# An Assessment of Largemouth and Smallmouth Bass Population Dynamics in Gull Lake

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## Environment

Gull Lake is a large inland lake located in the Kalamazoo River Watershed. Total surface area of this lake is 2,030 acres (8 km2), with maximum depths of 110 feet (34 m). The total volume of water is 73,798 acre-ft with an average depth of 36 ft. Gull Lake has a deep basin with 64 percent of the total area greater than 20 ft deep and 59 percent of the total volume greater than 20 ft deep (Figure 1). This deep, clear lake has numerous holes in excess of 75 ft (23 m), and has one large island in the south end known locally as "Grassy Island". Homes and cottages line the 18.5-mile shoreline; the majority of families are year-round residents. The area around Gull Lake was settled in the 1830s, especially the fertile Gull Prairie. The primary settlement on Gull Lake was Yorkville, located on the lake's outlet. At one time, several small manufacturing enterprises existed here, including a celery-flavored breakfast cereal maker. An interurban rail line once connected Gull Lake to nearby Battle Creek and Kalamazoo. The lake became a popular summer getaway for wealthy families, such as the Upjohns (pharmaceuticals), the Shakespeares (fishing tackle) from Kalamazoo and the Kellogg's (breakfast cereal) from Battle Creek.

Gull Lake was formed by glacial activity about 14,000 years ago, when large ice chunks broke off from a retreating glacier. The lake was about half of its current size until 1833, when a pioneer built a dam for his sawmill in Gull Creek. The dam raised the water level by 14 feet and almost doubled the size of the lake. Gull Lake's dam was upgraded to a sluice-gate structure in the 1880's. Since 1920, the Gull Lake Association owns, operates, and maintains the dam. The Association maintains lake levels about eight feet above its original pre-dam elevation. The Association draws down the water about eight to ten inches each fall to prevent ice damage to the shoreline, then raises the level to normal elevation after the ice melts. Seasonal alteration of lake levels has been in practice since the 1930's. Grassy Island at the southwest end of the lake used to be a peninsula connected to the mainland before construction of the dam. Two other islands, known locally as the "Hogs Backs," are about 20 feet under water in the middle of the lake. Prairieville Creek at the north end of the lake is the largest inlet to Gull Lake, with smaller inlets along the western and eastern shores originating from Wintergreen, Miller, and Little Long Lakes. Unlike most local lakes, there is no wetland along its shores and aquatic plant growth is sparse.

Observations in the 1970s suggested that Gull Lake was becoming increasingly productive, supporting undesirably high algal growth, prompting studies of the linkage between nutrient loading and algal blooms. These studies established that phosphorus was the principal limiting nutrient for algal growth in Gull Lake (Tessier and Lauff 1992). Citizen action, supported by state and federal grants, resulted in construction of a sanitary sewer around the perimeter of Gull Lake in 1984. This diversion of a significant source of phosphorus from Gull Lake resulted in a rapid reversal in eutrophication trends and marked improvement in water quality (Tessier and Lauff 1992). Current water quality in Gull Lake is considered good, although late-summer blooms of the blue-green alga Microcystis aeruginosa cause some concern (Dr. Stephen Hamilton, personal communication). This species produces microcystin, a toxin that is potentially harmful if water with abundant Microcystis cells is ingested directly without filtration or treatment.

Although most of the shoreline is private, there are two public access points on Gull Lake. The Prairieville Township Park on the north shore provides a four-lane boat launch ramp that accommodates 70 boat trailers. Another, much smaller access is on the northeast shore at the end of Baseline Road. The Kellogg Biological Station and Bird Sanctuary, owned by Michigan State University, are located on the eastern shore.

## History

Largemouth and smallmouth bass are an important sport fish in Gull Lake. Population dynamics related to the status of these populations and the fishing pressure endured by the population is of interest to managing sustainable populations. Black bass recruitment has been attributed to environmental variables (Maceina and Bettoli 1998; Sammons et al 1999) that create strong and weak year classes. Sport fish populations can be highly variable; therefore, it is critical for fishery managers to understand factors that regulate sportfish recruitment. Recruitment can be defined as the number of individuals coming into the exploited portion of a population.

Herein I describe population characteristics of largemouth bass in Gull Lake and compare year class strengths of the largemouth and smallmouth bass populations. General comparisons of population characteristics for largemouth bass are made between Gull Lake and Duck Lake, Calhoun County; both surveyed in the fall of 2011.

## Current Status

Largemouth and smallmouth bass (black bass) were collected using both a 21 ft modified Michigan DNR work boat with Smith-Root electrofishing gear and a standard Smith-Root electrofishing boat. The electrofishing gear was set to deliver pulsed direct current (30% cycle duty) on low range (250 volts and 60 pps) at 5 to 7 amps. Electrofishing runs were standardized by sampling distances of a half mile for each transect. There were 26 start points for transects around the perimeter of the lake (add figure). Each night transects were surveyed starting from a randomly selected point. The direction of sampling alternated each night between a clock-wise or counter-clockwise approach. Sampling duration varied with each transect but was generally 24 minutes or longer for each night of sampling. A dedicated crew recorded biological data and tagged fish collected from each electrofishing boat. Largemouth and smallmouth bass were measured to the nearest tenth of an inch; dorsal spines were removed for age estimation on 20 fish per inch group. Black bass equal to and larger than 14 inches were tagged with a Monel butt-end band (size 10 or 12) applied to the upper mandible. Tags were sequentially numbered to allow for identification of individual fish. All black bass collected received a left pelvic fin clip to evaluate tag loss and record recaptures for population estimates.

Size structure was quantified using a length-categorization system developed by Gabelhouse (1984). Proportional stock density (PSD) was calculated by the number of fish greater than quality length (12 inches) divided by the number of fish greater than stock length (8 inches). Differences in length frequency data were assessed by comparing the distribution of lengths obtained in Gull Lake with averages from Duck Lake, Calhoun County by a Kolmogorov-Smirnov asymptotic two-sample test. Weighted Mean lengths at age and age length keys were used for growth analysis. Differences in mean length at age were tested by using a two-way analysis of variance, controlling for age as a covariate. Mean growth index was computed to compare data to Michigan state averages as described by Schnieder et al. (2000). The mean growth index is the average deviations between the observed mean lengths and statewide seasonal (October) average lengths.

Estimates of population size for largemouth bass in Gull Lake were made for fish ten inches and larger using recaptures of tagged fish during subsequent electrofishing efforts. Population size was estimated by mark-recapture using closed-population models in program MARK (Otis et al. 1978). Each day of electroshocking was a capture event. The model selection tool within the program was used to select the appropriate model out of the eight models tested in program MARK (M0, Mb, Mt, Mh, Mth, Mbh, Mtb, Mtbh). Model M0 assumes equal probability of capture among all individuals over each sampling period, model Mb allows for trap response, model Mt assumes time varying probability in capture, and model Mh allows for heterogeneity in capture probability among all individuals (Pollock et al. 1991). Models Mth and Mtb both assume time varying capture probability but also incorporate individual heterogeneity in capture probability and trap response, respectively. Model Mbh account for trap response and individual heterogeneity in capture probability, while model Mtbh also incorporates time varying capture probability (Pollock et al. 1991).

Prior to release, largemouth bass were marked by removing a small portion of the left pelvic fin and recaptured fish were noted in subsequent catches. Because sampling took place over a relatively short period of time, no adjustments were made in the estimates to compensate for growth or mortality. Population estimates were then proportioned into four size categories (8-12 in, 12-14 in, 14-18 in, and >18 in) by multiplying the total estimate at each lake times the mean nightly relative stock density of each size group. Densities of 10-inch and longer largemouth bass (number/acre), as well as densities of the various size groups of fish, at each lake were calculated by dividing the estimates by total surface area.

Catch at age for all largemouth bass were estimated from a length at age key for use in the catch-curve analyses. Catch curve analyses were performed on age-structure data from electrofished largemouth bass by regressing the natural logarithm of the number caught in each year class against age for fish age 3 (complete or nearly complete recruitment to the gear in proportion to their abundance) and older. The slope of the regression is the instantaneous mortality rate (z) and the estimate of survival is equal to e-z (Ricker 1975). Relative year class strength obtained from the residuals of the catch curve was used as an index of recruitment. Only population data from one year was collected, therefore properties of the catch curve regression were examined as in Maceina (2004) where residuals of the catch-curve regression were used as indices of year-class strength or weakness.

## Analysis and Discussion

During the survey period a total of 2,542 captures of largemouth bass were recorded of which 2,144 were individually marked fish and 398 were recaptures. To capture black bass nearly 30 hours of sampling effort were recorded from 70 transects around the lake. Relative abundance of the largemouth bass population was 1.2 bass per minute. The best-fit model based on the chi-square goodness of fit test was model Mh, which generated an abundance estimate for all sized largemouth bass of 10,833 (95% CI 9,470-12,519) while the estimate for stock sized largemouth bass was 5,281 (95% CI 4,560-6,192).

Largemouth bass growth was at the statewide average length at age. Largemouth bass achieved the legal size limit of 14 inches at 5.7 years. Population mean length was 9.27 inches (se 0.063) in Gull Lake (Table 1). Mean state growth index was -1.1 with the largest fish measured at 21.7 inches in total length. Size distributions of bass by inch group were consistent. Length frequency distributions show four clear modes with a descending line of sizes greater than 12.0 inches (Figure 3). The mode at 3.0 inches represents age-0 fish collected during the fall, whereas the mode at 6.5 inches represents age 1 fish. Legal sized fish greater than 14.0 inches comprised only 5.8 percent of the catch. Size distributions of largemouth bass between 10.0 and 13.5 inches comprised 43 percent of the catch. Proportional stock density was 0.35 for largemouth bass and within acceptable range of 10-40%. The difference in largemouth bass mean lengths between Duck Lake and Gull Lake was statistically significant (t= 7.57, P=0.001). The distribution of total length (Figure 2) also differed significantly from Duck Lake (K-S asymptotic test statistic = 6.418; P = 0.0001). In comparison, legal sized largemouth bass achieved 14 inches at 8.9 years in Duck Lake, Calhoun County.

Inspection of catch curve plots of loge number at age against respective year classes showed minimal variation about the regression line (r2 = 0.93) and suggested that annual recruitment is nearly constant in Gull Lake (Figure 4). In Gull Lake, age 3 and older largemouth bass represented nine year classes. Of these fish, the 2006 cohort was the predominant year class and comprised 46% of the catch that was collected in fall 2011. Instantaneous annual mortality rate was -0.785 and corresponded to total annual survival of 45% and a theoretical maximum age of 12.3 years. The theoretical maximum age was similar to the maximum age collected from observed age-structure data.

Relative density estimates of largemouth bass in Gull Lake suggest that numbers of fish are highest in the Southern basin and along the northwest shoreline of Gull Lake (Figure 6). Relative density estimates were lowest along the eastern shoreline of the lake. A high proportion (62%) of largemouth bass collected had lacerations along the body of the fish. This may be a result of high encounters with northern pike or a high angler hooking wound rate.

A total of 171 smallmouth bass encounters were recorded and representing 6.3% of the black bass sample. Reasonable numbers of marked fish were not recaptured to generate a population estimate. Smallmouth bass average length at age was higher than largemouth bass from age 0 to age 5. There was very little survival of smallmouth bass older than age 5 with the maximum observed age at 9 years. The age 6 and 7 year classes were absent from the collection for smallmouth bass. Growth of smallmouth bass was at the state average rate. Theoretical maximum length was 19.7 inches (k=0.246, t0=-0.838) while the maximum observed length was 18.6 inches. Smallmouth bass achieved the legal size limit of 14 inches at 4.2 years. Age 1 smallmouth bass comprised 41% of the catch with 12% of the catch comprised of quality length fish (≥12 inches). Instantaneous natural mortality rate was 0.527 with a conditional mortality rate of 0.41.

Water temperature was recorded hourly from 04/27 through 12/07/2011 (Figure 5). Based on temperature recordings during this period, July recorded the highest maximum value at 86.1 oF on the 201 day of the year. July was the hottest month of the year with an average of 80 oF (se 0.126). Largemouth bass are a typical warm-water fish (optimal thermal habitat mean 84 oF) while smallmouth bass are slightly cooler adapted, with an optimal temperature of 80 oF. These temperatures occurred from May through June with duration of 48 days.

## Management Direction

Recruitment is one of three primary factors that structure fish populations, the others being growth and mortality. Stable recruitment reduces the complexity of managing fish populations. Variable recruitment affects the management of fisheries in many ways; fish abundance can fluctuate dramatically due to recruitment variation, size structure of fish populations can be influenced by irregular recruitment, and strong and weak year classes have been related to annual variation in angler catch rates. Recruitment of the largemouth bass population in Gull Lake appears to be stable with consistent year classes despite the high recreational effort towards fishing for bass. The size composition of the bass population appears to be affected by angling; however this perception is regarded as slight because of the high legal size limit (14 inch minimum) that regulates the harvest of bass and only permits harvest of the largest individuals.

Growth of bass in Gull Lake is at the state average providing acceptable inclusion of new fish into the exploited portion of the population just shortly before age 6. The relative abundance of fall-collected, age 0 fish provided an accurate measure of year class strength even though small fish may not have been fully recruited to electrofishing gear. The number of age 0 fish collected can be compared to the corresponding year class during subsequent years of sampling to verify this relationship. A positive association between age 0 fish abundance and yearclass strength has been demonstrated in other studies adding credence to this measure as an effective method for determining year class strength of bass (Paragamian and Wiley 1987).

Size structured indices for largemouth bass were indicative of a balanced population (Gabelhouse 1984). Size structured indices were higher in Gull Lake than Duck Lake, where the size structure was poor and mortality rates were higher in 2011.

Overall the population of bass in Gull Lake appears to be in good condition and fishing regulations appear to be appropriate as reflected in the status of this survey. Angling pressure is high in Gull Lake as measured during a creel census in 2002, however overfishing does not appear to be a problem and should alleviate some angler concerns regarding declining catch rates and high individual bass mortality at access points. Current size and creel regulations are adequately protecting the largemouth bass population. Biologists recommend that Gull Lake continue to be managed under the statewide regulation of a 14 inch minimum length limit with a creel limit of 5 largemouth bass per day. If mortality estimates exceed 54 % during future sampling events there may be a need to reduce the overall harvest limit or restrict the recreational fishing season, but so far the fishery is maintained by current harvest regulations and catch and release angling.

Production of largemouth bass and smallmouth bass in Gull Lake depends on temperature and spatial habitat distribution. Midsummer water temperatures recorded in 2011 favor a higher production of largemouth bass and are correlated with year class production of this warm-water fish. The spatial distribution is strongly favored to largemoth bass in the southern and northwestern basins of the lake where vegetative cover is greater. Smallmouth bass relative abundance is higher along the northeastern shoreline where coarse sediment and greater dropoffs are present. Largemouth bass are doing better in Gull Lake as a result of these conditions and should continue to be productive in the lake influenced by climate warming.

## References

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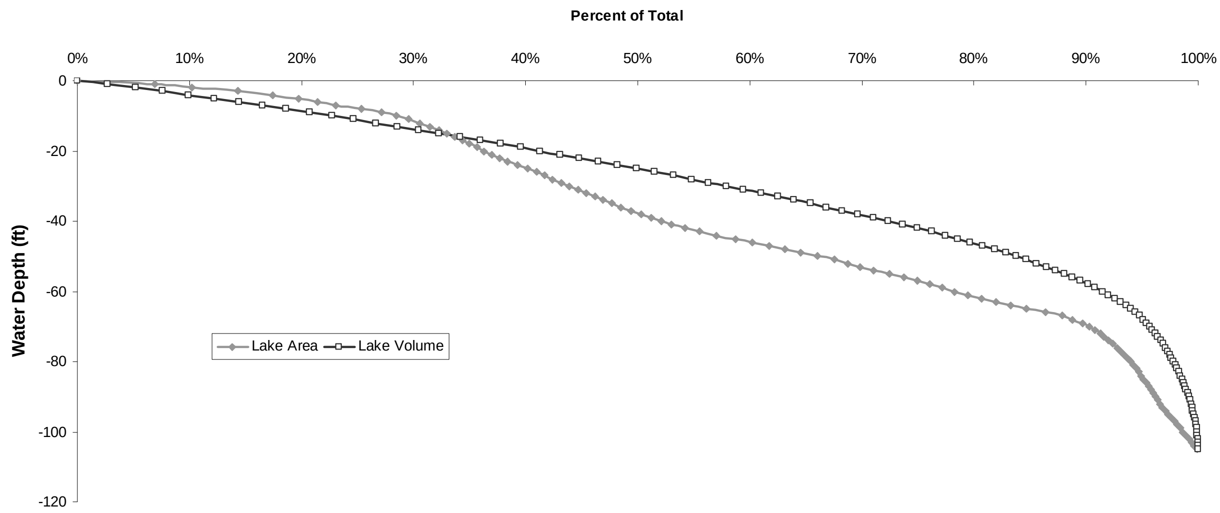


Figure 1. Hypsographic curve (Lake Area/Volume) of Gull Lake

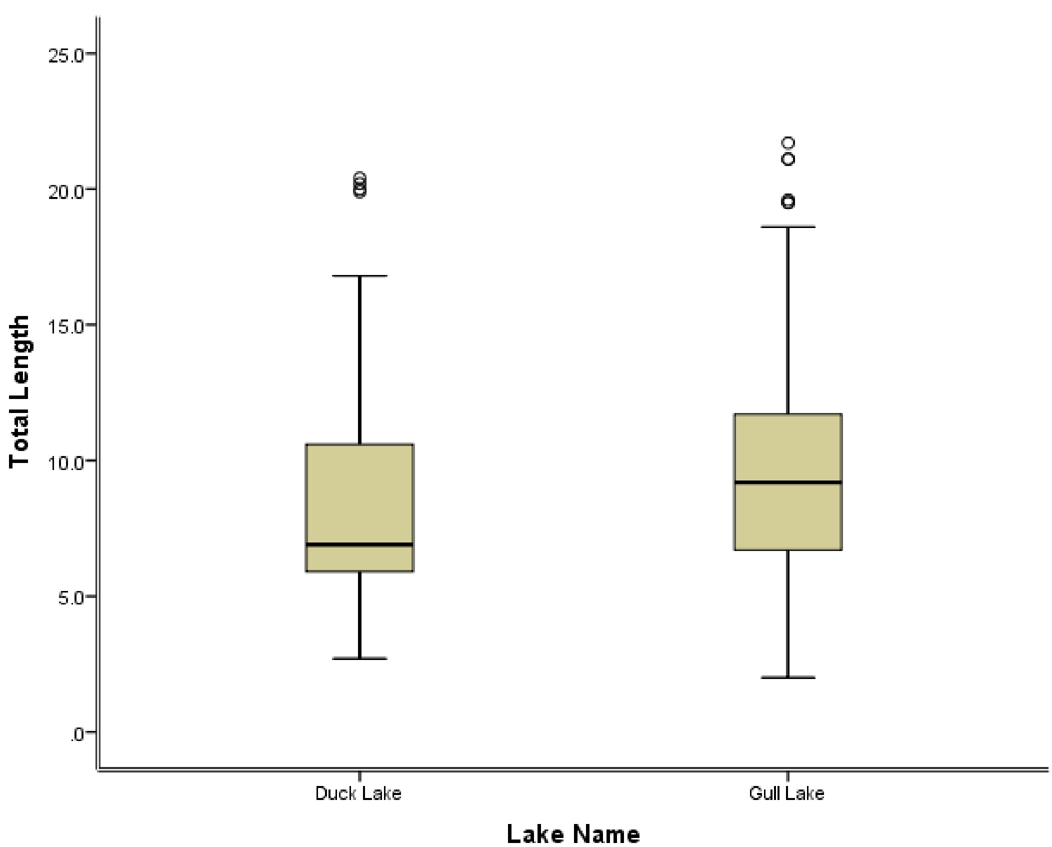


Figure 2. Box plot of Total Length for Largemouth bass in Duck Lake and Gull Lake, 2011.

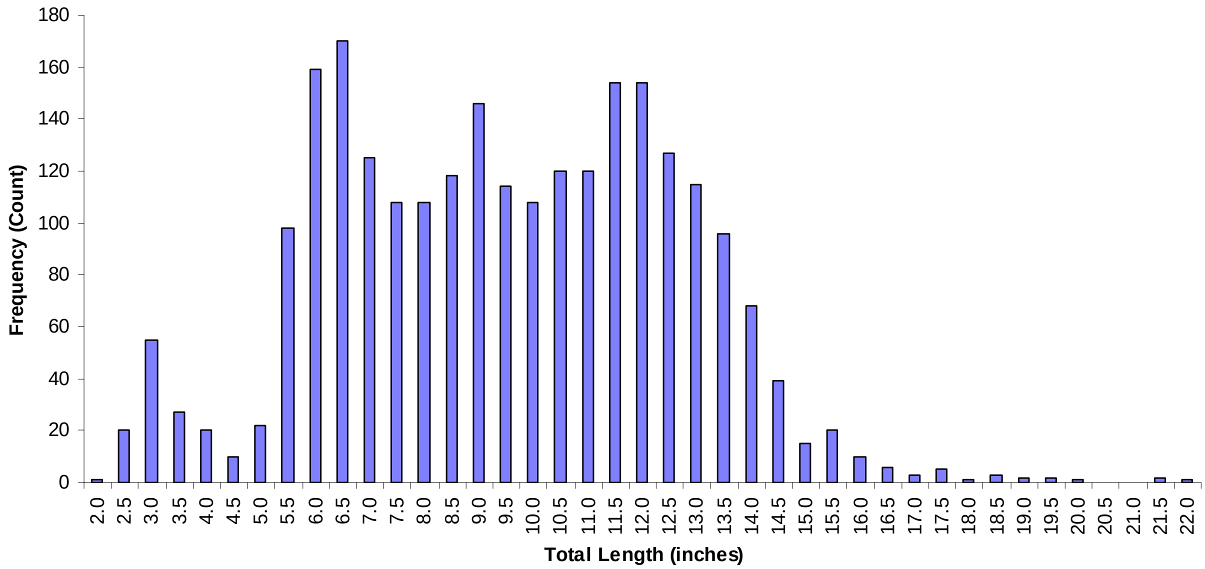


Figure 3. Length frequency histogram of largemouth bass in Gull Lake, 2011.

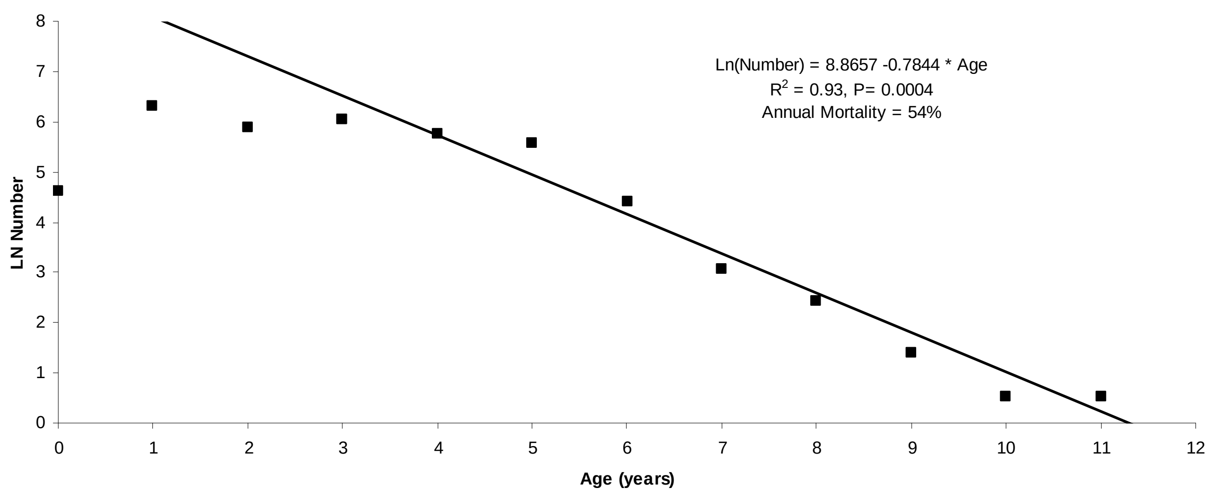


Figure 4. Catch curve and corresponding regression (ages 3-9) for largemouth bass collected from Gull Lake, 2011.

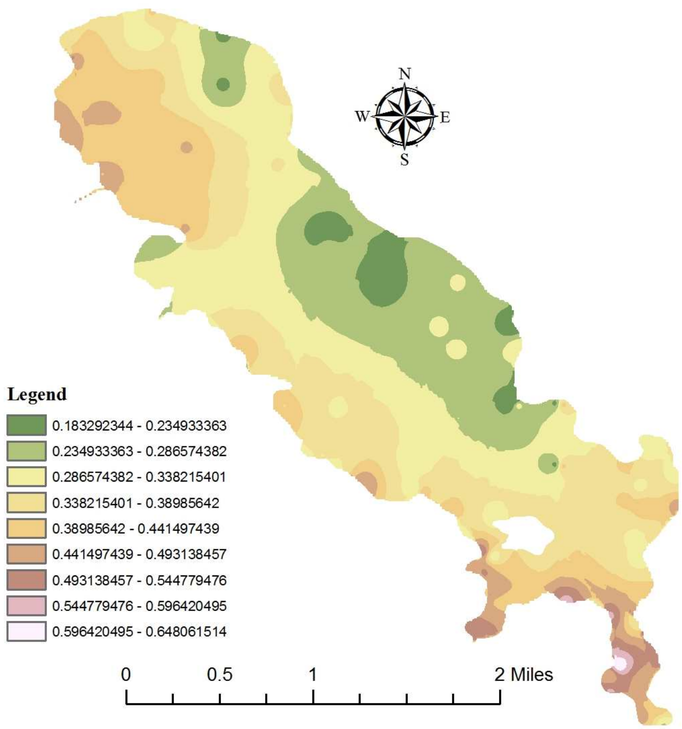


Figure 5. Relative density plot of largemouth bass in Gull Lake, 2011.

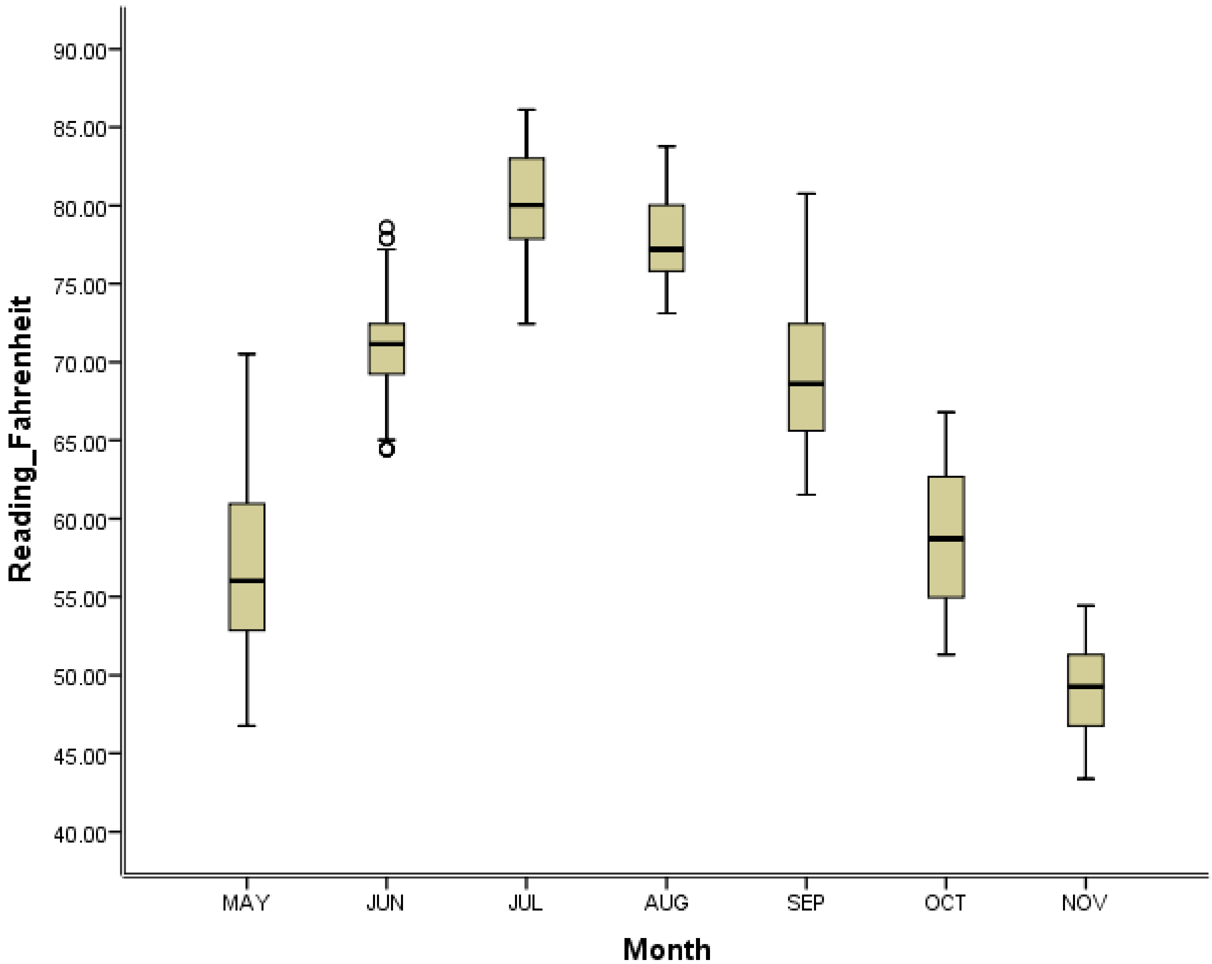


Figure 6. Monthly water temperatures recorded in Gull Lake, 2011.

Table 1. Population length measurements for Largemouth bass in Gull Lake

| | | | | |
|---|---|---|---|---|
| Gull Lake | Mean | | 9.277 | Se =.0631 |
| | 95% Confidence Interval for Mean | Lower Bound | 9.154 | |
| | | Upper Bound | 9.401 | |
| | 5% Trimmed Mean | | 9.288 | |
| | Median | | 9.200 | |
| | Variance | | 9.835 | |
| | Std. Deviation | | 3.1361 | |
| | Minimum | | 2.0 | |
| | Maximum | | 21.7 | |
| | Range | | 19.7 | |
| | Interquartile Range | | 5.0 | |
| | Skewness | | .050 | .049 |
| | Kurtosis | | -.342 | .098 |

Table 2. Mean length at age for largemouth bass collected from Gull Lake, 2011.

**Case Summaries**

Total_Length_In_Inches

| Age_Class | N Aged | Mean | Median | Std. Error of Mean | Std. Deviation | Variance | Range |
|---|---|---|---|---|---|---|---|
| 0 | 40 | 3.058 | 2.900 | .0704 | .4454 | .198 | 1.7 |
| 1 | 61 | 6.056 | 6.000 | .1117 | .8725 | .761 | 3.6 |
| 2 | 36 | 8.364 | 8.300 | .1308 | .7845 | .616 | 4.0 |
| 3 | 39 | 10.310 | 10.300 | .1406 | .8780 | .771 | 3.3 |
| 4 | 28 | 11.786 | 11.900 | .2203 | 1.1658 | 1.359 | 4.9 |
| 5 | 43 | 13.633 | 13.400 | .1529 | 1.0023 | 1.005 | 3.9 |
| 6 | 23 | 14.400 | 14.400 | .2838 | 1.3611 | 1.853 | 5.2 |
| 7 | 14 | 15.771 | 15.500 | .2762 | 1.0336 | 1.068 | 3.2 |
| 8 | 10 | 16.260 | 16.050 | .3506 | 1.1088 | 1.229 | 4.4 |
| 9 | 5 | 17.300 | 17.200 | .7740 | 1.7306 | 2.995 | 4.2 |
| 10 | 2 | 19.000 | 19.000 | .5000 | .7071 | .500 | 1.0 |
| 11 | 1 | 21.100 | 21.100 | . | . | . | .0 |
| 12 | 1 | 19.600 | 19.600 | . | . | . | .0 |
| Total | 303 | 9.871 | 9.900 | .2526 | 4.3965 | 19.329 | 18.7 |