Evaluating the effect of DOC concentration on feeding rate of juvenile yellow perch *(Perca flavescens)*

Chelsea Nobriga

Mentor: Stuart Jones

2011

BIOS 33502-01: Practicum in Field Biology

University of Notre Dame Environmental Research Center - East

7645 Notre Dame Lane, Land O'Lakes WI 54540

Abstract

Dissolved organic carbon (DOC) levels have been on the rise since the beginning of the 1990’s. DOC serves as an important source of energy for aquatic microorganisms and also plays a role in the establishment of a body of water as a sink or source of carbon dioxide. As such, aquatic ecosystems are quite sensitive to changes in DOC concentrations. Additionally, DOC reduces light penetration and thus visibility in the water. For planktivorous fish, increased DOC reduces their visual field and their ability to encounter prey. To examine whether feeding rate of juvenile yellow perch was affected by water color, I conducted feeding trials with tanks that contained different concentrations of DOC. Feeding rates of juvenile yellow perch was affected by the color of the water. By quantifying the change in zooplankton concentration across a 90 minute feeding period, we found feeding rates to be significantly reduced in the dark tank compared to the light tank (p=0.003). These findings are consistent with previous studies which asserted that when turbidity increases, encounter rate of fish and fish feeding behavior decreases. As a major prey and predator in the trophic cascade of aquatic ecosystems, planktivorous fish have major significance. If the feeding behavior of planktivorous fish changes, then we will witness compounding effects in the entire food web. Further investigation on the effects of DOC on size selectivity and predation risk will be crucial in building a well-rounded understanding of the effects of DOC on aquatic fish communities.

Introduction

Dissolved organic carbon (DOC) is generally defined as organic molecules of variable origin and composition found in aquatic ecosystems. Since the early 1990's there has been a noted increase in dissolved organic carbon levels across North America and Europe (Sucker and Krause 2010). Levels of dissolved organic carbon in British freshwaters ecosystems have steadily risen over the past two decades (Roulet 2006). In addition, bog ecosystems, due to terrestrial carbon loading, show a continuous accumulation of C at an average rate of 20–30 g C m−2yr−1 over the past 5000–10 000 years (Weidman *et al.* 2006). With current increases in DOC levels on a continental scale, it is crucial to understand the effect of this increase in DOC on aquatic ecosystems, especially on the resident fish and zooplankton populations and communities. These environmental changes have been responsible for alterations in the physical aquatic environment. The change in water color due to increased DOC appears to inhibit the response of primary producers to nutrients and thus will inherently affect other trophic levels within the environment (Carpenter 2001).

Absorption and scattering of light by suspended particles in turbid waters limits visibility in aquatic ecosystems (de Robertis *et al.* 2003). This scattering of light by suspended particles reduces apparent differences in brightness between an object and its background, thus decreasing visibility of the object. DOC serves as an important source of suspended particles in aquatic ecosystems. Thus, an increase in DOC concentration reduces light penetration in water by darkening the color to a brownish hue and increasing turbidity (Sucker and Krause 2010).

Turbidity is especially important in altering the physical environment of shallow or sheltered areas in aquatic ecosystems (Bonsdorff *et al.* 1997). Many juvenile planktivorous fish species take refuge in the littoral area, and are especially vulnerable to changes in turbidity and visibility. While juvenile planktivorous fish are capable of nonvisual feeding without great visibility they are significantly more efficient in an environment with adequate light (Ryer and Olla 1999). Feeding success affects growth and development of juvenile planktivorous fish and thus influences survival capability (Bannister *et al*. 1974). As important components of aquatic trophic cascades and food webs, any adjustment in the feeding behavior of planktivorous fish will have compounding consequences for the entire balance of the ecosystem.

The premise of the project is that high concentrations of carbon discolor lakes. The discoloring or staining of the lake water blocks available light and thus will affect the ability of fish to see their prey. I set up tank experiments to explore the effects of terrestrial carbon concentrations on the prey consumption of juvenile planktivorous fish. With higher DOC concentrations, the surrounding aquatic environment will become discolored and thus block available light. With less ambient light, the predators' (planktivorous fish) vision will be impaired, and consequently will have reduced prey consumption. I hypothesized that feeding rates of juvenile yellow perch (*Perca flavescens)* will be lower in tanks with higher concentrations of DOC as compared to the feeding rates in tanks without added DOC.

Methods

Planktivore Collection and Holding

Juvenile *P. flavescens* were collected from Brown Lake with a seine. Given current natural densities, twenty juvenile yellow were trapped for each of the three respective trials (Jones unpublished). The fish were contained together in a holding tank prior to their dispersal into the experimental tanks. Following IACUC protocol, dissolved oxygen and temperature levels were monitored in order to maintain suitable living conditions and to reduce shock. In order to mimic natural abiotic features, dissolved oxygen was kept between 8mg/L and 10mg/L and temperature was preserved at 18^0C to 20^0C.

Experimental design

The majority of my experiment took place in the Aquatic Lab at UNDERC. There were a total of three tanks, two experimental tanks and one holding tank. Each tank had a total volume of 1113.842 L, which helped to establish the amount of Super Hume necessary to darken the “dark” chamber. Immediately before experimentation, the juvenile perch will be conditioned and starved within their tank environments for about 12 hours (de Robertis 2003). There will be two experimental chambers, one “light” and one “dark.” The “light” experimental chamber will have a dissolved organic carbon concentration of about 8mg/l, which mirrors the natural DOC concentrations in Tenderfoot Lake. It is considered “light” in color because lakes with lower DOC concentrations generally have higher water clarity and are bluer in color (Pace and Cole 2002). The “dark” experimental chamber will have a dissolved organic carbon concentration of about 17mg/L, which was formulated by adding 9 mg/L to that of the natural concentration in Tenderfoot Lake. It is considered “dark” in color because lakes with higher DOC concentrations have higher humic and fulvic acid concentrations, which color the lakes brown (Pace and Cole 2002). Super Hume will be the means of increasing tank DOC concentrations and was acquired from UAS of America. Both tanks will be filled with water from Tenderfoot Lakes, which reflects a DOC concentration about 8mg/L. DOC of each experimental tank, assessed as color of water, will be measured using a spectrophotometer. Zooplankton assemblages were removed from Tenderfoot Lake between 8am and 9:30am, in order to account for any migration that the zooplankton might exhibit. Zooplankton density was also quantified prior to experimentation to ensure the prey density was not significantly different. To standardize the length of the lake perch, we only utilized juvenile yellow perch between 8.5 and 10.5 cm in length. The mean length of the fish per experimental tank ranged between 9.42 +/- SE 0.169 cm to 9.56 +/- SE 0.20.

After the feeding period ended, each fish was euthanized with an overdose on MS-222. MS-222, tricaine methane sulphonate, was elected due to its solubility in fresh water and efficiency in killing small numbers of fish (Close 1995). In addition, it is the only manner of killing fish that is approved by the IACUC. As a result, I quantified prey consumption by taking ten integrated tows in each experimental chamber after feeding had finished. The ten tow samples were concentrated using the zooplankton net. Five 2 ml subsamples were taken from each of the two combined tow samples, one for the “light” chamber and one for the “dark” chamber.

To calculate individual feeding rate for each of the two tanks, I took the difference between the initial zooplankton density and the remaining zooplankton density. I then divided this difference by ten to measure individual feeding rate of the ten fish. To change the units into zooplankton per hour, I divided by 1.5 hours.

Statistical Tests

I analyzed the experimental results with a two-sample t-test. I elected a two-sample t-test because I intended to assess whether the mean feeding rate for the two normally distributed populations was equal. The two normally distributed populations were the two tanks, “light” and “dark”. I also ran a Shapiro-Wilk test to assess the normality of the mean feeding rates in both the dark and light tanks.

Results

The mean feeding rate of 10 yellow perch after 90 minutes of feeding in the dark and light tanks was significantly different (Figure 1). There was a significant decrease in feeding rate in the tank with a higher DOC concentration, the dark tank (p=0.003, df=4, t= -6.4). The fish in the dark tank had a lower feeding rate (89.4 +/-SE 21.6) than the light tank had (285.6+/- SE 23.7). All the data was normally distributed based on the Shapiro-Wilk test (p=0.2).

Discussion

My findings demonstrate that DOC concentrations do affect planktivorous fish feeding rates (Figure 1). Specifically, planktivorous fish had reduced feeding rates in the tank with higher concentrations of DOC (p=0.003). This is consistent with previous studies on how turbidity or decreased light penetration negatively affects fish feeding rate. One explanation is that juvenile planktivorous fish in the face of turbidity or loss of visibility have been shown reduced feeding rates (Vinyard 1976). If their visual field is impaired, fish, as visual consumers, will be less able to distinguish their prey and thus will have reduced prey consumption.

In regards to the actual feeding rates, the mean feeding rate for both the light and dark tanks were slightly high. The average feeding rate in the dark tank was 89.4 zooplankton per hour +/- SE 21.6 and the mean feeding rate in the light tank was 285.6 zooplankton per hour +/- SE 23.7. One probable explanation for the high feeding rates is that I did not fully recover all the remaining zooplankton with the integrated tows in the tank. Thus, I overestimated the feeding rate. However, it is important to note that this methodological error was consistent across treatments. Even though our feeding rates were higher than expected, our treatment is still robust.

One must remember that juvenile yellow perch serve two purposes in the trophic cascade, prey and predator. My tank experiments did not examine the predation aspect and how turbidity might influence the ability of juvenile lake perch to evade predation. In his study, De Robertis concluded that moderately turbid waters may be advantageous for planktivorous fish because their encounter rates with zooplankton are less reduced by turbidity than their encounter rates with the piscivorous predators (de Robertis *et al*. 2003). In addition, piscivorous feeding is significantly more sensitive to turbidity than is the prey consumption of planktivorous fish (de Robertis 2003). Future work should consider these interactions in the context of DOC.

Another interesting area of study would be prey size selectivity as a function of DOC concentrations. In regards to size selectivity, since planktivorous fish feed voraciously and consume the larger size classes of zooplankton, any fish will selectively choose larger zooplankton (Gardner 1981). Thus, size selectivity has also been found to be independent of turbidity and loss of visibility (Vinyard and O'Brien 1976). Fish utilize past encounters with zooplankton to determine whether they will ignore or eat the prey and use this method for size selection (Gardner 1981). While turbidity has been considered to be independent of size selection, it must also be noted that when past encounters with zooplankton decrease, the prey have less knowledge about prey density and thus eat all zooplankton encountered. When past encounters with zooplankton increase, the prey knows the density of the zooplankton community and thus preferentially chooses the larger prey. Past encounters with zooplankton would decrease in a water body that has less light penetration and is darker in color. The issue of size selectivity warrants further investigation and would be better evaluated by dissecting the digestive tract of the experimental fish.

While the effects of turbidity and visibility on aquatic ecosystems have been thoroughly examined, more study should investigate the impacts of terrestrial carbon. Since the terrestrial carbon and water cycles do interact on many temporal and spatial scales, it is crucial to understand the consequences of each cycle on the other (Ball *et al.* 1987). Accurate quantification of carbon exchange at the landscape level is extremely important to determine carbon stock in the ecosystem and to more fully understand the carbon cycle. The current focus of terrestrial DOC transport to lakes is on microbes and food web use of terrestrial carbon as a resource. However, as I have found, it can also impact fish behavior and feeding rates.

Conclusions

Increasing DOC concentrations have been noted in many freshwater ecosystems across North American and Europe. As a major component of aquatic processes, DOC has numerous implications for the surrounding ecosystem. In this particular study, it was determined that prey consumption decreases when DOC concentrations increase. The mechanism behind this finding is that like turbidity, increased DOC levels decrease visibility in aquatic communities by decreasing light penetration and apparent contrast. While my experiment was limited in scope by including only one type of planktivorous fish, I anticipate that my findings will be generally relevant for this specific trophic level. The influence of predation on prey consumption of planktivorous fish and the idea of size selectivity serve as interesting areas of future study.

Acknowledgments

I would like to thank my mentor, Stuart Jones, for his support in the creation and execution of my research project. His knowledge of yellow perch, aquatic ecosystems, and terrestrial carbon were critical in the development of the project. I would also show my appreciation for all the work that Heidi Mahon did to allow my project to progress efficiently. Whether it was help setting up the experimental tanks, locating necessary field instruments, or collecting integrated tows; Heidi was always ready and willing to help. In addition, I would like to acknowledge the Bernard J. Hank Family Endowment for their financial support of my research efforts. Finally, I give thanks to all my cohorts in the UNDERC class of 2011 for their emotional support and willingness to lend a hand. I am specifically indebted to Casey Smith and Jake Zwart for their respective contributions.

References Cited

Ball, J. T., Woodrow, I. E. and Berry, J. A. 1987. A model predicting stomatal conductance and its contribution to the control of photosynthesis under different environmental conditions. In: *Progress in Photosynthesis Research* (ed. J. Biggins). Martinus Nijhoff Publishers, Dordrecht, 221–224.

Bannister, R. C. A., D. Harding & S. J. Lockwood, 1974. Larval mortality and subsequent year-class strength in the plaice (*Pleuronectes platessa* L.). In Blaxter, J. H. S. (ed.), The Early Life History of Fish. Springer-Verlag, New York: 21–37.

Bonsdorff, E., E. M. Blomqvist, J. Mattila & A. Norkko, 1997: Long-term changes and coastal eutrophication. Examples from the Åland Islands and the Archipelago Sea, northern Baltic Sea. - Oceanol. Acta 20: 319-329

Carpenter SR, Cole JJ, Hodgson JR, Kitchell JF, Pace ML, Bade D, Cottingham KL, and others. 2001. Trophic cascades, nutrients, and lake productivity: whole-lake experiments. Ecol Monogram 71:163–86.

Close, Bryony et al. 1995. Recommendations for euthanasia of experimental animals: Part 2. Working Party.

de Robertis, A., Ryer, C. H., Veloza, A. and Brodeur, R. D. (2003). Differential effects of turbidity on prey consumption of piscivorous and planktivorous fish. Canadian Journal of Fisheries and Aquatic Sciences 60(12): 1517-1526.

Gardner, Mark B., 1981. Effects of Turbidity on Feeding Rates and Selectivity of Bluegills. Transactions of American Fisheries Society. Volume 110: Issue 3.

Nurminen, Leena, and Jukka Horppila. "Efficiency of Fish Feeding on Plant

attached Prey: Effects of Inorganic Turbidity and Plant-mediated Changes in the Light Environment." *Limnology & Oceanography*, 51.3 (2006): 32.

Pace, M. L., and J. J. Cole. 2002. Synchronous variation of dissolved organic carbon in lakes. Limnology and Oceanography 47:333–342.

Roulet et al. 2006 Nature, 444: 283-284

Ryer, C.H., and Olla, B.L. 1999. Light induced changes in prey consumption and behavior of two juvenile planktivorous fish. Mar. Ecology Program Ser. 181: 41-51.

Sucker C., and K. Krause. 2010. Increasing:dissolved organic carbon concentrations in freshwaters: what is the actual driver? iForest 3: 106-108.

Vinyard, G. L; O'Brien, W. J. 1976: Effects of light and turbidity on the reactive distance of bluegill (Lepomis macrochirus). Journal of the Fisheries Research Board of Canada 33: 2845-2849.

Weimin, Ju, Jing Chen, Andrew Black, Alan Barr, Harry McCaughey, and Nigel

Roulet. "Hydrological Effects on Carbon Cycles of Canada's Forests and Wetlands." *Tellus: Series B*, 58.1 (2006): 16-30.

Figures

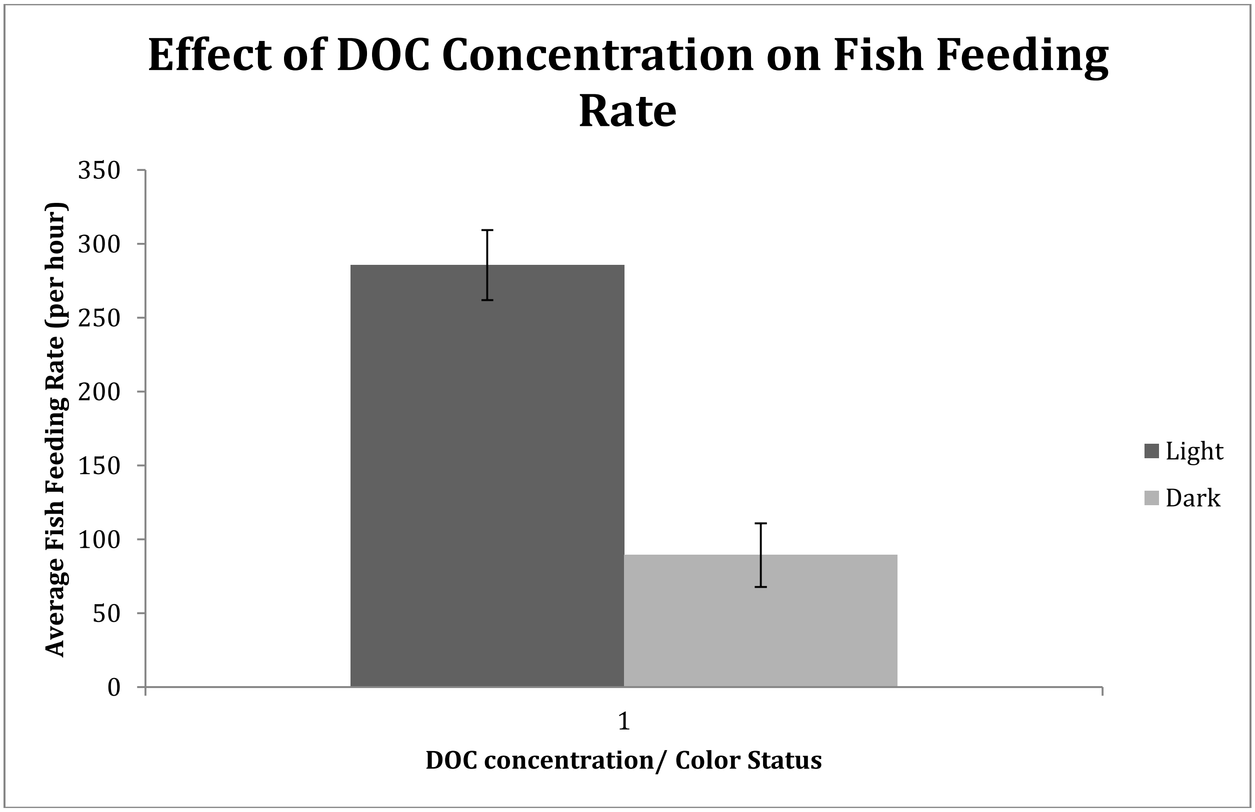

Figure 1. A graphical representation of a two-sample t-test, which examined whether juvenile yellow perch feeding rate differed between the dark and light tanks (p=0.003, df=4, t= -6.4). The mean feeding rates in the dark and light tanks were significantly different). The fish in the dark tank had a lower feeding rate (89.4 zooplankton per hour +/- SE 21.6) than the light tank had (285.6 zooplankton per hour +/- SE 23.7). All the data was normally distributed based on the Shapiro-Wilk test (p=0.2).