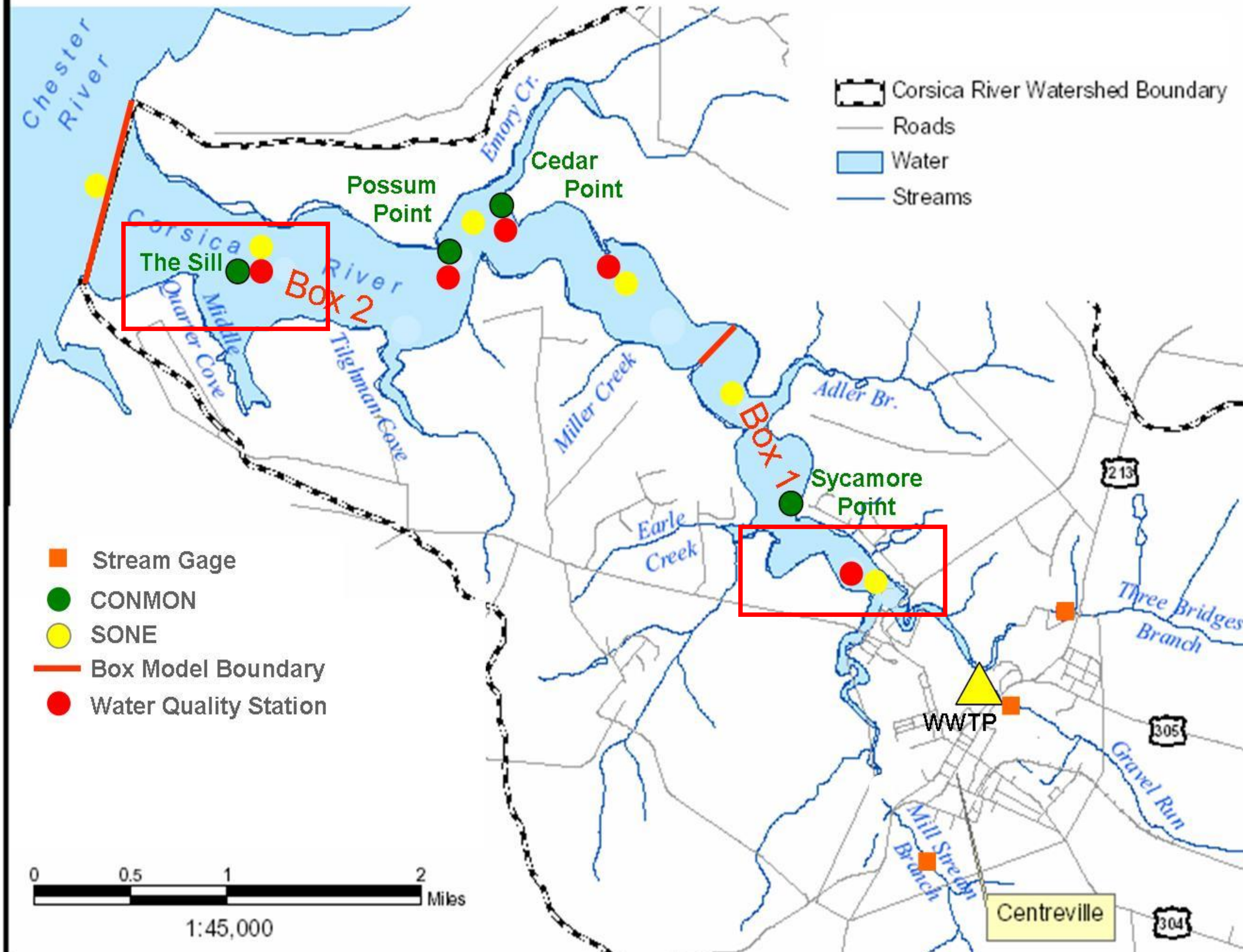
Corsica Model Grid

SCHISM-ICM

- 20m resolution on coast, 100m at the mouth;
- 5029 cells, 5 layers
- Simulation year = 2006
- Phase 5.3 Watershed Model Loads

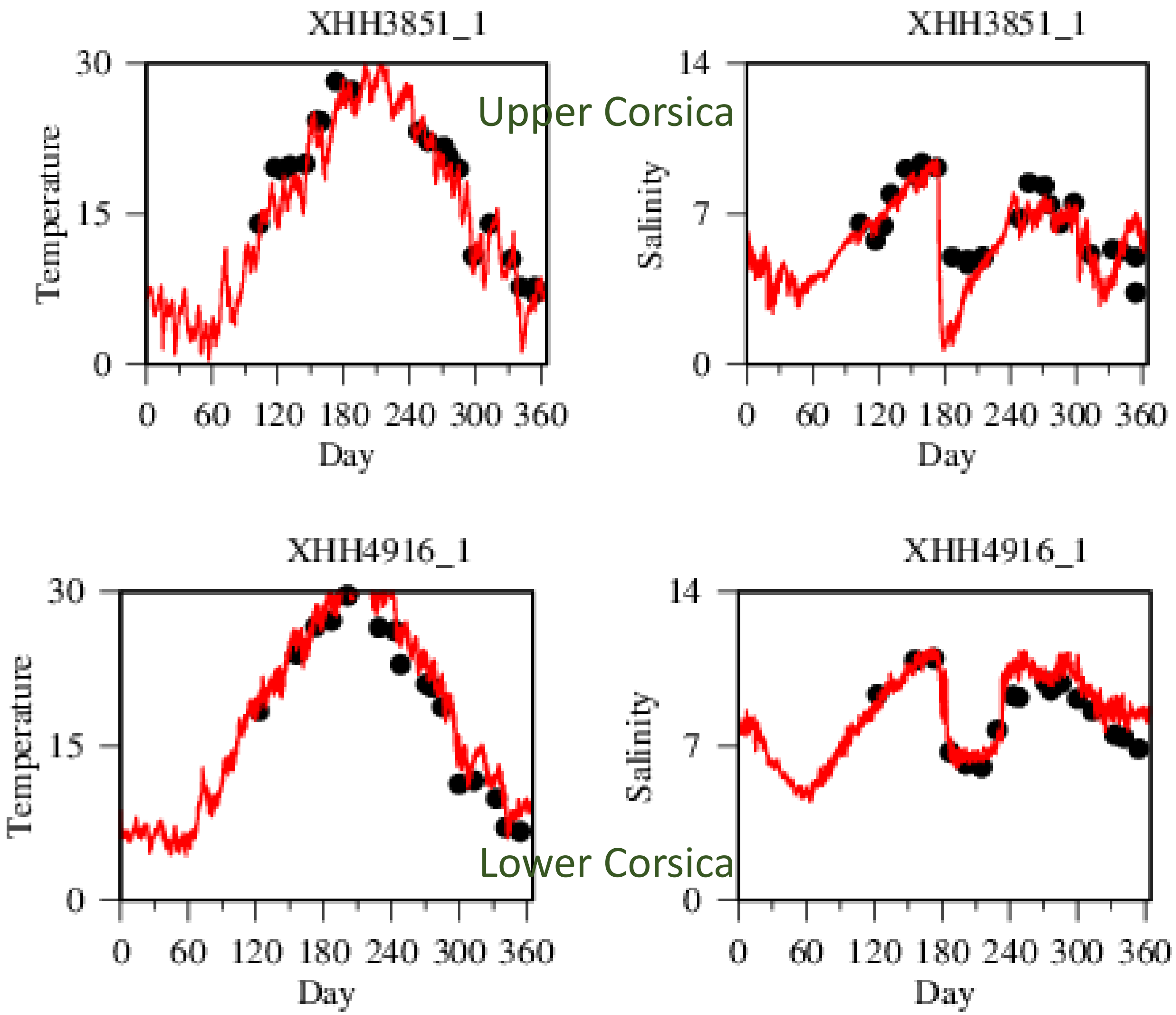


Corsica River and Key Features (map courtesy DNR)

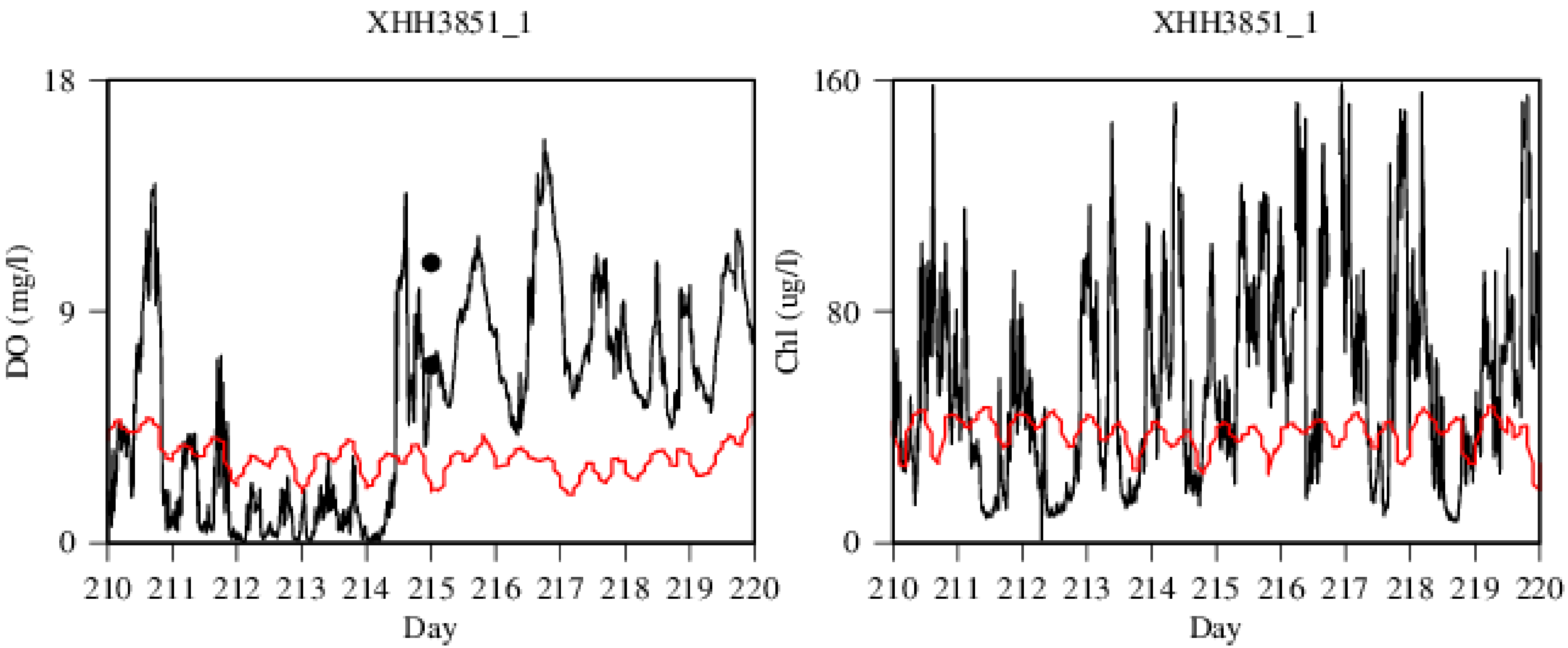



Old Fertilizer Plant
Basin with restricted flow that receives input from 2/3 major streams

Case Study: Validation of Water Temperature, Salinity, DO

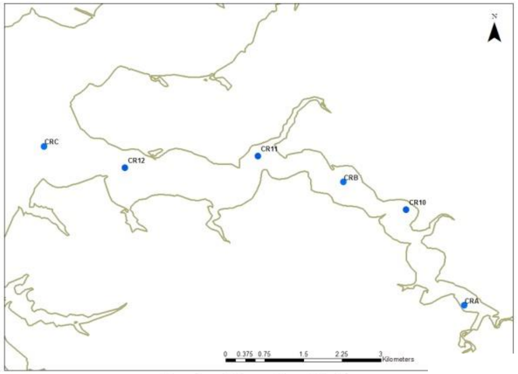


Short-Term Variation in Model *Underestimates* Observations

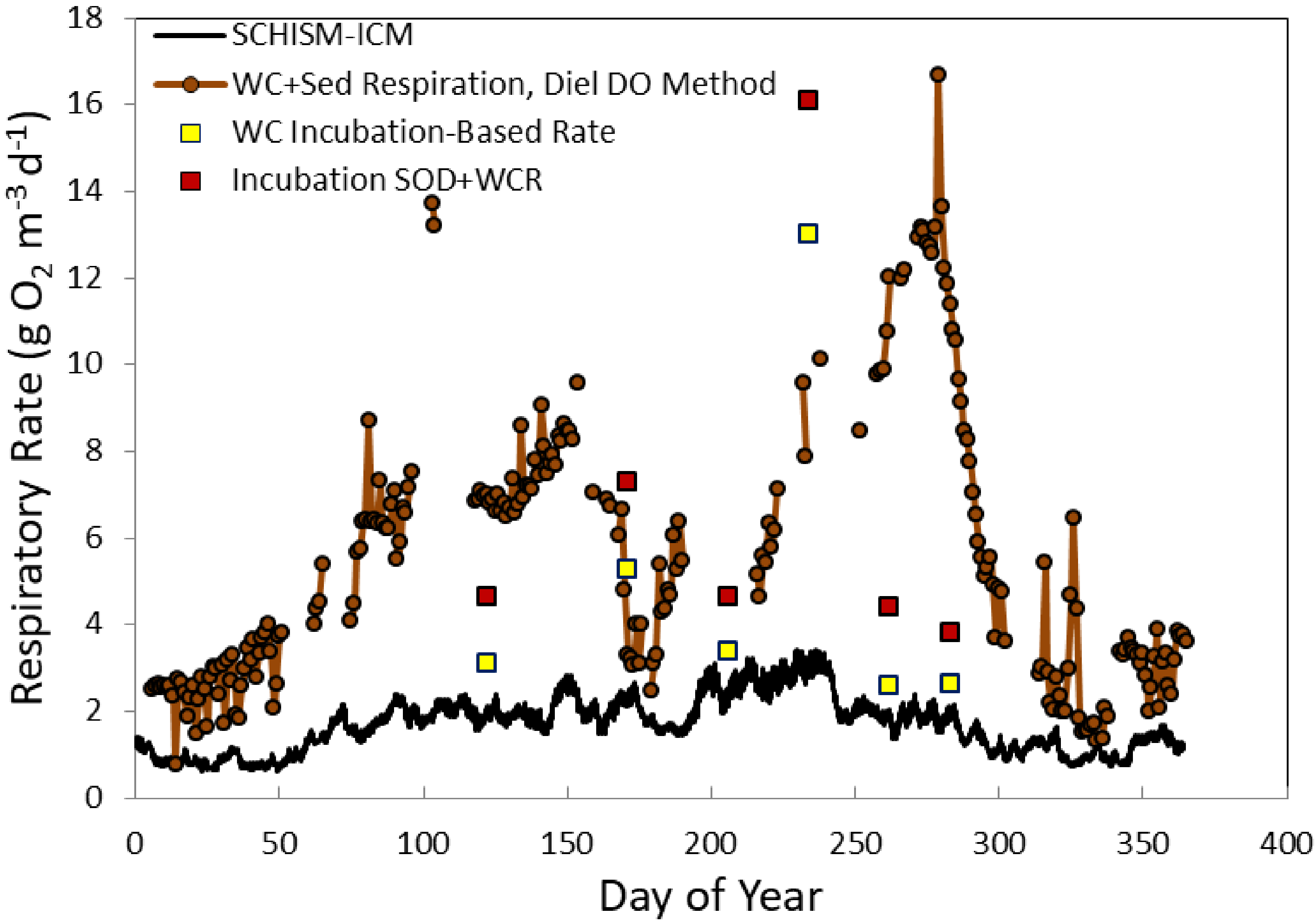


Model *Underestimates* Overall O_2 consumption

<u>Consistent with missed O_2 Variability</u>



Corsica River Flux Stations



Looking Ahead

(a) Is natural variability in PAR adequately forced on the model at short enough (~hour) time steps?

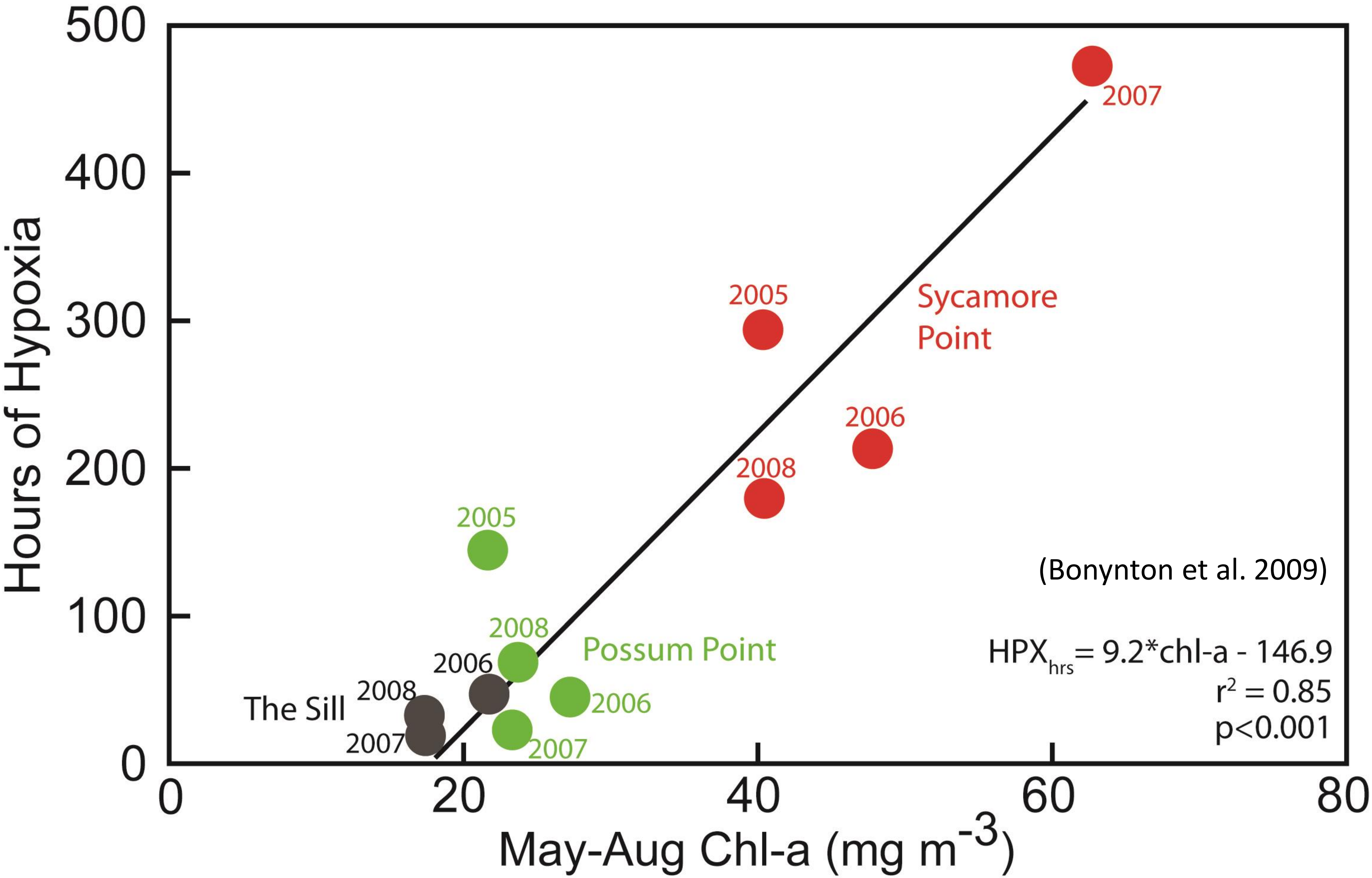
(b) Do the metabolic rates of primary production and respiration computed within the model agree with the substantial rates derived from observations?

(c) Is wind-stress properly applied in protected shallow tributaries, given most wind products are based on larger scales?

(d) Will fine-scale watershed model inputs be necessary to represent fine-scale effects of freshwater inputs to shallow waters and their associated circulation effects?

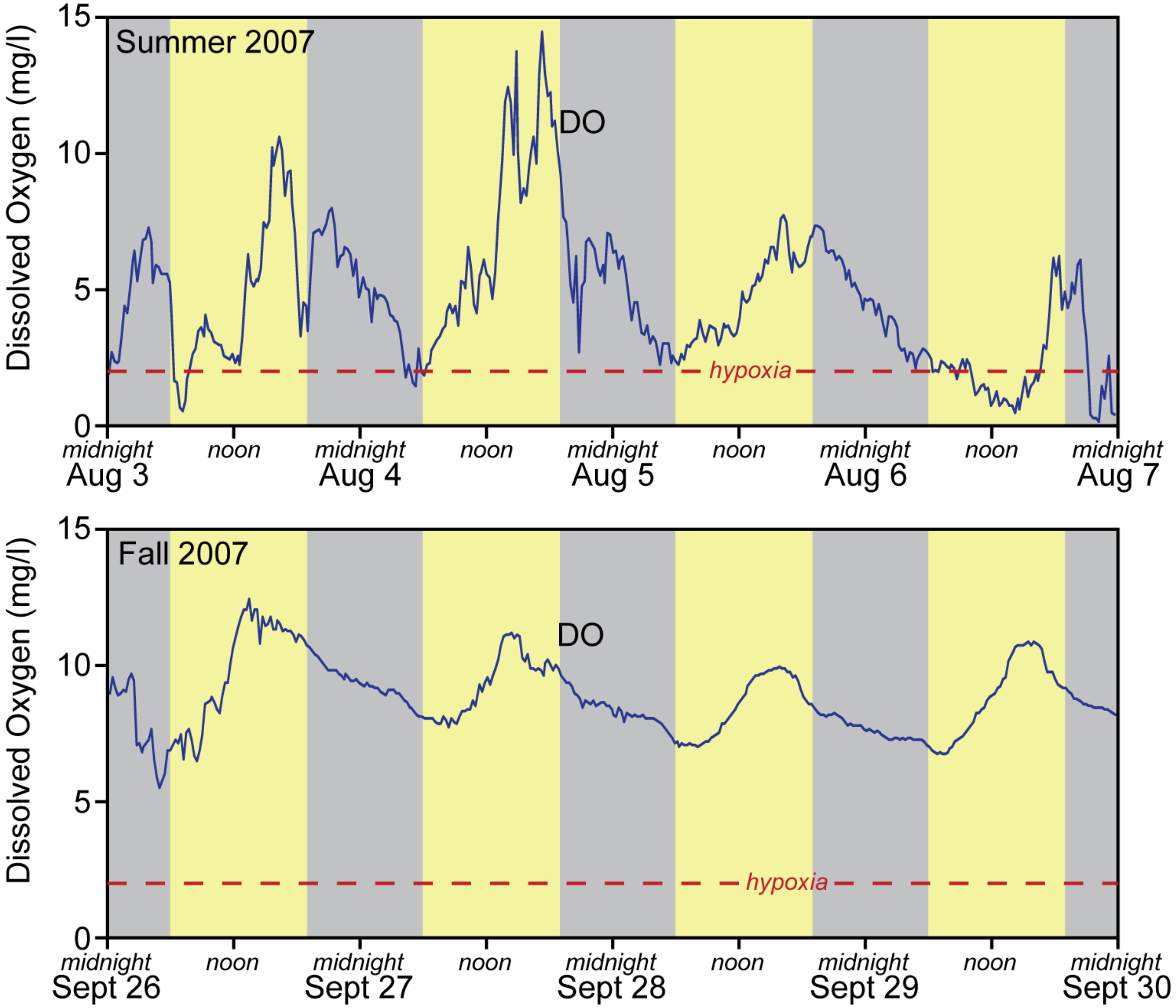
(e) many more……

Duration of Diel Cycling Hypoxia and Chlorophyll



Again, both spatial and inter-annual components of this relationship

Why the Corsica River? Dissolved O_2 Reaches Hypoxia at Night



Inter-Annual and Spatial Changes in CHL-a