The Impacts of Freeze-up on Dissolved Oxygen and Fecal Coliform

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Abstract

Water quality is one factor in the health of aquatic ecosystems. Dissolved oxygen is an important water quality parameter because it is essential for the survival of fish and other aquatic organisms that live in the ecosystem. In this investigation, I focused on how the process of freezing on a lake system in Fairbanks, Alaska affects water quality factors, dissolved oxygen and fecal coliform bacteria. The research question at the forefront of this project asks how the freezing of lakes affect dissolved oxygen and fecal coliform concentration. To carry out this investigation at different sites within one of the Tanana Lakes in Fairbanks, Alaska, I measured dissolved oxygen concentration in mg/L using Vernier Connect DO Probe and collected three water samples for fecal coliform bacterial analysis with Petrifilm Plates. After collecting data, I should see that the dissolved oxygen concentration will increase after the lakes freeze over. As far as fecal coliform is concerned, I expect to see a decrease in fecal coliform bacteria concentration as lakes freeze over. After conducting my investigation, I have concluded that the results weren't consistent enough to support my hypothesis and answer the research question. Further sampling is needed to accurately compare the data of dissolved oxygen and fecal coliform bacteria concentration in lakes at the time of freeze-up.

Question/Hypothesis

- The research question at the forefront of this project asks how the freezing of lakes affect Dissolved Oxygen and Fecal Coliform concentration. Dissolved oxygen is of interest because through the process of respiration, these aquatic organisms take in oxygen in order to survive, and other organisms, like bacteria use dissolved oxygen to decompose organic matter. Fecal coliform bacteria is paired with dissolved oxygen in this investigation because the feces that contain this bacteria consumes oxygen, and a high level of coliform bacteria could decrease the dissolved oxygen concentration of a body of water.

- Based on what we know about how oxygen is influenced by temperature, we should see that the dissolved oxygen concentration increases with a decreased water temperature. With Fecal Coliform concerned, we should expect to see decreased levels of bacteria when water temperature is influenced by freeze-up.

Introduction

Water quality is important when assessing how a specific ecosystem functions with a wide variety of environmental factors. Dissolved oxygen is an important component of water quality, due to the fact that a stable level of dissolved oxygen ensures that the organisms have a survivable habitat. Many types of bacteria can reduce the dissolved oxygen level, and the presence of fecal coliform bacteria can have a similar effect. The presence of fecal coliform bacteria, like E. coli creates a water quality issue due to the harmful effects of the bacteria on humans. In this Investigation, I focused on how the process of freezing on a freshwater habitat affects water quality factors, dissolved oxygen and fecal coliform bacteria. This experiment is of interest because knowing how these water quality factors are impacted by freeze-up can give land managers an insight on how to set certain water quality standards. Some of these standards include boiling water to kill fecal coliform bacteria, and ice fishing limits in areas with low dissolved oxygen levels. The concentration of dissolved oxygen is of interest because the change in oxygen levels can influence the overall water quality of a lake. If the dissolved oxygen concentration isn't at a susceptible level, that threatens the lives of organisms within the freshwater habitat. There are a variety of fish species that are stocked in the Tanana Lakes system, but rainbow trout are the most prevalent. Low levels of dissolved oxygen can negatively affect rainbow trout populations, but a dissolved oxygen level of 3 mg/l or less is fatal (Matthews and Berg. 1996). When there is open water on the lake, the dissolved oxygen concentration is heavily influenced by interactions between the atmosphere and elements of the water column (Zdorovennova et al. 2021). Open water increases the rate of photosynthesis in the lake and the overall dissolved oxygen level of the waterbody, so freeze-up would decrease the amount of open water and potentially decrease dissolved oxygen levels.However, cold water holds more dissolved oxygen than warm water. Since Tanana Lakes is heavily used for recreational purposes, such as swimming, fishing, boating and ice skating, the presence of fecal coliform bacteria is important to study year round. Similarly to dissolved oxygen, fecal coliform is influenced by environmental changes, and bacteria counts are expected to be influenced by freeze-up. This is due to the fact that coliform bacteria have a higher survival rate during the winter than during the summer (Davenport et al. 1976).

Research Methods

Planning Investigations

- To carry out the experiment, my plan was to collect data at Tanana Lakes ice fishing site, a freshwater lake in the Fairbanks area. For my site, I took samples at different locations around the lake around the time of freeze-up. Depending on the ice thickness of the lake, I collected my first set of samples near the ice skating area (Figure 1.), about 15 feet off the shore. If there was a layer of ice, I planned to drill through the ice with an ice auger and collect the dissolved oxygen concentration with a Vernier DO probe. To test for the presence of Fecal Coliform at each sampling site, 3 water samples were to be collected in 10 ml vials. After being stored in a refrigerator for several hours, the 3M Petrifilm plates were to be used to determine the number of coliform bacteria colonies and E. coli colonies present in each sample. I also planned to do Fresh Eyes on Ice GLOBE Observer Land Cover observations. I planned on taking samples about a quarter mile off the shore of the boat launch and then duplicating the experiment a few weeks later at the same locations to compare and contrast the data.

Figure 1. Aerial view of the first sampling site, which is the ice skating area, as marked by a pin

Figure 2. Photo of the first sampling site, which is about 15 ft off the shore

Carrying Out Investigations

To start the data collection, I went out to Tanana Lakes and concluded that the ice was 2-3 inches thick, which was just enough to walk on close to the shore at the ice skating area. After cutting a hole in the ice, I used the DO probe to collect the Dissolved Oxygen at that site, and the data was then uploaded to my phone using the Graphical Analysis app. I then collected 3 water samples in the vials described above and gave each vial the proper label. After collecting the samples, I made a Globe land cover observation. At my next site (pictured below), I walked a quarter mile away from the boat launch to collect samples where less humans have traveled. After further evaluation of the site, I discovered that this boat launch area is a slough connected to the Tanana River.I proceeded to follow the same procedure as above when collecting the samples, and performing the land cover observation. Back in my makeshift lab, I began to test my water samples with the Petrifilm plates. I applied 1 ml of water from each sample into separate plates, and followed the appropriate guidelines for using the Petrifilm plates. After applying all of the samples to their appropriate plate, the plates were stored at room temperature while the test was in progress. Three weeks later, I was able to go out to the same two sites and tried to duplicate my original experiment. Due to complications, I was only able to collect dissolved oxygen data at the ice skating area, which also means that no new water samples were collected to test for fecal coliform bacteria.

Results

Analyzing Data

After the data collection process was completed, it was time to collect my results. The dissolved oxygen data showed interesting results, especially the data collected on the first day. From the two sites, their respective DO concentrations had differed significantly, as depicted in the graph in Figure 5. Site 1 are the samples collected near the ice skating area and site 2 was the sample that was taken a quarter mile past the boat launch site.Site 2 DO levels dropped rapidly from the start and the trend reached equilibrium at 1.42 mg/L. This level is hypoxic and does not support life. As depicted in the graph, Site 1's DO concentration was much higher than site 2's, and the median DO concentration was 13.61 mg/L. The median DO concentration for site 1 three weeks later on the second day of sampling was 15.33 mg/L. The dissolved oxygen levels increased after 3 weeks, but not drastically. This level of dissolved oxygen is optimal for salmonids, which thrive in colder waters with high dissolved oxygen concentrations.

After all the plates were done testing for bacteria colonies, the results were surprising. Out of the six samples collected from two different sites, every one of them reported fecal coliform colonies, but Ice Skate 3 showed a suprising amount of colonies, and this result will be discussed more in the discussion.

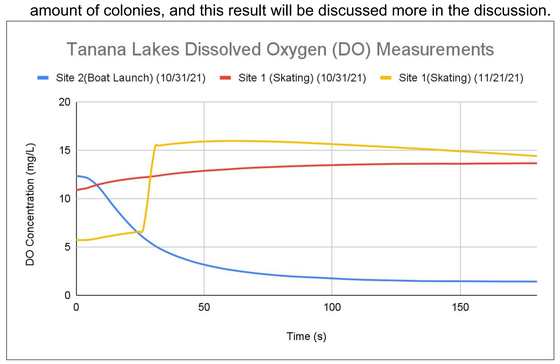
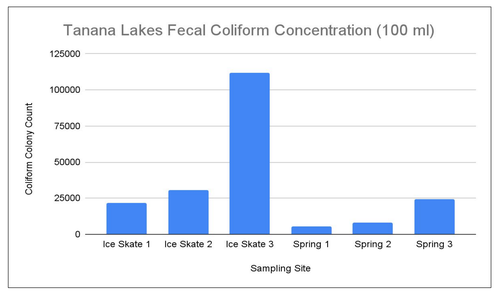


Figure 5. The dissolved oxygen concentration at site 2 is at fatally low levels, and can't support fish populations in that area. The dissolved oxygen at site 1 on both sampling dates are at the optimum levels to support fish populations.



Discussion

Interpreting Data

The results from this experiment helped answer the research question in various ways with different environmental factors heavily influencing the results. Site 1 and site 2 had a substantial difference in dissolved oxygen concentrations and there is a possible explanation for this. Site 1 is located on Tanana Lakes and isn't directly connected to any streams, but site 2 is actually a slough that connects to the Tanana River. Due to sloughs usually having more flow than a lake, the slough should have a much higher dissolved oxygen concentration than the data showed. After analyzing the environmental characteristics of site 2, like the extremely low dissolved oxygen concentration and overflow of water, these signs possibly suggest that site 2 is a methane bubble source. The main indicator that this is a methane bubble source is the low dissolved oxygen level from the seepage of methane.

As far as the fecal coliform bacteria is concerned, the number of colonies collected from a 1 mL water sample is surprising, but when the data is multiplied by 100, it surpasses the allowable amount of fecal coliform bacteria for recreational purposes. Visually, the charts that represent fecal coliform bacteria counts are substantially different per sampling site, but not statistically different. In this investigation, there is some possible sources of error. Due to equipment constraints, a new syringe wasn't able to be used for every sample. Even though a new syringe was used for the two sites, they had to be flushed out with distilled water for each sample per site. It is a possibility that some of the bacteria wasn't completely rinsed out before the syringe was moved to the next water sample.

Conclusions

- In my investigation, my results were thought provoking, but not conclusive, especially when Dissolved Oxygen is concerned. The dissolved oxygen data at site 1 doesn't completely confirm that dissolved oxygen levels increase as lakes continue to freeze over. As far as site 2 is concerned, it can't be confirmed that the site is a methane bubble source. Further sampling must be done at the location, like techniques that can test for the presence of methane.
- The biggest takeaway from the fecal coliform investigation is that each water sample had a large amount coliform bacteria colonies, especially in the areas that are used for recreational purposes, like ice fishing.

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