Relationships between Residence Time and Cyanobacterial Blooms in a Nutrient-Rich River System

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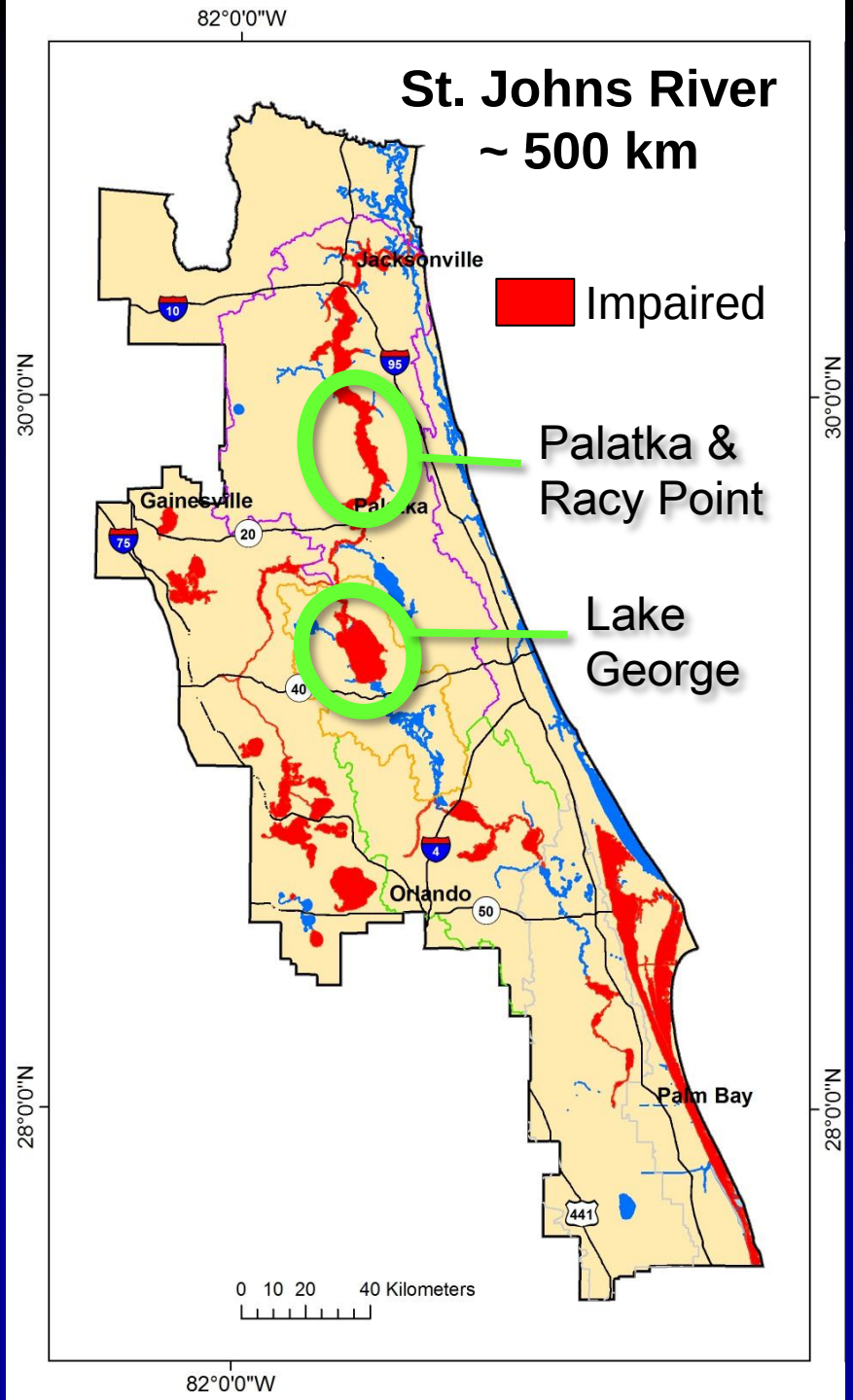
Residence Time and Cyanobacterial Blooms in the St. Johns River

Outline

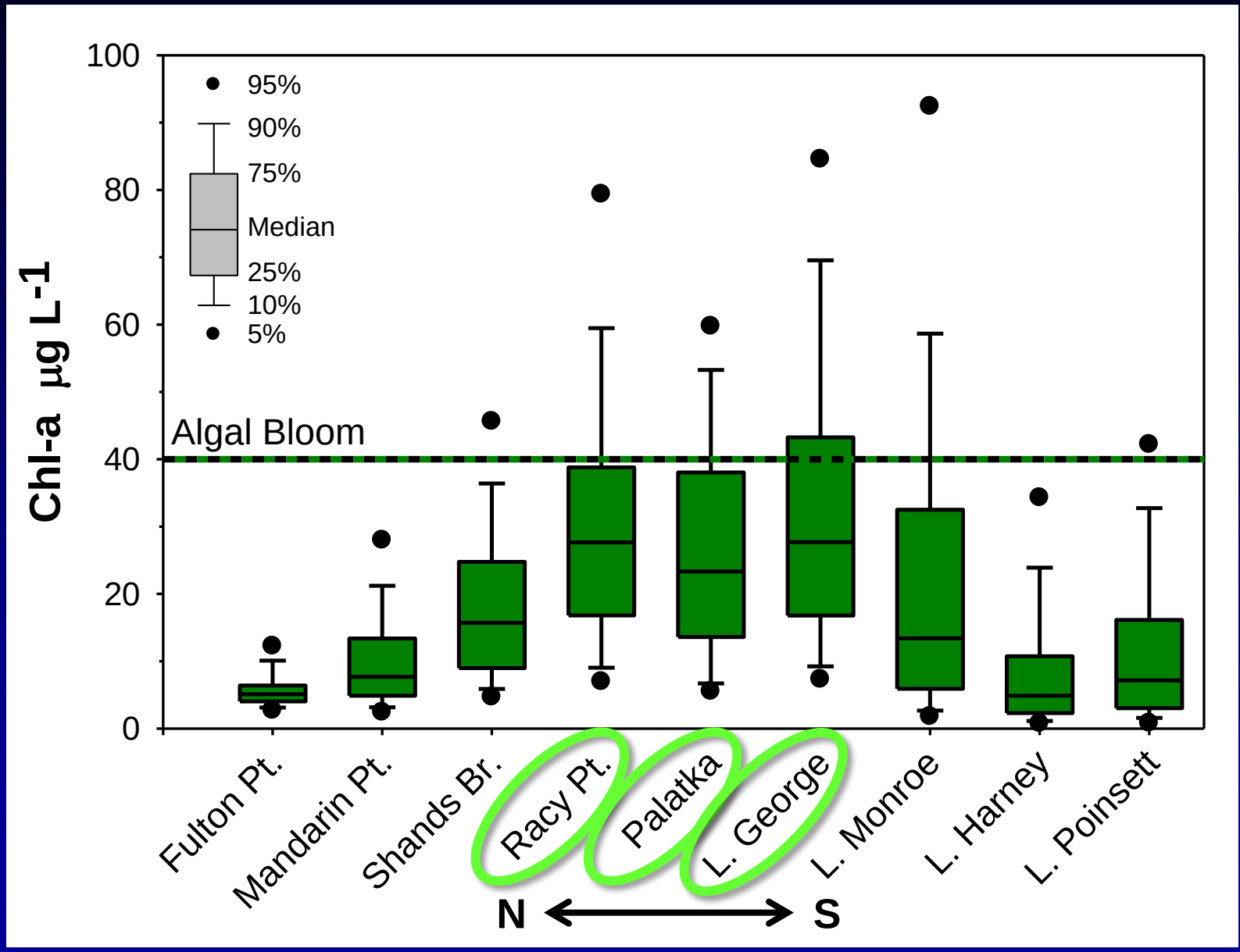
1. Existing impairment in water quality due to nutrients/algal blooms
2. Relationships between algal blooms, nutrients, and hydrology
3. Thresholds for adverse ecological effects of algal blooms
4. Would water withdrawals exacerbate the adverse effects of algal blooms?

Water Bodies in the St. Johns River Basin Impaired by Excess Nutrients

Water bodies with established total maximum daily loads (TMDLs) or listed as impaired by the Florida Dept of Environmental Protection

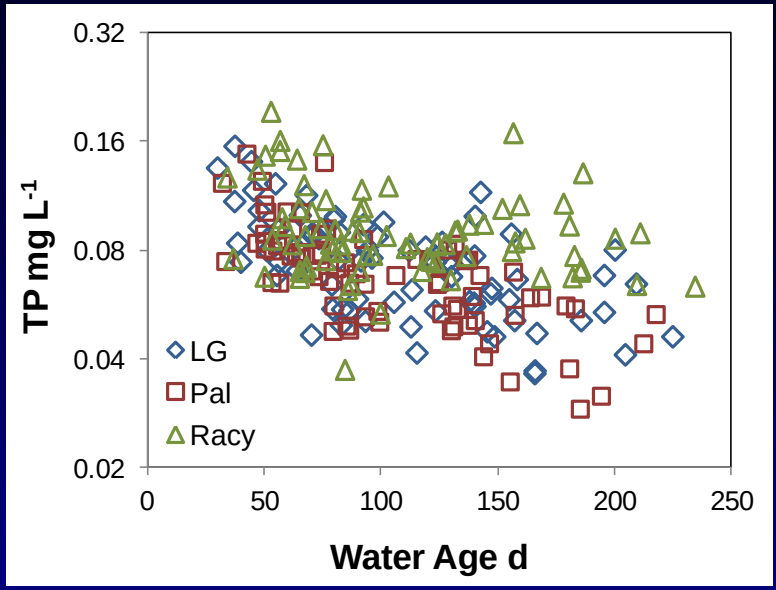


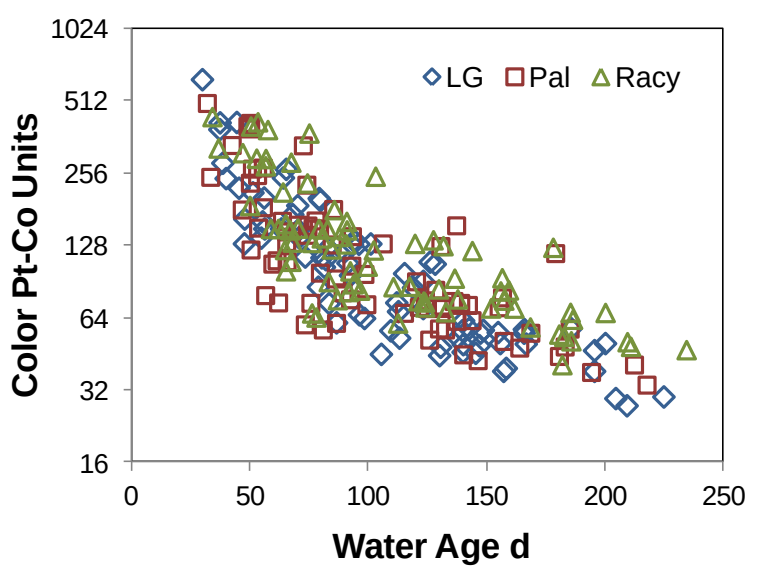
Chlorophyll-a Concentration 1995-2005

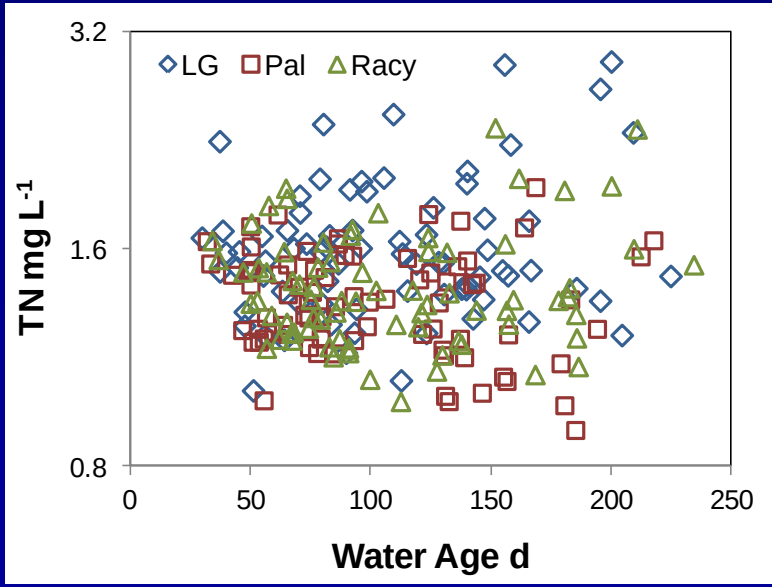


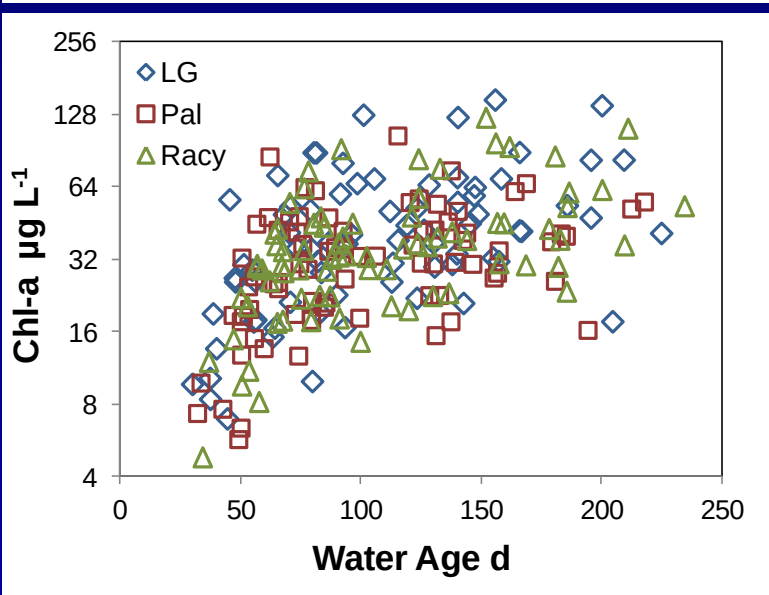
St. Johns River at Mandarin, August 2005, Microcystis

Relationships Water Chemistry – Water Age
(April-Oct, log Y-axes, 1995-2005)

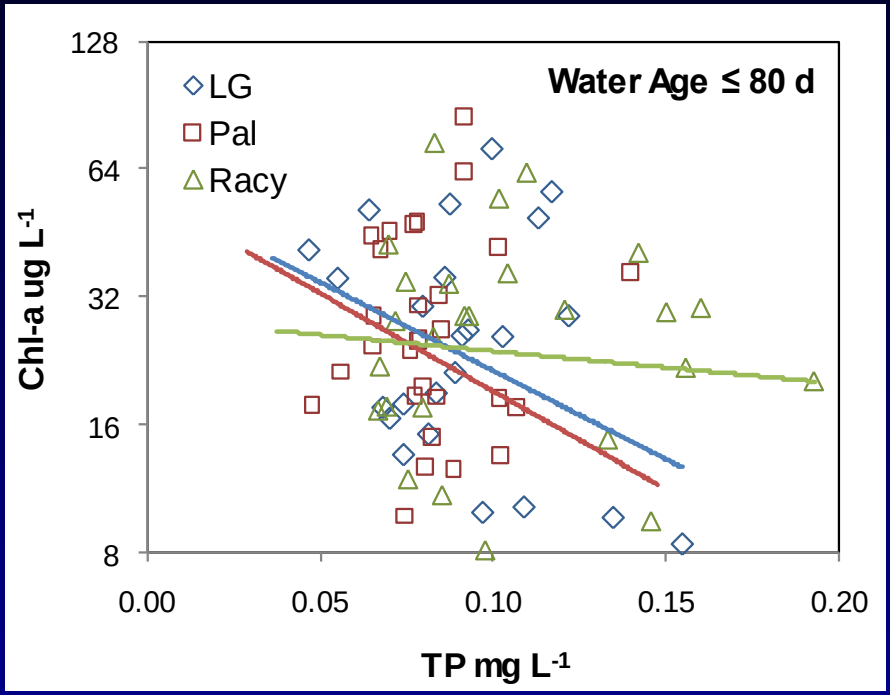


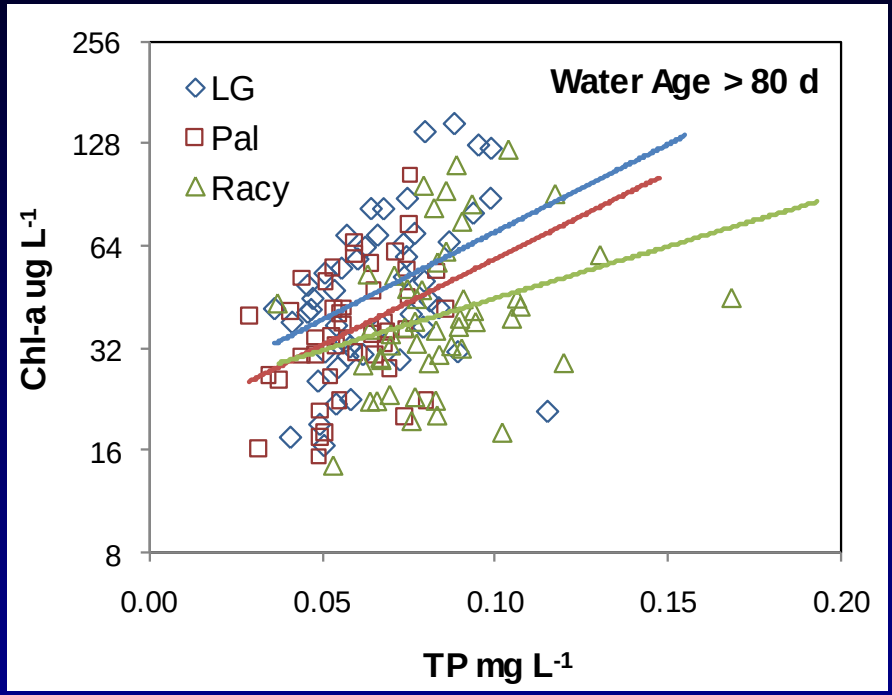






Chl-a vs TP Relationship
Slope Depends on Water Age





Negative relationship between Chl-a and TP at short retention times
(LG & Pal p = 0.05, Racy NS)

Positive relationship between Chl-a and TP at long retention times
(All regressions p < 0.05)

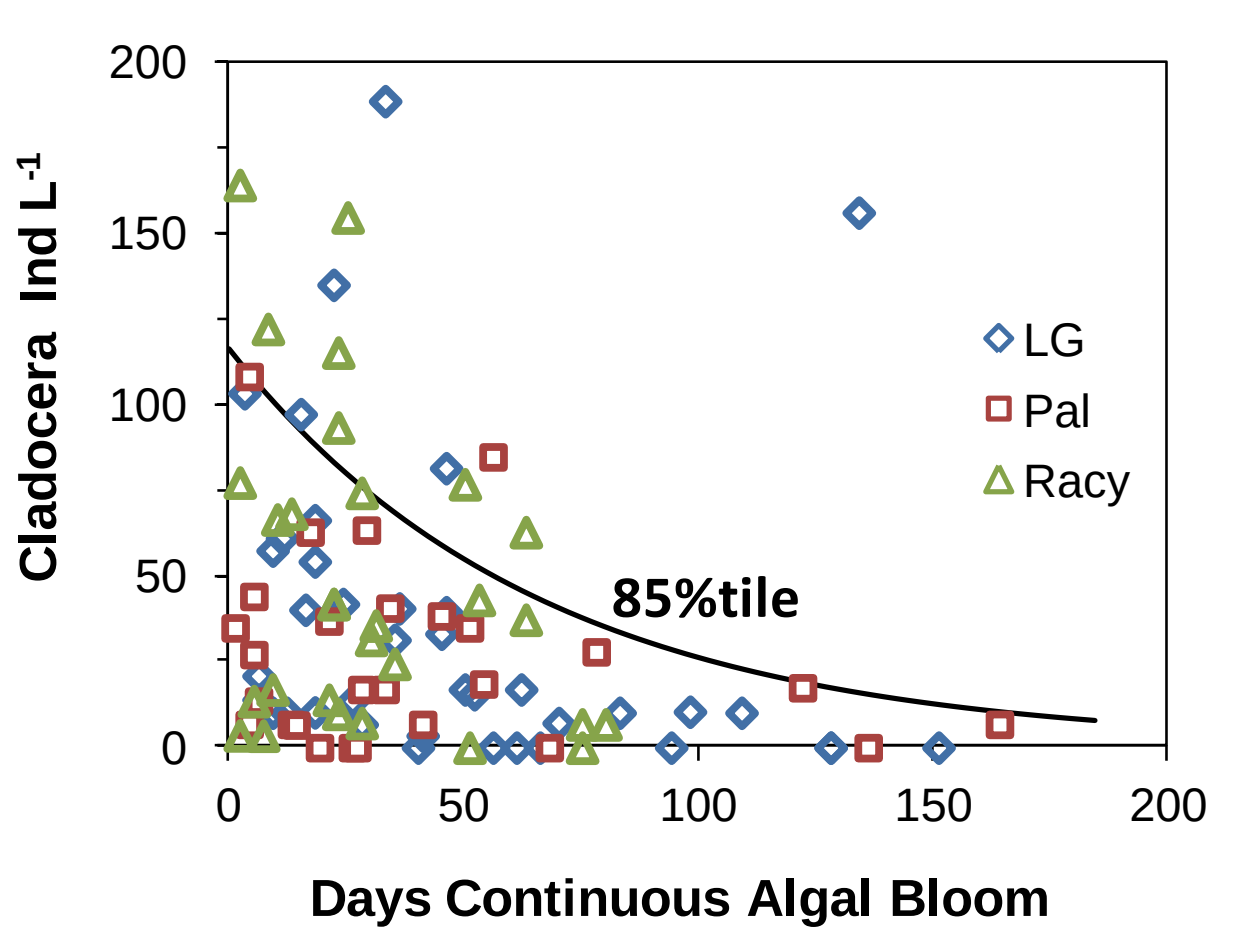
Monthly mean values, Apr – Oct, 1995 – 2005; log Y-scales; regressions ln(y) = mx+b

Hydro-Ecological Models

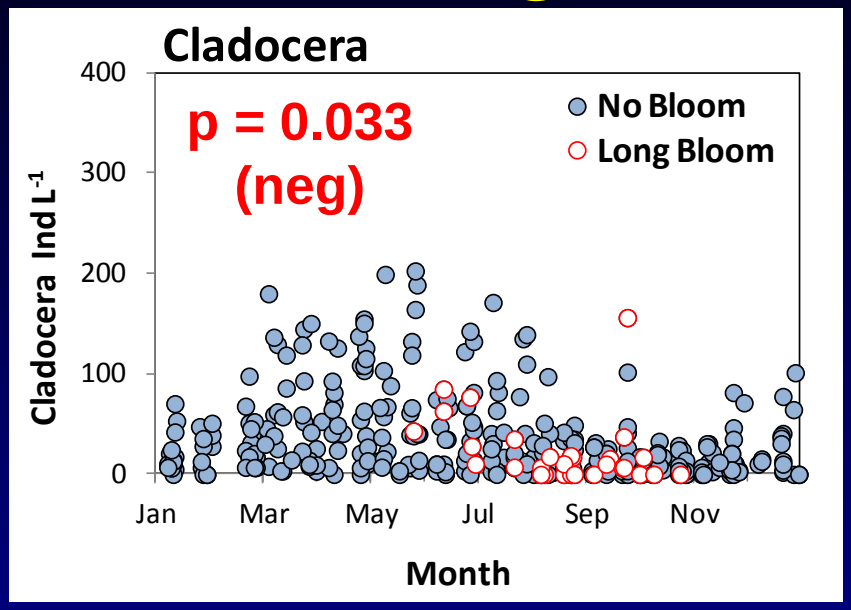
- Predict algal bloom metrics (dependent variables)
  - Bloom magnitude (Chl-a)
  - Bloom duration
  - Dinoflagellate abundance
  - N_2-Fixation
- Use hydrologic prediction (independent) variables: Water age and variables derived from water age
- Multiple linear and logistic regression
- Data sets 11 yr (1995 – 2005)

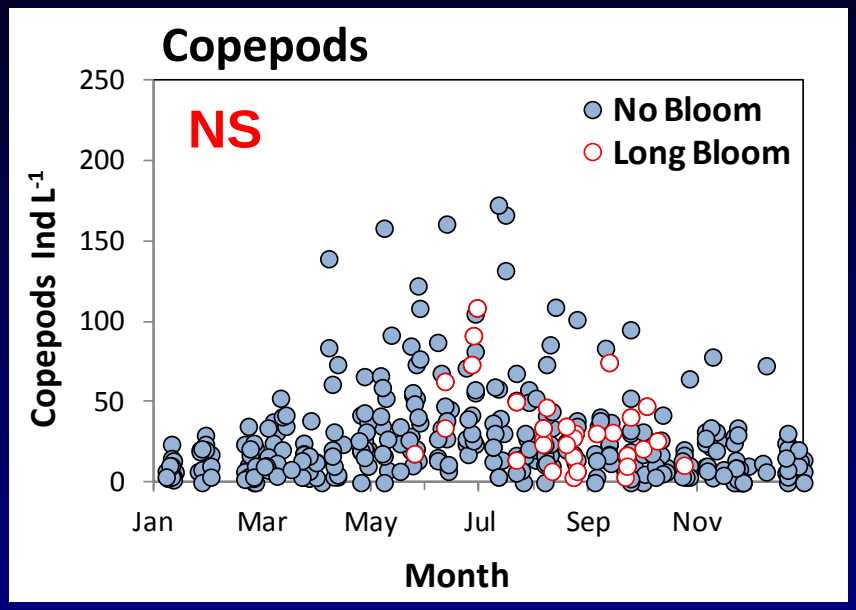
Example of Ecological Metric - Algal Bloom Duration

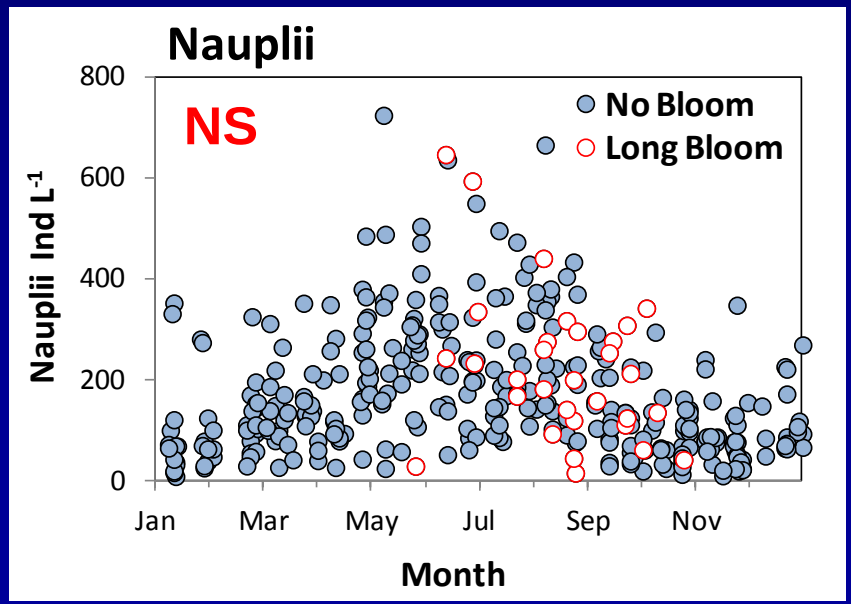
Abundance of zooplankton, e.g. cladocera, is reduced during extended algal blooms

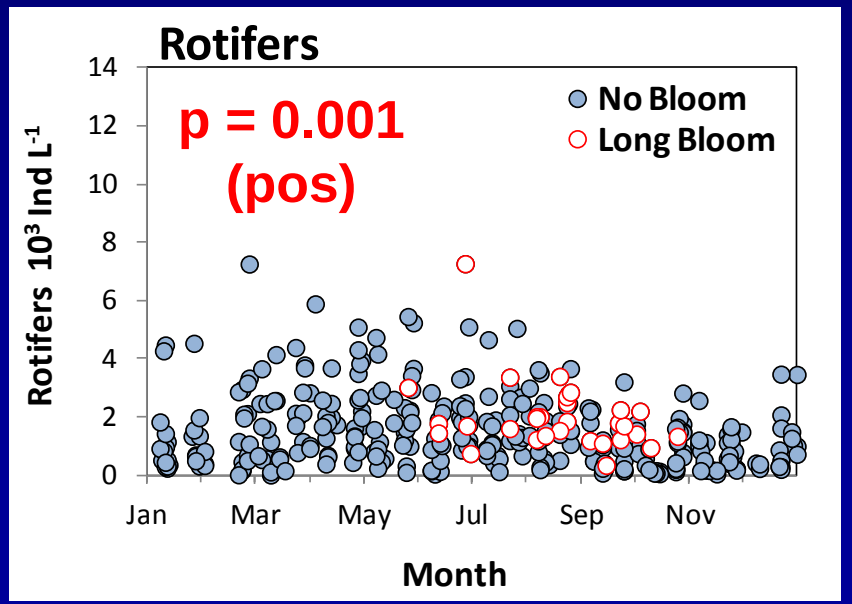


Decline in Zooplankton – Seasonal or Algal Bloom Effect?







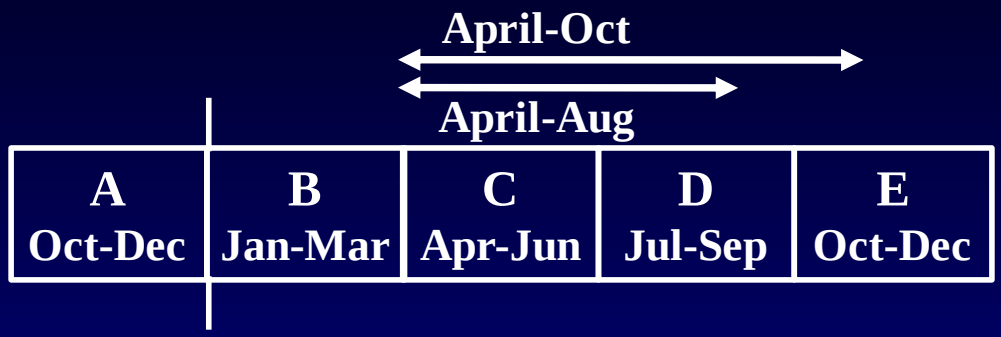


Hydro-Ecological Models
Dependent Variables: Algal Bloom Metrics

Algal Bloom Metric	Effect(s)	Measured Variable
Duration of freshwater algal blooms	Altered zooplankton community; reduction in fish production	Duration of longest annual bloom
Magnitude of freshwater algal blooms	1) Altered phytoplankton community; cyanobacterial toxins 2) Depletion of dissolved oxygen; effects on fish reproduction, growth, and mortality	Maximum annual bloom chl-a
Change (Δ) in N load	Additional N loading	Annual mass N added via N_2-fixation
Marine algal blooms	Potential toxic species	Maximum annual dinoflagellate biovolume

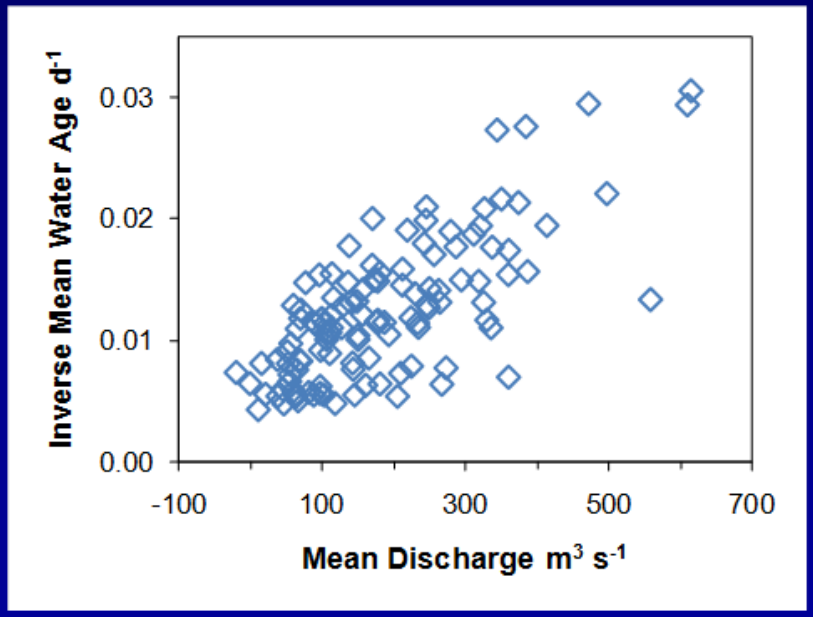
Prediction (Independent) Variables Based on Water Age (Residence Time)

1) Water age for five quarterly periods starting with the last quarter of the previous year, plus two growth season periods



2) Include mean, maximum, and minimum water age for each period

3) Include the inverse of each water age. Inverse water age is positively related to flow but without negative values at low-flows

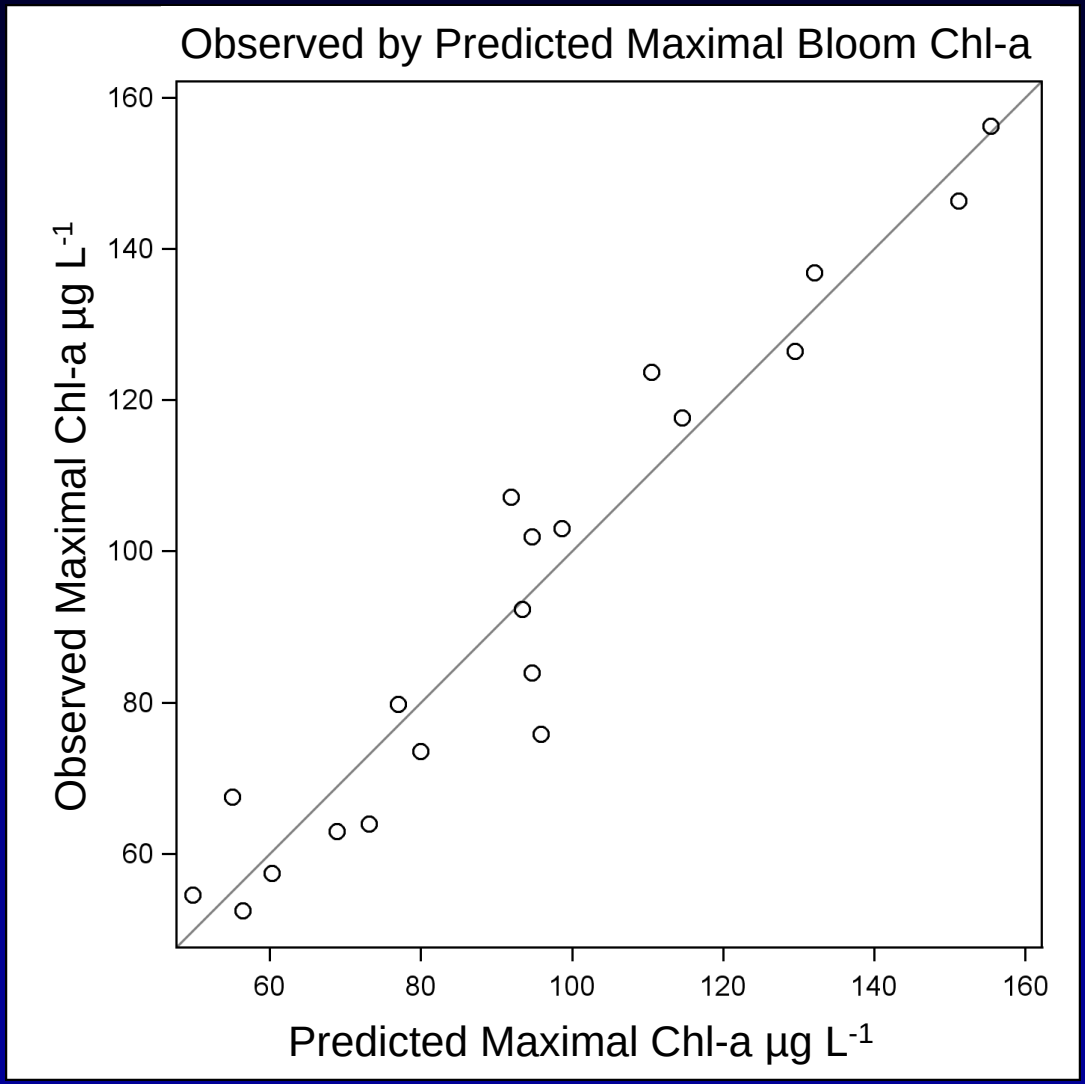


Monthly mean values Racy Pt & SJSR16

Hydro-Ecological Models
multiple linear and logistic regression

- 8 regression models needed to predict 4 algal bloom metrics across multiple river segments
- Used 7 linear regression models and 1 logistic regression model
- Linear regression models
  - 3 to 7 independent variables
  - Adjusted R^2 values of 0.80 to 0.97

Example – Prediction of Maximal Bloom Chl-a



Multiple Linear Regression
Adjusted $R^2 = 0.88$

Variable	Std Regr Coeff
MinAgeD	-2.318
invMinAgeD	-1.764
MeanAgeD	1.367
MaxAgeE	1.297
invMeanAgeE	0.755
invMean_Age_Apr_Oct	0.636
invMaxAgeA	0.540

Data set: Segments 3 & 4
LG12 & Racy Pt

Conclusions - 1

- The St. Johns River is impaired by cyanobacterial blooms caused by high nutrient levels
- Blooms are summertime events and are exacerbated by low-discharge
- Blooms cause altered food webs, low DO, algal toxins, and increased N loading through N_2-fixation

Conclusions-2

- Relationships between algal blooms and nutrients depend strongly on hydrology
- At low river discharge:
  - Lower phosphorus, dissolved color, and turbulence
  - Increased chl-a (relaxed light limitation)
- Algal bloom metrics (e.g. magnitude, duration) are predictable from residence time (water age) with regression models
- Modeled water withdrawals (~10^6 m^3 d^{-1} *) caused negligible worsening in algal blooms

* 262 x 10^6 gal d^{-1}

Any Questions?

The St. Johns River Water Supply Impact Study Final Report: *Chapter 8, Plankton*
http://floridaswater.com/watersupplyimpactstudy/

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