Survival of walleye eggs in Upper Red Lake and the Tamarac River

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Walleyes experience spawning runs each spring in the Tamarac River, a tributary of the Red Lakes. However, data about walleye egg survival in the lake and river is lacking. Mesh cages were placed in both the Tamarac River and Upper Red Lake to compare survival rates. A total of twenty cages were set, ten in the river and ten in the lake. Each cage contained one hundred fertilized eggs which were checked every third day to measure survival. Temperature (°C), dissolved oxygen (mg/L), and pH were measured at each cage location. The river had an average survival rate of 22% and the lake 8%. There was a significant difference in survival rates between the lake and river ($p = 0.007$), meaning that the river in the spring of 2015 was more suitable for walleye egg survival. Temperature did not differ significantly between the lake and river ($p = 0.12$) and therefore was not a likely cause of differences in egg survival. Dissolved oxygen significantly differed between the lake and river, ($p = 0.004$) however, it likely had little influence on survival because dissolved oxygen levels were in the optimal range for egg survival throughout the study in both systems. The lake had a lower survival rate than the river likely resulting from a higher average pH ($p < 0.001$). High average wind speeds may have also caused low egg survival in the lake.

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Introduction

Walleye (*Sander vitreus*) are a fish native to the state of Minnesota and highly targeted by anglers during open water and ice fishing seasons. In recent years, Red Lakes' walleye fishery has been under heavy regulation with strict daily limits and a protective slot due to decades of overfishing. The fishery collapsed in the late 2000s and finally recovered after a harvest moratorium and stocking efforts and is now at record levels of abundance (Brown and Kennedy 2013). The Tamarac River, a tributary of the Red Lakes, experiences walleye spawning runs each spring (Brown and Kennedy 2013), however, data related to egg survival in the river compared to the lake is lacking. Information about egg survival in the river and lake could aid managers in maintaining the current high quality of the fishery.

Walleye are lithophilic broadcast spawners that lay eggs over substrates and provide no parental care during the incubation period (Gillenwater et al. 2006). Walleye have been found to prefer gravel substrate 2.5-15.0 cm in diameter for spawning (Johnson 1961). Aspects of water quality including dissolved oxygen, temperature, and pH have been known to affect walleye egg survival (Bozek et al. 2011). Dissolved oxygen levels above 5.0 mg/L have been found to result in high egg survival (McMahon et al. 1984) and water temperatures between 6 and 19 °C (Bozek et al. 2011) are optimal for egg survival. The ideal pH range for walleye spawning is 6.0-9.0 and pH levels below 5.5 have been found to be detrimental to survival of eggs (McMahon et al. 1984).

Annual fluctuations in water level are likely to influence water quality and walleye year class strength. Red Lakes and the Tamarac River are located in Big Bog State Recreation Area in northern Minnesota. Bogs and wetlands are a vital part to many ecosystems. They absorb rain-water and prevent flooding in regions. Traditionally wetland ground water has an acidic pH, ranging from 3.0-5.0., and low dissolved oxygen levels around 3.0 mg/L (Winter 2002). Mixing of the acidic bog water with river or lake water can affect the dissolved oxygen and pH levels in those systems (Winter 2002). With water quality fluctuating from year to year based on water level, solid estimates of survival in both the lake and river in relation to pH, dissolved oxygen concentrations and temperature are needed.

The objectives for the study are 1) compare egg survival rates in the Tamarac River and Upper Red Lake, 2) compare survival to dissolved oxygen levels pH levels, and temperature, and 3) compare survival to wind speeds.

Methods

Walleye eggs from three mature females and milt from five mature males were collected from fish captured using trap nets set in the Tamarac River. The eggs and milt were placed in separate containers before they were mixed. The eggs were fertilized based on the method of Casselman (2006). For each trial, 100 eggs and a milt sample were placed 5 cm apart in the bottom of a dry container. Then 400 mL of fresh river water was poured over the eggs and sperm. This ensured a thorough mixing of the eggs and sperm, and that all the sperm were activated at the same time. After mixing for 45 seconds with a feather, the water was poured off the eggs, and fresh water was immediately added to wash off any remaining sperm.

The fertilized eggs were then placed into cages. Cages were constructed using 2.5 cm thickness plywood, and made into 15 x 15 x 15 cm boxes. The cages were covered by mesh screen (50 µm) to avoid egg predation, capture any dead eggs, and contain larval fish that have survived throughout the incubation period. Gravel, 4-10 mm, was placed at the bottom of the mesh cages to emulate proper spawning substrate of walleyes.

Ten cages were placed in the river, and ten cages were placed in the lake. Cages in the river were set approximately 6.5 km up the river and placed in an area with suitable spawning substrate. The cages were also far enough up the river to avoid being disturbed by the public. Once the first cage was set, each additional cage was placed 15 m further upstream. Cages in the lake were placed on the east shore. From the mouth of the river, the first cage was placed 1 km north. Cages were then placed every 50 m along the shore. All cages were placed in < 1 m of water. The cages were anchored, and staked to the bottom of the lake and river to stabilize them.

Cages were marked with buoys, and monitored every third day throughout incubation period, to measure temperature (°C), dissolved oxygen (mg/L), pH, and record the survival of walleye eggs to the larval stage. Winds speeds were recorded from Weather Underground (2014) to assess the possible influence on survival. Based on the methods of Corbett (1986), dead eggs were considered those that had a white speck and floated, and live eggs were those still stuck to the substrate, hyaline and turgid.

Data Analysis

After the data collection, a Shapiro-Wilks test was run to test normality egg the survival distribution. After determining the distribution was non-normal, a Welch two-sample t-test was run to compare the survival of walleye eggs in the river and the lake. Linear regression was run to test the affect wind had on survival. Independent t-tests were run to test for differences in the means of abiotic factors, such as pH, dissolved oxygen and temperature, between the lake and river. If there was a significant difference between the lake and river, a regression was run to test the number of dead eggs against that abiotic component.

Results

Due to high winds over the data collection period, two cages set in the lake were blown to shore and no data was able to be collected. According to Weather Underground (2014), the average wind speed over the course of the data collection period was 22.6 km. Wind speeds increased on average over the course of the study and were therefore correlated with time from hatch. The last three days of the study had an average wind speed of 31.0 km which is when the eggs started dying in the lake (Figure 1). The wind significantly influenced the overall survival of eggs in the lake ($p = 0.01$). Regression analysis also provided statistical evidence to suggest that wind factored in the survival of eggs in the river ($p = 0.02$). However, wind speed should not have affected cages in the river because they were protected by trees and the river bank.

All ten cages placed in the river produced larval walleye, and only six out of the eight cages in the lake produced larval walleye. The average survival rate in the river was 22% and the lake 8% (Figure 2). Survival was significantly higher in the river in comparison to the lake ($p = 0.007$).

There was no sign of egg mortality until May 5th, which happened in three out of five cages in the lake. There was no sign of hatching until May 8th. All the eggs were accounted for on May 8th when the study ended.

Over the course of the data collection period, temperatures and dissolved oxygen levels were optimal in both the river and lake. pH was in the optimal range in the river, and it was higher than optimal in the lake.

The river had an average temperature of 14.4 °C, and the lake had an average temperature of 13.8 °C. Temperature did not differ significantly between the lake and river ($p = 0.12$), therefore it was not likely the cause of survival differences observed between the two systems.

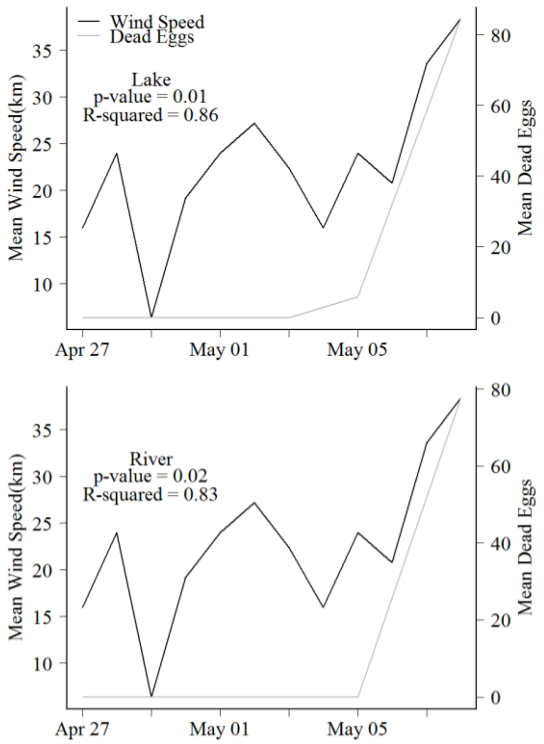

Figure 1. Average wind speed in Washkish, MN from 27 April 2015 through 8 May 2015 compared to mean number of dead eggs in the lake (top) and in the river (bottom). The black line represents the mean wind speed and the grey line represents the mean number of dead eggs.

The average dissolved oxygen in the river was 10.61 mg/L, and the average dissolved oxygen in the lake was 12.01 mg/L. Dissolved oxygen concentration significantly differed between the lake and river ($p = 0.004$). Dissolved oxygen concentration was not a significant predictor of survival in the lake ($p = 0.11$), but was related to survival in the river ($p = 0.002$). However, dissolved oxygen levels were within the optimal range for egg survival in both systems and were therefore unlikely to have large influences on survival.

The average pH in the river was 8.8, while the pH average was higher in the lake (9.1) and just over the ideal range of 6.0-9.0 (Figure 3). pH significantly differed in the lake and river ($p < 0.001$) and was related to low survival in both the lake and river ($p < 0.001$) (Figure 2).

Discussion

The average pH was on the high end of the optimal range in the river (8.8), and out of the optimal range in the lake (9.1). High winds and high pH in the lake were the most likely causes for low egg survival. According to Johnson (1961), the average survival of walleye eggs on a gravel substrate is 35%. In this study, all of the cages had gravel substrate in them to emulate suitable spawning substrate. Even though it was not a natural setting, the overall survival rate was below what was expected (22% river; 8% lake) and most likely the result of high pH and wind speeds in the lake.

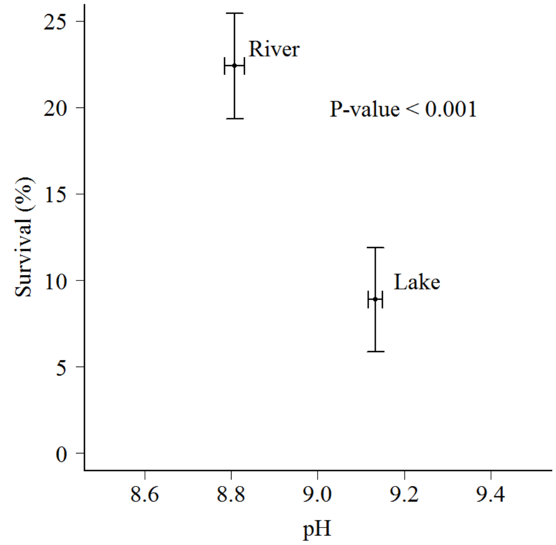

Figure 2. The relationship between mean egg survival and mean pH levels in both the lake and river from 27 April 2015 – 8 May 2015 with 95% confidence interval bars.

Normally, low pH values have a harmful effect on egg survival, but in a study done by Hulsman (1983), it was concluded that high pH values can have just as harmful effects. When conditions are too basic, walleye egg survival suffers because of the high number of OH^+ present. Even though the values of pH recorded in this study were just over the acceptable range, the best walleye egg survival rates come at a pH of 6.0 (McMahon et al. 1984). Elevated pH, values of 9.0 or higher, may be lethal to eggs and larval fish because of the toxicity of ammonia (Bergerhouse 1992).

Another likely factor leading to low survival in the lake compared to the river was wind speed. With the high winds experienced during the study, the lake was more affected compared to the protected stretch of river. Even though the cages were staked down, the wind made those in the lake unstable, tossing the eggs and gravel around likely resulting in increased mortality. Although regression analysis provided evidence to suggest wind speed did influence survival in the river as well, this is likely the result of a correlation between wind and time because cages in the river were completely stable and sheltered from wind.

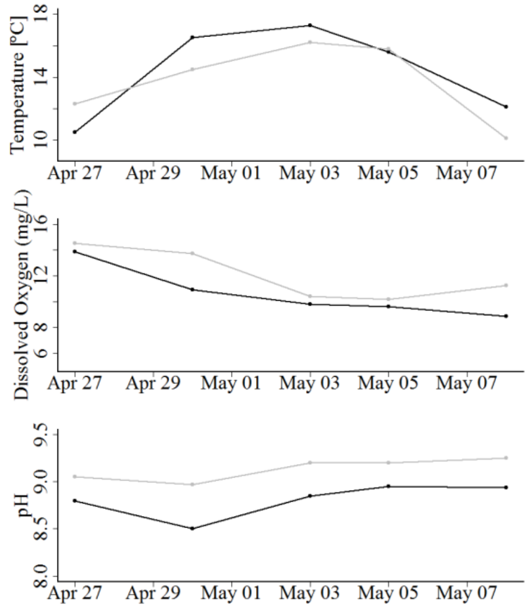

Figure 3. Temperature, dissolved oxygen, and pH levels from 27 April 2015 – 8 May 2015. The black line represents the river and the grey line represents the lake.

Raabe and Bozek (2014) found that wind and wave activity transports eggs and moves substrates and should be considered a critical factor in annual walleye egg survival and year-class strength. Also, the wind kept the water cooler in the lake and had a slower rate of warming water temperatures. Roseman et al. (1996), concluded that slow warming water rates, and high wind events lead to low survival of walleye eggs which is similar to the events that happened in this study.

The low hatch rates observed in this study were likely caused by high pH in both the river and lake systems. A combination of high pH and high average wind speeds likely resulted in lower hatch rates in the lake in comparison to the river.

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