# The Effects of Diet on Yellow Perch Morphology Throughout Lake Bemidji

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Morphology is very important as it looks at the arrangement of an organism's parts to determine their functionality, development, and how they could have changed through evolution. It is also important for the identification of species as it can show how closely species are related. This study examines if the morphology of yellow perch changes throughout Lake Bemidji. Along with examining a subset of five stomachs for each group (A-F) of yellow perch collected to determine if diet was a driving force behind morphological changes. The data collected in this study suggested that morphology does change throughout Lake Bemidji and that diet influences the morphology of yellow perch. The measurements driving these changes were the caudal peduncle depth, caudal fin depth, body depth, body width, mouth depth, and mouth width The stomachs showed small amounts of invertebrates belonging to the following groups: Amphipoda, Tricoptera, and Ephemeroptera. A comparison of the 2021 and 2022 data was made to determine if morphology can change from one year to the next. The evidence from this comparison suggests that morphology does change from one year to the next.

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**Introduction**

Lake Bemidji is a lake in Northern Minnesota that is primarily managed for walleye *Sander vitrues*, yellow perch *Perca flavescens*, northern pike *Esox lucius*, and muskellunge *Esox masquinongy*. Yellow perch are a major food source for the top three predator fish in Lake Bemidji. The pressure that yellow perch receive from predator fish can cause them to change morphologically to be able to find food and stay alive. Morphology looks at the arrangement of parts of an organism, to determine their function, their development, and how they were possibly shaped through evolution. This can be very important in species identification because there can be minute differences found between two otherwise very similar organisms.

The morphology of fishes has been intensively studied throughout history. A study focusing on how the morphology of Cyprinidae changed with their habitat over a 100-year period was done in Illinois. They had four main focuses: body size, sex, time, and hydrology in which they used museum collections to obtain some of their data (Jacquimen and Pyron 2016). After collecting all their data, they found that morphology changed over time in both lotic and lentic systems. Another study by Shoup and Broderius (2018) was done to determine how vegetation effects the feeding patterns of largemouth bass *Micropterus salmoides*. The study found that bass living in more vegetation were smaller than those living in less vegetation. The size difference was found to be caused by the ease of feeding due to more visibility and less energy going into finding prey. Another study in Sweden looked at the effects of habitat and food on the morphology of European perch *Perca fluviatilis*. This study discovered that perch in the littoral zone had deeper bodies because they were eating more macroinvertebrates. The perch studied in the pelagic zone were more streamlined as they were consuming more zooplankton and less macroinvertebrates (Svanbäck and Eklöv 2002). Another study by Eklöv and Svanbäck (2005) was done to determine how predation influences the adaptive morphology of young perch. This study demonstrated that there are differences in growth related to morphology based on the habitat that a fish was in. This showed a possible trade-off between foraging and the risk of predation which could be causing the morphological variation in young perch.

There has been little research done that looks at how morphology of fishes can differ in an individual body of water. Therefore, the first objective for this study is to determine if the morphology of yellow perch changes throughout Lake Bemidji. The second objective of this study is to determine if stomach contents are the driving force for the morphology of yellow perch.

**Methods**

For this study, yellow perch were sampled in six locations around Lake Bemidji (Figure 1; Table 1). At these locations, a total of 120 yellow perch were sampled. The mean length was 45 mm (SD = 4.0). The collections were done in mid-September of 2021 and 2022 using a seine net (15 m x 1.2 m: 6 mm mesh). Each perch collected in 2022 had a total of seven measurements taken using a micrometer. These measurements were body length, body depth, caudal peduncle depth, caudal fin depth, body width, mouth depth, and mouth width (Figure 2).

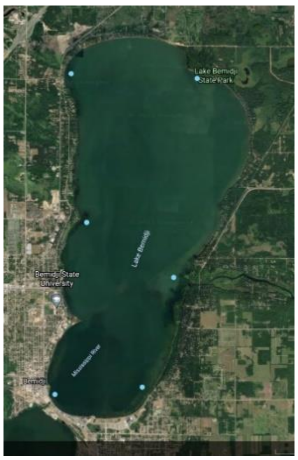

**Figure 1.** Each sample location for 2022 is marked with a blue dot. Going counterclockwise from the bottom left: Location A, Location B, Location C, Location D.

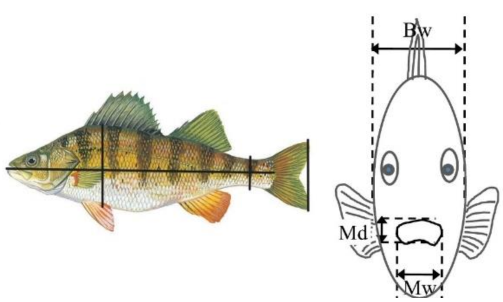


**Figure 2.** All yellow perch sampled had seven measurements taken. Starting from the top left the measurements were body length, body depth, caudal peduncle depth, caudal fin depth, body width, mouth depth, and mouth width.

As the perch were being measured the stomach of each perch was collected and placed in a small collection jar for later review. To start, a small subsample of five yellow perch from groups A-F were examined. Each stomach was carefully opened, and all contents were removed using a pair of tweezers. Then the contents were separated into different families of macroinvertebrates present in each stomach. Finally, contents were counted and recorded based on what macroinvertebrates were present. The data collected was used to determine if the driving force behind the observed morphological differences was diet.

**Table 1.** Location of collection sights starting in the southwest corner with location A, southeast corner for location B, middle east side for location C, northeast corner for location D, northwest corner for location E, and the middle west side for location F.

| Latitude | Longitude | Group |
|---|---|---|
| N47.4688° | W94.8779 ° | A |
| N47.4657 ° | W94.8524 ° | B |
| N47.4831 ° | W94.8393 ° | C |
| N47.5405 ° | W94. 8652 ° | D |
| N47.5321 ° | W94.8329 ° | E |
| N47.4856 ° | W94.8709 ° | F |

The R program was used to statistically analyze the measurements and diets recorded from the six groups of perch sampled. This was done to determine if there were any differences among each group and how each measurement and diet affected those groups. The vegan package in the R program was used to run a nonparametric multidimensional statistic (NMDS) to provide evidence of any differences within the groups. This evidence was then put through the ellipse package to show what was causing the differences seen in the figure created by the vegan package. This process produced three two-dimensional figures that showed the measurements effecting each fish and its placement, how the diets effected the placement of each fish on the figure, and the comparison of data from 2021 and 2022.

**Results**

Among the six groups of yellow perch that were sampled, there were definite morphological differences found (Figure 3; Table 2). Evidence suggests that the perch sampled have morphological differences based on the location that they are sampled from. The ellipses show little overlap in any of the groups (Figure 3). By having very little overlap in the ellipses it can be said that the perch are morphologically different. This can also be

**Table 3.** Means and standard deviations broken down for each group of yellow perch sampled.

| Location | CP_depth | Caudal_depth | Body_L | Body_Depth | Body_Width | M_Depth | M_Width |
|---|---|---|---|---|---|---|---|
| A | 4.74 | 12.79 | 52.96 | 14.19 | 7.38 | 5.86 | 5.66 |
| | (0.459) | (1.605) | (4.308) | (1.626) | (0.992) | (0.839) | (0.818) |
| B | 3.45 | 10.77 | 38.64 | 9.55 | 4.92 | 4.88 | 3.52 |
| | (0.412) | (1.588) | (4.169) | (1.294) | (0.569) | (0.508) | (0.783) |
| C | 3.59 | 12.09 | 41.47 | 10.16 | 4.89 | 5.38 | 3.69 |
| | (0.348) | (1.521) | (3.852) | (1.197) | (0.693) | (0.453) | (0.517) |
| D | 3.99 | 13.12 | 44.18 | 10.79 | 5.29 | 6.89 | 4.22 |
| | (0.434) | (1.945) | (4.260) | (1.376) | (0.908) | (0.743) | (0.834) |
| E | 3.75 | 12.43 | 42.65 | 10.18 | 4.92 | 6.24 | 3.53 |
| | (0.232) | (1.264) | (2.449) | (0.837) | (0.463) | (0.507) | (0.386) |
| F | 4.24 | 14.54 | 48.66 | 12.31 | 6.16 | 6.66 | 4.71 |
| | (0.452) | (1.739) | (4.606) | (1.620) | (0.859) | (0.836) | (1.219) |

suggested by the vectors as well. The vectors show how each measurement affects the placement of fish on the graph. The main measurements that contributed to these differences were: body width (P < 0.01), body depth (P < 0.01), caudal peduncle depth (P = 0.04), body width (P < 0.01), caudal fin depth (P < 0.01), and mouth depth (P < 0.01; Figure 3). Location A (southwest corner) was affected by the body depth and body width measurements.

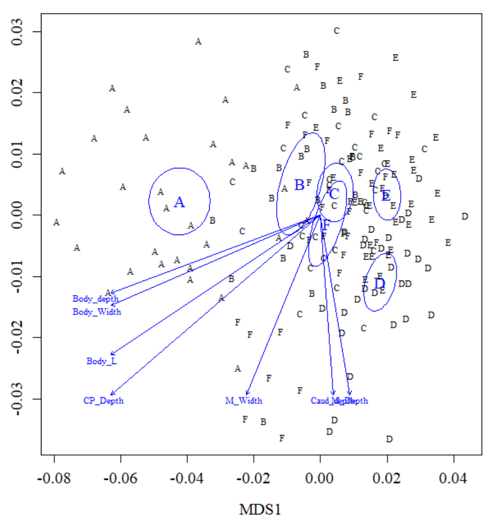


**Figure 3.** Each fish is represented by a letter corresponding with the sampling location and an ellipse showing a groups area on the figure. The vectors show each measurement and how it is affecting the placement of a fish on the figure.

These measurements are pulling to the left of the figure which causes fish in location A to be spread throughout the left side of the figure. Locations B (southeast corner), C (middle east side), and F (middle west side) were all grouped together in slightly off-center position on the figure. Location F and B had oblong shaped ellipses and seemed to be affected by the mouth width and caudal peduncle depth measurements. While location C was slightly oblong shaped and was affected by all the measurements evenly. The last two locations E (northwest corner) and D (northeast corner) were the furthest to the right on the figure and were most affected by the caudal fin depth and mouth depth measurements.

All fish in 2022 that were subsampled had contents in the stomach, with most of them containing Amphipods (Table 3). Location A had the highest number of amphipods present with an average of 8.8 (SD = 2.77) Amphipoda per stomach examined. All other groups had averages of 3.4 – 4.2 Amphipoda per stomach examined. Location B had moderate numbers of Amphipoda with an average of 4.2 (SD = 1.3) Amphipoda per stomach. Location B also had a stomach containing Ephemeroptera which averaged out to 0.4 (SD = 0.89) Ephemeroptera per stomach. Locations C-F had low amounts of invertebrates in the stomachs that were examined. However, locations D-F contained the most variety with Amphipoda and Tricoptera present in the stomachs.

When the effects of the measurements and stomach contents are compared together, a clear pattern can be seen. The fish in location A have more body depth to them and a higher amphipod content in the stomachs (Figure 4). The presence of Amphipoda appear to cause bigger bodies in the fish that are using these invertebrates as a primary food source. Locations D-F have deeper caudal fins and mouths with the presence of Amphipoda and Tricoptera. The presence of Tricoptera appeared to pull more to the right of the figure which correlates with the deeper caudal fins and mouths that are being observed in these locations. Location B has a moderate presence of Amphipoda and a low presence of Ephemeroptera in the stomachs examined. This location does not have any measurements that correlate with the presence of Ephemeroptera. The moderate levels of Amphipoda in the stomachs corresponded with the deeper caudal peduncles that were present in this group of fish. Finally, location C had low concentrations of Amphipoda and no measurements that strongly correlated with the presence of amphipods.

**Table 3.** Means and standard deviations of stomach contents broken down for each group sampled.

| Site | Amphipoda | Tricoptera | Ephemeroptera |
|---|---|---|---|
| A | 8.8 (2.77) | 0 (0.0) | 0 (0.0) |
| B | 4.2 (1.3) | 0 (0.0) | 0.4 (0.89) |
| C | 4.2 (2.17) | 0 (0.0) | 0 (0.0) |
| D | 4.2 (4.38) | 1 (1.41) | 0 (0.0) |
| E | 3.4 (2.41) | 0.8 (1.79) | 0 (0.0) |
| F | 3.4 (3.44) | 1.8 (1.79) | 0 (0.0) |

The data collected in 2021 was compared with the 2022 data. Evidence suggested that morphology changed within the year that each collection was made (Figure 5). The ellipses around each year show no overlap which suggests that there is a difference between 2021 and 2022. The vectors show what is causing the difference between the two years. The measurements used in the comparison were caudal peduncle depth, body depth, and body length. The measurements that effected 2022 were body length and body depth. These measurements pulled to the bottom left of the figure. The measurement effecting the 2021 data was caudal peduncle depth. This measurement pulled downwards on the figure.

## Discussion

In conclusion, the morphology of yellow perch does change throughout Lake Bemidji. There has been very little research done on how morphology changes in an individual body of water. A study on how predation influences the adaptive morphology of young perch was done at the University of Uppsala in Sweden (Eklöy and Svanbäck 2005). This study demonstrated that there are differences in growth related to morphology based on the habitat that a fish was in. This showed a possible trade-off between foraging and the risk of predation which could be causing the morphological variation in young perch.

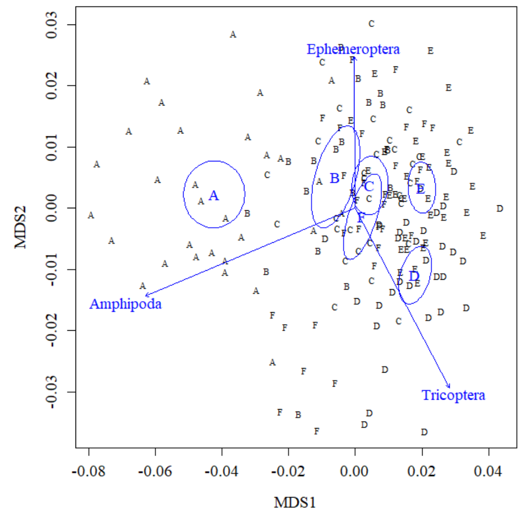


**Figure 4.** The three vectors in this figure represent the different macroinvertebrates found in the stomach contents and how they're affecting the placement of fish.

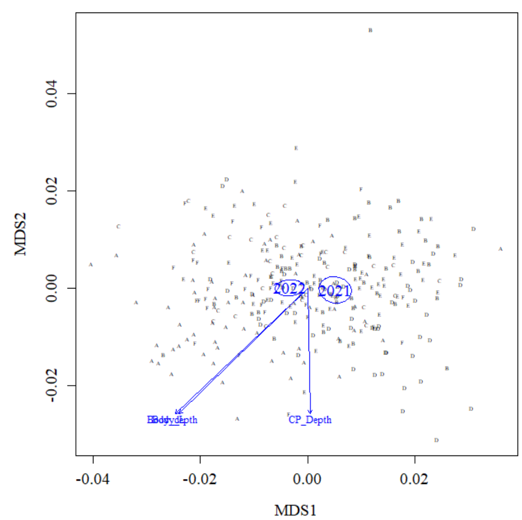


**Figure 5.** Three measurements from 2021 were compared with the same three measurements collected in 2022. These measurements were caudal peduncle depth, body depth, and body length. These metrics were used to determine if the fish from 2022 were morphologically different from the fish in 2021.

The second finding in this study was that diet does affect the morphology of yellow perch. There have been numerous studies on how diet can affect the morphology of fishes. Another study done in Sweden looked at the effects of habitat and food on the morphology of European perch. This study discovered that perch in the littoral zone had deeper bodies because they were eating more macroinvertebrates. The perch studied in the pelagic zone were more streamlined as they were consuming more zooplankton and less macroinvertebrates (Svanbäck and Eklöv 2002).

The final finding was that morphology can change from one year to the next. Most research has been done over a long period of time or across several bodies of water. However, data from 2021 and 2022 can be compared to show differences in morphology from one year to the next. A study focusing on how the morphology of Cyprinidae changed with their habitat over a 100-year period was done in Illinois. They had four main focuses: body size, sex, time, and hydrology in which they used museum collections to obtain some of their data (Jacquimen and Pyron 2016). After collecting all their data, they found that morphology changed over time in both lotic and lentic systems.

Overall, the results from this study were unexpected because a difference in morphology was not expected to be seen. The diet analysis of this study suggest that it influences morphology. However, more research would have to be done to determine if there is other factors influencing the morphology of yellow perch throughout Lake Bemidji. Other factors that could be studied are habitat, predator density, other diet sources, water temperatures, spawning, and macroinvertebrate densities.

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