OHIO DEPARTMENT OF HIGHER EDUCATION HARMFUL ALGAL BLOOM RESEARCH INITIATIVE PROJECT SUMMARY FORM

PROJECT TITLE: Artificial Floating Islands: a sustainable solution for nutrient reduction and cyanotoxin control.

INSTITUTION: The Ohio State University (in collaboration with Wright State University, Ohio State Extension, Mercer Co. Community & Economic Development and Soil & Water Conservation District, Grand Lake St. Marys State Park).

DEPARTMENT OF HIGHER EDUCATION FUNDS: $315,223
MATCHING FUNDS: $322,886

CO-PRINCIPAL INVESTIGATOR: Ozeas S. Costa Jr., PhD
AFFILIATION: The Ohio State University – School of Earth Sciences **EFFORT:** 1.00/year

CO-PRINCIPAL INVESTIGATOR: Jiyoung Lee, PhD
AFFILIATION: The Ohio State University – College of Public Health **EFFORT:** 0.80/year

ASSOCIATE INVESTIGATOR: Stephen J. Jacquemin, PhD
AFFILIATION: Wright State University – Lake Campus **EFFORT:** 0.45/year

ASSOCIATE INVESTIGATOR: Eugene C. Braig IV, MSc
AFFILIATION: The Ohio State University Extension – CFAES/SENR **EFFORT:** 0.45/year

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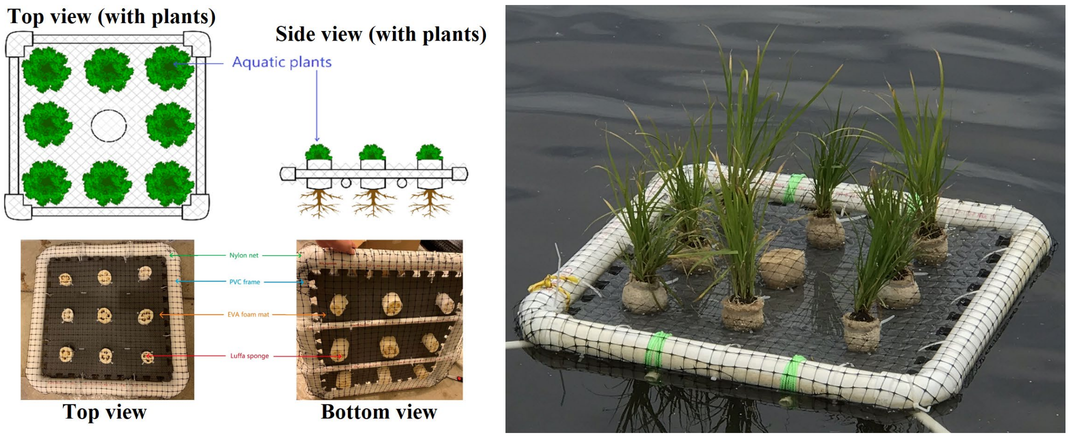
OBJECTIVES: The main goal of this project is to examine the effectiveness of AFI systems as an affordable, efficient, environment-friendly, and scalable method to remediate nutrient pollution and HABs in streams, lakes, and reservoirs in Ohio used for recreation and drinking water. Specific objectives of our proposed work include: (1) Determining nutrient-removal efficiency of various aquatic plants native to Ohio's wetlands and identifying combinations of plant species that provide highest nutrient-removal efficiency; (2) Determining the impact of physicochemical conditions (water temperature, pH, flow, and concentration of nutrients, dissolved solids, dissolved oxygen, ORP) on the nutrient-removal efficiency of the AFI systems; and (3) Determining the efficacy of AFI application on the control of cyanobacteria and cyanotoxins (microcystin, saxitoxin, anatoxin-*a* and BMAA). These objectives align with the identified top priorities across the State agencies: ***Ohio EPA***: ***Strategies and tools to evaluate or mitigate HABs and protect (improve) drinking water source quality*** (this project assess the efficacy of technology for cyanobacteria control and nutrient reduction; it supports the transfer of this technology to users/managers of recreational waters; it couples mitigation strategies with land use best management agricultural practices and integrate the project activities with larger source water protection initiatives that are planned or already underway); ***Identification, occurrence, and environmental drivers of emerging cyanotoxins in waters of Ohio*** (this project identifies factors driving the increase and occurrence of cyanotoxins in Ohio waters); ***Ohio DNR***: ***Research focused on assisting in identifying, constructing, and managing wetland restoration projects for the purpose of nutrient and sediment reductions that lead to a reduction in HABs*** (the controlled experiments in this project will identify the nutrient-removal efficiency of Ohio native aquatic plants that can be used in wetland restoration projects designed to reduce nutrients and HABs, as well as the physicochemical factors – and temporal/hydrological dynamics – that affect the nutrient-removal efficiency of these plants and plant combinations); ***Ohio Department of Agriculture***: ***Drainage retention/detention practice (e.g., ponds, basins, wetlands, enhanced waterways, two-stage ditches) research questions*** (this project will provide important information to establish best design parameters for nutrient-reduction wetlands, by identifying the nutrient-removal efficiency of aquatic plants common to Ohio's wetlands); ***Agricultural adaptation to climate change effects on nutrient runoff*** (the project will also evaluate how changes in precipitation – and other hydro-chemical parameters – affect the performance of floating wetland systems); ***Lake Erie Commission***: ***Development of additional BMP options for reducing DRP*** (this research will test the effectiveness of artificial floating wetlands in removing nutrients as an additional, low-cost, environmentally-friendly option for reducing reactive forms of nitrogen and phosphorus); ***Ohio Department of Health***: ***Prevalence and occurrence of all cyanotoxins (other than microcystin) in lakes, ponds and springs used for recreation and private drinking water supplies*** (results from this project will help evaluate the factors controlling the prevalence and occurrence of various cyanotoxins – as well as BMAA – and toxin-producing cyanobacteria (saxitoxin, anatoxin-*a* and microcystin) in a shallow lake used for public water and recreation); ***Cost effective treatment technologies for smaller scale (lower volume)***

drinking water treatment systems such as ponds or springs (this project will test the nutrient-removal efficiency of floating wetlands, a cost-effective treatment technology that can be used in small scale aquatic systems).

METHODOLOGY: We will construct and deploy a series of floating wetlands, called artificial floating island (AFI) systems to test the effectiveness of a variety of plant-bacteria associations in removing nutrients from selected locations along Grand Lake St. Marys (GLSM), which is the largest inland lake and among the top 10 waterbodies with highest microcystin levels in Ohio[1]. AFI systems of varying sizes and configurations will be constructed using 2-in PVC pipes and elbows for the AFI frame, 1-in EVA foam as the inside frame and support for luffa sponges, secured in place by a nylon net and zip-ties (figure below). Each luffa sponge will hold an individual aquatic plant seedling.



The AFI systems will be deployed at various locations throughout the lake, on both moving (lotic) and stillwater (lentic) sections. Some of the locations being considered include: a constructed wetland and canal at the NE portion of the lake, a refuge in the SW portion of the lake, by Montezuma Bay, a section along Beaver Creek, just south of Montezuma Township, and the canals of the old State Park office, NE section of the lake. These sites are being considered because of easy access, as well as for their location on public land (GSLM State Park and Mercer County lands). We have been working with local stakeholders (GSLM State Park and Mercer SWCD) to secure access and permits for work at these locations. Once deployment is concluded, concentrations of nutrients, metals and major ions – as well as water flow, pH, temperature, TDS, DO, and cyanotoxin levels – will be measured at regular intervals throughout the growing season (April-September), at multiple locations around the AFIs using handheld field meters and laboratory methods. Nutrient analysis of water samples will be undertaken at the Water Isotope and Nutrient Laboratory (WINL), at Ohio State Columbus Campus, using a Skalar SAN^{++} FIA system; analysis of major ions and metals will take place at the Trace Element Research Laboratory (TERL), also at Ohio State University Columbus Campus, using a Perkin-Elmer ICP-OES system. Analysis of cyanotoxins (saxitoxin, anatoxin-a, BMAA and microcystin) will be performed at Dr. Jiyoung Lee's lab at OSU with ELISA methods. This water quality monitoring will be used to determine the nutrient-removal efficiency of several aquatic plant species (and plant-species combinations), as well as their performance under a range of physical and chemical conditions. Potential species of aquatic plants to be used include *Pistia stratiotes*, *Carex comosa*, *C. hyalinolepis*, *C. lacustris*, *C. stricta*, *Nuphar lutea*, *Brasenia schreberi*, *Eleocharis pallustris*, *Scirpus fluviatilis*, and *Typha latifolia*. Algal biomass concentration (using the chl-a spectrophotometric method at the WINL) and heavy metal accumulation in algal tissue (using ICP-OES at the TERL) will also be measured, and then combined with water chemistry data to assess changes in lake water quality due to AFIs.

RATIONALE: The Grand Lake St. Marys watershed drains over 84,000 acres and is dominated by agricultural activities (row-crop and livestock production). This watershed has the highest livestock density in Ohio and the highest soil test P levels in the state. Runoff from farms and cities, as well the slow release of legacy nutrient pools and groundwater contamination, have been linked to the degraded water quality at GLSM, leading to frequent access closures to the public and a designation of "watershed in distress" by the ODA in 2011. This "nutrient pollution" represents a growing threat to public health and local economies, contributing to toxic harmful algal blooms (HABs), contamination of drinking water sources, and costly impacts on recreation, tourism, and fisheries. Communities throughout Ohio regularly face numerous

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[1] Gorham, T. *et al*. (2017) Ten-year survey of cyanobacterial blooms in Ohio's waterbodies using satellite remote sensing. *Harmful algae*, *66*: 13-19.

challenges from nutrient pollution, and almost half of our lakes, wetlands and streams are degraded by nutrient loading from phosphorus and nitrogen[2]. In response to the growing concerns related to nutrient pollution, a wide range of strategies (both technical and regulatory) are being tested. At the same time, a growing body of research suggests that **interception strategies** – those that filter out the nutrients before they reach surface waters – are more efficient, environment-friendly, and cost-effective methods to remediate eutrophic waters and tackle nutrient pollution[3]. Chief among these strategies is **phytoremediation** – the use of plants and associated microbes to reduce the concentrations and toxic effects of inorganic contaminants in aquatic environments[4,5]. Artificial Floating Islands (AFIs) is a phytoremediation technology that is growing in popularity[6], and have been used in rivers, lakes, and reservoirs worldwide for nearly 40 years. These floating treatment wetland systems involve the application of naturally occurring plants as floating wetlands on the water surface, where emergent plants are inserted in a buoyant mat suspended in a floating support, with the crowns and the shoots growing above the water level while the root system grows deeper into the water column[7]. The most recent estimates of nutrient removal rates by AFIs range from 26-78% for nitrogen and 30-71% for phosphorus[8], although some studies have reported nutrient removal rates above 90% for both N and P[9]. While the use of AFIs in nutrient pollution control and remediation has a long history worldwide, we are not aware of any current AFI applications in Ohio. A few initiatives do exist that use phytoremediation systems (e.g., an engineered wetland in Toledo using a combination of *C. stricta*, *P. virginianum*, *S. pectinate* and *P. vittata*; a wetland microcosm in Akron using a combination of *S. validus*, *C. lacustris*, *P. arundinacea*, and *T. latifolia*; and a soil phytoremediation system in Akron using *Helianthus annuus*). We are also aware of a recent deployment of floating algal mats at the Cuyahoga River, in Cleveland, and the Chadwick Lake in Columbus. The Grand Lake St. Marys Restoration Commission also installed floating algal mats on the lake between 2010-2013. But since no water quality monitoring was undertaken (both at GLSM and Cuyahoga River), it was not possible to evaluate the success of these experiments. ***This project aims to provide much needed data to validate the use of this technology and its effectiveness in cyanotoxin control in Ohio***. In addition, the proposed experiments will provide ***important benchmarks for the nutrient-removal efficiency of Ohio's native aquatic plants***, since, to our knowledge, such information is lacking. Because a large variety of AFI designs and macrophyte species combinations can be applied and adapted to different situations, simply transplanting a design that was successful elsewhere will not guarantee positive results. This is particularly important since the majority of AFI applications worldwide use plant species that are not common in Ohio's wetlands. By mimicking natural processes and conditions, AFI systems are environmentally-friendly (green infrastructure) and – compared to traditional gray infrastructure (water treatment plants) – can deliver water quality improvements with significantly smaller lifetime operational and maintenance costs[8]. This technology is also ***scalable to other water bodies and can readily be applied in other lakes and reservoirs in Ohio that are also facing nutrient pollution and HABs*** (e.g., Indian Lake, Seneca Lake, Buckeye Lake), helping us achieve both federal and state-wide nutrient-reduction goals, as required by USDA's national water quality initiative and new state and local initiatives such as H2Ohio and the Ohio EPA updated nutrient pollution strategy. ***The multi-institution, multi-disciplinary team*** assembled for this project includes an aqueous geochemist specialized in nutrient pollution (Ozeas Costa, School of Earth Sciences, Ohio State Mansfield Campus), an environmental health scientist specialized in contamination of pathogens and microbe-derived metabolites (cyanotoxins) and its linkage to health risks (Jiyoung Lee, College of Public Health, Ohio State Columbus Campus), an aquatic ecologist and current director of the Aquatic Ecosystems Program from Ohio State Extension (Eugene Braig, School of Environment and Natural Resources, Ohio State Columbus Campus), an ecosystem ecologist specialized in lake eutrophication (Stephen Jacquemin, Wright State University, Lake Campus), an engineer specialized in the use of farm practices and technical solutions for addressing water quality issues in GLSM watershed (Theresa Dirksen, Mercer County Community and Economic Development), and a watershed technician with the Mercer County Soil and Water Conservation District office in New Paris, Ohio (Sean Drew). An additional partner is the Grand Lake St. Marys State Park manager (David Faler), which will support the project with logistics and site access for the installation of the AFI floating structures.

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[2] OEPA – Division of Surface Water (2013) Ohio Nutrient Reduction Strategy. Final report, June 2013.
[3] Quilliam, R.S. *et al*. (2015) Can macrophyte harvesting close the loop on nutrient loss from agricultural land? *J. Environ. Manage.*, 152: 210-217
[4] Yu, S. *et al*. (2019) Efficiency of nitrogen and phosphorus removal by six macrophytes in eutrophic water. *Int. J. Phytoremediation*, 21(7): 643-651.
[5] Fernandez, L.G. *et al*. (2015) Phytoremediation of Contaminated Waters to Improve Water Quality. In: A.A. Ansari et al. (eds.), *Phytoremediation: Management of Environmental Contaminants*, Vol. 2, pp. 11-26.
[6] Afzal, M. *et al*. (2019) Floating treatment wetlands as a suitable option for large-scale wastewater treatment. *Nat. Sustain.*, 2: 863–871.
[7] Chang, Y. *et al*. (2017) Artificial floating islands for water quality improvement. *Environ. Rev.*, 25(3): 350-357.
[8] Wang, W. *et al*. (2020) Research and application status of ecological floating bed in eutrophic restoration. *Sci. Total Environ.*, 704: 135434.
[9] Kong, L. *et al*. (2019) Study on new artificial floating island removing pollutants. *Environ. Sci. Pollut. Res.*, 26(17): 17751-17761.