Age-Length Analysis of Northern Pike (*Esox lucius*) and Largemouth Bass (*Micropterus salmoides*) for Saint John's University Campus Lakes Compared to Higher Exploitation

Paige Folkerts[1] and Trevor Keyler[#]

[1]College of Saint Benedict & Saint John's University, USA
[#]Advisor

ABSTRACT

A length-at-age analysis was conducted for Northern Pike (*Esox lucius*) and Largemouth Bass (*Micropterus salmoides*) on Saint John's University campus lakes in Collegeville, MN to determine if growth differences exist when compared to higher exploitation Minnesota lakes. Anal fin rays were collected from Northern Pike on Stumpf Lake while otoliths were collected from Largemouth Bass on Lake Sagatagan. Both samples were prepared and analyzed by locating the focus and enumerating annuli. The length-at-age data collected was compared to other Minnesota lake length-at-age data for the respective species and showed quicker maturation for the species on higher exploitation lakes. It is likely that low exploitation on campus lakes leads to density-dependent declines in growth due to increased intraspecific competition. Additionally, fish on high exploitation lakes show quicker maturation to fill available niches. Von-Bertalanffy fitted growth curves were applied to the averaged data and R-Squared values for both Largemouth Bass and Northern Pike were high (>0.9). Provided length, our growth models are useful for predicting the age of both Northern Pike and Largemouth Bass on their respective campus lakes. The relatively pristine (few aquatic invasive spp. and runoff) St. John's campus lakes show an interesting dynamic where fish experience slower growth, but on average are older than comparable lakes with higher exploitation rates.

Introduction

Understanding the dynamics of fish populations for different ecosystems is necessary for proper stock assessment and the conservation of fishes. One metric used to assess the health of fish populations is length-at-age for a species.[1] Length-at-age analysis is conducted by measuring the length of a sample fish and determining the age of the fish by aging structures such as otolith or anal fin rays. Aquatic ecosystem health is directly tied to the health of a system's fishery and different conservation management plans are executed for different rates of exploitation (specific rate of fish removal from a lake). Conservation management not only benefits the species being measured, but it also benefits the ecosystem as a whole.[2] In turn, there is greater opportunity for both maximum biomass and profits for fisheries.

Different exploitation lakes have different biomass quantities, and it is important to analyze the difference to maximize benefits for both. High exploitation lakes are often associated with public access and motor use, whereas low exploitation lakes such as the campus lakes of Saint John's University, have limited access and restricted motor use.[3] Lake Sagatagan and Stumpf Lake are the two largest lakes on Saint John's University campus. Fishes here experience low exploitation rates and have very limited disturbance from point source pollutants, such as chemical/pesticide runoff, gasoline, and litter.

Additionally, motor restrictions help limit the introduction of aquatic invasive species associated with boat transfer between lakes. According to Gunderson (2018), invasive species, such as the zebra mussel (*Dreissena* *polymorpha*), consume high numbers of phytoplankton.[4] In turn, this lowers the nutrient availability of zooplankton for larval fish, which leads to higher mortality rates due to lack of nutrient resources. Low exploitation lakes similar to Saint John's University campus lakes, as a result, often have lower fish mortality rates. In turn, there is more intraspecific competition resulting in slower growth, lower weight, later sexual maturation, and lower spawning rates.[5]

Two of the most targeted fish species on Saint John's University lakes are Largemouth Bass and Northern Pike. Our objective was to determine if there is slower growth for the Northern Pike and Largemouth Bass on Stumpf Lake and Lake Sagatagan, respectively, when compared to higher exploitation lakes in Minnesota. In order to analyze growth rate, age of the fish samples must be determined. There are three common ways to determine fish age: scales, fin rays, and otoliths. Largemouth Bass age is best determined by analyzing otoliths.[6] Cheney (1971) provides evidence that fin ray annuli provide the most accurate age count for Northern Pike.[7] We predict low exploitation fisheries to have slower growth than high exploitation fisheries.

Methods

Largemouth Bass were collected via electroshock from Lake Sagatagan in May of 2019 with assistance from the Minnesota DNR. Approximately three Largemouth Bass were collected per inch designation, from 8 to 19 inches, totaling a sample size of 33. Largemouth Bass were measured and otoliths were removed for analysis via techniques described by Secor, et al. (1992).[8] Length measurements were originally taken in inches then later converted to millimeters for analysis. Largemouth Bass otoliths were analyzed via the crack and burn method. The otoliths were cracked down the middle of the focus, wet-sanded with mineral oil in a six grit series- from a course grit of CW-320 to a fine grit of CW-3000. The otolith was held with forceps and slightly burnt over a Bunsen burner for five seconds and mounted in adhesive putty under a 40X magnification dissecting scope. The annuli were analyzed using a fiberoptic gooseneck microscope illuminator for side illumination. An additional year was added to annuli counts due to early spring sampling and the lack of the current year's annuli being formed.[9] Comparison data used all samples; however, introspective analysis used only length average per age in years.

Northern Pike were collected via both Fyke netting and angling on Stumpf Lake between May and June of 2019. Length measurements were taken for collected Northern Pike and a small portion of their anal fin was removed for analysis. As in the Largemouth Bass measurements, the Northern Pike length was originally measured in inches and later converted to millimeters. All Northern Pike were released unharmed. Northern Pike anal fin rays were wet sanded with mineral oil in a six grit series- from a course grit of CW-320 to a fine grit of CW-3000. Fin rays were then mounted on a 40X magnification dissecting scope stage with adhesive putty. The annuli were counted by locating the focus and starting the count outward to determine the age. An additional year was added to the calculation due to the early collection.

Data was analyzed by comparison to higher exploitation lake data found on the Minnesota DNR archive. To analyze intraspecific data, Von-Bertalanffy fitted growth curves were applied to create an equation to predict the age of the species at any measured length.[10] Then R-squared values were found using Excel software, as well as the L_{inf}, K, and t_0 values of the Von-Bertalanffy fitted growth curves.

Results

Each sample, for both Largemouth Bass and Northern Pike, was analyzed for approximate age as shown in Figures 1 and 2. Largemouth Bass and Northern Pike in Saint John's University campus lakes show slower growth than higher exploitation lakes- Lake Minnetonka and Ice Clearing Lake respectively (Figures 3 & 5). Von-Bertalanffy fitted growth curves of the data, modeled via the equation:

$$Lt = Linf\left(1 - e - K(t - t0)\right)$$

estimate the age for Largemouth Bass and Northern Pike (Figures 4 & 6) and show high R-squared values of 0.940 and 0.910, respectively.

For Largemouth Bass on Lake Sagatagan, the growth rate (K), according to the Von-Bertalanffy fitted growth curve, is 0.17 mm per year. The age at which the Largemouth Bass would have “zero length” (t_0) is -0.43 years, and the length at which growth stops (L_{inf}) is 510 mm. These values, along with the individually measured length (L_t), gives an approximate age of the Largemouth Bass by the equation:

$$Lt = 510\big(1 - e - 0.17(t + 0.43)\big)$$

The data for Northern Pike on Stumpf Lake according to the Von-Bertalanffy fitted growth curve gives a K value of 0.24 mm per year, a t_0 value of -0.43 years, and a L_{inf} value of 914.4 mm. This gives an age prediction equation of:

$$Lt = 914.4\big(1 - e - 0.24(t + 0.43)\big)$$

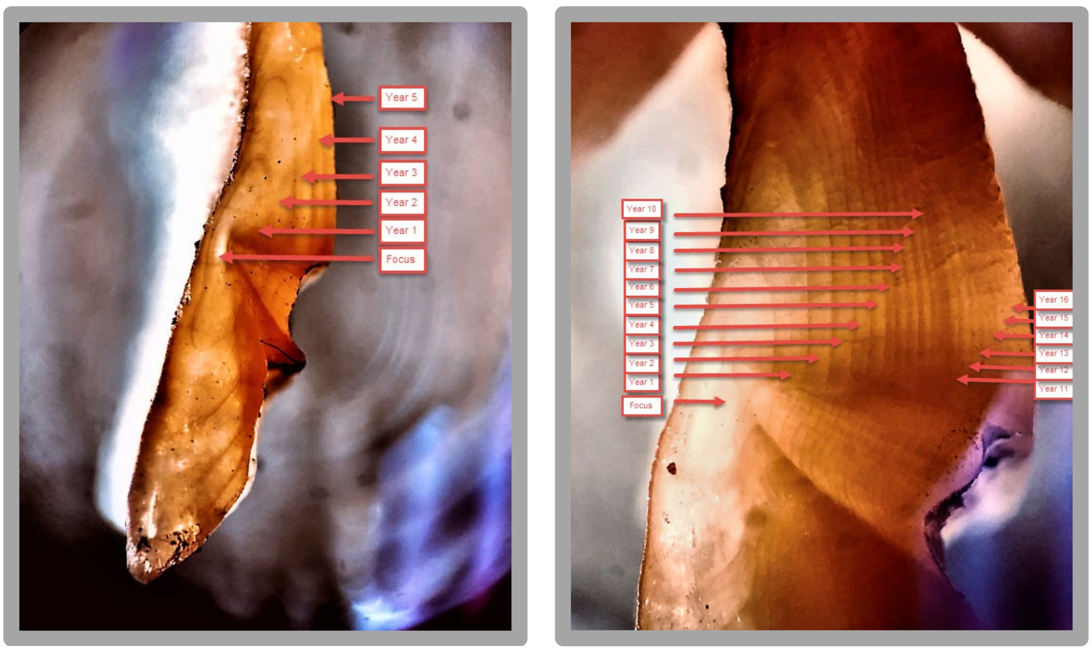

Figure 1. Largemouth Bass otolith at 40X magnification. The annuli were counted outward from the focus and an additional year was added to the final count due to early collection. N=33.

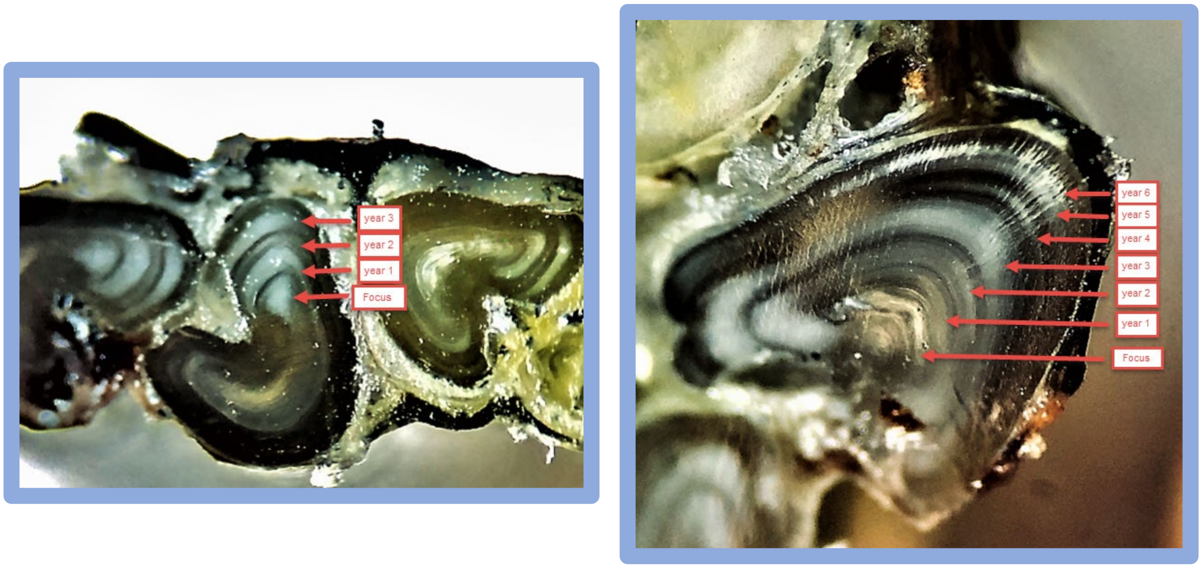

Figure 2. Northern Pike anal fin rays at 40X magnification. The annuli were counted outward from the focus and an additional year was added to the final count due to early collection. N=71.

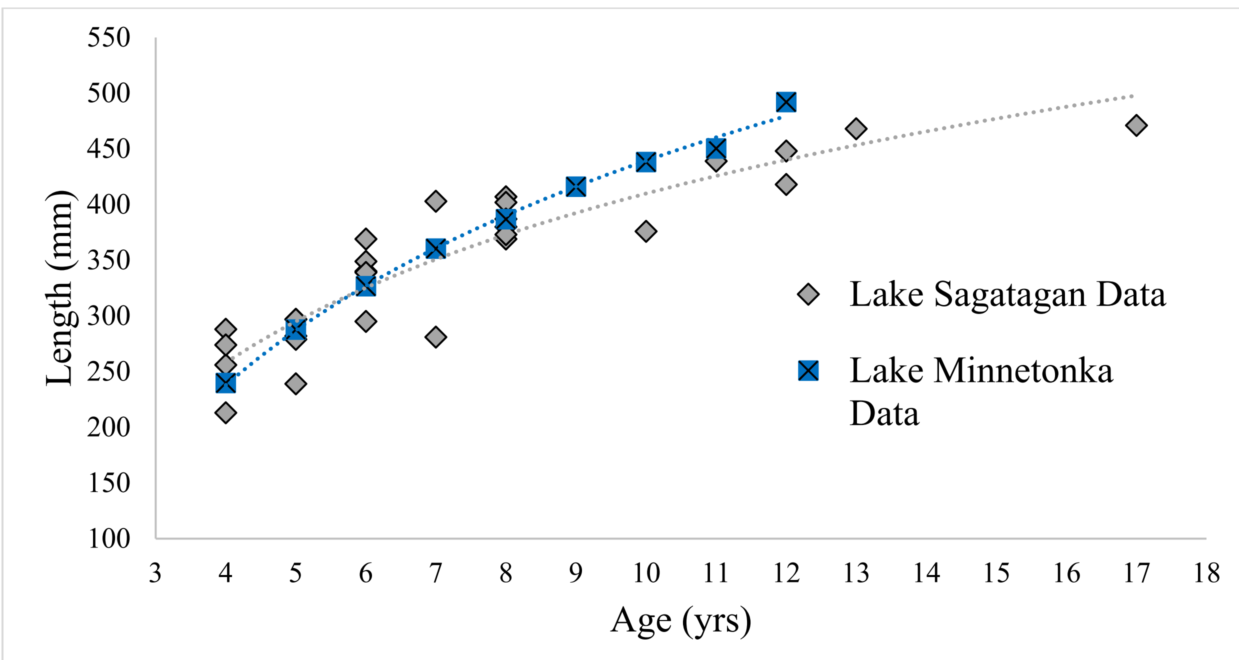

Figure 3. Largemouth Bass length-at-age Comparison of High (L. Minnetonka) and Low (L. Sagatagan) Exploitation Lakes. All Largemouth Bass length-at-age data points for Lake Sagatagan compared to previously collected average length-at-age data for Largemouth Bass on Lake Minnetonka.[11] Curves fit the logarithmic data. Trend lines show differences in growth. N=33.

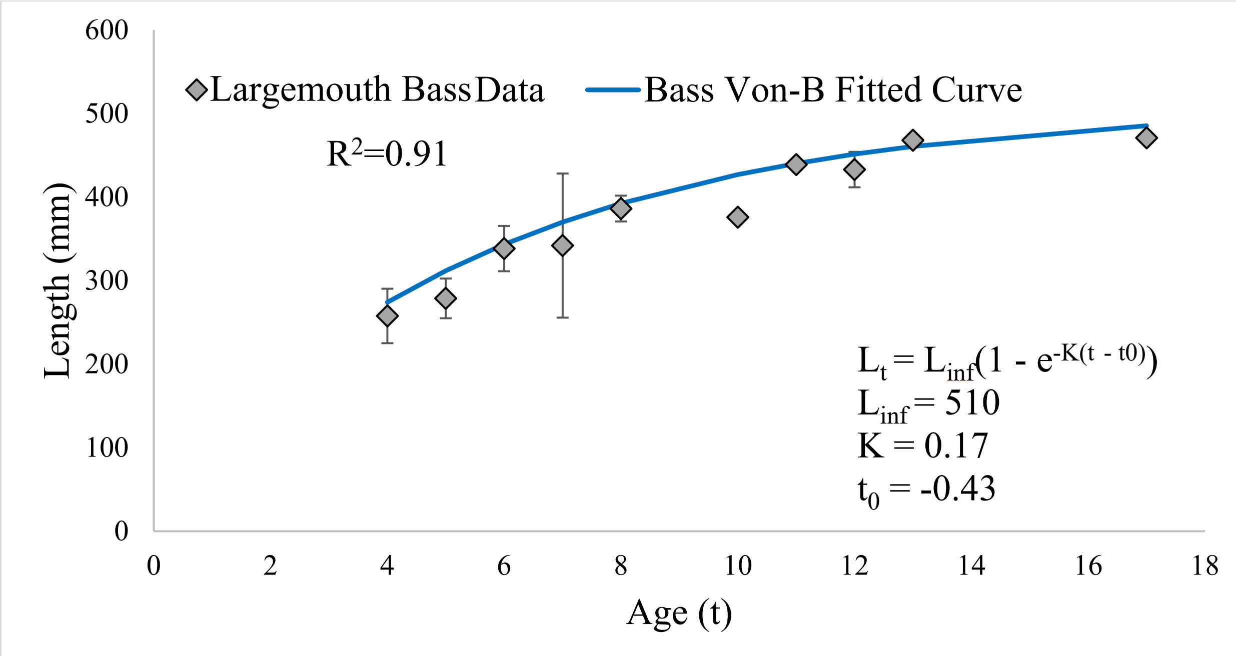

Figure 4. Von-Bertalanffy Growth Curve for Lake Sagatagan Largemouth Bass. Average length-at-age for Large-mouth Bass collected on Lake Sagatagan. The Von-Bertalanffy fitted growth curve approximates the average length-at-age of Largemouth Bass. The equation is used to estimate the age for any Largemouth Bass on Lake Sagatagan. Error bars are ± 1 standard deviation. N=33.

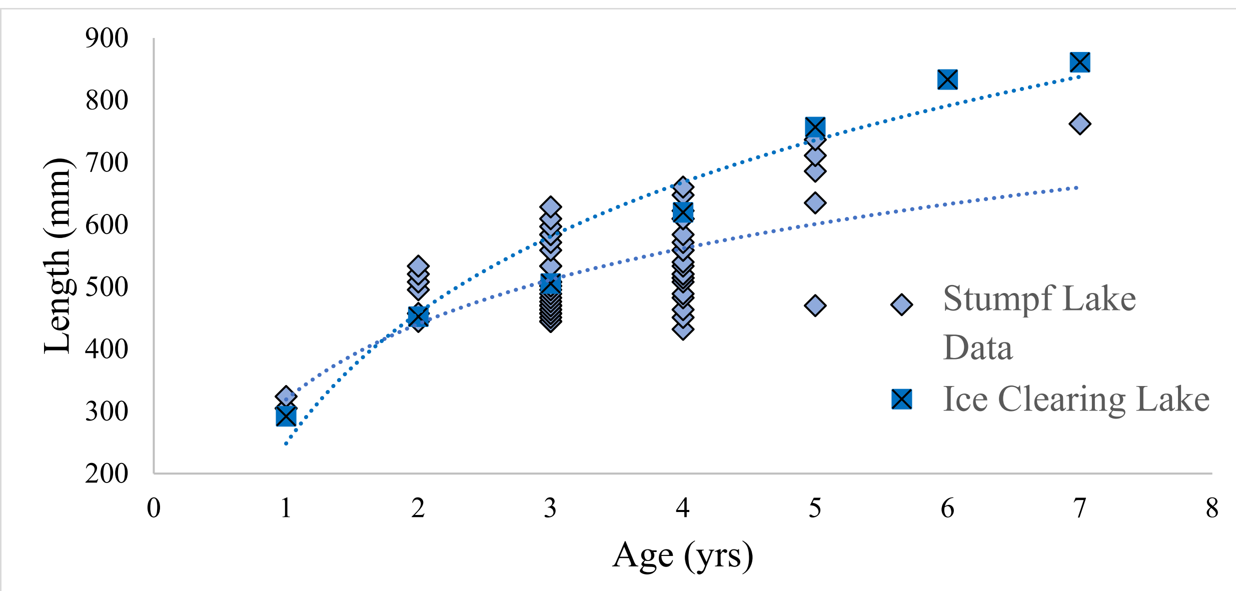

Figure 5. Northern Pike length-at-age Comparison of High (Ice Clearing L.) and Low (Stumpf L.) Exploitation Lakes. All Northern Pike length-at-age data points for Stumpf Lake compared to previously collected average length-at-age data for Northern Pike on Ice Clearing Lake.[12] Curves fit the logarithmic data. Trend lines show differences in growth. N=71.

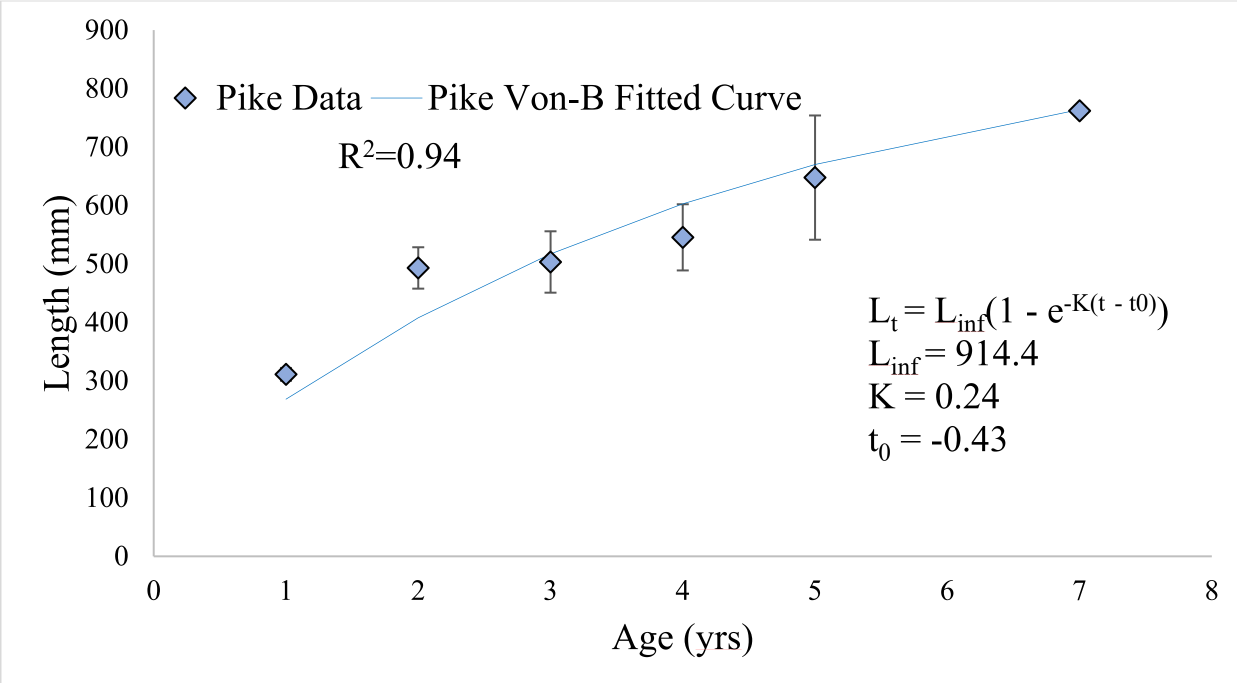

Figure 6. Von-Bertalanffy Growth Curve for Stumpf Lake Northern Pike. Average length-at-age for Northern Pike collected on Stumpf Lake. The Von-Bertalanffy fitted growth curve approximates the average length-at-age of Northern Pike. The equation is used to estimate the age for any Northern Pike on Stumpf Lake. Error bars are ± 1 standard deviation. N=71.

Discussion

In summary, for both Largemouth Bass and Northern Pike on St. John's campus lakes, there is a lower length-at-age compared to higher exploitation lakes. There is a greater disparity for length-at-age between Stumpf Lake Northern Pike and higher exploitation lakes (figure 5) compared to the disparity for length-at-age between Lake Sagatagan Largemouth Bass and higher exploitation lakes (figure 3). The collected data from St. John's campus lakes strongly fit with the Von-Bertalanffy fitted growth curves because of their high R^2 values of 0.91 and 0.94 respectively (figures 4 & 6).

We have shown the campus lakes of Saint John's University offer a low exploitation environment for their fish populations. This is most likely due to restricted motorboat use and limited access, resulting in less recreational fishing. Also, there is a lower rate of invasive species introduction, which allows for more nutrient availability to the fishes. Low exploitation rates lead to density-dependent declines in length-at-age.[5] Specifically, lower harvest by humans leads to increased intraspecific competition for limited resources resulting in decreased growth rate. Additionally, on higher exploitation lakes, fish will grow and mature at a faster rate in order to fill available niches. E.g. if a large Northern Pike is removed, a smaller Northern Pike may reach maturation quicker to fill the available niche. Raat (1988) has similarly shown that decreased maturation age correlates with increased mortality rate.[13]

Studies have shown that changes in mortality have been an evolutionary force for maturation rate and age. Barot et al. (2005) has shown that fishing mortality has the largest influence on selective pressure.[14] So, even the smallest adjustment in mortality rating, there is a substantial reaction regarding increased maturation rates. Another study has suggested that specifically size dependent mortality has been the root for early maturation for fish.[15] These trends can be attributed to the fishing regulations regarding the length of fish to be either kept or released. Regulations such as these further promote increasing maturation rates.

There are many factors to consider when analyzing the comparative data. In a similar article analyzing length-at-age of different species (Mooij et al., 1999), they attribute the difference of growth rate to environmental and habitat factors.[16] This could be a possibility for the Saint John's University lakes as well. Both Stumpf Lake and Lake Sagatagan are relatively small lakes which can be correlated to warmer water temperatures.[16] Warmer water temperatures allow for a more diverse array of microbes and other competitors for nutrients. This increased interspecific competition, on top of intraspecific competition does not allow for accelerated growth.

Conclusion

The campus lakes of Saint John's University offer a low exploitation environment for their fish populations. This is most likely due to restricted motor boat use and limited access, resulting in less recreational fishing. Low exploitation rates lead to density-dependent declines in length-at-age (Shaw et al., 2016). Specifically, lower harvest by humans leads to increased intraspecific competition for limited resources resulting in decreased growth. Additionally, on higher exploitation lakes, fish will grow and mature at a faster rate in order to fill available niches. E.g. if a large Pike is removed, a smaller Pike may reach maturation quicker to fill the available niche. Raat (1988) has similarly shown that increased mortality rates correlate with decreased maturation age.

Limitations

Because growth rates vary between systems, it is hard to confirm if there are different trends between species. Both Northern Pike and Largemouth Bass show slower rates of growth in the campus lakes. However, high exploitation lakes have different rates of growth according to fish species. This aspect of the research is limited because there is not data for every species on each Minnesota lake. If the comparison data of high exploitation lakes were from the same lake, the data would be more clear. Further studies should include length-at-age analysis for a larger array of fish species and comparisons to a multitude of other lake data.

Acknowledgments

The authors would like to thank Joe Stewig, MN DNR, for collecting Largemouth Bass samples via electroshock and his fish aging expertise; Kirk Olson, WI DNR, for suggesting the technique of anal fin ray analysis for Pike; Stephanie Shaw, WI DNR, for Bass growth literature; Amanda Bevan and Clark Cotton for assistance in data collection; and Kyle Rausch for netting assistance. Also, we would like to thank the MN DNR for allowing analysis of Largemouth Bass otoliths and John Geissler for supporting and assisting with this research. Finally we thank the College of Saint Benedict and Saint John's University as well as the FDRC for funding and support.

References

1. Arthington, A.H., Dulvy, N.K., Gladstone, W. & Winfield, I.J. (2016). "Fish conservation in freshwater and marine realms: status, threats, and management." *Aquatic Conservation: Marine and Freshwater Ecosystems*. 26.1. Pg 838-857.
2. Bonfil, R. (2005). "The purpose of stock assessment and the objective of fisheries management, In Management techniques for elasmobranch fisheries." *FAO Technical paper*. 474. Pg 6-14.
3. Saint John's Abby. (2010). Order of Saint Benedict Policy and Saint John's University Policy. *CSBSJU Policy.*
4. Gunderson, D. (2018). Measuring the impact of invasives in Minnesota lakes is complicated, inconclusive. *MPR news.*

5. Shaw, S.L. & Allen, M.S. (2016). "Quantifying Recruitment Compensation in Florida Largemouth Bass, with Implications for Fisheries." *Transactions of the American Fisheries Society.* 145.3. Pg 462-475.
6. Klein, Z.B., Bonvechio, T.F., Bowen, B.R. & Quist, M.C. (2017). "Precision and Accuracy of Age Estimates Obtained from Anal Fin Spines, Dorsal Fin Spines, and Sagittal Otoliths for Known-Age Largemouth Bass." *Southeastern Naturalist.* 16.2. Pg 225-234.
7. Cheney, W.L. (1971) "Life History Investigations of Northern Pike in the Tanana River Drainage." *Alaska Department of Fish and Game.* 12. Pg 2-8.
8. Secor, D.H., Dean, J.M. & Laban, E.H. (1992). "Otolith Removal and Preparation for Microstructural Examination." *Belle W. Baruch Institute for Marine Biology and Coastal Research.* Pg 19-57.
9. Elzey, S.P., Trull, K.J. & Rogers, K.A. (2015). Massachusetts Division of Marine Fisheries Age and Growth Laboratory: Fish Aging Protocols. *Massachusetts Division of Marine Fisheries.*
10. Allen, K.R. (2011). "A Method of Fitting Growth Curves of the von Bertalanffy Type to Observed Data." *Journal of the Fisheries Research Board of Canada.* 23.2. Pg 163-179.
11. Bauer, B.J. (2011). Standard Lake Survey Report: Special Assessment- Electrofishing targeting Largemouth Bass All Ages. *Minnesota Department of Natural Resources: Fisheries Management.*
12. Jacobson, P.C. (1992). "Analysis of Factors Affecting Growth of Northern Pike in Minnesota." *Minnesota Department of Natural Resources*. 424.1. Pg 18.
13. Raat, A.J.P. (1988). "Synopsis of Biological Data on the Northern Pike." *FAO Fisheries Synopsis.* 30.2. Pg 19-20.
14. Barot, S., Heino, M., Morgan, M.J., Dieckmann, U. (2005). "Maturation of Newfoulndland American plaice (*Hippoglossoides platessoides*): long-term trends in maturation reaction norms despite low fishing mortality?" *ICES Journal of Marine Science.* 62.1. Pg 56-64.
15. Baskett, M.L., Levin, S.A., Gaines, S.D., Dushoff, J. (2005). "Marine reserve and design and the evolution of size at maturation in harvested fish." *Ecological applications: Ecological society of America.* 15.3. Pg 882-901.
16. Mooij, W.M., van Rooij, J.M. & Wijnhoven, S. (1999). "Analysis and Comparison of Fish Growth from Small Samples of Length-at-Age Data: Detection of Sexual Dimorphism in Eurasian Perch as an Example." *Transactions of the American Fisheries Society.* 128.3. Pg 483-490.