Linking nutrients, algal blooms and impairments in the tidal fresh James River

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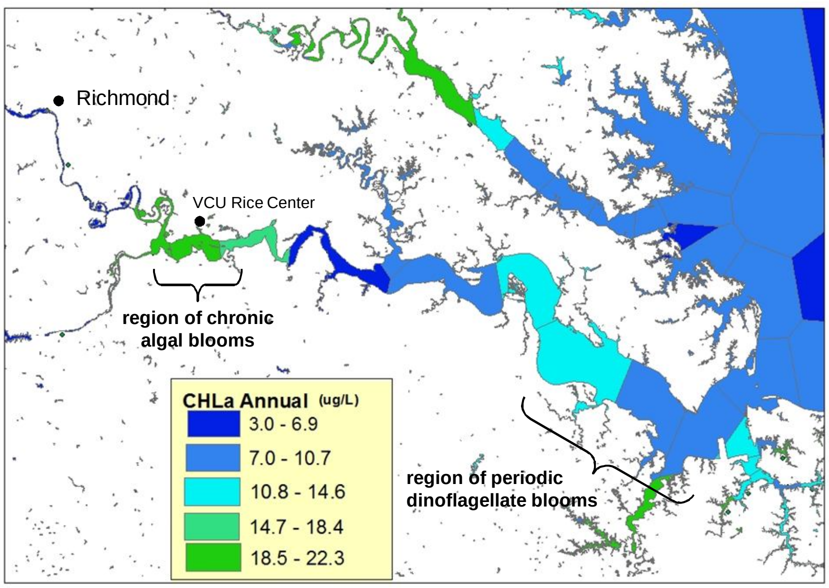
James River Estuary

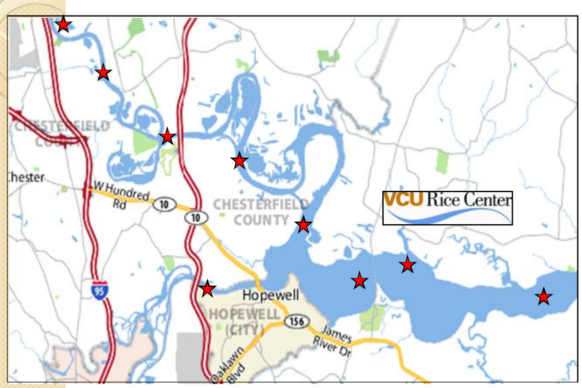


Data from DEQ CBP monitoring (2005-2010)

Research Questions

- Why is the tidal fresh segment a hot spot for phytoplankton production?
  - factors regulating phytoplankton growth
- Nutrient sources supporting algal blooms and nutrient retention in the CHLa maximum?
- What is the fate of algal biomass?
  - grazing, export, sedimentation
- Deleterious effects of algal blooms?
  - establishing criteria protective of designated uses

Algal Blooms in the Tidal Fresh James

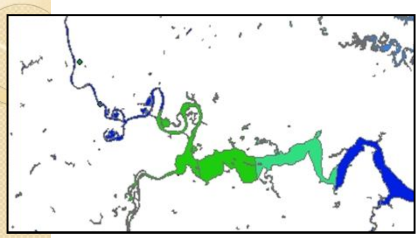


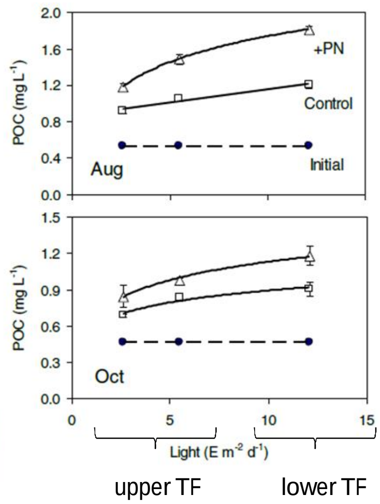
Sampling locations for VCU weekly monitoring (2010-present).

Persistent blooms occur in the region where the James transitions from a narrow, deep channel to a wide shallow channel.

Shallow areas provide more favorable light conditions which allows for great nutrient utilization by phytoplankton.

Light and Nutrient Use Efficiency



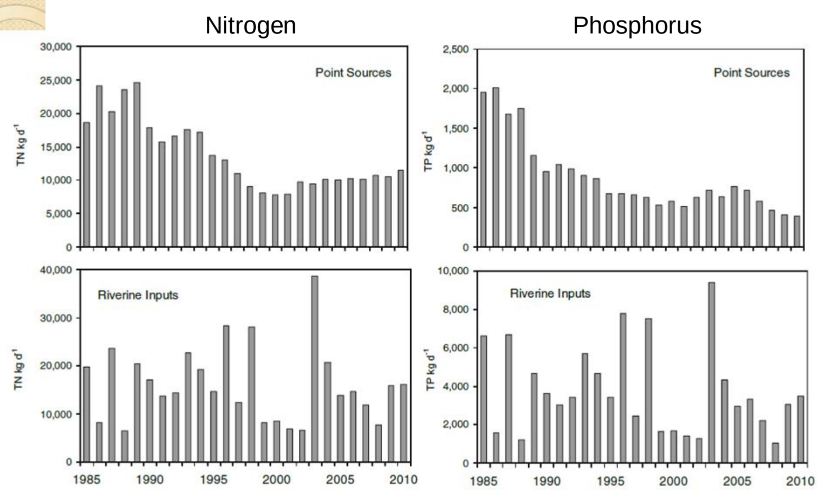


Partial release from light limitation allows for greater nutrient utilization.

	Upper TF	Lower TF
Photic Depth	2.5 m	2.0 m
Mean Depth	5.5 m	3.1 m

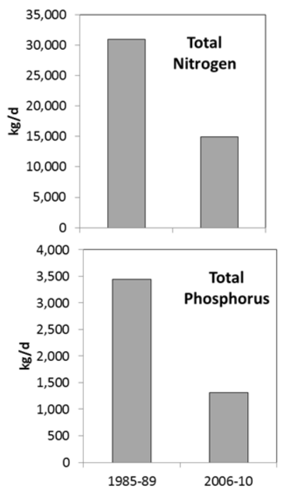
Above: sample of monthly bioassay experiments performed May-Oct 2012.

Sources of Nutrients to the TF James



Daily mean N & P loads from the upper James watershed and local point sources (1985-2010). Point sources are from NPDES; riverine inputs are from USGS RIMP.

Response to Nutrient Reductions



Summer Daily Inputs (Jun-Sep)

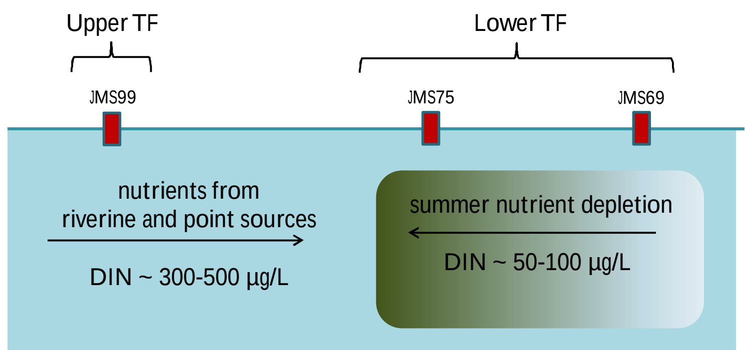
Indicator	Response
Estuarine nutrient concentrations	Yes ↘
Phytoplankton nutrient limitation	Yes ↗
Phytoplankton abundance (CHLa)	Not yet →

Phytoplankton Nutrient Limitation: a historical perspective.

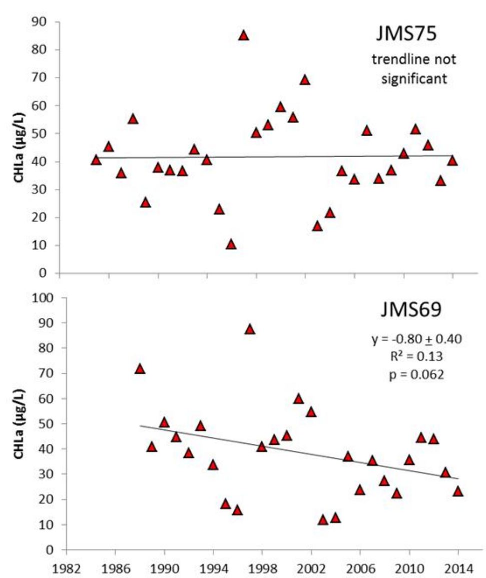
	1992-93*	2012**
No. experiments	11	12
Nutrient limitation detected	0	11
Dissolved inorganic N (mg/L)	0.45	0.25
Phosphate (mg/L)	0.022	0.013

Comparison of data at station JMS75 from Fisher et al. 1999* and Wood & Bukaveckas 2014** suggest a decline in estuarine nutrient concentrations and greater severity of algal nutrient limitation in response to decreasing point source inputs.

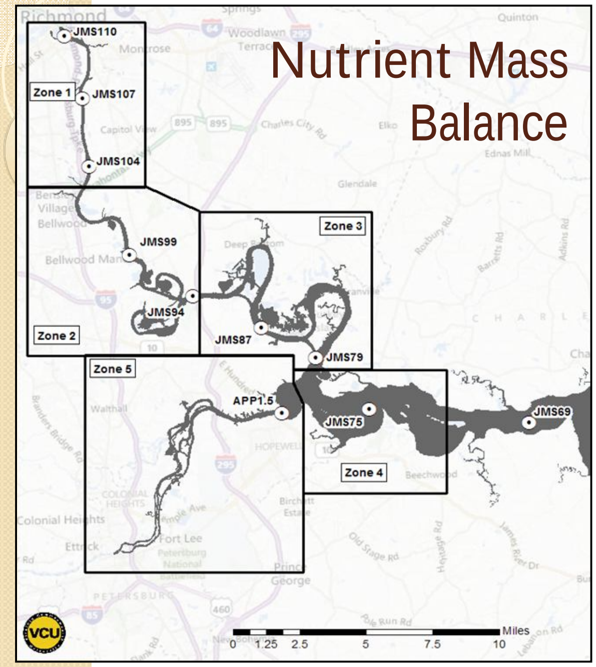
Expected Changes in CHLa in Response to Nutrient Reductions



Long-term Trends in Summer Mean CHLa (1985-2014) from monthly monitoring (CBP).



Nutrient Mass Balance



Box model for TF James

- data for 2007-2010
- point sources & CSOs
- riverine inputs and local ungauged sources
- tidal exchange
- no direct atmo deposition or gw

Nutrient Retention in TF James

Retention mg/m^2/d (% of inputs)

biotic via assimilation | abiotic via sedimentation

	PO_4	NH_4	NO_3	TN	TP
Annual	8 (65%)	29 (49%)	51 (37%)	181 (38%)	40 (38%)
Summer	11 (85%)	42 (79%)	100 (77%)	177 (58%)	6 (30%)
Winter	5 (52%)	21 (29%)	24 (13%)	192 (24%)	66 (37%)

PO_4, NH_4, NO_3: dissolved inorganic fractions retained in lower TF during summer

TN, TP: includes particulate fractions retained in upper TF during winter

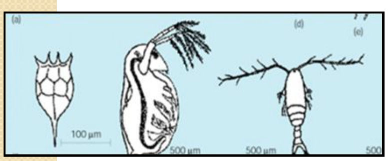
What is the fate of algal biomass?

- Fate of algae = fate of nutrients: export vs. sequestration vs. recycling
- Implications for modeling CHLa and establishing nutrient caps:
  - 1 lb N or P = X lbs CHLa
  - where X is influenced by grazing
  - less grazing = lower nutrient cap to reach attainment (e.g., of CHLa standard)

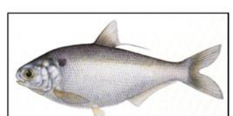
Biomass Removal via Grazing

Primary consumers in tidal-fresh James:

- Zooplankton (rotifers, *Eurytemora*, *Bosmina*)
- Benthic filter-feeders (Wedge Clams - *Rangia*)
- Fish (Atlantic Menhaden, Threadfin Shad, Gizzard Shad, juvenile Blue Catfish)



Rangia Cuneata[1]



Gizzard Shad[3]

Estimating Grazing Rates

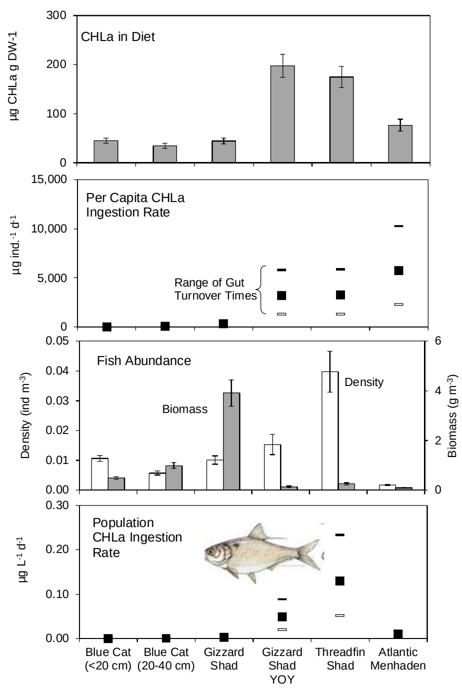
Community Grazing = Abundance x per capita grazing rate

Zooplankton	Single station, 2/month, 2013-15	Taxon-specific grazing (literature)
Benthic filter-feeders	CBP benthic surveys, annual 2001-10, 25 stations	Measured *Rangia* grazing rates monthly (2012)
Fish	3 survey periods, 30 transects each, 2012-13	Monthly gut contents (CHLa); literature estimates of gut turnover

Fish Grazing

Planktivorous fish consume 1,000's µg CHLa/ind/d, but their densities are insufficient to remove significant quantities of CHLa.

Corresponding values for zooplankton and *Rangia* are somewhat higher (~1 µg CHLa/L/d).



Ecosystems (in review)

Grazing compared to production and other losses:

The main fate of algal production is Respiration (74%).

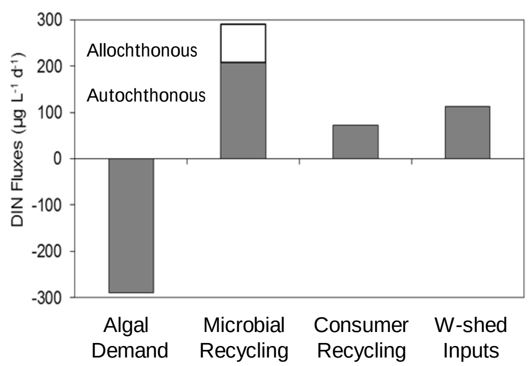
Grazing accounts for 15% of production and 4% is exported to lower James.

Data are mean daily values for March-November 2012-13.

Fate of Algal Biomass and Sources of N

Microbial recycling sufficient to meet algal N demand.

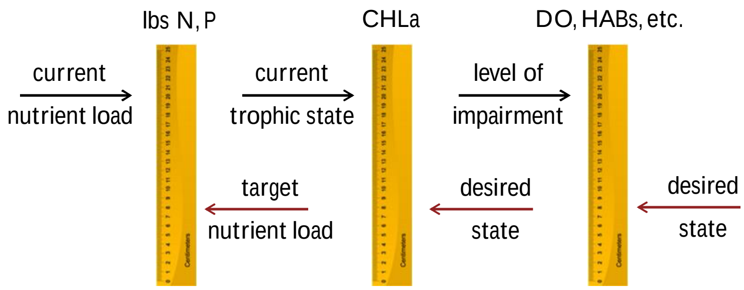
Grazing = 25% of algal N demand and external inputs are equivalent to 39% of demand.



Data are mean daily values for March-November 2012-13.

Linking Nutrients, Algae, Impairments

- Establishing nutrient reduction targets requires quantitative linkages:
  - between impairments and algal abundance (e.g., CHLa).
  - between algal abundance and nutrient loads.



James River CHLa Study (2012-2017)

$3 million study funded by Commonwealth of Virginia (administered by Department of Environmental Quality).

- understand when, where, and why of algal blooms and impairments.
- assess whether current CHLa-based standards are protective of designated uses.
  - How much CHLa is 'too much'?
- improve water quality models – specifically, their reliability to predict CHLa under changing nutrient load scenarios.

Old Dominion University | VCU | HRSD | William & Mary VIMS | CEC | HDR HydroQual | Tetra Tech

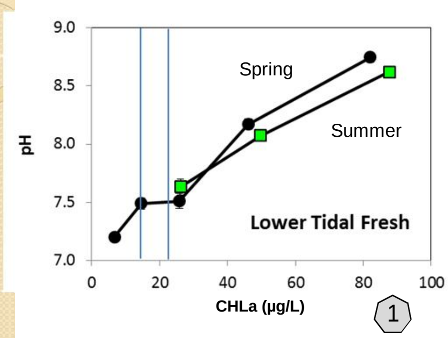
Assessing Protectiveness of Water Quality Standards

Are current CHLa standards protective of aquatic life designated uses? A dual-probability approach:

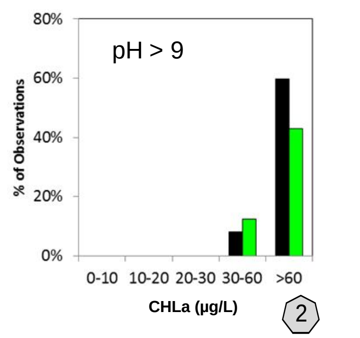
- What is the risk of deleterious effects at a given CHLa concentration?
- What is the likelihood of exceeding that CHLa concentration (e.g., at attainment of current standard)?

CHLa	p (DO<5)	p (CHLa)	p (combined)
0-30	1%	50%	0.5%
31-60	10%	35%	3.5%
61-90	50%	15%	7.5%

Example: Algal Blooms and Daytime pH Maxima

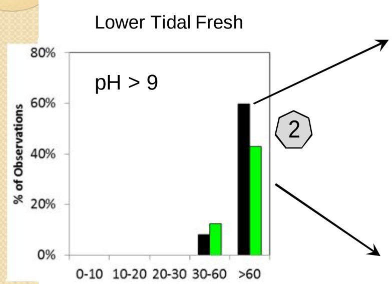


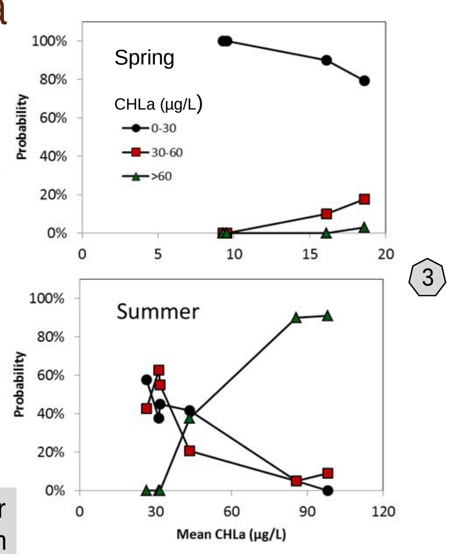
Relationships between mean pH and mean CHLa in Lower TF segment during Spring and Summer. Vertical lines denote current criteria.



Risk of daytime pH maxima exceeding 9.0 as a functions of CHLa in the Lower TF segment.

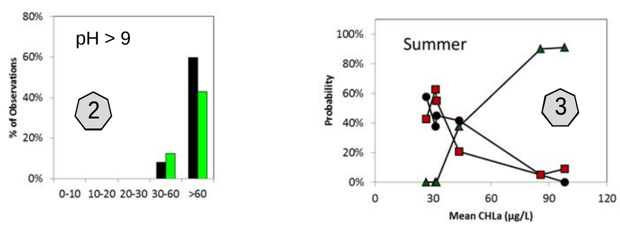
Daytime pH Maxima



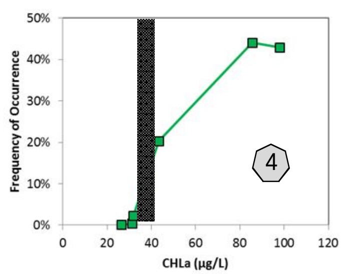


Probability of occurrence for various CHLa ranges in relation to mean CHLa

Risk of Daytime pH Maxima > 9

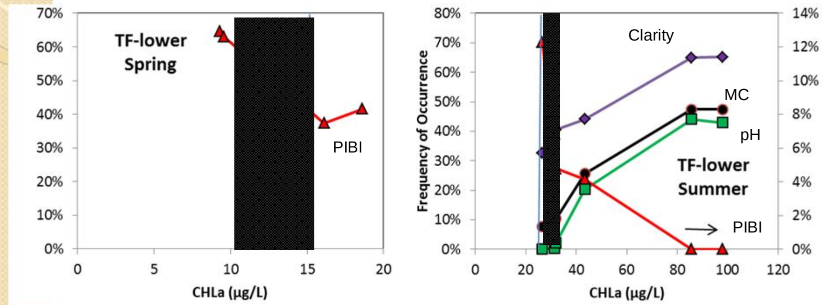


Suggested Protective Range for CHLa criteria = 32-43 µg/L



Expected occurrence of daytime pH maxima >9 in relation to summer mean CHLa

Assessing Protectiveness



Lower TF	Spring	Summer
Current Criteria	15	23
Metrics (p<0.05)	PIBI	Clarity, MC, pH, PIBI
Protective Range	10-16	27-31