Carbon cycle science in the Florida Coastal Everglades: Research to inform landscape management

Tiffany G. Troxler, Evelyn E. Gaiser, Jordan N. Barr, Josh Breithaupt, Sean P. Charles, Carlos Coronado, Stephen Davis, Jose Fuentes, Daniel Gann, Stephen Kelly, John S. Kominoski, Christopher J. Madden, Sparkle Malone, Viviana Mazzei, Jennifer Richards, Fred H. Sklar, Shelby Servais, Joseph Donny Smoak, Joseph Stachelek, Greg Starr, and Benjamin J. Wilson

Florida Coastal Everglades carbon cycle research

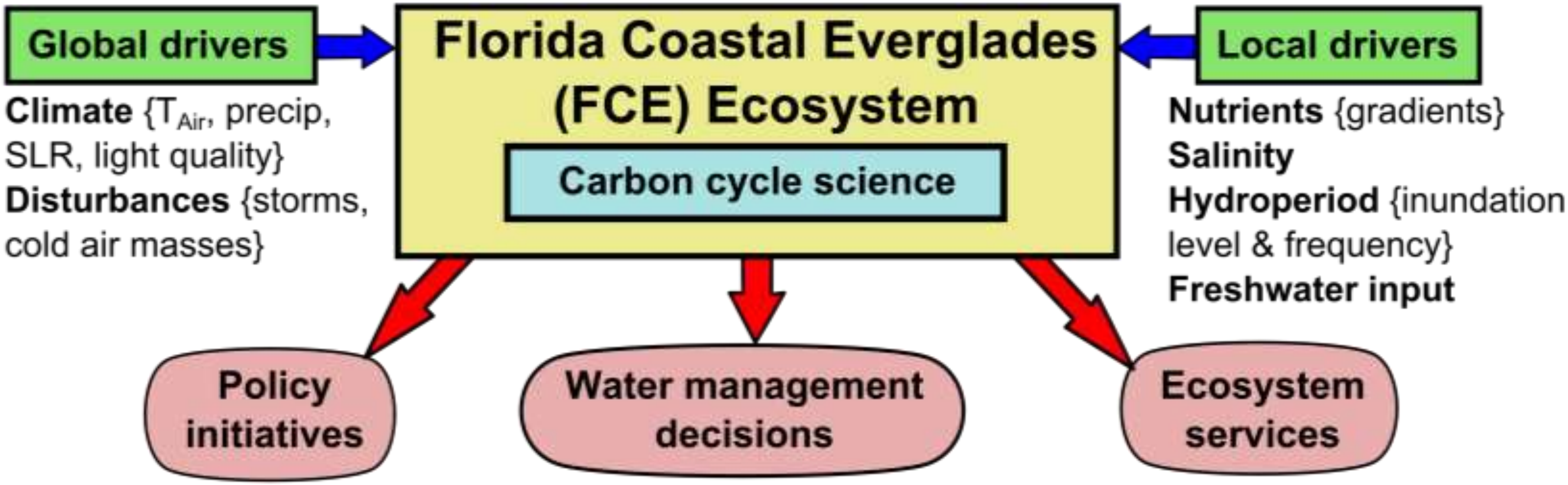
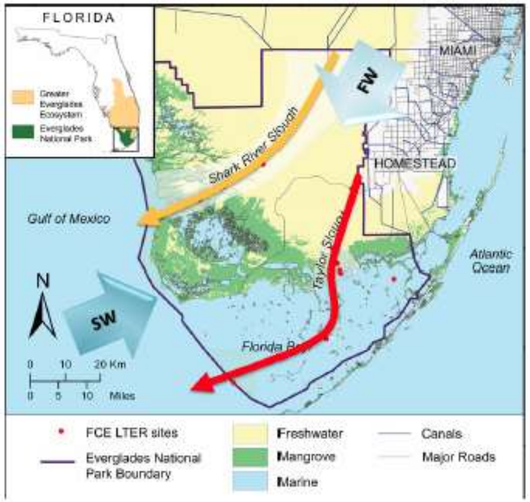
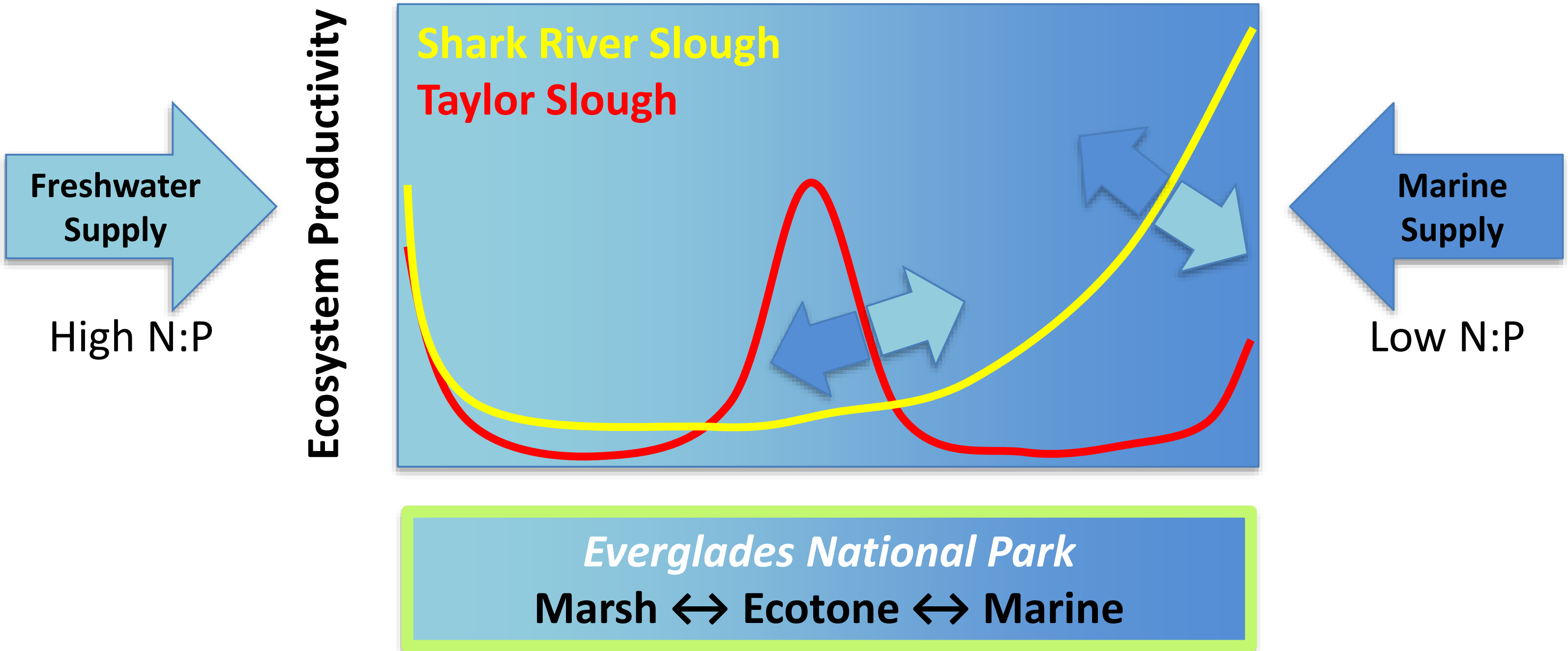


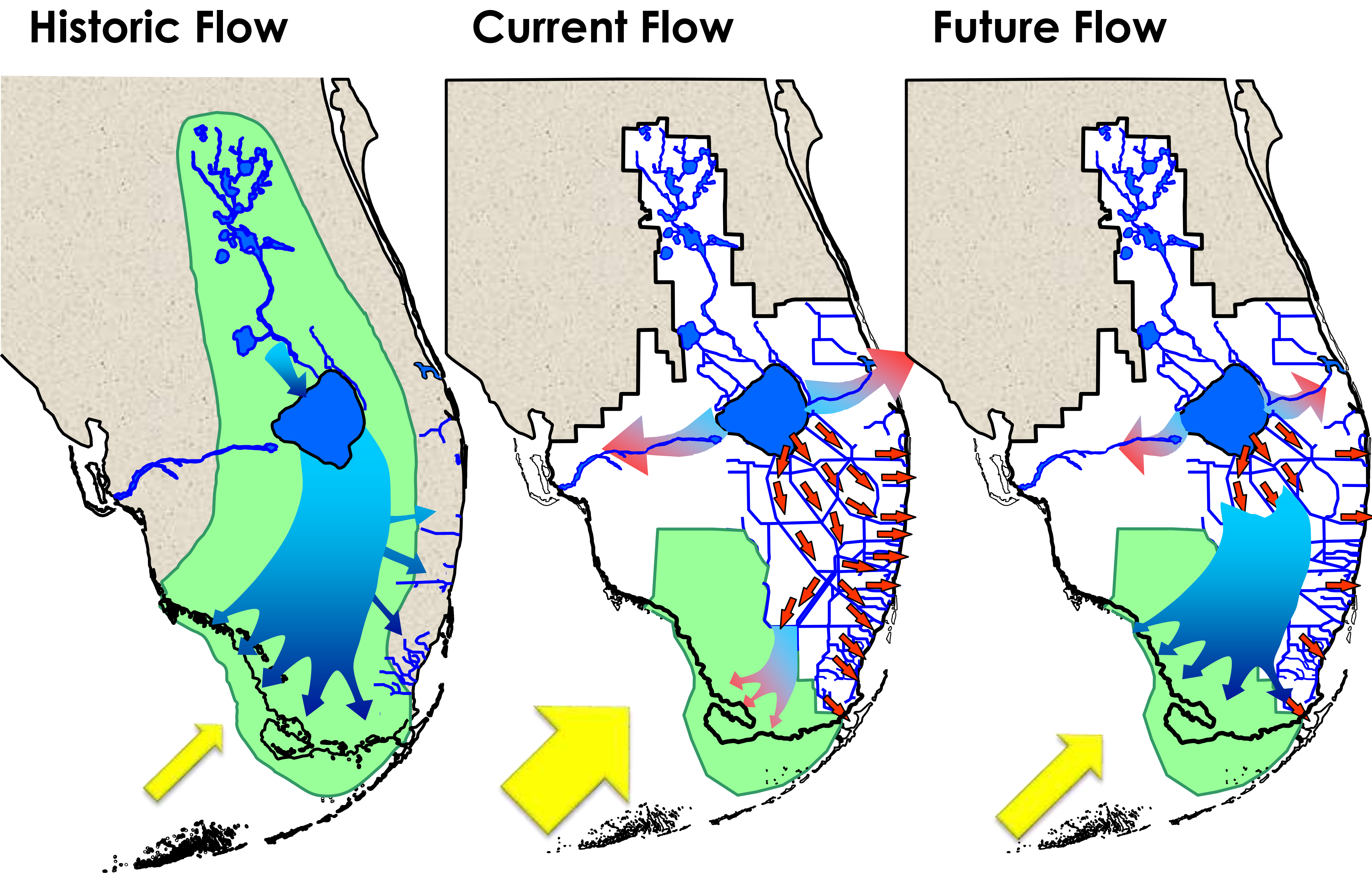
Image on left: Flow is restored beneath the 1-mile bridge at the Tamiami Trail along the northeast boundary of the Park, May 2013. Project cost: $93 million USD. Everglades science helped inform the cost benefits of this project and a proposed additional 2.6 mile bridge.



ECOTONE IN THE BALANCE

The Everglades ecotone expresses the balance of marine and freshwater influences, driven by local to global socio-hydrological presses and pulses



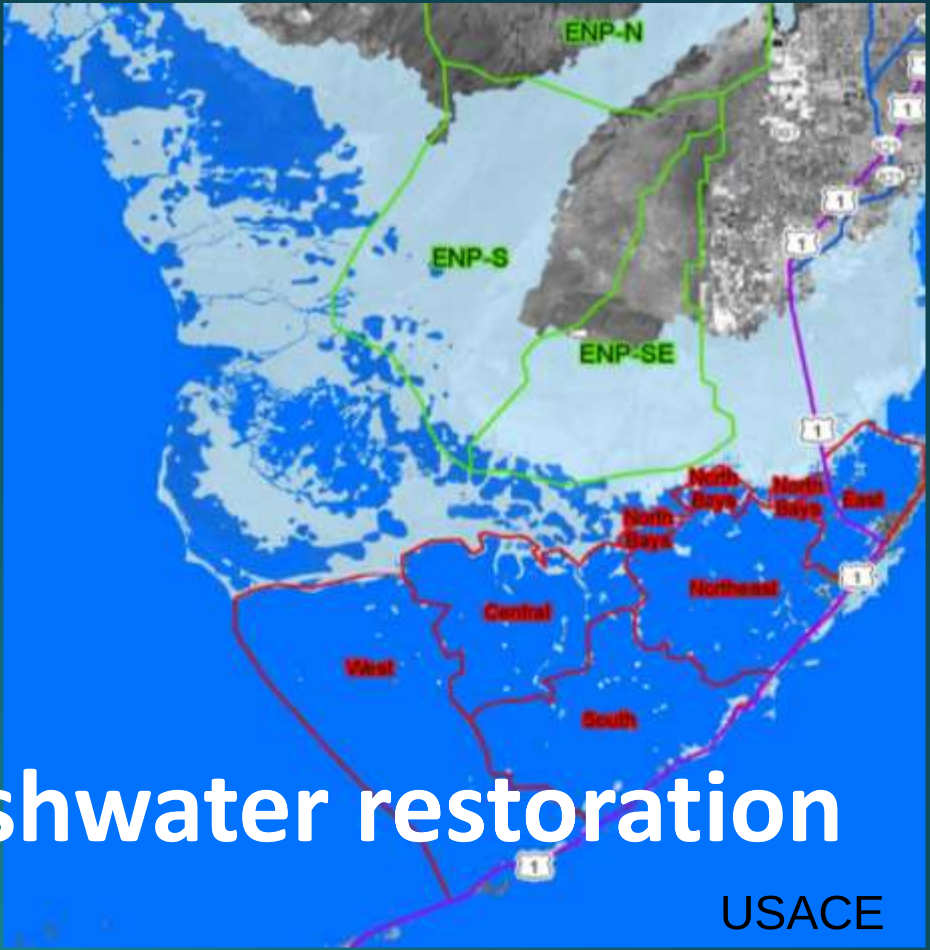


Arrows show dry season seawater INFLUX into the Everglades creeks and groundwater (not to scale)

Carbon dynamics determine the persistence of coastal Everglades wetlands

2 Foot SLR
+ Flow Restoration

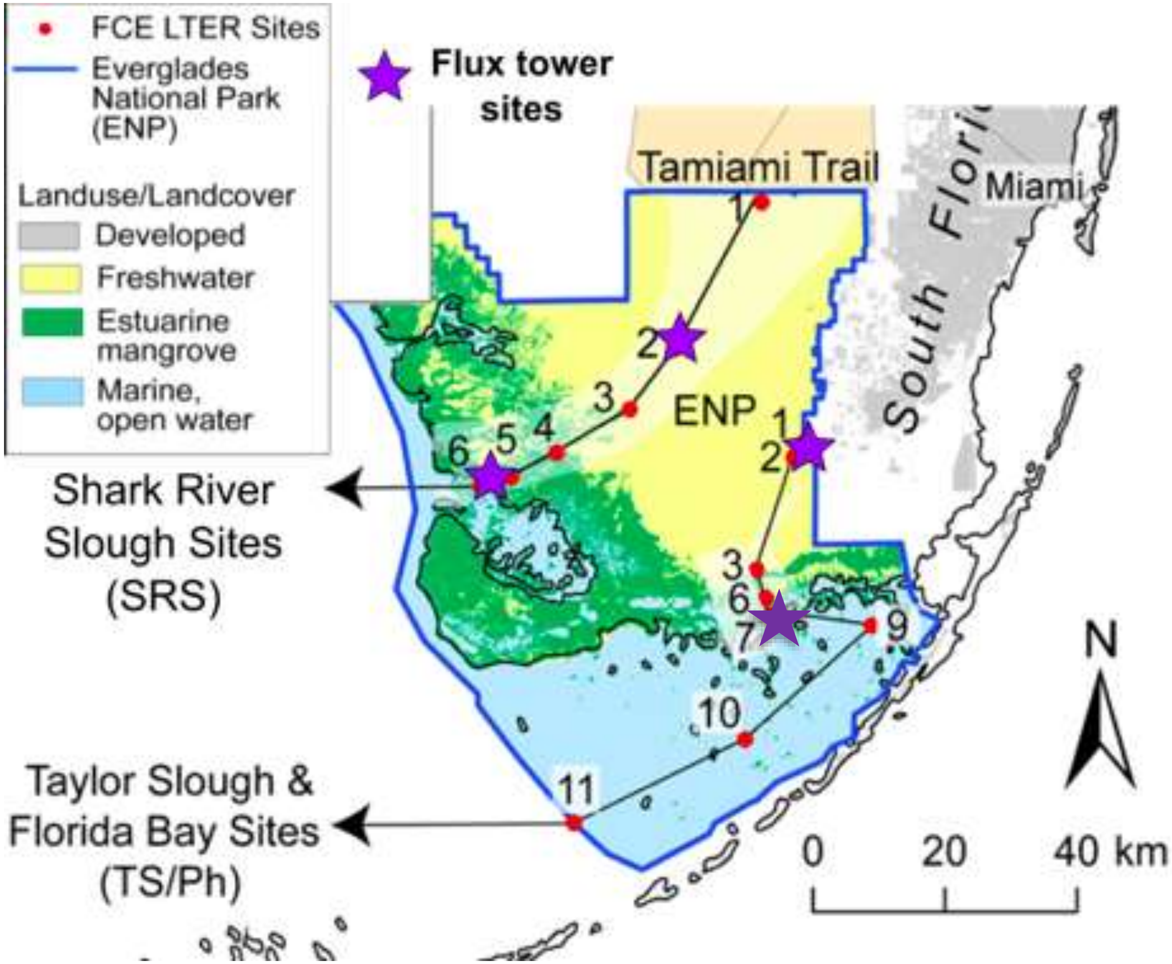
2 Foot SLR
No Flow Restoration



Sea level rise & freshwater restoration

USACE

Florida Coastal Everglades – integrated approaches to understanding landscape change



- Net ecosystem exchange
- Primary producer composition & productivity
- Sediment accumulation and storage
- Hydrology
- Biogeochemistry
- Surface water-groundwater dynamics
- Remote sensing
- Mechanistic and Landscape modeling

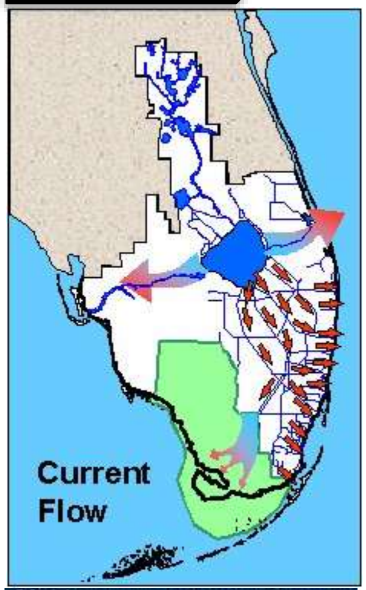
Sea-level rise and coastal vulnerability

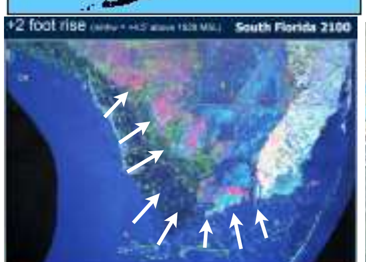
Drivers of primary productivity

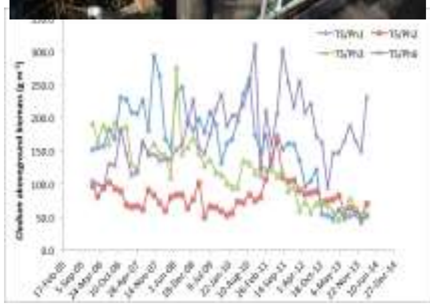
Mechanistic studies and long-term data

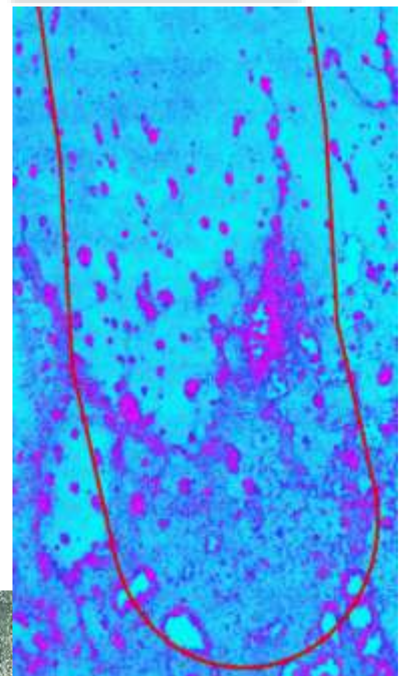
Class-specific vegetation biomass and C Estimates

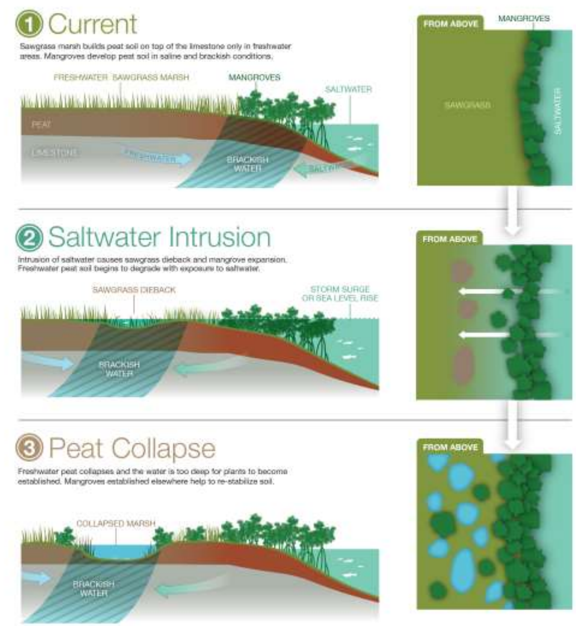
New models of coastal vulnerability











Florida Coastal Everglades carbon cycle research

Shark River Slough (SRS)

Freshwater Slough

Oligohaline Ecotone

Marine

Taylor Slough (TS/PH)

Carbon dynamics are largely modulated by changes in primary productivity

- Biomass dynamics (and legacies) control how communities will respond to future impacts of water management and sea level change and drive changes in ecosystem carbon stocks and fluxes.
- Organic matter accumulation and turnover are the primary processes controlling soil formation and accretion in mangrove forests and sawgrass marshes in the ecotone.

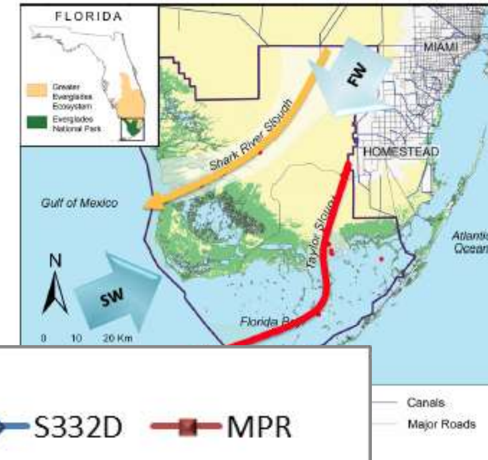
Values for annual net ecosystem C balance (NECB), net ecosystem exchange (NEE), and derived aquatic C (Aq C) export [NECB = -NEE + Aq C (flux)]

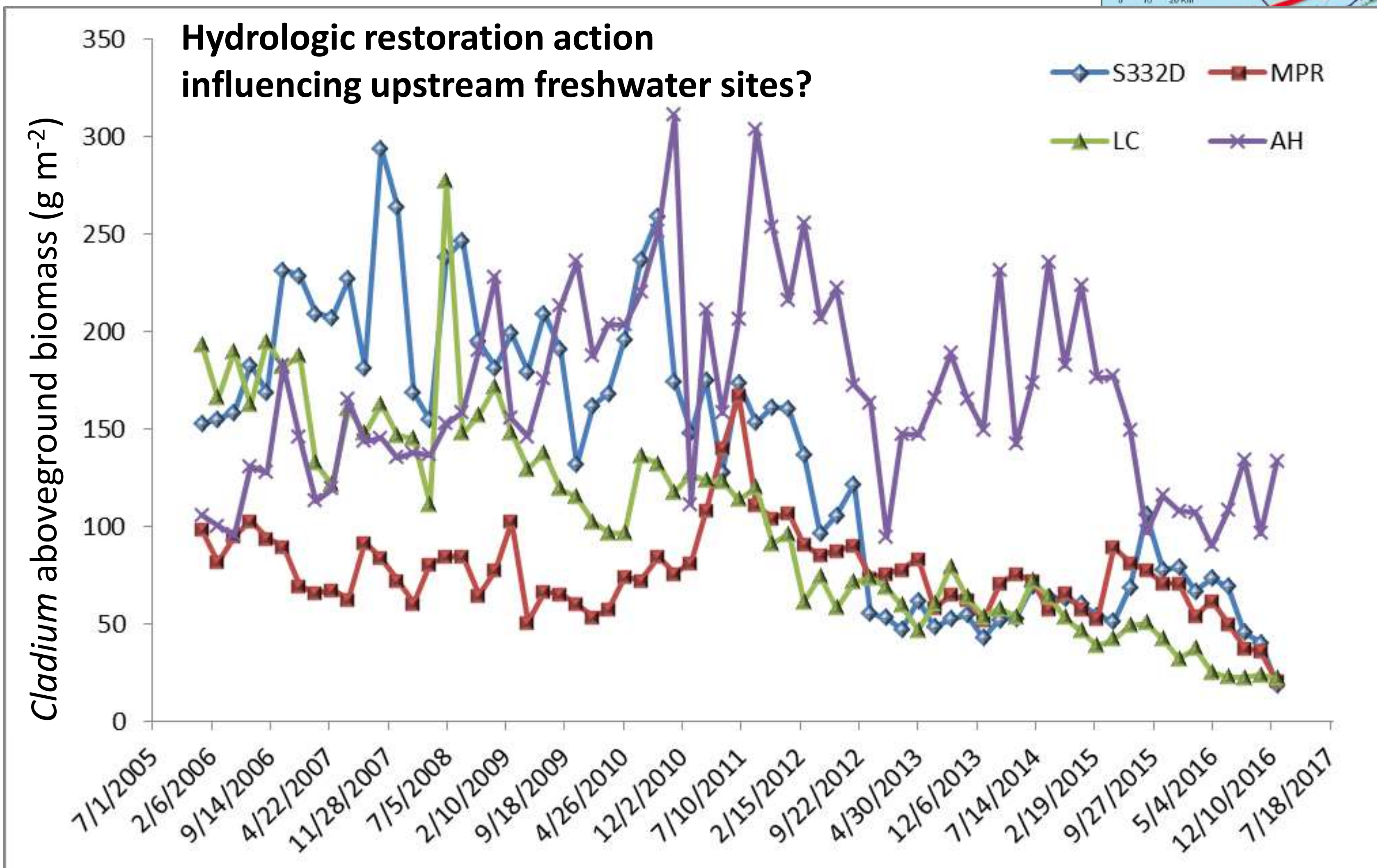
Ecosystem	Site	g C m^{-2} yr^{-1}		Soil	AG	BG	Aq C Export
		NECB	−NEE				
Marsh	SRS	621 ± 59	−45 ± 16	90	291 ± 35	240 ± 48	666 ± 61
	TS	457 ± 61	50 ± 15	90	122 ± 12	245 ± 60	407 ± 63
Mangrove$^{\psi}$	SRS	1,038 ± 88	1,170 ± 127	194	638 ±36	206 ± 80	−131 ± 155
Seagrass	FL Bay				75 ± 40		

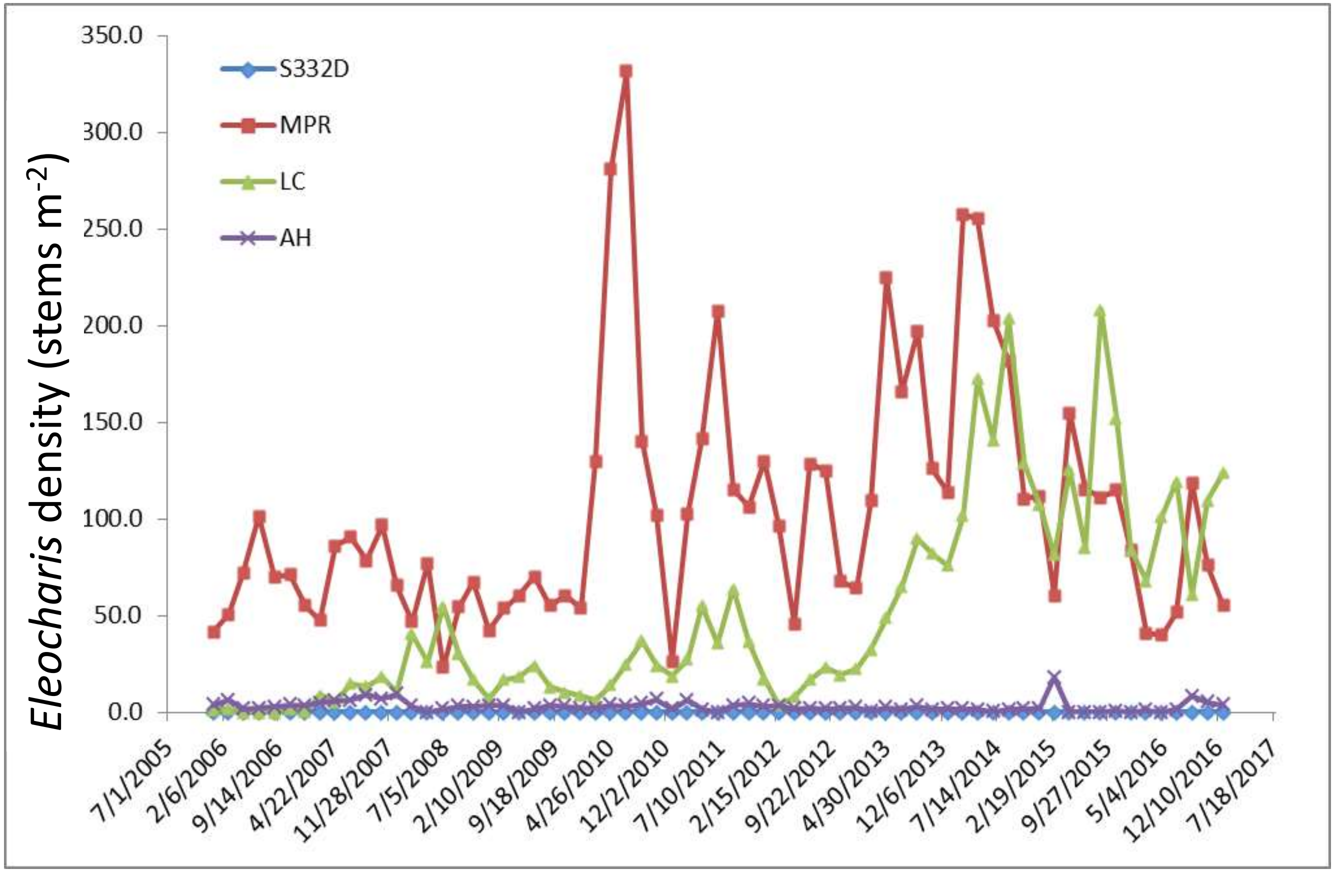
$^{\psi}$ Mangrove root production estimates for size classes < 2 mm to 20 mm in diameter (to a depth of 90 cm).
AG = aboveground. BG = belowground. SRS = Shark River Slough. TS = Taylor Slough.

Troxler et al., 2013

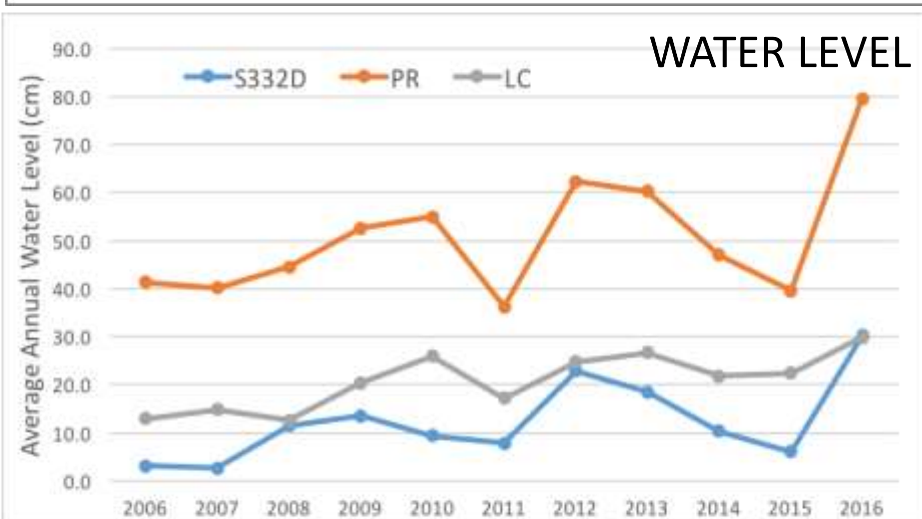
I. Influence of hydrologic change on marsh aboveground sawgrass biomass

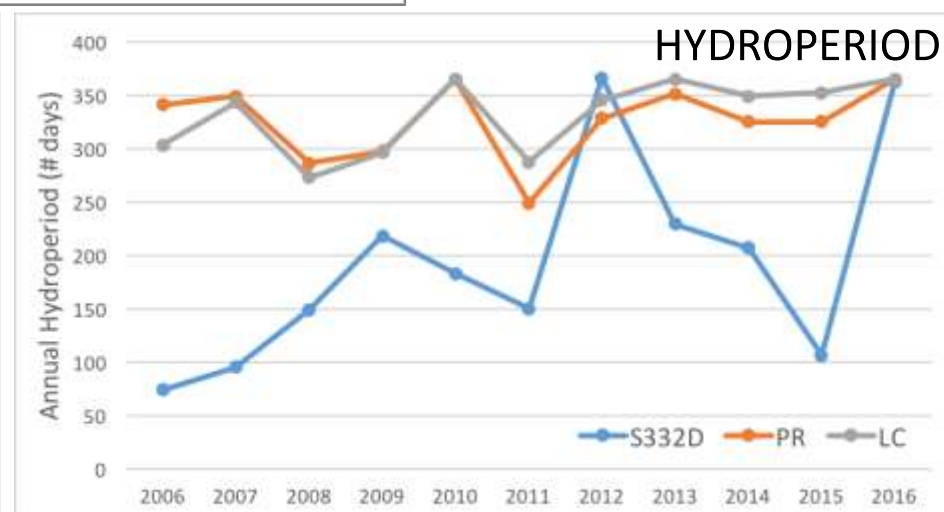






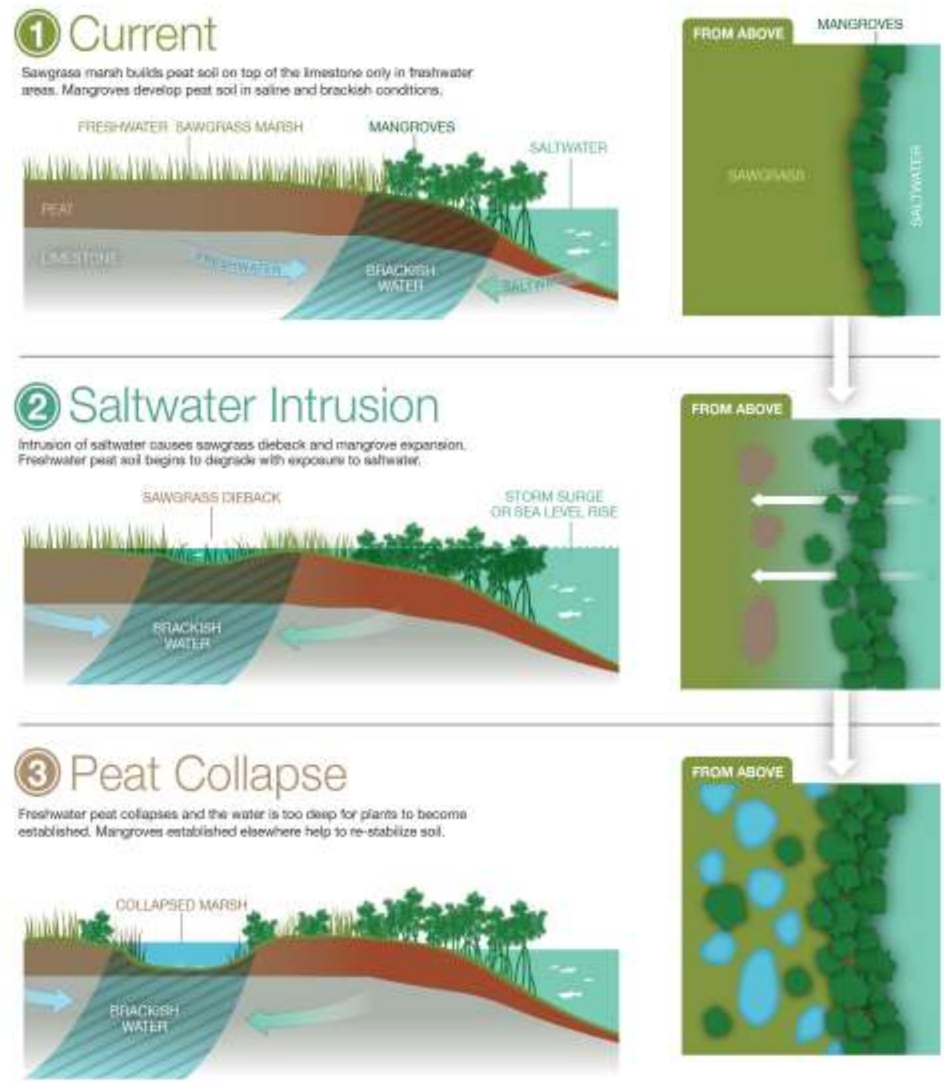
Independent lines of evidence





II. Influence of salinity on marsh aboveground sawgrass biomass and net ecosystem exchange

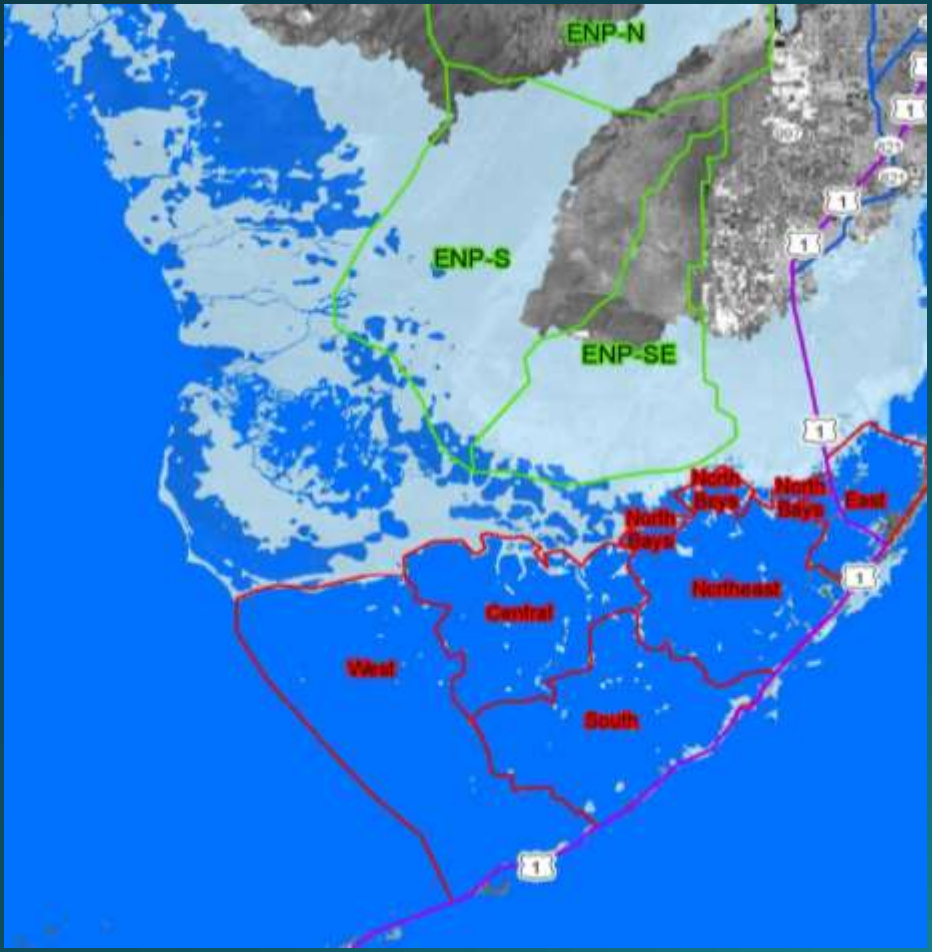
- Sea levels projected to rise up to another 0.15m by 2030 and 0.5m by 2060.
- As sea levels rise, salinity & inundation will increase.
- Further peat collapse is projected.
- Mechanisms hypothesized include decreased plant productivity and increased microbial respiration.



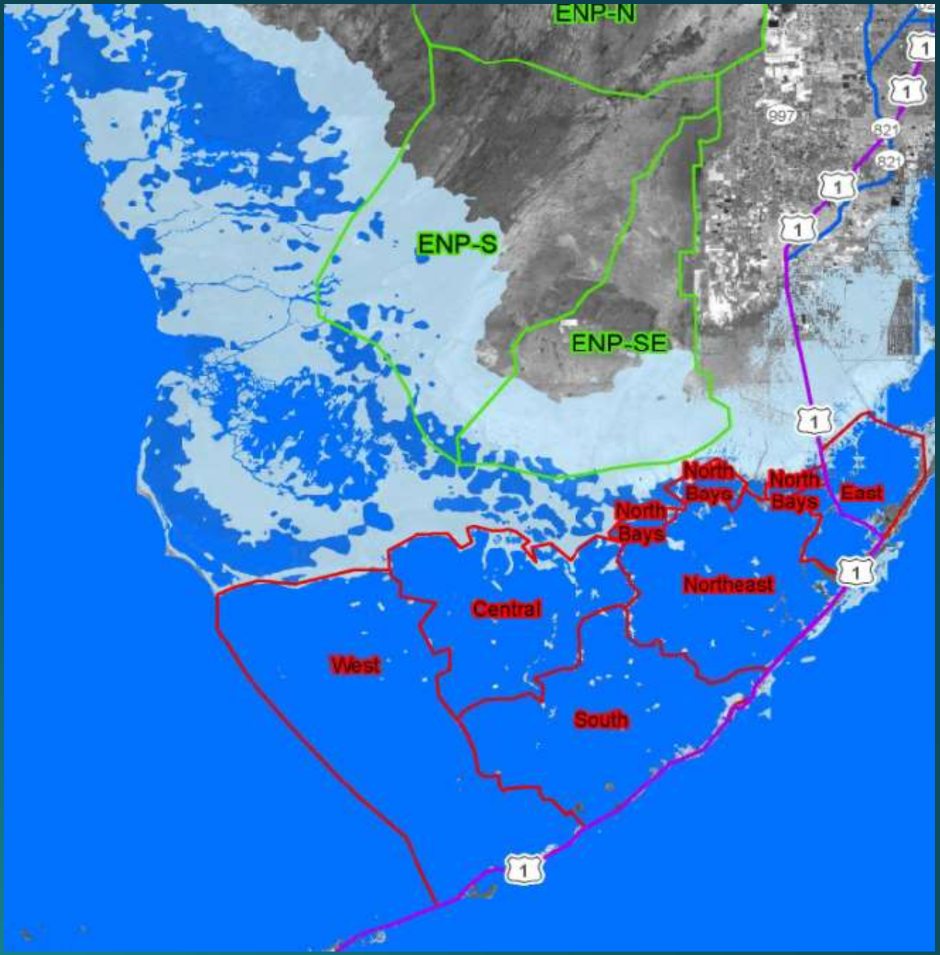
H2Graphics & Davis

Sea level rise with freshwater restoration

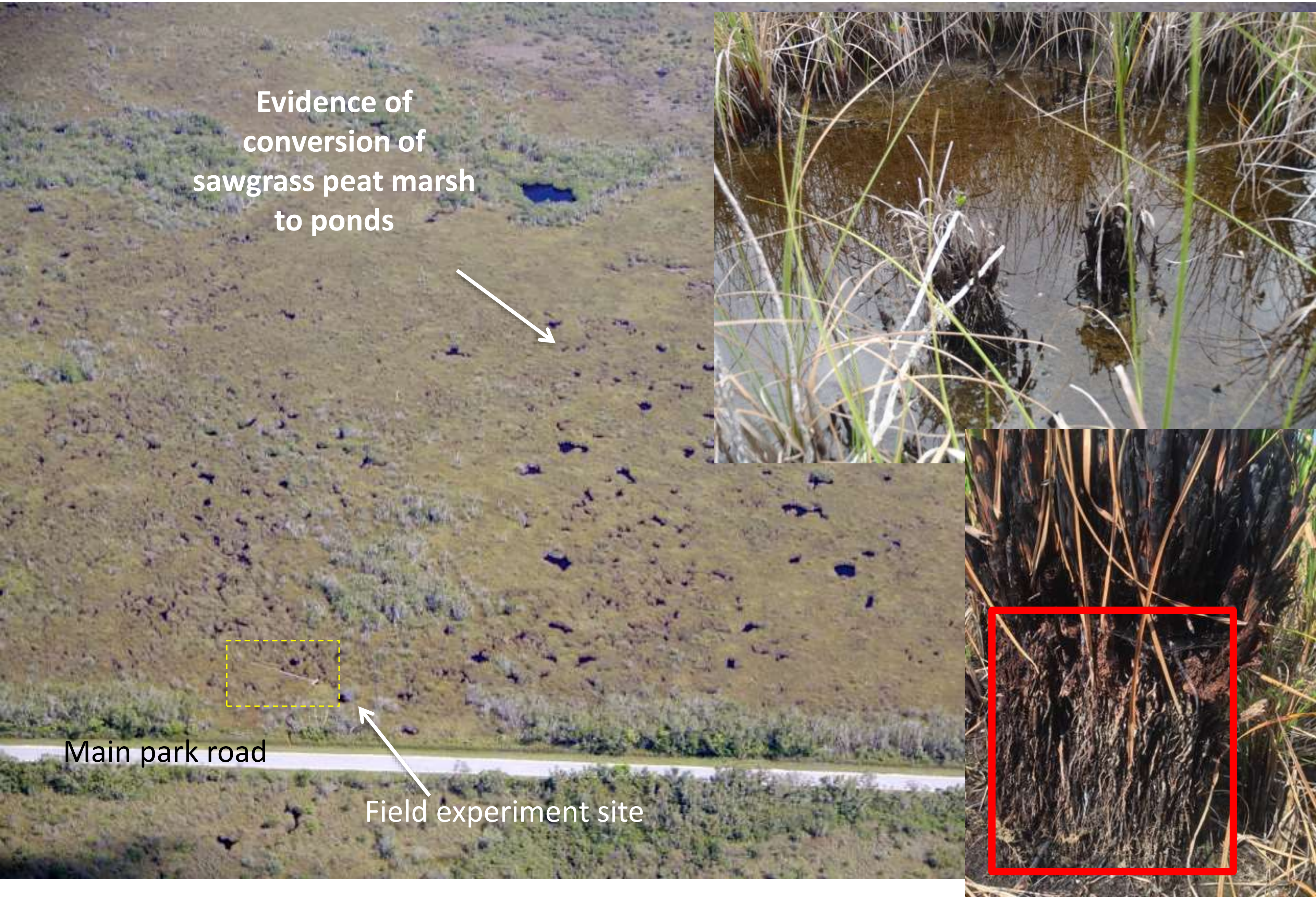
2 Foot SLR
No Flow Restoration



2 Foot SLR
+ Flow Restoration



EVERGLADES NATIONAL PARK

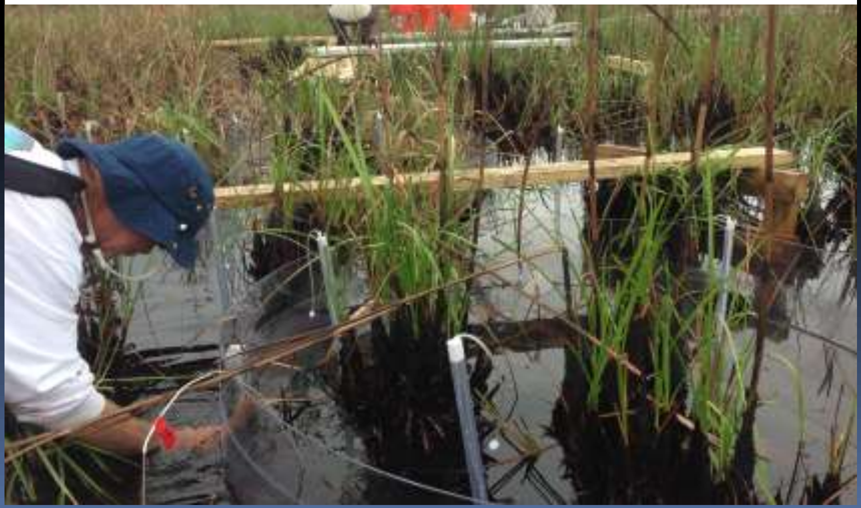


The effects of projected sea-level rise on Everglades coastal peat marsh ecosystems

Objectives:

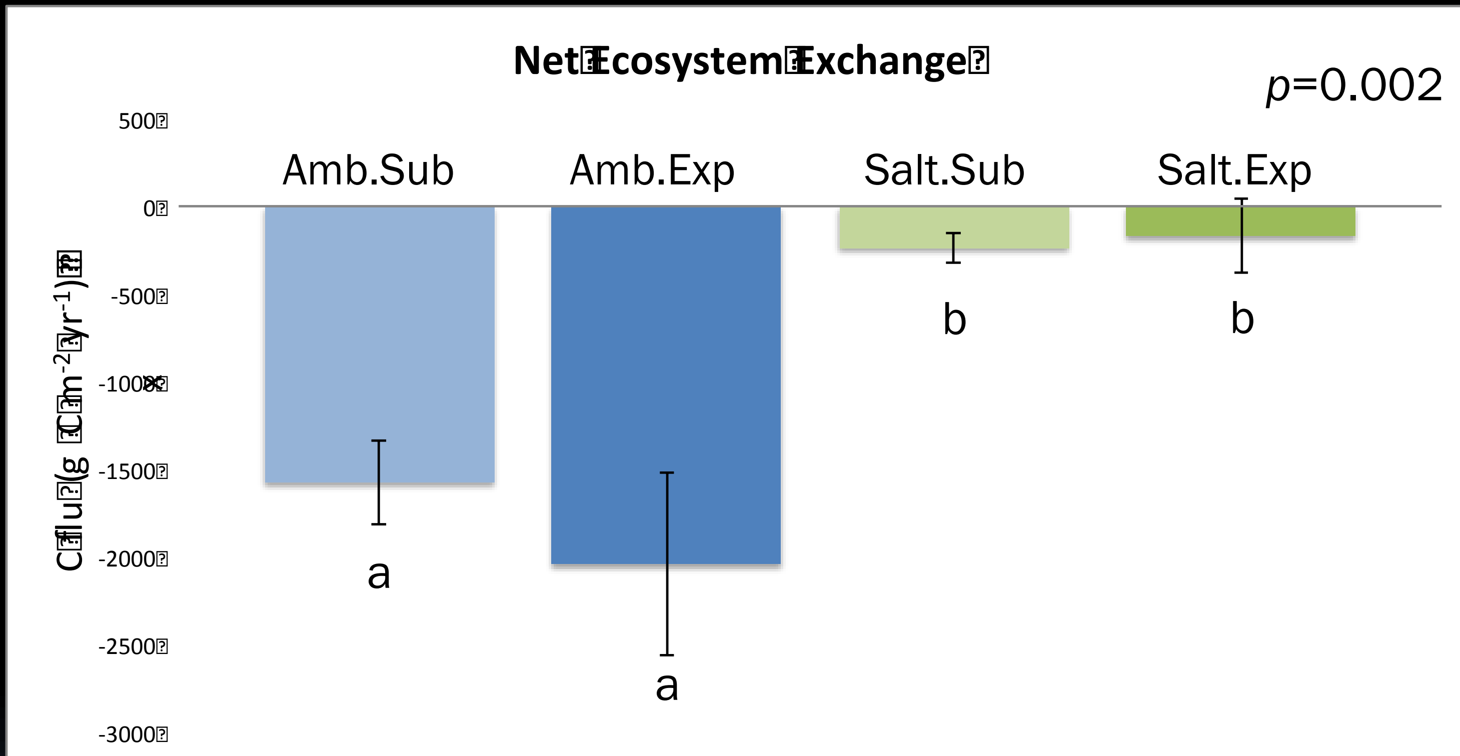
1) Investigate the potential for and mechanisms of peat collapse in coastal freshwater and brackish marsh ecosystems of the southern coastal Everglades using integrated mesocosm and field manipulations
2) Develop actionable information and best management practices for water management and conservation of coastal south Florida

FIELD EXPERIMENTS IN FRESHWATER & BRACKISH SITES



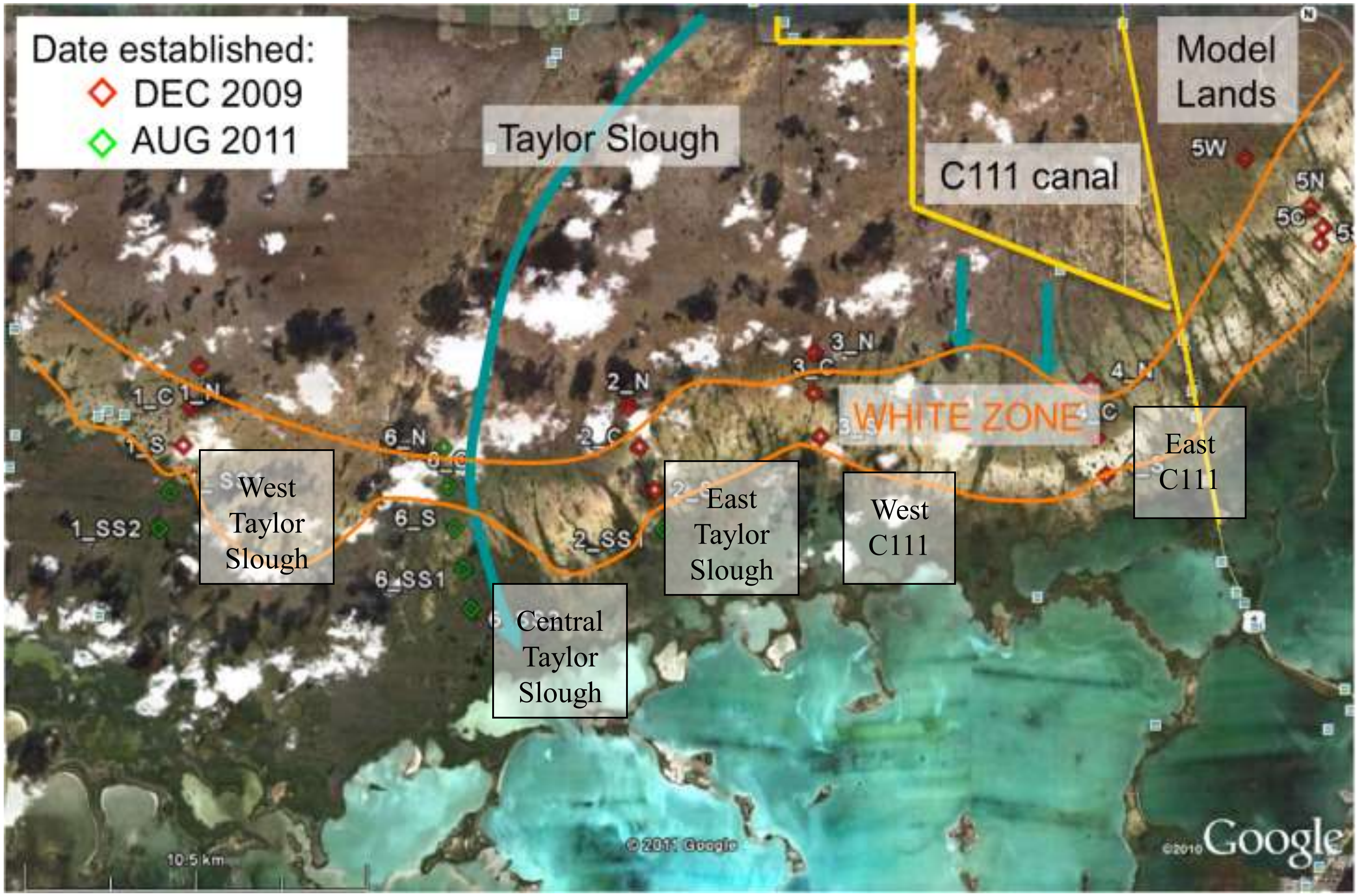
OUTDOOR MESOCOSMS

Ecosystem response coincides with sawgrass biomass response in outdoor mesocosms



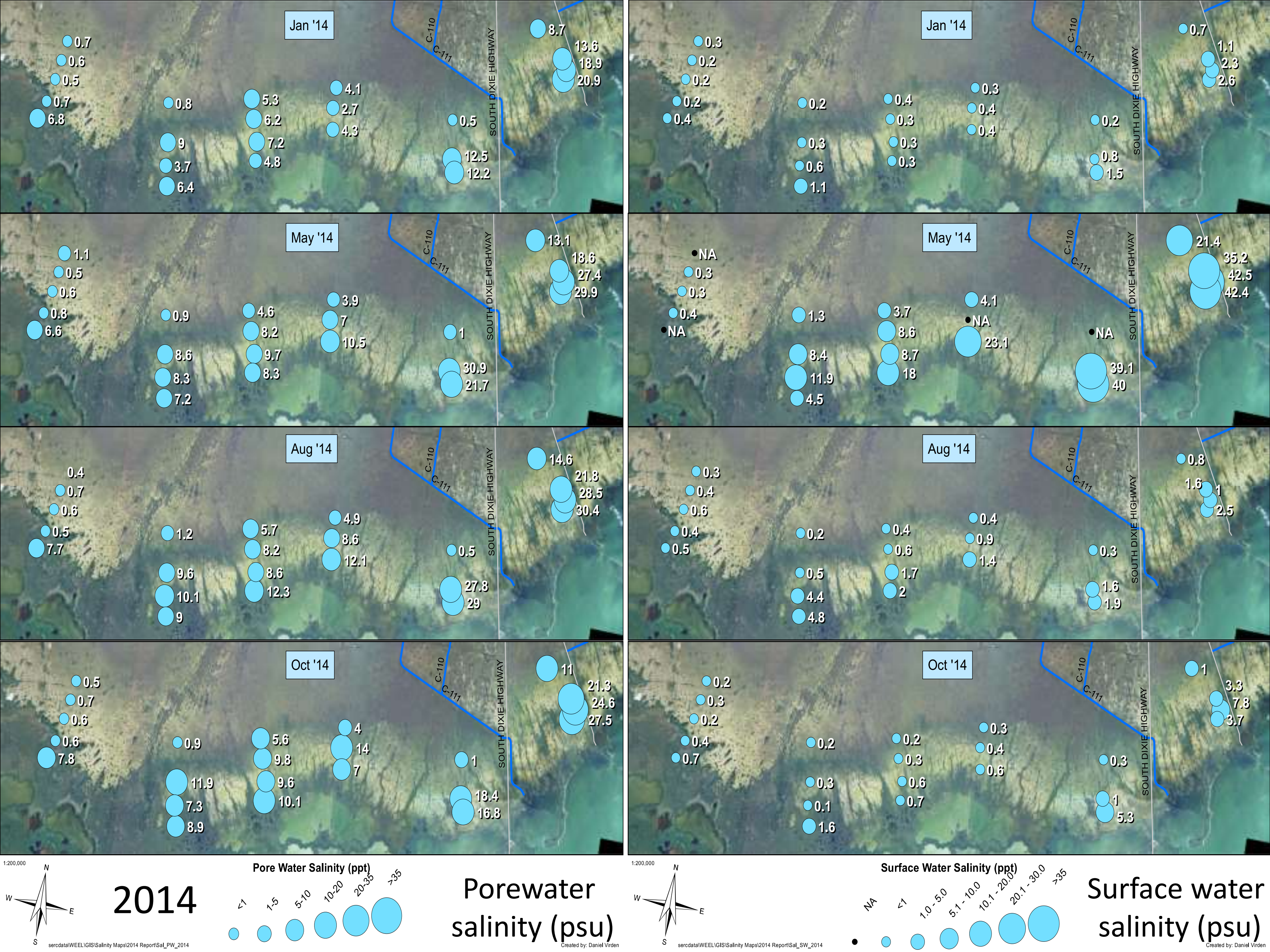
- Elevated (20 psu), continuous salinity exposure significantly decreased plant CO_2 uptake (NEE)
- Inundation had no effect on NEE
- Decreased NEE coincided with decreased aboveground biomass and adventitious root biomass

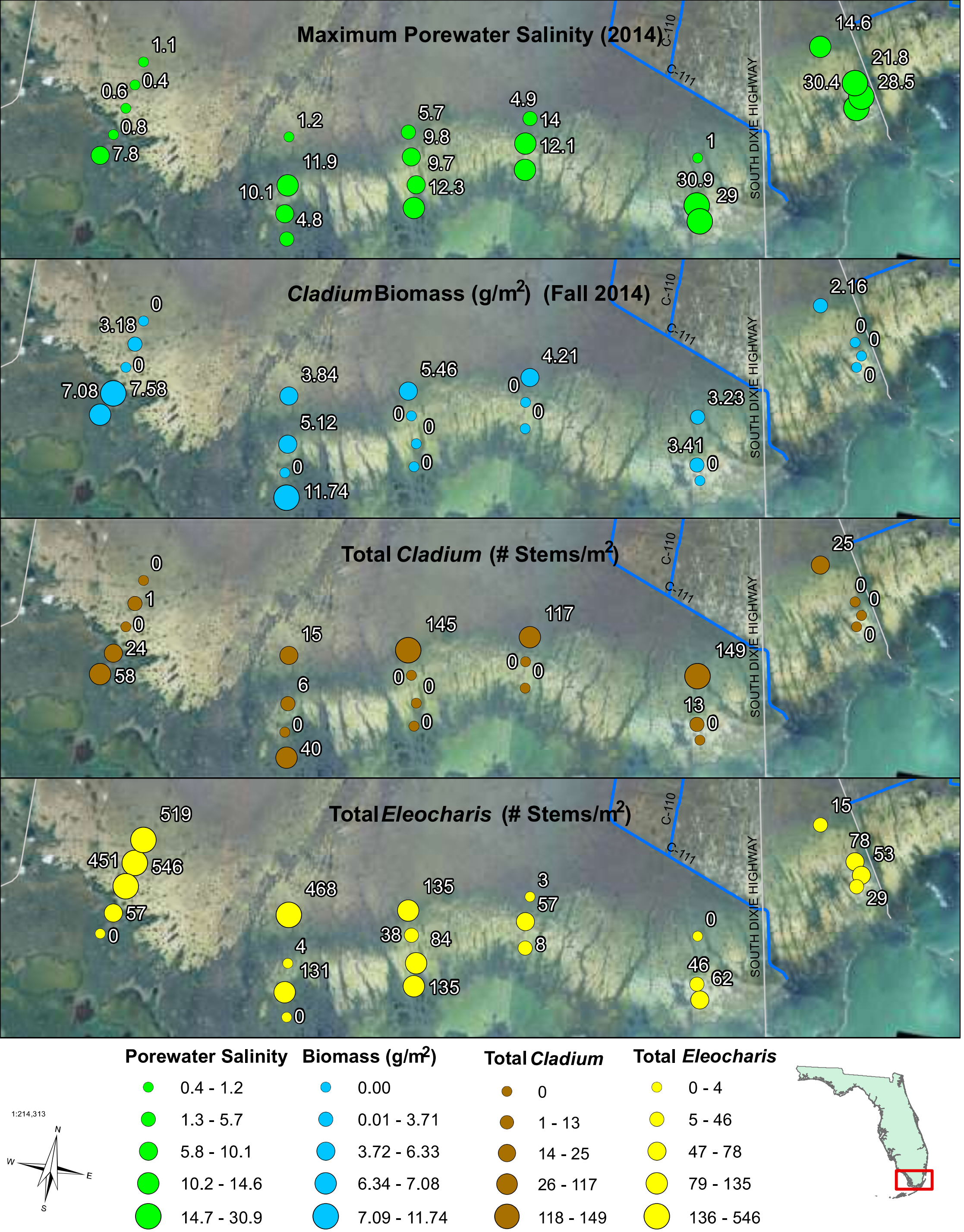
III. Spatio-temporal dynamics along the "White Zone" and landscape change



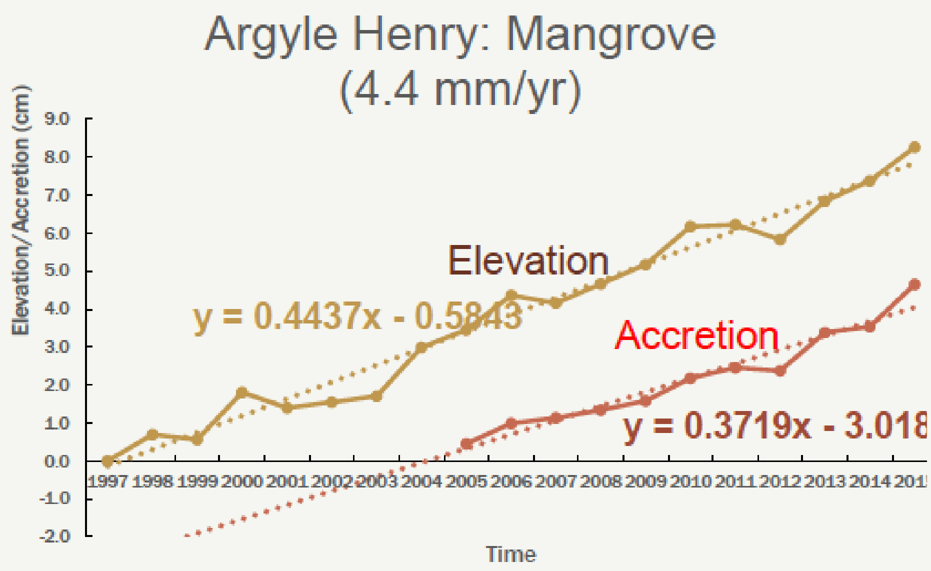
- Surface water and porewater salinity, DOC, inorganic nutrients (3-4/yr)
- Soil pH, Eh, OM, TP, TN, TC (annual)
- *Cladium* biomass & *Eleocharis* density (wet/dry season; 2014-present)

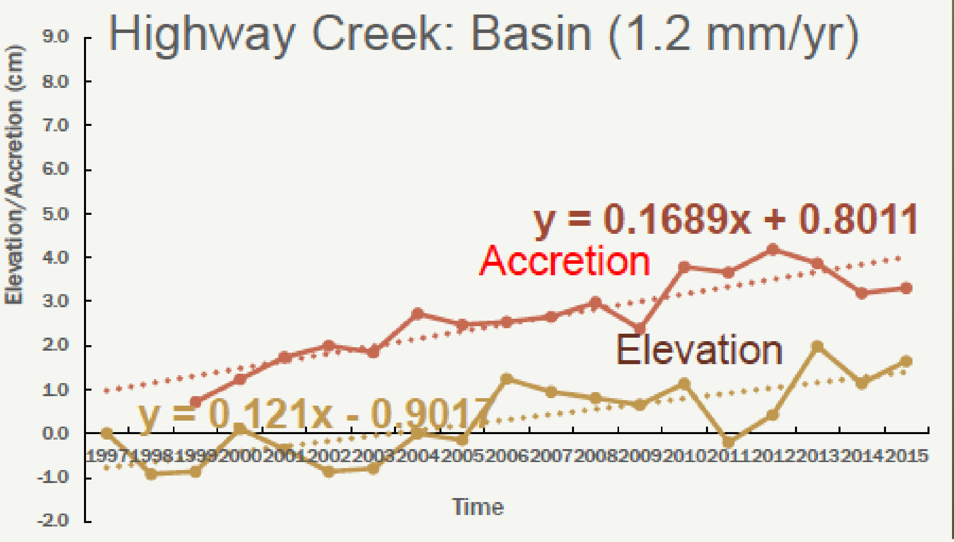
Salinity transect sites in Everglades National Park identifying West, Central and East Taylor Slough transects (1, 6 and 2, respectively) West and East C111 transects (3 and 4) and transect east of US1 in the Model Lands (5).

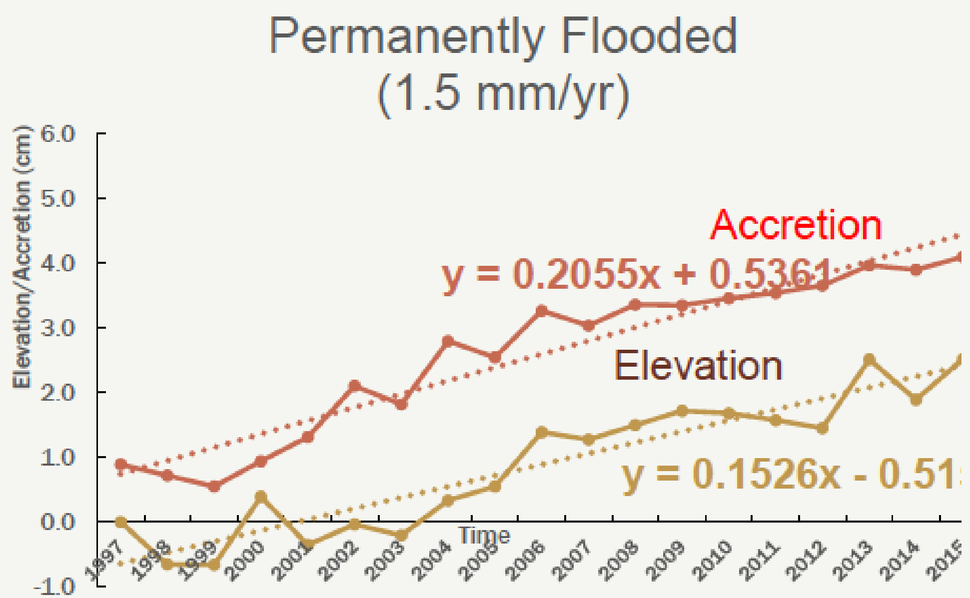

Jan '14
C-110
C-111
SOUTH DIXIE HIGHWAY
0.7
0.6
0.5
0.7
6.8
0.8
9
3.7
6.4
5.3
6.2
7.2
4.8
4.1
2.7
4.3
0.5
12.5
12.2
8.7
13.6
18.9
20.9
Jan '14
0.3
0.2
0.2
0.2
0.4
0.2
0.3
0.6
1.1
0.4
0.3
0.3
0.3
0.3
0.4
0.4
0.2
0.8
1.5
0.7
1.1
2.3
2.6
May '14
1.1
0.5
0.6
0.8
6.6
0.9
8.6
8.3
7.2
4.6
8.2
9.7
8.3
3.9
7
10.5
1
30.9
21.7
13.1
18.6
27.4
29.9
May '14
NA
0.3
0.3
0.4
NA
1.3
8.4
11.9
4.5
3.7
8.6
8.7
18
4.1
NA
23.1
NA
39.1
40
21.4
35.2
42.5
42.4
Aug '14
0.4
0.7
0.6
0.5
7.7
1.2
9.6
10.1
9
5.7
8.2
8.6
12.3
4.9
8.6
12.1
0.5
27.8
29
14.6
21.8
28.5
30.4
Aug '14
0.3
0.4
0.6
0.4
0.5
0.2
0.5
4.4
4.8
0.4
0.6
1.7
2
0.4
0.9
1.4
0.3
1.6
1.9
0.8
1.6
1
2.5
Oct '14
0.5
0.7
0.6
0.6
7.8
0.9
11.9
7.3
8.9
5.6
9.8
9.6
10.1
4
14
7
1
18.4
16.8
11
21.3
24.6
27.5
Oct '14
0.2
0.3
0.2
0.4
0.7
0.2
0.3
0.1
1.6
0.2
0.3
0.6
0.7
0.3
0.4
0.6
0.3
1
5.3
1
3.3
7.8
3.7
1:200,000
N
W
E
S
2014
Pore Water Salinity (ppt)
<1
1-5
5-10
10-20
20-35
>35
Porewater salinity (psu)
sercdata\WEEL\GIS\Salinity Maps\2014 Report\Sal_PW_2014
Created by: Daniel Virden
1:200,000
Surface Water Salinity (ppt)
NA
<1
1.0 - 5.0
5.1 - 10.0
10.1 - 20.0
20.1 - 30.0
>35
Surface water salinity (psu)
sercdata\WEEL\GIS\Salinity Maps\2014 Report\Sal_SW_2014
Created by: Daniel Virden

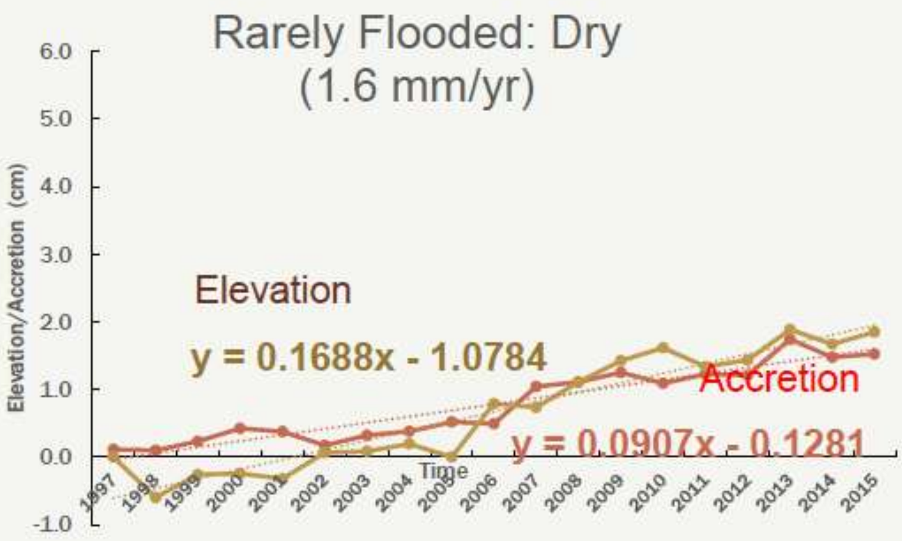


- Days since flow from S332D & C-111 influence surface water salinity greatest in sites east of TS & in W & E C-111 (including southern most sites)
- No effect on porewater salinity
- Very low *Cladium* biomass, absent in most “white zone” sites
- Inverse relationship between *Cladium* and *Eleocharis* stem density

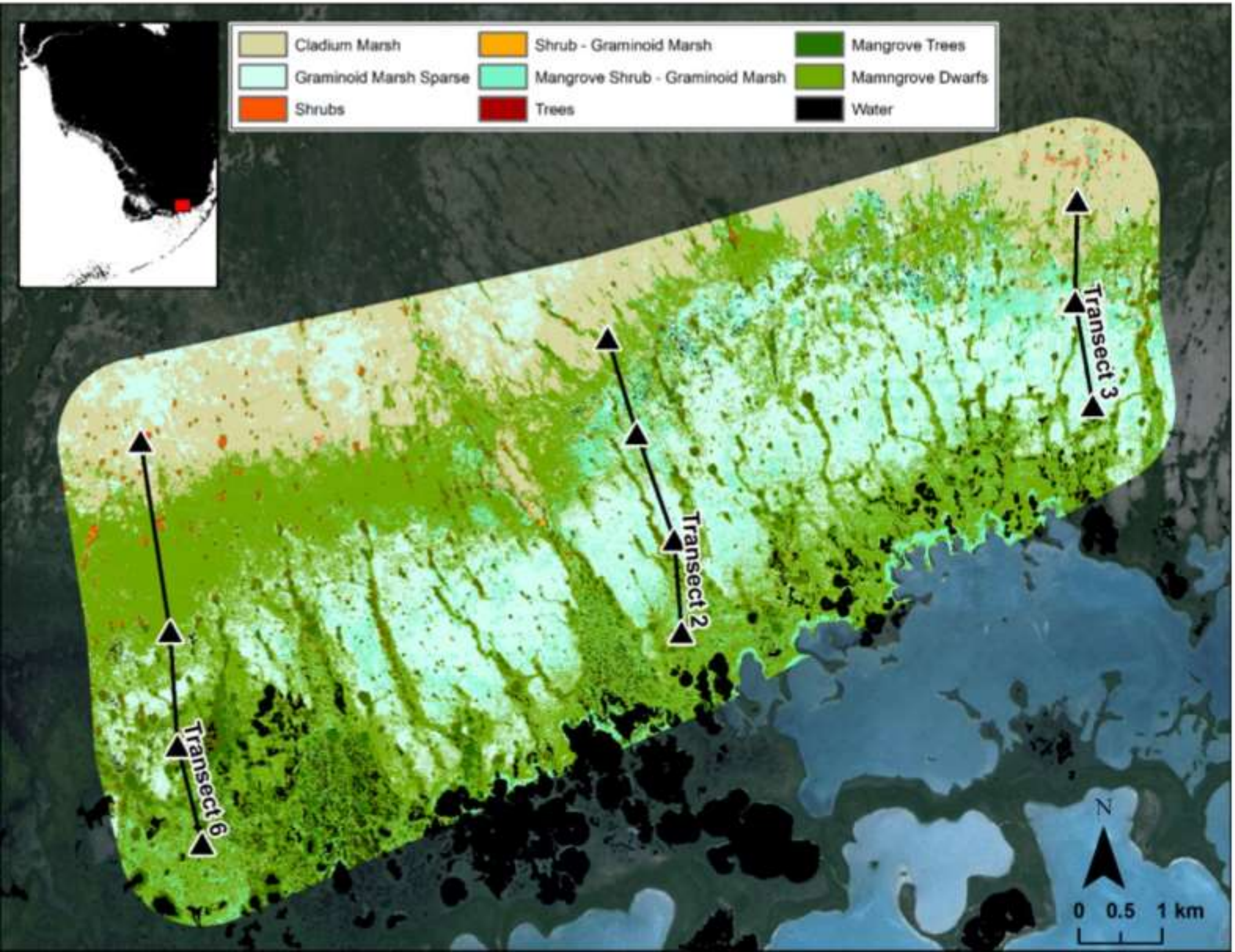

Argyle Henry: Mangrove
(4.4 mm/yr)
Elevation
y = 0.4437x - 0.5843
Accretion
y = 0.3719x - 3.018
Elevation/Accretion (cm)
Time


Highway Creek: Basin (1.2 mm/yr)
y = 0.1689x + 0.8011
Accretion
Elevation
y = 0.121x - 0.9017
Elevation/Accretion (cm)
Time


Permanently Flooded
(1.5 mm/yr)
Accretion
y = 0.2055x + 0.5361
Elevation
y = 0.1526x - 0.51
Elevation/Accretion (cm)
Time


Rarely Flooded: Dry
(1.6 mm/yr)
Elevation
y = 0.1688x - 1.0784
Accretion
y = 0.0907x - 0.1281
Elevation/Accretion (cm)
Time

Coastal ecotone mapping

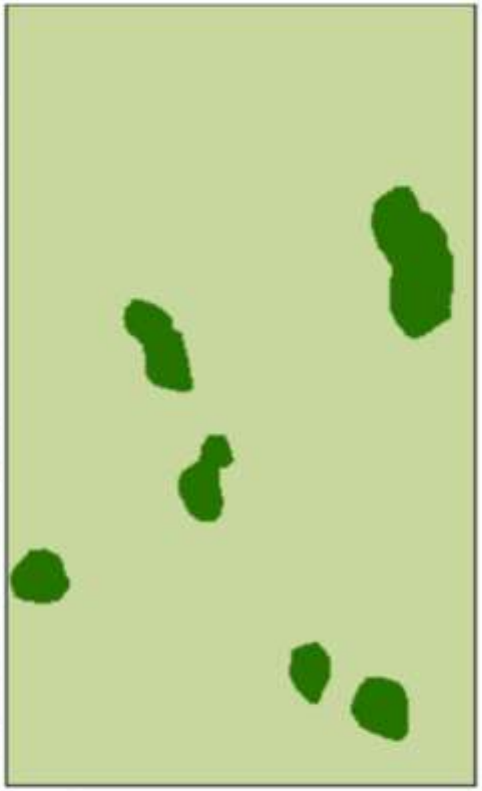


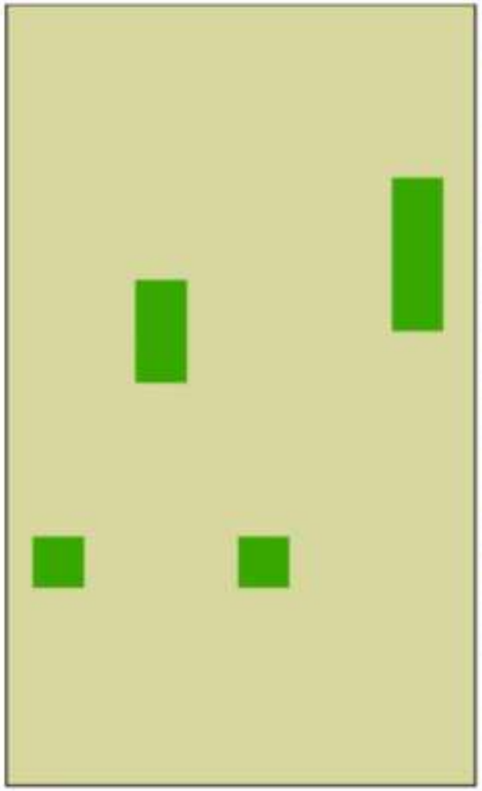
Remote sensing facilitates detection of patchy, fine-scale changes with high spatial precision

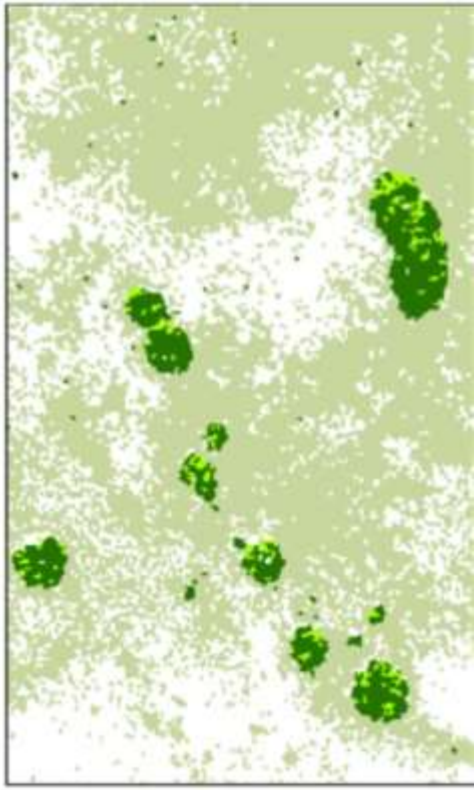
- high spatial resolution of satellite data
- adequate spectral resolutions to map classes of interest

Gann & Richards

Visual vs. Automated – Grid vs. Vector







Mixed mangrove
Mangrove Scrub - Red

Source: University of Georgia
MMU: ~ 10,000 m2
Data: Aerial Photography 1994/95
Method: Manual Polygon Digitization

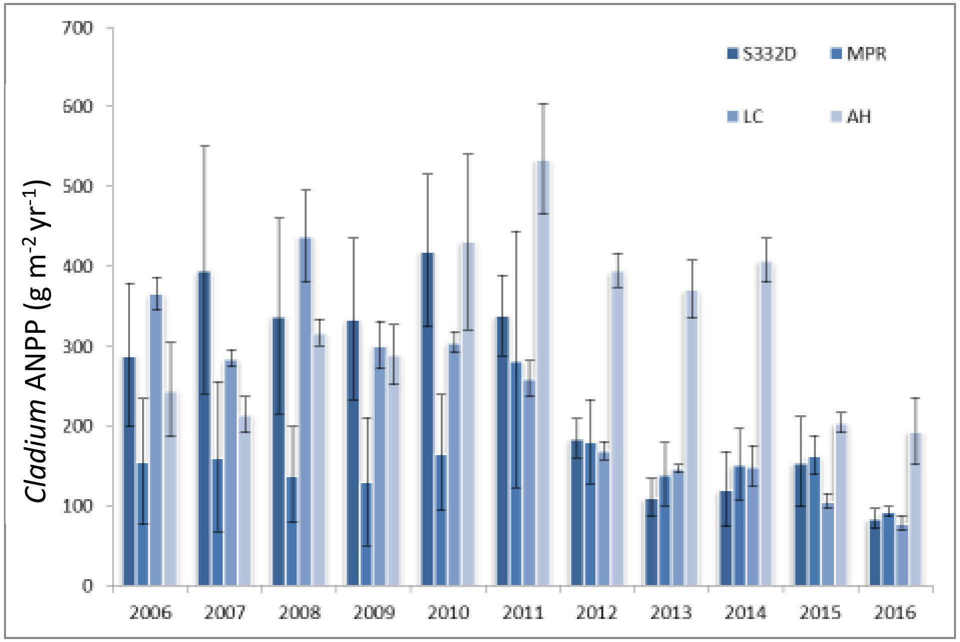
Transitional Bayhead Forest
Red Mangrove Scrub-Open Marsh

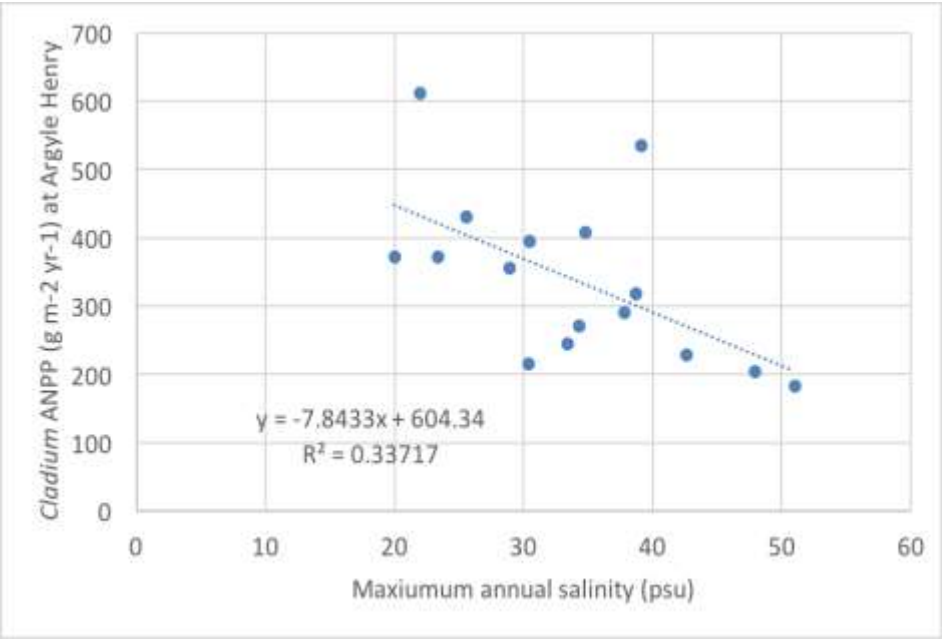
Source: SFCN
MMU: 2,500 m2
Data: Stereo Photography 2012
Method: Grid Interpretation

Marsh Sparse Vegetation
Non-Mangrove Shrub
Mangrove Tree
Mangrove Dwarf

MMU: 16 m2
Data: World View 2 - 2012
Method: Random Forest Classifier

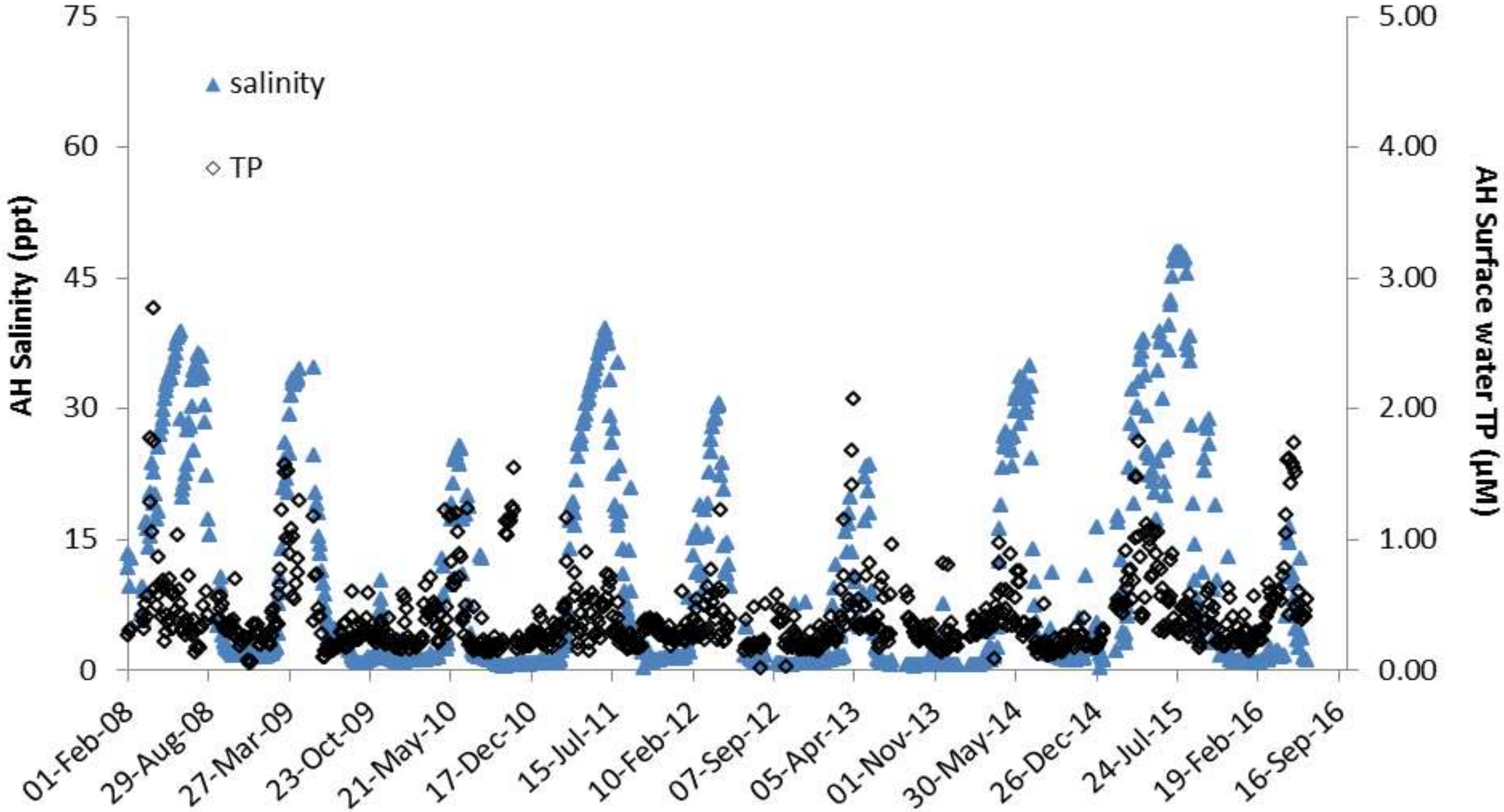
IV. Influence of salinity & TP on marsh aboveground sawgrass biomass



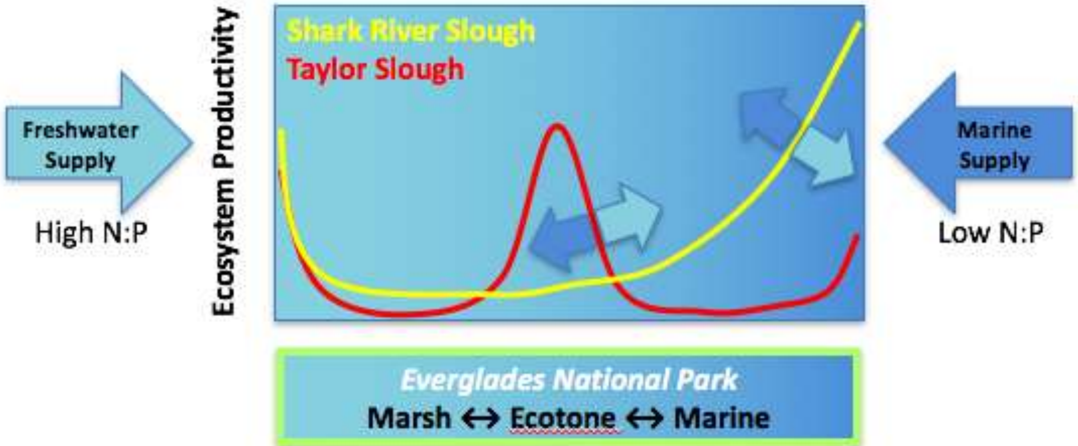


Taylor Slough freshwater and coastal marsh sites – sawgrass ANPP and salinity at Argyle Henry

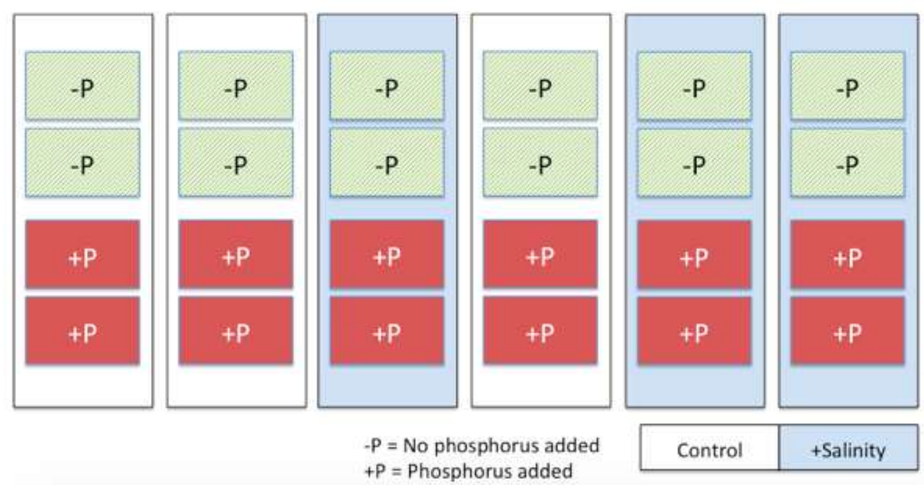
Surface water salinity and TP at Argyle Henry



Subsidy P - salinity stress experimental manipulation

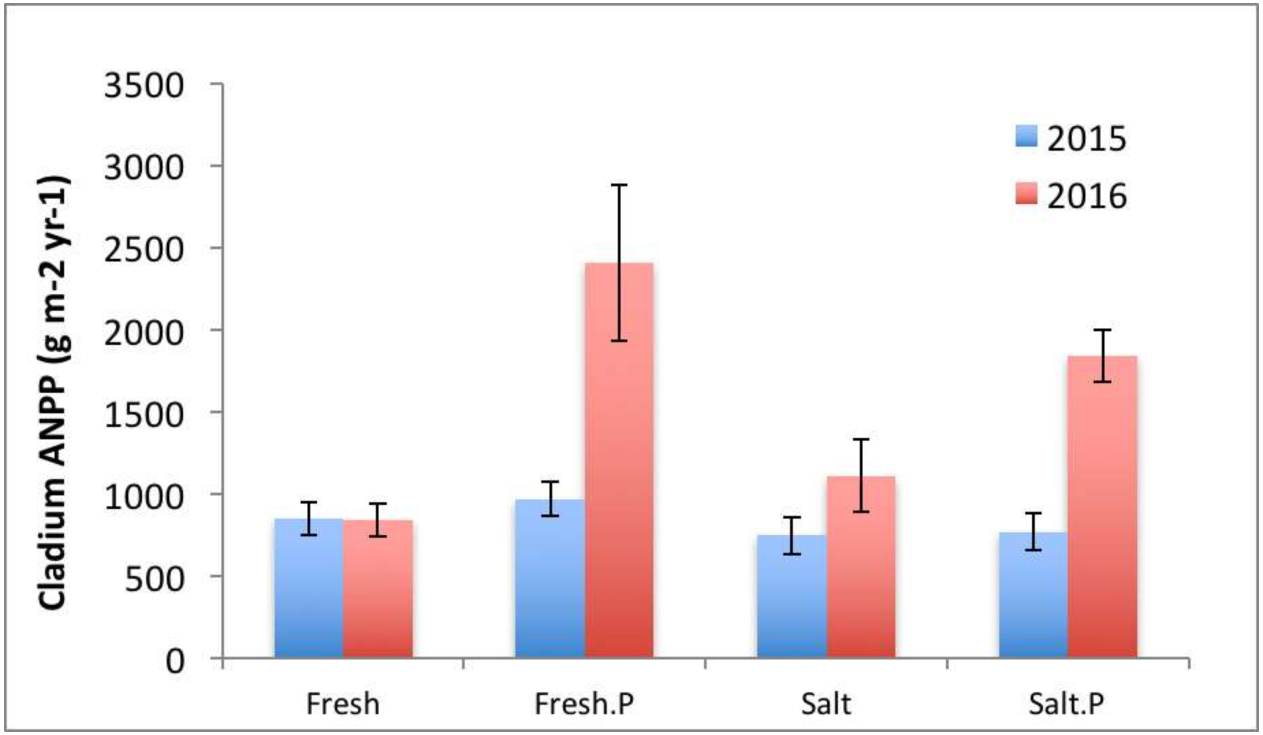


How will increasing discharge of brackish water elevated in P influence sawgrass productivity in freshwater peat marsh?



Florida Bay Interagency Science Center, Key Largo, FL

Subsidy P - salinity stress experimental manipulation – freshwater peat marsh



- Continuous dosing with 10 psu salinity water did not influence ANPP after 2 years
- Low level phosphorus addition increased ANPP after 2 years
- Salinity dampened ANPP under conditions of low P additions
- More work is needed

Florida Coastal Everglades carbon cycle research: some lessons learned

- ✓ Different elements of the Everglades ecotone exhibit different signatures of carbon sources and sinks.

- ✓ Inundation and salinity levels largely control the magnitude of carbon sources and sinks. More work is needed to understand subsidy (P) – stress (salinity) interactions.

- ✓ Integrating high resolution vegetation mapping and ecosystem characteristics and dynamics will enable landscape change detection and improved scenario development

- ✓ Freshwater releases represent an important tool for water managers to mitigate peat collapse and carbon losses in the Everglades, and to ameliorate landscape-level reductions in vegetated landscape.