Unraveling dual influences of increasing nutrients and changing flow regimes on bloom potentials along the middle Cape Fear River

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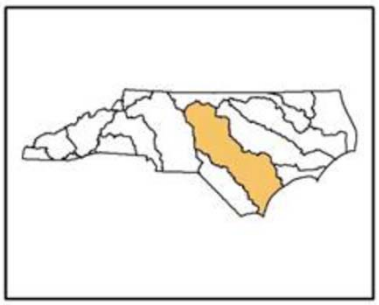
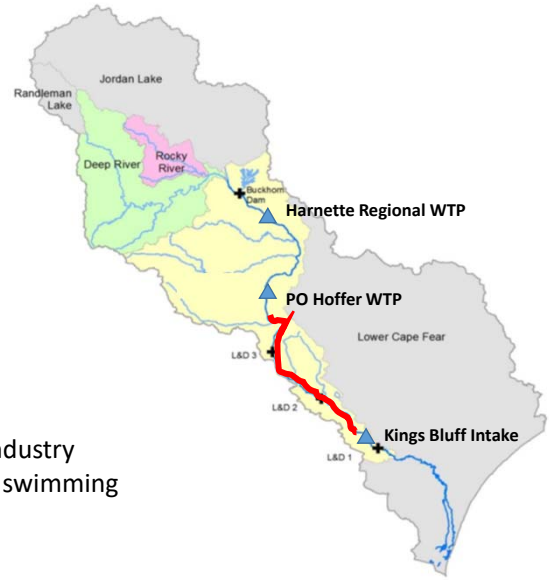
The Middle Cape Fear River





1) Water supply: >0.5 million & industry
2) Recreation: boating, fishing, & swimming

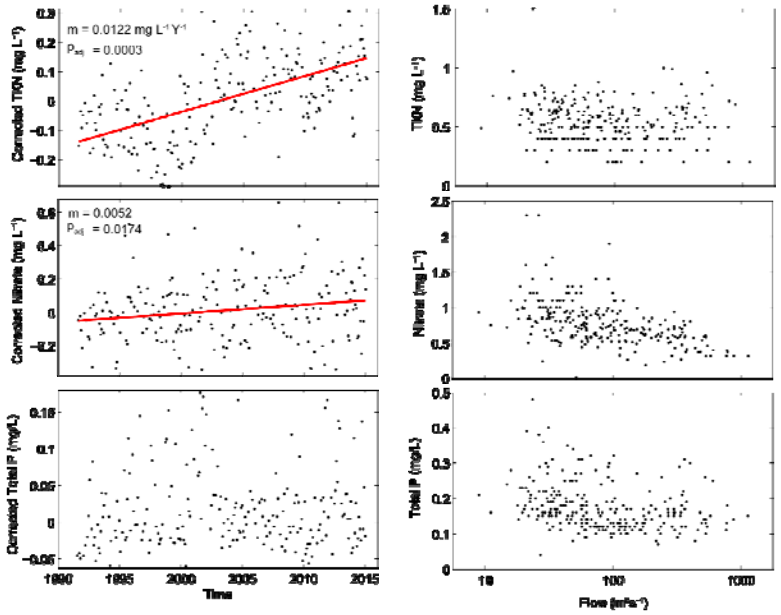
Three Bloom Requirements: Nutrients, Light, & Time to Grow All Three Modulated by River Flow

"the appropriate combination of environmental factors necessary to favor proliferation of Cyanobacteria seems unlikely to occur in the middle CFR" (Dubbs and Whalen 2008)

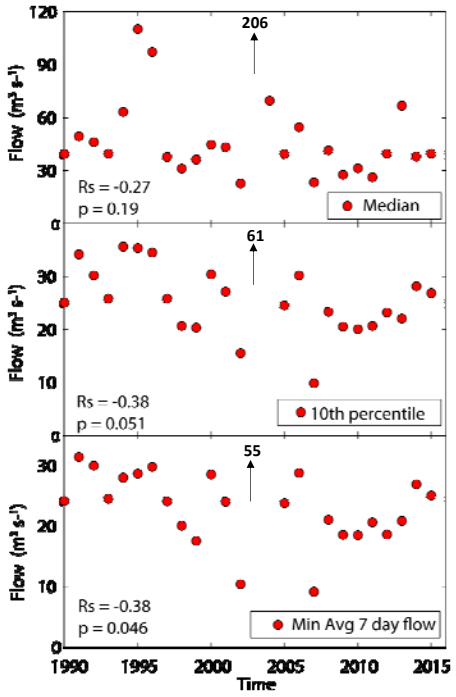
Photo credit: Stephanie Pettergarrett, NCDENR-DWR

Major blooms started the next summer in 2009, then 2010, 2011, 2012

Nutrients: N Has Increased Over Time & Nutrient Availability is Higher Under Low Flows

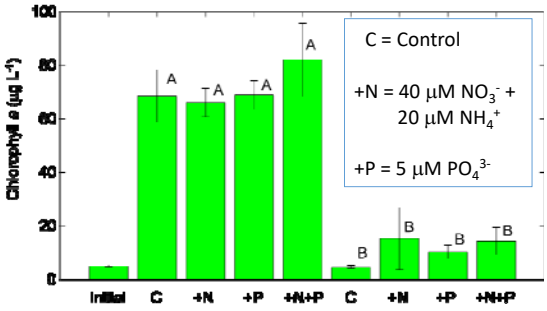


Trend toward lower summertime (June – September) low flows



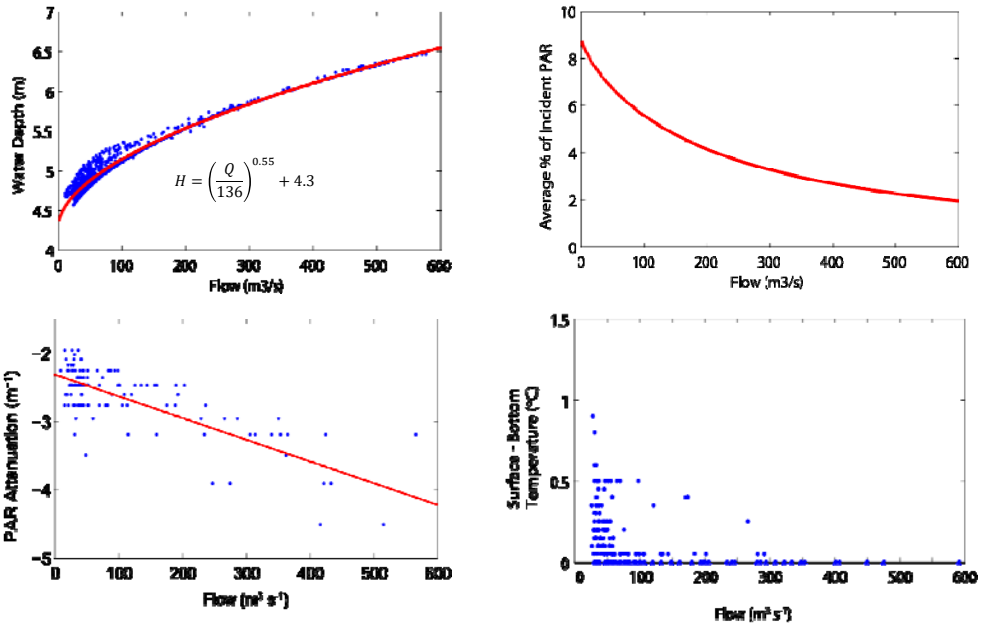
In Situ Nutrient Addition Bioassay at Two Different Depths July 2017

Incubated at 0.4 m Incubated at 1 m

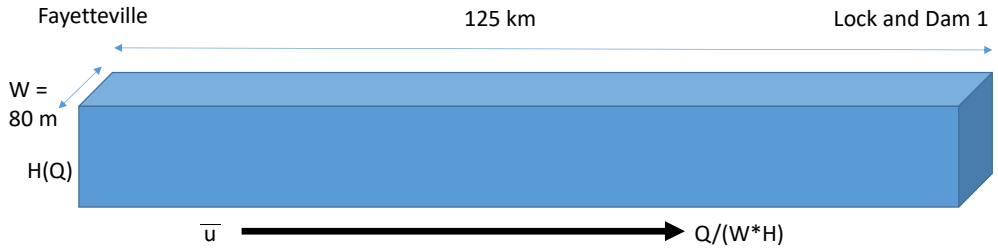


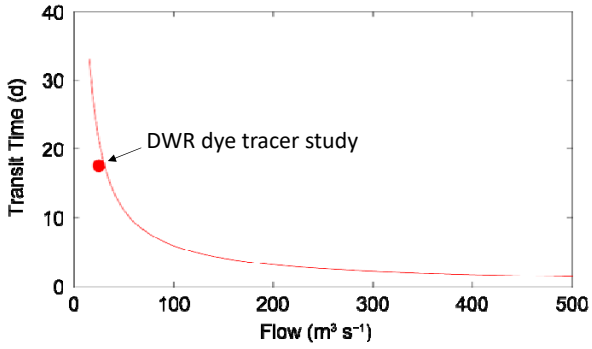
Corroborated Nutrient Replete/ Light-Limited Growth Reported by Dubbs & Whalen (2008)

Light availability: Strongly flow related due to depth, light attenuation, and mixing/ stratification



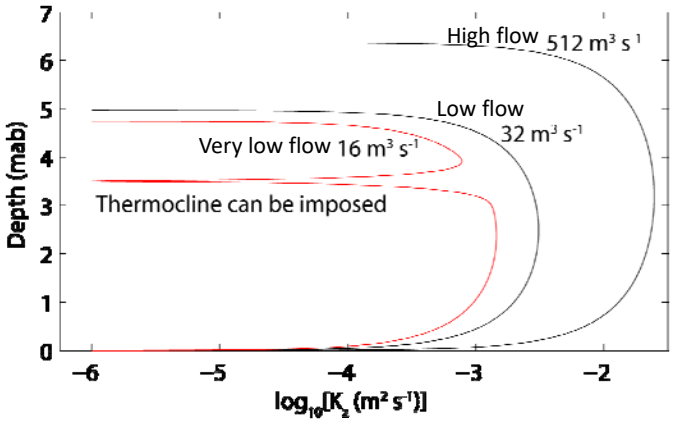
Time to Grow: Time of travel determined by flow and river morphology





The Physics

Mixing Determined by Bed Stress



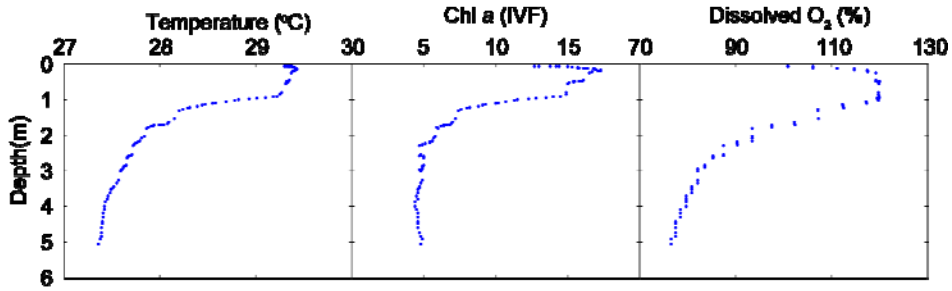
Phytoplankton Vertical Position Determined by Random Walk

$$z_{n+1} = z_n + \underbrace{w_p \Delta t}_{\text{motility}} + \underbrace{K'(z_n)\Delta t}_{\text{deterministic term}} + \underbrace{R\left[\frac{2K\left(z_n + \frac{1}{2}K'(z_n)\Delta t\right)\Delta t}{r}\right]^{1/2}}_{\text{random term}}$$

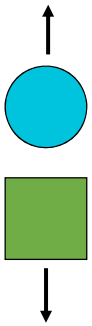
Ross and Sharples (2008)

Observed Effects of Stratification

June 20, 2016. Upstream of Lock and Dam 1 near Elwell Ferry

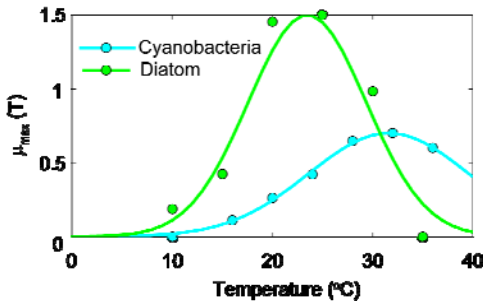


The Biology



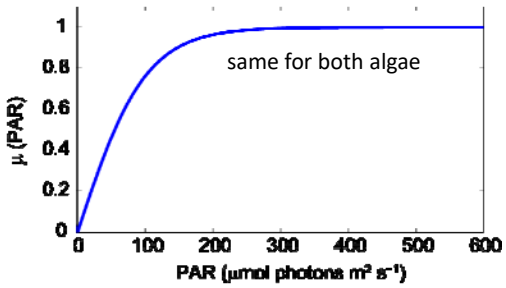
Floating Cyanobacteria
w_s = + 0.5 m/h

Sinking Diatom
w_s = - 0.5 m/d



$\mu = \mu_{max}(T) * \mu(I) - 0.05 * \mu_{max}(T)$

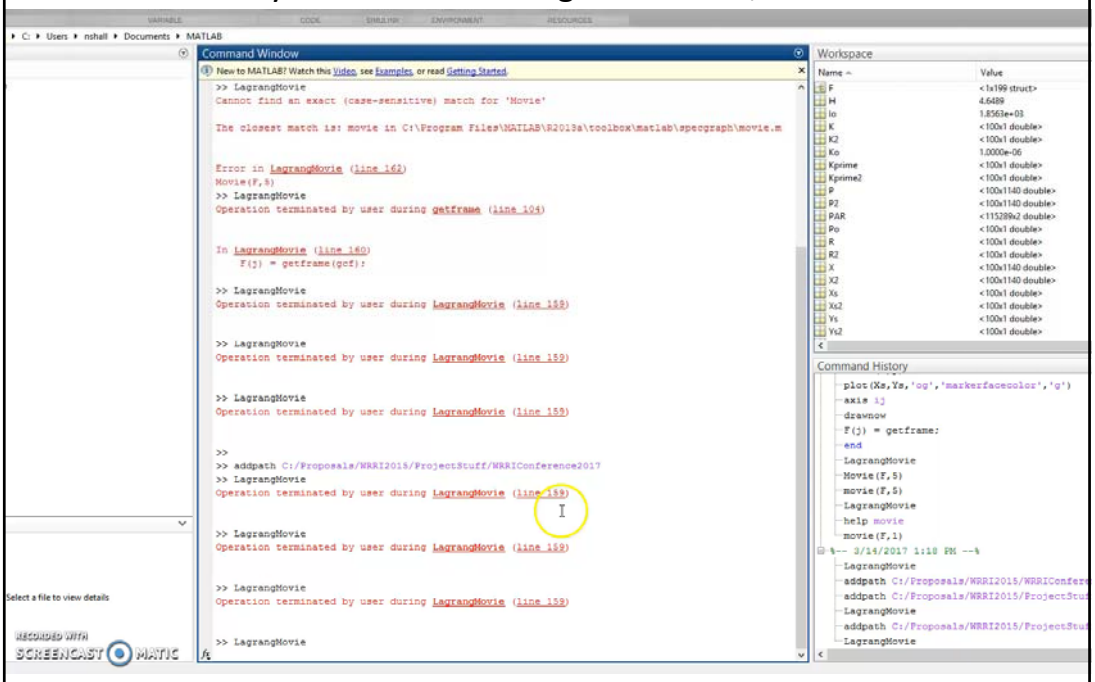
Light and temperature limited growth with loss of 5% μ_{max}



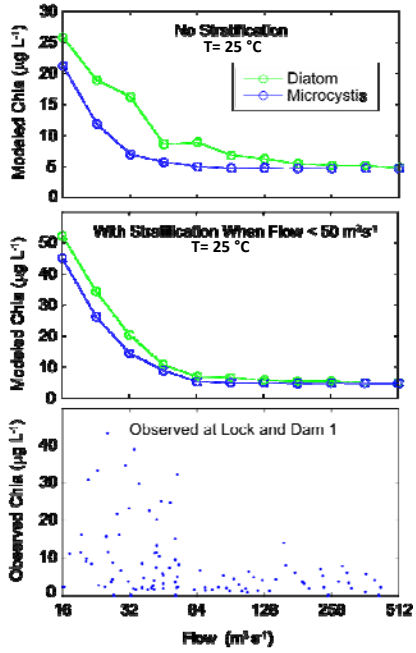
$PAR = PAR_o exp(-K_{PAR}Z)$; $K_{PAR} = K_{BG} + K_{chl}$

light attenuation due to background and self shading

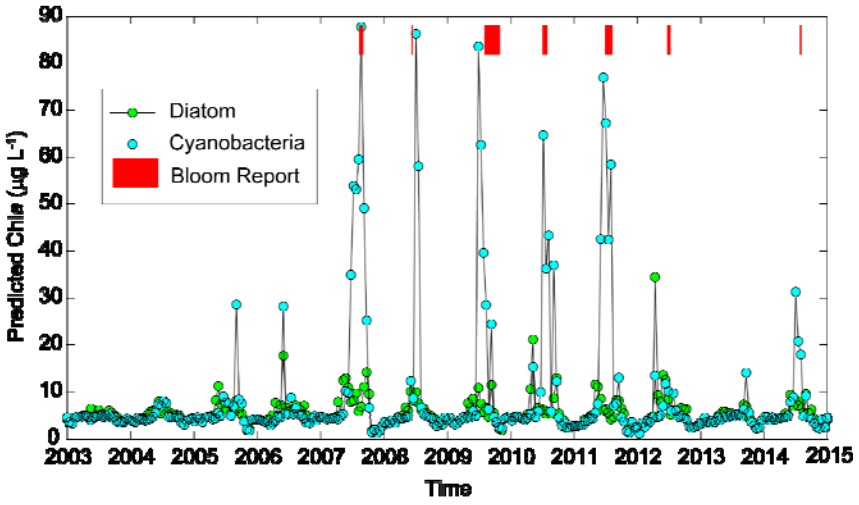
Position of Cyanobacteria During Model Run, Flow = 20 m^3s^{-1}



Model Captures Relation of Biomass to Flow



Hind Casts of Reported Blooms



Flow from USGS at Lock and Dam1
Water Temperature from Interpolated Biweekly Observations DEQ/MCFRBA
Air Temperature and Incident Light from RAWS Turnbull Cr. Station

Conclusions/ Comments

1) Recent, extreme, summertime low-flow events provide sufficient light and travel times for bloom development

2) Stratification likely plays an important role in determining overall phytoplankton biomass and competitive dominance by positively buoyant cyanobacteria

3) Recent increase in blooms likely related to flow rather than increasing nutrient concentrations because nutrients are, and have been, replete for a long time

4) Reducing the magnitude of blooms along the Middle Cape Fear will likely require thinking about managing nutrient concentrations rather than loads.

a) Loads are strongly influenced driven by high flow events when conditions disfavor blooms

b) Point sources ensure nutrient satiety during low flows.

Tarheel plant: 0.1 m3/s flow, 120 mg/L of TN ~12,000 mg/s

River: 1.5 mg/L of TN flux at flow of 20 m3/s ~24000 mg/s