Evaluation of a Floating Algae Cultivator for Water Pollution Control and Biomass Production

Peter Byrley, Dr. David Blersch
Ecosystem Restoration through Interdisciplinary Exchange (ERIE) Program, Department of Civil, Structural, and Environmental Engineering
State University of New York at Buffalo

ABSTRACT SUMMARY

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. Thus proposed in March of 2012 was the design and testing of a novel floating algae cultivator. The design has small capital costs, requires no energy input for operation, and recovered biomass from the apparatus has the potential to be used as a feedstock for biofuel production all contributing to a potentially cost-effective technology for pollutant nutrient recovery. Preliminary results show that the recovered biomass has a high ash content versus ash free dry mass. Results of this study on the performance of the apparatus will provide operational parameters that can inform the design for viable large-scale *in situ* algal production for water quality mitigation in the lower Great Lakes watersheds.

ALGAL CULTIVATION TECHNOLOGY

Cultural eutrophication is the enrichment of surface waters from human-generated nutrient sources resulting in deleterious water quality impacts. As the human population has grown around the Great Lakes and invasive *Dreissena* mussels have appeared, increased levels of nitrogen and phosphorus have been found in the Great Lakes[1]. As a result, excessive algal growth has occurred which has negatively impacted local waterways in terms of fishing, recreational boating, biodiversity and beach quality[2].

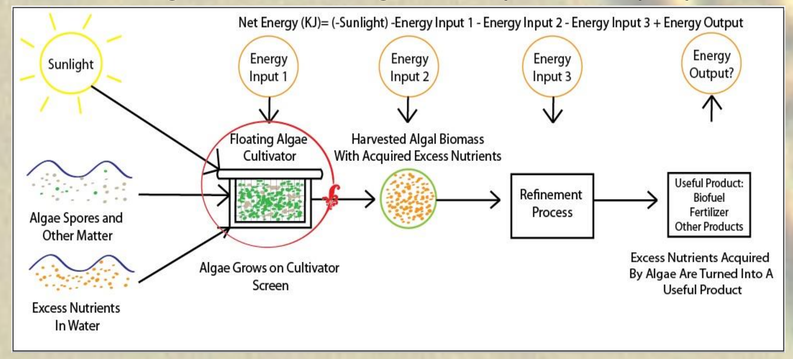

Figure 1: Schematic of the Water Remediation Process Using a Floating Algal Cultivator

A potentially viable and sustainable option for removing excess nutrients from surface waters is through controlled cultivation of algal turfs[3]. Because of their high level of primary production, algal turfs can be utilized in engineered cultivation systems to absorb pollutant nutrients and thus improve water quality[4]. New research from the Chesapeake Algae Project (ChAP) at the College of William and Mary has resulted in a design for an offshore floating algal cultivator that achieves high productivities with lower energy inputs compared to land-based systems in the Chesapeake region[5]. Inspired by this work, the UB Algae Research Team has developed a simpler floating cultivator prototype for testing productivities in the nearby watersheds in the Great Lakes (Figure 1).

Wild algae from the natural environment was expected to colonize on the floating cultivator screen directly, using it as a coarse substratum for basal stalk attachment. After colonization, the growing turf would absorb excess nutrients from the surrounding water and periodic harvest of the biomass would remove the nutrients from the system. Collected biomass can then be used after various refinement processes to produce bio-fuels, fertilizers or other products[6].

MATERIALS AND METHODS

Four cultivators were built to specification (Figure 2) using commercially-available materials (Table 1). A HOBO temperature/PAR data-logger was deployed on each cultivator at each location to continuously monitor temperature and light levels. One was south facing while the other is north facing, to determine greatest sunlight intensity and smallest sunlight intensity, respectively. Material that collected on the screen was harvested on a periodic (usually 7-9 days) basis using a common ice scraper and ten gallon bucket.

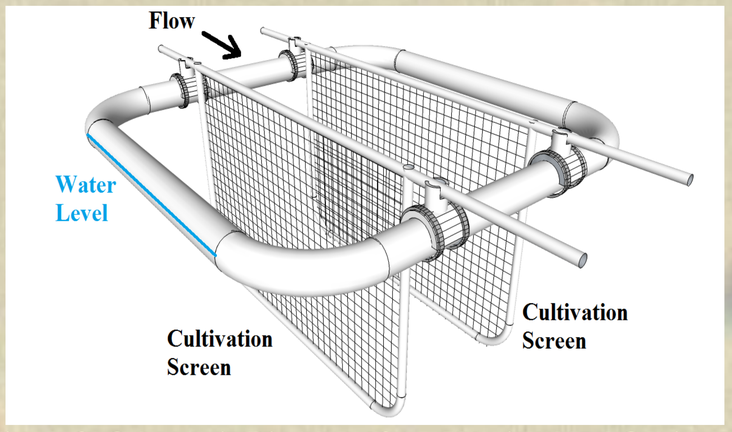

Figure 2: Schematic Diagram of the Floating Algal Cultivator

Table 1: Materials and Deployment Parameters of the Algal Cultivators

Materials:	PVC piping, Plastic Bat House Netting, Worm Drive Hose Clamps (SS16), Plastic Zip Ties
Unit Cost:	$83.92
Overall Dimensions (m):	1.0 length X 1.0 width X .54 depth
Screens Per Unit:	2
Total Growth Area (m^2):	3.95
Orientation of Growth Area:	Vertical
Sites of Deployment:	A: River, B: Lake
Water Flow Conditions:	A: Unidirectional, 3 m^3/s discharge B: Multidirectional, wind-driven, variable

(A) Ellicott Creek Site

(B) Lake LaSalle Site

Figure 3: Deployment Locations in Amherst, NY

RESULTS

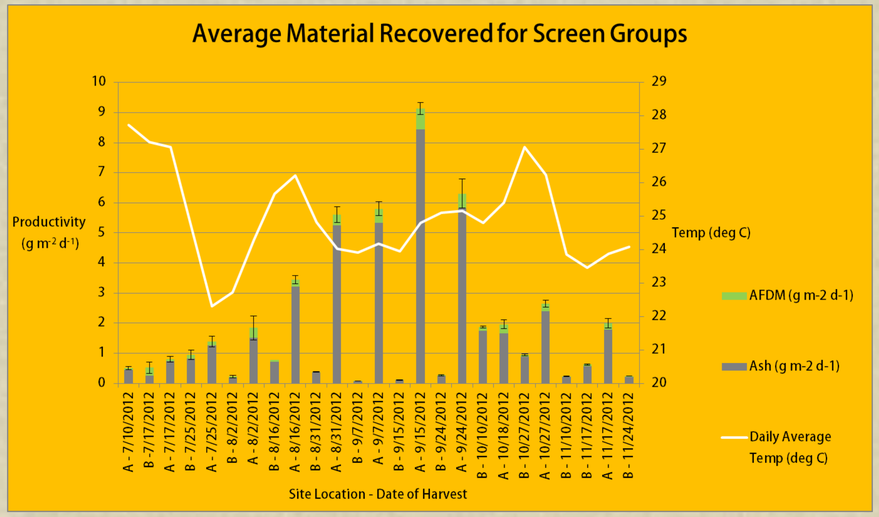

Figure 4: Harvest Results

Results from harvests showed that recoverable biomass had high mean ash content (87.3% ± 11.8%, n = 90). In addition, overall production numbers did not seem to correspond to temperature or light trends.

Table 2: Productivity Results for Regular Harvests of Cultivator Screens

Parameter	Mean (±S.D.)	Range
Overall Productivity (g AFDM m^{-2} d^{-1})	0.185 (±0.239)	0.0003 - 1.444
Productivity River (A) (g AFDM m^{-2} d^{-1})	0.298 (±.196)	0.0003 - 1.444
Productivity Lake (B) (g AFDM m^{-2} d^{-1})	0.0566 (±0.0739)	0.001 - 0.474

Overall, low AFDM productivity was found for all systems (Table 2). Also, AFDM productivity at the river site (A) was 5-10 times greater, suggesting that water bodies with unidirectional flow are better suited for this technology. Microscopic analysis of recovered samples revealed several species of cyanobacteria and diatoms such as *Oscillatoria* and *Frustulia,* respectively. Possible reasons for low AFDM include lateral disturbance of growing medium, loss from heterotrophic grazing, loose attachment of algal species, and possible loss from harvest methods.

Final analysis reveals that this technology has productivities on the low end of algal production technology (typically around 5 g m^{-2} d^{-1})[3] More tests with altered designs will need to be performed to determine the suitability of the substratum materials. Future 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 this process could result in the development of large scale, low-cost, low-energy usage technology for the removal of excess nutrient pollution in local waterways for mitigation of cultural eutrophication.

REFERENCES

1. Higgens et. al. 2008. An Ecological Review of *Cladaphora Glomerata*. (Chlorophyta) in the Laurentian Great Lakes. Phycological Society of America. 44: 839-854
2. Buhvestova et. al. 2010. Nitrogen and Phosphorus in Estonian Rivers Discharging into Lake Peipsi: Estimation of Loads and Seasonal and Spatial Distribution of Concentration. Estonian Journal of Ecology. 60(1): 18-38
3. Adey, W. H., & Loveland, K. (2007). *Dynamic aquaria*. (3 ed., pp. 159-169). Oxford, UK: Elsevier Inc.
4. Adey, W. H. et. al. 1996. Purification of Industrially Contaminated Groundwaters Using Controlled Ecosystems. Ecological Engineering. 7: 191-212
5. Clark, C. 2011. Environmental remediation and renewable energy through high-yield algal aquaculture. Poster presentation at the 4th National Conference on Ecosystem Restoration, August 1-5, Baltimore Marriott Waterfront, Baltimore, MD.
6. Mulbry et. al. 2008. Treatment of Dairy and Swine Manure Effluents Using Freshwater Algae: Fatty Acid Content and Composition of Algal Biomass at Different Manure Loading Rates. Journal of Applied Phycology. 20: 1079-1085

ERIE Ecosystem Restoration Through Interdisciplinary Exchange

ACKNOWLEDGEMENTS:

Research funding and support provided by the ERIE Scholarship Fund, ERIE Program, NSF and UB Center for Undergraduate Research and Creative Activities (CURCA). The authors acknowledge Elizabeth Hennessy for her preliminary work on the project and Dr. Alan Rabideau for material support, as well as the Great Lakes Center of Buffalo State College in Buffalo, NY.

University at Buffalo The State University of New York