Estuaries as microbial bioreactors: relationships between organic matter, bacterial productivity, and microbial diversity in the Columbia River Estuary

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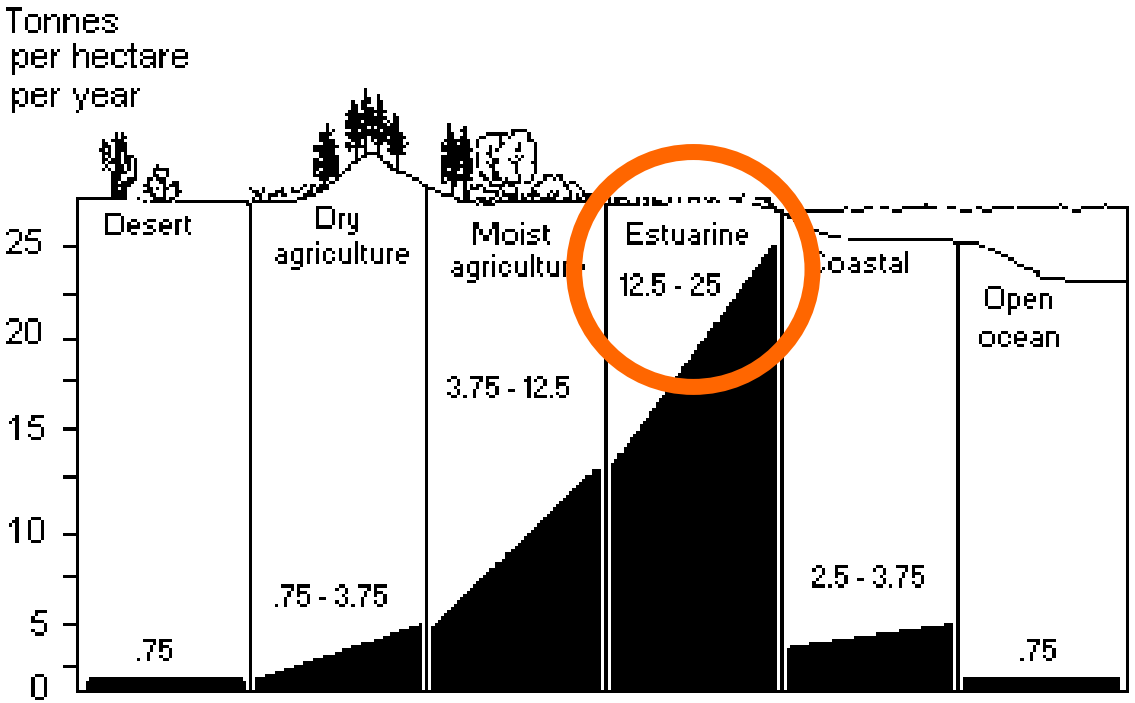
CMOP
Center for Coastal Margin Observation & Prediction

Estuaries are population centers

- Nearly 50% of the U.S. population live near estuaries
- Human populations have flourished around estuaries and deltas since they were formed by sea level rise 5K-10K years ago

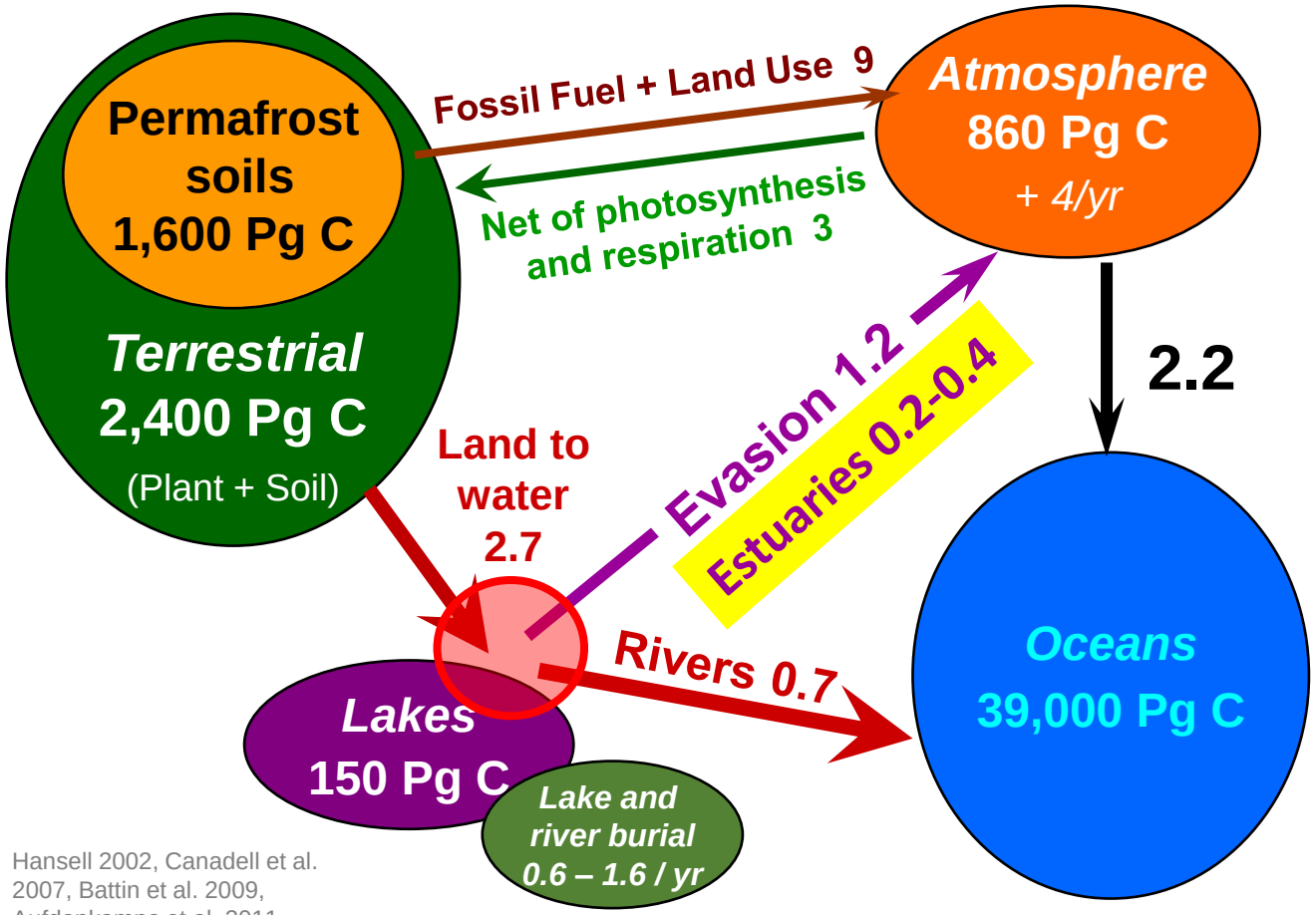
Estuaries!

- Highly biologically productive



Biological productivity

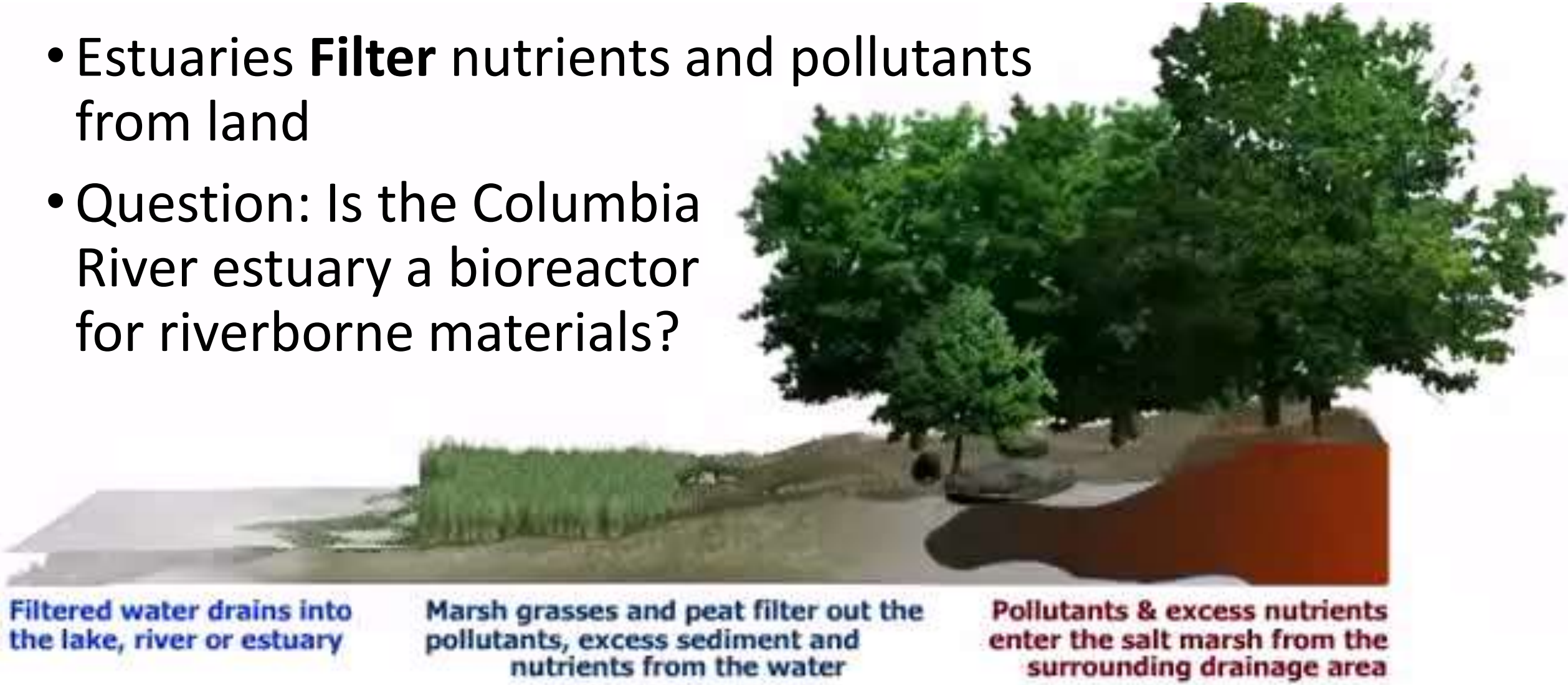
- Key for global carbon cycle



Hansell 2002, Canadell et al. 2007, Battin et al. 2009, Aufdenkampe et al. 2011, Tarnocai et al. 2009, Batjes 1996, Kling et al. 1991, Cai 2011

Estuaries as bioreactors

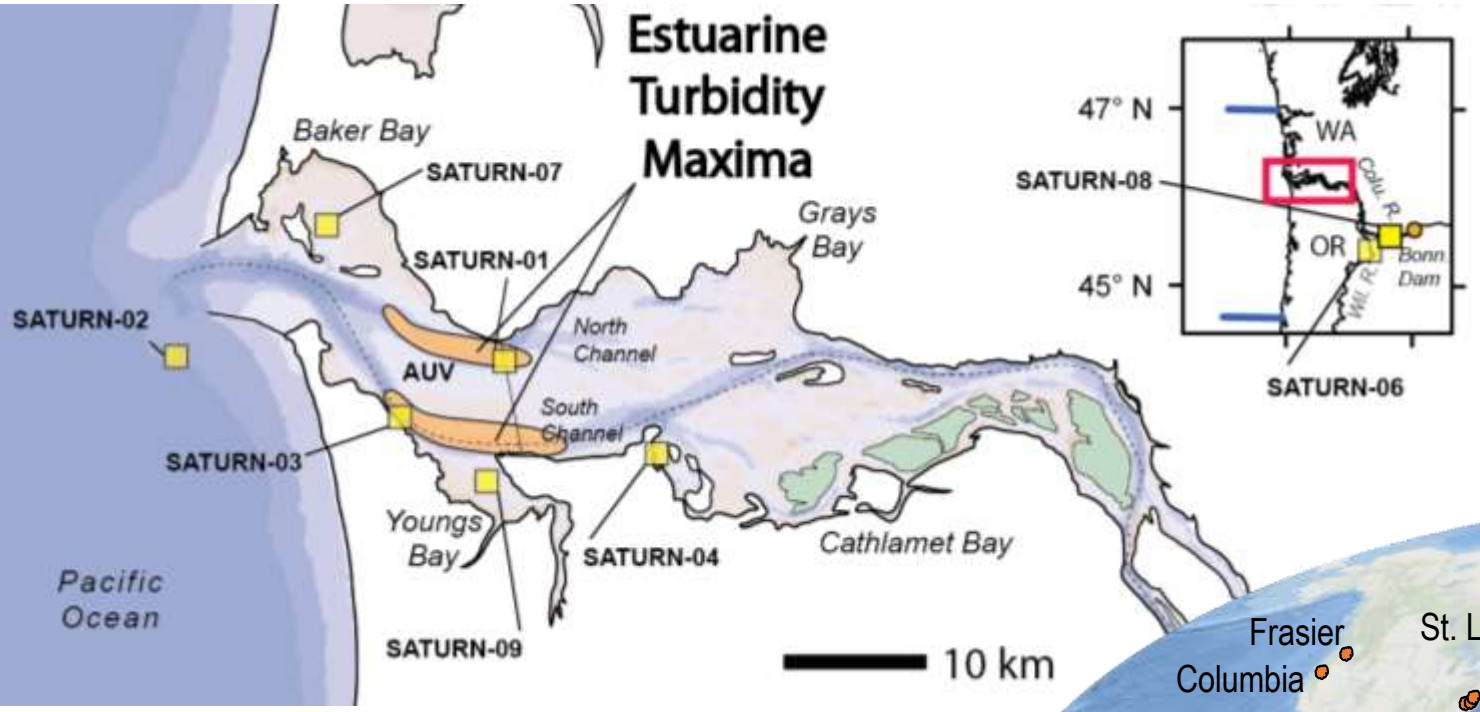
- Estuaries **Filter** nutrients and pollutants from land
- Question: Is the Columbia River estuary a bioreactor for riverborne materials?



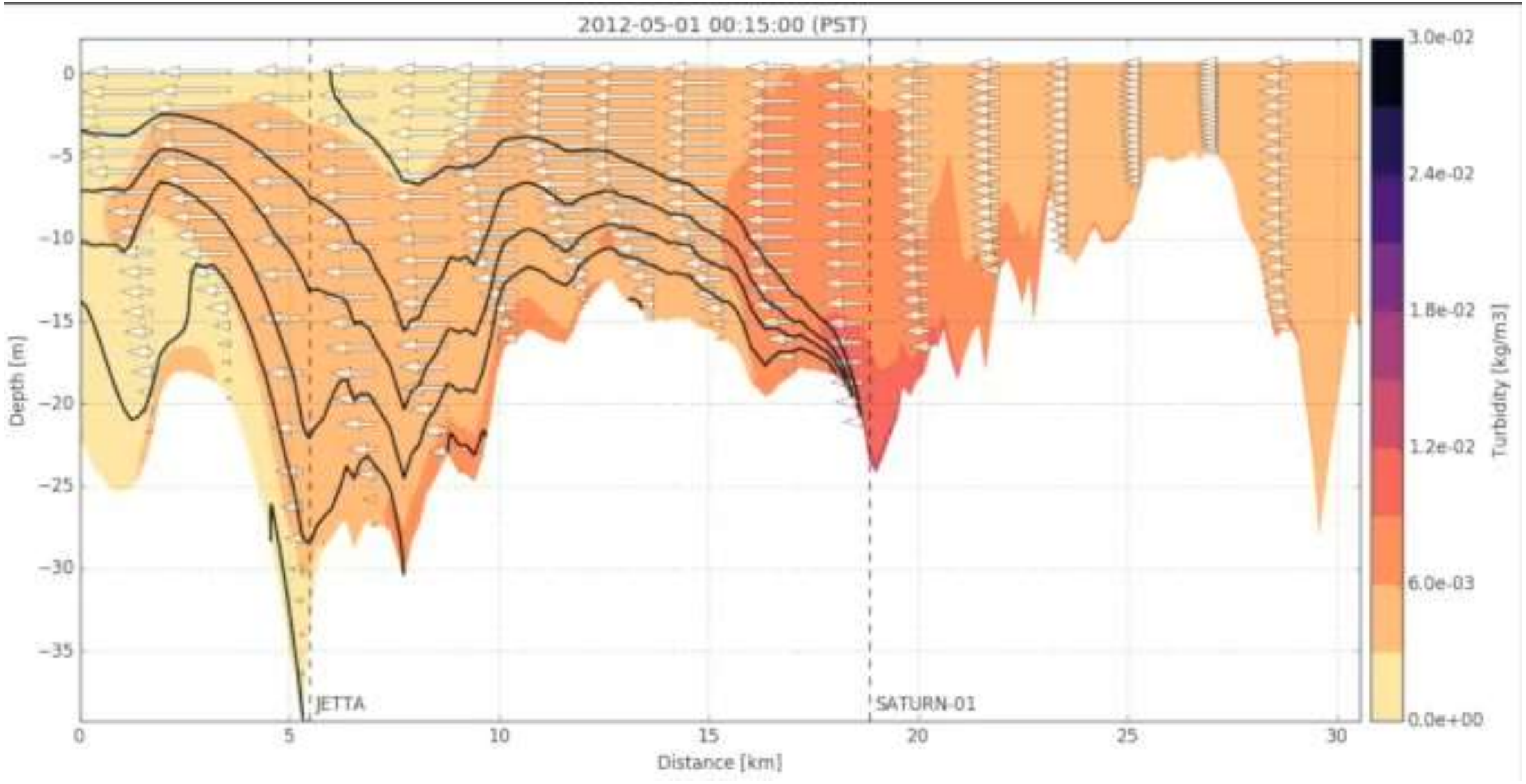
http://oceanservice.noaa.gov/education/kits/estuaries/media/supp_estuar03a_marsh.html

Estuarine Turbidity Maxima

- Physical definition: Persistent turbid region near the head of salinity intrusion in estuaries created by several physical processes.
- Biogeochemical definition: Persistent turbid regions that enhance particle degradation & accelerate organic matter respiration

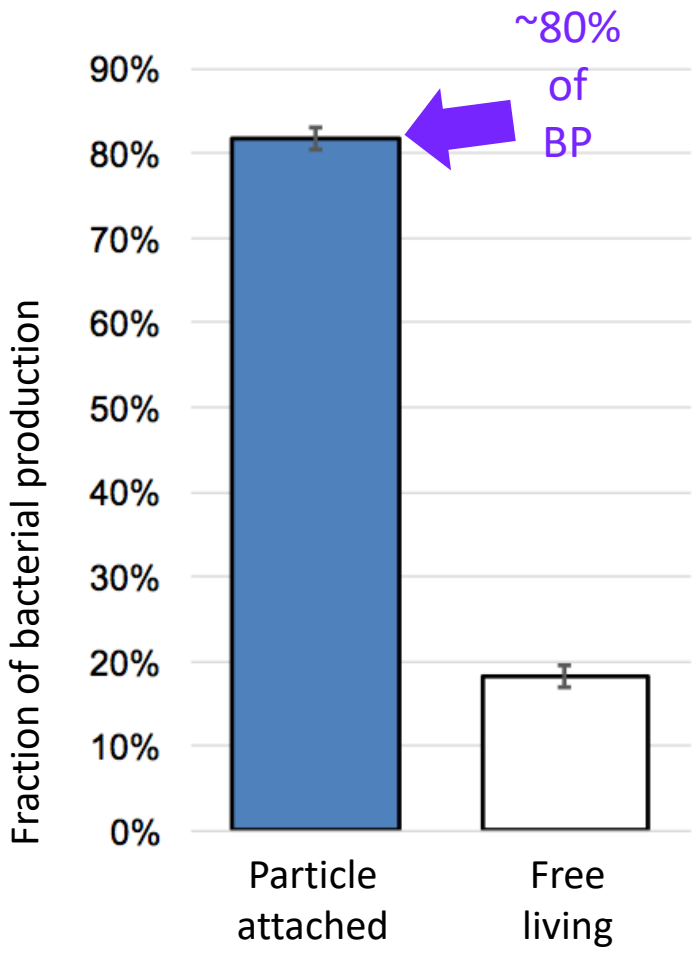


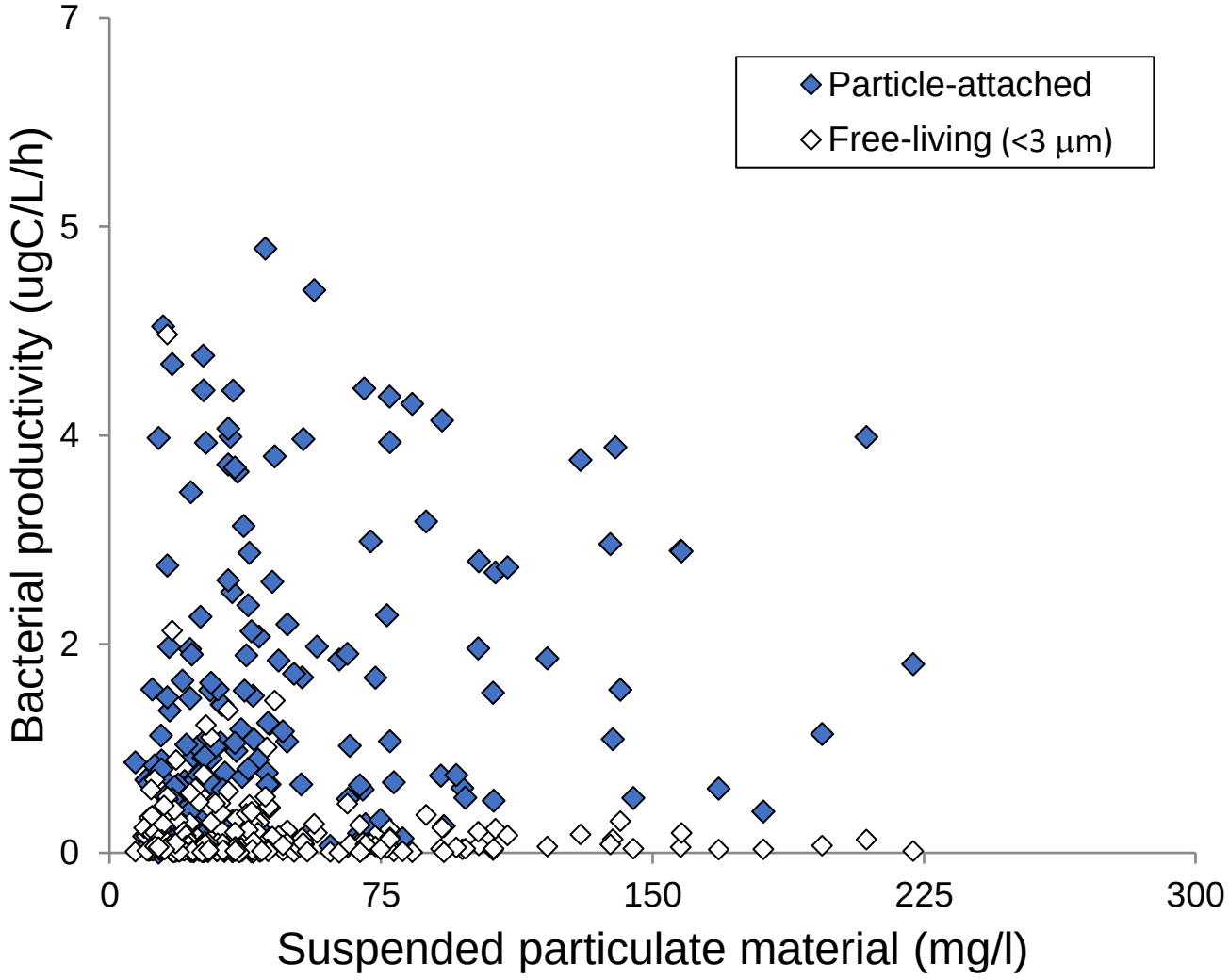
ETM animation - model



Bacterial productivity

Particle-attached bacteria dominate bacterial productivity (BP)





(Turbidity)

LMER dataset (1992-1999)

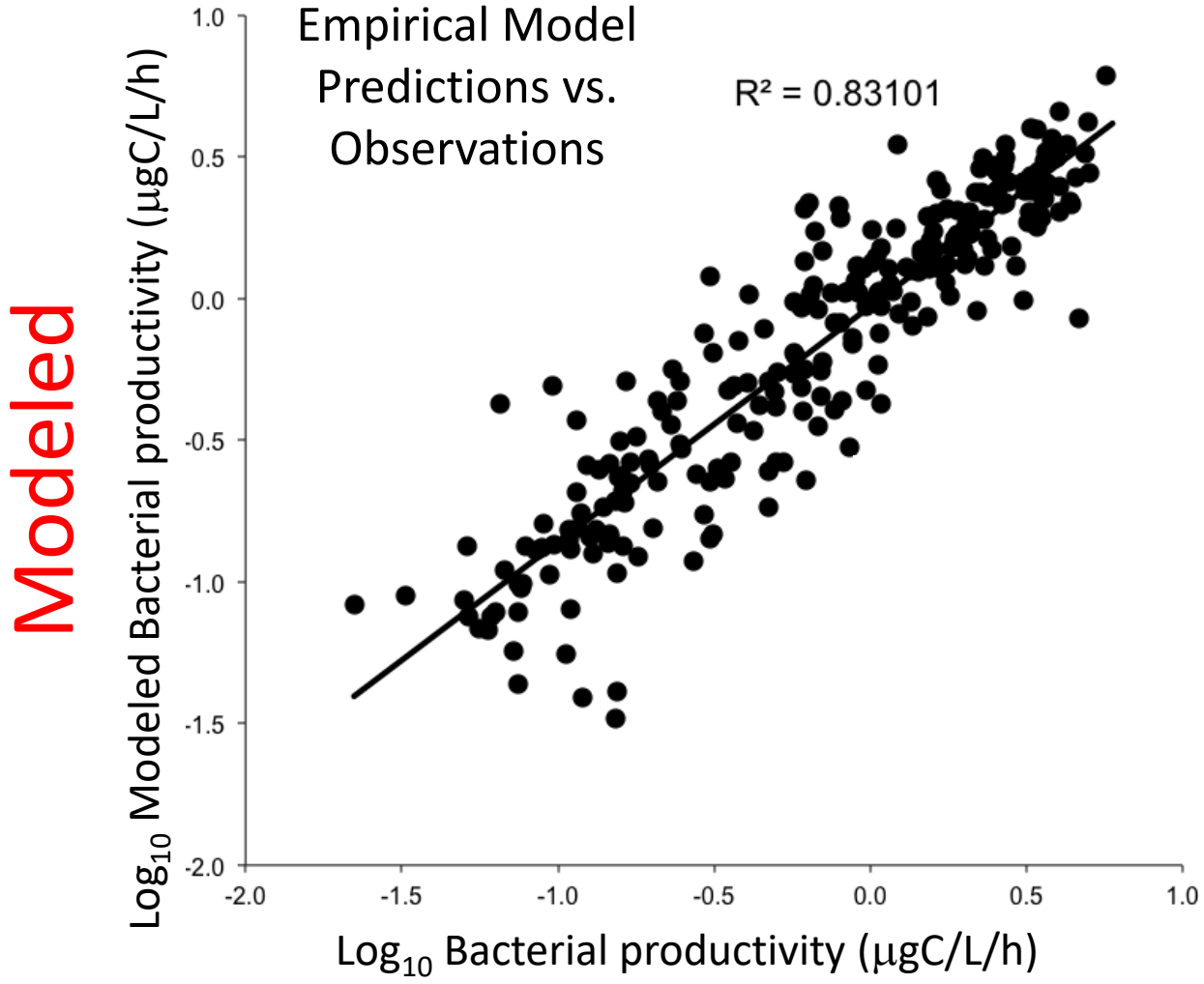
Bacterial productivity model

Quadratic regression model predicted Bacterial Productivity from:

- Turbidity
- Temperature
- Intermediate salinity
- River chlorophyll *a*

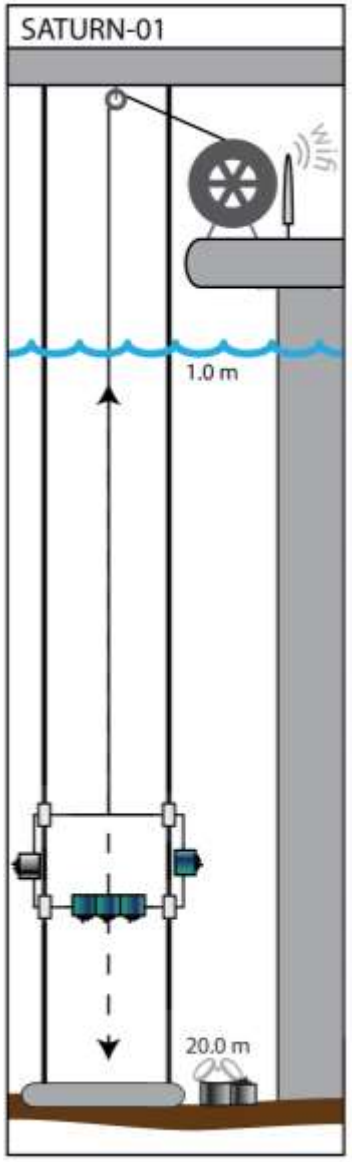
Suggests BP depends on

- Particle concentration
- Organic matter quality

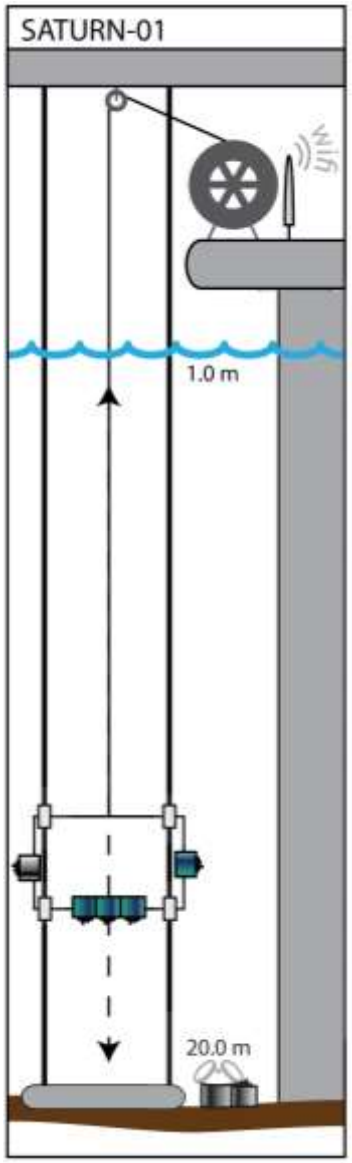


Crump et al. (2017)

Predicting Bacterial Productivity



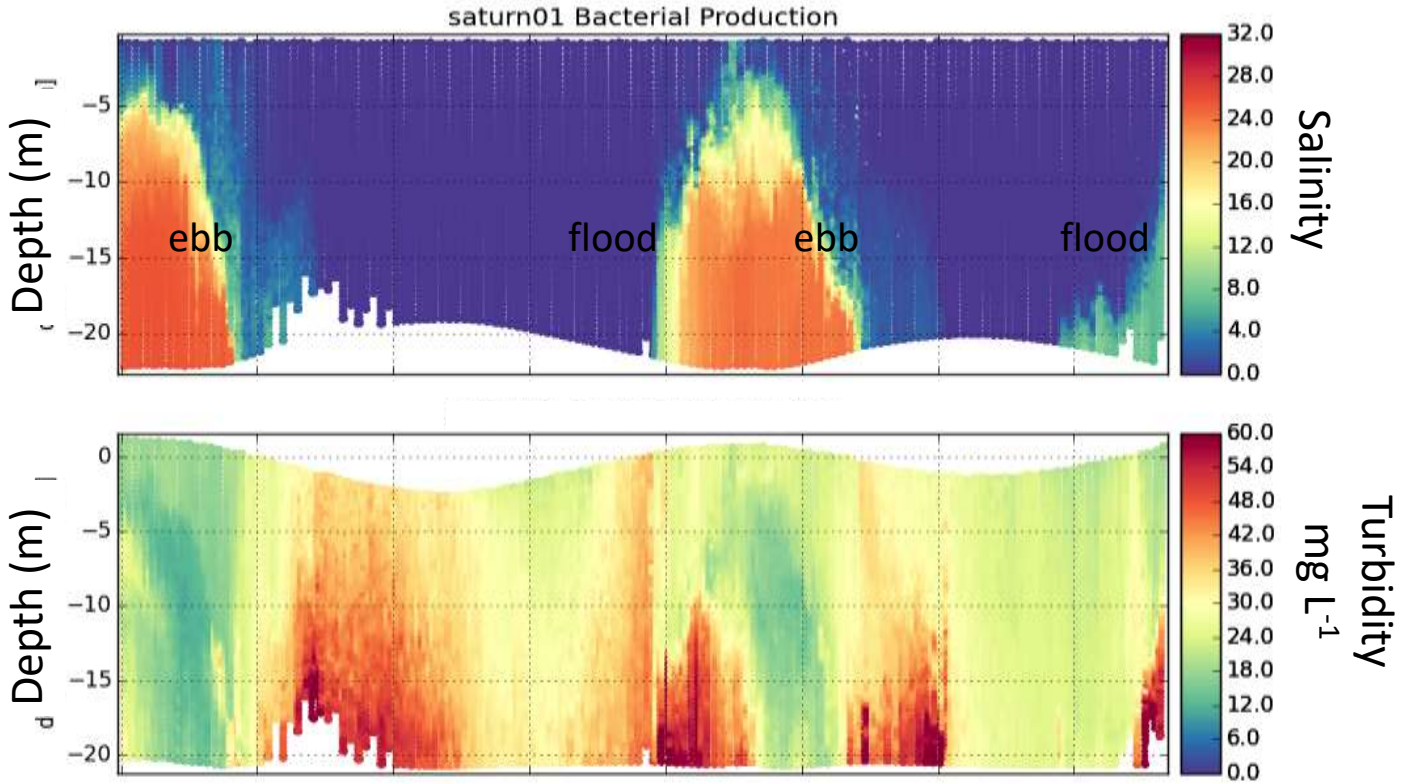
ETM trapping ~ doubles BP in summer



Salinity

Turbidity

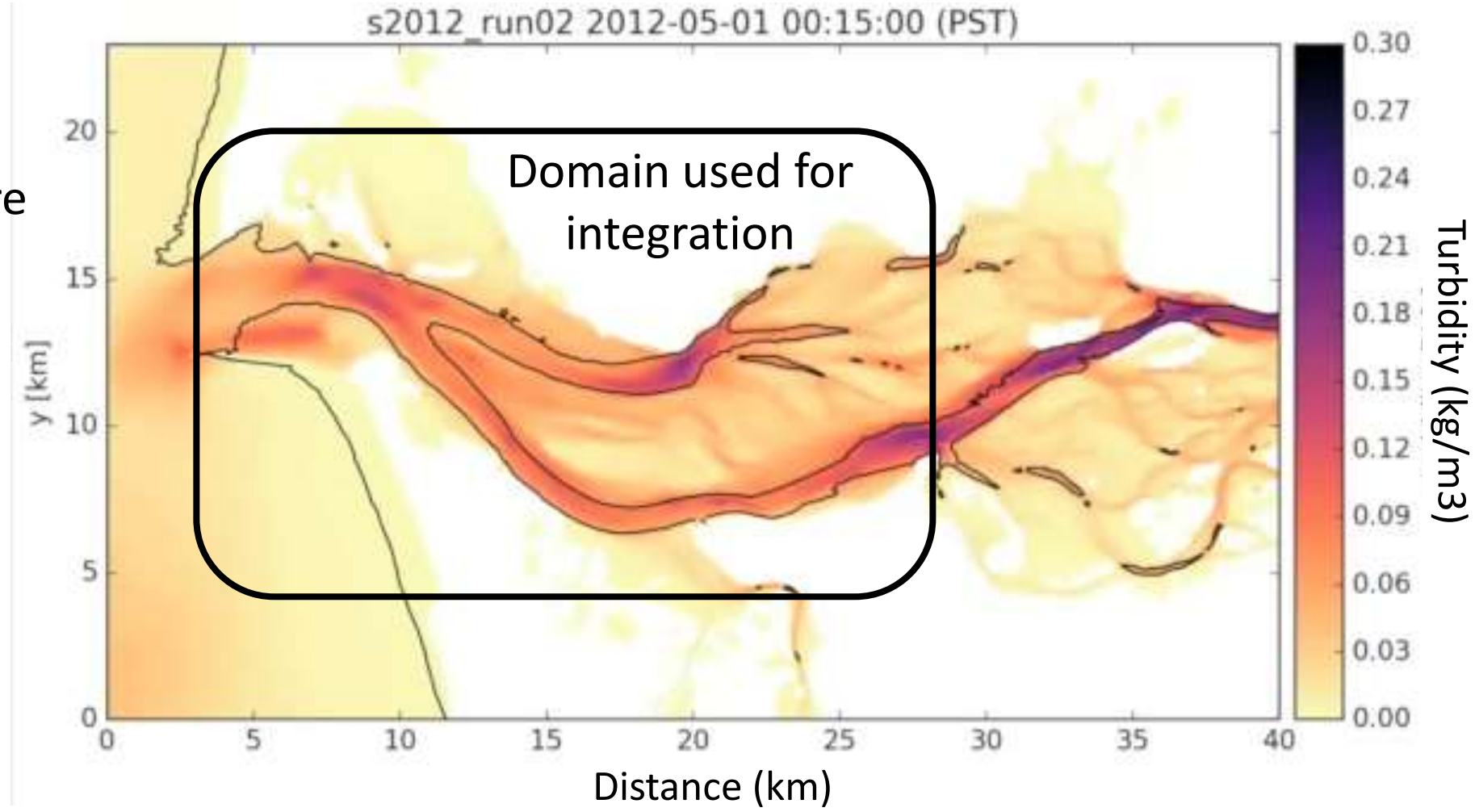
Modeled BP
with no ETM



Daily integrated model results for 2012

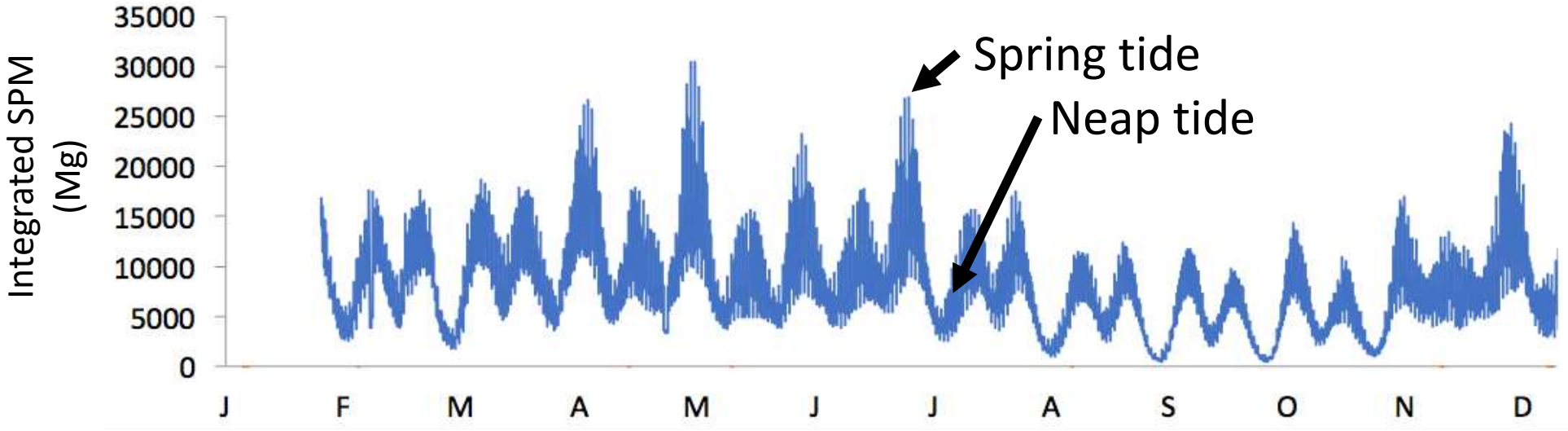
Calculated hourly integrated BP from:

- Modeled temperature
- Modeled salinity
- Modeled turbidity
- Measured river chlorophyll

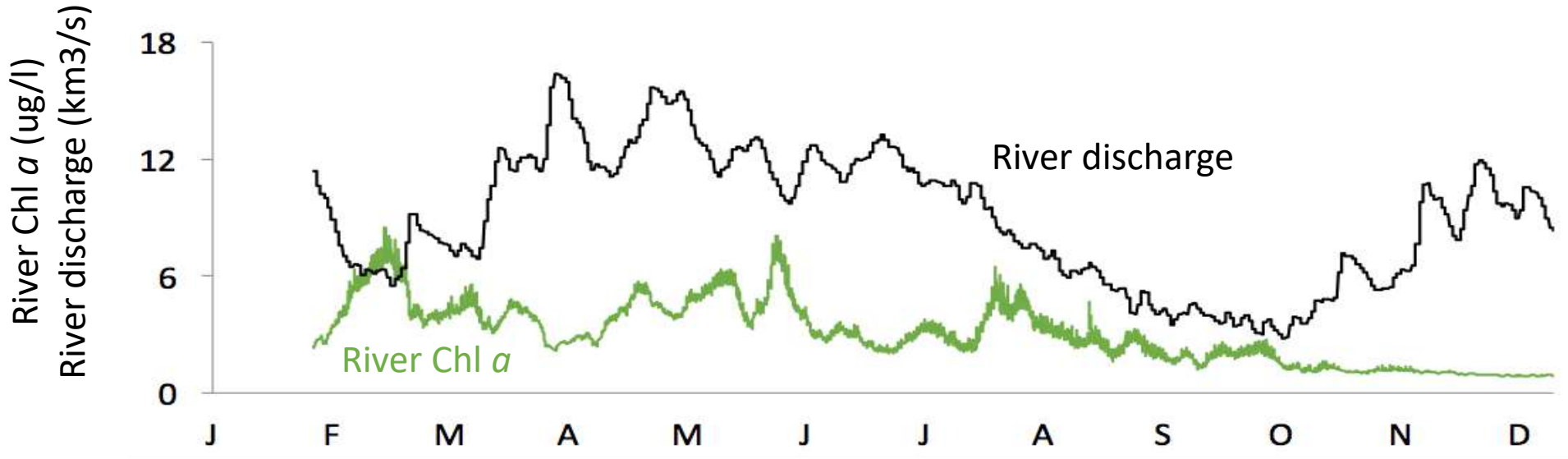


Suspended particle mass and river chlorophyll *a*

Suspended particle mass ranges from: 1000 tons to 30,000 tons



Chlorophyll *a*: Peaked in Feb., March, and July



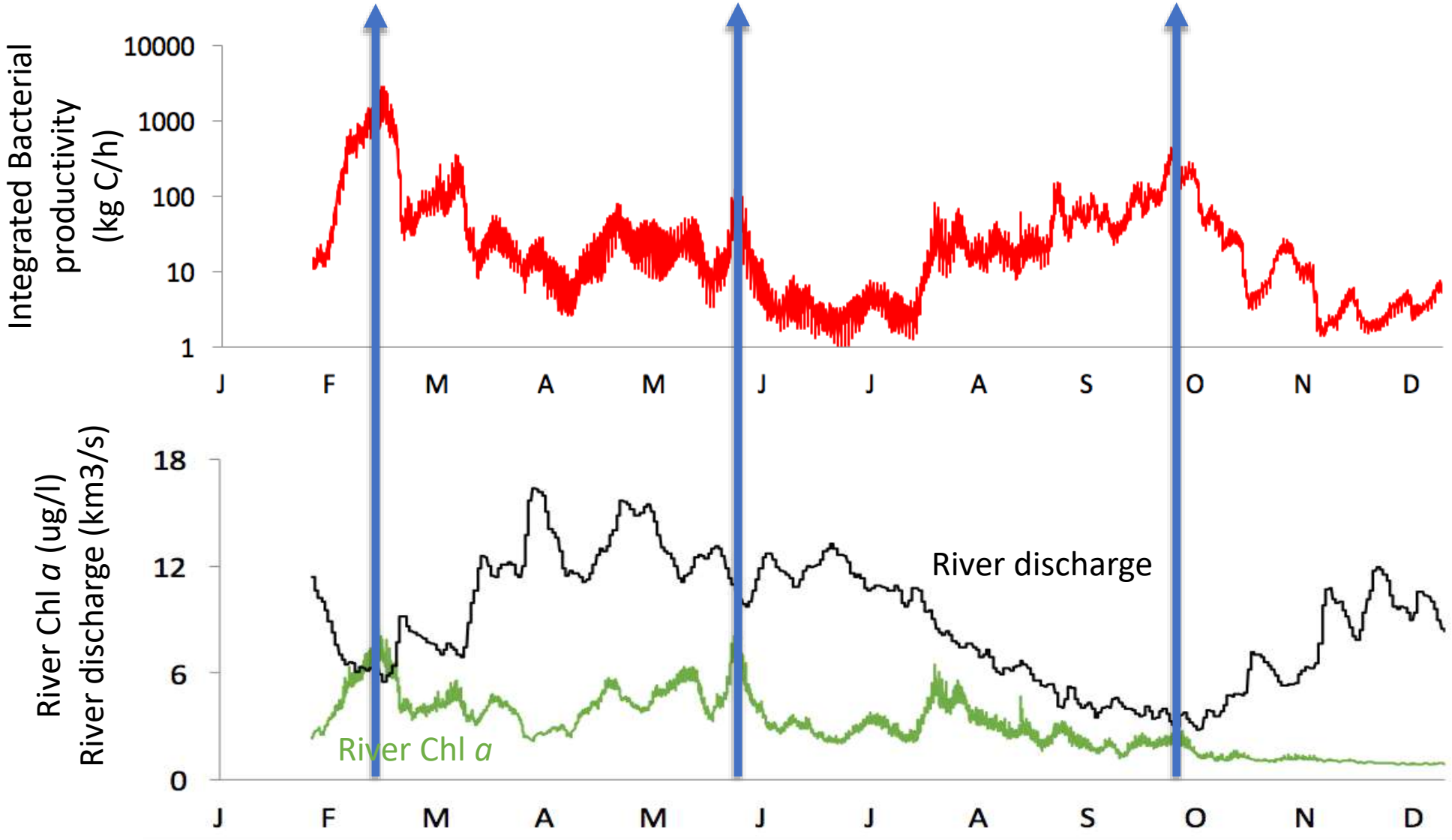
Integrated bacterial productivity

Feb. = Peak BP
High chl *a*
Low discharge

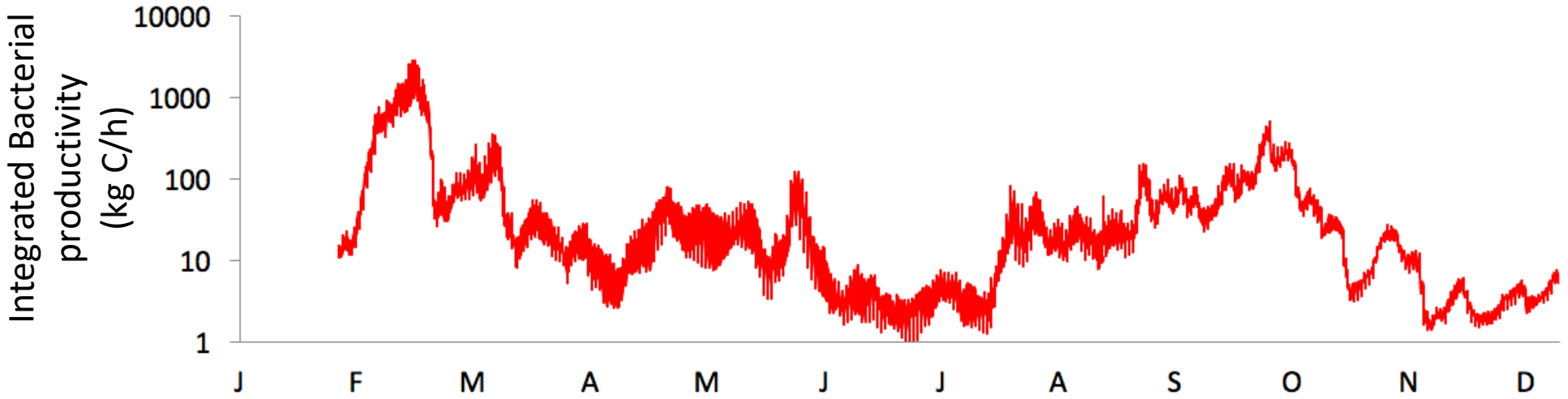
Spring = lower BP
High chl *a*
High discharge

Fall = High BP
Lower chl *a*
Low discharge

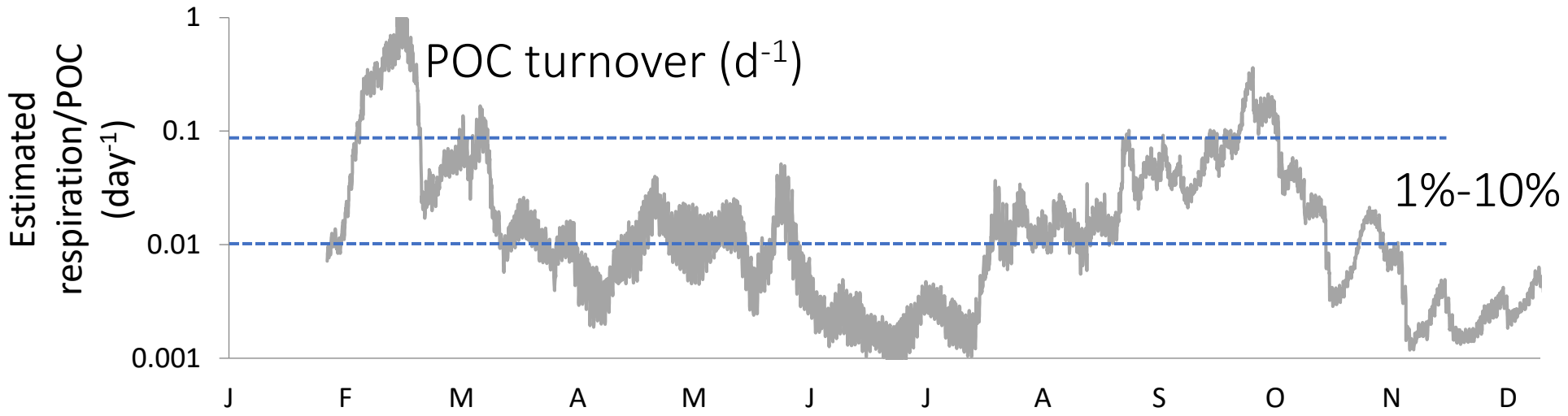
Integrated Bacterial productivity ranged from:
<10 kgC/h to
>1000 kgC/h



Organic matter turnover time



Respiration = BP x 10



Conclusions

- Particle trapping in ETM can double bacterial productivity
- Bacterial productivity is enhanced during periods of low river discharge and high particle trapping
- Is the Columbia River ETM a bioreactor for riverborne materials?
  - Yes - especially when river discharge is low and chlorophyll is high
  - ETM bacteria respire 1% to 10% of river particulate organic matter annually

CMOP Team ETM

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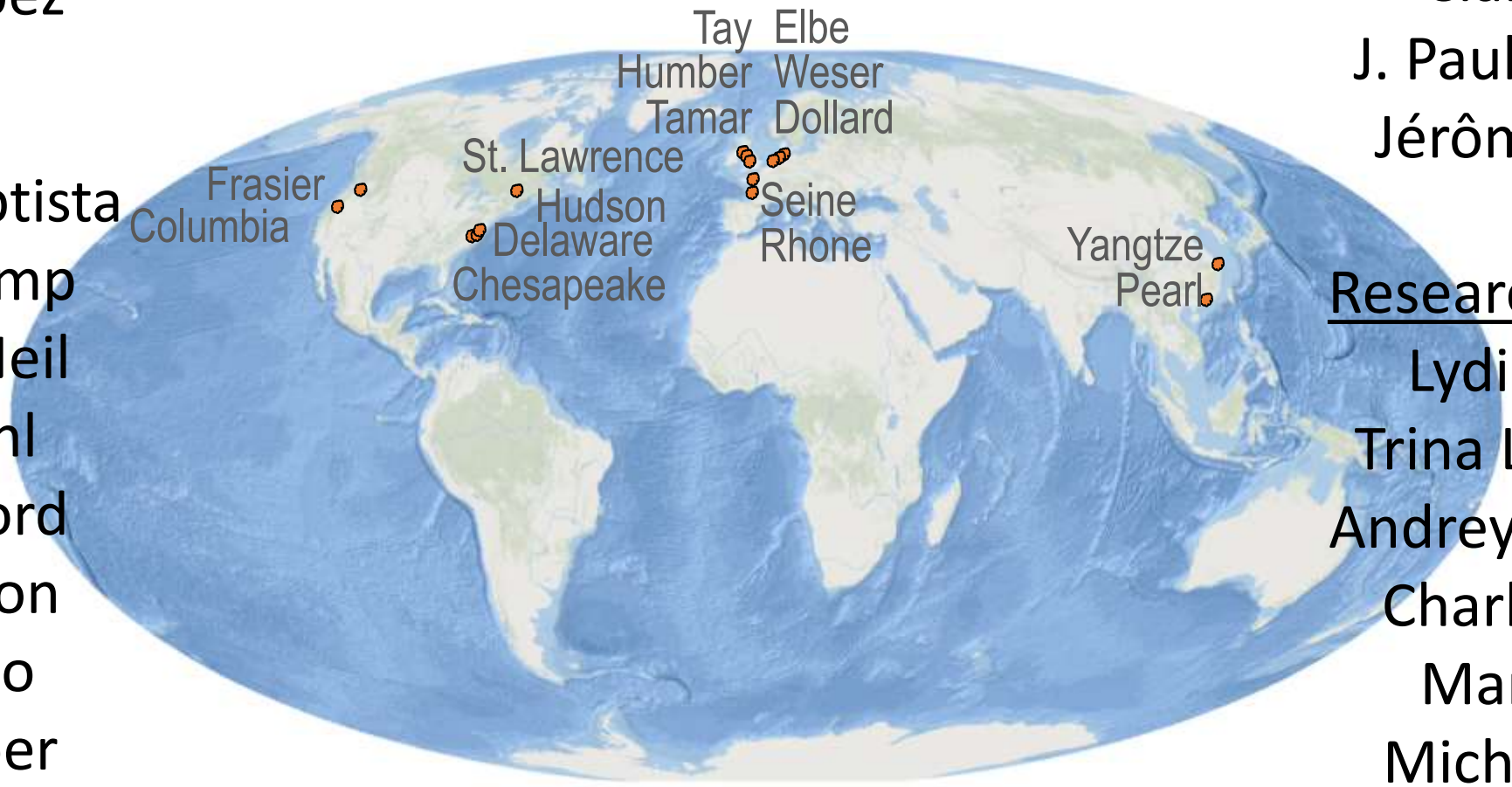

Post docs

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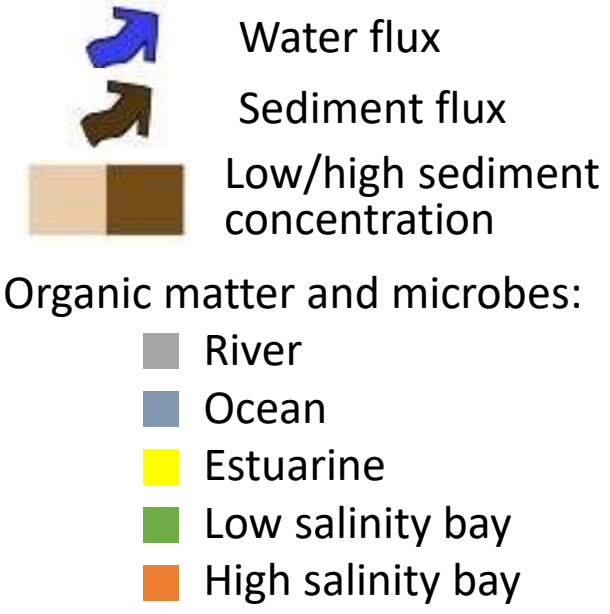
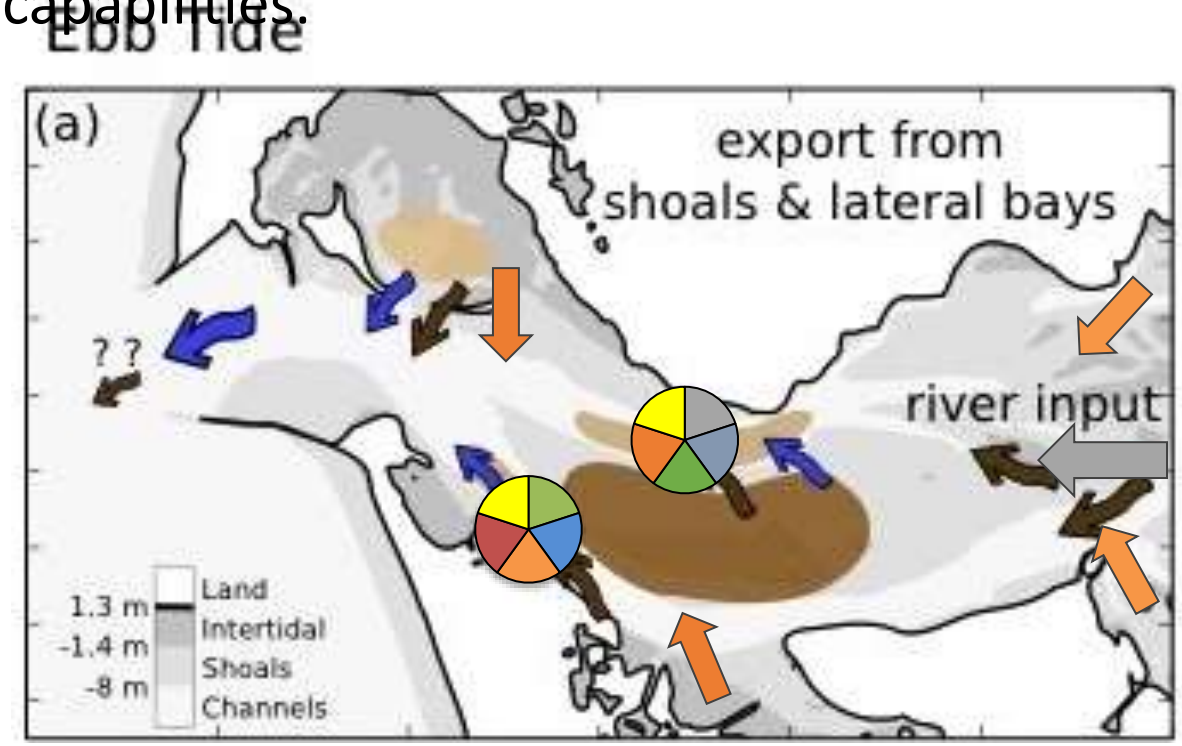
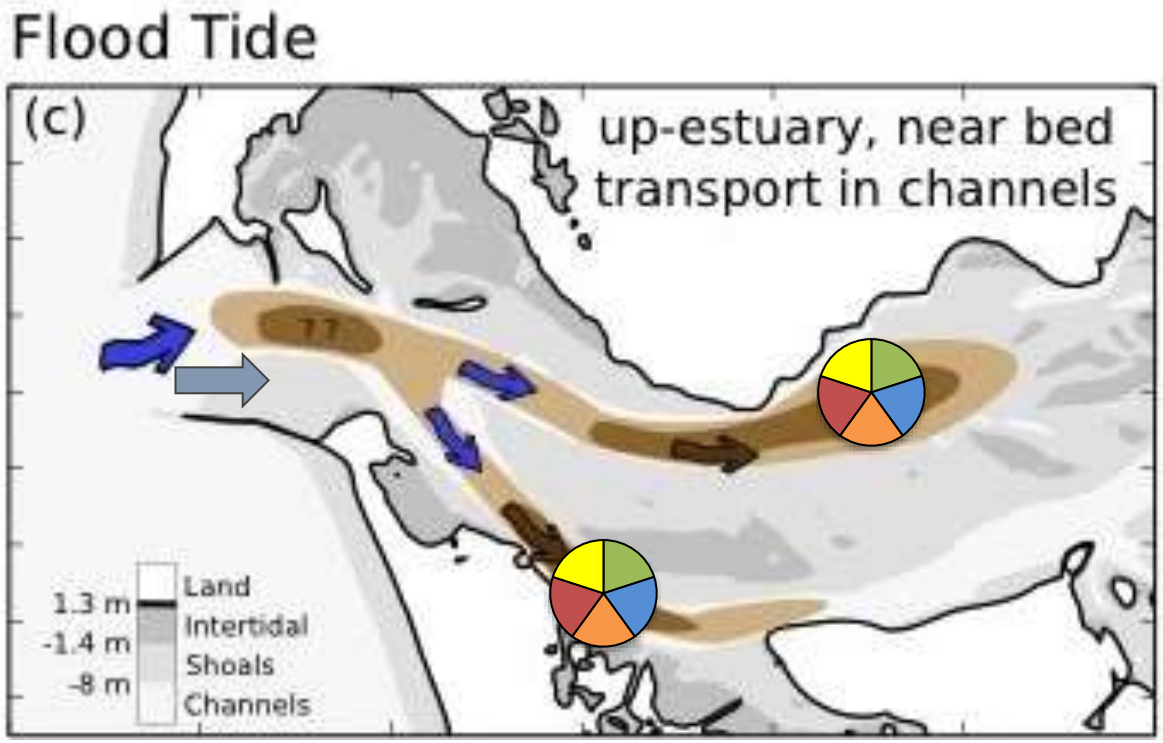
Columbia River ETM conclusions

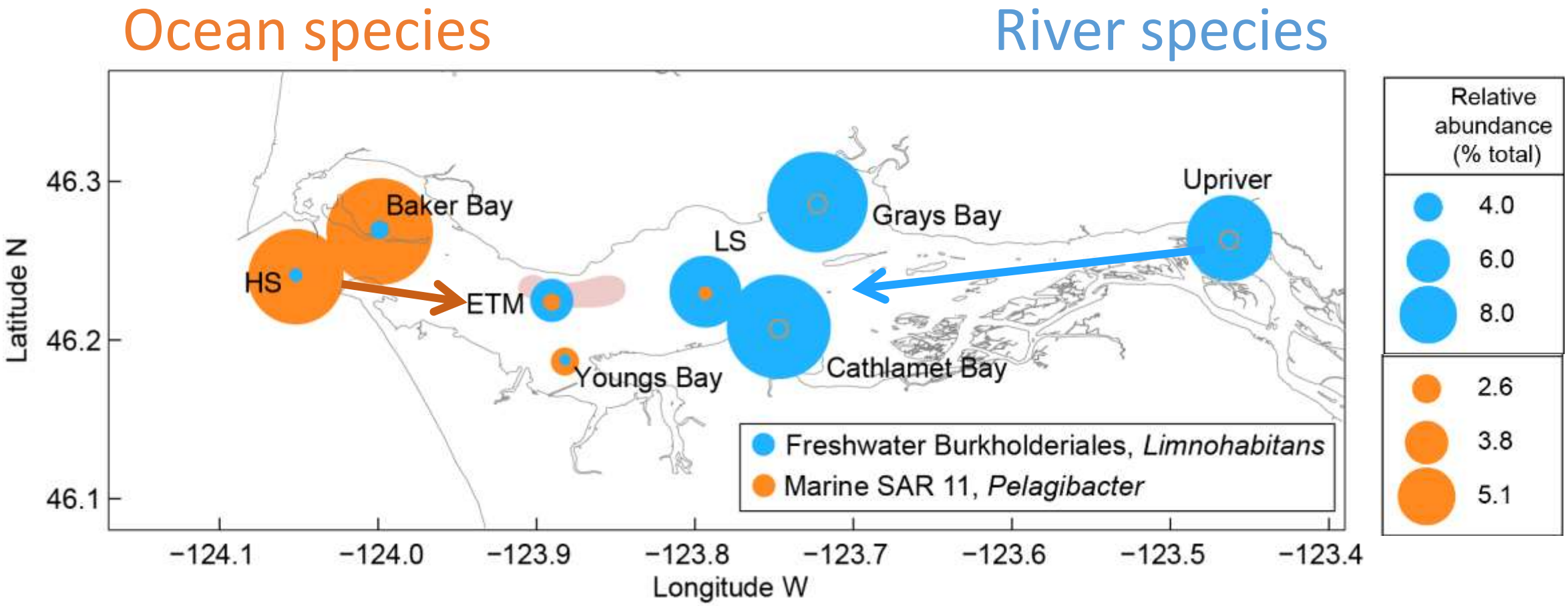
ETM accumulate detritus and microbes from diverse and seasonally-varying sources, and, by extending particle residence time, ETM approximately double the bacterial productivity in estuarine channels, accelerate the remineralization of organic matter, and provide a stable environment for a genetically diverse microbial community with potential for broad metabolic capabilities.







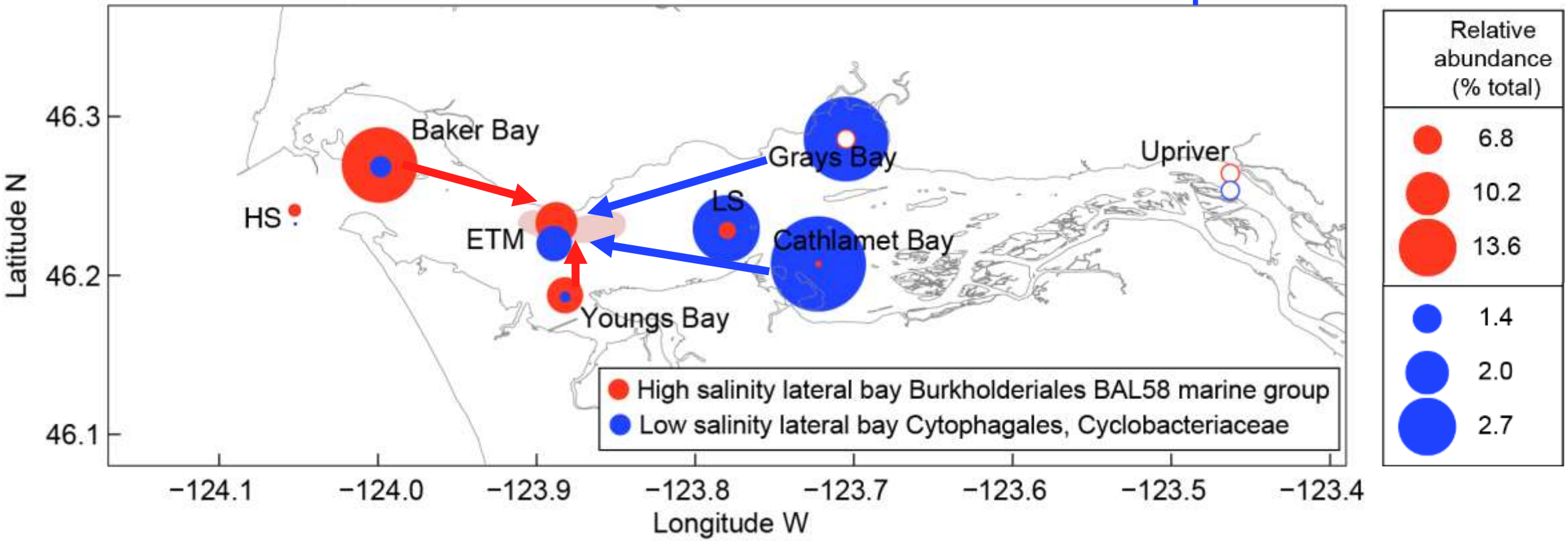
ETM = microbe mixing zone



ETM = microbe mixing zone

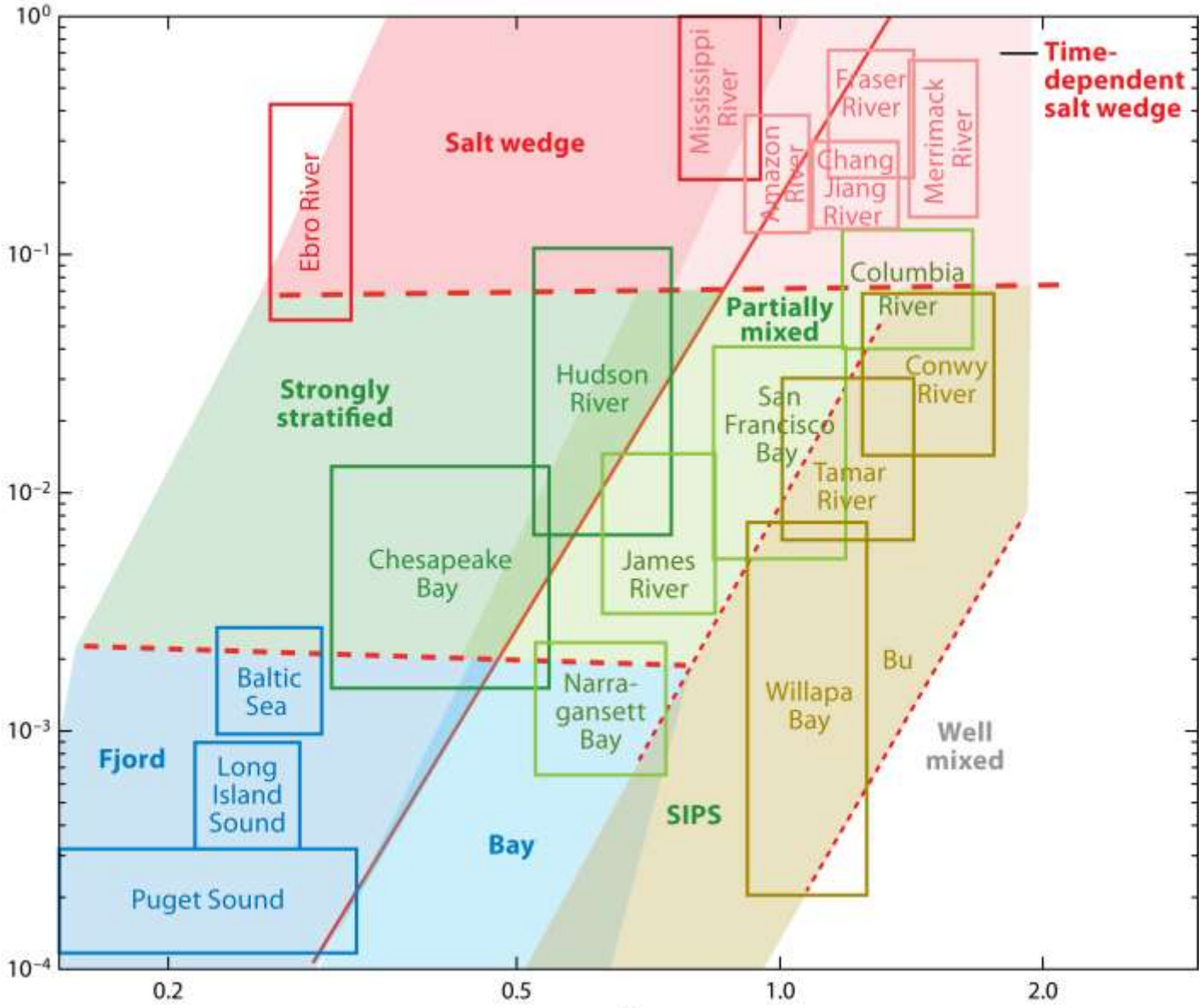
High-salinity
estuarine species

Low salinity
Estuarine species



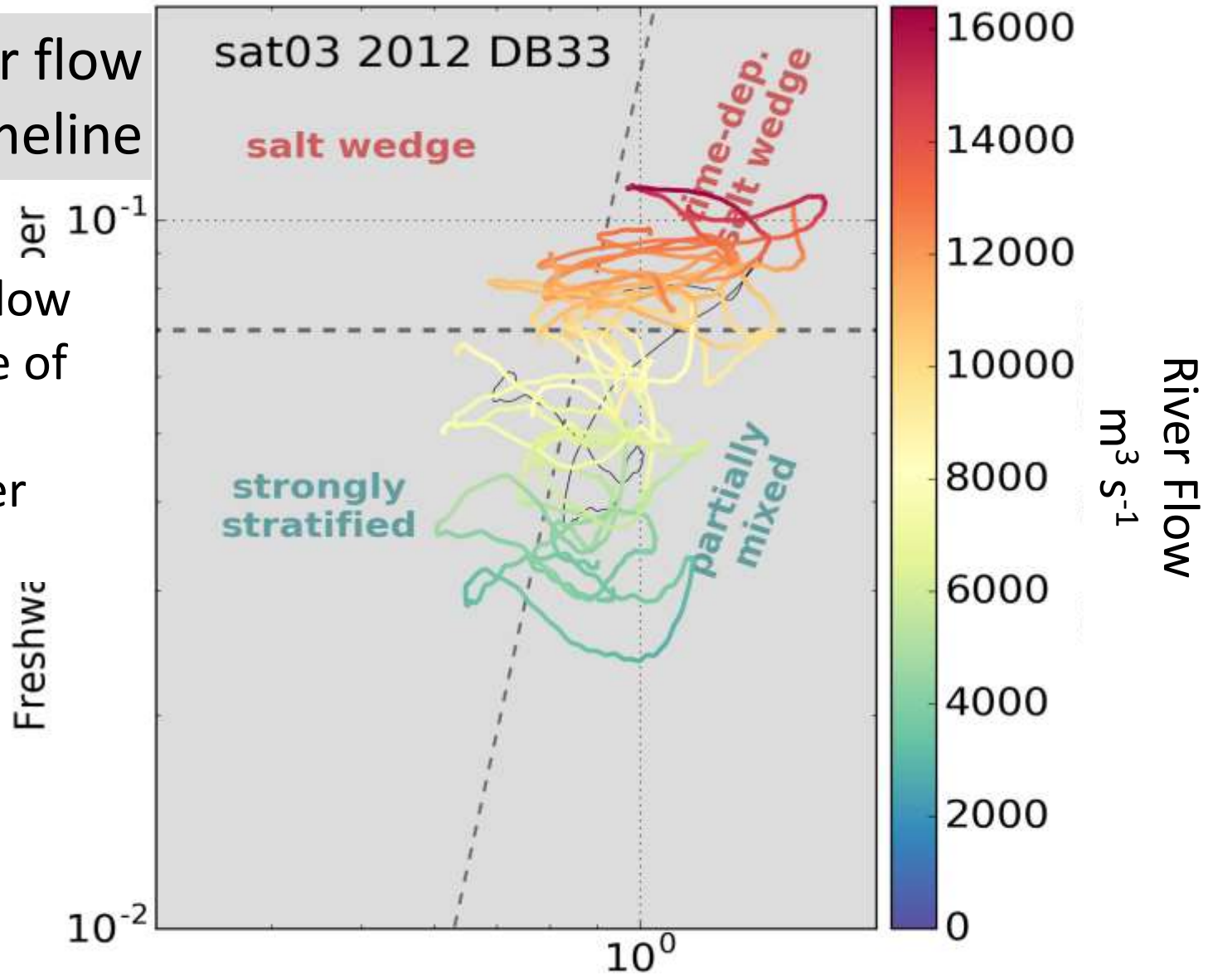
Estuarine Classification

Freshwater flow scaled to size of estuary (Freshwater Froude #)



Tidal velocity scaled to mixing impact (Mixing #)

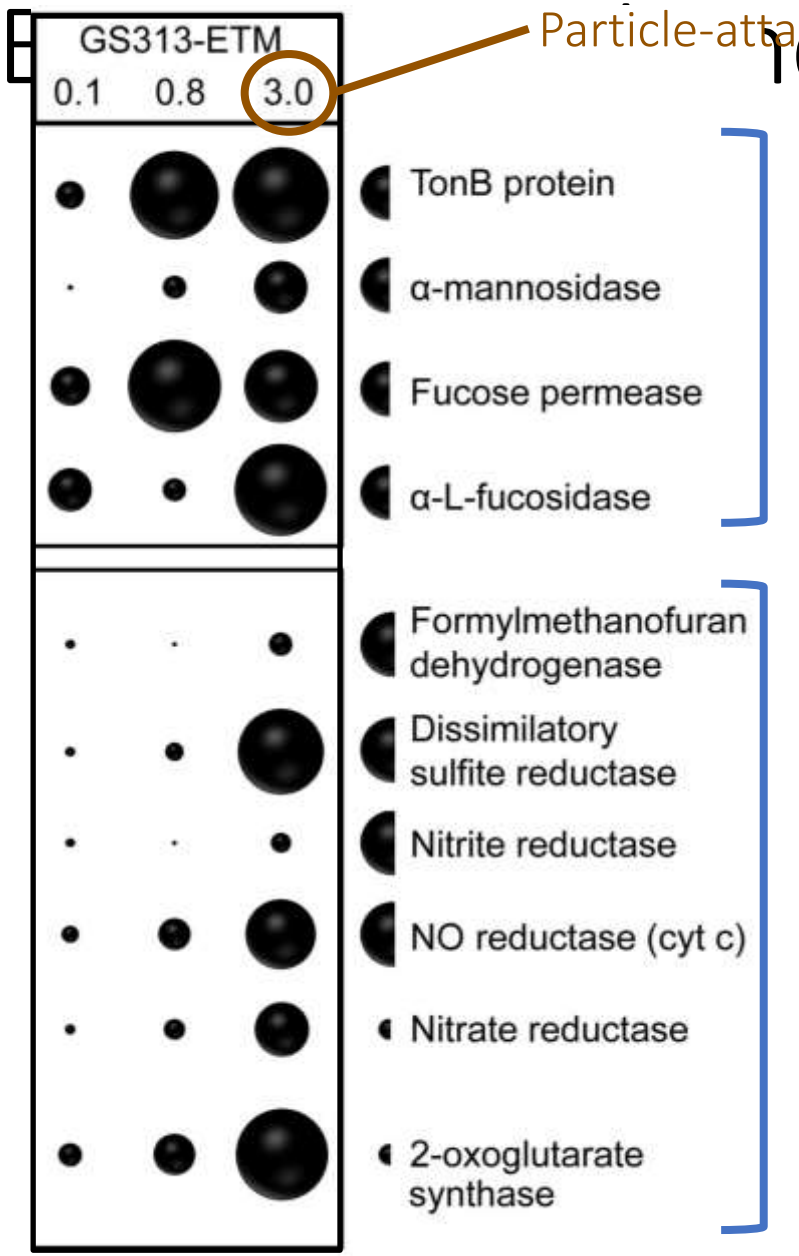
River flow timeline



Freshwater flow scaled to size of estuary (Freshwater Froude #)

Tidal velocity scaled to mixing impact (Mixing #)

Icement

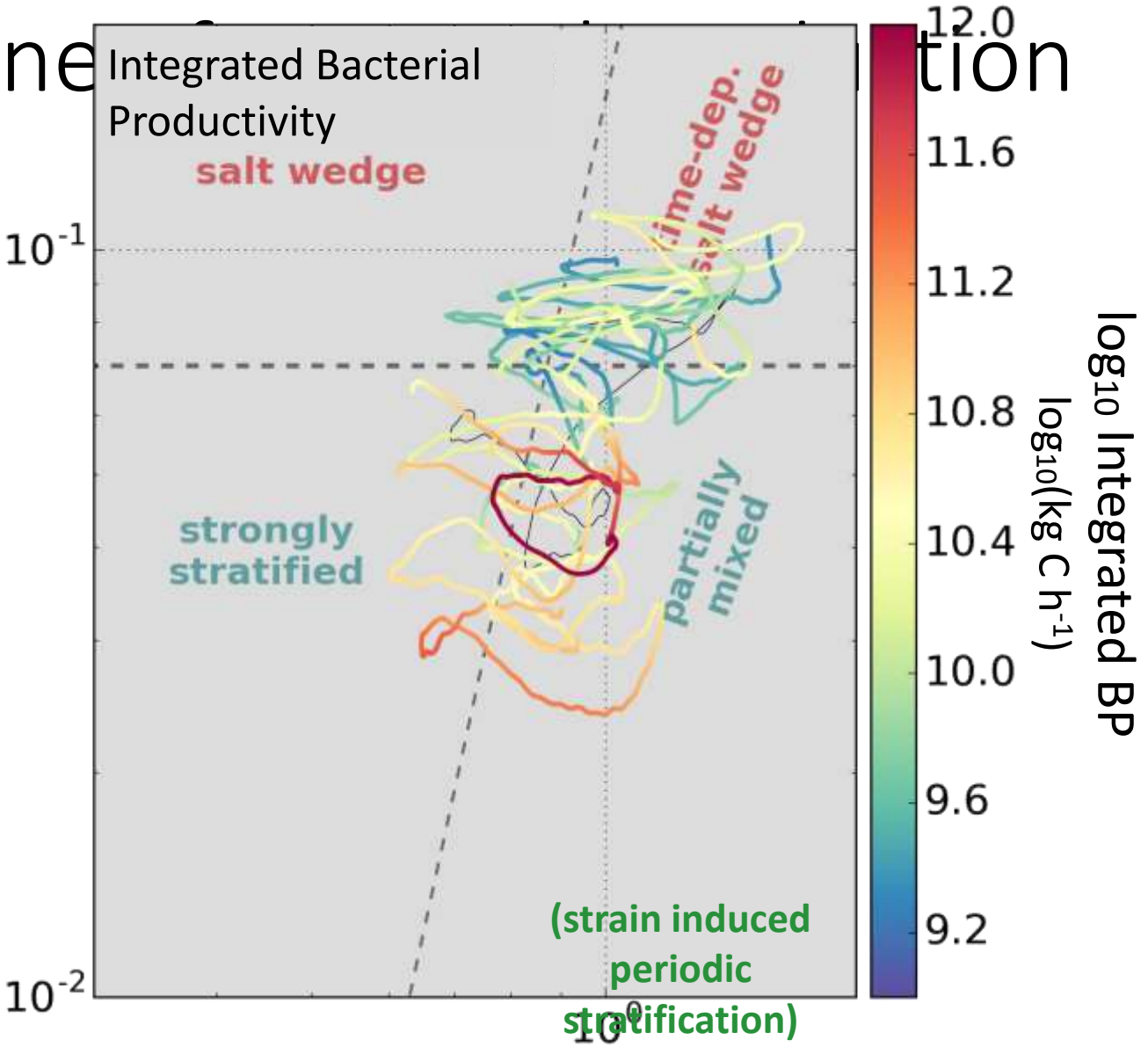


Phytoplankton bloom utilization and DOM assimilation

Anaerobic pathways

Smith et al. 2013

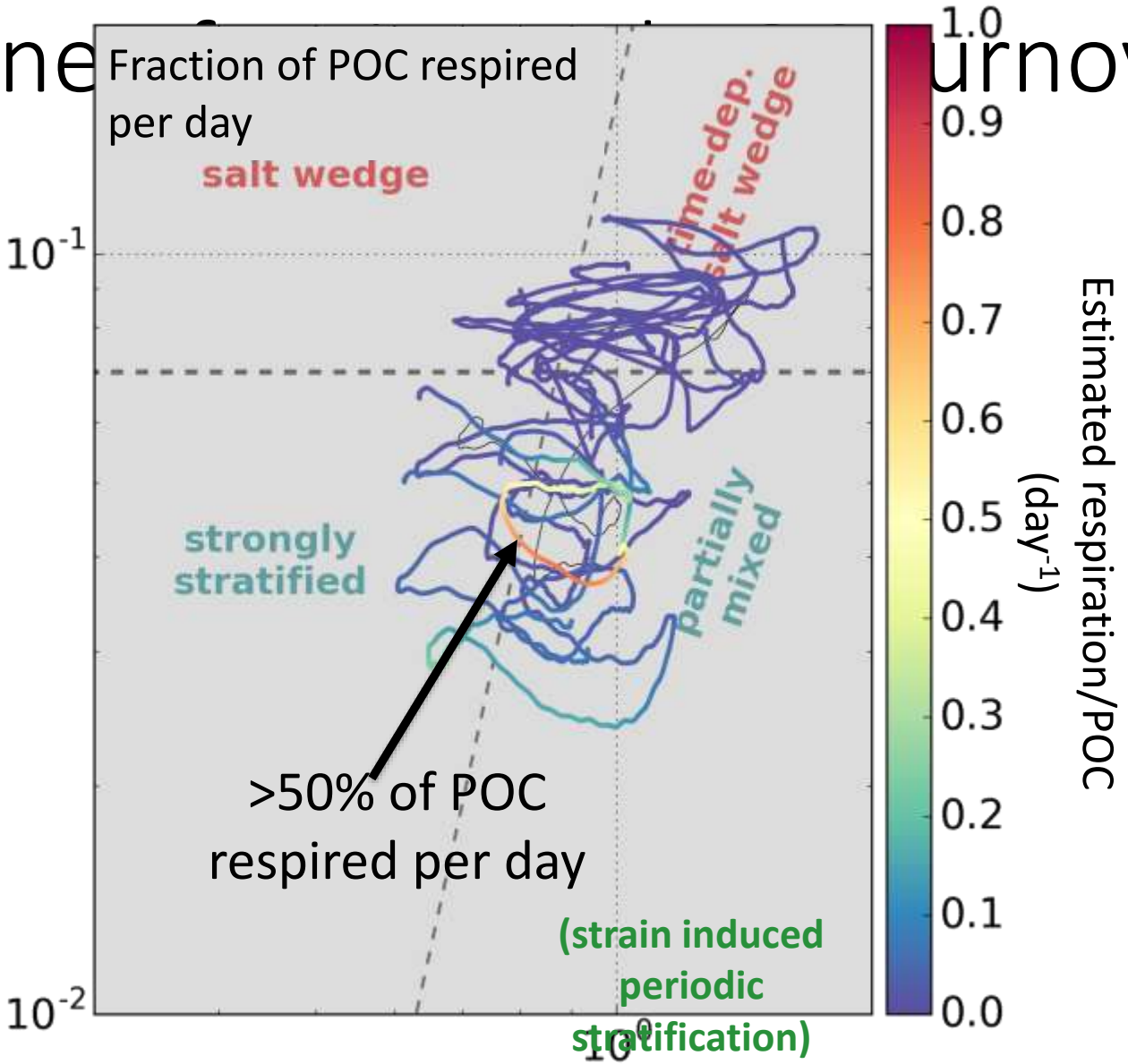
Timeline [illegible] tion



Freshwater flow scaled to size of estuary (Freshwater Froude #)

Tidal velocity scaled to mixing impact (Mixing #)

Timeline [illegible] urnover



Freshwater flow scaled to size of estuary (Freshwater Froude #)

Tidal velocity scaled to mixing impact (Mixing #)