Carbon fixation by the invasive common reed under current and near future CO_2 and nitrogen conditions

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Background

Phragmites australis (common reed) is aggressively invading tidal marshes along the Atlantic Coast, and could dramatically **alter carbon cycling dynamics** through its **strong responses to global change**[1,2].

We sought to determine whether rates of *Phragmites* carbon fixation differ:

1. Among **genotypes***
2. Under environmental conditions indicative of **global change** (Table 1).

Using a **greenhouse experiment** and a **simulation** model based on a manipulative field study, we compared **photosynthetic rates** under conditions of ambient and near future **CO_2 levels** crossed with oligotrophic and eutrophic **nitrogen levels** (Table 1).

Table 1. Environmental conditions used in both experiments.

	Low N loading (<5 g m^{-2} yr^{-1})	Moderate N loading (25 g m^{-2} yr^{-1})
Ambient CO_2 (~400 ppm)	Control	+N
Elevated CO_2 (ambient + 300 ppm)	+CO_2	+CO_2+N

* Although there are native genotypes in North America, we were specifically interested in genotypes within the invasive lineage (haplotype M).

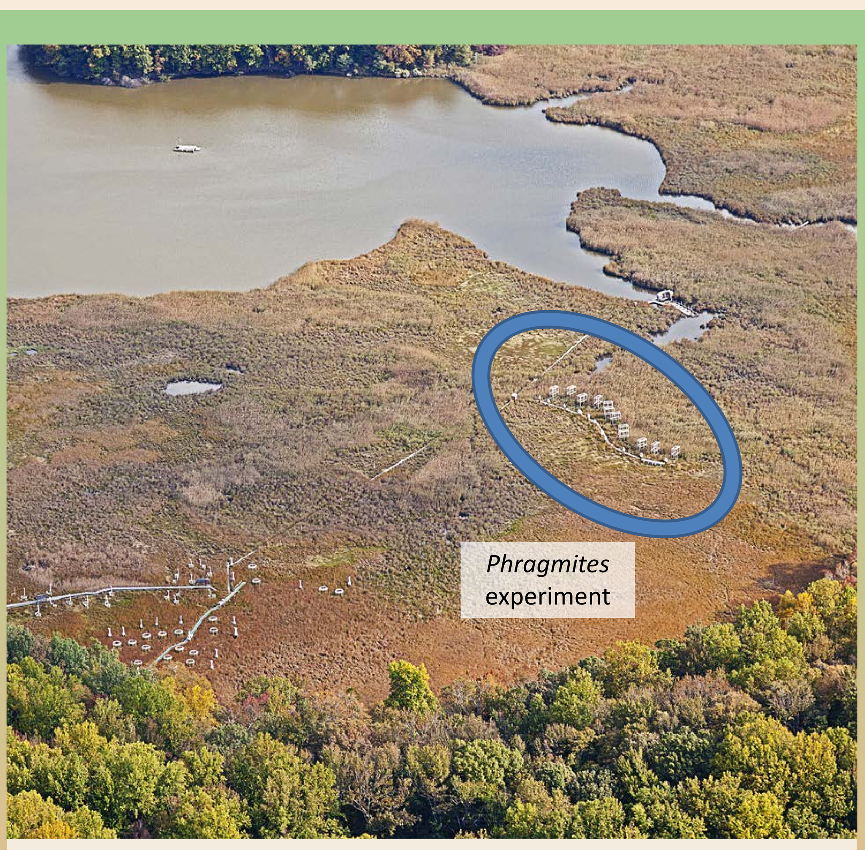

Fig 1. The Smithsonian's Global Change Research Wetland on the Chesapeake Bay, Maryland. With rising sea levels, coastal wetlands will also have to rise (via peat accumulation) to persist. Photo Credit: Chuck Gallegos.

Acknowledgements

- This work was supported by grants from NSF LTREB (DEB-0950080) and Maryland Sea Grant (SA7528114-WW), as well as the Bryn Mawr College Summer Science Program, Biology Department, and Bucher-Jackson Postdoctoral Fellowship.
- We thank Patrick Megonigal, Gary Peresta, Andrew Peresta, Adam Langley, Eric Hazelton, Caitlin Bauer, Josh Shapiro, Sydne Record, Franzisca Eller, Rich WIllard, and the SERC Phytoplankton Lab.

References

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Methods

Results

Discussion

Greenhouse

Fig 2. Greenhouse chambers on the Bryn Mawr College campus. *Phragmites* plants growing in 3 chambers were given 700 ppm CO_2. Half of the plants in each chamber were fertilized weekly.

Fig 3. After 10 weeks, CO_2 fluxes were measured under controlled conditions.

Genotype Comparison

- CO_2 fluxes and biomass accumulation were compared among four genotypes of *Phragmites* (denoted A, 14, and 45) from a Chesapeake Bay tidal marsh in Maryland (Fig 1).
- Plants were propagated from rhizome fragments and grown for 10 weeks (Fig 2) under 4 combinations of CO_2 and N (Table 1).
- CO_2 fluxes were obtained using a greenhouse gas analyzer while plants were sealed in gas-tight containers (Fig 3). Net CO_2 fixation (photosynthesis – respiration) was calculated from the rate of decline in CO_2 flux with lights set to 1000 µmol m^{-2} s^{-1}. Fluxes were normalized to the leaf area of each plant.
- Biomass of dry roots, rhizomes, stems, and leaves were measured at the conclusion of the experiment. The total biomass of all organs is reported here.

- Biomass accumulation **differed between two genotypes** (Fig 4).
- All genotypes had **higher rates of CO_2 fixation** & greater biomass at harvest **under eutrophied conditions** (Fig 4).

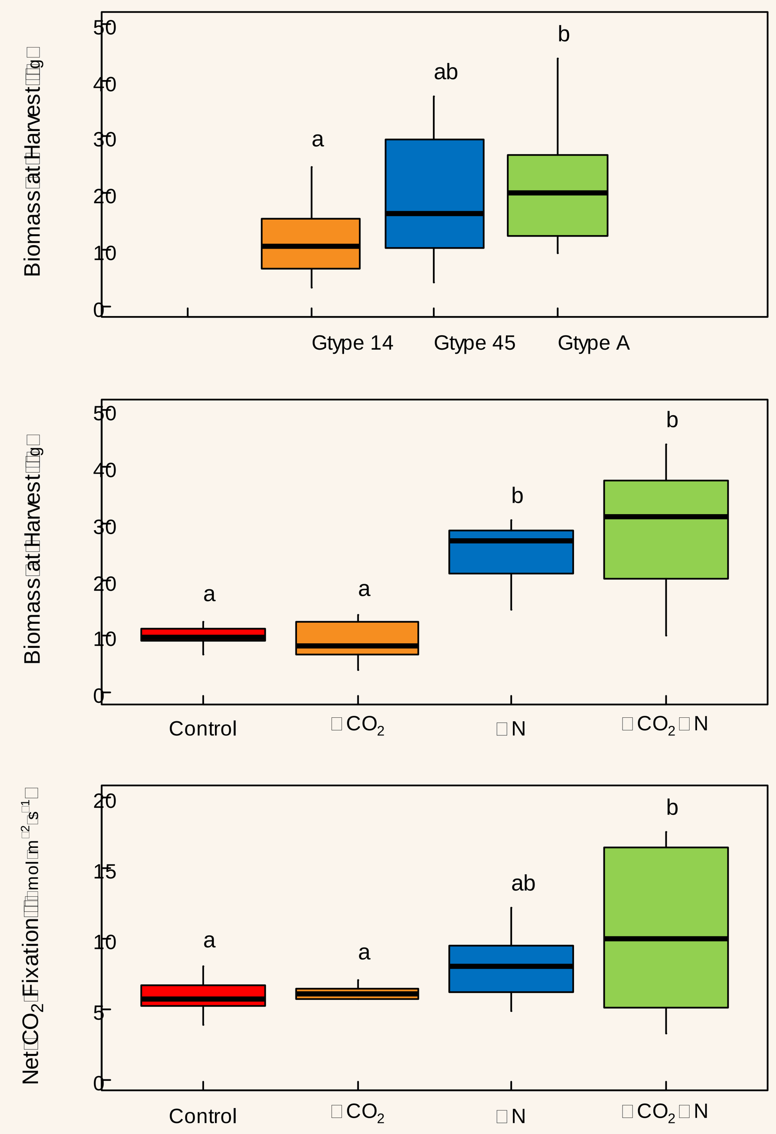
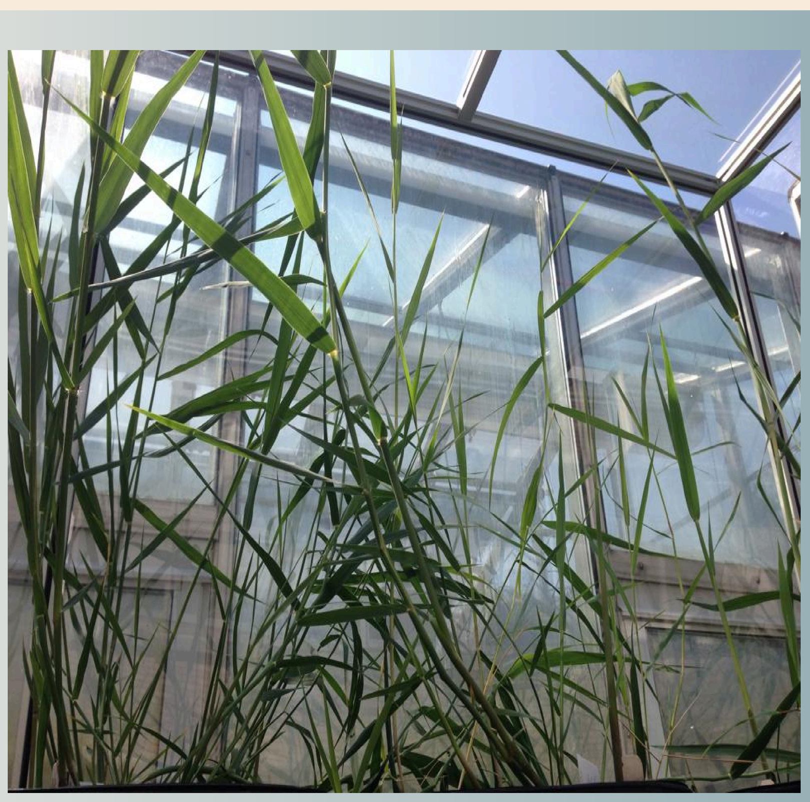


Fig 4. Carbon fixation by simulated *Phragmites* stand at daily intervals.



- This research provides experimental support for the observation that eutrophication likely facilitates *Phragmites* invasion[4].
- If N loading to waterways is allowed to increase, or is not managed with expanding urban areas and agriculture, **N proliferation could accelerate *Phragmites* spreading rates**.
- If some genotypes are particularly responsive to CO_2 or N (this experiment lacked the power to detect such differences), **intraspecific competition** could lead to genetic filtering and selection for **genotypes especially responsive to N**.
- We will next evaluate **differences in N metabolism** in these genotypes (via the glutemate synthetase enzyme).

Field / Simulation

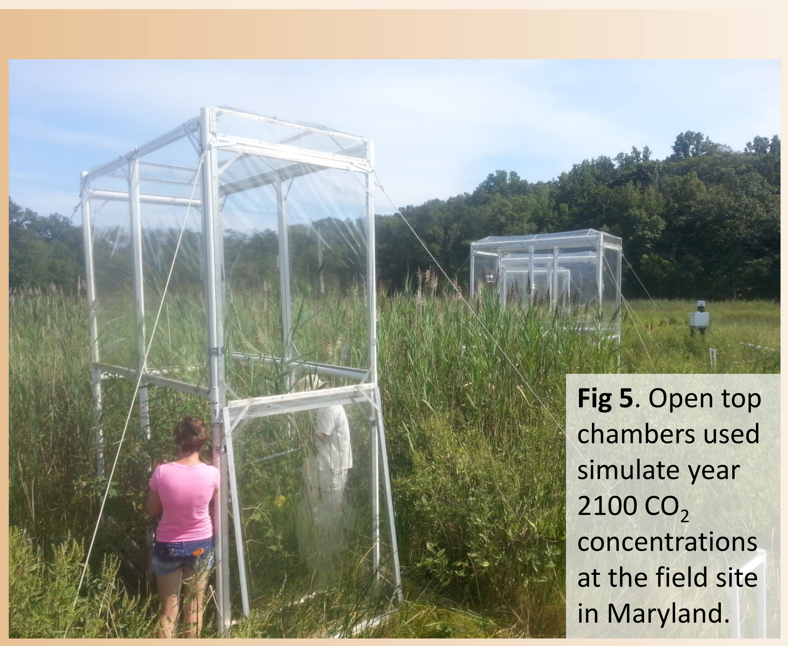


Fig 5. Open top chambers used simulate year 2100 CO_2 concentrations at the field site in Maryland.

Manipulative Field Study

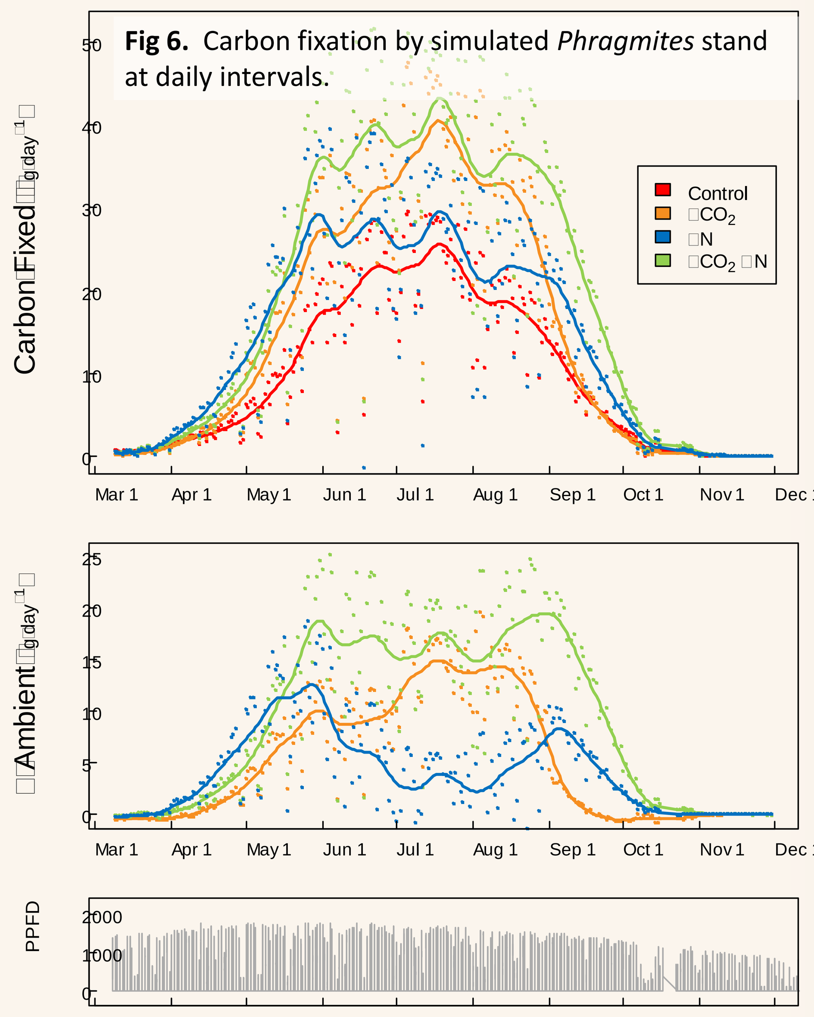
- In 2010, open top chambers (n=12) placed at the invading edge of a *Phragmites* stand on the Chesapeake Bay, Maryland, at the Smithsonian's Global Change Research Wetland (Figs 1&5).
- CO_2 and N applied each growing season (Table 1).
- Empirical data on photosynthesis, canopy structure (stem elongation, leaf area, etc.) and light availability (PPFD) were collected in 2013.

Simulation Model

- Carbon fixation by monotypic *Phragmites* stands (100 stems in 1 m^2) was modeled through the 2013 growing season.
- In the model, canopy growth was simulated at daily intervals, while carbon fixation was simulated hourly. Individual leaves were tracked, with a constant longevity assumed (100 day). Light was attenuated through 10 cm canopy layers[3].

- ***Phragmites* carbon fixation was strongly stimulated** by elevated CO_2 and nitrogen (Fig 6); the model projected a **near doubling** of its annual carbon fixation rate in eutrophied Chesapeake Bay marshes under near future CO_2.

Fig 6. Carbon fixation by simulated *Phragmites* stand at daily intervals.



- Increased C fixation resulted from changes in changes in phenology (earlier growth and later senescence) as well as accelerated photosynthetic rates.

Fig 7. *Phragmites* rhizomes when soil has been removed. Photo credit: Bob Meadows.

- Unlike the greenhouse experiment, this study showed that *Phragmites* will increase its growth as CO_2 levels rise.
- Even if the expected fraction (75%)of fixed carbon is respired, much would be **stored belowground** as rhizomes (Fig 7).
- **Peat accumulation** could be greater than in native marshes under future levels of CO_2, and greater than in *Phragmites* invaded marshes currently, especially where N loading is moderate to high.
- Through accelerated **surface accretion**, *Phragmites* may prevent some marshes from drowning under **rising sea-levels**.
- Although native wetland species may also respond to global change, they may rarely be able to compete with uncontrolled *Phragmites*.
- **Prioritizing where to control *Phragmites*** and where not to control it may become a critical management question.