Walleye Diet Stable Isotope Analysis on Black Lake, MI

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Abstract

Walleye populations have been decreasing in Black Lake. A diet analysis of Black Lake walleye could show the walleye's place in the food web and potentially help determine the reason for their decline in population. This study examines diet to determine what walleye are eating in the lake. By looking at the overlap of stable isotope signatures of walleye (average δ^{15}N 8.2, average δ^{13}C -31.27) and possible prey species, walleye were found to eat common shiner (average δ^{15}N 7.4, average δ^{13}C -30.3). At least one prey species was missing from the analysis since there was no expected clumping around the walleye stable isotope signature. In a study conducted on a Canadian Shield Lake, the signature for the most commonly cited prey species, yellow perch was determined (average δ^{15}N 11.3, average δ^{13}C -28.4). Since this isotopic signature is close to that of walleye, and assuming that yellow perch in Black Lake have similar isotopic ratios, it was analyzed in place of yellow perch from Black Lake. Using a linear mixing model walleye in Black Lake could hypothetically be eating a higher percentage of common shiner. Further analysis of isotope signatures of larger, pelagic fish such as yellow perch should be done in order to find the missing walleye prey species.

Introduction:

Walleye (*Sander vitreus*) are a popular angling fish for sport and consumption. The Michigan DNR stocks them across the state for this purpose (DNRE, 2010). Walleye are also an important consumer in the food webs of their ecosystems. As juveniles, walleye are known to eat macro invertebrates and switch to piscivory as soon as their mouth gape becomes wide enough to swallow fish (Chipps et. al, 2007). Juvenile walleye have even been stocked in Minnesota wetlands to suppress minnow populations, showering their importance in top down conrtol of minow populations (Chipps et. al, 2007). As a larger fish, walleye are known to eat minnows (family Cyprinidae), rainbow smelt (*Osmerus mordax*), white perch (*Morone americana*), and yellow perch (*Perca flavescens*) (Overman et. al, 2001; Chipps et. al, 2007).

Walleye are common in the Laurentian Great Lakes and interior lakes of Michigan, including Black Lake in Cheboygan County (Michigan DNR 2010; Minnesota DNR 2010). Walleye populations in Black Lake are decreasing. Concerned residents involved in the Black Lake Association requested help conducting research on the cause.

There are many possible reasons for the population decline of walleye in Black Lake. Overfishing is a worldwide problem for game fish such as walleye, and the Michigan DNR allows each fisherman to catch five fish per day (Dodds, 2002; DNR 2010). Reduction in habitat for spawning and juveniles may also be an anthropogenic factor in walleye population decline. Shoreline and aquatic plants are important for walleye recruitment (DNR, 2010).

Zebra mussels are thought to have been introduced to Black Lake in 2003 and could be behind the decline in Walleye (Stoermer, 2007). Zebra mussels may be behind the decline because they change energy pathways from pelagic to benthic reducing chlorophyll-a and changing the plankton community (Forney et. al, 1999). For example zebra mussels caused shifts in juvenile walleye diet from zooplankton to benthic invertebrates, in Lake Oneida, New York, and this has had a negative impact on walleye population (Forney et. al, 1999).

Lastly, a vius could be causing the decline in walleye population. It has been documented that this virus has been killing fish in both Europe and North America (DNR, 2010). However, this is unlikely the cause of the decline in Black Lake because the symptoms would likely have been noticed and reported by anglers. Symptoms include obvious hemorrhaging of the skin, large red patches and bloody scales. The Michigan DNR has also been tracking the spread of the virus and have recevied no report of it in Black Lake (DNR, 2010).

Black Lake is over 10,000 acres in size, the ninth largest inland lake in Michigan, and is built up with many homes and cottages (Tip of the Mitt Watershed Council, 2010). The Lake is monitored by Tip of the Mitt Watershed Council, who describes the lake as exceptionally clean. Seven streams feed Black Lake, providing allochthonous inputs of carbon and its dark color. There is no obvious reason for walleye decline and little research has been done on walleye in Black Lake. If the diet of the Black Lake walleye were to be analyzed, it would show the walleye's place in the food web and potentially help determine the reason for their decline in population. There are two common methods for diet analysis: stomach content analysis and stable isotope analysis.

The traditional method of stomach content analysis is difficult, intrusive and time consuming. It requires catching a large number of fish and either pumping their stomachs or dissecting them to identify their stomach contents. Very often, it is difficult to identify the organisms because they have undergone digestion to some degree. This type of analysis is also limited in that it only provides information on the species being consumed at that moment in time and this can change quickly as prey populations rise and fall or seasons change (Overman et. al, 2001; Dodds, 2002).

Stable isotope analysis is becoming the most widely used method for researches to analyze diet and food webs (Overman et. al, 2001; Kurl, 2009; Hagley et. al, 1999). Stable isotope ratios that include carbon, nitrogen, oxygen, copper and sulfur can be used. Previous studies have shown the stable isotope signature of an organism expresses a combination of ratios present in its food source (Hagley et. al, 1996). Unlike the short-term snap shot viewed through stomach content analysis, stable isotope analysis provides a long-term overview of diet (Bertolo and Paradis, 2008). However, caution must be taken when using this method. Previous research has shown that an organism's stable isotope signature is not souly based on their diet. Specifically, in walleye, it has been shown to vary with age separately from consumption patterns (Overman and Parish, 2001). Length, weight and trophic level have also been shown to make a difference in many predatory fish's δ^{15}N signature (Overman and Parish, 2001).

In this study, carbon and nitrogen isotopic ratios of possible prey species were compared to those of walleye, with the assumption that walleye will have a ratio similar to that of their prey. Even though literature suggests walleye are piscivorous during their adult stage, it is possible that the food web in Black Lake does not follow the norm. We will analyze the most common species that walleye in Black Lake may be preying upon in order to account for this possibility. Determining the diet of walleye could hold the key to their decline or simply lay the foundation for future studies.

Materials and Methods:

Water Quality:

Water quality was measured by the University of Michigan's Biological Station summer semester, 2010, limnology class; detailed methods can be found in their paper. Water quality variables were measured at N 4527.25, W 084^{o}15.429. Secchi depth was taken ten times and averaged. Temperature and dissolved oxygen where measured three times at meter intervals using Hydro lab and were averaged.

Collection:

Biotic samples were taken on Black Lake on July 22nd, July 26th, and July 30th of 2010. The sites were spaced along the south and west edges of Black Lake at boat ramps in the state park, state forest, and two public access sites (Fig. 5). Three samples of walleye flesh of similar size were taken from local fishermen, at the state park and the state forest, and preserved on ice in plastic bags. Small fish were collected using seines at all four sites. Species found in relatively high abundance, shiner and logperch, were placed in a plastic bag, killed with a small stone and preserved on ice. The remaining fish were identified to species to determine population distribution and released. Crayfish were caught using a herding method and a d-net;

at the state forest, state park and one of the public boat launches. These were placed in plastic bags and put on ice. Macro invertebrates were caught using dip nets and kick nets at the state forest and state park boat ramps, and one of the public access boat launches. Odonata and Ephemerotera were collected and put on ice.

Chemical Analysis:

The fish, crayfish and macroinvertebrate samples were kept in a -80 (C) freezer until completely frozen. Samples where then freeze-dried. The samples were stored in a desiccator, to keep the samples dry until they were ground into powder with a grinder. A mass spectrometer was used for stable chemical isotope analysis. Nitrogen and carbon isotope ratios were compared.

Data Analysis:

The average signature ratios of $\delta^{15}N$ and $\delta^{13}C$ were plotted for each species on a graph and compared. The species plotted closest to walleye were assumed to be eaten by the walleye. Standard deviation was used to decipher a range of possible isotope signatures. Walleye's signatures were subtracted by three $\delta^{15}N$ and one $\delta^{13}C$, to compensate for trophic enrichment, as these are numbers are commonly used for consumers (Bertolo et. al, 2008; Beavdion et. al, 2001; Adams and Sterner, 2000). However, there appeared to be at least one crucial prey item missing, as walleye was not at the center of a clump of species whose isotopic signatures add up to walleye's. Since further sampling was not an option, stable isotope signatures of possible prey were taken from literature of research conducted in similar regional ecosystems. Three yellow perch signatures were taken and averaged. Since literature most commonly cited yellow perch as prey of walleye, yellow perch isotopic signatures were used. The data were then analyzed using a linear version of the mixing model, $F_1= (\delta^{15}N_{sample}- \delta^{15}N_{source2})/(\delta^{15}N_{source1} - \delta^{15}N_{source2})$, $F_2= 100- F_1$, to determine in what proportion of possible prey items walleye diet was composed.

<u>Results:</u>

Limnology:

The maximum depth of Black Lake, as found in the literature, was 50m (Tip of the Mitt Watershed Council, 2010). Secchi depth was measured to be 3.6m. The temperature of Black Lake decreased with depth in a pattern resembling that of a stratified lake (Fig. 1). Dissolved oxygen also decreased exponentially with depth, but the hypolimnion was not anoxic (Fig. 2).

Catch:

The fish species caught during sampling were: sand shiner (*Notropis stramineus*), log perch (*Percina caprodes*), white sucker (*Catostomus commersonii*), common shiner (*Luxilus cornutus*), large mouth bass (*Micropterus salmoides*), spottail shiner (*Notropis hudsonius*), yellow perch (*Perca flavescens*), and blunt nose minnow (*Pimephales notatus*) (Table 1). The most common fish caught by a large margin were sand shiner, followed by spottail shiners. Crayfish (Order Decapoda), dragonfly larvae (Family Odonata), and mayfly larvae (Family Ephemeroptera) and scuds were also caught (Table 1). Many scuds (Order Amphipoda) and zebra mussles were found at every site except the State Park.

Stable Isotope Analysis:

Walleye (average δ^{15}N 8.2, average δ^{13}C -31.27) was not clumped with other species as expected (Fig. 3; Table 3). Common shiner was the closest (average δ^{15}N 7.4, average δ^{13}C -30.3) and its standard deviation overlapped, indicating it could be a prey source. Log perch weren't much further away (average δ^{15}N 6.7, average δ^{13}C -30.7), though their standard error bars did not overlap. Dragonfly (average δ^{15}N 5.7, average δ^{13}C -30.4), mayfly (average δ^{15}N 4.3, average δ^{13}C -30.3), and crayfish (average δ^{15}N 5.4, average δ^{13}C -28.1) were too far removed from walleye to possibly be prey. The stable isotope signature of yellow perch (Figure 4, Table 3) found in literature research on nutrient poor Canadian shield lakes (average δ^{15}N 11.3, average δ^{13}C -28.4) was close enough to walleye to be considered a prey item (Dick et. al, 2004). Using a linear version of the mixing model, walleyes' diet was comprised of 17% yellow perch and 83% common shiner.

Discussion:

Stable isotope analysis showed that our sampling missed at least one prey species for walleye. A search of the literature showed that the most commonly cited prey of walleye, that was also present in Black Lake, to be yellow perch. These data came from a relatively close region, the Canadian Shield lakes, but it is important to note that these lakes are slightly different ecosystems. These lakes are very shallow and nutrient poor (Dick et. al, 2004). Since they are from similar small inland lakes, the yellow perch found there are likely to have similar isotopic signatures to those found in Black Lake. However, this may be the reason that yellow perch's carbon isotope ratio was heavier than walleye's (Figure 4, Table 3). Canadian shield lakes are less likely to have autochthonous inputs from plants which have lighter carbon rations than Black Lake, which has seven stream inputs carrying in tannin, and many deciduous trees throughout its watershed.

Using the signature in a linear version of the mixing model suggested walleye diet could be comprised of yellow perch and common shiner, about thirty percent and seventy percent respectively. This suggests that yellow perch is not the primary prey of walleye, but minnows are. However, it is also important to note that yellow perch's isotope signatures vary widely due to their wide diet breadth (Dick et. al, 2004). It could be possible that yellow perch in Black Lake have a more similar isotopic signature to walleye. Stable Isotope signatures also vary substantially among consumers (Kendall et. al, 2003). Three walleye samples may not be enough to get a good average. As it is, the mixing model results do not explain why walleye are declining because minnow are easily found in mass abundance in Black Lake (Table 1).

The original Black Lake data, did not satisfactorily conclude the prey species of walleye. The prey item missing from this research likely has a higher $\delta^{15}N$ signature than minnows and possibly walleye and a lower $\delta^{13}C$ signature, to balance the higher $\delta^{13}C$ and lower $\delta^{15}N$ provided by minnow (Fig 3; Table 3). The species we sampled where all in the littoral zone. Fish species in this zone are less likely to be piscivorors and are thereby more likely to have lower $\delta^{15}N$ (Dodds, 2002). Previous studies have shown that there is a high differentiation of isotopic signatures between the pelagic and littoral zones (Beaudion et. al, 2001; Hagley et. al, 1996). This prey item could possibly be pelagic yellow perch as described earlier or another large fish, as they would be piscivorous, leading to higher nitrogen levels. Another possible prey item that could have higher $\delta^{15}N$ and lower $\delta^{13}C$ could be leaches (Hirudinea), as they have been shown to have signature typical of a top trophic level due to feeding on blood (Jones and Waldron, 2003).

There are a great deal of studies that could be done in the future to better understand walleye diet. Sampling tissue of larger fish, such as pelagic yellow perch, game fish, larger forage fish and leeches could find the prey species missing from this study. Another possible area of study would be predator-prey interactions between walleye and their prey, which could have many implications for walleye populations.

Ontonogenic competition may also be a good interaction to study. Literature has heavily suggested ontonogenic competition between juvenile walleye and yellow perch may also be decreasing walleye recruitment (Browne and Rasmussen, 2009; Hagley et. al, 1996). Research could be conducted to see if yellow perch outcompete walleye small enough to be gap limited to zooplankton, as this has been seen to happen in other studies (Dodds, 2002; Hagley et. al, 1996). It may also be interesting to reasearch what stage walleye populations are vulnerable at.

Zebra mussels' effect on zooplankton community could potentially be impacting walleye recruitment as well. Zebra mussels are prolific filter feeders and can change phytoplankton communities of lakes, thus changing zooplankton communities and affecting juvenile walleye (Stoermer, 2007; Dodds, 2002). One study found zebra mussels were the cause of juvenile walleye diet shifts from zooplankton to benthic invertebrates, in Lake Oneida, New York, and had negative impacts on walleye population (Forney et. al, 1999). Chlorophyll-a has been declining in Black Lake since 1990, indicating that phytoplankton are decreasing (Tip of the Mitt Watershed Council, 2010). Though this has been occurring since before the introduction of zebra mussels in 2003, zebra mussels may be adding to their decrease and thereby decrease the zooplankton population available to juvenile walleye (Stoermer, 2007).

This study is a preliminary research project on possible causes of walleye decline in Black Lake. It was unable to conclude the complete diet of walleye, but it suggests that walleye are consuming minnows and at least one other organism that is feeding higher on the food web. Based on our hypothetical analysis with yellow perch from other lakes and literature on other lakes, one of these other organisms may be yellow perch. To continue diet analysis, larger, pelagic fish should be sampled. There are many other possible reasons for walleye to decline and plenty of opportunity for future research.

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Appendix.
Figures:

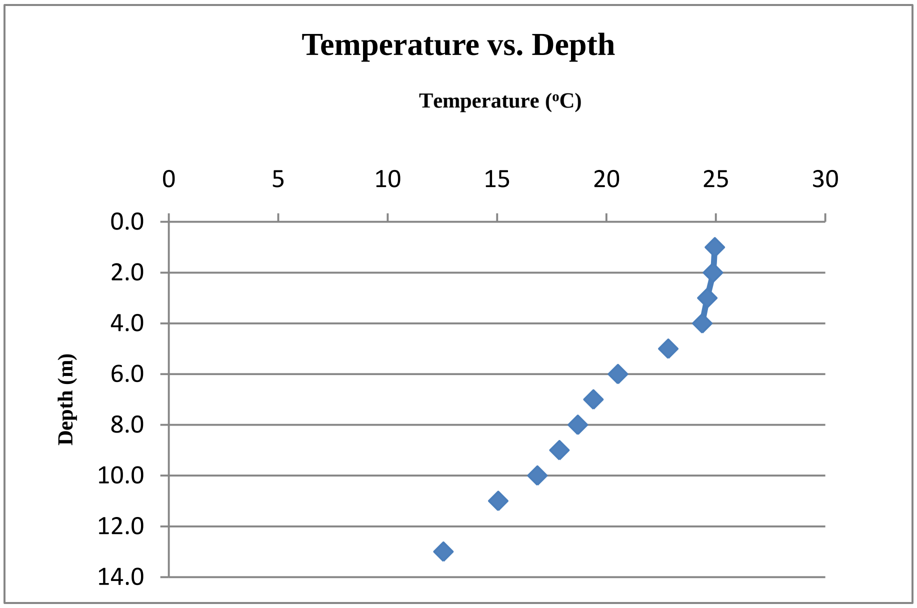

Figure 1. Temperature decreases with depth. The pattern indicates the lake is stratified.

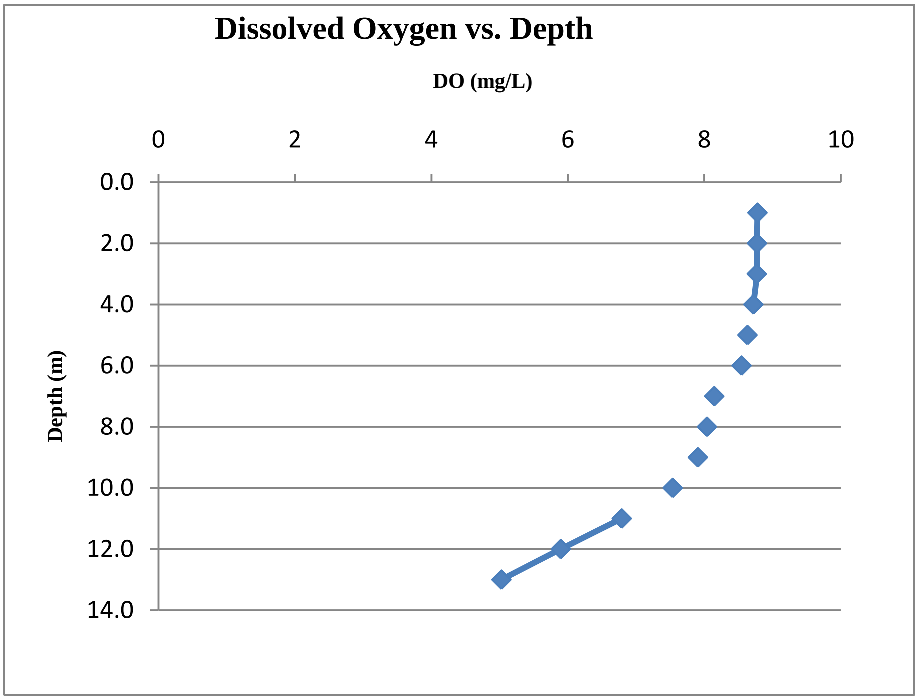

Figure 2. Dissolved Oxygen exponentially decreases with depth, but the hypolimnion is not anoxic.

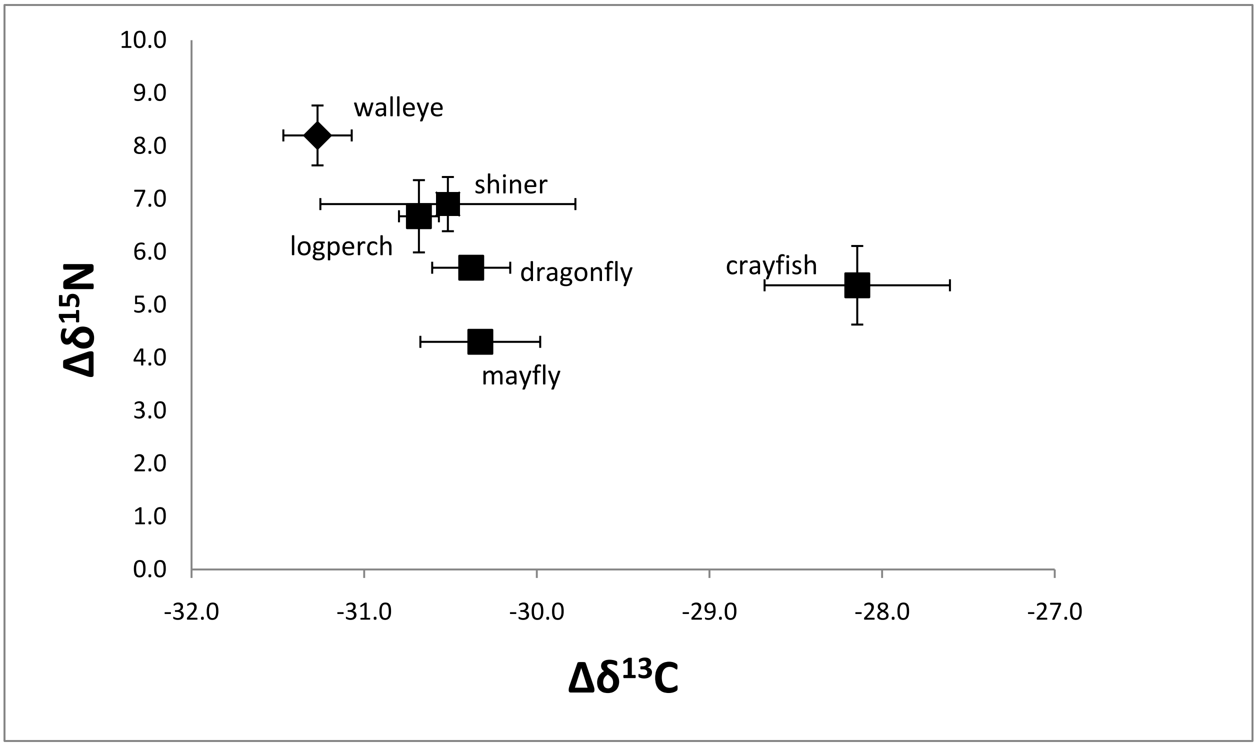

Figure 3. Stable Isotope Analysis: The standard error bars for walleye and common shiner overlap, therefore walleye is likely consuming them. Walleye could also possibly be consuming logperch since they are close in ratios. One or more prey item is missing, for there is no expected bunching around walleye.

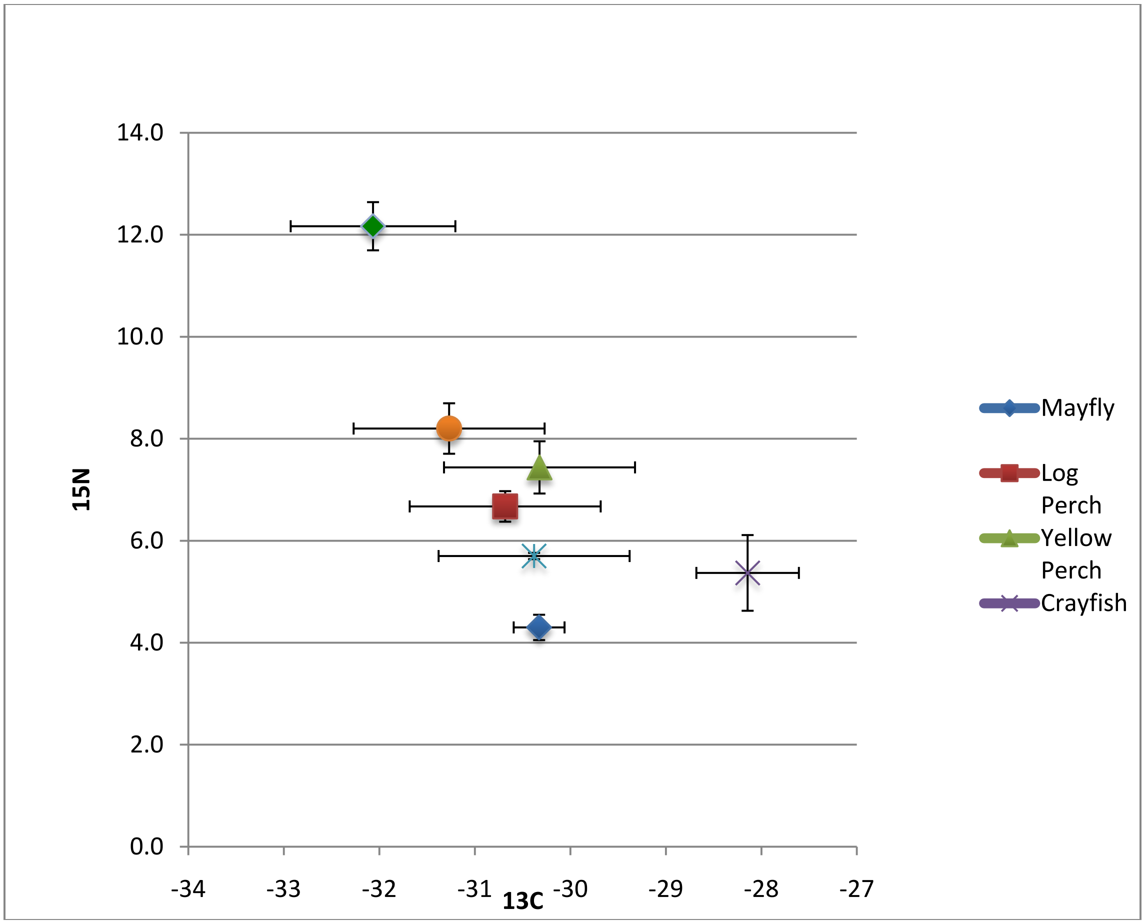

Figure 4. Stable Isotope Analysis with Yellow Perch: This graph shows stable isotope signatures for walleye and possible prey species including yellow perch (Dick et. al, 2004).

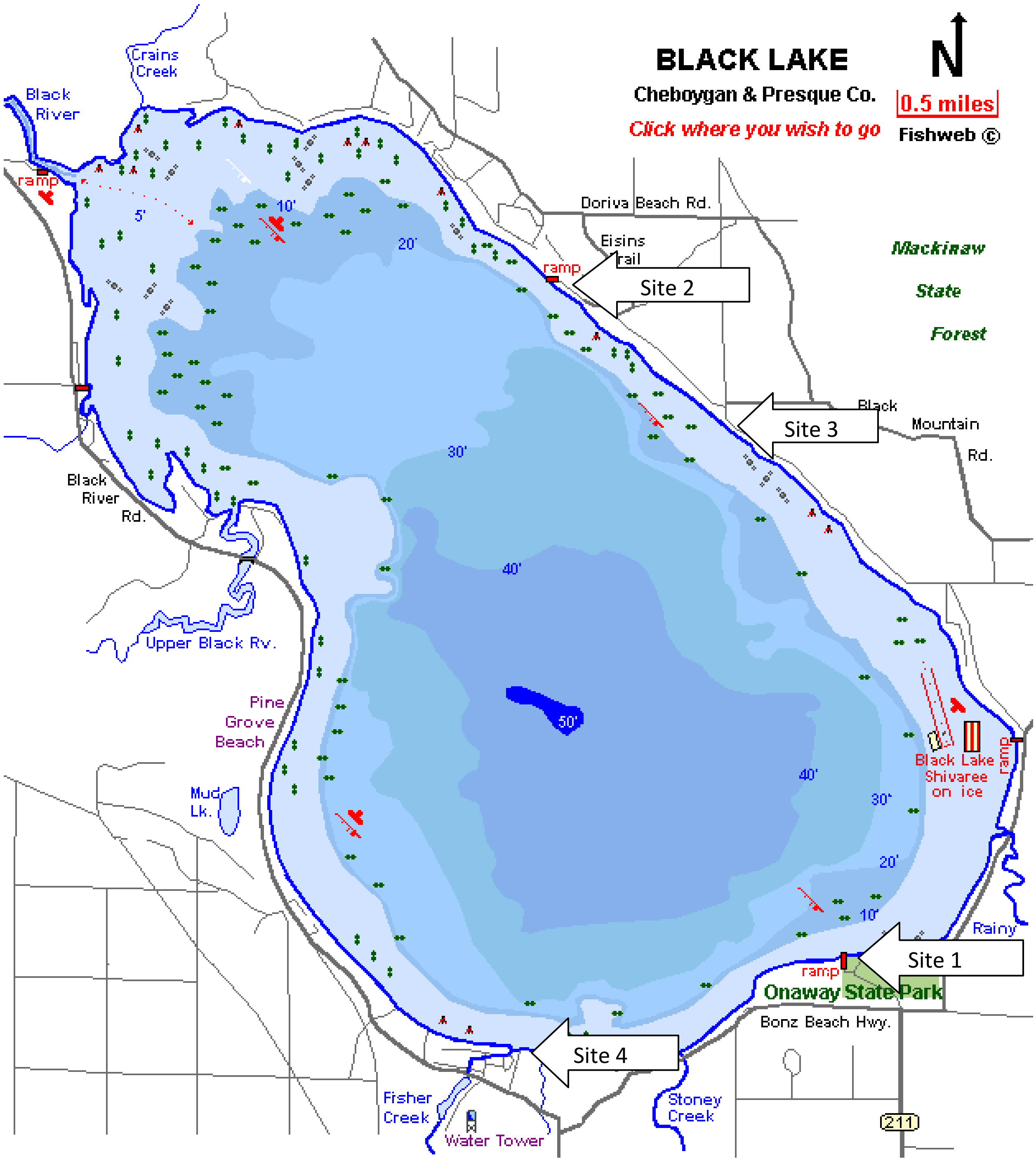

Figure 5. Black Lake: This figure is a map of Black Lake and shows the sites sampled in this study.

Tables:

Species	Site 1	Site 2	Site 3	Site 4	Total
Sand Shiner	170	2	264	0	**436**
Log Perch	1	0	0	0	**1**
White Sucker	0	2	12	0	**14**
Common Shiner	0	7	32	2	**41**
Largemouth Bass	0	1	0	0	**1**
Spottail Shiner	0	7	16	135	**158**
Yellow Perch	0	0	9	0	**9**
Blunt-nose Minnow	0	0	16	0	**16**

Table 1. Fish Species Collected on Black Lake: This table shows the number of species collected at each site and their total across all of the sites. It is interesting to note the large number of shiner species.

Species	Site 1	Site 2	Site 3	Column1	Total
Crayfish	2	1	0	0	**3**
odonata	0	2	0	1	**3**
Mayfly	0	6	0	0	**6**

Table 2. Macroinvertebrates Collected on Black Lake: This table shows the number of species collected at each site and their total across all of the sites.

Species	d15N	%N	d13C	%C
Mayfly	4.3	8.6	-30.3	42.7
Log Perch	6.7	10.8	-30.7	43.5
Shiner	7.4	11.2	-30.3	45.2
Crayfish	5.4	7.5	-28.1	35.9
Odonate	5.7	10.7	-30.4	48.9
Walleye	11.2	14.0	-30.3	45.2
*Yellow Perch	11.3	N/A	-28.4	N/A

Table 3. This table displays the delta values averaged from three organisms of each species.
* Yellow perch is taken from the litueratur (Dick et. al, 2004)