Florida Bay Biogeochemistry and Phytoplankton Blooms: Synthesis for Ecosystem Management and Restoration

David Rudnick, Christopher Madden, Stephen Kelly
South Florida Water Management District

Joseph Boyer, Rudolf Jaffe, Henry Briceño, Rene Price
Florida International University

Patricia Glibert
University of Maryland

Cynthia Heil
Florida Fish and Wildlife Conservation Commission

Steven Blair
Miami-Dade Department of Environmental Resource

Marguerite Koch
Florida Atlantic University

Christopher Kelble
AOML/NOAA

December 10, 2008
Nutrient Cycling and Phytoplankton Bloom Studies: Progress Over Last 3 Years

- Continued water quality monitoring (but current hiatus) (SFWMD-FIU, NOAA, MD-DERM, USGS, ENP)

- Water quality indicator developed (Boyer, Kelble, Ortner, Rudnick)

- Nutrient budgets: creek inputs, groundwater input, improved Atlantic and Gulf boundary estimates (Boudreau, Woods, Zucker, Rudnick, Troxler, Price, Swarzenksi, Gibson, Boyer, Hamrick)

- DOM characterization, source, fate, effect research (Jaffe, Boyer, Rudnick, Kelly, Glibert, Heil)

- P cycle: sediment chemistry, seagrass, microbial role (Koch, Zhang, Heil, Glibert, Boyer)

- Prolonged eastern FL Bay phytoplankton bloom started in 2005: phenomenology and mechanisms (Rudnick, Boyer, Glibert, Heil, Blair, Kelble, et al.)

- Model development (Hamrick, Madden, Glibert, Nuttle, Cosby, Boyer)
Nutrient Cycling and Phytoplankton Bloom Studies: Learning from an Unexpected Event

Eastern cyanobacterial bloom phenomenology and mechanisms

Importance of:
• long water residence time
• disturbance: tropical storm events and human activity
• storm timing relative to drought
• stratification and dissolved oxygen?
• P sources, availability, and microbial process efficiency
• dissolved organic nutrients
• seagrass as a nutrient reservoir
• seagrass – phytoplankton feedback cycle
• sponges
Florida Bay Water Quality Indicator: a Report Card for Restoration Managers

SUMMARY FINDING: Re-suspension of nutrients from the 2005 hurricane season resulted in algal blooms in many regions of the southern estuaries and may cause continued algal blooms in the bay for some time. However, this is expected to subside within a few additional years in lieu of further significant hurricane activity and if water flows to the southern estuaries is improved should return to predominantly green for all regions with the possible exception of BMB. If water flows do not improve the areas will probably remain yellow.

KEY FINDINGS:
1. The majority of regions assessed had significant algal bloom activity that appears to have been predominantly influenced by the heavy 2005 hurricane season aggravated for the eastern bay by road construction on US 1.
2. The majority of regions assessed had chlorophyll-α and algal blooms rated as moderate (yellow).
3. The majority of regions assessed where the chlorophyll-α was higher than the median do not appear to be indicative of long-term negative trends.
4. The most commonly occurring condition was large spatial coverage of algal blooms and elevated chlorophyll-α concentrations.
5. Overall eutrophic symptom expressions were geographically variable and appear to be explainable from existing phenomenological conditions of hurricane activity overall exacerbated by road construction along US 1 in the eastern areas of the bay.
Eastern Florida Bay and southern Biscayne Bay
Barnes Sound TP and chlorophyll-a concentrations (1991-2007)

TP (μM)

Chl-a (μg/l)


Oct 05

Nov 05
Total phosphorus concentrations in eastern Florida Bay and southern Biscayne Bay

From FIU-SFWMD (J. Boyer)
Spatially averaged chl-a (2006-2007):
- Bloom brackets U.S.1
- Highest near Key Largo
Hurricane Katrina

Wind Speed During 2005 Hurricane Season

Wind Speed at Joe Bay Station (MPH)

6/1 6/21 7/11 7/31 8/20 9/9 9/29 10/19

Wilma
Katrina
Dennis
Rita
Arlene

From W. Abtew
Florida Bay Algal Blooms: C-111 Canal Water Discharge and Regional Chlorophyll-a (pointing toward additional causes)
2005 Disturbances and Barnes Sound chlorophyll-a

- Mangrove clearing begins (Apr)
- Soil mixing begins (Jul)
- Hurricane Katrina with canal P loading (Aug)
- Hurricane Rita (Sept)
- Hurricane Wilma (Oct)
Barnes Sound TP and TOC increases (2000 - 2007)
Distribution of elevated TOC concentrations (mg/l): 2006 vs. 2000-2005
SAV Cover Decrease in Blackwater Sound (2005-2006)

Data from FHAP (Hall and Durako)
Nutrient Bioassay Experiments:
What nutrients are controlling this bloom?

Barnes Sound Bloom (10/22/06)

The Bloom:
- responded to any N addition
- greatest response to DON + DOP
- Utilized both inorganic & organic N & P

From C. Heil, FWRI
Budget of Elevated TP and TOC and Potential Sources

<table>
<thead>
<tr>
<th>Total P (metric tons)</th>
<th>Total organic C (metric tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>400</td>
</tr>
<tr>
<td>10</td>
<td>800</td>
</tr>
<tr>
<td>15</td>
<td>1200</td>
</tr>
<tr>
<td>20</td>
<td>1600</td>
</tr>
</tbody>
</table>

Oct 2005 elevated TP
Mean elevated 2006 P or C
Mean elevated phyto biomass

Potential Sources:
- C-111 Canal load (hurricane)
- Mulched U.S. 1 mangrove
- U.S. 1 mangrove (below-gr.)
- U.S 1 mixed soil
- SAV mortality (above-gr.)
- SAV mortality (below-gr.)
- Detritus import (hurricane)
- Ground water import (hurric.)

??
Low Bottom Dissolved Oxygen Following Hurricane Katrina

From Miami-Dade DERM (S. Blair)
Nighttime Anoxia in Lake Surprise (Sept-Oct 2008) With Rain Event

From Kelly et al. 2008
Sponge Mortality in Eastern Florida Bay

Frequency of occurrence (in benthic quadrats)

From SFWMD 2009 SFER (data from Miami-Dade DERM)
Phytoplankton blooms and SAV mortality: hypothesized cause and effect

- Increased phytoplankton blooms
- Increased water column nutrients
- Decreased light penetration
- SAV mortality
- Sponge mortality
- Anoxia, sulfide toxicity
- Decreased SAV P/R
- Increased sediment destabilization
- Increased suspended sediment
- Sediment destabilization
- Increased water column nutrients
- Rain events w/ stratification

External nutrient, sediment loading
Summary

- Water quality conditions and biogeochemistry reflect both watershed linkage and internal dynamics

- 2005-2007 eastern Florida Bay phytoplankton bloom provides insight of these linkages & dynamics and stability of ecosystem structure (benthic vs. pelagic)

- Phytoplankton bloom initiation related to hurricane and US Highway 1 construction disturbances:
  - C-111 Canal discharge (especially P) with Katrina, Rita
  - post-Katrina stratification, hypoxia/anoxia?
  - wind, surge disturbance of sediment, ground water
  - dissolved organic matter from disturbed peat soil / mangrove near US 1 (nutrient source, oxygen demand)
  - hurricane-construction disturbance interactions

- Phytoplankton bloom sustained by:
  - SAV mortality and feedback cycle
  - Decreased grazing (sponge mortality)
  - Long water residence time with efficient P cycling
  - Use of dissolved organic nutrients by *Synechococcus*