Assessment of a Floating Algae Cultivator For Water Pollution Control and Biomass Production

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ABSTRACT SUMMARY

The research proposed here is to optimize the design of a floating cultivator for attached filamentous algae for water quality management applications in the lower Great Lakes region. Eutrophication of waterways in the Great Lakes region has become a significant water quality issue in the past few decades. At the same time, process design for attached algae cultivation has matured and proven to be effective for water quality management in other regions of the country. Preliminary investigation using pilot-scale units on the Buffalo River, however, has shown relatively low rates of biomass production despite high energy inputs, suggesting limited application of this technology in the region. Thus proposed is a novel floating algae cultivator which has shown promising biomass production at low energy cost in previous applications elsewhere.

RESEARCH QUESTIONS

1. **Will the floating algal cultivator have algal biomass production rates comparable to other algal production reactors tested at the same sites?**
2. **What is the quality of the recovered biomass as bio-fuels feedstock?**
3. **Will algal production with floating cultivators be more economically viable for sustainable water quality improvements?**

THE ISSUE: CULTURAL EUTOPHICATION

Years of industrial and agricultural runoff being deposited into lakes, rivers and streams has led to elevated levels of nitrogen and phosphorus in water bodies in the Great Lakes region. These two nutrients are of major concern because either one is usually the limiting factor for algal growth in aquatic systems. Excess nutrients in surface waters stimulate algal growth in excess of natural controls in a process known as cultural eutrophication[1]. This excessive algal growth has a large negative impact upon local waterways. Large amounts of decaying algae consume dissolved oxygen creating hypoxic conditions. Degradation of water quality ensues and there is a consequent loss of biological diversity.

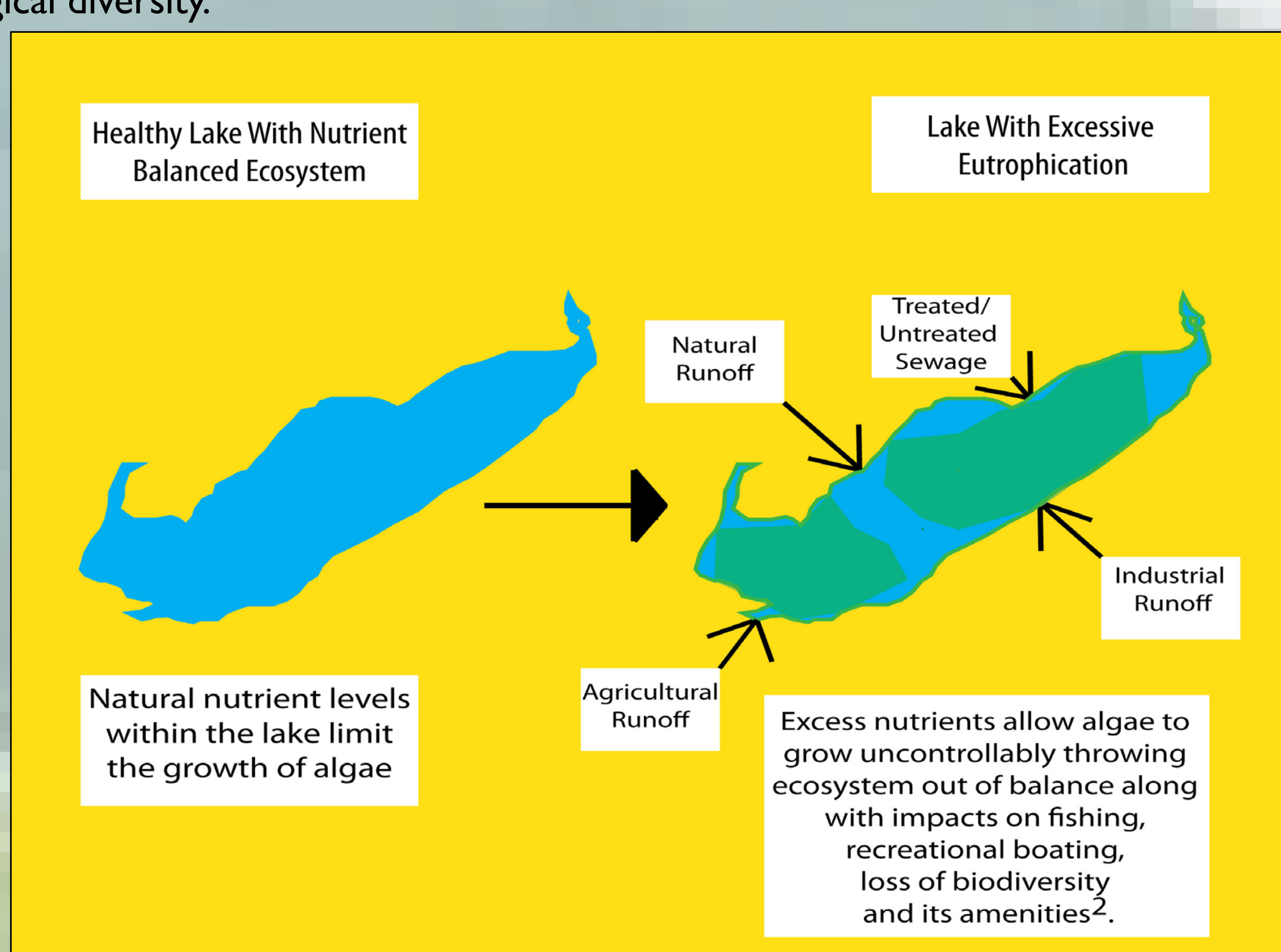

Figure 1: Diagram of Cultural Eutrophication

ALGAL CULTIVATION TECHNOLOGY

A viable option to remove excess nutrients from surface waters is through the use of mini-engineered algal turf ecosystems. In the early 1980s, while studying tropical coral reefs, Dr. Walter Adey found that the high rate of plant production was mostly accomplished by a small group of algae known collectively as an algal turf. This short, mat-like group of algal filaments has an actual tissue production rate of 5-20 g $m^{-2}d^{-1}$in natural, low-nutrient environments, a rate several times faster than most terrestrial plants. It was discovered that these algae turfs (that have a high level of photosynthesis and primary production) could be utilized in engineered cultivation systems to adsorb pollutant nutrients and thus improve water quality. This mini-engineered ecosystem is what as known as an Algal Turf Scrubber (ATS)[3].

Figure 2: Terrestrial-Based ATS

In previous studies done throughout the last year, ATS units in operation at the Buffalo State Great Lakes Center (see Figure 2) have had low algal productivities with an annual average of less than 5 g m^{-2} d^{-1}.[4] At these productivities, scaling up for more industrial applications would require prohibitive amounts of land to have useful impact upon waterway pollution levels. New research from the Chesapeake Algae Project (ChAP) at the College of William and Mary has resulted in a new design for offshore floating apparatus for algal cultivation that achieves higher biomass production densities than land-based applications in the Chesapeake region[5]. As a result, the UB Algae Research Team has developed a similar floating cultivator prototype for deployment in the near-shore Great Lakes environment.

As shown in Figure 3, native algal species will attach and grow on the floating algae cultivator screen by collecting sunlight and excess nutrients. Harvesting of the biomass will remove adsorbed nutrient pollution from the waterway. This biomass can then be used in various refinement processes to produce bio-fuels, fertilizers, or other products[6].

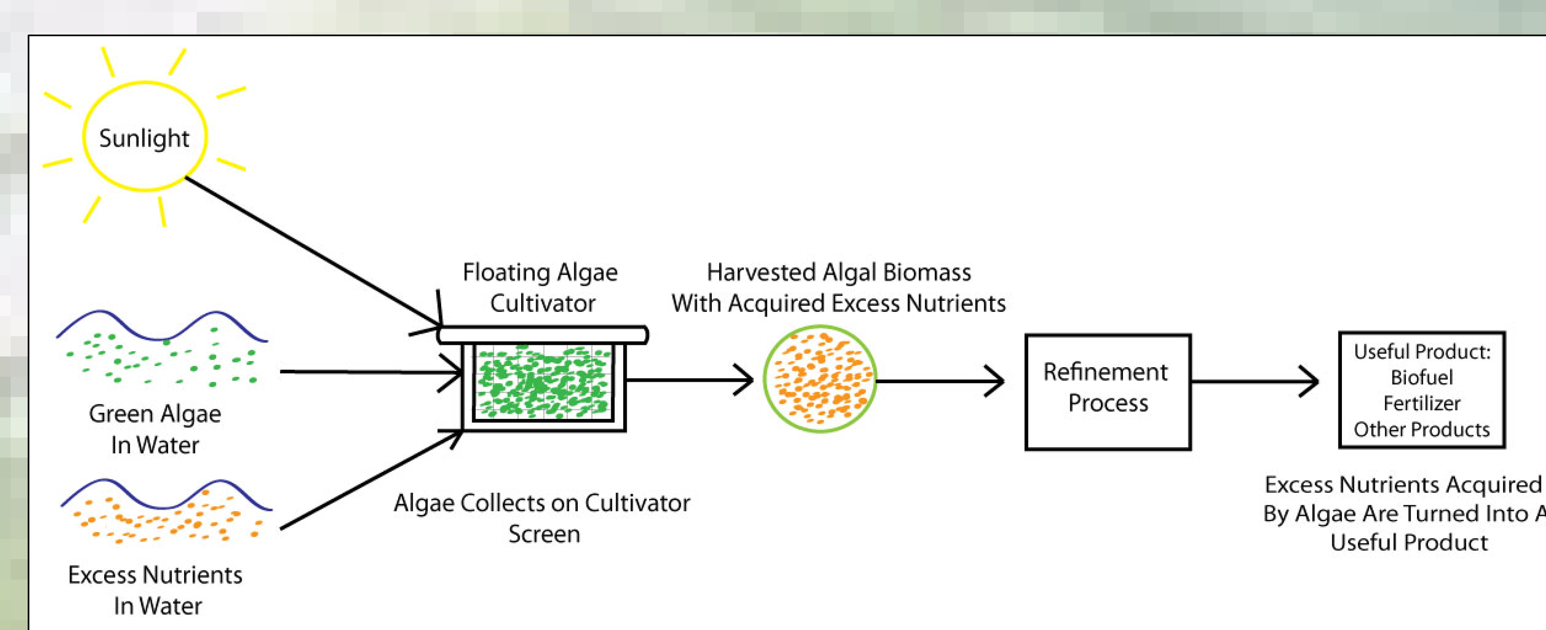

Figure 3: The Floating Cultivator Remediation Process

METHODS AND MATERIALS

A floating apparatus for cultivation of benthic algae has been designed and tested for operability. Each floating cultivator is constructed from 2" PVC pipe as the floating rails, with algal screen racks constructed of ½" PVC. Each cultivator is 1 m^2 on the water surface, and supports three algal screen racks vertically. Each screen rack is 1 m^2, and each screen can be colonized by algae on both sides, yielding a total growing surface area of 6 m^2 per m^2 of water surface. Each apparatus requires about $50 to construct using off-the shelf materials.

Three locations around western New York have been selected for deployment of the floating algal cultivators. These are Tonawanda Creek (Clarence, NY), Lake Lasalle, UB Campus (Amherst, NY), Buffalo River mouth, Great Lakes Center (Buffalo, NY). At each location, two cultivators will be deployed via an anchoring system. Once placed in the waterway, the cultivator requires no energy to operate. A HOBO temperature/PAR data-logger will be deployed on one cultivator at each location to monitor continuously temperature and light level. A typical raceway algal cultivator and pump will be deployed in the riparian zone at each site as well to serve as an experimental control. Algae from each cultivator unit will be harvested weekly using a shop vac. At the time of harvest, grab samples from the waterway will be taken and stored for later nutrient analysis. Samples of algae will be taken and stored as necessary for taxonomic analysis and for chlorophyll-a analysis.

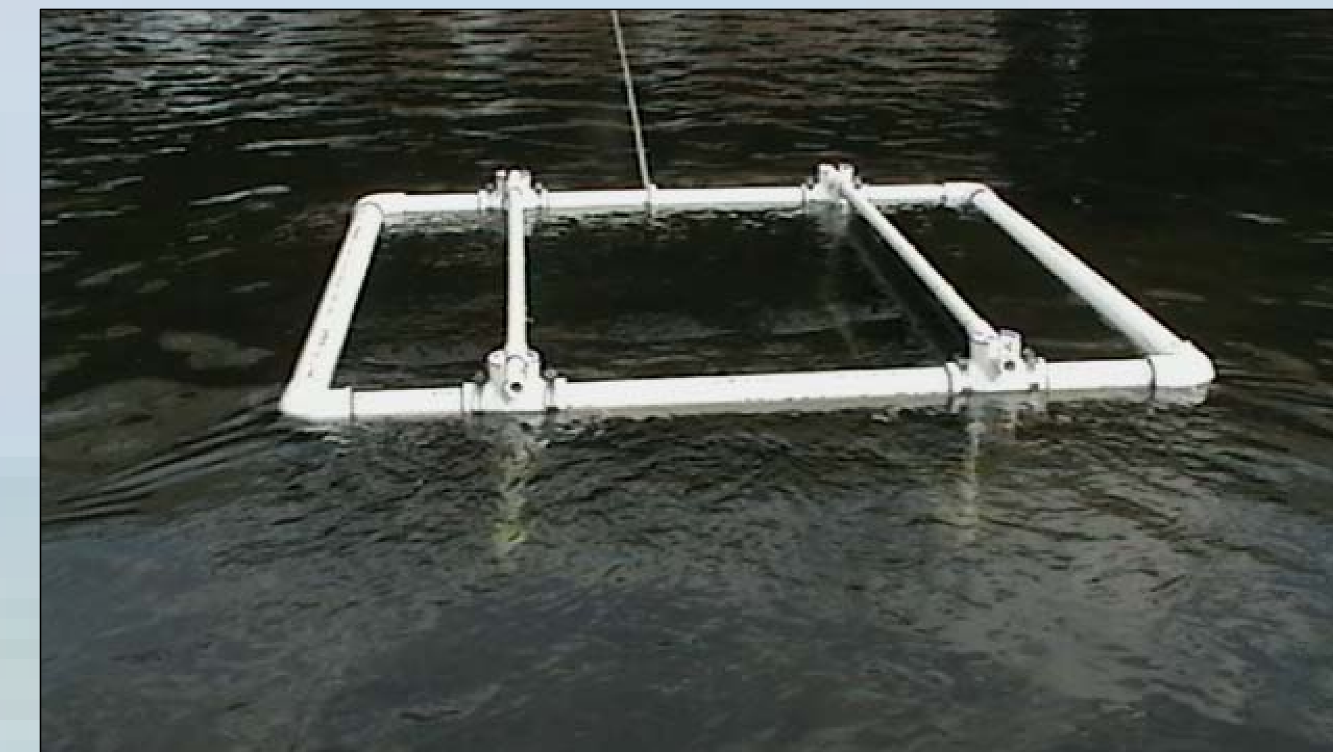

Figure 4: Floating Algae Cultivator Prototype

Harvested algal biomass will be air-dried in the lab and weighed, and productivity will be calculated as the average biomass production per unit area per day. Subsamples of algal biomass will be taken and analyzed for water and ash content. Subsamples of algal biomass will be sent to external labs for analysis for nitrogen and phosphorus content, carbohydrate content and type, and fatty acid content. Water samples will be analyzed for concentrations of nitrogen (NH_4^+ and NO_3^-) using spectrophotometry. Algal subsamples will be analyzed for species using digital microscopy. Algal subsamples will be analyzed for chlorophyll-a concentration using the trichromatic-acetone method[7] and spectrophotometry. In addition, energy calculations on terrestrial ATS units will be done to assess energy conserved by using floating cultivator units.

Productivity species assemblage data will be analyzed for seasonal trends, and correlations with water phosphorus and nitrogen concentrations and with algal biomass phosphorus concentration. Algal biomass phosphorus content, carbohydrate content, and fatty acid content will be analyzed for correlations with water concentrations, temperature, and species assemblages.

IMPLICATIONS OF RESULTS

This study will yield information toward the optimization of an algae cultivator in the near-shore Great Lakes environment. Data will reveal whether floating cultivators algal biomass production rates are comparable to competing terrestrial-based technologies and if floating cultivators are a feasible remediation technology. Results of algal production, energy usage calculations, nutrient uptake, carbon content, and content of carbohydrate and fatty acids will allow modeling of the economic viability of large-scale algal production processes in the region. In particular, carbohydrate and fatty acid content will reveal the quality of the biomass as a bio-fuel feedstock. Scaling up of this process could result in the development large scale, low-cost, low-energy usage technology for the removal of excess nutrient pollution in local waterways for mitigation of cultural eutrophication.

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