Carbon Pool Dynamics in a Phosphorus-Impacted Wetland (Everglades, FL)

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Abstract

Wetlands function as a major sink of carbon, but also release C through microbial respiration. Human disturbances, such as hydrologic changes and nutrient additions, often increase the rate at which wetland C is released to the atmosphere. In water conservation area 2A (WCA-2A), a managed hydrologic unit within the Everglades, a historically P-limited wetland is receiving high concentrations of P. The goal of this study was to determine if anaerobic respiration and the character of the C pools differed between P-enriched areas and un-enriched areas of the wetland. Results indicate un-enriched soils (0-10cm) store the most TC (μ=3341g C m^{-2}) and organic C represents >97% of the TC at all sites. Anaerobic CO_2 and CH_4 production was significantly greater in the un-enriched detritus than all other sites ($p<0.05$). The mass of C lost to anaerobic respiration annually represents between 32% (un-enriched detritus) and 2% (un-enriched soil) of the TC pool, with turn-over rates from anaerobic respiration between 4 and 67 years, respectively. Neither CO_2 nor CH_4 production was correlated with TP, but CO_2 was positively correlated with liable OC ($p<0.001$). On average, 73% of the anaerobic C produced was as CO_2-C, and 27% as CH_4-C. Overall, the TC pool of the soil is significantly larger and more stable than that of the detritus. TP no longer appears to drive anaerobic respiration, but rather liable C availability. As a result, un-enriched detritus (characterized by periphyton) has the highest rate of C production and the fastest C turn-over rate.

Methods

- Soil (0-10 cm) and detritus/floc (when present) was collected at 118 sites in WCA-2A.
- A sub-set of 34 sites along the P gradient were selected to establish a transect (Figure 1).
- Parameters measured at all sites included: bulk density, TP, and organic matter content (LOI) .
- Parameters measured along the transect included: Liable organic C (LOC), total LOC, microbial biomass C (MBC), CO_2 and CH_4 flux.
- CO_2 and CH_4 flux was determined using anaerobic serum bottle incubations and analyzed on a gas chromatograph.
- Statistical analysis (ANOVA, linear regression, and correlations) were conducted in SAS.
- Vegetation, TP, site location, and pervious publications were used to categorize site trophic status.

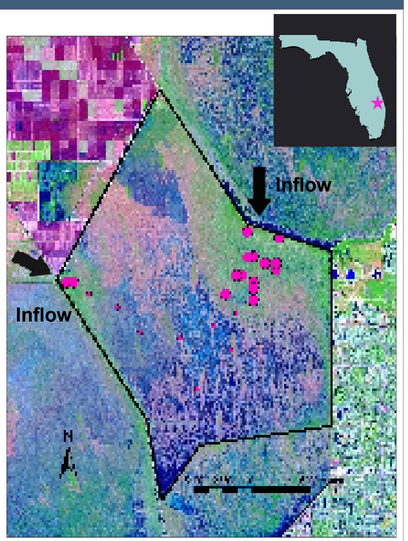

Figure 1. Geographic location of WCA-2A and a Landsat image indicating the location of the 34 sites chosen for the TP transect. Larger circles represent P-enriched sites and smaller circles represent oligotrophic sites. Water inflow structures (the source of the P) are indicated by black arrows.

Results & Discussion

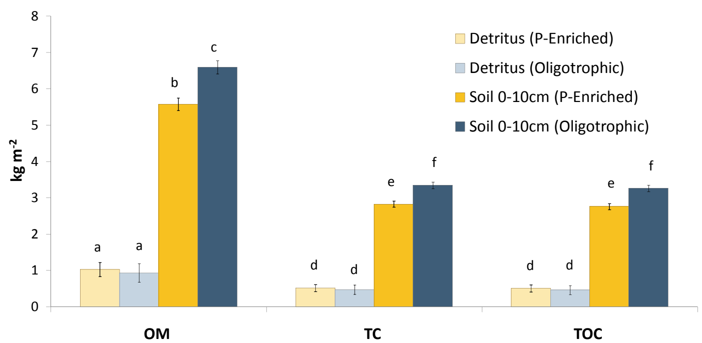

Figure 2. Mean organic matter (OM), total carbon (TC), and total organic carbon (TOC) storage for both depth and trophic status. For detritus, n=74, for soil, n=118.; error bars represent standard error. Different letters represent significantly different means at p<0.05.

- **Existing C pools:** The average depth of the detritus/floc layer was 8.6 ± 3.6 cm. Organic matter storage (g C m^{-2}) was significantly greater in the surface soils than the detritus ($p<0.001$) and greatest in the oligotrophic soils ($p<0.01$; Figure 2). The thick rhizomes of the *Typha d.* that dominate P-enriched sites result in a significantly lower bulk density ($p<0.05$). TC was ~50.5% of the OM, and >97% of the TC was organic (Figure 2).

- **Anaerobic Decomposition:** CO_2 production was significantly greater in the detritus than the soil ($p<0.05$), and oligotrophic detritus had the greatest rate of CO_2 ($p<0.01$) and CH_4 ($p<0.05$) production (Figure 3). The high rate of anaerobic C production in the oligotrophic detritus is likely a product of high concentrations of liable C in periphyton, which is found in abundance at oligotrophic sites.

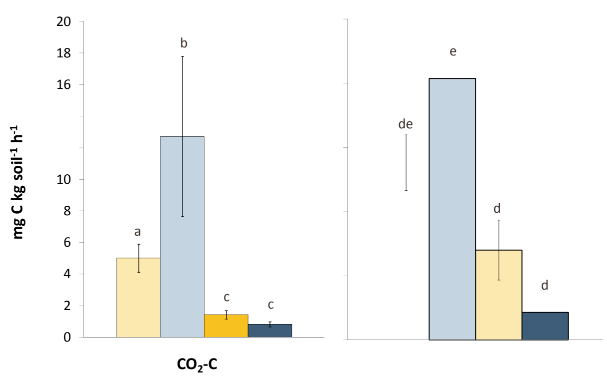

Figure 3. Mean anaerobic CO_2 and CH_4 production among the sub-set of samples, n=34. Error bars represent standard error. Different letters represent significantly different means at p<0.05.

- **CO_2:CH_4:** The ratio of CO_2:CH_4 production was highly variable (range 0.5- 79) and not correlated with depth or trophic status. On average, 73 18% of the C produced was as CO_2-C, and 27 18% was as CH_4-C (Figure 4).

- **Controlling Factors:** Carbon dioxide production showed a strong positive relationship with LOC, TLOC, and MBC ($p<0.001$), but none of these variables were correlated with CH_4 production.

- **C Turnover:** Anaerobic decomposition releases C (g m^{-2}) equivalent to between 2 to 32.5% of the existing TC pool annually, without accounting for accretion (Table 1). Anaerobic decomposition causes the oligotrophic detritus C to turn-over the fastest (3.7 years) and oligotrophic soil the slowest (67.5 years; Table 1).

Table 1. *Values with different letters are significantly different at p < 0.05. For TC, n=118, for all others, n=34. Calculations do not account for accretion.*

Layer	Trophic Status	TC (g m^{-2})	TC annual loss to anaerobic decomposition (%)	TC turn-over rate anaerobic decomposition (years)	Anaerobic decomposition decay rate (years)
Detritus	P-Enriched	517 ± 38_a	12.2 ± 2.2_c	8.8 ± 10.4_f	0.1 ± 0.04_h
	Oligotrophic	471 ± 48_a	32.5 ± 3.4_d	3.7 ± 16.0_f	0.3 ± 0.2_i
Soil (0-10cm)	P-Enriched	2827 ± 99_b	4.2 ± 1.4_e	35.1 ± 7.0_{fg}	0.04 ± 0.01_j
	Oligotrophic	3341 ± 123_b	2.0 ± 2.2_e	67.5 ± 10.4_g	0.02 ± 0.01_j

- **Basic C Budget:** Combining the present data with previously determined accretion rates and aerobic CO_2 production, we can construct a simple C budget (Figure 5).

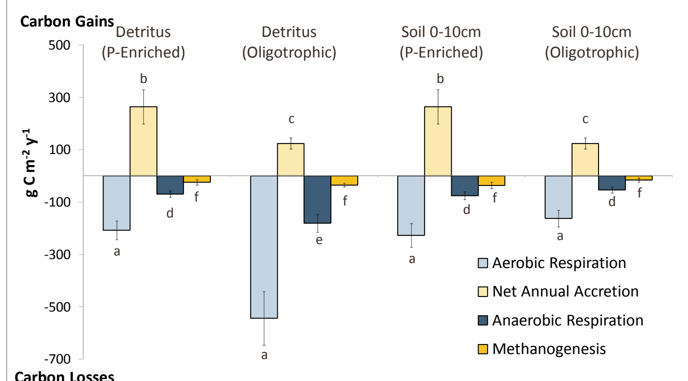

Figure 5. Estimated C budget for the detritus and soil , P-enriched and oligotrophic areas. For respiration values, n=34, for accretion, n=74 (detritus) and 118 (soil). All values represent means and error bars represent standard error. Different letters represent significantly different means between depth and trophic status at p<0.05. Accretion estimates are based on Reddy et al., 1993 and aerobic respiration rates are estimated from Wright and Reddy, 2001.

Conclusions

- Surface soil in oligotrophic areas of WCA-2A have the largest and most stable pool of C.
- Detritus in oligotrophic areas of WCA-2A are the most active C pool, producing the greatest flux of anaerobic CO_2 and CH_4.
- Anaerobic respiration is no longer correlated with TP concentrations, as previous research had found, but is strongly correlated with indicators of labile C (LOC, TLOC, and MBC).
- Recent changes in water conveyance patterns in WCA-2A may have altered the availability of labile C, creating a greater limitation to microbial activity than TP under some circumstances.
- Future research should quantify the lability of detrital matter at a larger scale, including seasonally, to determine if TP is no longer the limiting factor for anaerobic decomposition in WCA-2A.