**Hardwired for Efficiency?**

**The Effect of DOC on Bluegill Feeding Efficiency**

Charmaye OldElk

Advisor: Dr. Todd Crowl

Little Bighorn College, Crow Agency Mt.

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Land O'Lakes, WI 54540

charmayeoldelk@yahoo.com

**Abstract**

This study describes how different levels of DOC affect fish feeding efficiency. Using Super Hume to simulate different DOC concentrations, I conducted feeding trials using Bluegill fish from both a light-colored lake and a dark-colored lake and Daphnia. The goal was to determine which fish was the most efficient feeder in the different DOC levels. The results showed DOC did not affect their feeding efficiency. The results were similar to the hypothesis I had in the beginning that the high DOC fish that was placed in the low DOC tank would have eaten more than the other fish.

**Introduction**

Lakes around the world are increasing in concentrations of dissolved organic carbon (Monteith et al. 2007). Dissolved organic carbon, also known as DOC, is made up of organic compounds less than 0.45 micrometers. DOC plays a serious role in protecting aquatic plants and animals from the toxic effects of x-ray energy contact (Schindler and Curtis 1997). DOC also changes the lake color dark brown, a concept known as browning (Monteith et al., 2007). This affects the organisms that live in lakes by lowering oxygen and blocking the light from penetrating the lake (Stasko et al., 2012). This increase in DOC comes from leaf fall, run off, and increased carbon dioxide emissions from climate change (Monteith, et al. 2007). DOC is important to study because the aquatic system of the lake is affected by what is happening in the terrestrial system (Polis, et al. 1997).

Bluegill fish are native to North America, where they can be found in streams, lakes and ponds. They usually hide in or around old tree stumps or other underwater objects. They like to find shelter in submerged plants and in the shade along the banks. When bluegills are small, they seem to weigh more, but as their height increases their weight decreases. Bluegills mostly feed on small aquatic invertebrates known as zooplankton. Bluegills play a very important role in the food web by controlling primary consumers, the zooplankton (Hambright and Hall 1992). This experiment will use bluegills because they are easy to maintain in the lab.

DOC makes it harder for bluegills to find their prey (Stasko, et al. 2012). Bluegills are visual predators and DOC affects the light availability in the lake. My project will investigate whether bluegills from a dark lake have adapted to the dark lake or if they are simply eating less. I would like to know how DOC affects Bluegill feeding efficiency. What happens if a bluegill acclimated to a certain level of DOC is transplanted into water of a different color?

I predict that my most efficient feeders will be the fish from Hummingbird Lake placed in a light tank, because those bluegills are adapted to feeding in the dark, but by putting them in the lighter water, it will be easier for them to feed. I predict that my least efficient feeder will be the fish from Bay Lake placed in a dark tank because the bluegills from Bay Lake are adapted to light DOC but by placing them in the high DOC; it will make it harder for them to feed. I would expect that the bluegills placed in their normal DOC concentrations will not feed as effectively as the dark fish placed in light tank, but they will be more effectively then the light fish in the dark tank.

**Materials and Methods**

*Organism Collection*

In order to test bluegill feeding efficiency, I caught bluegills from both high and low DOC lakes. My high DOC Lake was Hummingbird Lake, with a concentration of 19.53mg/L. My low DOC

Lake was Bay Lake, with a concentration of 5.26mg/L. I placed five minnow traps in each lake to collect the bluegills. I used a vertical tow net to collect zooplankton (Daphnia) from Bay Lake.

*Feeding Trial Setup*

In the lab I set up four 1-liter tanks, two with low DOC and two with high DOC. I used Super Hume to simulate high (approximately 25mg/L) and low (approximately 6mg/L) DOC concentrations. After I collected the fish from the field, I placed them in 4-gallon acclimation tanks for 24 hours to clear their digestive system. I also recorded length (cm) and weight (g) for each bluegill.

I had collected many fish from Bay Lake, but not many from Hummingbird Lake, just enough for me to do five trials. I used two fish from Bay and two fish from Hummingbird Lake per feeding trial. I placed one fish from Bay Lake in a low DOC tank and one fish from Hummingbird Lake in a low DOC tank. I also placed one fish from Bay Lake in a high DOC tank and one fish from Hummingbird Lake in a high DOC tank. For each feeding trial, I added 50 Daphnia per tank. Trials were replicated five times.

*Data Collection*

After each trial, I would filter the tank water through a fine mesh filter and pour the remaining results in a container. Then I would take it back to the lab and count the remaining Daphnia using a microscope. Then I would subtract the number of Daphnia that I counted from the original total of 50 to determine the number of daphnia that the fish consumed.

*Statistical Analysis*

I ran two different statistical analyses. First was a linear regression statistic to see if either fish body length or weight was a significant factor in determining how much a fish ate.

The second statistical analysis I used was an independent two-sample t-test to see if the fish from different lakes had different feeding efficiency in each DOC level.

**Results**

As both body length and body weight increased, the number of daphnia consumed also increased (Figure 1 and Figure 2, respectively). But the linear regression was not significant for either (length, $R^2$ = 0.058; p=0.305; weight, $R^2$ = 0.090; p=0.196). The p-value indicates that body length or weight was not affecting bluegill feeding.

The most efficient feeders were the fish from Hummingbird Lake that were placed in a low DOC tank (Figure 3). In the high DOC tank, both fish from Bay and Hummingbird Lakes ate approximately the same number of daphnia. The difference between them was not significant ($p>0.05$). In the low DOC tank, Hummingbird fish ate more daphnia than the Bay fish, but the result was not significant ($p>0.05$).

**Discussion**

When I started the trials I had my mind set on my original project question: does DOC affect bluegills feeding efficiency? Then a couple trials into the project, I was not seeing the results I predicted, so I got to thinking of other ideas that could affect my results. I thought that maybe bigger fish would eat more and smaller fish would eat less. When analyzing the mass and length of the fish, however, it turns out that fish size was not disturbing the fish feeding efficiency. This result means that DOC is the only thing affecting the fish.

I predicted that my most efficient feeders would be the fish from Hummingbird Lake placed in a light tank because the bluegills were adapted to feeding in the dark, but by putting them in the lighter water, it would be easier for them to feed. The most efficient feeders were who I thought it was going to be in the first place. It is possible that the Hummingbird fish had adapted to the darker water color, but by placing him in the light DOC, it is almost like someone had turned the light on.  This result suggests that fish in high DOC lakes are not just eating less because they need less food.  They might be eating less because their food is harder to find.

I predicted that my least efficient feeders would be the fish from Bay Lake placed in a dark tank because the bluegills from Bay Lake were adapted to light DOC but by placing them in the high DOC, it would make it harder for them to feed. My prediction was incorrect.  The least efficient feeder happens to be the fish from Bay lake that was in the low DOC tank.  I think this is because those fish were so adapted to those conditions that they did not even try to find their food within the trial time.  They were so comfortable that they assumed the Daphnia were not going anywhere.  With a longer trial time, maybe I would have seen the results I predicted.

Both fish from Bay and Hummingbird Lake that were placed in the high DOC tanks ate more than the Bay fish that was placed in the low DOC tank. In lakes, Daphnia come out only at night to eat. The fish must fight for their food in the lake so the result is maybe that the fish from Bay Lake that was placed in high DOC simulated to the night and the Bay fish ate a lot. The fish from Hummingbird Lake were immune to the DOC and had at equal amount of Daphnia than the Bay fish that was placed in the high DOC.

To improve this study, I could have made the trial time longer to improve the results. I could have run more than one trial on the same fish to see if the results were different. For future similar research, I could place two fish from different lakes in the same DOC level tank to see who eats more. Another trial might be to see who has the best survival rate in either high or low DOC level. I could also research which fish from each lake is the alpha in each DOC level.

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**Figures**

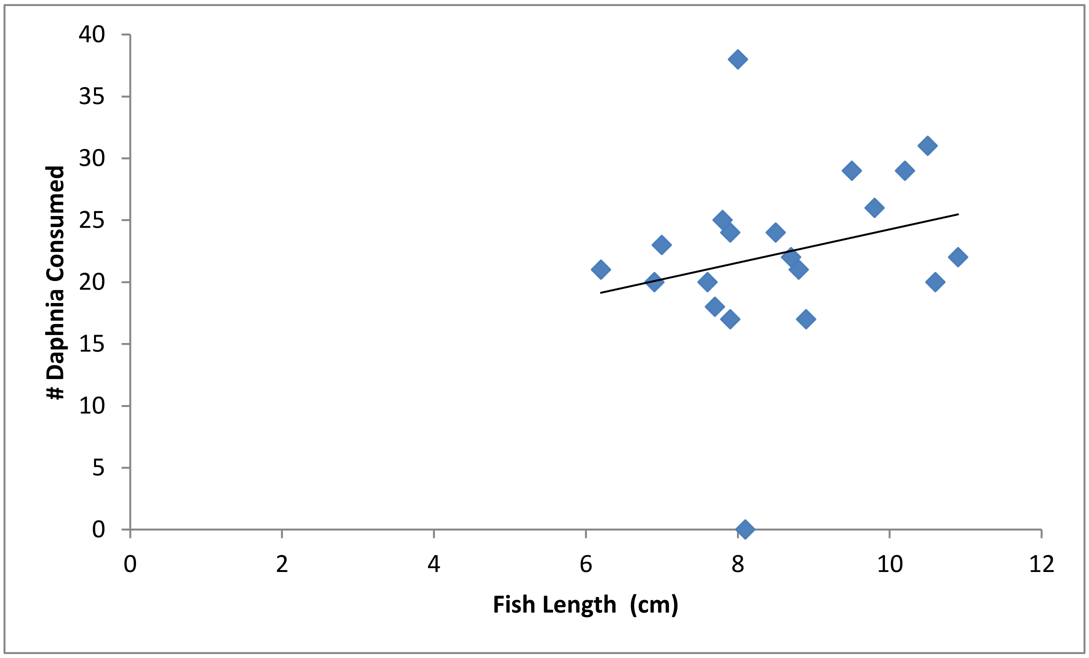


Figure 1. The relationship between fish length and the number of Daphnia consumed ($R^2$ = 0.058; p=0.305).

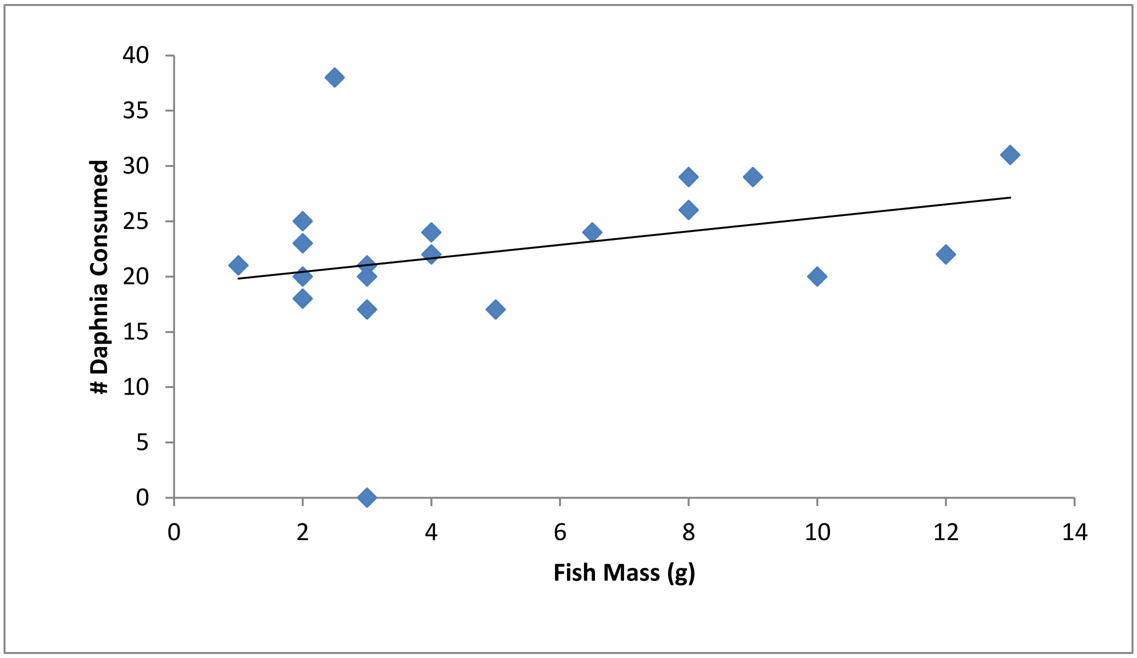


Figure 2. The relationship between fish mass and the number of Daphnia consumed ($R^2$ = 0.090; p=0.196).

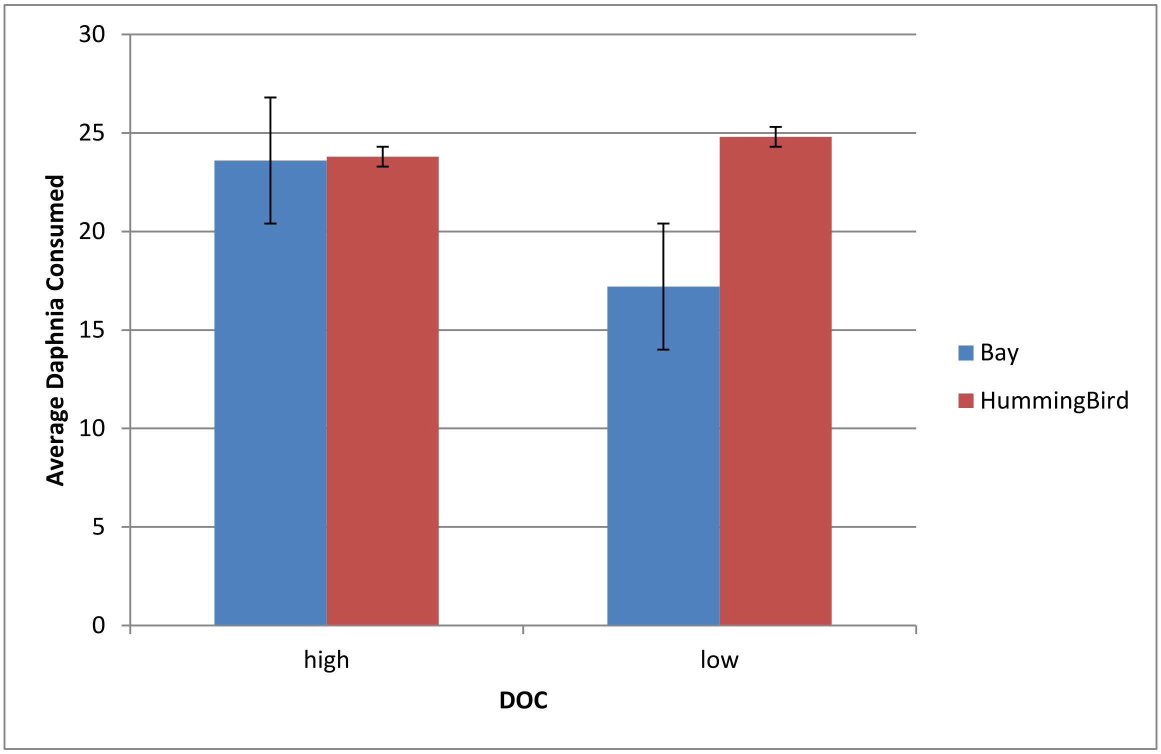


Figure 3. Average number of Daphnia consumed by Bay and Hummingbird fish in high or low DOC. In the high DOC tanks the average number of Daphnia consumed was not significantly different (p=0.95). In the low DOC tanks the average number of Daphnia consumed was not significantly different (p=0.212). Error bars represent standard error.