# Microbes, Nutrients, and Twitter: What We Have Learned from a WRRI Student Grant

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## What Are Floating Islands?

- Hydroponic plant growth systems that
  - **Improve water quality**
  - Enhance aquatic and terrestrial habitat
  - Regulate water temperature
  - Enhance aesthetics
  - Supply organic matter and dissolved $O_2$

Figure 1 (Source: Water Online)

- Floating islands are comprised of
  - Native wetland plants
  - Porous floating media

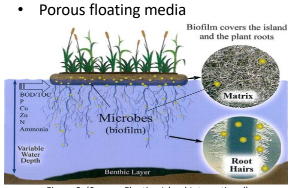



Figure 2 (Source: Floating Island International)

- Applications include
  - **Stormwater**
  - Swine lagoons
  - Aquaculture waste
  - Algal control
  - Erosion control

## Introduction

### How Do Floating Islands Improve Water Quality?

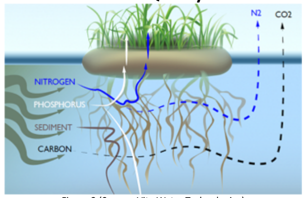



Figure 3 (Source: Vita Water Technologies)

- **Nitrogen (N)**
  - Denitrification
  - Plant uptake
  - Microbial assimilation
  - Algae uptake + sedimentation
- **Phosphorus (P)**
  - Sedimentation of adsorbed P
  - Plant uptake
  - Microbial assimilation
  - Algae uptake + sedimentation
- **Sediment**
  - Filtration + sedimentation by obstruction from mat and suspended roots
  - Humic complexing + flocculation
  - Biofilm sorption + entrapment + sloughing
- Carbon (C)
  - Microbial assimilation
  - Microbial respiration
- Metals (Cu + Zn)
  - Precipitation/complexation/flocculation
  - Plant uptake
  - Biofilm sorption + entrapment + sloughing

## How much coverage is enough?

Incremental Pollutant Removal Rates for FTW Pond Retrofits

| Pollutant | Raft Coverage in Pond | | | | |
|---|---|---|---|---|---|
| | 10% | 20% | 30% | 40% | 50% |
| TN | 0.8% | 1.7% | 2.5% | 3.3% | 4.1% |
| TP | 1.6% | 3.3% | 4.9% | 6.5% | 8.0% |
| TSS | 2.3% | 4.7% | 7.0% | 9.2% | 11.5% |

Table 1

- Wang and Sample (2013) conducted meta-analysis of 12 mesocosm-scale studies to determine pollutant removal rates (Table 1)

Previous Study of Floating Islands in NC

| Coverage | 9% Coverage | | | 18% Coverage | | |
|---|---|---|---|---|---|---|
| Pollutant | TN | TP | TSS | TN | TP | TSS |
| Pre-Retrofit Mean Conc. Reductions (%) | 36 | 36 | 92 | 59 | 57 | 89 |
| Post-Retrofit Mean Conc. Reductions (%) | 48 | 39 | 78 | 88 | 88 | 95 |

Table 2

- In Winston et al. (2013), field-scale study in North Carolina's Piedmont was conducted and significant mean concentration reductions of TN, TP, and TSS were significant, but influent concentrations varied between pre- and post-retrofit periods (Table 2).
- In North Carolina, >5% coverage with floating islands receives BMP credits for
  - TN: 30% lower EMC
  - TP: 40% lower EMC

### Research Objectives

- Quantify treatment improvement of a stormwater wet pond with a floating island retrofit
- Determine areal mass removal rates of nitrogen and phosphorus for design specifications and nutrient crediting
- Characterize microbial community structure in a floating island system to better understand treatment mechanisms and capabilities
- Investigate spatial variations in microbial communities in floating island systems
- Compile available literature and design guidelines for state water quality planners and stormwater managers

## Methods

### Mesocosm-Scale Study

- Vegetated floating islands and unvegetated floating islands were placed in individual mesocosms in a greenhouse. Mesocosms were filled with enriched water from a local stormwater/irrigation pond (Figures 4 & 5).
- Turbidity and concentrations of $NO_3^-$ and DOC were measured with a field spectrophotometer in each mesocosm at a high temporal resolution.
- One mesocosm trial was conducted in Fall 2017 and two additional trials with be conducted in Summer 2018.

Figure 4

Figure 5

### Microbial Community Analyses

- Solution pipetted from floating island mats, root wash from composite root sample (3 species), and surface sediments were collected weekly.
- Grab samples and sediment samples were also collected weekly for chemical analyses.
- FAME (fatty acid methyl ester) analysis (Agilent 780B Gas Chromatography system) was utilized to detect fatty acids from living and dead cells and identify organism type based on certain fatty acids that are specific to cell membranes of certain organisms (Table 3).

| Fatty Acid | Organism Type | Fatty Acid | Organism Type |
|---|---|---|---|
| i13:0 3OH | Bacteria (Gram -) | cy19:0 | Bacteria (Gram -) |
| i15:0 | Bacteria (Gram +) | 20:0 | Bacteria (cyanobacteria) |
| a15:0 | Bacteria (Gram +) | 16:0 | Fungi |
| i17:0 | Bacteria (Gram +) | 16:1ω5 | Fungi (AMF) |
| a17:0 | Bacteria (Gram +) | 18:1ω9 | Fungi |
| cy17:0 | Bacteria (Gram -) | 18:2ω6 | Fungi |
| i17:0 3OH | Bacteria (Gram -) | 18:3ω6 | Fungi |
| 17:1ω6 | Bacteria | 10Me 16:0 | Actinomycetes |
| 18:1ω5 | Bacteria | 10Me 17:0 | Actinomycetes |
| i19:0 | Bacteria | 10Me 18:0 | Actinomycetes |
| a19:0 | Bacteria | 20:4ω6 | Protozoa |

Table 3

## Methods

### Field-Scale Study

- Field site is located in stormwater wet pond (9000 ft²) on NC State's west campus near Wolf Village apartments
- Pond was split with impermeable barrier into Tx and control sections (~2500 ft²/side) (Figure 6)
- Tx side has 14 4'X8' islands that were grown for >18 months prior to installation in a baffle formation of 3 rows

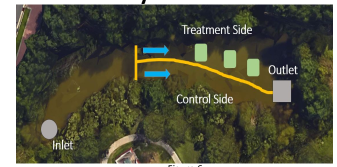



Figure 6


Figure 7

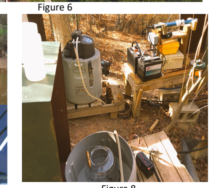


Figure 8

- Weirs evenly divide flow at inlet of Tx and control sections
- Riser outlets for each section are split (Figure 7)
- 1 automated sampler collects flow-weighted samples during events at the inlet of the pond
- Each split outlet has an automated sampler that collects flow-weighted samples during events (Figures 8)
- Field spectrophotometer is used for continuous, multi-point sampling during and between events in Tx and control sections (Figure 9)
  - Sampling at 10-minute resolution for $NO_3^-$ and turbidity
  - 2 points near the outlet in each section (Figure 10)
- Grab samples that are collected immediately after and between events and flow-weighted sampling from inlet and outlets during events undergo
  - Laboratory analysis for calibration of spectrophotometer for $NO_3^-$ and TSS (based on turbidity)
  - Additional laboratory analysis for TN and TP

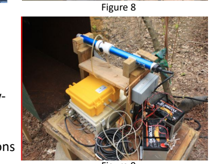


Figure 9

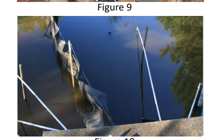


Figure 10

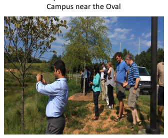
## Outreach

High School juniors and seniors plant floating islands with native wetland plants

Graduate students install a divider between treatment and control sections of the field-site

Graduate students rest after a long day of volunteering to set-up the field study

High school students place an island into a stormwater pond on NC State's Centennial Campus near the Oval



Faculty members from throughout the country tour a site during a conference

### North Carolina

- Site Tours for Regional Stormwater Teams
- Community Volunteers
- Regional Conference Presentations

### NC State University

- Demonstration Site
- On-Campus Research Sites
- Campus Press Features
- Undergraduate Researchers
- Student Volunteers

### United States

- Tours for Faculty and Conferences
- Twitter
- National Conference Presentations
- Engineering Summer Camps

### Why Twitter?


- Concisely disseminate current research Provide digestible updates on our research and outreach
- Promote understanding of floating islands and their benefits
- Tell the story of our team
- Show what researchers/engineers really look like

**Follow Us**


**Tweet**

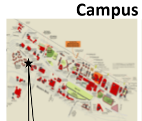
@ncstate_FIs

#floatlife

#floatingislands

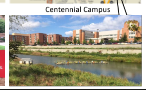
#teamfloatingislands

### Campus Presence



Main Campus

Centennial Campus



Faculty from around the country watch a demonstration of the floating island sampling system

Representatives from the City of Raleigh's Stormwater Department listen to a presentation on studying nutrient uptake

A local Boy Scout earns a badge by installing goose netting

Undergraduates run mesocosm experiments with an undergraduate research grant

High school students leave their mark on goose nets for floating islands

## Preliminary Results

### Field-Scale Study

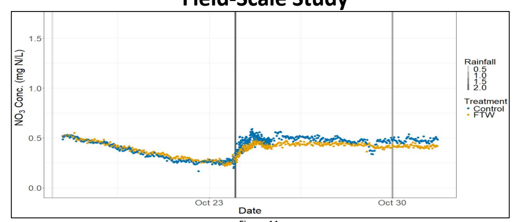



Figure 11

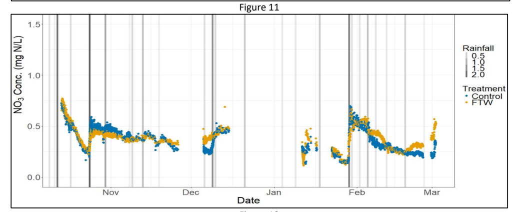



Figure 12

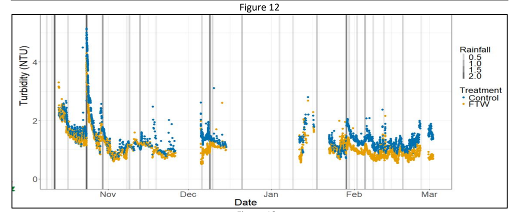



Figure 13

- In October, $NO_3^-$ concentrations were slightly lower in the Tx section between events (Figure 11)
- After October, $NO_3^-$ concentrations were not consistently higher in either section (Figure 12)
- Reductions in $NO_3^-$ concentration on Tx side do not reflect NC BMP credit, but monitoring has only occurred during dormant season so far (lower plant uptake and microbial activity)
- Turbidity is consistently higher in the control section (Figure 13)

## Preliminary Results

### Microbial Community Analyses

- Presence of a distinct cluster for each sampling location suggests unique community structures (Figure 16)
- Sediment appears to provide the most conducive environment for biomarkers of bacteria (except for 17:1ω6 and i19:0), fungi, and actinomycetes (Figures 14, 17, 18)
- Root environment provides a unique source of nutrition and/or habitat that supports protozoa communities (Figure 15)
- Root zone and mat samples tended to exhibit more variability than sediment samples
  - Dynamic communities and environments
  - Shorter establishment period
- Fungal biomarkers were observed in all locations and in substantial concentrations, indicating potential for floating islands to degrade a variety of organic compounds, such as PAHs, EDCs, and pesticides
- Correlations between shifts in sediment biomarkers and water quality parameters suggest significant exchange at sediment-water interface
- Sulfate-reducing bacteria (17:1ω6) were observed in all three locations, especially in mats, suggesting potential for floating islands to treat sulfate, other oxidized forms of sulfur, and hydrocarbons

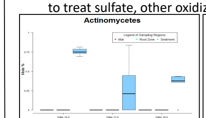



Figure 14

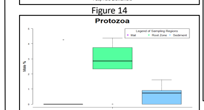



Figure 15

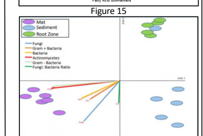


Figure 16

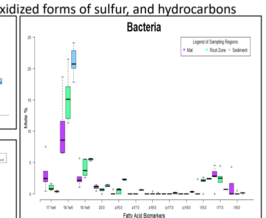



Figure 17

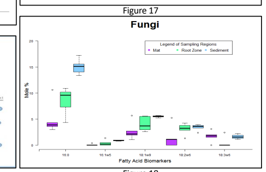



Figure 18