An Applied Ecological Modeling Study of the Florida Bay Seagrass Community: Examining Alternate Ecosystem States

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Introduction

The seagrass community that carpets much of Florida Bay is dominated by turtle grass (*Thalassia testudinum*) and shoal grass (*Halodule wrightii*). In fresher areas of the mangrove ecotone, widgeon grass (*Ruppia maritima*) is common. These submersed aquatic vegetation (SAV) communities are considered keystones of the ecosystem and critical indicators, providing:

- Habitat and food
- Nutrient uptake
- Sediment stabilization

Seagrass beds began to die in the 1980s and dieoff continues sporadically to this day. This is considered to be partially the result of diversion of freshwater from Florida Bay, leading to often-chronic hypersaline conditions harmful to the ecosystem. Management plans within CERP and Minimum Flows and Levels (MFLs) initiatives are focused on restoring freshwater flow to the bay to re-establish estuarine conditions for a healthy seagrass ecosystem.

An ecological simulation model was developed for SFWMD USGS and FCELTER. The model is used in support of restoration, management and research in Florida Bay to:

- Calculate the optimum conditions for seagrasses
- Evaluate effectiveness of restoration strategies
- Calculate nutrient uptake capacity of SAV
- Predict pelagic-benthic interactions and dominance

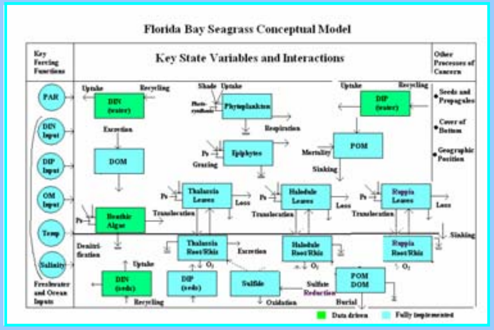

Figure 1: Conceptual model underlaying the numerical simulation model.

Model Description

The model (Figs. 1, 2) is developed for six basins in the bay (Fig. 3), and describes seagrass and microalgal dynamics. It is programmed in MATLAB with a timestep of 3 h. Competition between seagrass species is implemented through density limitation and sharing of nutrient pools and PAR. Calibration of the model was achieved through least-squares minimization of the summed squared error of the biomass of both species.

Acknowledgements

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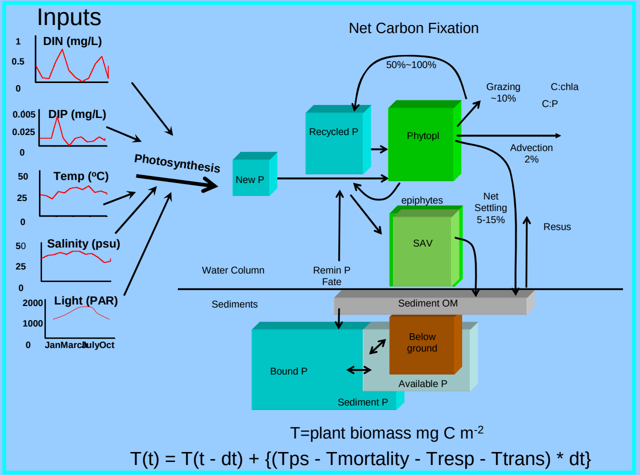
Reference

Cosby, B. and W. Nuttle 2004. Final Report: MarkIII Runs and Estimated Water Budget 1970-2000. SFWMD Contract C-15975-WO05: FATHOM and PHAST Model Expansion to Support Development of Minimum Flows and Levels for Florida Bay. Environmental Consulting and Technology, Inc. Project Team Marshall, F.M., B. Cosby, and W. Nuttle.

Plant Production, Mass Balance and Biogeochemistry



T=plant biomass mg C m^{-2}

$$T(t) = T(t - dt) + \{(Tps - Tmortality - Tresp - Ttrans) * dt\}$$

Figure 2: Detailed conceptualization of core biogeochemistry in the model and the generic equation governing the growth of SAV. Equations for each plant are parameterized with species-specific coefficients. Data input examples shown at left.

Calibration

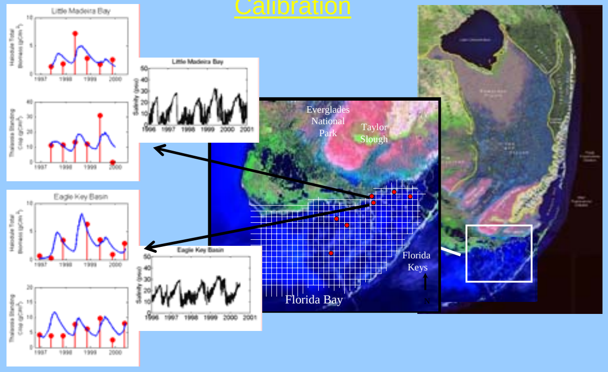


Figure 3: Calibration results are shown along with salinity data for two basins near Taylor River-a fresher site near the mouth and one 5 km bayward. The model output (blue) was calibrated to monitoring data (red points) collected by Miami-Dade DERM, Florida FWCC FHAP program and Univ. of VA. Salinity data were recorded every 15 min by the USGS and ENP.

Results: Hindcasts using FATHOM model salinities

Thirty year hindcasts of SAV for 1970-2000 at three sites were performed using the FATHOM water balance model's (Cosby and Nuttle 2004) hindcast salinities as input to the SAV model. In Little Madeira Bay and Eagle Key Basin, adjacent to Taylor River (Fig. 4 top right) the model shows that:

- Mixed beds of *Thalassia* and *Halodule* were favored during fresher periods when salinities were sustained below 40 psu
- *Halodule* dominated when monthly average salinities remained below 30 psu
- Sustained salinities above 40 psu occurred during three historic droughts (green rectangles) and *Thalassia* dominated at those times

In Whipray Basin in the central bay farther from fresh inputs, mixed-species beds persisted throughout the period despite less variable and high (marine) salinities, indicating salinity effect on SAV is complex and location-specific.

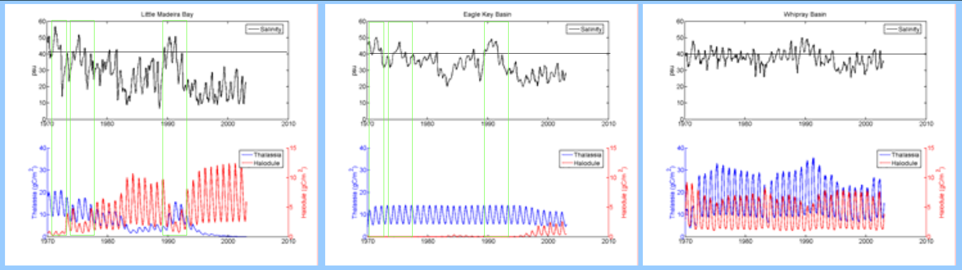


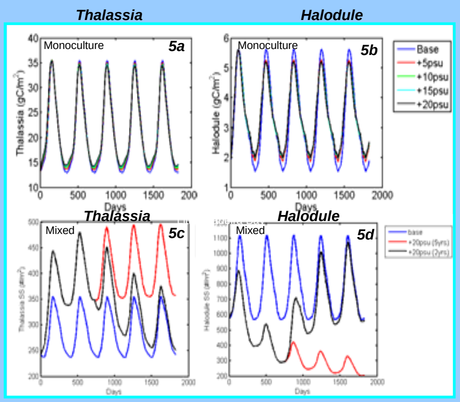
Figure 4. Results of a 33 yr hindcast study. Monthly average salinities were simulated for each basin by the hydrologic model FATHOM in black. *Thalassia* (blue) and *Halodule* (red) shift in response to salinity. Hypersaline periods are framed in green. Note differing scales for SAV axes.

Results: SAV Harm and Recovery

In an analysis of significant harm to SAV and its recovery, salinity was increased from baseline levels (blue) by up to 20 psu for three or five years in monoculture and mixed species plots.

The model predicts:

- Both species tolerate high salinity in monoculture beds (Fig. 5a, b top)
- In a mixed bed, species follow opposite trajectories with *Thalassia* (Fig. 5c bottom left) dominating *Halodule* (Fig. 5d bottom right) at higher salinities.
- During elevated salinities *Thalassia* (black, red 5c) increased above those of baseline salinity (blue 5c) levels, while *Halodule* (black, red 5d) was outcompeted and rapidly declined.
- When salinity was restored to baseline levels at 720 days, *Halodule* did not recover to previous levels for another three years (black 5d).
- After a five year exposure (red 5c, d), *Thalassia* increased by nearly 50% and remained elevated while *Halodule* continued to decline.



Little Madeira Bay

Figure 5. Five-year simulations for Little Madeira Bay. Modeled SAV tolerance of hypersalinity in beds is high for *Thalassia* and *Halodule* (5a, 5b) in monocultures. In a mixed species bed, competition allows *Thalassia* (5c) to thrive while *Halodule* (5d) declines. Recovery is > 3 years after salinity stress is removed on day 720 (5d black line).

Results: Ecosystem State Changes

Elevated water column P (blue bar) for four months (width of bar) increased phytoplankton chla from <1 ug/L to 15-20 ug/L (Fig. 6a), similar to concentrations in recent bay blooms. PAR was severely attenuated as a result (Fig. 6b), causing a sharp decline in SAV (Fig. 6c). The effect persisted for years despite the rapid reduction of P loading to pre-bloom levels, and led to a state change in the bay from benthic to pelagic dominated. This owes to the assumptions of efficient P recycling (85%) and long water residence times (2% d^{-1} turnover) parameterized in the model.

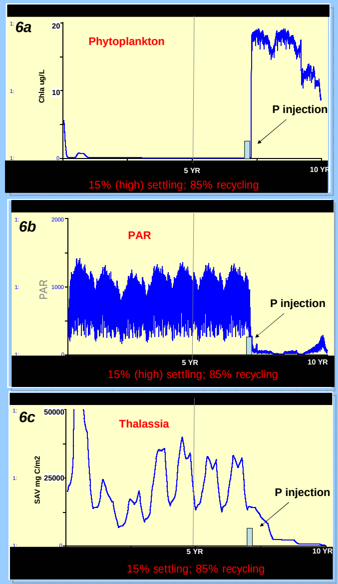


Figure 6. State change to pelagic (6a) from benthic (6c) production due to PAR reduction (6b).

Summary

Our model demonstrates that the effect of hypersalinity *in situ* is a function of SAV tolerance, resource conditions and interspecific competition affected by salinity stress. *Halodule* tolerance in presence of *Thalassia* differs from its response in a monoculture. *Halodule* near freshwater inflows is favored by < 30 psu and poorly tolerate salinities > 40 psu. *Thalassia* dominates under hypersaline conditions. Phytoplankton blooms strongly affect SAV via light attenuation. Efficient nutrient recycling maintains the effects of nutrient increases and bloom conditions on temporal scales of months to years.