A Synthesis of Models to Simulate Benthic-Pelagic Coupling in Florida Bay: Examination of Ecosystem Restoration and Climate Change

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Florida Bay and the Everglades Watershed: SFWMM, TIME, SICS Model Domains
Integration of Watershed Hydrologic Models

Langevin et al. (2004)
Grid Mesh for Florida Bay Environmental Fluid Dynamics Code (EFDC) & Water Quality Model

Hamrick (2006)
FATHOM (Flux Accounting and Tidal Hydrology Ocean Model)

Cosby et al. (2005)
Florida Bay SAV Numerical Ecological Model Calibration Sites

Nuttle et al. (2005)

Everglades National Park
Taylor Slough
Florida Keys
Florida Bay
Florida Bay Seagrass Conceptual Model

Key State Variables and Interactions

- **DIN (water)**
  - Uptake
  - Recycling
- **Phytoplankton**
  - Uptake
  - Photosynthesis
- **DIP (water)**
  - Uptake
  - Recycling
- **DOM**
  - Excretion
- **Epiphytes**
  - Grazing
  - Mortality
  - Sinking
- **POM**
- **Thalassia Leaves**
  - Loss
  - Translocation
- **Halodule Leaves**
  - Loss
  - Translocation
- **Ruppia Leaves**
  - Loss
  - Translocation
- **Thalassia Root/Rhiz**
  - Excretion
  - Translocation
  - Sulfide
  - Sulfate Reduction
  - Burial
- **Halodule Root/Rhiz**
  - Translocation
  - Sulfate Reduction
- **Ruppia Root/Rhiz**
  - Translocation

**Key Forcing Functions**

- PAR
- DIN Input
- DIP Input
- OM Input
- Temp
- Salinity
- Freshwater and Ocean Inputs

**Other Processes of Concern**

- Seeds and Propagules
- Cover of Bottom
- Geographic Position

**Data driven**

**Fully Implemented**

Madden et al. (2007)
Environmental Effects on Plant Growth

- **Nitrogen Uptake**: Shows the relationship between nitrogen concentration (uM) and nitrogen uptake. Halodule and Thalassia have different uptake rates.

- **Phosphorus Uptake**: Demonstrates that phosphorus uptake increases with concentration. Thalassia exhibits higher uptake compared to Halodule.

- **Temperature Effect**: The growth of Halodule and Thalassia varies with temperature (°C). Madden et al. (2005) found that specific temperatures optimize growth for each species.

- **Sulfide Toxicity**: Illustrates the impact of sulfide concentration (mM) on plant growth. Halodule and Thalassia show different tolerances to sulfide toxicity.

- **Salinity Effect**: Shows how salinity (psu) affects the growth of Halodule and Thalassia. Higher salinities reduce growth in both species, but the extent varies.

- **PAR and Light Intensity**: The relationship between light intensity (PAR in μE) and growth, with Halodule and Thalassia showing varying sensitivities to light intensity.

Salinity

SAV

High Salinity

Salinity output from FATHOM Cosby et al. (2005)

SAV from Madden et al. (2006)
Integrating the FATHOM and SAV Models for MFL: *Halodule* Model Response to Salinity
Eastern Florida Bay Algal Bloom

Chlorophyll a (μg/l)
2006-2007 average

Chlorophyll a (μg/l)
Jan 8-10, 2008
Seagrass Community Phytoplankton Module

- **N Substrate**: NH4, NO3, urea
- **New P**: Advection
- **Recycled N&P**: 40%~100%
- **Phytopl**: Grazing 0-20%, Variable C: chla, Variable C:P
- **Epiphytes**: Advection (TT=10-120 d)
- **SAV**: Net Settling 1-15%
- **Resuspension**
- **Geochemical Sequestration**
- **Remin P**: Bound P, Available P
- **Below ground**: Sediment OM
- **Sediment P**: Bound P
- **Available P**: Sediment P
- **Geochemical Sequestration**: NH4, NO3, urea
Characteristics of the Phytoplankton Module

- Dependency on Recycling
- Dependency on Retention Time
- Dependency on Grazing Rate
- P Limitation/Injection and Bloom
- N Substrate Preference
- Mechanistically Incorporates Variables Linked to Climate Change: depth, light, temperature, salinity response
Basin Turnover Time and P Recycling Efficiency

- Turnover = 20d: Recycling = 0.4
- Turnover = 40d: Recycling = 0.6
- Turnover = 60d: Recycling = 0.8
Grazing (Sponges)

Filtration $= 10\% \text{ d}^{-1}$

Filtration $= 15\% \text{ d}^{-1}$
Model Sensitivity

- Least Sensitive to Turnover Time
- Nutrient Competition (epiphytes)
- Recycling Efficiency
- Grazing

Most Sensitive to New Nutrient Inputs (in sufficient quantity)
Barnes Sound Algal Bloom Simulation: P injection (Road? C111? Other?)

- **Chla** (ug/L)
- **PAR**
- **SAV mg C/m²**

15% (high) settling; 85% recycling
SAV Decline in Barnes Sound

Frequency of quadrats with high density and sparse vegetation

Oct 05 - Jan 06

Begin increase in freq. of sparse cover Oct 2005 - Jan 2006

(DERM data; Rudnick et al. 2008)
Conclusions

- Due to shallow, highly coupled nature, bay is poised
- Model can identify inflection or “tipping” points where system has a potential to undergo state change
- Sometimes small change = Big Change
- We are somewhere between a Box of Models and a Real Model Synthesis
- We can use simple transport and heuristic models to understand ecological responses
- Models are now being used in synthetically in developing statutory freshwater requirements and in evaluating restoration designs in the context of climate change
- SAV Model Fortran algorithms are incorporated in EFDC and
- Model links to FATHOM, therefore SAV and WC/WQ module interacts with 2x2, RSM, SICS, PHAST and the HYCOM boundary
- Upwardly linked to GAM Higher Trophic Models and HSMs
- Will be linked to the mangrove transition zone model