Process Rates Parameterization in a Blackwater River Estuary - The St. Johns River, FL

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St. Johns River WMD
**SJRWMD Surface Water Quality Monitoring at the “Sub-Ambient” Temporal Scale**

- **Automated Samplers** – Since 1987; used to characterize urban and ag stormwater, treatment efficiencies

- **In-Situ Autonomous Sensors:**
  - First St. Johns R. networks established mid 1990s (USGS, NOAA, NOS)
  - Provided data stream in sync with hydrologic, meteorological drivers
  - Indispensable for time-varying hydrodynamic and WQ model calibration necessary for dynamic river estuary settings
Lake George

- Florida’s 2nd largest lake
  - 210 km² (46K acres), uniform ≈ 3.5 m depth
- Head of tide for SJRE
- CDOM limits photic zone
- 95% of load from upstream; adjacent inflow primarily springs
- Focus for Water Supply Impact Study effects on phytoplankton
- Eutrophic - Recently listed as nutrient impaired, needing TMDL
Lake George CM Programs

- Long-Term (USGS) -
  - Bloom peaks, phytoplankton biomass, TMDL targets compliance
  - Sediment re-suspension
- 2009 Survey Objectives:
  - Vertical stratification and bottom water anoxia - strength, persistence, setup and disruption
  - Patterns in R and GPP through bloom cycles
Conceptual Model – Lake Productivity

- Shallow; limited temperature-density stratification
- SOD, underwater light are factors in water column DO balance
- Uncertainty regarding various fluxes can make explicit computations difficult

Adapted from Staehr et al., 2010. Limnol. Oceanogr.: Methods 8: 628–644
Lake George Productivity Parameters - Methods

Staehr et al., 2010. Limnol. Oceanogr.: Methods 8: 628–644
Lake George – Event Scale Processes

L. George Chlorophyll-α
May - September 2009

- Ambient Grab Chl-a
- 3-Hr Wind > 90th %ile
- 12-Hr Wind > 80th %ile
- Phycocyanin Chl-a

Lab Chlorophyll-α, μg/L

Phycocyanin, BG Cells/mm³
(Fluorescence, ex. = 595 nm, em. = 650 nm)
L. George – Phytoplankton Productivity
Syncing Standing Stock w/ Productivity

Lake George *In Situ* DO Data, 2009

Exponential

Senescence

Diatom Dominance

Late Summer

Carbon, g/m²/da

GPP  R  GPP  R  GPP  R  GPP  R
The Ocklawaha River

- One of Florida’s Unique artesian spring-fed rivers, impounded since 1968 by Kirkpatrick Dam
- Invasive aquatic plants management: reservoir draw down every 3 years
- During drawdowns:
  - Elevated N and P
  - Algal blooms
  - Low DO
- What are processes that lead to adverse WQ?

YSI EXO Deployment
Nov. – Jun 2012
Rodman Reservoir Drawdown 2012

In Situ DO

Ocklawaha R. Highway 19, 11/22/11 - 6/11/12

Graph showing DO saturation and GPP and R values during drawdown and refill periods.
Problem: Dramatic shifts in primary producer communities from rooted macrophytes to benthic algae and periphyton, with concomitant changes in fish and invertebrate communities\(^1\).

- Increases in NOx implicated as a driving factor
- Fundamental question – what is NOx processing in springs, how does it affect primary producer structure and function?

\(^1\)(Scott et al., 2004; Munch et al., 2006).
Overall Objectives:
- N loading sources, pathways and processes
- Assess drivers of productivity changes, primarily NO$_x$
- Focus on Silver River (Alexander Springs as reference)
- Physicochemistry research elements:
  - Sources and Sinks of Nutrients
  - Nitrogen Dynamics and Metabolism
Spring Run Whole Ecosystem NO$_3$ Processing Assessment Conceptual Approach*

- Continuous DO and NO$_x$ permit simultaneous measure of production & N assimilation
- C:N indicate primary producer dominance
- Longitudinal network allows reach segment calculations
- Mesocosms to assess assimilation w/o replenishment

*Cohen et al, 2011, SJRWMD Technical Publication
In Summary . . .

- CM data essential for describing events and processes operating at sub-ambient (hours to weeks) time scales.
- Necessary or extremely valuable when assessing compliance with magnitude-duration-frequency criteria.
- Pre-deployment data quality objectives should consider:
  - Numerical precision
  - Ancillary measurements
  - Time step
  - Site heterogeneity
- Data sets get big – need for processing algorithms and automated non-conformity detection. Challenges:
  - Time format, sync and interval when merging data sets or applying rate coefficients
  - Smoothing and filtering may be necessary for noise
  - Rules for “cherry picking” should be defined
Submersible UV Nitrate Analyzer (SUNA) made by the Satlantic Corporation (Halifax, Nova Scotia)
Measurement interval 15 minutes
gross primary production (GPP) and ecosystem respiration (R) in units of g O2/m2/d
Reaeration is the most uncertain parameter
Biological processes dominate diel N pattern
N-saturated systems – Primary producers do not assimilate N at night – Underlying assumptions: Since all diel variation is ascribed to autotrophic uptake, the remaining N loss (i.e., the difference between observed concentrations and the flow-weighted input concentration) is ascribed to heterotrophic removal, the bulk of which is denitrification dissimilatory pathways further parsed through stable isotope fractionation
Lake George –
Surface sonde assumed to represent Photic zone; 2/3rds depth aphotic (diagram); Include USGS, as representative of mid aphotic, use to extrapolate to antecedent bloom; assume daily increases in mid depth DO due to photic zone diffusion, not in-situ productivity; instrument types
NEP = GPP – R; Assume R constant, GPP determined from daytime O2 rate based on data (Standard approaches described by Cole and Caraco (1998), Staehr, Coloso et al. (2008), and Vachon Bar charts like Coloso et al (2008) to show GPP, R and NEP
Areas of greatest uncertainty with method: reaeration and mixing depth of respiration. Stability of layers greatly influenced by wind; compare diffusion rate (Coloso 2008) to advective mixing; Result was that wind, instead of suppressing R, enhanced R by mixing bottom water – contrary to common assumption.
Greater
Ocklawahaa River Reservoir Management Effects

Reservoir w/ management drawdowns every 3 years to control nuisance invasive aquatic plants
Effects on WQ – nutrient export, algal blooms, change in hydrologic regime – manifested in low DO
Challenges to productivity calculations – tide causing oscillating velocity for reaeration
• Nitrogen enrichment effects on primary producer structure and function (Cohen and Heffernon)

• Continuous C and N metabolism – integrative measure of combined autotroph and heterotroph productivity

• Methods widely attributed to Odum (1957)

• Approaches to parameterization
  – Mechanistic – Explicitly calculate flux, reaeration, underwater light, etc.
  – Empirical – Use data as integrator, constrainer of aggregate processes

• Estimates of oxygen reaeration will use published relationships with flow velocity where the nighttime regression (Owens 1973) or peak DO lag (Chapra and DiToro 1992) techniques cannot be validated.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Primary Production</td>
<td>GPP</td>
<td>g O₂ m⁻² d⁻¹</td>
</tr>
<tr>
<td>Net Primary Production</td>
<td>NPP = 0.1875 * GPP</td>
<td>mol C m⁻² d⁻¹</td>
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<tr>
<td>Ecosystem Respiration</td>
<td>RE</td>
<td>g O₂ m⁻² d⁻¹</td>
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<tr>
<td>Net Ecosystem Production</td>
<td>NEP = GPP - RE</td>
<td>g O₂ m⁻² d⁻¹</td>
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<tr>
<td>Production:Respiration</td>
<td>P:R</td>
<td>unitless</td>
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<tr>
<td>Autotroph N assimilation</td>
<td>UₙN</td>
<td>mg N m⁻² d⁻¹</td>
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<tr>
<td>Denitrification</td>
<td>UₙN</td>
<td>mg N m⁻² d⁻¹</td>
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<tr>
<td>Autotrophic P assimilation</td>
<td>UₙP</td>
<td>mg P m⁻² d⁻¹</td>
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<tr>
<td>Abiotic P retention</td>
<td>UₙP</td>
<td>mg P m⁻² d⁻¹</td>
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<tr>
<td>Ecosystem stoichiometry*</td>
<td>NPP:UₙN:UₙP</td>
<td>unitless</td>
</tr>
</tbody>
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* - Note that for ecosystem metabolism stoichiometry, the mass flux of autotroph assimilation of P and N is converted to a molar basis using the atomic mass.