

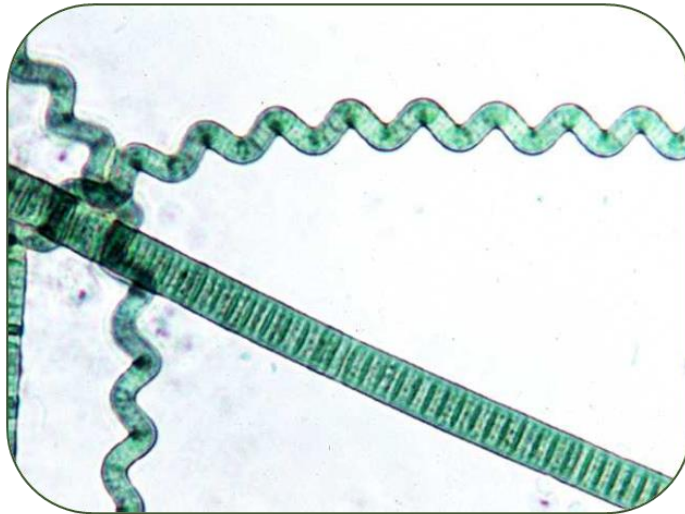
Spring 2019 Sustainability Grant Proposal for Under \$500

Project Title: Piloting a Small-Scale Photobioreactor and Assessing the Nutritional Aspects and Bioremediation Abilities of the Photosynthesizing Bacteria *Spirulina*

Project Leader: Tess Eidem, Ph.D.

Co-participants: Rex Schweighofer and Robert Haseltine

Spirulina Photobioreactor Project



**High Protein
Nutritional Supplement**

**Carbon Capture
Abilities**

**Bioremediation
(pH and hydrocarbons)**

Summary

Goals: The overarching goal of our project is to build a small-scale photobioreactor that cultivates the photosynthesizing bacteria from the genus *Spirulina*. A photobioreactor is an aqueous closed-system designed to encourage the growth of photosynthetic microorganisms by controlling variables like nutrient availability, pH, light, and temperature. The *Spirulina* species was chosen due to its tolerance to a wide variety of pH conditions, its high nutrient and protein value, and its carbon capture and bioremediation abilities.

This pilot system will be designed to:

- Harness the bioremediation abilities of photosynthesizing *Spirulina* (pH normalization and contaminant removal)
- Harvest high-nutrient, high-protein *Spirulina* species for human and animal consumption
- Provide foundational understanding and data for future scaling and bioremediation implementation with local businesses (Moonstone Farms, Hop and Hex)

Project Justification and Relevance:

Spirulina has been intensively studied in recent years following research on the potential benefits to human health. *Spirulina* has benefits linked to the human immune system, anti-viral activity, cancer prevention, and the cardiovascular system. This cyanobacterium has exploded in the fitness industry as is widely used as a supplement for a healthy life. *Spirulina* has a 60-70% protein composition along with numerous amounts of healthy micronutrients, such as beta-carotene and gamma linolenic acid, that the human body requires to operate on a day to day basis (Capelli, 2010).

In addition to these nutritional benefits, *Spirulina* has also been harnessed in bioremediation efforts to remove environmental contaminants and restore balance to water systems. *Spirulina* is ubiquitous and can grow in numerous diverse environments ranging in pH concentration, tolerate environmental contaminants, and survive in diverse temperatures. This “micro-algae” can be used to normalize pH of water systems and clean contaminated water. *Spirulina* has been shown to absorb heavy metals and can remove up over 70% of lead in contaminated water sources (Chen and Pan, 2005) and can absorb diesel fuel, removing it from the environment (Mishra and Mukherji, 2012). Moreover, *Spirulina* is a photosynthesizer and has tremendous abilities to fix atmospheric CO₂, reducing greenhouse gases, and producing oxygen in the process.

The Adirondacks face several challenges in which *Spirulina* may be a useful and sustainable tool. Farmers and people need source of high-nutrient, low cost biomass like that provided by *Spirulina*. Carbon dioxide is a byproduct of many industrialized activities and its

release from local Adirondack breweries during fermentation contributes to greenhouse gasses. In addition, wastewater from brewery cleaning practices often fall outside of acceptable pH range for municipal water systems and cannot be “poured down the drain,” leaving small breweries to dispose of the water on their own. Moreover, soil and groundwater contamination with petroleum-based products continues to be a problem in many communities.

This pilot project will allow us to build a *Spirulina* photobioreactor to optimize and test growth conditions as well as biomass output. This project can then be expanded, re-designed, scaled, and integrated into the local community’s needs in collaboration with Hop and Hex Brewery (opening in summer 2019) and Moonstone Farms. Dr. Eidem has been in communication with these small businesses and there is tremendous potential for future development to:

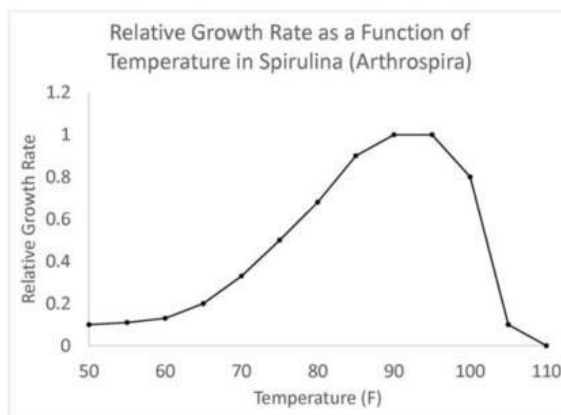
- 1) Utilize the carbon dioxide produced in the brewing process as a nutrient for photosynthesizing *Spirulina*
- 2) Normalize the pH of brewing wastewater through the natural action of *Spirulina* before releasing into the municipal water systems
- 3) Harvest the *Spirulina* species for consumption of animals and potentially humans as a sustainably derived, high-nutrient energy source
- 4) Test the bioremediation abilities of *Spirulina* to break down diesel and other environmental contaminants

Methods:

The *Spirulina* Farming Kit (Algae Research and Supply) was chosen due to its low cost, simplicity, quality assurance, and reduction in construction process. Since this kit will be purchased from a manufacturer, we will have access to resources and support to help us troubleshoot any issues we may encounter. Additionally, kits purchased for education applications come with extra supplies to aid in overall project productivity, and once cultivated, we can continue to improve upon the design. Two kits will be purchased: one will be used to optimize growth conditions, test CO₂ capture, and vary pH. This kit will also be sampled for human consumption. The second kit will be used to test the bioremediation of diesel (not for human consumption).

This project will act as a proof-of-principle experiment to ensure we can successfully grow *Spirulina* species in the laboratory and perform several bioremediation experiments. Based on the current literature, *Spirulina* has been found to grow best in warm water but can tolerate a range of temperatures from 32-90°F and variable levels of pH (Ciferri, 1983). Ensuring the culture stays within this range of conditions will be achieved by culturing the bacteria indoors with the use of both artificial light during the nighttime, and indirect sunlight during the daytime. We will continually monitor growth throughout the process and test the pH and temperature to ensure the environment does not become too acidic or basic to limit adequate growth. We will

harvest the *Spirulina* within the first 1-3 weeks. Each 5-gallon kit is predicted to yield approximately 1 lb of wet weight *Spirulina*. We will compare this harvested *Spirulina* to commercially available sources by performing protein and nutrition tests.



Once we determine the optimal growth conditions for *Spirulina*, we will expand our experiments to explore the other potential applications of the cyanobacteria. Using the literature to guide our test conditions, we will pilot several experiments, including:

- 1) pH normalization with *Spirulina* to determine its potential in neutralizing brewing wastewater
- 2) Carbon dioxide addition and the influence on growth to understand the potential uses of *Spirulina* for carbon capture of CO₂ during the brewing process
- 3) Test bioremediation of diesel with *Spirulina* by testing pH using other chemical and spectrophotometric tests to determine the abundance of diesel fuel after treatment.

Importantly, this foundational work will provide the knowledge and experience to expand this project to meet the sustainably derived nutrition source, bioremediation, and carbon capture needs of local businesses, specifically with our collaborators Hop and Hex Brewery and Moonstone Farms. Moreover, this work could also be expanded in the Fall 2019 Bioremediation course taught by Dr. Eidem and/or as advanced capstone projects for Mr. Haseltine and Mr. Schweighofer (and others), continuing to return on the Sustainability Grant's investment.

Budget Table:

Item	Cost	Use
Algae Research Supply: Spirulina Farming Kit (2)	\$200	Grow and harvest <i>Spirulina</i> to examine colonies under microscope, and investigate factors effecting growth (pH, CO ₂)
Generic 10-gallon Aquarium Tank (2)	\$50	Required item to use with the <i>Spirulina</i> farming kit.
Aquarium Air Pump (2)	\$60	Provide CO ₂ for growing micro-algae
USDA Organic Spirulina Powder	\$70	Comparison between farmed <i>Spirulina</i> and organic processed spirulina supplement.
1 gallon of diesel fuel	\$5	To test absorption of diesel by spirulina in contaminated water.
5 lb CO ₂ Cylinder	\$60	Test carbon capture abilities of <i>Spirulina</i> and how this influences growth

Total Project Cost = \$445

Timeline:

- Pre-spring break: continue to research about uses of *Spirulina* for hazardous cleanup and nutrition.
- Upon approval of project:
 - 3/25-3/29: order harvest kit, additional supplies, and *Spirulina* supplement
 - 4/1: begin supplementation of *Spirulina* (5 g daily)
 - 4/2: begin construction of *Spirulina* farm prior to microbiology class with Dr. Eidem supervision
 - 4/4: complete construction of *Spirulina* farm after lab for controlled group and diesel fuel treated group
 - 4/4-4/23: Examine growth of *Spirulina*, study colonies, record observations on effects from supplementation. Test pH of controlled tank and treated tank, and continually monitor pH weekly in both tanks, recording differences and observations.
 - 4/25: Present our results and observations of study and supplementation.

Supporting Documentation:

Capelli, B. and G.R., Cysewski. 2010. Potential health benefits of *Spirulina* microalgae. Nutrafoods, 9:19-26.

Ciferri, O. 1983. *Spirulina*, the edible microorganism. American Society of Microbiology, 47:551-578.

Mishra, P.K. and S., Mukherji. 2012. Biosorption of diesel and lubricating oil on algal biomass. US National Library of Medicine National Institutes of Health, 2:301-310.

Chen, H. and S., Pan. 2005. Bioremediation potential of *Spirulina*: toxicity and biosorption studies of lead. Journal of Zhejiang University Science, 6:171-174.