An Ecological Model of Seagrass Dynamics in Florida Bay: Hypothesis Testing and Sensitivity Analysis

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Introduction

Florida Bay is a subtropical, karstic estuary that receives fresh water input from the Florida Everglades. To understand mechanisms of seagrass growth, production, distribution and community structure in the bay, an ecological model of *Thalassia testudinum* dynamics was developed. There are two primary objectives of the model:

- to predict quantitative effects of proposed Everglades restoration plans to be implemented by water management
- to understand the ecology of seagrasses and causes of seagrass die-off

Here, we present four applications of the model to demonstrate its versatility and the types of analyses that are being performed in support of Florida Bay restoration.

Conceptual Model

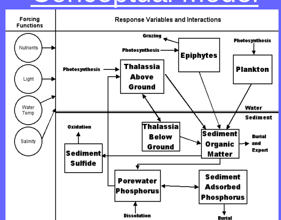


Figure 1: Florida Bay *Thalassia testudinum* conceptual model.

Study Sites

Three site-specific models were calibrated that include a range of community types and environmental conditions: 1) in the northern transition zone with direct freshwater inputs (Little Madeira Bay); 2) in the west, central bay with more oceanic influences (Rabbit Key Basin); and 3) in an intermediate region which experiences hypersalinity events (Rankin Lake).

Model Specifications

- dt: 3 hrs
- 1m^2 spatially averaged unit model, basin-specific
- units: mg C m^{-2}
- MATLAB platform

Calibration

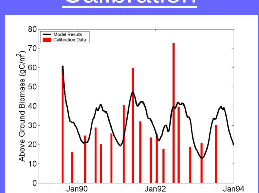


Figure 2: Calibration results for Rankin Lake.

Sensitivity Analysis of Factors Controlling Production

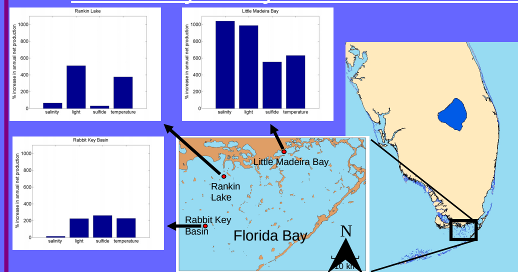


Figure 3: Map of Florida Bay basin sites displaying the relative impacts of controlling factors on seagrass production.

Basins in Florida Bay vary in the relative influence of controls on seagrass production. There is a gradient of increasing P concentration, salinity and sediment depth from east to west with the northeastern bay being the most fresh and most nutrient-limited. Nutrient limitation is the dominant control for all basins.

The relative impact of additional controlling factors was determined by sequentially releasing the limitation of seagrass growth rate imposed by each of four potential stresses: salinity, light, sulfide, and temperature. Model sensitivity was quantified as the % increase in net annual production (=total photosynthesis - respiration - mortality) resulting from optimization of the controlling factor.

Of the four stresses examined, Little Madeira, impacted by low salinity, low light, higher organic input and cooler temperature is most constrained. Rankin Lake, subjected to higher nutrients and epiphyte loads, showed light to be the most significant control. Rabbit Key Basin has a stable oceanic salinity regime, rendering other controlling factors more significant, but the overall environment in Rabbit is more benign than other basins, reflected in higher biomass accumulation (see calibration figures on this poster).

Tolerance of Hypersalinity events

Rankin Lake Salinity

- Salinity in Rankin Lake from 1990-2000 ranged from 15 psu in October of 1995 to 62 psu in April of 1990.
- During this period, the duration of hypersalinity (>40 psu) ranged from 0 to 338 days.

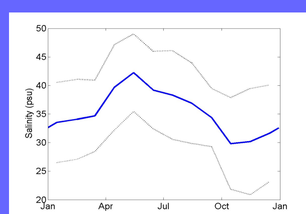


Figure 4: Salinity curve (1990-2000) used as a forcing function for Rankin Lake model with the average hypersalinity (>40ppt) event lasting for 49 days. The curve is an average of monthly salinities over ten years, peak salinity occurring on May 15. Dotted gray lines are one standard deviation.

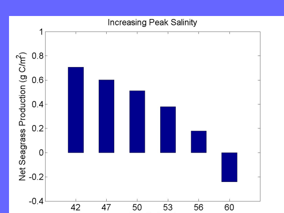


Figure 5: Raising peak salinity while holding the duration of the hypersalinity event constant caused a decrease in net annual production. At 60 psu, net annual production was negative.

Scenarios. The following salinity variables were manipulated to determine seagrass sensitivity to episodes of hypersalinity in Rankin Lake:

1) Level of peak salinity during event
2) Duration of event
3) Shift of onset of event in time

Figure 6: Shifting the salinity curve from the base case centered on May 15 caused significant changes in seagrass productivity. Moving the event forward resulted in a decrease in annual net production because hypersalinity stressed plants in the critical early growing season. Earlier salinity stress also increased the coincidence with the cold temperature stress from early in the year. Delaying the salinity stress 15 and 30 d allowed a separation between temperature and salinity stresses and an increase in biomass.

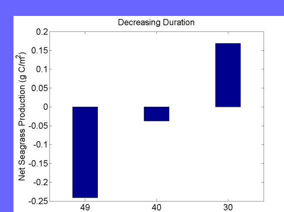


Figure 7: Results from changing duration of a hypersalinity event that peaked at 60 psu from the base case of 49 days to 40 and 30 d. Shorter periods of exposure to high salinities increased the net annual production.

Hypotheses testing for 1992 Biomass Decline

In late 1992, data from several basins reflect a sharp decrease in *T. testudinum* biomass, coincident with the passage of Hurricane Andrew in August. The Rabbit Key Basin model here explores the possible mechanisms for the decline in biomass via two potential impacts of a strong storm affecting Florida Bay.

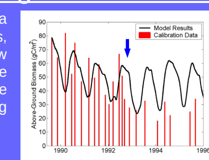


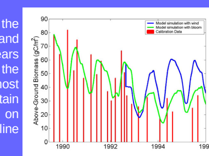
Figure 8: Initial calibration of Rabbit Key Basin without including storm disturbances. Data show a rapid biomass decline (indicated by the arrow) that is not captured by the model.

Simulation of a wind event

Wind creates a shearing force at the sediment surface resulting in mechanical detachment of above ground seagrass biomass and perturbation of surficial sediments:

- Remove 25% of biomass
- Dilution of phosphorus in porewaters by 10% and reduction of sulfide by 10% through increased aeration and oxidation.

Figure 9: Simulation results demonstrate the effects of a 24 hr wind event (blue line) and an algal bloom that persists for three years (green line). The wind event decreased the biomass initially but recovery is almost immediate. The algal bloom can maintain lower levels of biomass but the impact on seagrasses is gradual and the rapid decline observed in 1992 was not captured.



Simulation of increased land run-off

Increased flow of water from precipitation may have resulted in nutrient additions to the bay and temporary phytoplankton blooms:

- Raised water column chlorophyll concentrations from 0.5-2 to 5-7 μg/l, thereby decreasing light at canopy height by 40% and increasing organic input to sediments.

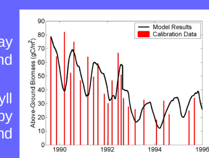


Figure 10: Simulation results incorporating both a wind event and a persistent algal bloom closely fit the calibration data. In August of 1992, a persistent algal bloom began due to the increased runoff caused by Hurricane Andrew. The hurricane also elevated wind speeds in the bay causing shearing of above ground biomass.

Spatial Variability Within Basins

Figure 11: Map of the two sites in Little Madeira Bay. Both sites are permanent sampling stations with continuous data sets starting in 1996.

To investigate the influence of local heterogeneity within basins, and to validate the model, the calibrated model for inner Little Madeira Bay was applied to a second location in the outer bay that is exposed to different environmental forcings. Simulations applied local salinity, water temperature, and water column nutrient concentration data from the two sites and resulted in significantly different biomass curves, closely corresponding to empirical data:

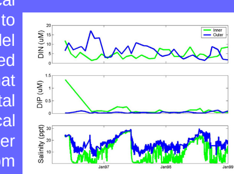


Figure 12: Comparison of nutrient and salinity data from the inner and outer Little Madeira Bay sites used to investigate heterogeneity.

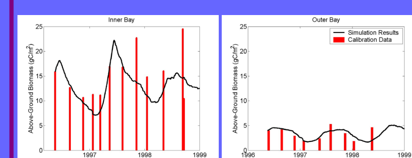


Figure 13: Using the same calibration but different environmental conditions for two points in Little Madeira Bay, the model yielded the appropriate level of change in above-ground seagrass standing stock. This indicates that the other parameters are relatively uniform across the basin.

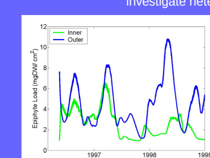


Figure 14: Model simulations show that epiphyte loads may be partly responsible for the decrease in seagrass standing stock at the outer Little Madeira Bay site. An additional factor enhancing inner bay production may be a higher organic matter content (not pictured) yielding higher nutrient concentrations in the sediment.

Summary

This model of seagrass dynamics in Florida Bay allows the exploration of hypotheses that would be impossible to examine through empirical experiments. Model simulations can separate the effects of environmental parameters that are often correlated or confounding and can predict the effects of changes in environmental parameters due to climate, management, or stochastic events. Multiple sites within basins can be modeled to produce fine-scale understanding of spatial variability in seagrass production within the bay.

Acknowledgements

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