Spatial and temporal variability of annual greenhouse gas fluxes from a constructed wetland in an arid region

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Background

- **Wetlands** support ecological functions that result in valuable services to society, including water purification.
- Wetlands are also sources of **greenhouse gases** (GHG), such as **nitrous oxide (N_2O), methane (CH_4), and carbon dioxide (CO_2).**
- Many **constructed treatment wetland systems** (CWS) have been developed to remove nutrients from secondarily-treated water, but little is known about the contributions of GHG fluxes in arid regions.
- **We aimed to investigate the GHG fluxes emitted from the Tres Rios CWS to increase our knowledge of ecosystem dynamics of constructed ecosystems in arid regions.**

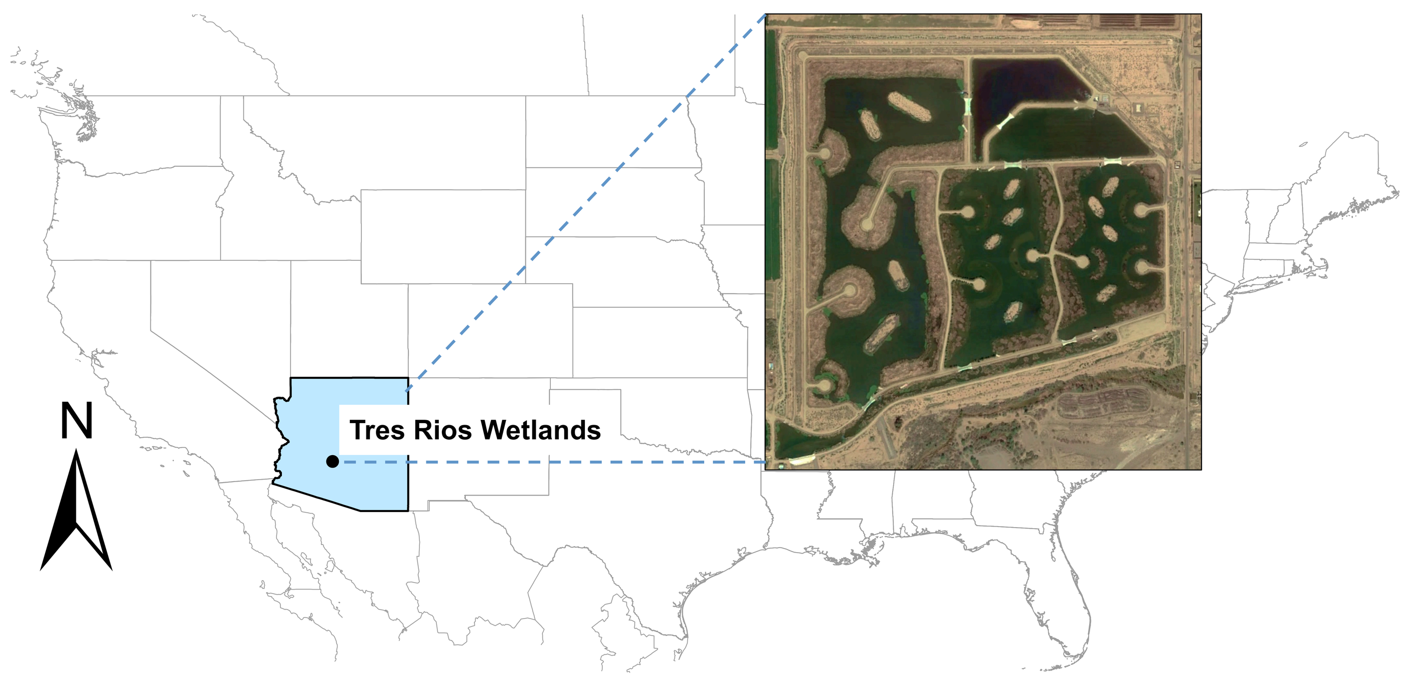


Figure 1. The Tres Rios Constructed Wetland is located in the Sonoran Desert approx. 20 kilometers east of the City of Phoenix, Arizona, USA. Insert shows the complete 180 ha Tres Rios CWS.

Site Description and Methods

- The Tres Rios CWS Study Cell 1 is approx. 42 ha with 21 ha of it shallower, with emergent vegetation from the genera *Typha* and *Schoenoplectus* and with a mixture of clay and sandy loam soils (fig 1).
- Cell of 1 has an approx. N loading rates between 1.55 - 4.48 g N m^{-2} d^{-1} and it removes approx. **30-40% of excess N** from the surface water.
- The regional average **temperatures** can range from 12° C in the winter to 33° C in the summer and an avg. annual **precipitation** of 230 mm/yr.

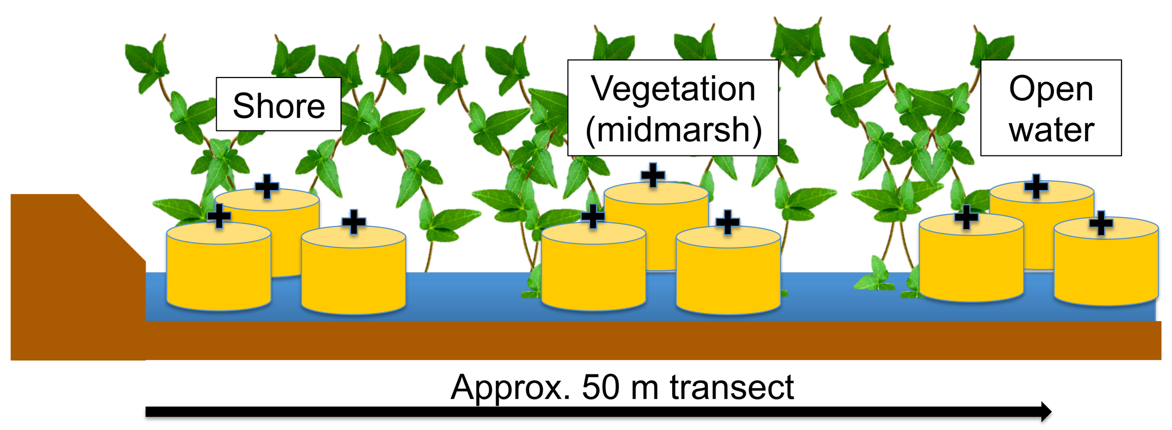


Figure 2. Representation of chamber placement along a transect.

- Fluxes of N_2O, CH_4, and CO_2 were investigated from a **whole-system** perspective and from a **vegetated-marsh to open-water** gradient.
- We have been utilizing the **floating chamber technique** to collect and measure gas samples from two **transects** in the vegetated-marsh area: near to **inflow** and **outflow**; and along three gradient **subsites** within the transects: **shoreline, midmarsh, and open-water** (figs. 2 and 7).
- Gas samples were taken from three replicated chambers with floating collars every 15 min during a 45 min period at 800, 1000, and 1200 hrs every other month.
- Samples were analyzed using a Varian CP-3800 GC and fluxes were calculates using the *Flux=(V * C_{rate})/A;* where *V* is the chamber volume, C_{rate} is the change in gas concentration, and *A* is the area enclosed by the chamber.

Results

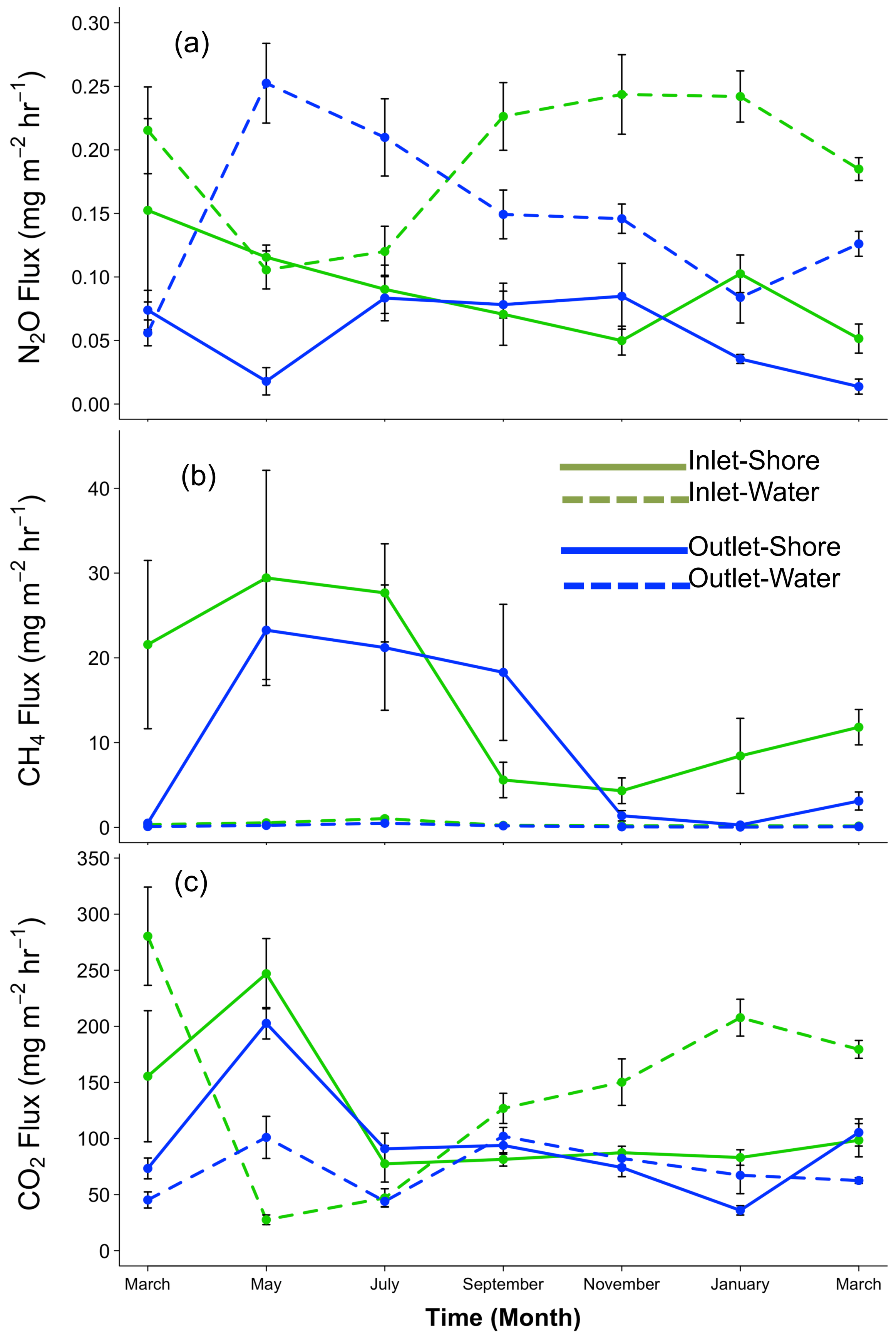


Figure 3. Significant spatial and temporal differences observed from (a) N_2O, (b)CH_4 and (c)CO_2 fluxes emitted from the Tres Rios CWS between March of 2012 and 2013.

Spatial Variability

- We found two **significant spatial patterns** in GHG fluxes in the CWS, between the inflow and outflow transects and along the transect gradient subsites (fig 3).
- **Between the transects**, we found larger CO_2 and N_2O fluxes at the inflow compared to the outflow ($p<0.001$) but not CH_4 (fig 3).
- **Along the transect gradient subsites**, N_2O fluxes were lower at the shoreline ($p<0.001$) compared to CH_4 fluxes, where the lowest fluxes were observed at the open-water subsite ($p<0.001$) (fig 3).

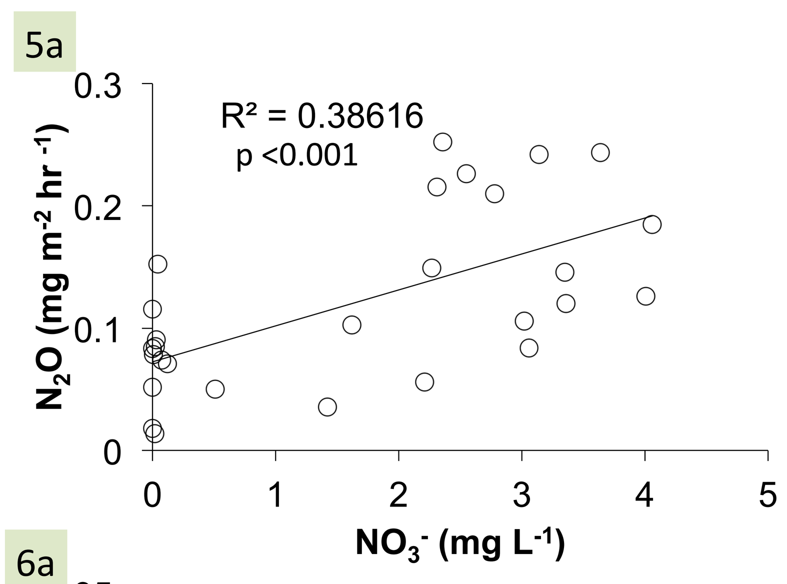
Temporal Variability

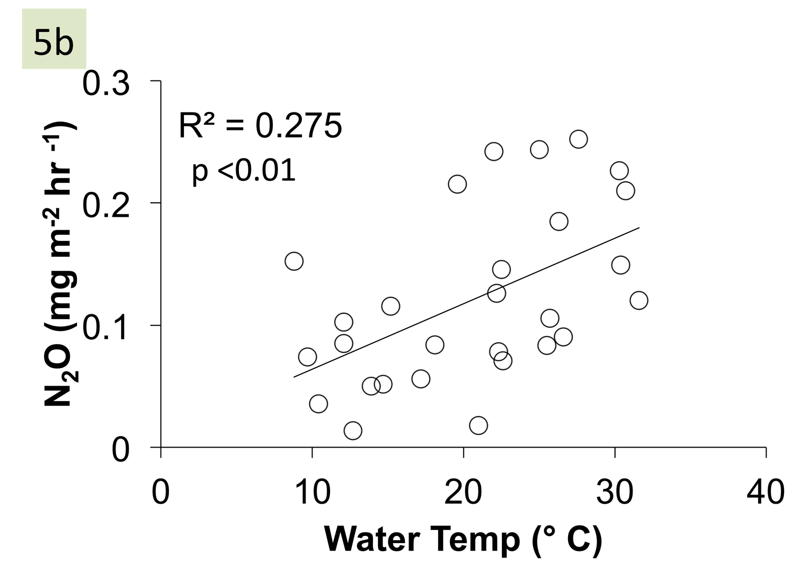
- There were no significant differences between the three diurnal sampling times.
- From March 2012 to March 2013, we found **seasonal differences** in CO_2 and CH_4 fluxes ($p<0.001$), but not in N_2O fluxes (fig 3).
- CH_4 fluxes were higher in late spring and summer compared to the fall, winter, and early spring months (fig 3b).
- CO_2 fluxes were higher in the spring months compared to summer and winter months (fig 3c).

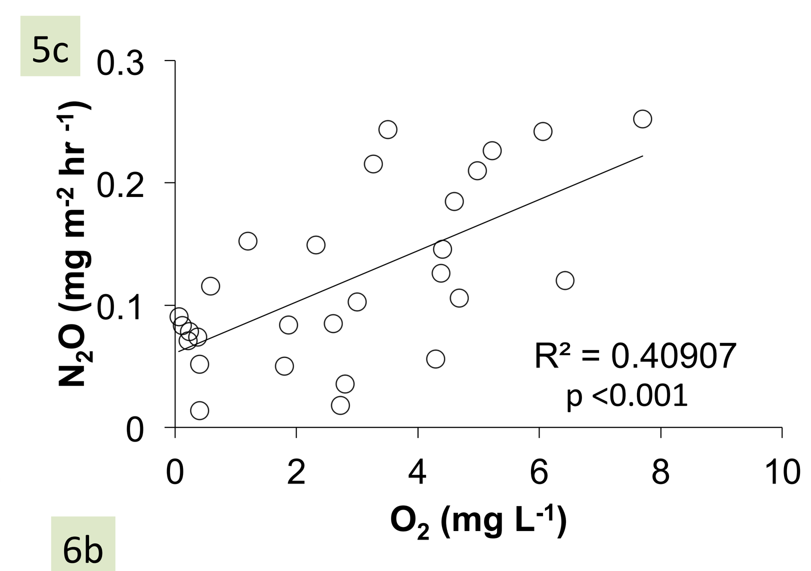
Aquatic Environmental Factors

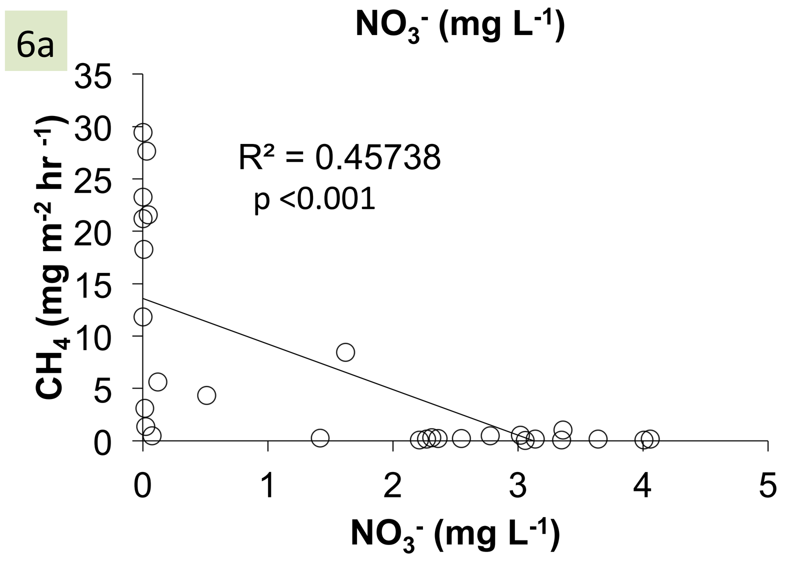
- The **nitrate (NO_3^-), ammonium (NH_4^+), water temperature (°C) and oxygen (O_2)** were different between the open-water and shoreline subsites on both transects (all p <0.0001).
- However, these were not significantly different between the inlet and the outlet transect across the CWS.
- Water temperature showed some **seasonal differences** between: July-January (p = 0.03); July-March 2012 (p=0.01); March 2012-September (p=0.04).

Potential Factors Controlling Fluxes

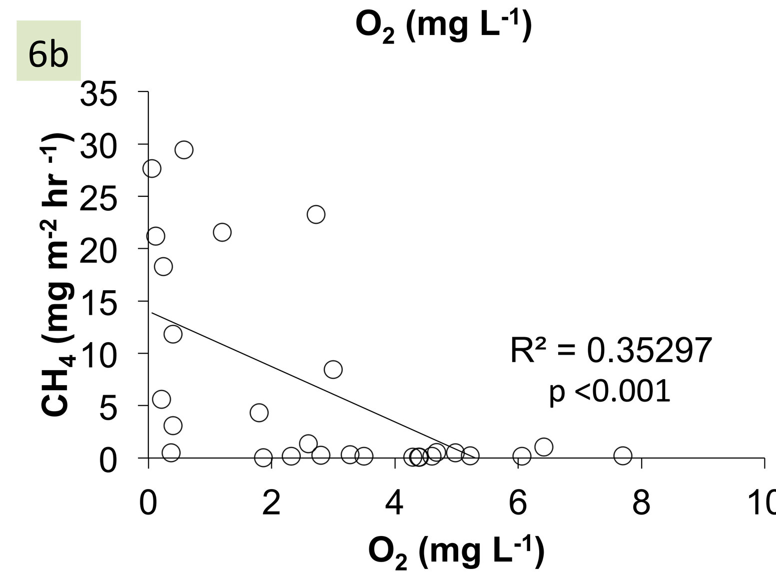








- **N_2O** fluxes were significantly correlated with **NO_3^-, NH_4^+** (not shown), **water temperature,** and **O_2** (fig 5a-5c).
- **CH_4** fluxes were significantly correlated with **NO_3^-, NH_4^+** (not shown), and **O_2** (fig 6a-6b).
- **CO_2** fluxes were not significantly correlated with any of the four recorded environmental factors.



Conclusions

Table 1. Averaged annual fluxes of greenhouse gases emitted from the Tres Rios CWS between March 2012 and March 2013 (mean±std.dev.) and extrapolated annual fluxes for the entire Tres Rios CWS.

	N_2O (mg m^{-2} hr^{-1})	CH_4 (mg m^{-2} hr^{-1})	CO_2 (mg m^{-2} hr^{-1})
Inlet	0.13 ±0.09	6.91 ±14.43	134.72 ±84.45
Outlet	0.09 ±0.08	5.26 ±12.87	87.19 ±55.36
Shoreline	0.07 ±0.08	12.93 ±19.66	107.26 ±72.73
Vegetation	0.08 ±0.06	5.04 ±9.71	116.61 ±68.34
Open Water	0.17 ±0.09	0.28 ±0.37	108.82 ±83.77
Anual Flux (g m^{-2} yr^{-1})	**1.06**	**58.23**	**910.74**

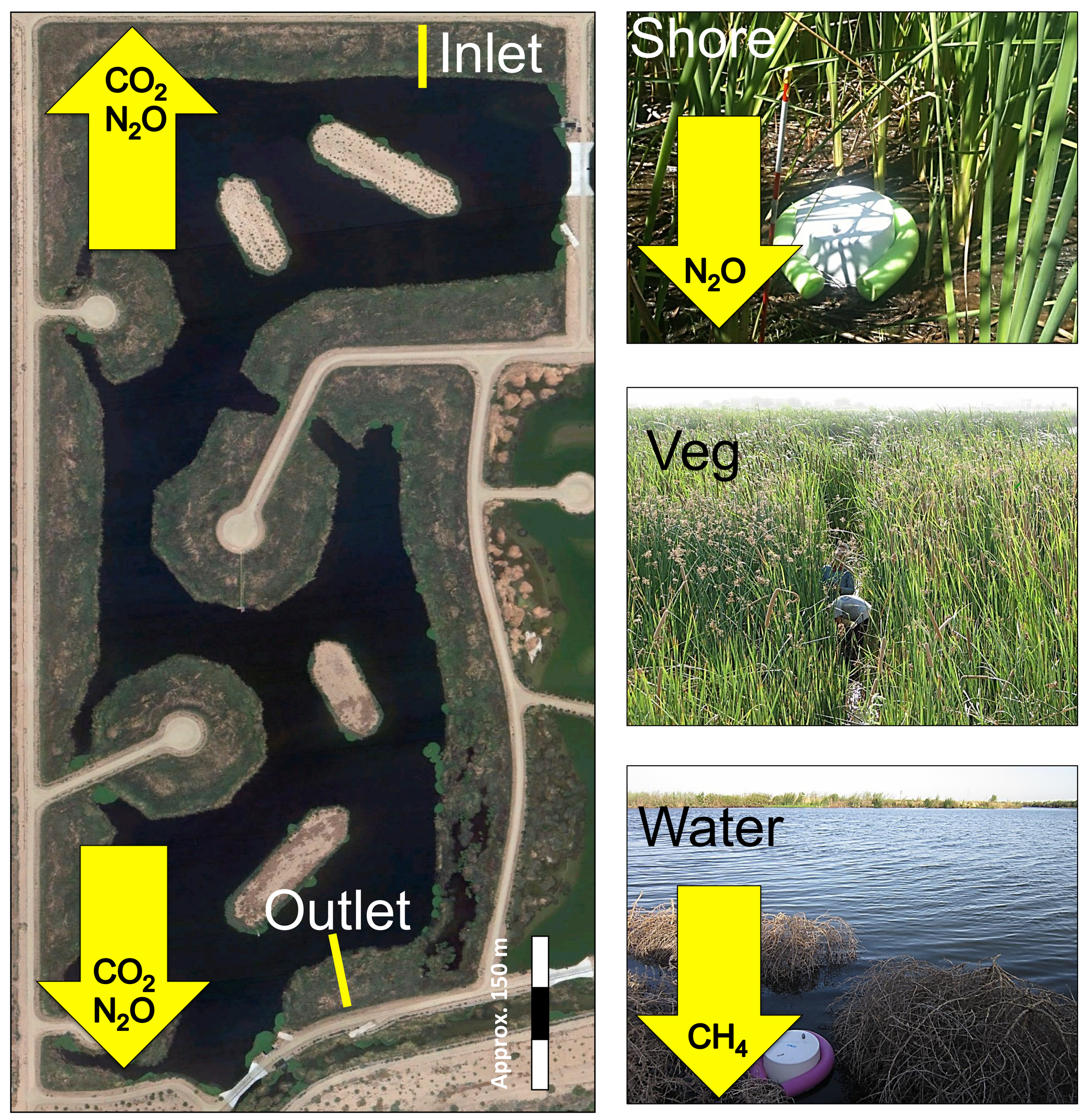


Figure 7. Left: Illustrations of Cell 1 showing the location of the Inlet and Outlet transects. Right: Images representing the subsites along the transects. The yellow arrows depict the significant spatial differences of specific gas fluxes at the whole-system and transect gradient.

Conclusions

- Lower N_2O fluxes may be explained by a combination of differences in the **water column height, hydrology** or higher **NO_3^-** levels in the open-water compared to the shoreline because of higher N uptake in the marsh area.
- We are **continuing** the sampling to acquire an extensive temporal resolution other data as well as planning to capture fluxes from the vegetation and soils.
- Due to the increased development of CW worldwide, it is important not just to study their **effectiveness** in purifying water but also the **design** factors and the environmental conditions that might promote fluxes of GHG.

Acknowledgments

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