GROWING DEGREE DAYS COMPARED TO GROWTH OF WALLEYE AND SAUGER FROM DIFFERENT SYSTEMS

Ben Hoover
Aquatic Biology Program
Bemidji State University
Bemidji, MN, USA
benjamin.hoover@live.bemidjistate.edu
Faculty Sponsors: Dr. Andrew W. Hafs (andrew.hafs@bemidjistate.edu)

***Abstract*—Walleye *Sander vitreus* and Sauger *Sander canadensis* exist in most river and lake systems across the state of Minnesota and have historically been a highly sought-after species. Variable water temperatures play a significant role in the growth of cold-blooded organisms such as walleye and sauger. Therefore, the objective of this study is to test for a relationship between growing degree days (GDD) and the growth of walleye and sauger from Lake Pepin, Leech Lake, and Lake of the Woods. Data for growth and age was readily available and was sourced from MN DNR lake survey database from 2006 to 2023. Growing degree data was sourced from Weather Underground. A regression test was performed on the data, and Akaike Information Criterion (AIC) scores were generated. This study conducted four regressions tests on the data set. There is a clear upward trend showing a positive correlation between GDD and growth, indicating that as GDD increases so will growth. Additionally, a consistent correlation between growth and year was observed with Leech Lake and Lake of the Woods following a clear trend overtime, while Lake Pepin differed. Growing degree days and year indicated a correlation between Leech Lake and Lake of the Woods while Lake Pepin again differed. These findings highlight a significant relationship between both GDD and year, and growth and year. This variation may also be influenced by several factors such as forage species, nutrient loading, and geographic location.**

I. Introduction

Walleye and sauger have historically been one of Minnesota's top sport fish (Olson 1958). Metabolic rate of fish is largely determined by the ambient temperature of their environment (Chezik et al. 2014). Therefore, variable water temperatures play a significant role in the growth of cold-blooded organisms such as walleye and sauger. The optimal temperature for growth of walleye and sauger is 4.62 ℃ (Honsey et al. 2023).

Fish growth is defined as the increase in size usually measured by length or weight. Fish growth only happens within certain temperature ranges, of which the upper and lower temperature thresholds are well established for many species. Walleye and sauger begin to grow at a minimum temperature of 4.62 ℃ (Honsey et al. 2023), while the upper limit for growth is 30 ℃ (Hasnain et al. 2013).

Air temperatures have been increasingly surrogated for surface water temperatures (Chezik et al. 2014). Air temperatures also show a high correlation with surface water temperatures (Chezik et al. 2014), with historical air temperature databases being more extensive and easier to find. Growing degree days is described as the thermal opportunity for growth and development (Chezik et al. 2014). Therefore, the objective of this study is to test for a relationship between growing degree days and growth of year one walleye and sauger from Lake Pepin, Leech Lake, and Lake of the Woods.

II. Methods

Lake Pepin is the smallest of the three systems, with a surface area of 188.55 km^2. It is one of the few lakes with a major river flowing through it. Due to its connection to the Mississippi river, Lake Pepin drains a significant portion of the state. Leech Lake is the second largest system in this study, covering a total surface area of 451.33 km^2. The largest system included in this study is Lake of the Woods, with a surface area of 3,849.92 km^2.

The growth data was taken from the Minnesota DNR Large Lake Database which uses gillnets to sample multiple systems for game fish such as walleye and sauger (MN DNR 2025). The growth data was readily available and was taken from the large lake database. The data was broken down by the system it came from, year of capture, age of fish, and length of fish. The analysis for growth of walleye and sauger were pooled. This is because sizes generally do not differ until later in life.

The growing degree day data was collected from Weather Underground (2025) which is a website with historical weather data. Air temperatures were obtained from local airports near the systems. The airports used were the Red Wing Regional Airport for Lake Pepin, Warroad International Airport for Lake of The Woods and, Bemidji regional airport for Leech Lake.

Maximum monthly temperatures and minimum monthly temperatures were used to calculate growing degree days. Monthly maximum and minimum temperatures were input into the equation (Equation 1). The equation then output the amount of growing degree days for given a month. Any negative GDD was input as a zero. Growing degree days were then summed for a given year. With both maximum and minimum temperatures being represented as Tmax and Tmin with Tbase being represented as the temperature at which walleye and sauger begin to grow. Equation one shows the formula for growing degree days (Uphoff et al. 2013).

$$\mathrm{GDD} = \left[\frac{T_{\max} + T_{\min}}{2}\right] - T_{\mathrm{base}}$$

Equation 1: This equation was generated to calculate growing degree days (Uphoff et al. 2013). Growing degree days represented as GDD and temperature represented as Tmax and Tmin and temperature at which walleye and sauger start to grow represented as Tbase.

Four regression tests were performed on the data set with each regression focusing on a different section of the data. The series of models tested were length as a function of GDD with lake as an additive, length as a function of GDD times lake, length as a function of lake, and length as a function of GDD (Table 1). Akaike Information Criterion (AIC) scores were generated. AIC score is a number used to determine which model is best supported, the lower the AIC score the better.

TABLE. 1. MODELS REPRESENTING LENGTH (MM) WITH GDD (2006-2023) AND LAKE FROM LAKE PEPIN, LEECH LAKE, AND LAKE OF THE WOODS.

Model	AIC
Length ~ GDD + Lake	318.5
Length ~ GDD * Lake	320.5
Length ~ Lake	332.4
Length ~ GDD	364.3

III. Results

The results show a clear relationship between GDD and length at age one. With ranges for both being listed below. Lake Pepin's ranges were 210 to 362 mm and 74 to 86 growing degree days. Leech Lake's ranges were 178 to 366 mm and 52 to 70 growing degree days. Lake of the Woods ranges were 128 to 416 mm and 44 to 69 growing degree days.

The best supported model was length as a function of GDD with lake as an additive variable (AIC = 318.5; Table 1). The fitted model was plotted using slope of GDD and length from each system (Figure 1). This shows a positive relationship between length and GDD (Figure 1).

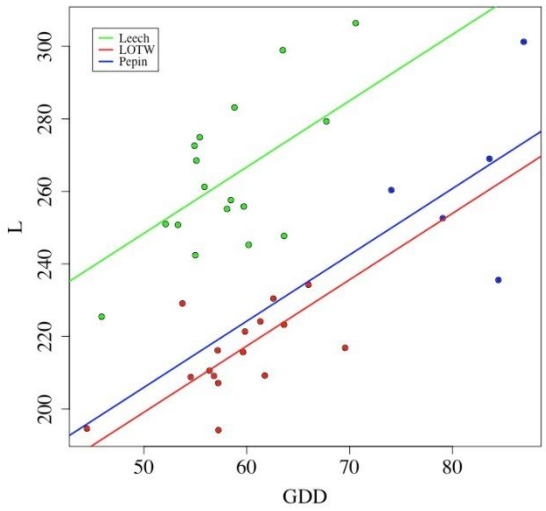

Fig. 1. Length (L; mm) plotted against growing degree days (GDD) from 2006 to 2023 for Lake Pepin, Leech Lake, and Lake of the Woods. Data was collected from MN DNR lake survey data base.

The growth data consists of lengths from 2006 to 2023. The data shows a correlation between GDD and growth for all years and between systems (Figure 2). The relationship is shown in years such as 2009 which shows a sharp drop for both GDD and growth in Leech Lake and Lake of the Woods (Figure 2 and Figure 3). While Lake Pepin shows an upward trend in growth (Figure 2). This trend is also shown in GDD compared to year suggesting a relationship (Figure 3).

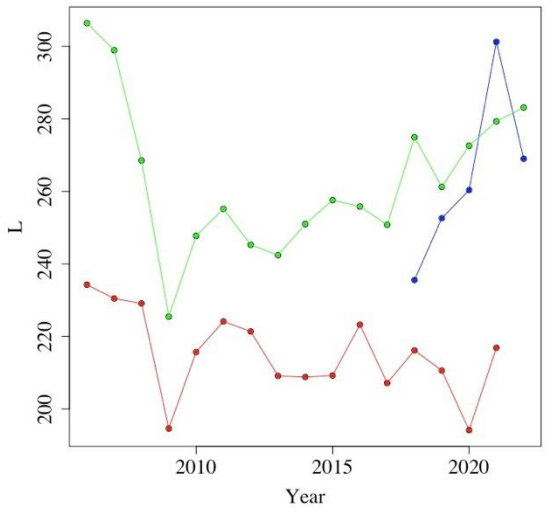

Fig. 2. Length (L; mm) plotted against year from 2006 through 2023 for Lake Pepin, Leech Lake, and Lake of the Woods. Data was collected from MN DNR lake survey data base.

GDD plotted over year shows a correlation between the amount of growing degree days for certain years (Figure 3). This correlation can be seen as a warming or cooling trend (Figure 3). There is a clear correlation between Leech Lake and Lake of the Woods. Growing degree days for both systems are

nearly identical. While Lake Pepin differs with an increased amount a growing degree days over time (Figure 3).

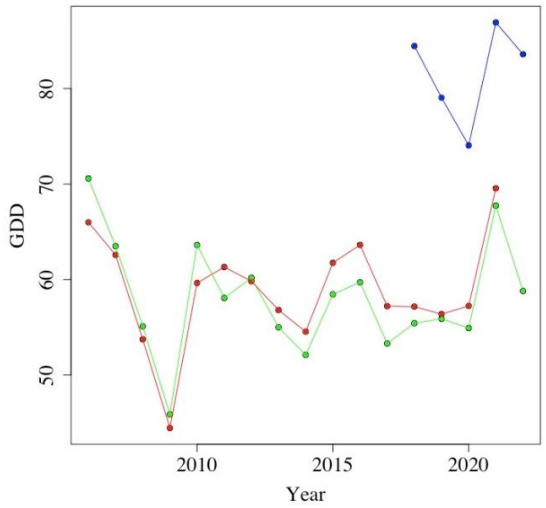

Fig. 3. Growing degree days (GDD) plotted against year from 2006 to 2023 for Lake Pepin, Leech Lake, and Lake of the Woods. Data was collected from MN DNR lake survey data base.

IV. Discussion

There is a clear positive relationship between growth and growing degree days. This correlation suggests that GDD may affect growth of cold-blooded organisms. The positive relationship between GDD and growth may be down to an increase in water temperature. This increase in temperature should increase a fish's thermal opportunity for growth and development (Chezik et al. 2014). There is evidence to suggest that as growing degree days increase fish may experience higher growth rates (Uphoff et al. 2013).

There is a consistent correlation between growth and year that was observed. The correlation could be influenced by the air temperature. Air temperatures are increasingly being surrogated for surface water temperatures (Chezik et al. 2014). With this correlation being seen in Leech Lake and Lake of the Woods with length data seeming to follow one another (Figure 2). This trend is also seen with GDD and year with Leech Lake and Lake of the Woods (Figure 3). This relationship between the two can be seen in multiple years. 2009 showed a sharp decline in GDD and growth suggesting a relationship.

The correlation between growing degree days and year is very interesting. There is a clear correlation between Leech Lake and Lake of the Woods, while Lake Pepin stands on its own. This close correlation maybe because of their close geographic location. Lake Pepin again differs from the other systems with a higher amount of GDD. Perhaps this is because Lake Pepin is further south than the other two systems. This also reveals an interesting relationship with growth of walleye and sauger as it seems to follow the amount of growing degree days in each year.

References

[1] Chezik, K.A. 2013. *Fish growth and degree-days: Advice for selecting base temperatures in both within-and among-lake studies*. University of Minnesota.

[2] Chezik, K.A., N.P. Lester, and P.A. Venturelli. 2014. Fish growth and degree-days I: Selecting a base temperature for a within-population study. Canadian Journal of Fisheries and Aquatic Sciences 71:47–55.

[3] Chezik, K.A., N.P. Lester, and P.A. Venturelli. 2014. Fish growth and degree-days II: selecting a base temperature for an among-population study. Canadian Journal of Fisheries and Aquatic Sciences 71:1303–1311.

[4] Glibert, P.M. 2010. Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco Estuary, California. Reviews in Fisheries Science 18:211–232.

[5] Hasnain, S.S., B.J. Shuter, and C.K. Minns 2013. Phylogeny influences the relationships linking key ecological thermal metrics for North American freshwater fish species. Canadian Journal of Fisheries and Aquatic Sciences 70:964–972.

[6] Hilborn, R, R.O. Amoroso, E Bogazzi, O.P. Jensen, A.M. Parma, C. Szuwalski, C.J. Walters. 2017. When does fishing forage species affect their predators? Fisheries Research 191:211–221.

[7] Honsey, A.E., A.L. Rypel, and P.A. Venturelli. 2023. Guidance for selecting base temperatures when using degree-days in fish growth analyses. Canadian Journal of Fisheries and Aquatic Sciences 80:549–562.

[8] Meerbeek, J. 2017. Large Lake Monitoring Program Annual Completion Report: Lake Pepin, 2008. In: Academia.edu. https://www.academia.edu/30784267/Large_Lake_Monitoring_Program_Annual_Completion_Report_Lake_Pepin_2008. Accessed 23 Oct 2024.

[9] Minnesota Department of Natural Resources. 2025 Minnesota's largest Inland Lakes. In https://www.dnr.state.mn.us/top10lakes/index.html. Accessed 24 Apr 2025.

[10] Olson, D.E. 1958. Statistics of a walleye sport fishery in a Minnesota lake. Transactions of the American Fisheries Society 87:52–72.

[11] Smith, D.M., C.D. Hilling, S.A. Welsh, and D.I. Wellman. 2022. Differences in population characteristics and modeled response to harvest regulations in reestablished Appalachian walleye populations. North American Journal of Fisheries Management 42:612–629.

[12] Sullivan, M.G. 2003. Active management of walleye fisheries in Alberta: dilemmas of managing recovering fisheries. North American Journal of Fisheries Management 23:1343–1358.

[13] Uphoff, C.S., C.W. Schoenebeck, and W.W. Hoback, 2013. Degree-day accumulation influences annual variability in growth of age-0 walleye. Fisheries Research 147:394–398.

[14] Venturelli, P.A., N.P. Lester, T.R. Marshall, and B.J. Shuter 2010. Consistent patterns of maturity and density-dependent growth among populations of walleye (*Sander vitreus*): application of the growing degree-day metric. Canadian Journal of Fisheries and Aquatic Sciences 67:1057–1067.

[15] Weather Underground. 2025. Accessed 24 April 2025. https://www.wunderground.com/.