Primary Productivity in Everglades Marshes Demonstrates the Sensitivity of Oligotrophic Ecosystems to Environmental Drivers

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Introduction

As anthropogenic effects continue to impact ecological systems, it is increasingly important that we understand the linkages between environmental drivers and primary productivity. In oligotrophic ecosystems in particular, primary productivity may be a bellwether ecological parameter for observing and forecasting the effects of environmental change. This may be demonstrated with long-term data on aboveground net primary production (ANPP) from an oligotrophic wetland ecosystem, the Florida Everglades. We used a non-destructive ANPP technique that is applicable to any continuously growing (e.g. tropical or subtropical) herbaceous system.

Hydrologic modifications over the past 100 years (including construction of over 2500 km of canals and levees and hundreds of water control structures) have had two important effects: 1) the canal-levee network has segmented the remaining Everglades into several large impoundments, dramatically inhibiting the natural tendency of water to flow south to Florida Bay and the Gulf of Mexico; and 2) drainage has reduced hydroperiods and mean-annual water depths in most of the remaining Everglades. Our study focused on a portion of the southern Everglades where a hydrologic restoration removed structural barriers to water inputs in one region but not another.

Based on the autoecology of *C. jamaicense*, we hypothesized that ANPP would be negatively related to changes in water depth or hydroperiod. Given that the former is a primary goal of Everglades restoration, we investigated how the plant community responded to this hydrologically-controlled reduction in ANPP.

As well as demonstrating a non-destructive technique for continually measuring aboveground live biomass over a 12 month growing season, we will also present an ANPP model which includes terms for both change in live biomass and for biomass turnover.

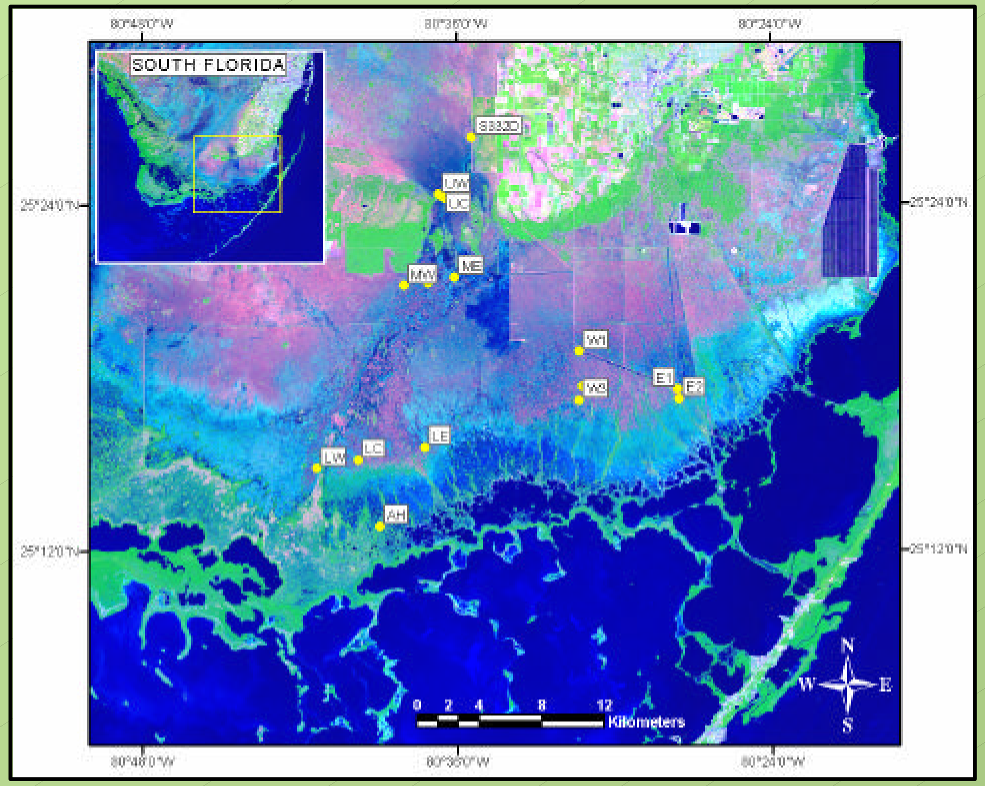

Figure 1. Satellite image of C-111 Basin and Taylor Slough highlighting long-term *Cladium* biomass plots.

Study Area

This study was conducted in the southern Everglades, in a region that includes the C-111 Basin and Taylor Slough (Figure 1). The landscape is dominated by sawgrass marshes and tree islands and interspersed with wet prairie and slough communities.

Triplicate 1 m^2 permanent plots were installed at all 16 southern Everglades sites.

- ☐ In late 1997 at W-1, W-2, and W-3; and in late 1998 at E-1 and E-2 all located in the C-111 Basin.
- ☐ In mid-1999 at UW, UC, UE, MW, MC, ME, LW, LC, and LE all located in Taylor Slough.
- ☐ In late 1999 S332 at the northern boundary (Figure 2) and AH at the southern boundary (Figure 4).

Sites were chosen to be primarily oriented with water flow and anchored at key canal water inputs. C-111 sites were established after levee removal from the C-111 canal in 1997.

Figure 2. Aerial view of site S332 and the L-31 canal (northern boundary).

Figure 3. Aerial view of C-111 area near W-1

Figure 4. Aerial view of site AH (southern boundary).

Methodology

Sawgrass Aboveground Live Biomass Measurements and Modeling

☐ Total number of sawgrass culms were counted, and one-third of these were randomly selected for non-destructive phenometric measurements. These included:

culm diameter at base, total number of live leaves, length of all live leaves, and inflorescence height (if present).

☐ Total number of all other plant species were counted.

These measurements were used to yield a live biomass value for each individual plant measured (g dw plant^{-1}). The mean per-plant live biomass was then multiplied by the total culm density of each plot to generate a live biomass estimate (g dw m^2) for each bi-monthly sampling event.

Model Calibration

To bracket the size ranges of plants at a given location and time of year, plants were haphazardly harvested near the plots from all sites over two years. The aforementioned phenometric parameters were measured for each of the harvested plants, dried at 70° C and then weighed.

Sawgrass Leaf Mortality Measurements and Modeling

Ten plants in each plot were also selected and tagged with numbered bird bands for bi-monthly counting of the number of live and dead leaves. The average change was calculated for the number of live and dead leaves, and these calculations were used to generate a regression model to predict % mortality (%MORT).

Annual Net Primary Productivity (ANPP)

ANPP was calculated by summing the bi-monthly changes in live biomass (live standing crop = LSC) and losses to turnover (%MORT) over a twelve month period. Due to distinct wet and dry seasons, an ANPP year is described as beginning in either December or January, depending on the sampling cycle of the transect.

$$ANPP = \sum_{t=1}^{6} (\Delta LSC + MORT) * k$$

where t = bi-monthly sampling intervals k = 1 if (MORT + DLSC) = 0, k = 0 if (MORT + DLSC) < 0

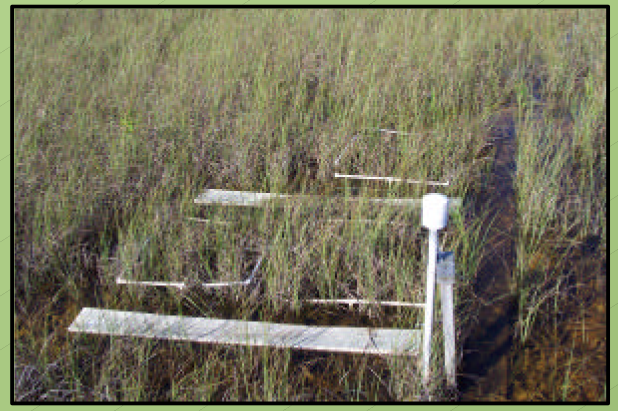

Figure 5. *Cladium* plots at LC with an Infinities Acoustic water level gauge.

Figure 6. Measuring plots at LC (Gustavo Rubio, Jeff Wozniak, Adam Wood, Isaac Adatto)

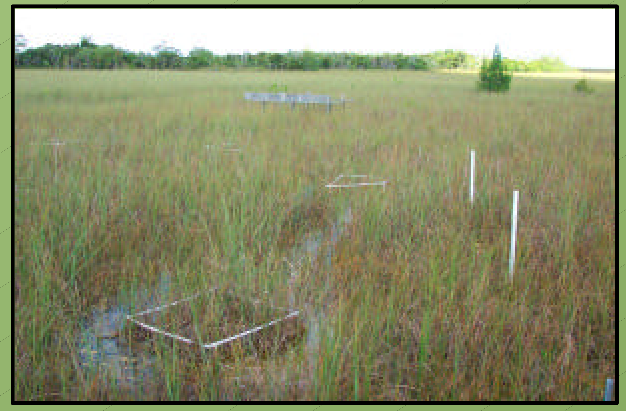

Figure 7. Permanent *Cladium* plots at site W-1 near the C-111 canal.

Table 1. Annual mean (in g dw m^{-2}; ±1 SE), annual maximum value, and annual minimum value of live aboveground biomass of *Cladium jamaicense* Crantz. At the five C-111 sites (top) and 11 Taylor Slough sites (bottom). In all cases, means are calculated on 6 bi-monthly samples measured at 3 plots.

		1999				2000				2001				2002			
Site	**rel. Hydropd.**	**mean**	**(SE)**	**max**	**min**	**mean**	**(SE)**	**max**	**min**	**mean**	**(SE)**	**max**	**min**	**mean**	**(SE)**	**max**	**min**
W-1	longer	300	24	493	88	188	12	280	107	158	14	262	51	147	9	242	83
W-2	longer	368	24	662	272	309	14	450	233	247	15	331	156	176	8	253	126
W-3	longer	220	11	299	147	179	10	274	119	159	10	244	65	130	6	167	81
E-1	shorter	632	41	956	375	548	36	820	290	639	51	1191	301	511	44	929	295
E-2	shorter	288	12	403	214	272	8	346	209	196	14	328	132	122	6	190	95
S332-D	shorter					188	20	363	58	161	10	226	96	139	10	203	79
UW	shorter					121	10	205	62	123	11	190	55	105	10	169	35
UC	intermediate					173	15	290	98	220	13	357	147	193	11	299	137
UE	longer					144	10	234	77	209	15	355	118	164	10	246	90
MW	shorter					122	5	173	93	117	7	180	72	89	5	117	51
MC	intermediate					167	7	237	121	141	9	212	80	114	7	171	72
ME	longer					159	6	210	120	181	10	262	92	142	9	210	83
LW	longer					262	11	359	190	317	24	482	161	215	13	348	148
LC	longer					345	17	437	201	335	11	464	264	204	11	289	139
LE	longer					242	13	364	146	219	13	308	136	171	7	248	118
AH	longer					312	19	509	182	211	18	396	59	150	15	313	64

Table 2. Mean annual water depth (in cm above soil level at each site), hydroperiod (# days y^{-1}), and mean Eleocharis sp. Stem density for all locations with site-specific hydrologic data.

	1999			2000			2001			2002		
Site	**mean WL**	**hydropd.**	**Eleo. Dens**	**mean WL**	**hydropd.**	**Eleo. Dens**	**mean WL**	**hydropd.**	**Eleo. Dens**	**mean WL**	**hydropd.**	**Eleo. Dens**
W-1	13.4	276.0	105.7	19.6	214.0	101.7	20.4	211.0	41.7	15.8	289.0	40.1
W-2	24.0	280.0	2.0	16.8	225.0	0.9	19.2	229.0	0.4	19.7	318.0	0.9
W-3	27.2	286.0	56.2	19.7	235.0	42.3	22.4	238.0	28.6	23.1	327.0	18.8
E-1	11.8	168.0	0.0	13.7	148.0	2.7	14.2	170.0	0.0	12.4	158.0	0.0
E-2	14.3	188.0	64.8	14.3	175.0	64.1	18.2	170.0	40.9	16.4	157.0	32.3
UE				39.9	269.0	19.2	42.5	186.0	15.6	37.8	226.0	21.2
ME				22.0	337.0	58.4	25.6	216.0	52.1	19.8	309.0	21.0
LC				14.7	339.0	0.0	19.4	235.0	0.0	21.5	316.0	0.0

Results

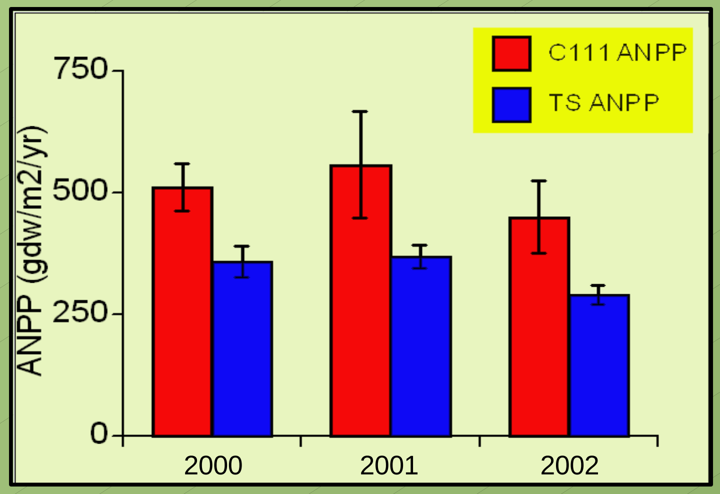

Figure 8. Annual mean ANPP for all C-111 Basin (red) and Taylor Slough (blue) sites for years in which data were available for both.

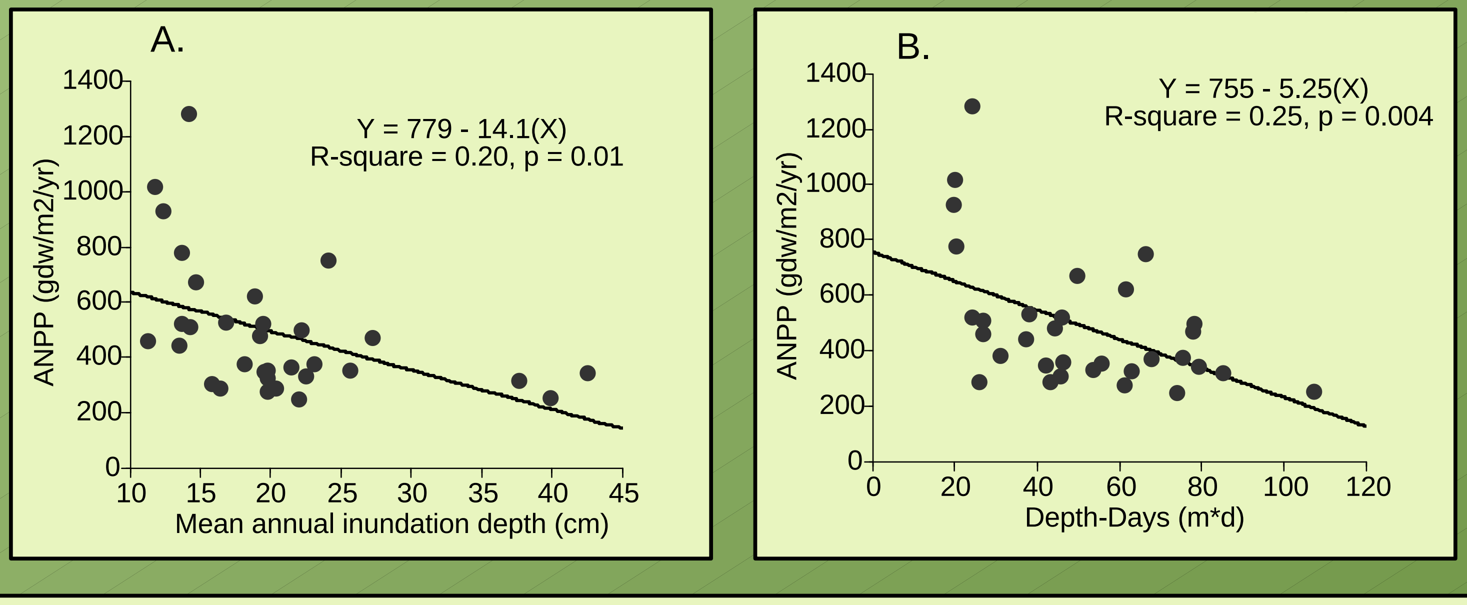

Figure 9. (A) Mean annual water depth vs. ANPP. (B) Depth-days (mean annual water depth*hydroperiod) vs. ANPP for sites W-1, W-2, W-3, E-1, E-2, UE, ME, and LC.

Conclusions

With this project, we have presented a technique for non-destructively and repeatedly sampling ANPP in grassland ecosystems with a 12 month growing season. ANPP was significantly negatively related to both mean annual water depth and to depth-days (a hybrid variable, similar to "degree-days" used by meteorologists, calculated as the product of mean water depth and hydroperiod) This finding suggests that, as water depths increase in the southern Everglades, sawgrass may decline.

Sawgrass ANPP and *Eleocharis* stem densities were also negatively related, suggesting that *Eleocharis* rapidly replaces *C. jamaicense* when the latter is declining. We found that nearly 40% of the spatial and temporal variability in sawgrass productivity was explained by depth-days and *Eleocharis* density. Given that higher water levels and longer hydroperiods is a goal of Everglades restoration, our results are significant: A decline in sawgrass, the "charismatic macrophyte" of the Everglades, and nearly simultaneous replacement with deeper water species such as spikerush is not necessarily detrimental or ecologically disruptive.

Our ANPP and plant community composition data demonstrate that oligotrophic ecosystems are particularly sensitive to environmental change and thus excellent systems for studying ecological responses to exogenous drivers.

Acknowledgements

Many thanks to the Wetland Ecosystems Lab at FIU and to the swarms of people involved in field and lab assistance over the years.

Data and information on this poster was obtained primarily from D.L. Childers, G. Rubio, D. Iwaniec, D. Rondeau, E. Verdon, & C. Madden (in submission) Primary Productivity in Everglades Marshes Demonstrates the Sensitivity of Oligotrophic Ecosystems to Environmental Drivers

Permission to access our sites in Everglades National Park was granted through Department of the Interior research permits. This research was supported by the South Florida Water Management District under several sequential contracts, and by the National Science Foundation through the Florida Coastal Everglades Long-Term Ecological Research Program.

A special thanks to Mike Rugge for great maps, David Iwaniec and Colin Saunders for lending "technical" support, and especially to Dan Childers for giving a kid a shot at the big time.