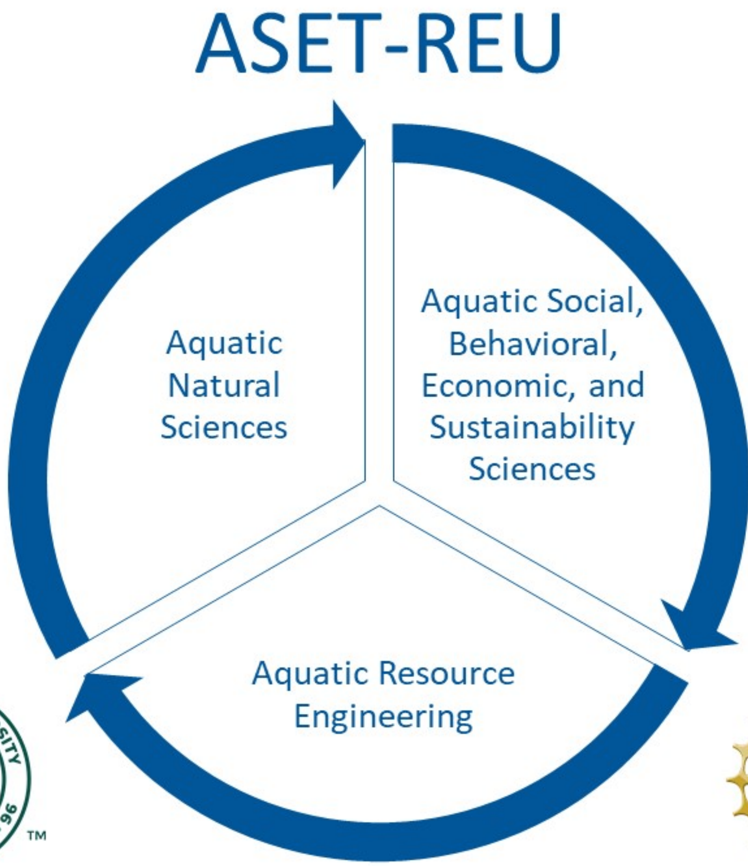
2021

ASET REU Poster Symposium



11:00 am - 12:00 pm

Thursday, 5 August 2021

Adirondack Lodge

Clarkson University

Potsdam, New York

Contents

SCHEDULE OF EVENTS

Time	Location	Activity and Invitees
10:00 am	Adirondack Lodge	Poster Set-up (Scholars Only)
11:00 am	Adirondack Lodge	Poster Presentation (Scholars, Mentors, Campus Community, and General Public)
12:00 pm	Adirondack Lodge	Lunch Reception (Scholars, Mentors, Campus Community, and General Public)
12:59 pm	Adirondack Lodge	Lunch Reception Ends – Scholars to debriefing (Snell B10L)

ACKNOWLEDGEMENTS

We thank

- Vicki Wilson and Diana Richardson of the Biology Department for their administrative assistance to ASET REU staff,
- the Environmental Health and Safety Office (Erica Arnold) and Chief Inclusion Office (Dr. Jen Ball and Bria Cole) for providing onboarding seminars,
- the Residence Life Office for housing assistance,
- the CUPO Office for proving a poster printing,
- to the faculty and staff mentors for providing research and personal support for the ASET Scholars,
- Herbert Fountain for serving as the scholar liaison/undergraduate ASET program assistant,
- Jeffery Taylor for providing COVID protocol assistance and connections with the Outdoor Club,
- Phillip White-Cree for providing an “Indigenous History of the St. Lawrence River” seminar and for helping facilitate our partnership with the St. Regis Mohawk tribe,
- the Rourke family in Akwesasne / Hogansburg for access to the St. Lawrence River via their property,
- Asher Pacht for providing a tour of Beacon Institute for Rivers and Estuaries,
- for the administrative assistants in the Biology, the Civil and Environmental Engineering, and the Chemical and Biomolecular Engineering departments for providing assistance to the ASET Scholars,
- to the Chief Inclusion Office and the Provost Office for financially supporting two of our ASET scholars,
- the National Science Foundation for providing funding via award number 20-508484 to PI’s Alan D. Christian and Andrew David.

SCHOLARS AND FACULTY MENTORS

ASET Scholar	ASET Scholar Home Institution	ASET Faculty Mentor
Falkenstein, Anna	Univ. of Science and Arts of Oklahoma	Alan Christian
Freeman, Sammi	Clarkson University	Michelle Crimi
Fuentes, Lauren	University of Puerto Rico: Mayaguez	Abul Baki
Jordan, Jennifer	University of South Florida	Lisa Podlaha-Murphy
Luan, Kiet	University of Texas Austin	Lisa Podlaha-Murphy
Montgomery, Ian	Saint Michael's College	Abul Baki
Orellana, Natasha	Vassar College	Alan Christian
Phelix, Morgan	Rensselaer Polytechnic Institute	Taeyoung Kim
Ross, Kate	University of Texas Austin	Thomas Holsen
Saunders, Jatea	Berea College	Susan Bailey
Tjandra, Davin	North Carolina State University	Yang Yang

ABSTRACTS

(Alphabetical Order of Scholars)

Falkenstein

Mesohabitat Scale Simple and Complex Ecohydraulic Conditions Associated with Freshwater Mussels in Low Flow Conditions at a Headwater Stream

Antoinette Falkenstein[1,2], Natasha Orellana[2,3], and Alan Christian[2]

University of Science and Arts of Oklahoma Chickasha, Oklahoma, USA, [2]Clarkson University Potsdam, New York, USA, [3]Vassar College Poughkeepsie, New York, USA

While freshwater mussels are important contributors to community and ecosystem dynamics and provide ecosystem goods and services, freshwater mussels are considered one of the most endangered freshwater groups in the world. Ecohydraulic requirements and constraints at the mesohabitat scale (e.g. riffle, runs, pools, glides) are an area of study that may provide insight into factors influencing freshwater mussel distribution and abundance. The objective of this study was to assess simple and complex ecohydraulic requirements of mussels at different mesohabitats during summer low flow conditions using a case-study approach at Grannis Brook, New York. We hypothesized that there would be differences in simple and complex ecohydraulic variables among different mesohabitats and that freshwater mussels will be found in mesohabitats with low relative shear stress (RSS), medium spatial variation of RSS, and little substrate movement. Our Grannis Brook study reach (~110 m) is located at a third order stream reach with a 31.3 km watershed located in the Eastern Great Lakes Lowlands ecoregion. We used the Basin Area Stream Survey to identify seven mesohabitats in the study reach and we inventoried geomorphological features, substrate, instream cover, and riparian cover at randomly selected perpendicular to flow transects in each mesohabitat. Along each transect, we sampled for mussels from 1 m^2 quadrats and measured depth, velocity, substrate type and calculated complex ecohydraulic variables. We will present our findings of ecohydraulic variables among mesohabitats, if we found a relation between mussel density and ecohydraulic variables, and how our findings relate to similar studies. In the future, we plan to collect data at medium and high flow year-round in different seasons to compare the ecohydraulic data and calculations and have a better understanding of flows effect on ecohydraulic variables on freshwater mussel abundance and distribution.

Freeman

Desorption of PFAS from IDW Solids by Soil Washing with Oxalic Acid

Samantha Freeman[1], Michelle Crimi[2], and Juby Varghese[1]

[1]Institute for a Sustainable Environment, [2]Civil and Environmental Engineering, Clarkson University, Potsdam, NY, USA

Per- and polyfluoroalkyl substances (PFAS) have been utilized for both commercial and industrial applications since the 1950's, posing a large threat to ecosystems and human health due to their distinct properties such as high environmental persistence, biomagnification, and high toxicity. Due to widespread use of these compounds in aqueous firefighting foams (AFFF), PFAS has accumulated in soils and groundwater, and can be found in investigation derived waste (IDW) generated from firefighting training sites. This study focused on the removal of 30 PFAS molecules including precursors, short-chains, and long-chains from IDW solids using a soil washing technique that incorporated oxalic acid. Oxalic acid solutions were prepared with and without pH adjustment to neutral pH for the following concentrations of oxalic acid: 0 mM, 2 mM, 4 mM, and 20 mM. Samples from two sites were tumbled end-over-end, in triplicate, for either 72-hour washes or for three consecutive 24-hour washes to determine the efficacy of oxalic acid in removing PFAS at various durations as well as the duration of time required to remove PFAS. PFAS concentrations for each wash scenario was determined using liquid chromatography–mass spectrometry (LC-MS). Oxalic acid solutions (2-20mM) with neutral pH increased the PFAS desorption, with a range of 17.55 - 343.90 %, which indicates that electrostatic interactions may influence the desorption of anionic PFAS from the IDW solids. The pH adjusted solutions may have removed more PFAS than distilled water due to oxalate-metal complexation with metals present in the IDW solids, which detaches the negatively charged head of PFAS from the oxalate-metal complex through electrostatic repulsion. Three consecutive 24-hour washes combined removed more PFAS than 72-hour washes which indicates that short wash durations may be effective in removing more PFAS than extended washes. The two sites displayed different PFAS removal behaviors based on concentrations, and one concentration of oxalic acid could not be determined as effective for precursors, short-chains, and long-chains. Therefore, it is recommended that a sequential wash scenario be applied where one concentration is used to target one class of PFAS followed by additional concentrations to remove residual PFAS classes. Overall, these results demonstrate that soil washing with neutral pH oxalic acid solutions for three consecutive 24-hour washes is an effective method to remove PFAS contaminants from IDW solids which will open-up new avenues of PFAS remediation efforts of IDW solids as well as other contaminated soils and sediments.

Fuentes Velázquez

Physical Transport and Retention Properties of Microplastics in a Vegetated Channel

Lauren D. Fuentes Velázquez[1,2], Ryan Pierce[2], Usama Butt[2], and Dr. Abul B. M. Baki[2]

[1]Department of Chemical Engineering, University of Puerto Rico, Mayagüez, PR
[2]Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY, USA

Microplastics (MP) are polluting plastic particles that range from 1-5 mm in size, that are primarily sourced from industrial pellet production or secondarily sourced from the physical, biological or chemical fragmentation of bigger plastic waste. High levels of plastic production and waste have caused an alarming availability of MP in waterways. The abundance of MP particles in marine and riverine environments presents a risk to aquatic ecosystems, species and food webs, and therefore a threat to human food safety. Therefore, it is important to understand the dynamics of MP in the riverine systems. This study experimentally investigates the transport and retention patterns of MP particles in a vegetated channel. A total of six experimental scenarios, with/without vegetation under high and low flow events, were conducted in the ecohydraulics flume to examine the transport and retention of MP. For vegetation scenarios, plastic aquarium plants were attached to the flume bed with a 7% and 10% vegetation density in the observation area. An acoustic Doppler velocimeter (ADV) was utilized to measure the flow hydraulics in the observation area. This study proposed relationships between MP transport/retention and flow hydraulics, as well as new experimental data for future development of MP dispersion and retention models.

Jordan

Enhanced Degradation of Methylene Blue with Layered Ni-Fe/WO_3 Nanostructure Composite Films Electrodeposited onto Graphite

Jennifer A. Jordan[1,2], Arash Bahrololoomi[3], and Elisabeth J. Podlaha-Murphy[2]

University of South Florida, Tampa, FL, USA, [2]Department of Chemical and Biomolecular Engineering, Clarkson University, Potsdam, NY, USA, [3]The Center for Advanced Materials Processing, Clarkson University, Potsdam, NY, USA.

Pollution from textile companies stain water bodies, inhibiting aquatic photosynthesis and lowering oxygen levels. Teratogenic, carcinogenic, and mutagenic dye pollutants harm fish populations and further lower aquatic health. In order to cost-effectively treat dye contamination, this study investigates the efficiency and stability of a composite photoelectrocatalyst composed of tungsten trioxide, nickel-iron, and graphite for decolorization and decontamination of polluted waters using methylene blue (MB) as a model dye. To prepare the composite catalyst, Ni-Fe clusters and WO_3 thin films were electrochemically deposited onto a graphite surface using recurrent galvanic pulses and potentiostatic techniques respectively. Cyclic voltammetry (CV) using an electrolyte containing 10 μM MB in 10 mM phosphate buffer saline and 100 mM potassium chloride at room temperature on screen-printed electrodes identified the region where the Ni-Fe/WO3 graphite composite catalyst resulted in a large anodic current 1.9-2 V, which included the oxidation of water, chlorine, and organic. Electrolysis by chronoamperometry (CA) was implemented with and without light, in a single compartment electrochemical cell. The color change was measured using absorbance spectrophotometry. Carbon oxygen demand (COD) measurements confirm oxidation of total organic and provide insight color change due to decomposition of MB at the working electrode or conversion to leucomethylene blue at the counter electrode. As Ni-Fe can oxidize under electrolysis conditions applied for MB degradation, inspection by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used to observe the stability of the composite catalyst. Overall, with an increase in the electrolysis time there was a clear change in the electrolyte color. After 2 hours, the coloration of the MB solution dropped by 78% and after 16 hours, 89%. COD analysis indicated that degradation of methylene blue by the Ni-Fe/WO_3 graphite catalyst was enhanced by 100 W/m^2 UV light with similar amounts of methylene blue but with a 19% drop in organic material, indicating less conversion of methylene blue to leucomethylene blue and an overall more efficient degradation. The SEM and EDS images showed that WO3 adhered well to the carbon for at least 4 hours of CA, but broke down gradually over 16 hours through detachment from graphite surface. Accordingly, Ni-Fe was detectable after 4 hours but undetectable at 16 hours.

Luan

Electrodeposition of Cu-Fe and Cu-Fe-TiO_2 Electrocatalysts for Nitrate Reduction

Kiet Luan[1-2], Cheng Wang[2], and Elizabeth Podlaha-Murphy[2]

[1]Department of Physics and Mathematics, The University of Texas at Austin, Austin, TX, USA and [2]Department of Chemical and Biomolecular Engineering, Clarkson University, Potsdam, NY, USA

Nitrate (NO_3^-) is one of the most common contaminants found in groundwater. The contaminant infiltrates subterranean water from wastewater systems, agriculture, and other human activities. NO_3^- is reduced into nitrite (NO_2^-), a toxic compound within the human body. Exposure to nitrite can lead to methemoglobinemia (blue-baby syndrome) and long-term exposure to even low-levels have been linked to increased rates of cancer thus rendering the consumption of groundwater undesirable. Current solutions to denitrify groundwater through biological methods, ion exchange, and catalytic treatment have unique drawbacks. Electrocatalytic reduction presents an alternative to these prompting studies into more cost-effective catalysts for nitrate reduction. Herein, we electrodeposited copper (Cu) and iron (Fe) coupled with titania (TiO_2) on to a nickel (Ni) electrode (Fe-Cu-TiO_2/Ni) to reduce NO_3^- to nitrogen gas (N_2) or ammonia (NH_3). The electrocatalyst was prepared from a solution containing iron (III) sulfate ($Fe_2(SO_4)_3$) with copper sulfate ($CuSO_4$) onto a rotating cylinder electrode utilizing a galvanic square wave for 300 cycles with current density of 50 mA/cm^2 for 1s and 0 mA for 1s. The composition of the deposits were determined using x-ray fluorescence spectroscopy (XRF) and the morphology was inspected with scanning electron microscopy (SEM). Following electrodeposition, nitrate reduction was carried out in a single compartment cell with a platinum counter electrode and a saturated calomel reference electrode (SCE). The concentration of nitrogen containing species were determined spectrophotometrically. During the electrocatalytic reduction of nitrate at a constant potential of -1V vs SCE, Fe-Cu/Ni had a higher reduction of NO_3^- to NO_2^- compared to Fe/Ni and Cu electrodes. It was also found that Fe-Cu/Ni is more selective towards NH_3 producing little to no N_2. Nitrate reduction experiments on Fe-Cu-TiO_2/Ni are compared to the electrocatalysts without TiO_2.

Montgomery

Flow Hydrodynamic Requirements for Freshwater Mussels

Ian Montgomery[1,2], Abul Baki[2], Andrew Tota[2], and Amir Golpira[2]

[1]Saint Michael's College, Burlington, VT, USA and [2]Clarkson University, Potsdam, NY, USA

Freshwater mussel's increased vulnerability presents dangers to the ecosystems that rely on them for filtration and nutrient benefits. In an attempt to understand the optimal flow field for freshwater mussels, specifically the Elliptio Complanata, we used scale models to recreate riverine characteristics in an open channel flume. Measurements of mesohabitats from Grannis Brooke, a nearby field site, were analyzed and simulated to investigate flow hydrodynamics and morphology in mussel habitat. Within each mesohabitat, velocity profiles were measured, as well as near-bed mean and turbulent flow fields, which were recorded in the vicinity of mussels. We replicated a riffle, run, pool, and glide sequence in the flume where mussels were observed within these different mesohabitats. The model couples streamflow velocities, substrate profiling, and depth profiling in order to test our hypothesis that mussels experience forces and bed shear stress great enough to dislodge them from their channel bed. We expect mussels to experience different forces in different mesohabitats, elevating bed shear stress levels in mussel beds from flow rate changes. In addition, we will examine the possible relationship between mussel density and flow field in each mesohabitat. This model can be used for future studies investigating mussel declination from amplified climate change impacts and habitat fragmentation as well as flow characteristics on mussel habitat suitability.

Orellana

Freshwater Mussel Demographics and Microbial and Parasitic Biomes: A Mussel "Health" Case Study of Grannis Brook

Natasha Orellana[1,2], Antoinette Falkenstein[2,3], Susan Bailey[2], Andrew David[2], and Alan Christian[2]

[1]Vassar College, Poughkeepsie, New York, USA, [2]Clarkson University, Biology Department, Potsdam, New York, USA, and [3]University of Science and Arts of Oklahoma, Chickasha, Oklahoma, USA

Freshwater mussels throughout the world are demonstrating declining in population size due to a variety of global change drivers. The aim of this study was to investigate several measures of mussel "health" including density, size frequency distribution, Fulton's condition factor, and microbial and parasitic biome associations and to assess if mussels in different mesohabitats (e.g. riffle, run, pool, glide) have different "health". We hypothesized that 1) there will not be differences in mussel density, size frequency distribution, condition factor, and protozoan and microbial biomes among mesohabitats, 2) that there will be a high microbial morphological diversity in mussel mantel and hemolymph samples indicative of "healthy" mussels, and 3) that there will be a low parasite count in mussel mantle tissues all indicating "healthy' mussels. Our case study was at a 110-meter reach of Grannis Brook near Crary Mills, New York, a third-order stream in the Eastern Great Lakes Lowland ecoregion. Mussels including *Elliptio complanata* were sampled from randomly selected transects established from seven predetermined mesohabitats (2 riffles, 2 runs, 2 mid channel pools, and 1 glide) with collections obtained along transects from either 1m^2 quadrads or haphazard collections across. Sampled mussels were identified to species, measured for length, width, depth, and wet weight, sampled for microbial biomes via mantle swabs and hemolymph extractions. Further, three individuals from each transect were transported to the lab, held in aerated aquariums pooled by mesohabitat, and observed and sampled for metazoan parasites. We statistically analyzed each "health" variable using a 1-way ANOVA. Correlation between the mussel demographics and microbial and parasitic biomes also will be investigated. We will report on the findings of our hypotheses with particular emphasis on the microbial and biome parasitic associations. DNA analysis and PCR of mantle tissue from five of 30 mussel samples found a single COI fragment which had a 100% genetic similarity to the trematode *Polylekithium ictaluri*. We anticipate our findings will add to the growing literature of mussel "health" and aid conservation and management of this imperiled fauna.

Phelix

Identifying System Design and Operating Parameters to Enable Energy-efficient Redox Flow Desalination of Brackish Water

Morgan Phelix[1,2,3], and Taeyoung Kim[2,3]

[1]Rensselaer Polytechnic Institute, Troy, NY, USA, [2]Department of Chemical and Biomolecular Engineering, Clarkson University, Potsdam, NY, USA, and [2]Institute for a Sustainable Environment, Clarkson University, Potsdam, NY, USA

Identifying a sustainable way to supply freshwater is vital for the future of mankind, especially considering our growing population, limited fossil fuels, and water pollution. While conventional thermal distillation and reverse osmosis are proven for seawater desalination, electrochemical approaches are well-suited to brackish water due to relatively low energy requirements for the salt concentration ranging from 1,000 and 10,000 mg/L. Redox flow desalination (RFD) is a recently developed electrochemical technique to separate salt through ion exchange membranes via a redox couple. Our research focused on identifying key design and operating parameters, including the feed channel thickness, freshwater productivity, and redox electrolyte composition/flow rate, to enable efficient water desalination. The experiment was conducted in a 4-channel flow cell divided by alternately arranged cation and anion exchange membranes, using 20 mM NaCl solution that was fed to the central channels. A redox electrolyte containing 2 mM ferri/ferrocyanide in 0.5 M NaCl was recirculated through the outer channels for continuous operation. The effluent concentration of the central channel streams (i.e., diluate and concentrate) and voltage profiles were monitored while applying constant current using a potentiostat. The feed channel thickness played a major role in reducing the energy consumption per unit freshwater volume from 26.2 (480 µm) to 11.9 (240 µm) Wh/m^3 for deceasing 20 to 15 mM NaCl due to largely to the solution resistance. Producing a large volume of freshwater per unit time and area (i.e., productivity) required more energy to drive the redox reaction, which was partly reduced by increasing the redox electrolyte concentration or recirculation flow rate due to the enhanced availability. Overall, these relationships would lead to the development of a low energy method for brackish water desalination, as a promising solution for sustainable water supply around the globe.

Ross

'Forever Chemical' No More: an Answer to the Nationwide PFAS Water Contamination Problem

Katherine C. Ross [1,2], Rui Li [2], and Thomas Holsen[2]

[1]Department of Civil, Architectural, and Environmental Engineering, University of Texas, Austin, TX, USA and [2]Center for Air and Aquatic Resources Engineering and Sciences, Clarkson University, Potsdam, NY, USA

Per- and polyfluoroalkyl substances (PFAS) are a class of anthropogenic chemicals which have a wide range of industrial and commercial applications. PFAS have been shown to be bioaccumulative and toxic and they are known as "forever chemicals" due to the strong carbon-fluorine bond. Plasma is an electrically conductive mixture of highly energetic radicals (OH radicals and aqueous electrons), which can efficiently degrade PFAS. Although a plasma reactor can completely degrade long-chain PFAS ($C \geq 6$) within minutes, it is significantly less effective for short-chain PFAS ($C<6$) due to the low plasma-liquid interface concentration. To address this problem, a cationic surfactant (cetrimonium bromide, CTAB) was added, which transports the short-chain PFAS to the interface through electrostatic interactions between CTAB and PFAS. Reverse osmosis (RO) is widely used to remove PFAS from contaminated water. However, this process produces RO reject which is highly conductive and contains high concentration of PFAS. In this study, RO reject (50 mS/cm) was treated in a plasma reactor for 6 h with CTAB dosed every 0.5 h starting at 1 h. Twelve PFAS were detected with concentrations ranging from 34 - 18000 ng/L. Long-chain PFAS were removed below the detection limit within 10 min. Short-chain PFAS were 28 -100 % degraded in 1 h with the exception of perfluorobutanoic acid (PFBA, C4). CTAB addition at 1 h significantly improved the degradation of short-chain PFAS. Ultrashort-chain-PFAS (C1-C3) were ~60% degraded within 6 h. The addition of CTAB inhibited long chain PFAS removal but promoted short and ultra-short chain removal. In highly conductive solutions, perfluorobutane sulfonate (PFBS, C4) removal by CTAB was enhanced by the salting out effect but PFBA and ultrashort-chain PFAS removal by CTAB was inhibited. Overall, the results indicate that plasma-based water treatment with addition of CTAB can be a viable approach for RO reject treatment.

Saunders

Experimental Tests of Food Supplementation Approaches in Biological Pest Control

Jatea Saunders[1] and Susan Bailey[2]

Berea College, Berea, KY, USA and Department of Biology, Clarkson University, Potsdam, NY, USA

Through direct and indirect effects, invasive species can cause the extinction of native plants and animals, degrade biodiversity, and permanently modify environments. Invasive species can have massive economic consequences as well as fundamental ecosystem disturbances in aquatic environments. For example, the Eurasian watermilfoil present in many New York rivers is a highly invasive aquatic plant that outcompetes native aquatic plant species, diminishing biodiversity. When plants grow into dense mats on the water surface, they can alter water quality as well as fish abundance and dispersion. Biological pest control is the practice of using an organism that will predate upon or otherwise attack a pest species to decrease the pest population to a level where it is no longer considered a pest. To be truly effective, biocontrol predators must present a potential non-toxic, self-sustaining alternative to chemical pesticides. Biocontrol predator populations can be highly efficient, however, sometimes problems arise, and they cannot sufficiently suppress the pests. One way to fix this may be to supplement the predator with an additional food source. In the laboratory, we developed a bacteria-protozoa experimental system as a model for testing the efficacy biocontrol approaches. In this controlled lab system, we tested how varying amounts of protozoa predators, *Tetrahymena thermophila,* and varying amounts of supplemental food impacted the number of pest bacteria, *Pseudomonas fluorescens*. Results from these experiments will be used to determine the optimal combination of biological predators and supplemental food amounts that should be added to a system to maximize the efficiency and impact of a biological pest control approach.

Tjandra

Mitigation of Harmful Algal Blooms (HABs) by Electrochemical Oxidation: Optimum Conditions for Full-Scale Application

Davin Tjandra[1,2], Shasha Yang[2], and Yang Yang[2*]

[1]Department of Biological Sciences, North Carolina State University, Raleigh, NC, USA and [2]Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY, USA

Harmful algal blooms (HABs) are a large-scale problem that impact both the ecological health of an environment, by hoarding much needed nutrients and sunlight; as well as the health of the community via the release of carcinogenic toxins into drinking water. In this study, an electrochemical oxidation (EO) process was developed to pump and treat algae and related toxins. The reaction is based upon the oxidation of water molecules and chloride to generate OH and free chlorine ($HClO/ClO^-$) as oxidants to inactivate algae cells and degrade cyanotoxins. We aimed to find the optimum conditions that maintain at least 50% algae and toxin removal efficiency while keeping low energy consumption and low formation of disinfection byproducts (DBPs) including trihalomethanes (THMs), haloacetic Acids (HAAs), and perchlorate. We started testing at a lab scale with lake water spiked with microcystis aeruginosa (most common algae in HABs) that mimicked the concentration of an average algal bloom. Lab testing indicated the best conditions being 10 mA/cm^2 at 10 mins, progressing to pilot testing at Lake Neatahwanta which runs at 5 GPM we found that the current density of 10 mA/cm^2 to be significantly better than the 7 mA/cm^2 current density. All this testing culminates to a final test on a barge which runs at 100 GPM. While the 10 mA/cm^2 current density has shown to have the best removal, DBP analysis has not yet been completed and thus a conclusion cannot be reached yet. However, if the 10 mA/cm^2 condition proves to yield high DBP levels we will have to search for alternative solutions.