How Will Warming River Temperatures Affect Aquatic Ecosystems?

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Abstract

To grasp a better understanding of climate change, we conducted an experiment that compares river temperatures to dissolved oxygen levels. If river temperatures rise then dissolved oxygen (mg/L) levels will decrease, because as water heats up, its molecules move faster, which weakens the bonds between the molecules and dissolved oxygen, allowing oxygen to return to the atmosphere. To test this hypothesis, collect water from a local freshwater source and obtain a dissolved oxygen kit and a thermometer. Record the dissolved oxygen level and temperature in a data table on the laptop. Repeat this procedure for four trials, each spaced about one week apart, which ensures trials from differing conditions, and more accurate results. To conclude, as river temperatures rose, the dissolved oxygen levels went down. To put our results into context, we assessed how these trends could impact local aquatic ecosystems; as when an ecosystem faces low dissolved oxygen levels it may lead to stress, decreased growth rates, alterations of food webs/balance, migration changes, and even death.

Introduction

If river temperatures rise then dissolved oxygen (mg/L) levels will decrease, because as water heats up, its molecules move faster, which weakens the bonds between the molecules and dissolved oxygen, allowing oxygen to return to the atmosphere. The rationale for beginning this project was due to the rising concern regarding climate change, and in greater context, the way that global warming is happening worldwide, causing ocean and river temperatures to rise. These issues are being brought to attention by nature preservation organizations, environmentalists, and social movements led by youth, who have rising concerns for the welfare of the environment. Understanding the dynamics of anthropogenic climate change and the potentially harmful conditions it creates are key to protecting all aquatic organisms, from microscopic plankton to large fish and mammals. This understanding would allow for the ability to develop strategies to conserve the environment.

Global warming is the ultimate cause that is endangering our ecosystems, and if climates continue to worsen, dissolved oxygen levels will decrease progressively, affecting many essential aquatic organisms and eventually will pose the threat of extinction or endangerment of many species. Many things contribute to global warming, but pollution from human activity seems to be the most significant. National Geographic (2019) states, “Current levels of the greenhouse gases carbon dioxide, methane, and nitrous oxide in our atmosphere are higher than at any point over the past 800,000 years, and their ability to trap heat is changing our climate in multiple ways.” The amount of foreign substances being released into our world is concerning, and these pollutants come from more than many believe.

The majority of these greenhouse gases come from fossil fuels; which is the burning of resources like coal, oil and natural gas for electricity, and heat and transportation; like cars, factories, and power plants. “Worldwide emissions of carbon dioxide (CO_2) from burning fossil fuels total about 34 billion tonnes (Gt) per year. About 45% of this is from coal, about 35% from oil and about 20% from gas.” (World Nuclear Association, 2024) This makes up about 40% of all pollutants released into the atmosphere unnaturally each year, with the levels only increasing. Another way pollutants are emitted is through acidification, or when the ocean absorbs carbon dioxide from the atmosphere. This changes the pH of the water, making it more acidic. Acidic oceans make it difficult for corals, oysters, and other shellfish to build and maintain their calcium carbonate shells and skeletons, which can potentially lead to their decline. Also, methane, an extremely potent gas, is released into the environment from landfills and agriculture. This gas accounts for almost 30% of all pollutants released, and is able to displace and crowd out the oxygen molecules that are being produced, leading to less oxygen. (IEA, 2022) “The gases let light through but then keep much of the heat that radiates from the surface from escaping back into space, like the glass walls of a greenhouse. The more greenhouse gases in the atmosphere, the more dramatic the effect, and the more warming that happens.” (National Geographic, 2019) It is also important to note that the ocean absorbs around ¼ of the carbon dioxide emitted from unnatural practices yearly. The reason for preserving nature and limiting pollutants is because all of these gases being released are limiting oxygen levels, and not only affecting all organisms, but even faster impacting the aquatic ecosystems-since warm water cannot hold as much oxygen as cold water.

Rising ocean and river temperatures, driven by the accumulation of greenhouse gases and human-induced pollution, have been shown to affect both freshwater and marine ecosystems in multiple ways. Poff (2002) states, “Aquatic and wetland ecosystems are very vulnerable to climate change. The metabolic rates of organisms and the overall productivity of ecosystems are directly regulated by temperature. Projected increases in temperature are expected to disrupt present patterns of plant and animal distribution in aquatic ecosystems.” Coral bleaching is happening nationally, due to the rising temperatures. When water is too warm, corals will get rid of the algae living in their tissues which causes the coral to turn completely white. (NOAA, 2024) The EPA (2025) states, “Increased ocean temperatures and changing ocean chemistry are the greatest global threats to coral reef ecosystems. These threats are caused by warmer atmospheric temperatures and increasing levels of carbon dioxide dissolved in seawater.” They continue to share that the reefs are dying out, and are extremely important in ecosystems because they serve as homes and protection. The warmer temperatures are killing off important producers like microscopic algae, which are an essential food source for thousands of species. Marine food webs are actively being changed, causing many species to respond to food web alterations such as: shifts in range, distribution, migration routes, and diet. It also may have physiological consequences, like changes in body condition and health as well as influencing exposure to predation, pathogens, toxins, and risks associated with human activities, which affects reproductive success and survival.

To conclude, rising temperatures from global warming are decreasing dissolved oxygen levels in aquatic ecosystems, threatening species and disrupting food webs. Pollution, especially from greenhouse gases, worsens these effects. Reducing fossil fuel use and pollutants is essential to protect ecosystems and ensure a sustainable future.

Methods and Materials

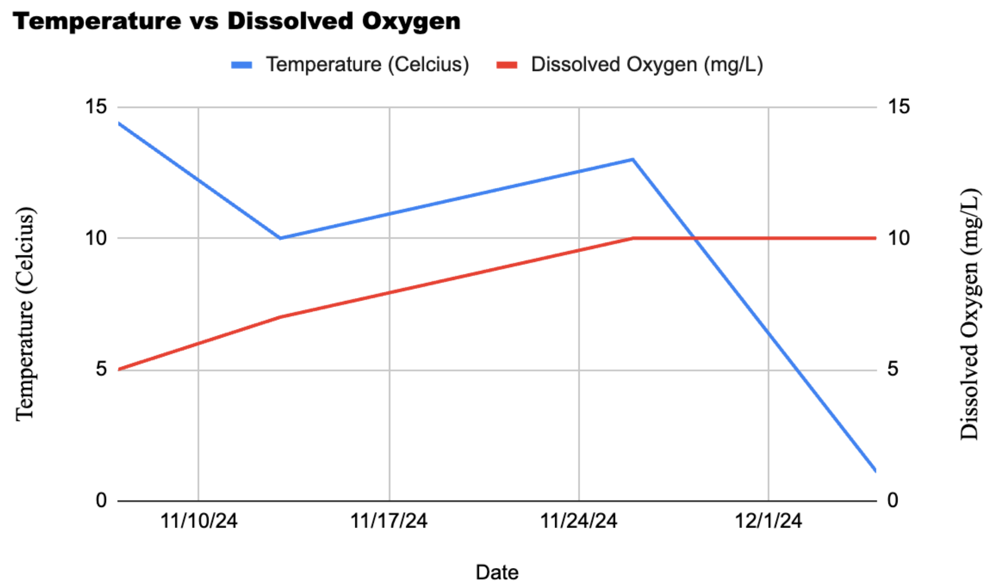
To conduct this experiment, materials that were used include, a dissolved oxygen kit and probe from CHEMetrics model R-7512, a laboratory style thermometer, a water bucket, a local freshwater source, a beaker, a pipette, and a computer. Use the dissolved oxygen protocol and the water temperature protocol from GLOBE.gov.

To measure dissolved oxygen levels, start by collecting water from a local freshwater source in a bucket, filling it about halfway. Next, obtain a dissolved oxygen kit and a thermometer. Begin the dissolved oxygen measurement by taking a clean beaker and filling it with 25 mL of the water sample. Insert the clear reactant-filled probe into the beaker, ensuring the small tip is placed at the bottom. Once the tip breaks, allow the fluid in the probe to change color for approximately five seconds. Then, remove the probe from the water, gently tip it up and down about 5 to 10 times to ensure a consistent color. Compare the color's saturation to the provided testers. Then, record the dissolved oxygen level in a data table on the laptop. To measure the temperature, place the thermometer into the bucket of water and wait for the temperature to be consistent. Once the temperature is consistent, record the temperature on the thermometer in the data table on the laptop. Repeat this procedure for four trials, each spaced one week apart, which allows for the tracking of data over time.

Before collecting water from a site, check for pollution or toxins that could potentially be harmful. When collecting the water, make sure to do it carefully and wear proper clothing. Be sure to break the tip of the dissolved oxygen probe in the water and when you dispose of it, make sure there are no tiny pieces of glass left behind that could cut someone.

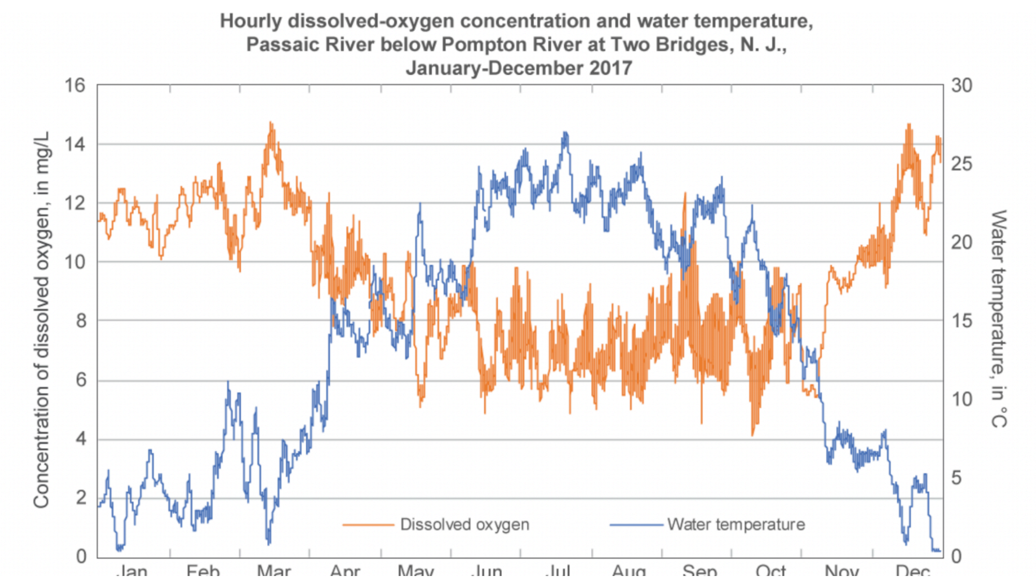
To analyze our data we created graphs and tables comparing the tests to each other as well as to outside sources. We will also use statistical analysis like standard deviation and standard error of the average.We collected data over 4 different trials. In each trial we sampled 25 mL of water and determined dissolved oxygen levels, as well as temperature data for each of the 4 trials. The number of trials is N=4.

Presentation of Data and Results



Graph 1. Temperature versus dissolved oxygen data. Collected by Alexa Potts and Aurora Puskala.

Graph 1 above shows the relationship between the dissolved oxygen and temperature data collected. On November 7, 2024 the temperature was 14.4 degrees celsius and the dissolved oxygen was 5 mg/L. On November 13, 2024 the temperature was 10 degrees celsius and the dissolved oxygen was 7 mg/L. On November 26, 2024 the temperature was 13 degrees celsius and the dissolved oxygen was 10 mg/L. On December 5, 2024 the temperature was 1.1 degrees celsius and the dissolved oxygen was 10 mg/L. Overall, the trend is when the temperature decreases, the dissolved oxygen levels increase. We have one outlier, that is on November 26, 2024 when the temperature was at 13 degrees celsius (an increase from the last measurement) the dissolved oxygen level was 10 mg/L (also an increase from the last measurement.) Reasons for this outlier could be human error in measuring either the temperature or dissolved oxygen levels, instrumental error where the temperature probe could have been faulty or the dissolved oxygen kit was defective, or the sample could have been taken in a different location of the river where there was a more abundant source of aquatic plants producing dissolved oxygen.



Graph 2. Hourly dissolved-oxygen concentration and water temperature collected by USGS.

Looking at this outside source (*Graph 2*, USGS), we can compare our data to the data collected by USGS to have a better understanding of our data and research question. In this data set, when the temperature increases, the dissolved oxygen decreases and we can see this over a long period of time. The overall trend of the graph is similar to our data except for the fact that more data was collected in their experiment, allowing the trend to be more clear and their findings to be more accurate. Based on this and our data that we collected, we can assume that if we had collected more data over a longer period of time, we would see the same overall trend that USGS displayed.

Conclusion

After completing all procedures and looking into the causes and effects of climate change, we have obtained a greater understanding of global warming and its impact on aquatic ecosystems. Significant temperature changes are frequently overlooked, yet they pose a threat not only to the environment but to all organisms within these ecosystems. To better understand the severity of this issue, we conducted an experiment that analyzed the relationship between temperature fluctuations and their impact on dissolved oxygen availability for aquatic species. From our data, we were able to draw the conclusion that as temperatures rise, dissolved oxygen levels decrease. To keep this experiment as accurate as possible, we controlled the area from where samples were collected, used the same temperature probe and dissolved oxygen kit consistently, and ensured data was collected at persistent times of day. We displayed our data as a line graph, and were able to visually compare and analyze the relationship between temperature and dissolved oxygen on select days. This allowed us to identify a trend between the two environmental variables, and compare our findings with other published data, and theoretical values, which frequently showed similar results. The United States Geological Survey (USGS) found similar results after recording data from the Passaic River, although it was over a much longer period of time. Our data also aligns with the theoretical values that suggest similar outcomes due to the fact that warmer water holds less oxygen, and the idea that in warmer temperatures organisms have higher oxygen demand. To put our results into context, we assessed how these trends could impact local aquatic ecosystems; as when an ecosystem faces low dissolved oxygen levels it may lead to stress, decreased growth rates, alterations of food webs/balance, migration changes, and even death

Discussion

If we were to do this project again, there are several ways that it could be improved. First, the data would be more accurate and clear if the data was collected over a longer period of time and more frequently. For example, collecting data 3 times per week for a year. Next, we could have taken three different measurements each time we collected data so we could get the average of the temperature or dissolved oxygen levels per water sample, allowing the data to be more precise and accurate. We also could have collected more data from other freshwater sources and compared them to each other to ensure our experiment's consistency. Our results, although not over a long period of time, still hold a significant amount of meaning that goes well beyond the classroom, as all nations are being affected by global warming and climate change-which is a severe threat. The stress from warming waters and lower dissolved oxygen levels are getting worse daily, and pushing many ecosystems into critical situations, and irreversible damages. A recent study by the Environmental Protection Agency (EPA) demonstrated the many dangers for aquatic ecosystems regarding rising temperatures on an organism's oxygen supply/well being. They were able to conclude that low dissolved oxygen is directly correlated to respiratory distress in aquatic organisms, and leads to the death of many species; like mayflies, stoneflies, caddisflies, and salmonid fish. (EPA, 2024) It also prevents important oxidation and redox reactions, which are essential for the availability of inorganic compounds. Without sufficient dissolved oxygen levels, and reduced inorganic compound availability, many species can't maintain a healthy metabolism. This can cause a chain reaction of issues including; decreased growth, stress, and even death/extinction. If we don't raise awareness and take action, these issues will continue to accelerate, and over time lead to mass fish and species killings. The EPA also states; "Certain human activities, such as agricultural, residential, and industrial practices, can contribute to DO depletion (or, less frequently, DO supersaturation) and subsequent biological impairment" (EPA, 2024). We can act by reducing chemical contaminants, organic loading, fertilizers, landfills, and resource degradation; while promoting sustainability, improving waste management, conserving biodiversity, and restoring ecosystems.

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