Project Summary

Project Title: An Analysis of Fish Attraction and Oxygen Sanctuary Creation Utilizing Newly Developed Oxygenation Techniques

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Abstract

A significant cause of unproductive fish populations in water bodies is low dissolved oxygen (DO). Several factors cause low DO at the bottom of an enclosed water body including lack of photo-oxygenation due to limited light and reduced reaeration due to a decrease or an obstruction of water circulation. Low DO in bottom water causes many detrimental effects in aquatic organisms including decreased reproduction, increased susceptibility to disease, and mortality.

This work will utilize a developmental oxygen delivery device capable of delivering water supersaturated with oxygen directly to the bottom of a water body. Prior research has shown the DO delivered by the device completely remains in solution and is only lost through aerobic biological processes. The device will be deployed to a regional lake, and its capabilities to produce a sanctuary of high DO water in lower levels of the water column will be tested. Fish response to the oxygen plume will be examined, and the potential for using this device for fish attraction and oxygen sanctuary production will be determined.

An Analysis of Fish Attraction and Oxygen Sanctuary Creation Utilizing Newly Developed Oxygenation Techniques

Undergraduate Researcher
Mentor:

Background

Similar to terrestrial animals, fish and other aquatic organisms require oxygen to perform metabolic activities. Aquatic organisms obtain oxygen from microscopic oxygen gas bubbles, or dissolved oxygen (DO) in water, which passively diffuses into an aquatic organism's bloodstream. The rate of oxygen diffusion depends on the concentration of dissolved oxygen in the water. If too low a DO concentration exists, fish and other aquatic life can experience decreased reproduction, hampered swimming ability, increased susceptibility to disease, and mortality (Ricklefs and Miller, 2000).

Both physical and biological processes govern DO in a volume of water. Oxygen enters a water body through contact with the atmosphere in a process known as reaeration (Chambers and Mill, 1996). During reaeration, atmospheric oxygen passively diffuses into water across the surface boundary of a water body because of the oxygen concentration gradient existing between air and water. Oxygen also enters a water body through plant photosynthesis according to the reaction $6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2$ in a process referred to as photo-oxygenation (Ricklefs and Miller, 2000). Oxygen is consumed from the water during aerobic respiration by aquatic life including bacteria, algae (during dark respiration), and fish.

In a body of water the lowest concentration of dissolved oxygen is typically found at the lower levels of the water column. In deep bodies of water, light cannot reach bottom water levels preventing photo-oxygenation (Phang, 1991). During summer months, temperature stratification can occur, preventing circulation between cold bottom water and warm surface water, and thereby not allowing bottom water access to the atmosphere. Also, the majority of oxygen consumption occurs at the bottom where sunken organic mater accumulates and decomposes through aerobic processes (Deas and Orlob, 1999). The difference between DO concentrations at the surface and the bottom of a water body can be significant. During times of great temperature stratification or when ice covers the surface and prevents reaeration, the bottom waters of lakes can become anoxic.

All aquatic organisms require a specific level of DO. For a lake to be productive for a specific species of fish, the DO concentration must be adequate at a water level where the water temperature is desirable for that species. Since cold water fish species require low temperature water to survive, they typically congregate at the bottom of a water body during warm weather months, making many lakes unproductive or deadly to the fish if DO levels at the bottom drop too low (USEPA, 1973). Introducing large quantities of oxygen to the bottom of a water body may provide oxygenated sanctuaries that could potentially attract fish and allow them to survive and even thrive during low DO periods.

Objectives

The objectives of this project are to:

1 Investigate the feasibility of providing oxygen sanctuaries at the bottom of a representative lake using a newly developed oxygenation technique.

2. Determine the effects of the oxygen plume on attracting and sustaining populations of fish.

Methods

Injecting bottom water with DO will be done using the *Portable Water Ecosystem Oxygenator* designed by Osborn, Matlock, and Teltschik[1]. This device has been proven

[1]The *Portable Water Ecosystem Oxygenator* is patent pending. For the sake of brevity, full operating details will not be discussed in this document.

effective to deliver oxygen to water bodies at a rate 12 times faster than bubble aeration using 1/6 of the energy (Osborn, 2004). A National Science Foundation SBIR grant has been received for further developing this device for wastewater treatment, and prior research has proven the device capable of treating remotely located water bodies. The oxygenator supersaturates water with oxygen by atomizing high pressure water within a vessel containing high pressure oxygen gas. The device is then able to deliver water supersaturated with dissolved oxygen to any location in a water body with low DO (Osborn, 2004). Since the device can inject oxygen a great distance away from the physical location of the unit in the form of micro-bubbles that rise much slower through the water column, the oxygenator allows treatment of bottom lake waters without disturbing the surface.

Field tests completed during research this summer with an Honors College Undergraduate Research Grant have proven the device is capable of delivering a precise mass of oxygen to a water body with virtually no DO loss to the atmosphere. The research, conducted on local streams, has also shown the device is capable of creating large plumes of water saturated with oxygen that diminish only as biological processes consume the DO. During the research it was observed, but not quantified, that fish migrated upstream to the source of oxygen. The device is the first aeration tool with the potential to raise and sustain the DO of water at the bottom of a body of water. Funding through a SURF grant will allow an undergraduate to conduct the first field trials with the *Portable Water Ecosystem Oxygenator* for this application.

The *Portable Water Ecosystem Oxygenator* will be deployed on Lake Atalanta in Rogers, Arkansas. A cooperative agreement has been established with the City of Rogers Department of Parks and Recreation to pursue this research. Officials have agreed to provide initial support for this project. Lake Atalanta features several optimal criteria for determining fish response to bottom water oxygenation including: a wide variety of fish of both cold water species – trout – and warm water species – bass, bream, catfish; an observed inability to support trout during summer months likely due to low DO bottom water; and observed thermal stratification potentially creating relative high and low DO regions due to cold spring water inflow and atmospheric temperature variations.

Prior to deployment, a depth, temperature, and oxygen concentration profile will quantified for Lake Atalanta using a boat, GPS unit, and DO probe. Based on the profile, two sites will be selected to oxygenate. One site will represent a region having a relatively saturated DO – likely a site near the inflow of the spring, and one site will represent a region of relatively low DO – likely a site near the bottom in the middle of the lake.

The device will then be transported and set up at the site. The oxygenator will be operated for a period of time at the lake while adjusting its working set points to achieve optimal oxygenation. During this preliminary test, observations will be made regarding the oxygen plume including its volume, DO, and movement. Parameters including DO, temperature, depth, and position will be taken before, during, and after running the device so to quantify to extent and duration of the oxygen plume.

Once the data has been analyzed and the behavior of the oxygen plume is more clearly understood, the device will be deployed at each of the predetermined sites. The magnitude of fish concentration in the oxygen plume will be measured using a wide area sonar device. The number of strikes reported by the sonar device will represent the number of fish in a given area. Images of the sonar screen will be taken for further analysis. Sonar fish tallies, as well as DO, temperature, depth, and position, will be made one day before, two hours before, during, two hours after, and one day after each deployment. Fish numbers will be taken directly in and around the entire volume of the oxygen plume. Sonar measurements will also be taken before and after the deployment in areas outside the reach of the oxygen plume to give any indication of fish movement to the plume.

Following all deployments, data will be analyzed to indicate any change in fish concentration as the device is deployed. Data regarding the oxygen plume characteristics will also be further analyzed. A literature review will then be conducted to investigate the potential of the device to create oxygen sanctuaries and to attract fish. An economic study will also be preformed to weigh the cost benefit ratio of using the device for such tasks.

Significance of Research

The *Portable Water Ecosystem Oxygenator* is capable of more effectively oxygenating water systems than traditional aeration processes. The technique employed by this device is unique in that it can maintain an oxygen rich environment at the bottom of the water column. The device could be used to prevent fish mortality and associated water quality problems, increase the productivity of fish for aiquiculture and recreational activities, and assist in fish population studies. In addition to the data collected, the research venture will be an extremely valuable learning experience. This research will not only allow me to put the knowledge obtained in class into real practice, but will accelerate my educational experiences and propel me to strive toward future research opportunities. The work will allow me to combine my personal interests in fishing and outdoor activities with engineering design research to create technological solutions to environmental problems.

Project Schedule

Jan 2005 through April:

This time period will be used to prepare for all deployments. Trips will be made to Lake Atalanta and officials from the city of Rogers will be contacted to determine water conditions, access points to the lake, and electricity delivery. Delivery rates required of the oxygenator will be assessed and operating adjustments will be made to make the device ready for the specific deployment sites. All preparatory measures before actual deployment will be taken during this time including programming the data acquisition probes, acquiring a sonar device, preparing field equipment, and accumulating supplies.

April through May

The preliminary deployment will be conducted during this time. Prior to, during, and following the oxygenation process, data will be collected as previously outlined. From this data, the volume, duration, and concentration of the oxygen plume and the oxygenator operating set points will be examined.

May through July:

During this period, the two deployments will be conducted. As aforementioned, oxygenation and fish count analysis will be conducted during this time.

July – October

Analyses of oxygenation and fish response will continue. The literature review and economic analysis will be preformed. Results will be compiled and examined, and conclusions drawn. An article on the project will be written hopefully to be included in a peer-reviewed publication.

References

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