Analysis of Boating Motions on Biodiversity

Kimberly Savitsky

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Discovering Research

"I want you to be encouraged that whether or not they have the extension and your project is submitted, you have done an exemplary job. I am most proud of your fantastic, quality work and it is worth it, ultimately because you are making an incredible paper and building yourself up as a research scientist." "You are a researcher, and it flows through your veins!" Such comments were graciously said to me by my mentor at my high school within my four years of research there. Looking back, I still become perplexed and amazed at how much has changed within me since that first day of high school. I would have never been able to see myself now, with such a strong background and experience in independent research. This idea of analyzing, describing, building, and enhancing the work of past research work was illuminated to me simply from my rather impulsive choice in joining a club at McNair Academic entitled "Science Research." Quite frankly, I hadn't the slightest inkling to what I was diving into. Like anything that seems to accompany the rights and lefts made in life, this became a defining moment in not only my high school career but also a compass in determining my next steps moving forward. One can call it love at first sight, but that could be wrong. Through the trials and errors of each and every day at my research station in that corner of the chemistry classroom that brought to life the research visions of about thirty students every year, came the realization that the frustrations and wrong paths were even more valuable and noteworthy than the simple notion that the idea plainly worked. Most importantly, I found my outlet in which I could recharge my battery, which is quite opposite to the tired feelings leaving the lab around seven in the evening. It was the invoking sense of continuation for some answer, for acknowledgement of making a right or left, that ensued me to act on what scientific lab reports in high school don't always give you the liberty to do.

Environmental Analysis

The water source on Earth is rapidly diminishing, and this is not new knowledge nor of new concern. Boating has been concluded to be a significant source of pollution; this focus has been centered around shoreline erosion, turbidity issues caused by uprising nutrient sediments, and chemical pollutants. Physical turbulence is not yet known to solely influence ecosystems, so this research centers on the re-suspension of water. Salt and freshwater ecosystems were created using a glass aquarium, plate glass, silicon seal, PVC pipes, and air and water pumps. Determining the severity and specific impacts of boating on photosynthesis and respiration gives clear and comprehensive views of water quality that is dependent on aquatic life.

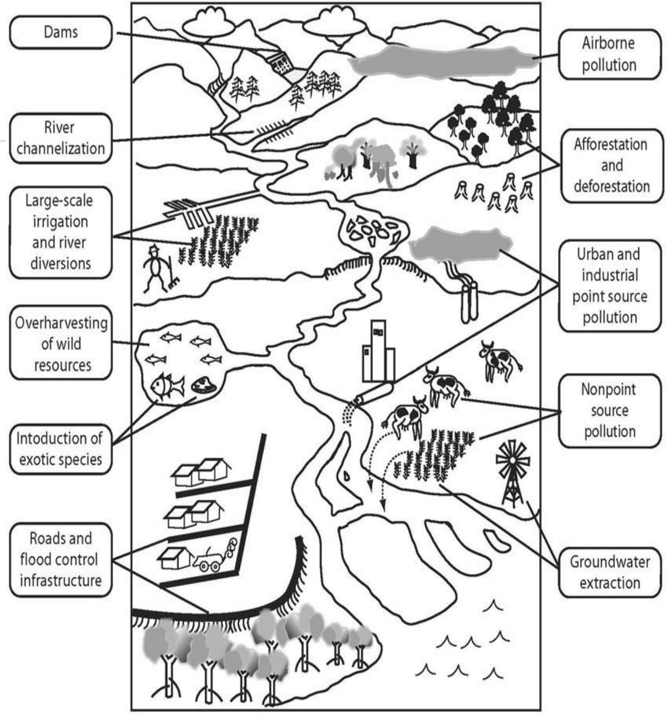
There are innumerable issues and problems that have complicated many aspects of life on Earth. I felt compelled to study one that cannot be ignored: water quality. Despite increasing efforts to decontaminate water supplies in third world countries, the problem is predicted to be magnified into second and even first world countries within the next fifty years. The 1% of Earth's total water supply is available to humans for agriculture, drinking water, and industrial use, with only 0.3% of freshwater sources available from freshwater bodies such as rivers, lakes, and swamp land. With pollution through the emission of fossil fuels, industrial wastes, and lowering water levels due to global warming are putting water ecosystems in danger. Nothing is more important to us as a species, and I received specific inspiration after reading a research paper entitled "Effects of boating activities on aquatic vegetation in the Stockholm archipelago, Baltic Sea" by Erickkson, et al. Curiosity towards the direct, sole effects of boating's physical impacts on healthy living of aquatic life led to this study.

As water becomes a source of global concern, not only in terms of its quality and clarity but also in terms of quantity and supply as the world population continues to grow, it is imperative that research and engineering collide to determine a manner of regulation so that the world's most integral resource is conserved and distributed properly.

For a moment, just think about it. Think about waking up in the middle of the night, thirsty, and not being able to access water because it is rationed so that the rest of your community can share the resource. Imagine using the restroom and having no water in the toilet because water is only cleaning out the latrine once a day. Although such scenarios seem quite extreme and impossible to many living in first world countries, this can become a reality at the rate at which water is being consumed and the inefficient manner it is being distributed.

So, the question becomes “Why wouldn’t I spend three years of my life conducting research on this while in high school?” instead of “Why did I do it?.”

The severity and unpredictable nature about Earth's water supply is coming to be an issue of naturally changing water patterns and human activities. The two greatest forces that can deplete healthy water supplies are pushing the issue beyond third world countries. Among pollution and misuse, wars for water in developing nations, and altering ocean currents and wind patterns, the Earth's freshwater supply, of which humans can use only 1%, is quickly becoming an international concern. Water is a resource that is taken for granted in first world countries, and recent natural disasters have left many in such countries without warm water, opening their eyes to living without the resource seen on 70% of the Earth and 90% in the human body itself. Water not only quenches thirst and provides the body a medium in which to conduct cellular processes, but it also allows food



supplies to survive for fishing industries, maintains clear water and high organism biodiversity that controls the food webs of life. Proper water levels allow for the functioning of natural climate patterns that dictate conditions on Earth, such as droughts, floods, and natural disasters. My research over the last three years has taken this big picture into consideration, and I have asked specific questions regarding boating activity impacts on organisms from algae to mussels. Learning what allows these natural organisms to surviv

Diagram I

healthily in their ecosystems and ensuring a high biodiversity level is maintained in those like the Tennessee Duck River has broader implications on what human activities, such as boating, are critical to keeping the freshwater supply on Earth. With much research focused on water pollution from industrial wastes to oil spills, research is now being redirected to more analyses on biodiversity [see **Diagram I**]. Knowing whether or not boating is influential in organism behavior within rivers can lead to regulations on boat manufacturers; the boat mechanism that propels the boat forward, whether via propellers or hydroelectric turbines, could be a target in ensuring boat compatibility with the ecosystems directly affected. Furthermore, as scientists and engineers continue to improve water supply levels and quality in third world countries through chemical treatments of volatile organic chemicals and nitrates due to human activity, innovative methods of faucet-purification systems of harsh chemicals and agricultural pesticides could enhance this work. How easy water could be purified with such faucets of that capability! After studying biodiversity of organisms in the Duck River (*Unio* mussels and *Elodea*), I would venture into studies of aquatic ecology, evolution, and migration patterns influenced by human activity. I believe these experiments are united yet interdisciplinary to solve the water issue.

Role of Mathematics

I find it quite abstruse and incomprehensible that many times mathematics and science are differentiated as different subjects, whether it is in the classroom or in the eyes of many individuals within the general public. Mathematics is clearly defined as "the science of numbers and their operations, interrelations, combinations, generalizations, and abstractions and of space configurations and their structure, measurement, transformations, and generalizations. . ." as stated by the Merriam Webster's Dictionary. Mathematics is simply a branch of science that coexists with chemistry, biology, and physics as the general names for investigating and explaining all there is to life.

Mathematics is also a tool that enhances the integrity and definiteness of scientific research by implementing a quantitative approach to an otherwise less reliable and subjective approach that is solely based on observation. While the other forms of scientific research, such as observing, questioning, hypothesizing, and determining the most appropriate procedures and materials, are also central components to the process, so is verifying all that data with some form of mathematics, be it as a structural frame for analysis with statistics or the basis for experimentation as it is with investigating quantum computing.

In the case of my experimentation, I had to learn basic statistical procedures in order to determine whether the data I collected was a result of the changes I implicated on the freshwater ecosystems or due to random chance or some other procedural error. Utilizing a program on a TI-84 graphing calculator called DataMate, I collected dissolved oxygen, and later in the research, turbidity values for accounting the physical and chemical conditions of the system during different periods of stimuli, whether it was a row boat simulation or propeller (two-blade or three-blade structure).

I had to learn and adapt the process of conducting an ANOVA (ANalysis Of VAriance) analysis to determine such factors as p and F values. Without any sort of background in statistics up to that point, I had to study the major components of conducting an ANOVA and translating those results to the significance of the data obtained from the ecosystem. Basically, I was studying and analyzing the data for statistical significance, noting if any changes in the dissolved oxygen, carbon dioxide, or turbidity levels in the ecosystem were a result of my own implications. If supported to be statistically significant, then I was able to be more definitive on my conclusions that resulted. If not, I was given a clue as to what the next step should be: continue experimentation for more trials, alter some aspect of the ecosystem, or completely change a component of the setup. Such results from the statistics portion of the research only enhanced the validity and accuracy of any conclusions made and reinforced the following procedures that I would have to follow up with in order to increase precision and eliminate the ambivalence in any of the results or conclusions in addressing my hypothesis.

Just to reiterate, mathematics is just another subfield of what are generally called the sciences. Specifically within scientific research, in any field, mathematics only enhances the accuracy and precision of data results, no matter the type of experiment conducted. Proceeding further in higher level research studies, I will utilize only more sophisticated methods of not only statistical analysis but a greater variety of mathematical interpretations in any subfield of research, be it in medicine or pharmacy. Thus, no matter what you are interested in, from computer science to environmental management, realize that math is an integral portion to research or your study of the subject. If you find it absent, question the accuracy of what you are studying and identify whether or not math would make the argument stronger. Chances are, it will.

Summary: Independent Research on the Effects of Physical Motions Generated by Various Boating Mechanisms on Freshwater Ecosystems

The research that I have conducted has a strong background in terms of past experimentation. From Mississippi and Minnesota to the Lagoon of Venice, scientists have studied boating impacts on water quality. These related past works have inspired to study a different dimension other than wake zones, pollution by

chemical and metals given off by watercraft, shoreline erosion, and nutrient sediment mixing from the bottom of water bodies. Past research publications have concluded with analyses of indirect and direct effects of ecosystems within these topics. However, my research is entirely focused on dissolved oxygen content of a river ecosystem that results solely from the physical turbulence on organisms' quality of life subjected to these boating activities. It is centered on the conscious efforts to analyze human activities' effect on biodiversity directly, with worries on water quality and depleting water sources. In summary, this research has a unique focus on studying direct, singular boating motion on aquatic plant, animal, and algae species for the purpose of seeing impacts water supply.

More Detail: The Analysis of Boating Motions on Biodiversity: The Duck River

The Tennessee Duck River is one of the most diverse ecosystems in North America. It is also one of the many essential freshwater ecosystems that support human life with clean water, healthy seafood, and profitable fish markets. *Azolla caroliniana* and *Lemiox rimosus* are among two of the many species living in the Tennessee Duck River freshwater ecosystem that are either being threatened or killed by a host of environmental changes caused by human activities. To save these two species, it is necessary to evaluate their response to different water motions caused by various watercrafts. So, to analyze their growth, oxygen production, and overall contribution to a vital ecosystem, similar species, that of *Elodea canadensis* and *Unio crassus* were subjected to two different types of watercraft motion. Throughout three trials each, the *Elodea* and the mussels were individually subjected to rowboat re-suspension of water using an air pump and air line tubing to model an air-mixing-with-water motion, characteristic of the physical labor of paddling in boats used in rivers (such as kayaks). During experimentation, the two species were also subjected to the more disruptive motion of a propeller. The minimal stress of the rowboat was predicted to be beneficial to both plant and animal due to increased air mixing gases into the water. The propeller was inferred to be detrimental with its substantial turbulence in the water body. The growth of *Elodea canadensis* and *Unio crassus* were determined using the amount of dissolved oxygen produced and consumed, respectively, measured using a dissolved oxygen test kit. These experimental data were then compared to the data of the dissolved oxygen of the freshwater ecosystem with no additional watercraft activity. Contrary to what was hypothesized, the row boat stimulus caused the *Unio crassus* to decrease the amount DO produced. The mussels, which are sensitive to stress and remain closed if they feel threatened, were negatively affected by the vibrations of the bubbles on the surface of the water. The row boat stress proved to benefit the *Elodea*; the plant, which is used to stress in natural rivers, produced more oxygen as a result of the added air mixing in carbon dioxide into water. Also contrary to what was hypothesized, the propeller stresses benefited the *Elodea canadensis*: again the plant is accustomed to river stress and may benefit from slight water resuspension. However, for the mussel, it was easier to maintain DO levels if there were no additional stresses that prevented it from moving (which requires opening its shell). Overall, both the row boat stress and the propeller allowed the aquatic plant *Elodea canadensis* to match and increase its oxygen contribution to the stressed environment. In addition, both the propeller and row boat stresses inhibited the *Unio* mussels' ability to produce enough oxygen that would be essential to the ecosystem. Thus, both general motions were concluded to have different impacts on an aquatic plant and animal species; the plant was able to sustain greater stress and benefit from it more so than the animal was.

Detailed Results

The dissolved oxygen values collected and analyzed with the saltwater samples of the first study were relatively inconclusive, in regards to directly addressing the hypothesis that the propeller would more negatively affect the alga *Fucus vesiculosus* than the rowboat simulation (air stone and air line tubing) would. The results are documented below in the **Results Appendix** on page 14.

These data show great fluctuations and uncertainty, which is a reason why nothing can be determined from them, except for the fact that the boating motions have some effect on the alga's production of oxygen. (Figure II) As seen in Figure I, the positive control could not meet the dissolved oxygen levels of the experimental variables; this demonstrated the difficulties without temperature regulation in the tank.

Based on the comparisons of the dissolved oxygen values (second study) for the negative and positive controls to the manipulative variables due to two stresses, the initial hypotheses were both supported and rejected. Based on Tables I and II, the average dissolved oxygen content of the *Unio crassus* in their natural current environment was approximately 10 parts per million, ppm. Both additional stresses decreased the amount of oxygen in the water; the DO levels decreased from 10 ppm to 9.3 ppm due to both the rowboat and propeller as independent factors. In addition, Table II demonstrates the immediate and prolonged effects of the propeller stress on the ability for the mussels to utilize oxygen. Initially, the DO remained about the same as it did in the natural current; however, once the stress was implicated for a continuous 45-minute cycle, the DO level decreased to 9.3. Thus, it supports the overall trend of the propeller's negative impact on the mussels to live comfortably in the environment. Using more oxygen, they are reducing the DO levels of the water; since DO is such a critical component for all aquatic life, lower levels of DO put stress on the ecosystem. This has occurred to the mussels subjected to a row boat and propeller stress.

Additionally, the analysis of continuous and noncontinuous stress implied by the propeller was utilized to determine whether or not prolonged stress affected the ability for the mussels to engage in healthy, natural, living in the ecosystem. As seen in the bar graph in Graph I below, against initial belief, prolonged stress was actually beneficial to the mussels. The noncontinuous nature of the propeller stress allowed the DO level to fluctuate in the ecosystem; this rapid fluctuation added even greater stress to the mussels, who by nature, react to feeling. The mussels were not adapted to behaving normally when their environment was in rapid change.

In contrast to the stresses' impact on the *Unio crassus*, the row boat and propeller allowed the *Elodea Canadensis* to meet the dissolved oxygen level of its natural environment, and in the case of the propeller implication, the *Elodea* was able to increase the amount of DO in the water: in other words, the aquatic plant was able to photosynthesize naturally despite the motion stresses. The comparisons that were made to decipher the effects on the *Elodea* can be seen in Tables III and IV (see **Results Appendix**, page 15).

Once again, the prolonged effect of the propeller stress was analyzed, this time, on the aquatic plant. The consistent DO levels for the *Elodea* at 10 ppm indicate that prolonged stress did not affect the ability for the plant to photosynthesize. Furthermore, the graphical interpretation of the two stresses on the *Elodea canadensis*, shown in Graph II, demonstrates that the plant was not affected in terms of producing an appropriate amount of oxygen for the water ecosystem. The minimal range of DO levels, from 9.6 ppm to 10.0 ppm, indicates that the stresses did not inhibit the plant's state of health in the water ecosystem.

The minimal motion generated by both the row boat and propeller did not generate enough kinetic energy to increase the water temperature itself. If it did, the amount of DO to remain in the water as a soluble gas would decrease, and thus, the levels of DO would read to be lower than what is healthy. In larger vessels that could contribute a significant temperature change to the water, the support of appropriate temperatures despite watercraft becomes essential to the analysis of motion effects on wildlife. Graph III clearly shows the inverse relationship between temperature and dissolved oxygen; thus, even in aquatic environments subjected to watercraft motion, temperature continues to play a vital role in the ecosystem's DO level and vivacity.

Conclusions

The row boat stress decreased the amount of oxygen the *Unio crassus* mussels could maintain by 0.1 ppm (0.1mg/L). In the same way, the propeller's resuspension of the water caused the mussels to decrease oxygen production by 0.1 ppm (0.1mg/L). The negative effects on the mussels were greater than that on the *Elodea*. The *Elodea canadensis* was able to produce more oxygen with the added stress of both the row boat and propeller. The *Elodea* did in fact benefit more from the row boat stress than did the *Unio* mussels. Thus, in summary, boating motions have varied effects on different aquatic species, from those of plant to animal. The contrast in the ability of *Elodea canadensis* to increase dissolved oxygen water concentrations suggested that aquatic plants are more tolerable to external stresses. The *Unio crassus* mussels, feeding and moving with their shells open, were susceptible to physical stress that caused them to stay closed for a longer period of time. The watercraft stresses of the row boat and propeller allowed them to remain closed and decrease their metabolic activities, thus, decreasing the levels of dissolved oxygen consumed in the water. The biodiversity of organisms in ecosystems such as those of the Duck River has been affected in terms of different species of aquatic life.

Most Recent Experimentation: Summary

With the global population growing at an exponential rate, water is a simple polar molecule that doesn't get too much credit, despite providing clean water for drinking, bathing and other sanitation purposes, fresh seafood, and a power source. Human activities more than ever are taking their tolls on the environment, but it is the physical motions generated by watercraft that are at the focus of this research. A freshwater ecosystem was constructed that focused on freshwater mussel species; a twenty gallon aquarium was fitted with a piece of glass plate and suction-cupped water pumps to flow water in a circular motion within a rectangular tank. Freshwater mussels of the species *Unio crassus* and *Elliptio complanata* were subjected to the surrounding environment of two different types of recreational boating propellers, one being a two-blade boat propeller and the other, a three-blade model. Analyzing the water samples of the ecosystem, recording dissolved oxygen (mg/L) with a dissolved oxygen probe, carbon dioxide concentrations (mg/L), turbidity (NTU) with a spectrophotometer-like device, and pH, the river quality was closely monitored. DO levels remained as consistent as those of the natural current no matter the number of blades on the propeller there were; two blade propellers maintained a closer environment to that of a natural current as opposed to the three blade ones that decreased CO2 concentrations, an indication of lower cellular respiration in *Unio crassus* and *Elliptio complanata.*

Acknowledgements

This research could not have been possible without the continual guidance of my two mentors, Mr. Jeremy Stanton and Mr. Robert Toegel. Mr. Stanton provided support in terms of idea formulation and aid in lab obstacles, in addition to having proofread this summary of research. Mr. Toegel's aid with building a proper propeller system was invaluable. Thanks is also warranted to Mr. O'Donnell for his cooler that allowed me to conduct this experiment, as well as to Dr. Judith S. Weis, a professor and marine researcher at Rutgers University-Newark, whose expertise in her field allowed me to accurately perform this research. Finally, the monetary aid of the Young Science Achiever's Program in correspondence to the MIRTHE program at Princeton University made this possible.

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Results Appendix

FIGURE I

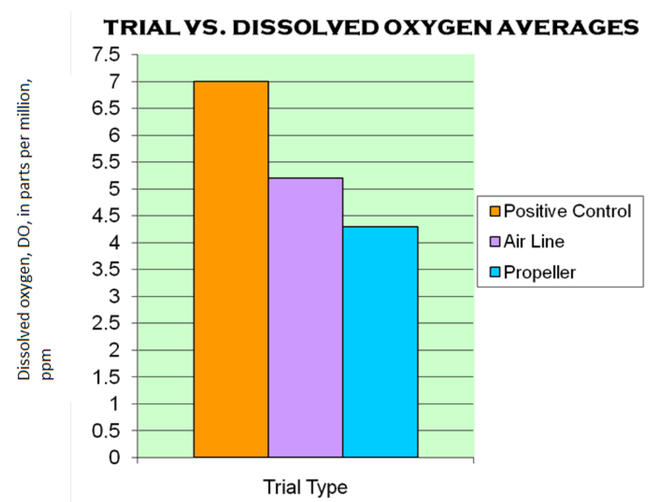


FIGURE I This graph plots a line showing the amounts of dissolved oxygen in the water during the positive control experimentation (natural current in saltwater with *Fucus vesiculosus*). The algae was interpreted to be living quite healthily in its natural current, of the Hudson River. After stabilizing in the environment, the algae contributed to a fairly constant increase in the amount of DO in the tank.

FIGURE III

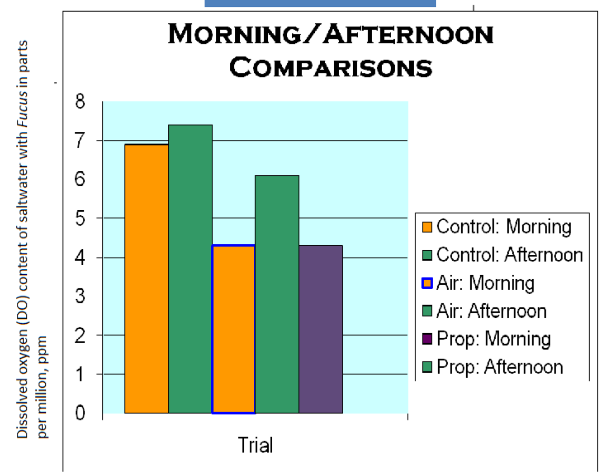


FIGURE III This bar graph shows the comparison between the morning and afternoon values of DO in each saltwater environment during the respective trials. Note that the propeller does not have a value for the afternoon due to the fact that it was not numerically significant to use in comparison.

FIGURE II

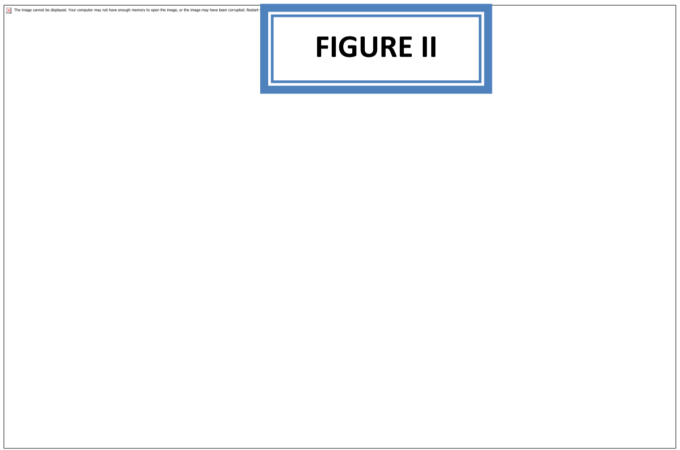


TABLE I

Unio crassus subject to Row Boat Stress

Negative Control (rowboat)	Pos[illegible]	Experimental Variable [illegible]oat/*Unio crassus*)
9.9	[illegible]	9.4
9.6	[illegible]	10
10	10	9.4
9.6	10	9.2
9.8	9.9	9.2
9.8	9.8	9.3
10.1	9.9	9.1
10.2	10	9.1
9.9	10	8.7
9.9	10.0	9.3

TABLE II

Table II: A Comparison of the Dissolved Oxygen Levels of Experimental Trial: *Unio crassus* subject to Propeller Stress

Negative Control (propeller)	Positive Control (mussels)	Experimental Variable (propeller/*Unio crassus*)
9.4	10	9.8
8.8	10	9.4
9.4	10	9.4
9	10	10
9.2	9.9	10
9.4	9.8	9.6
9.9	9.9	9.6
9.5	10	9.3
9	10	9.3

Key: 🟥 Dissolved oxygen levels 30 minutes after stress initiation 🟩 Dissolved oxygen levels 45 minutes after stress initiation

TABLE III

Table III: A Comparison of the Dissolved Oxygen Levels of Experimental Trial: *Elodea canadensis* subject to Row Boat Stress

Negative Control (rowboat)	Positive Control (*Elodea canadensis*)	Experimental Variable (rowboat/*Elodea canadensis*)
9.9	9.5	9.7
9.6	9.5	9.8
10	9.8	10.0
9.6	9.2	10.0
9.8	9.2	10.0
9.8	9.3	10.0
10.1	9.9	10.0
10.2	9.9	10.0
9.9	10.0	10.0
9.9 (av)	9.6 (av)	9.9 (av)

GRAPH I

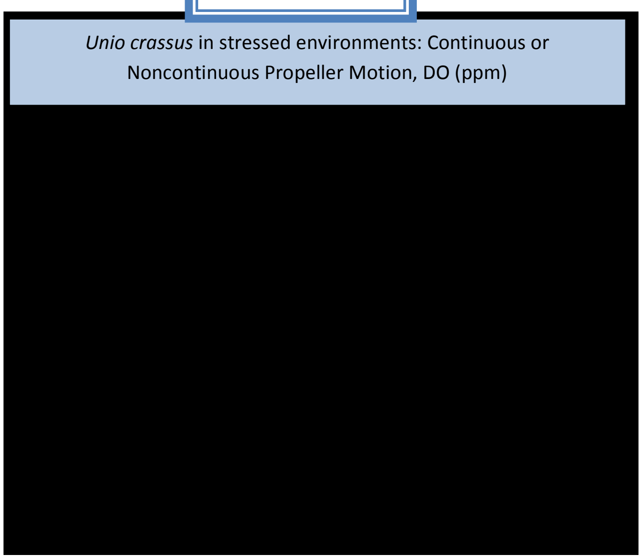


TABLE IV

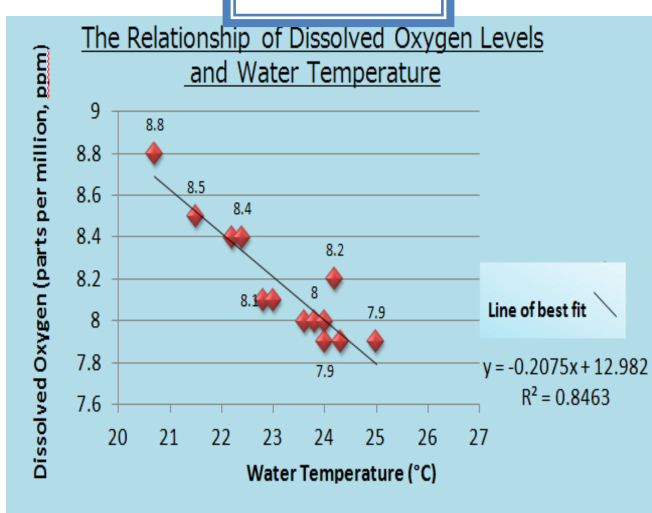
Table IV: A Comparison of the Dissolved Oxygen Levels of Experimental Trial: *Elodea canadensis* subject to Propeller Stress

Negative Control (propeller)	Positive Control (*Elodea canadensis*)	Experimental Variable (propeller/*Elodea canadensis*)
9.4	9.5	10.0
8.8	9.5	10.0
9.4	9.8	10.0
9	9.2	10.0
9.2	9.2	10.0
9.4	9.3	10.0
9.9	9.9	10.0
9.5	9.9	10.0
9	10.0	10.0

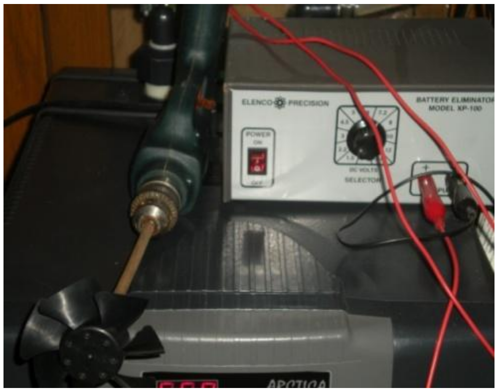
Key: 🟥 Dissolved oxygen levels 30 minutes after stress initiation 🟩 Dissolved oxygen levels 45 minutes after stress initiation

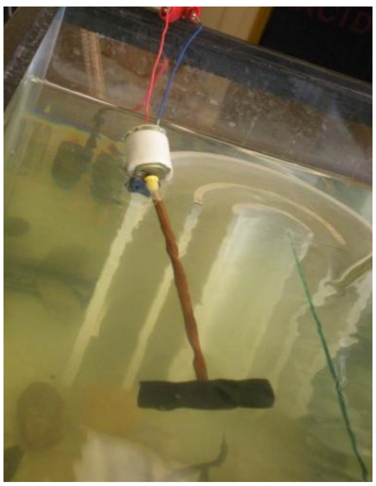
GRAPH II

GRAPH III



Experimentation Apparatus Appendix





Unio crassus was stored in a separate tank of distilled water before being subjected to experimentation.

The entire procedure used for *Unio crassus* was duplicated for *Elodea canadensis.*

A closer view of the suction-cupped air pumps on the side of the glass tank: they allowed for a continuous water flow simulating that of a river.

The cooler maintained a constant temperature of approx. 15 degrees Celsius for a stable ecosystem home to living organisms.

The air pump connected the air line tubing to a filter inside the tank.