The contribution of evapotranspiration and evaporation to the water budget of a treatment wetland in Phoenix, AZ, USA

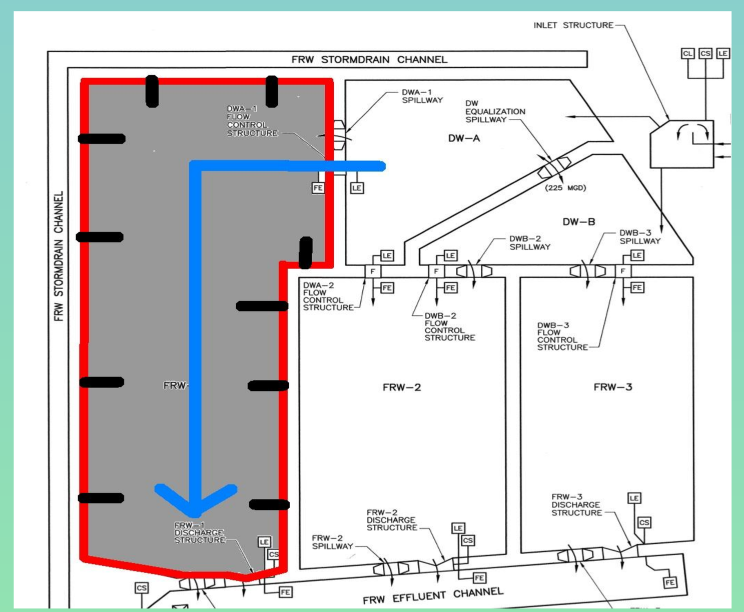
Christopher A. Sanchez[1,2], Daniel Childers[1], Laura Turnbull[1], Benjamin Warner[1], and Nicholas Weller[1]

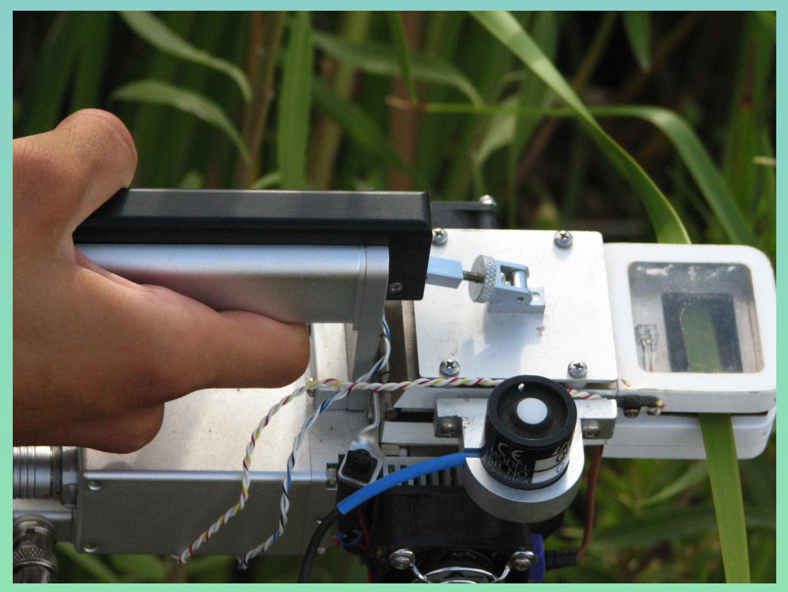
[1]Arizona State University School of Sustainability, [2]University of Miami

Abstract and Introduction

One of the most important aspects of any wetland is the water budget. Quantifying how evaporation and evapotranspiration contribute to water residence time is crucial to understanding the cycling of biogeochemically active and non-active solutes through the water column, plants and soils—particularly in arid climates. **We measured evapotranspiration and evaporation rates in a constructed treatment wetland in Phoenix during the summer, when both rates were at annual maxima and wastewater inflows were at an annual minimum**. *Our primary objectives were*: 1) to measure the rates of wetland evaporation and evapotranspiration bi-weekly using a handheld infrared gas analyzer, and; 2) calculate a whole-system summer water budget using these rates plus inflow and outflow data. *We hypothesized that*; 1) the summer water balance will lead to seasonal evapoconcentration of bioactive solutes and salts, and; 2) this will put substantial stress on the ability of wetland plants and soil microbes to perform the desired ecosystem services of nutrient uptake and transformation. These water flux data and summer water budget will contribute to our overall goal of quantifying the hydrology budget for the Tres Rios treatment wetland, and will improve our general knowledge of wetland water treatment capacity in dryland areas.

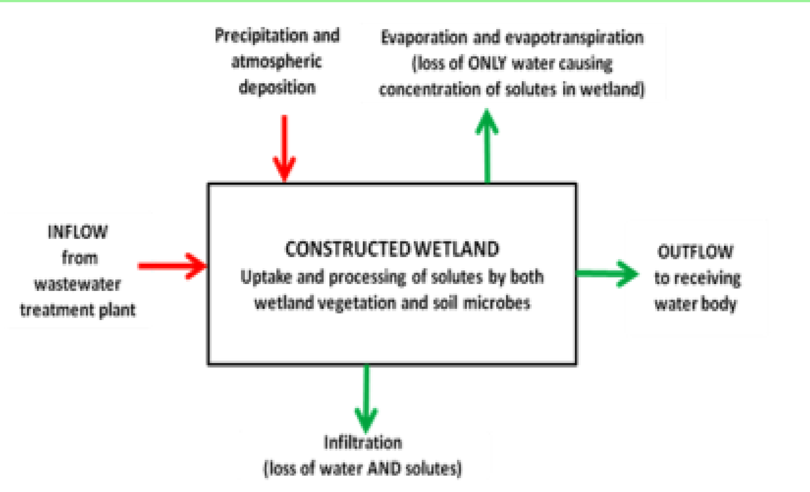
Experimental Design and Field Sampling





- 10 shore-to-open-water transects were distributed proportionally across flow cell based on the total area of vegetated subsections (vegetation bracketed by roads).
- We used a point-intercept transect method to randomly sample 5 quadrats per transect.
- In each quadrat we used a handheld infrared gas analyzer (IRGA) to sample upper and lower canopy leaves of each species present.
- Round or triangular stemmed Schoenoplectus macrophtyes required the use of a custom pliable leaf chamber extension to prevent the crushing of plant tissues by the IRGA sampling chamber.

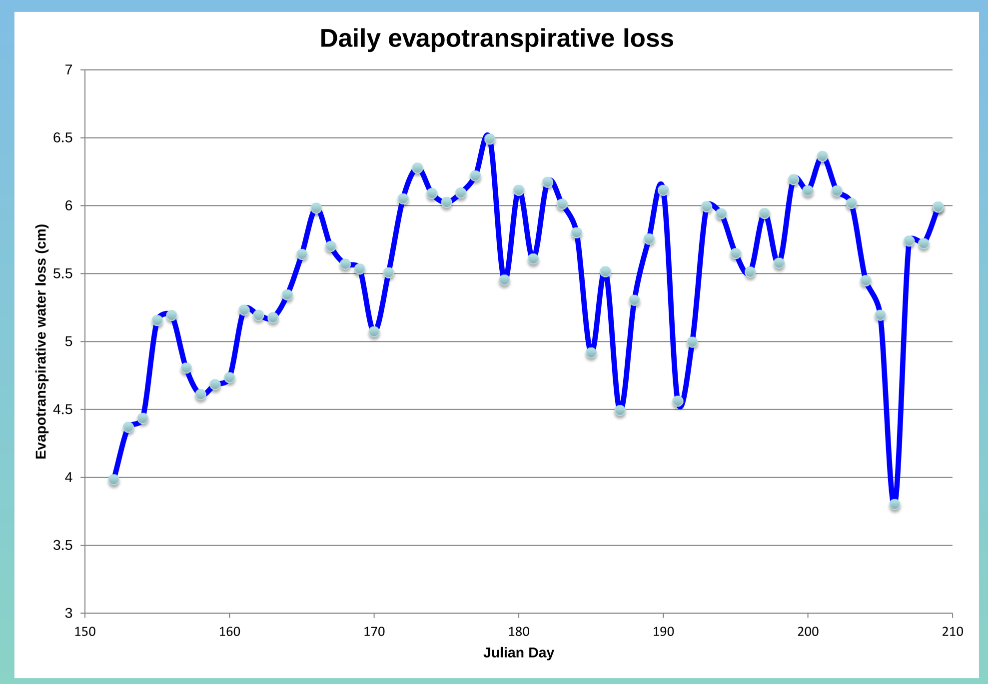
Water Budget Model Development

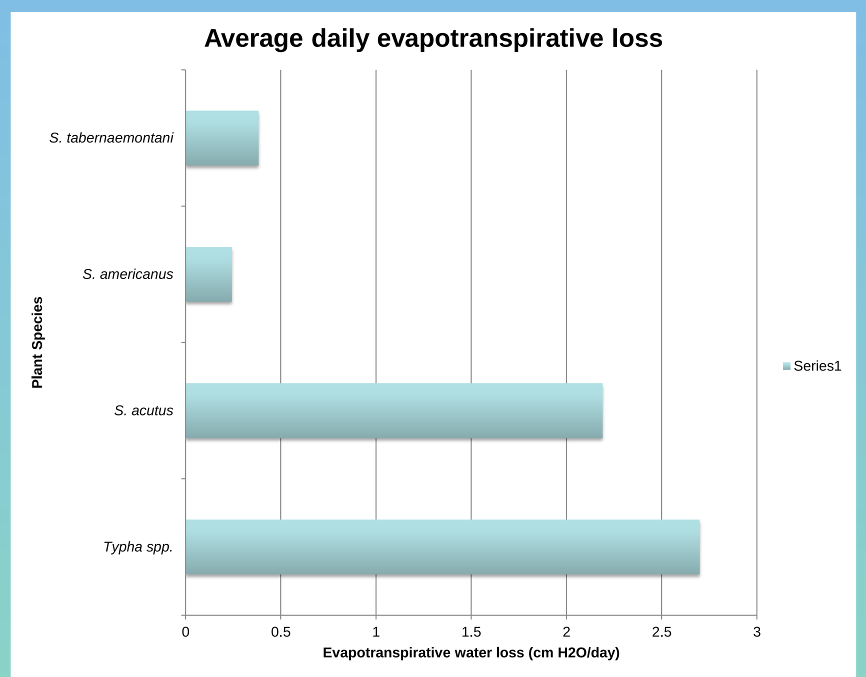


1. Species-specific IRGA measurements included evapotranspiration, air temperature, relative humidity, and solar radiation. Evapotranspiration (ET) is measured in mmol H_2O/m^2 of leaf area/sec.
2. In-chamber leaf area to biomass ratios were measured to transform raw IRGA ET measurements to mmol H_2O/gdw/sec
3. We used dimensional analysis to convert ET measurements to cm^3 H_2O/gdw/sec.
4. Multivariate regressions were generated to establish which climatic variables were statistically significant in determining ET for each species and to create models to predict ET from these variables.

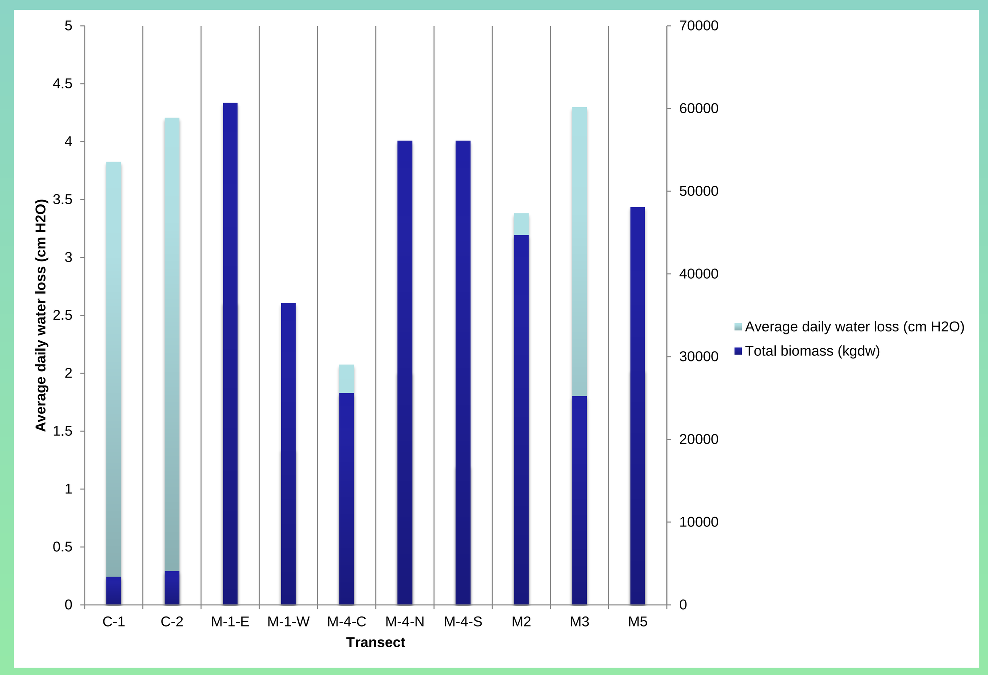
5. In order to use time-series weather data from a nearby station (Buckeye, from http://ag.arizona.edu/AZMET/), we regressed simultaneous solar radiation, air temperature, and relative humidity data to generate proximity correction factors. Using those, we applied hourly data from Buckeye to the multivariate models (#4) to produce time-series ET (in cm^3 H_2O/gdw/hr) estimates for June and July 2011.
6. We then scaled these ET estimates for each species using species-specific biomass (gdw/m^2) per transect to yield hourly ET loss per transect per hour.
7. We averaged hourly ET readings across the 10 transects and summed averages to yield daily ET rates (cm^3 H_2O/m^2/day) for the entire wetland system.
8. Finally, we used dimensional analysis to convert ET measurements to cm H_2O/day across the entire system.

Results





Site	Inflow Conductivity	Outflow Conductivity	Inflow Temperature	Outflow Temperature
Whole System	1960	1932	30.7	30.6
M-1-E	1758	2092	29.7	24.6
M-1-W	1757	2125	29.4	24.5
M-2	1740	2532	29.9	25.1
M-3	1753	1900	30.1	24.5
M-4-N	1766	1782	31.5	24.6
M-4-C	1747	1774	30.7	25.8
M-4-S	1752	1766	30.2	26.3
M-5	1755	2121	31.4	27.1
C-1	1750	2185	30.3	24.9
C-2	1736	1829	29.9	24.7



- *Typha spp.* had the highest ET rate of all macrophytes present, as well as the highest average daily ET loss and the greatest biomass across the wetland.
- We observed that bioactive solute and salt concentrations, as measured by specific conductivity, increased in each transect along a gradient from inflow (open water) to outflow (shore).
- Average daily ET loss was much higher than open water evaporative losses measured with evaporation pans. Evaporation pans measured a loss of approximately 1.7 cm per day, whereas average daily ET loss was 5.5 cm per day.
- Plant biomass increases along a gradient from system inflow to outflow.

Discussion and Conclusions

- Tres Rios, an arid wetland system, evapotranspires considerably more water than mesic wetlands, as predicted. Pauliukonis and Schneider (2001)[1] reported average ET rates for *T. latifolia* of .575 cm/day in a wetland in the northeastern United States, while Koch et al. (1993)[2] reported average ET rates for *T. domingensis* of approx. 1.08 cm/day in the Florida Everglades. These values are far below the ET rates of *T. latifolia* and *T. domingensis (Typha spp.)* in the Tres rios system. In addition, Jacobs et al. (2002)[3] report a maximum system-wide ET loss in June in Prairie Preserve, FL, of .618 cm/day, far below the minimum Tres Rios system-wide ET loss in June.
- Solute concentration gradients within transects indicate that the wetland plants are greatly evapoconcentrating bioactive solutes and salts due to high plant ET and water evaporation rates, as expected.
- The observed inflow/outflow biomass gradient indicates that wetland plants are providing their ecosystem service of uptaking and transforming nutrients present in influent (biomass accumulation is inversely related to nutrient concentration).
- We observed wetlands plants growing continuously over the period of IRGA sampling. Primary growth accumulated so rapidly that much of it fell over, with secondary regrowth already beginning. This serves as a preliminary indicator that the plants are maintaining their ability to grow and uptake/transform nutrients despite extremely large evaporative losses.

Acknowledgements

We would like to thank the City of Phoenix for their cooperation and assistance with our research at the Tres Rios Wastewater Treatment Facility. We would also like to thank…

1. Pauliukonis and Schneider (2001). Temporal patterns in evapotranspiration from lysimeters with three common wetland plant species in the eastern United States. Aquat. Bot. 71, pp.35-46
2. Koch M. and Rawlik P. (1993). Transpiration and stomatal conductance of two wetland macrophytes (*Cladium jamaicense* and *Typha domingensis*) in the subtropical Everlades. Am. J. Bot. 80, pp.1146-1154
3. Jacobs et al. (2002). Evapotranspiration from a wet prairie wetland under drought conditions: Paynes Prairie Preserve, Florida, USA. Wetlands 22, pp. 374-385.