PERSPECTIVE OF SCALE IN ESTUARINE MANAGEMENT: CLIMATE CHANGE MAKES IT IMPERATIVE

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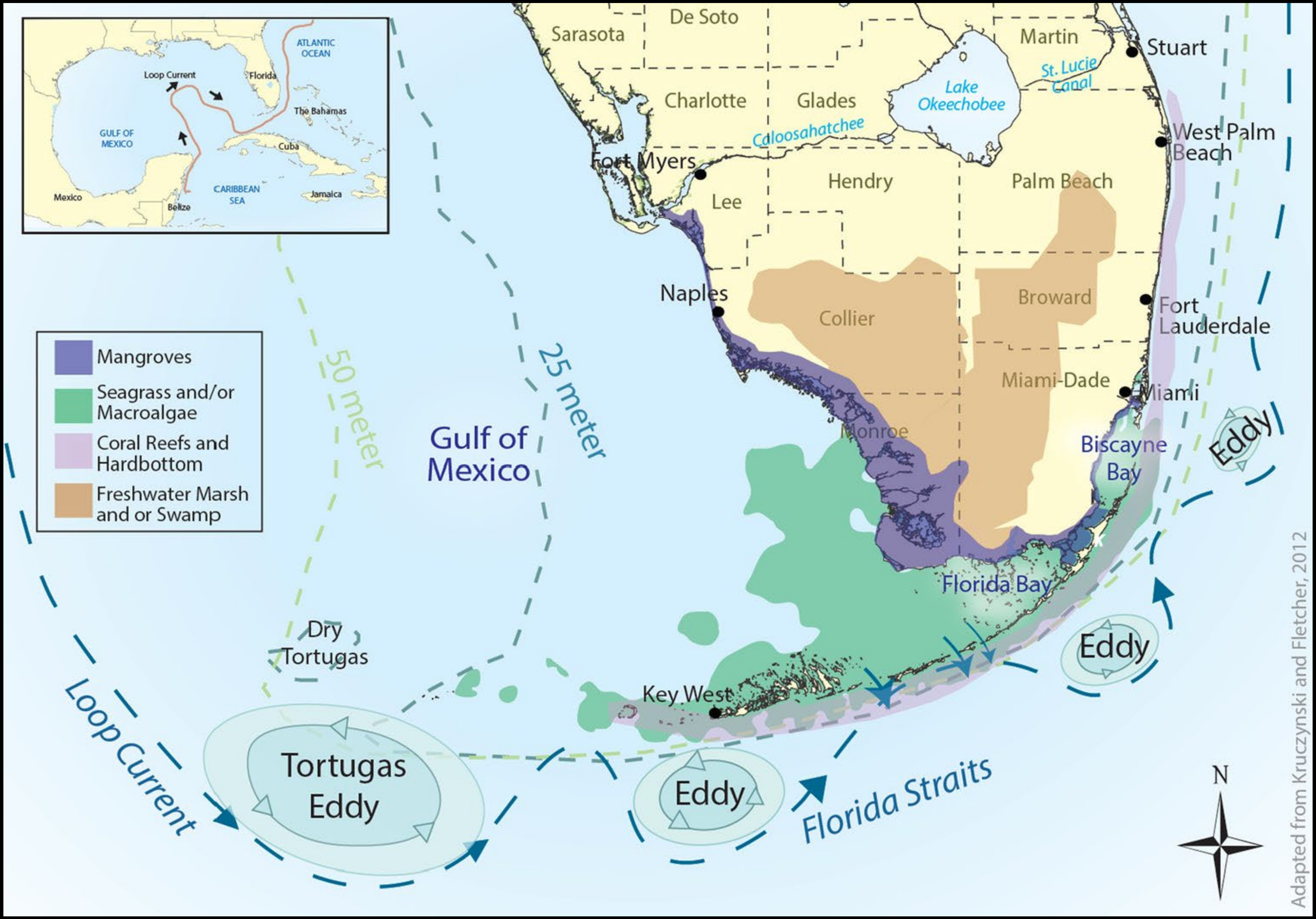
and the Shoulders of Odum's Legacy

Nothing in Everglades Restoration makes sense except in the light of Scale

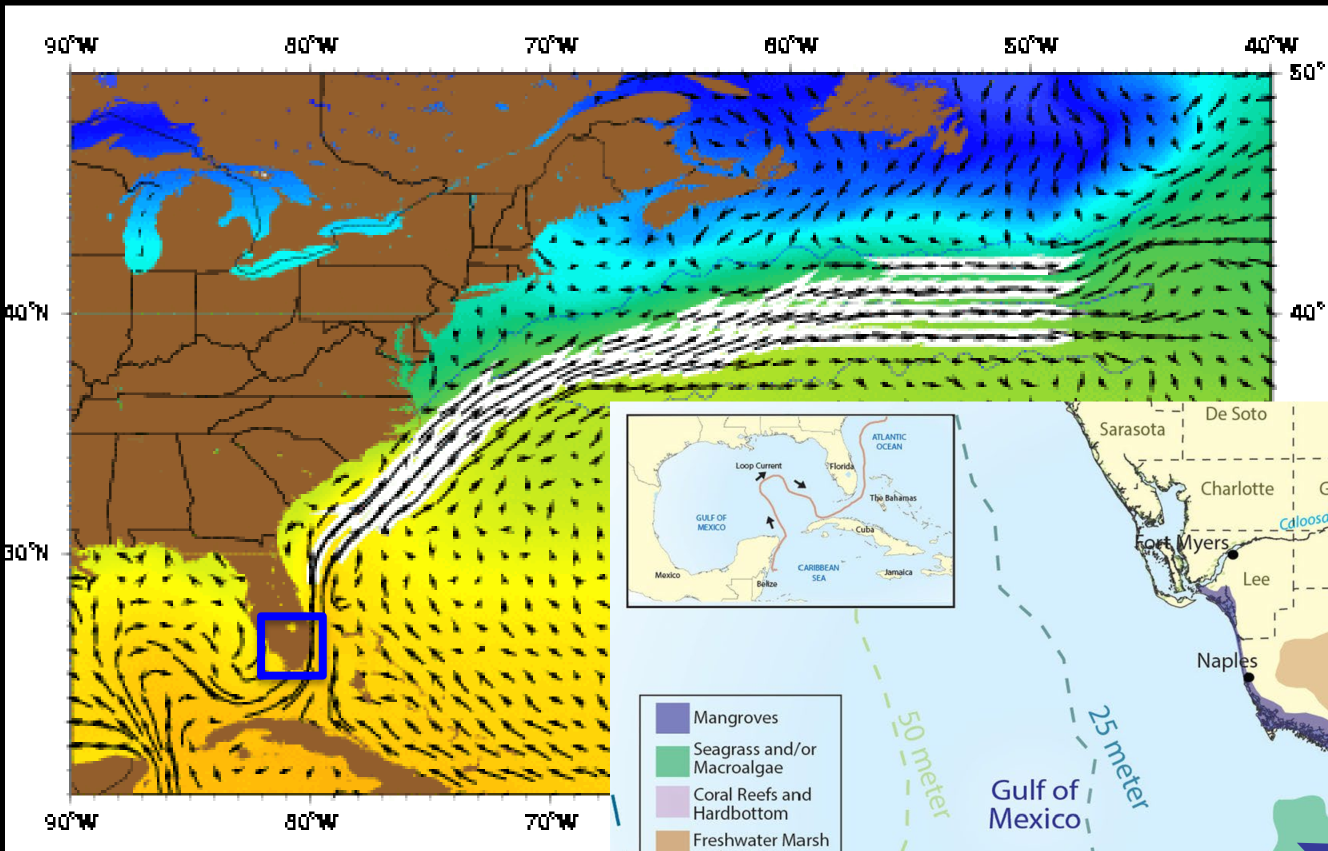
AI Overview

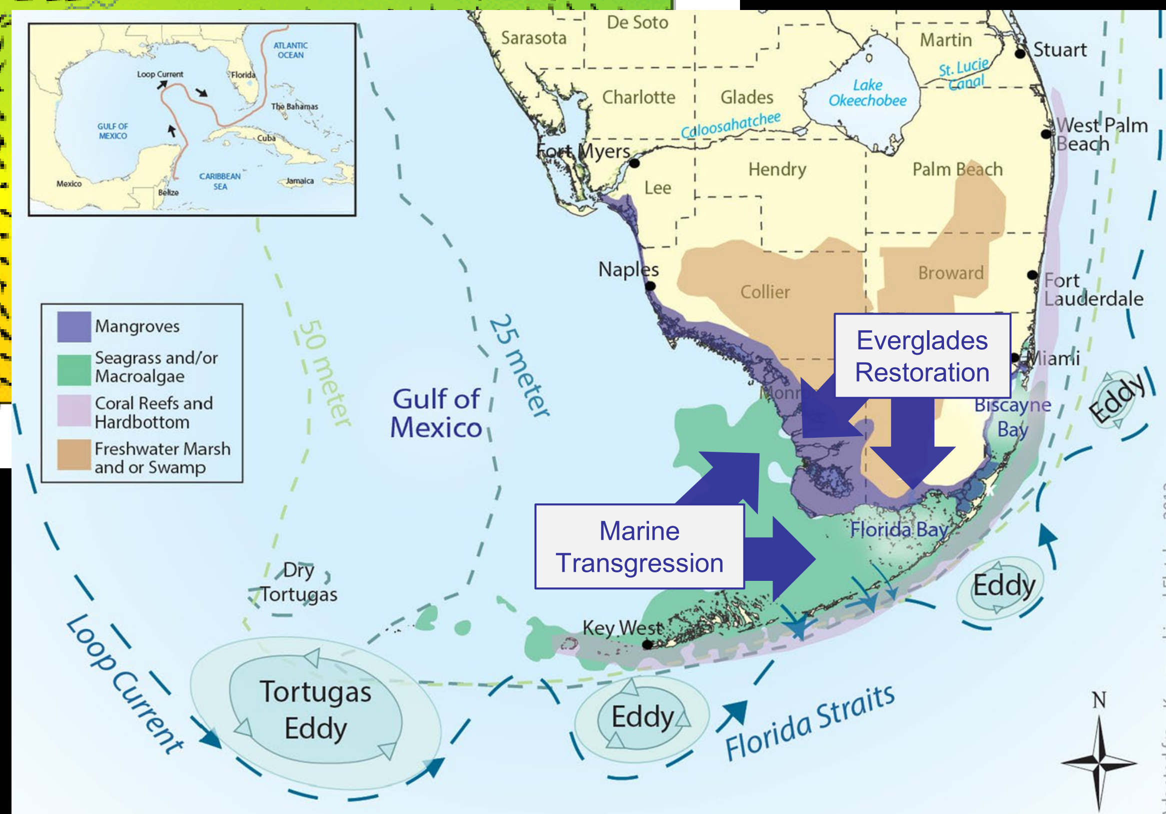
In the context of ecology, Odum emphasized the importance of "scale" because it recognized that ecological processes and relationships can vary significantly depending on the size and scope of the system being studied, highlighting the need to analyze ecosystems at multiple scales to fully understand their dynamics and interactions across different levels, from individual organisms to entire landscapes.

GREATER EVERGLADES' COASTAL MARINE FOUNDATION COMMUNITIES



Strong Regional Drivers
(Climate, Currents, Ocean Temperature)





Specific Future Climate Scenarios (2060)

I. 1.5 Foot SLR Increase (9.5 mm y^{-1})
II. +1.5 °C Temperature Increase
III. 490 ppm CO_2
IV. +/- 10% Change in Precipitation

Environmental Management
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Climate Change Projected Effects on Coastal Foundation Communities of the Greater Everglades Using a 2060 Scenario: Need for a New Management Paradigm

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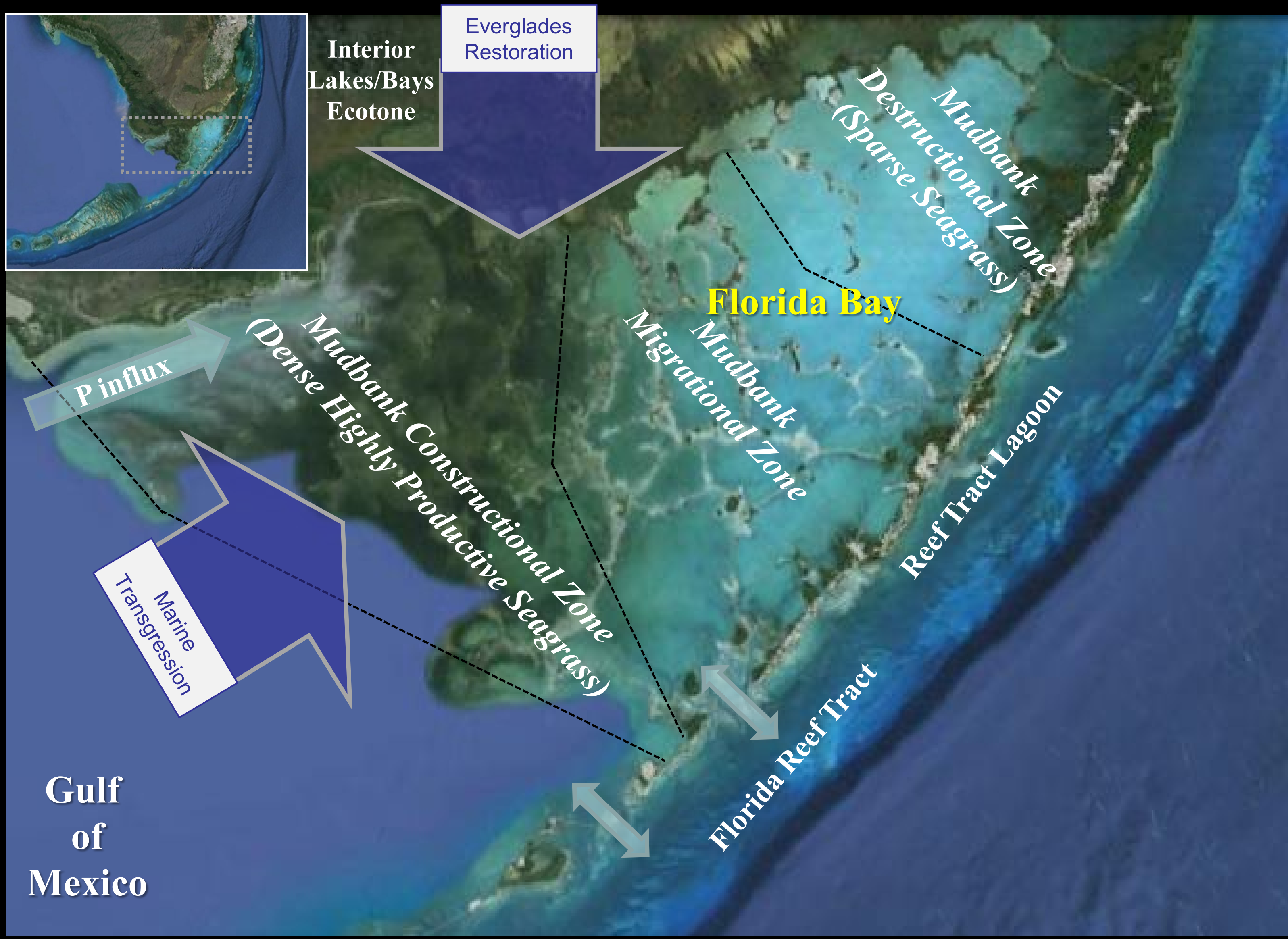
Abstract Rising sea levels and temperature will be dominant drivers of coastal Everglades' foundation communities (i.e., mangrove forests, seagrass/macroalgae, and coral reefs) by 2060 based on a climate change scenario of +1.5 °C temperature, +1.5 foot (46 cm) in sea level, ±10 % in precipitation and 490 ppm CO_2. Current mangrove forest soil elevation change in South Florida ranges from 0.9 to 2.5 mm year^{-1} and would have to increase Florida. Uncertainties in regional geomorphology and coastal current changes under higher sea levels make this prediction tentative without further research. The 2060 higher temperature scenario would compromise Florida's coral reefs that are already degraded. We suggest that a new paradigm is needed for resource management under climate change that manages coastlines for resilience to marine transgression and promotes active ecosystem

Foundation Community	Effect	Strength	Indirect/ Direct	Summary/Comments	Confidence (L,M,H)
				Sea Level Rise (46 cm)	
Mangrove	(-)	3	D	• Everglades' forest elevation change < 3 mm y^{-1} • Storm surge, salt intrusion and loss of peat	• MH • LM
Seagrass/ Macroalgae	(-)	2-3	I	• Wetland and mudbank erosion/nutrient flux leads to low light • Shift seagrass to phytoplankton system under low light conditions	• L • L
Coral Reefs	(-)	2-3	I	• Water quality ↓ with wetland & mudbank erosion and Gulf/FL Bay/Reef connection	• L
				Temperature Rise (+1.5°C)	
Mangrove	(-/0)	1-2	D-I	• Optimal temperatures ↓ (25-30 °C) • High thermal tolerance (~40°C) • High temperature can ↑ soil salinity • Thermal and salinity stress ↓ root production important counter ↑ sea levels	• M • M • H • LM
Seagrass/ Macroalgae	(-)	1-2	D-I	• Long water residence time FL Bay - ↑ temperatures (36-40°C) at thermal limits • Hypersalinity (60-70 psu) with ↑ temp • Greater exchange with sea level rise may ameliorate this temperature/salinity stress • Hypoxia & toxic sulfides sediments ↑ with ↑ temp	• H • H • L • H
Coral Reefs	(-)	3	D-I	• Currently at thermal limits - ↑ bleaching • Decadal decline in reef building corals in Florida and wider Caribbean region • Increased coral disease with ↑ temperature • Species-specific resilience	• H • H • MH • LM
				Increase Atmospheric CO_2 (490 ppm)	
Mangrove	(+/0)	1	D	• Increased CO_2 ↑ photosynthesis if CO_2 limited • Increase above and below-ground production	• L • L
Seagrass/ Macroalgae	(+/-/0)	1-2	D/I	• Some seagrass/fleshy macroalgae ↑ growth & photosynthesis with ↑ CO_2 • Calcifiers & sediments ↑dissolution ↓calcification	• LM • L
Coral Reefs	(-)	1-2	D/I	• Daily variance CO_2 ↑ (~325–725 ppm) in FL Bay • Short-term global ocean 2060 level irrelevant • Long-term ↑ dissolution ↓ calcification & release calcium-bound nutrients from sediment • Lower $CaCO_3$ saturation ↓ net calcification • Refugia patch reefs in seagrass ↓ CO_2 • Reef structure ↓ integrity ↑ bioerosion	• MH • M • L • L • LM • L
				Higher Precipitation (10%)	
Mangrove	(+)	2	D/I	• Lower salinity stress • Greater above- and below-ground production • Mitigate sea level rise influence at inland boundary • % increase in precipitation to ameliorate impacts	• H • LM • L • L
Seagrass/ Macroalgae	(+)	2	D	• Less hypersalinity in northern FL Bay • Modest effect on central bay /western areas • % increase in precipitation to ameliorate impacts	• MH • MH • L
Coral Reefs	(0/+)	1	I	• Not likely to affect reefs unless affect temperature	• MH
				Lower Precipitation (10%)	
Mangrove	(-/+)	2-3	I	• Increased salinity stress & > saltwater intrusion • > oxidation freshwater peats & fire probability • increase mangrove movement inland • Percent increase in precipitation cause impacts	• MH • MH • MH • L
Seagrass/ Macroalgae	(-)	2-3	D/I	• Increased hypersalinity events FL Bay • Increased hypoxia • Less seagrass biodiversity at ecotone • Percent increase in precipitation cause impacts	• MH • M • MH • L
Coral Reefs	(0/-)	1	I	• Not likely to affect reefs unless affect temperature	• MH

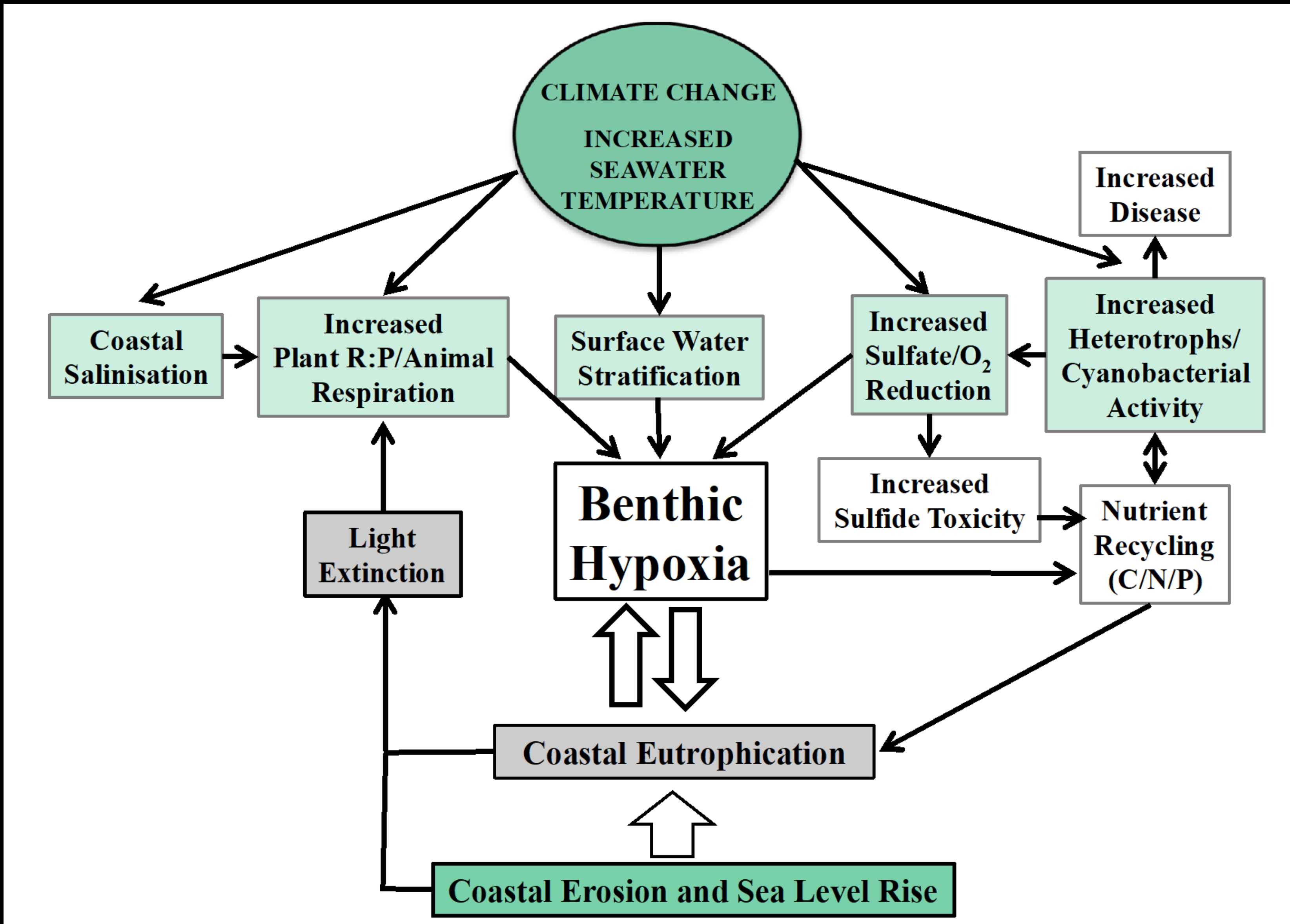
Koch et al. 2014

SEAGRASS ECOSYSTEM AS A CASE STUDY

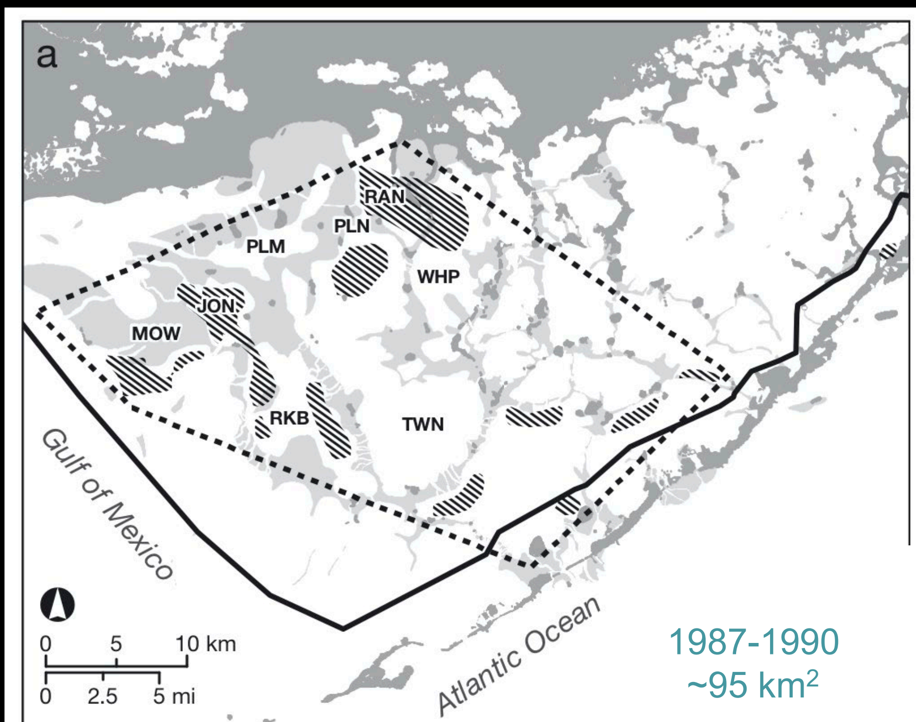


Climate Effects on Seagrass Ecosystems

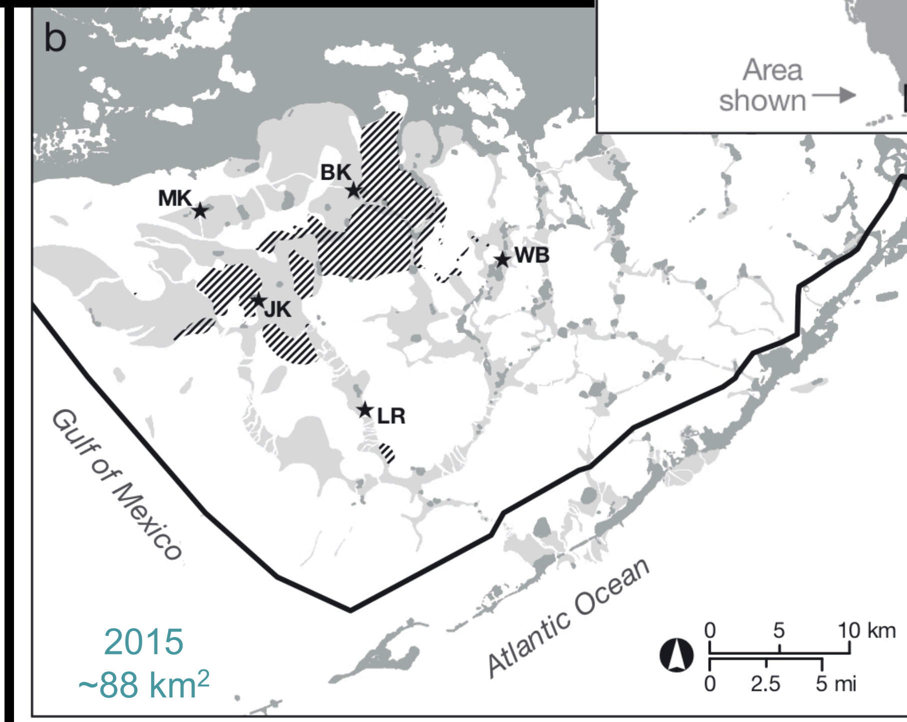
Foundation Community	Effect	Strength	Direct	Summary/Comments	Confidence (L,M,H)
Sea Level Rise (46 cm)					
Seagrass/	(-)	2-3	I	• Wetland and mudbank erosion/nutrient flux leads to low light • Shift seagrass to phytoplankton system under low light conditions	• L • L
Temperature Rise (+1.5°C)					
Seagrass/	(-)	1-2	D-I	• Long water residence time FL Bay - ↑ temperatures (36-40°C) at thermal limits • Hypersalinity (60-70 psu) with ↑ temp • Greater exchange with sea level rise may ameliorate this temperature/salinity stress • Hypoxia & toxic sulfides sediments ↑ with ↑ temp	• H • H • L • H
Lower Precipitation (10%)					
Seagrass/	(-)	2-3	D/I	• Increased hypersalinity events FL Bay • Increased hypoxia • Less seagrass biodiversity at ecotone • Percent increase in precipitation cause impacts	• MH • M • MH • L


CLIMATE CHANGE
INCREASED SEAWATER TEMPERATURE
Increased Disease
Coastal Salinisation
Increased Plant R:P/Animal Respiration
Surface Water Stratification
Increased Sulfate/O2 Reduction
Increased Heterotrophs/ Cyanobacterial Activity
Benthic Hypoxia
Increased Sulfide Toxicity
Nutrient Recycling (C/N/P)
Light Extinction
Coastal Eutrophication
Coastal Erosion and Sea Level Rise

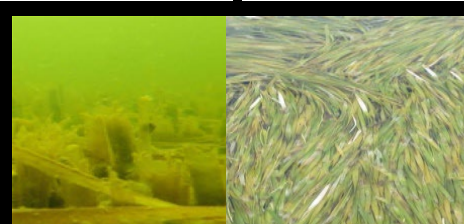
South Florida and Globally
Large-Scale Seagrass Mortality "Die-Off" Events
Attributed to Hypoxia- multiple drivers



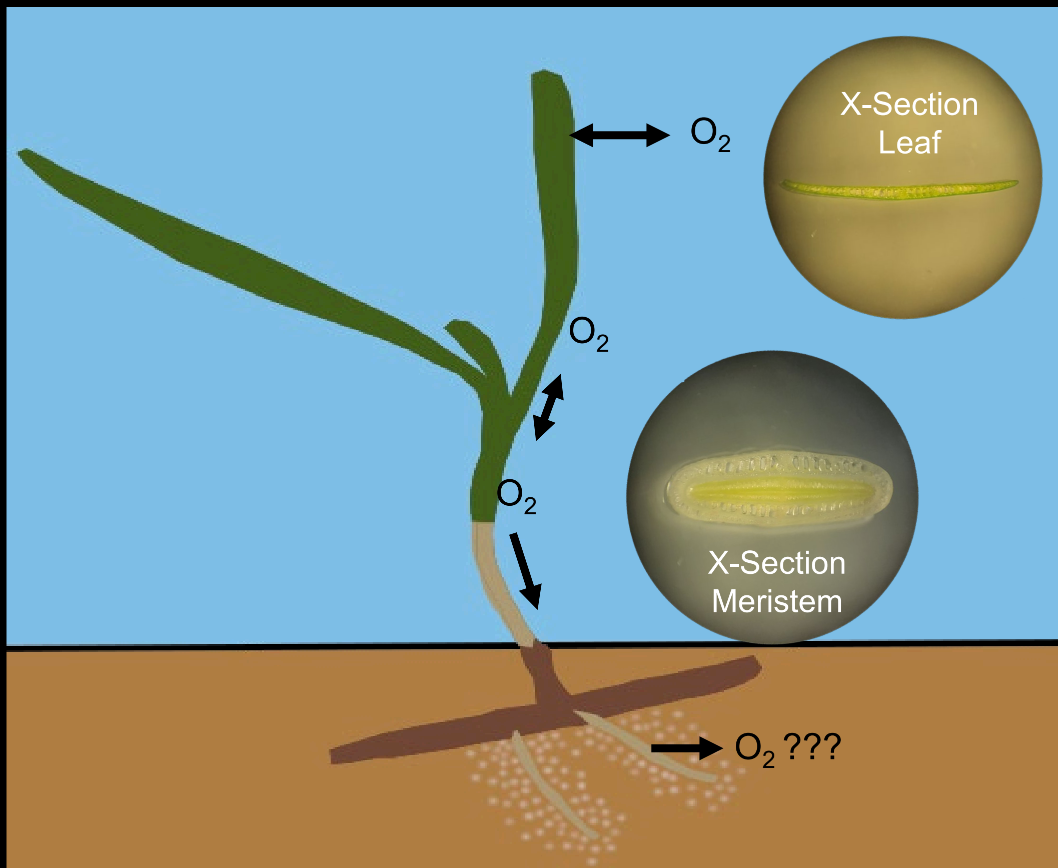
After: Robblee et al. 1991

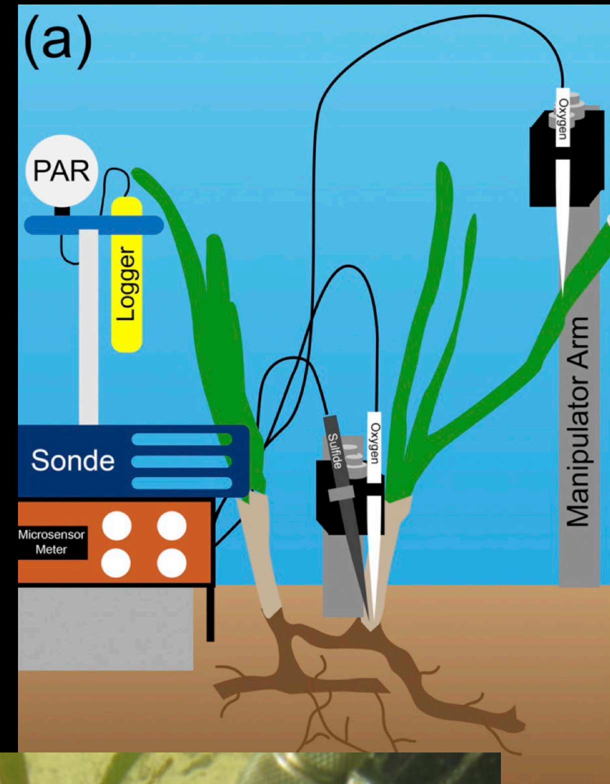


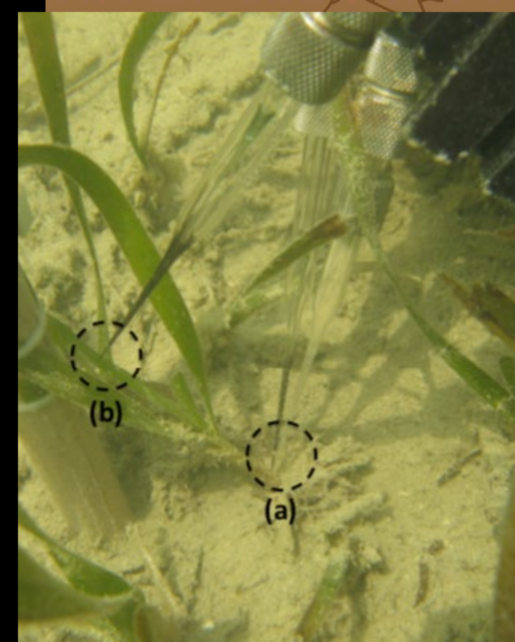
Hall et al. 2016



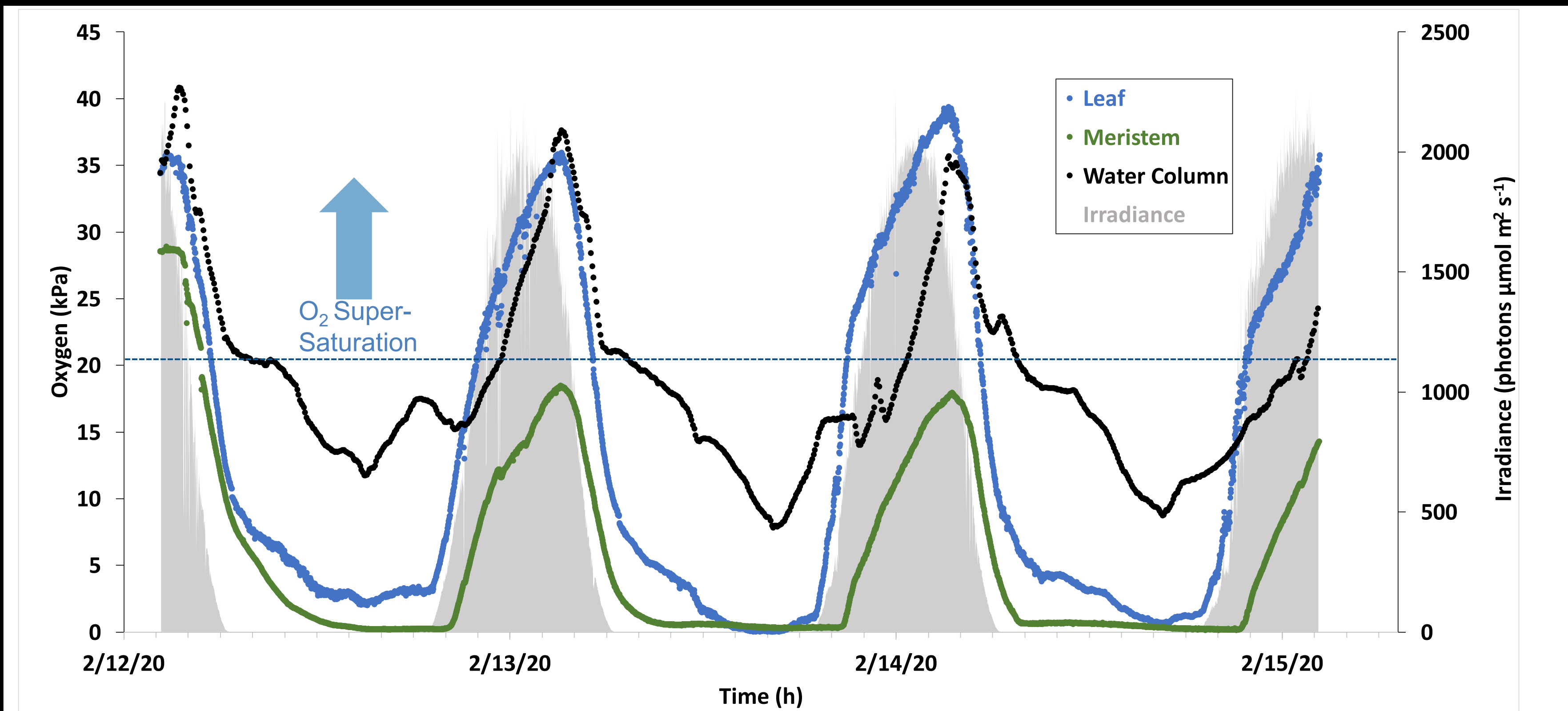
Oxygen Dynamics





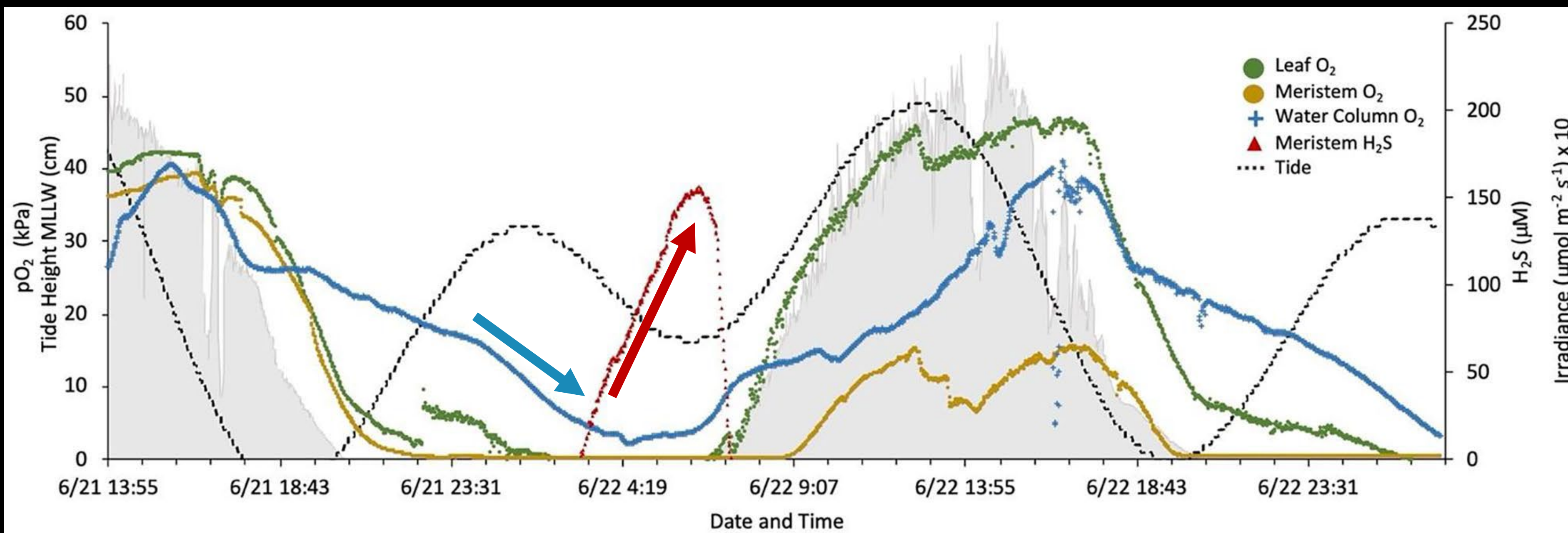


Supersaturated O_2 Day in Leaf and Water Column

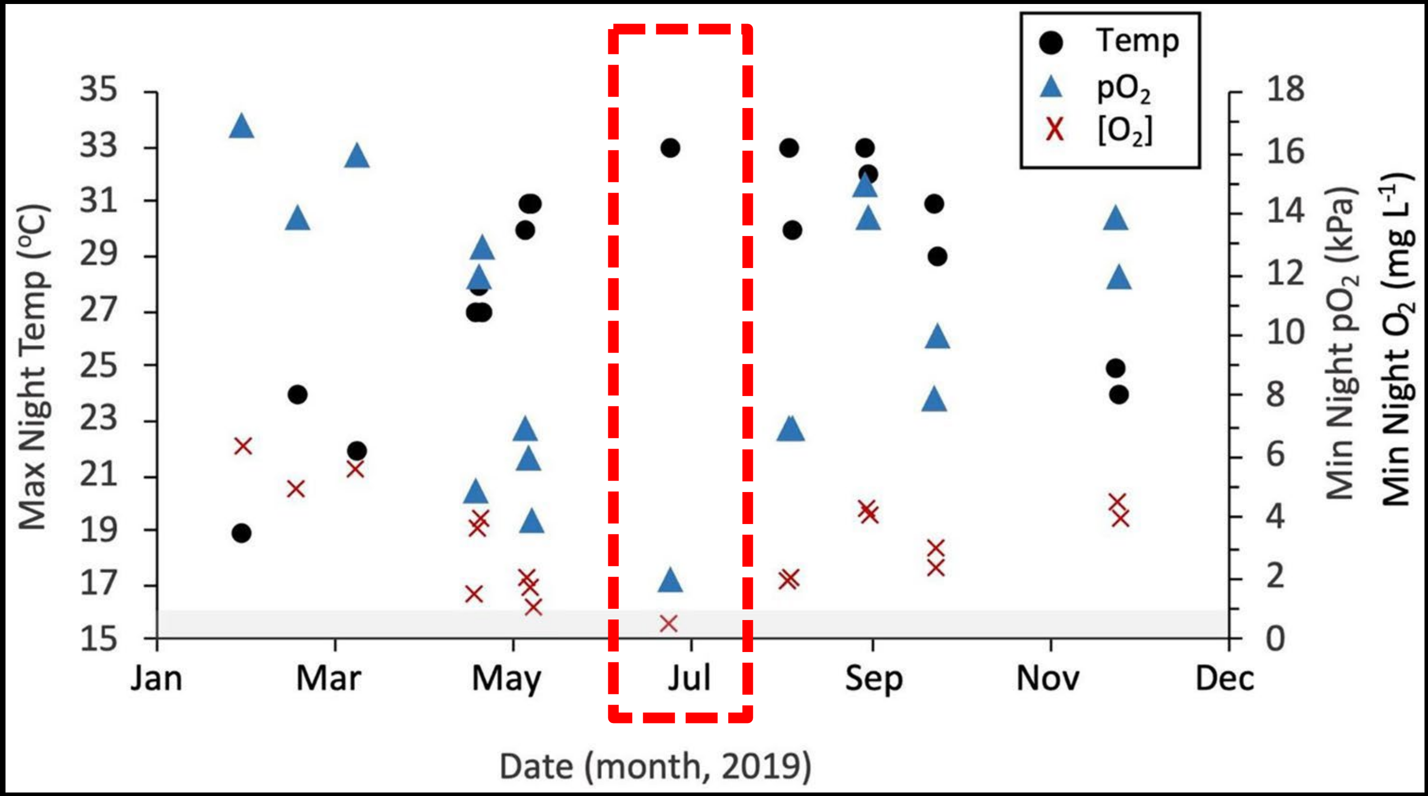


Koch et al. 2022a

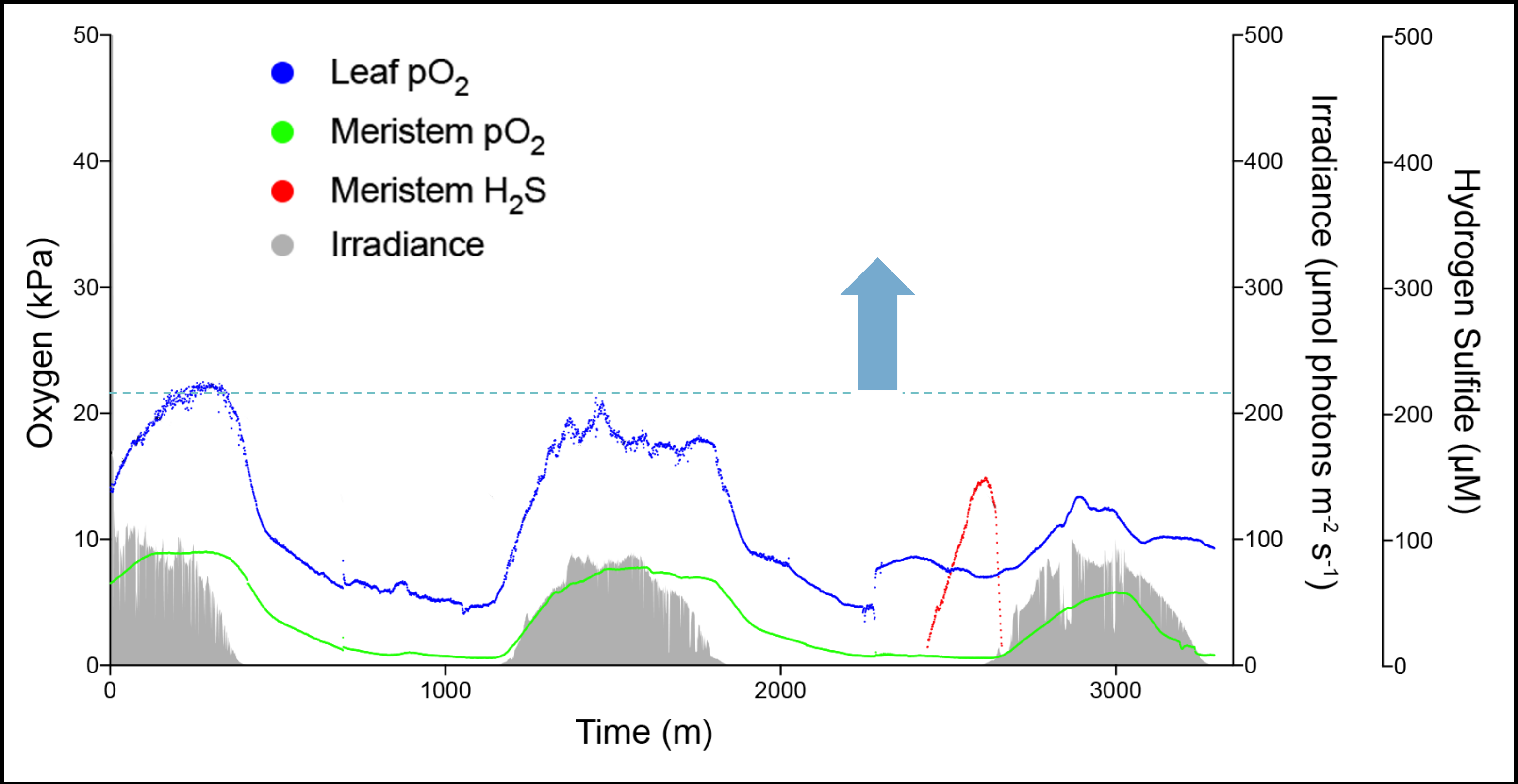
Water Column Hypoxia Corresponded to Meristem H_2S Intrusion



Meristem H_2S Intrusion at Highest Temperature and Lowest Water Column O_2



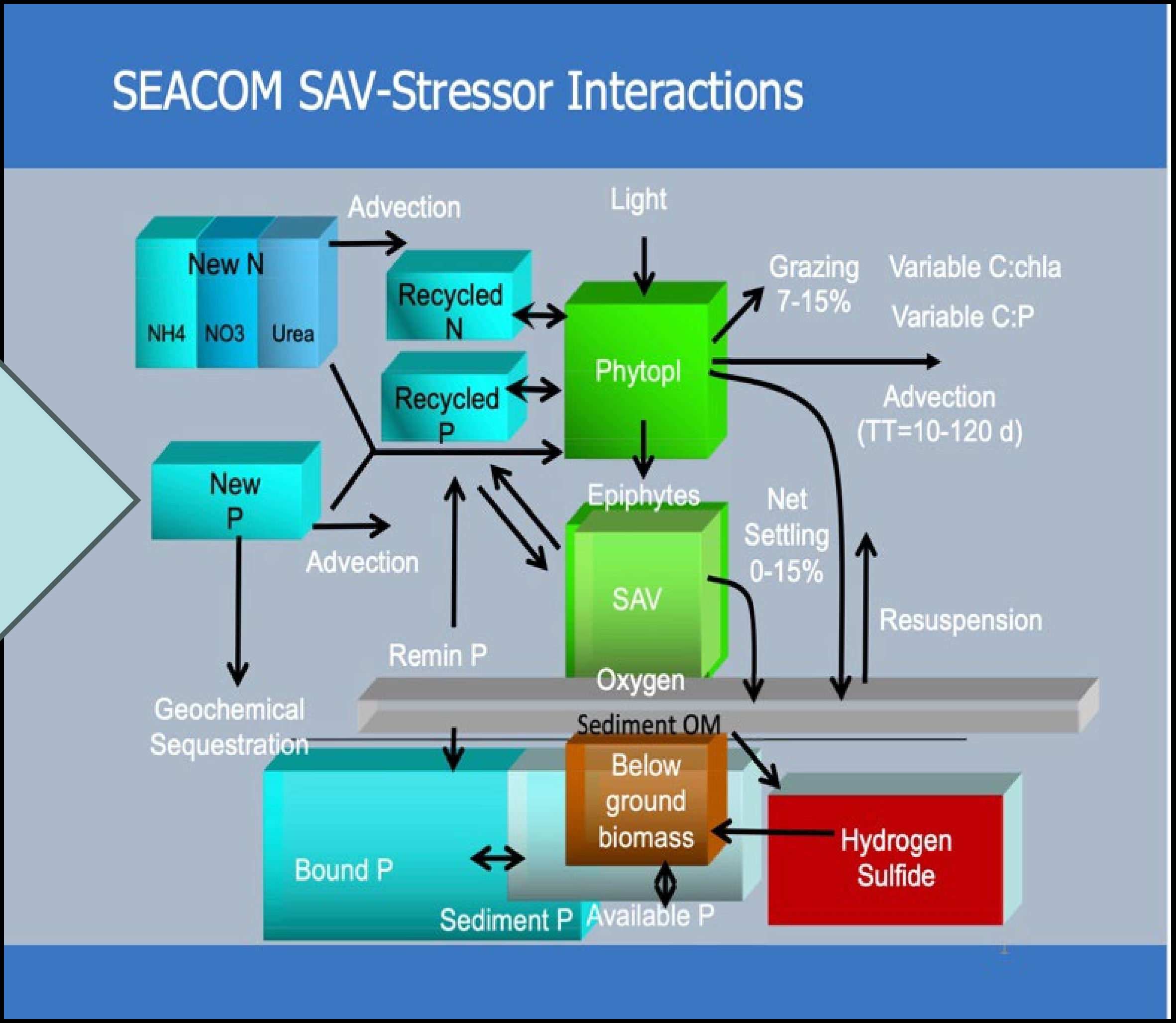
Low Light Experiments High Frequency of H_2S in Meristems



Koch et al. 2022b

INTEGRATE SMALL-SCALE PHYSIOLOGY DATA INTO ECOSYSTEM MODEL

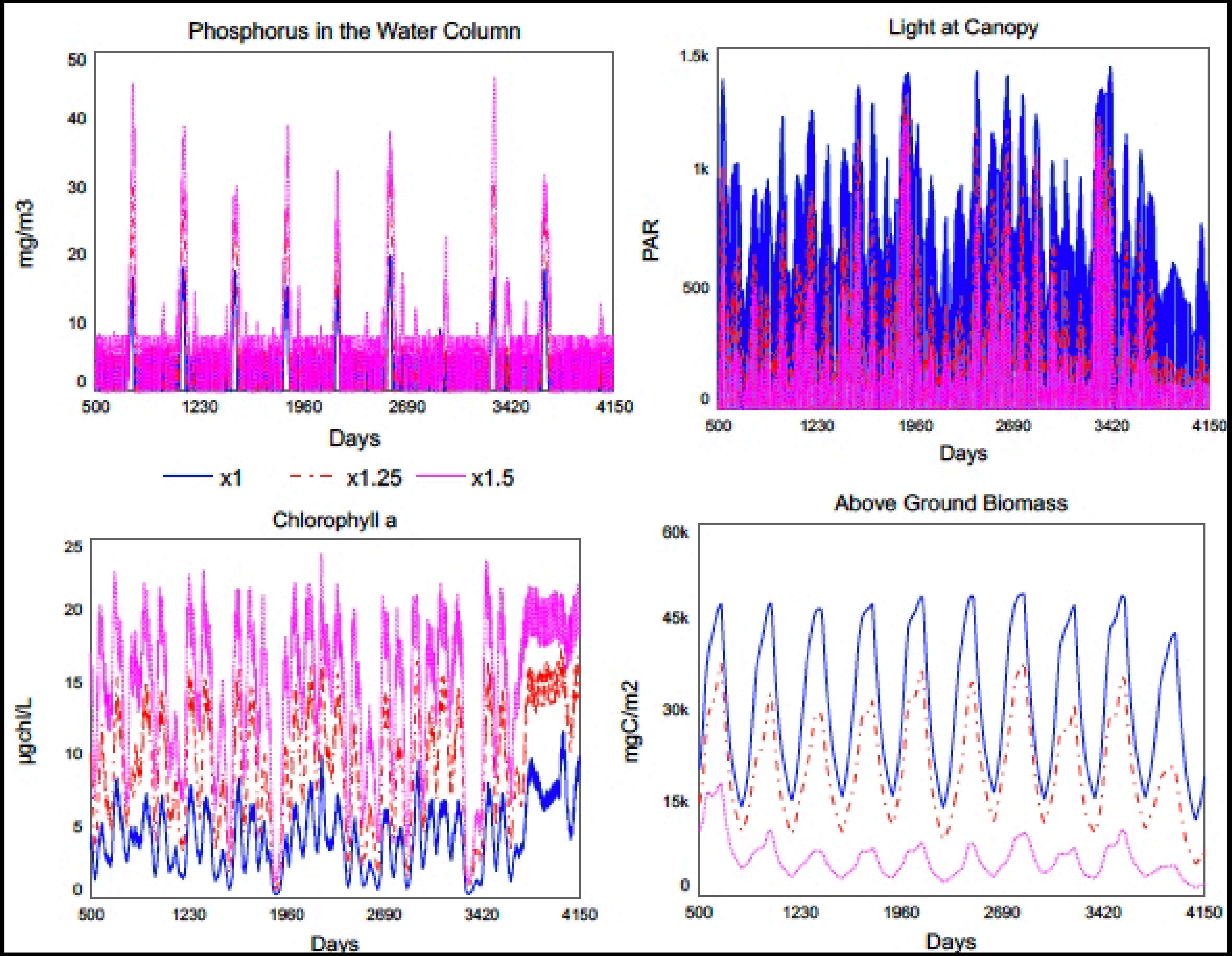
Parameterize
Seagrass Model
Focus on Stressors



Madden et al. 2016

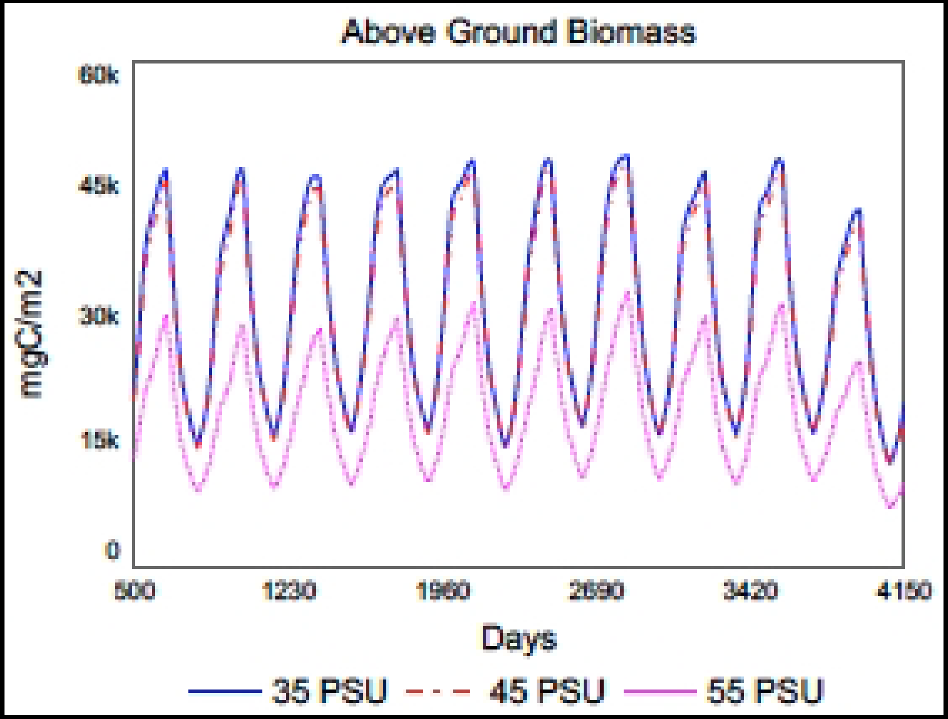
Climate Change Seagrass Scenarios

1. Increased Nutrient Pulses (x1.25, 1.5), Stimulate Phytoplankton Blooms, Lowers Light at Canopy, and Drives Down Seagrass Biomass

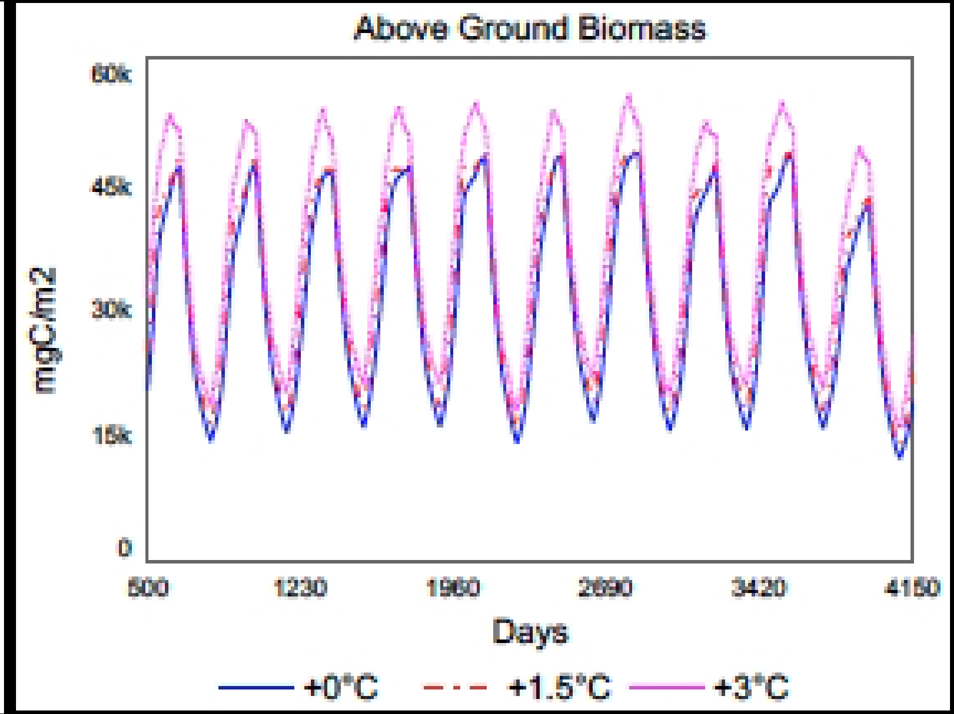


Climate Change Seagrass Scenarios

2. Hypersalinity (55 psu) Directly Lowers Photosynthesis and Biomass

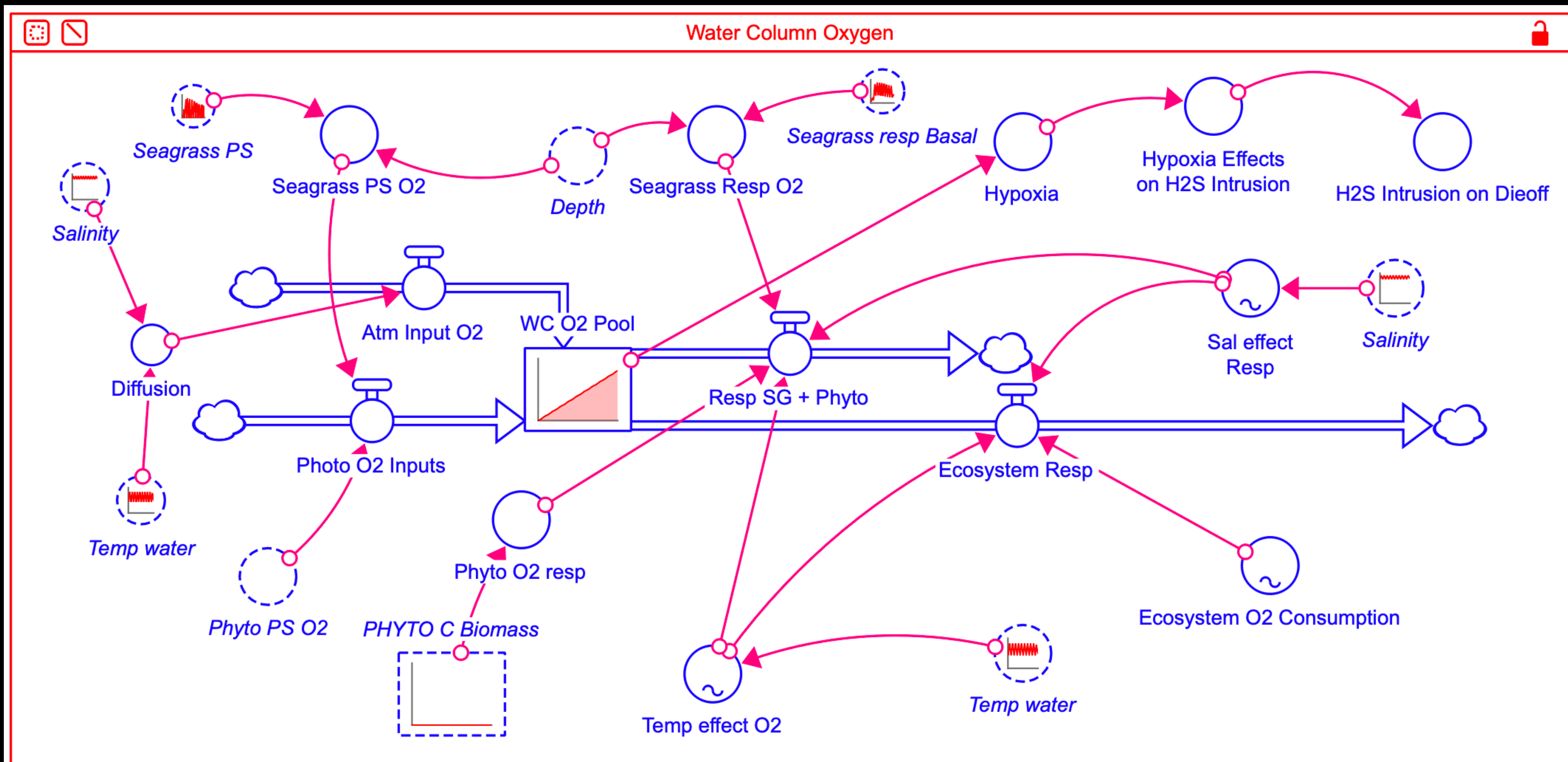


3. Increase in Temperature (+3oC) Increases Photosynthesis and Biomass



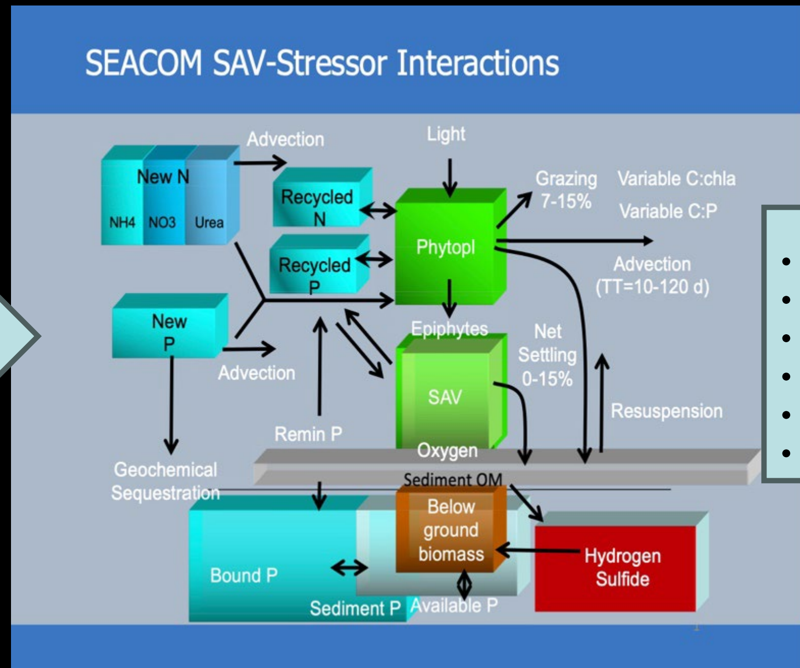
Missing from the Current Seagrass Model: Hypersalinity/Temperature Effects on Oxygen in the Water Column!

Water Column Oxygen Dynamics Module Florida Bay

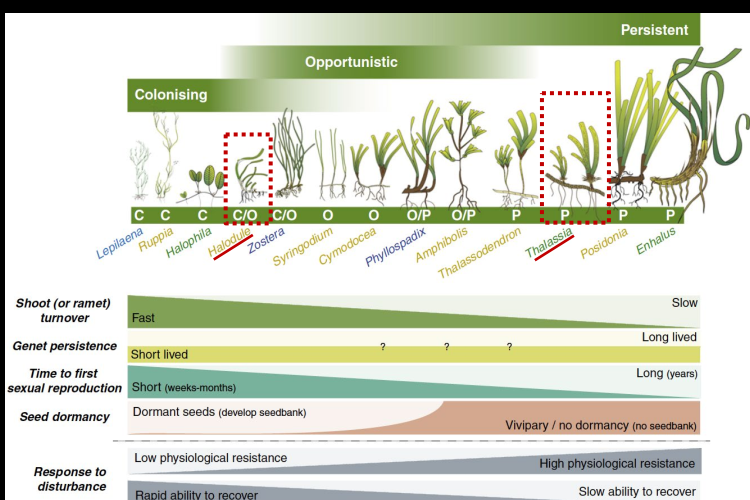


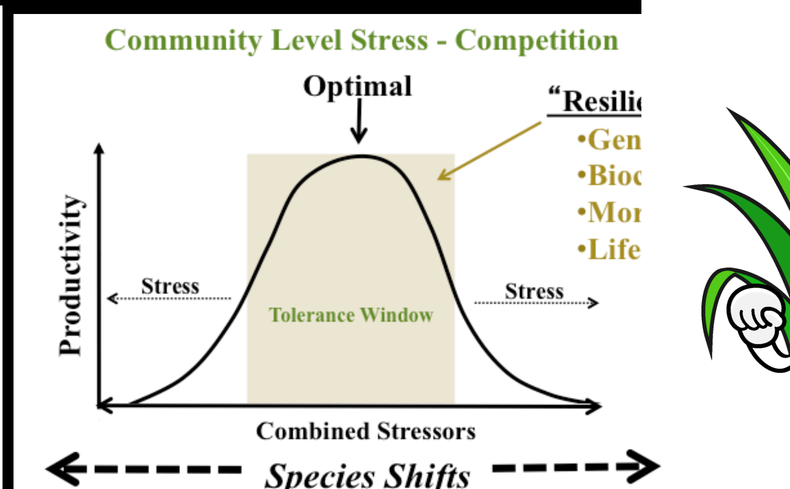
SCALE TO ECOSYSTEM AND LANDSCAPE

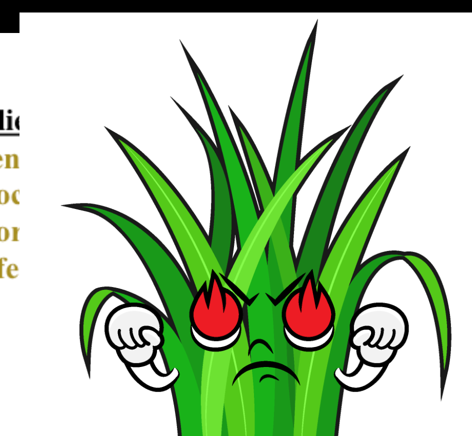
- Long-Term Water Quality Data
- Climate Change Scenarios
- Conditions Landscapes



- Management Seagrass Health
- Water Column Oxidation
- Drivers of Seagrass Decline
- Thresholds/Triggers Die-offs
- Climate Change Drivers
- Nutrient Cycling-Flux







Howard Thomas Odum (1924–2002)

“He had a trait common to many Hutchinson students of being able to focus simultaneously on the fine detail and the big picture, both temporally and spatially, without losing sight of either.”

John J. Ewel
U. S. Forest Service
Honolulu, Hawaii

This is our challenge!


Questions?