THE EFFECTS OF LENGTH, WEIGHT, AGE, AND GENDER ON MERCURY CONCENTRATIONS IN BURBOT IN NORTH-CENTRAL MINNESOTA LAKES

Liam Hanley
Department of Biology, Aquatic Biology Program Bemidji State University
Bemidji, MN, USA
liam.hanley@live.bemidjistate.edu
Faculty Sponsors: Dr. Andrew W. Hafs (andrew.hafs@bemidjistate.edu) and Tyler Orgon (tyler.orgon@redlakenation.org)

***Abstract*—Burbot *Lota lota* in north-central Minnesota lakes have the potential to reach large sizes and consume large volumes of prey. This caveat may make burbot susceptible to higher rates of biocontamination, bioaccumulation and biomagnification. The objective of this study was to determine how changes in age, length, gender, weight, and lake affect total mercury concentrations in burbot. In this experiment 28 burbot were angled from three lakes: Cass (n = 17), Winnibigoshish (n = 4), and Bad Medicine (n = 7). Then tissue samples were taken from each fish and were lyophilized and homogenized. Homogenized tissue samples were analyzed by a Milestone TriCell Dual Beam Direct Mercury Analyzer (DMA-80evo) while following EPA protocol 7473. Average total mercury concentration was 0.1248 mg/kg (SD = 0.0717) in Cass Lake; 0.1022 mg/kg (SD = 0.0352) in Lake Winnibigoshish; and 0.0435 mg/kg (SD = 0.0176) in Bad Medicine Lake. Linear regression analysis using AIC scores were used to determine the effects of each variable on total mercury. The best supported model attributed changes in total mercury with changes in length, age, weight, and lake. It was found that as fish weight and length increase total mercury concentration increased. Furthermore, consumption advisory guidelines place burbot in 1-2 servings a week for safe consumption.**

I. INTRODUCTION

Mercury Hg is a dangerous aquatic contaminant that can significantly negatively impact human health (Rice et al. 2014). Mercury is most commonly found within contaminated fish, seafood, and wildlife (Rice et al. 2014). Mercury in aquatic systems is frequently found in two main forms, monomethylmercury $MeHg^{+}$, and environmental mercury or Hg_2^{2+} (Ullrich et al. 2001). Due to mercury's ability to bio-magnify and bioaccumulate, there is a need for state, federal, and tribal agencies to develop fish consumption advisory guidelines to ensure the safety and protection for their citizens.

Bioaccumulation is an issue for predatory fish species that have slower growth rates and live longer (Bentzen et al. 2016; Le Croizier et al. 2019). These are highly common phenotypic traits for burbot. Burbot are the only freshwater cod present in Minnesota and tend to be a slower growing, older, and benthic living fish species (Walther et al. 2022). Burbot are one of two species that have a circumpolar distribution (McPhail and Lindsey 1970). They often are used as a bioindicator of water quality and climate change (Stapanian et al. 2010). Similarly, burbot are frequently species of concern or endangered within their southern ranges with the rise of acidification, global warming, and aquatic pollution (Stapanian et al. 2010).

Since burbot generally have slow growth and potential to reach large lengths this makes them potential candidates for bioaccumulation and biomagnification. Additionally, burbot are widely sought after by anglers due to their white flakey meat with the frequent nickname being “poor man’s lobster”. Their common consumption by the public caused the need for a further analysis into total Hg concentrations in burbot. Therefore, the objective of this study was to determine the effects of length, weight, age, and gender on mercury concentrations in burbot in North-Central Minnesota lakes.

II. METHOD

Burbot were sampled from three lakes: Bad Medicine, Cass, and Winnibigoshish. Burbot were captured by conventional angling from the months of January until ice off during the 2023 ice fishing season. After landing, all burbot were euthanized by cranial concussion (Clark et al. 2012). Total number of burbot sampled were (n=28), with 22 males, and 6 females being captured.

Sample collection followed (US EPA 2000), and US Geological Survey (Scudder et al. 2008) sampling protocols. Measurements taken for each fish were total lengths (±1 mm), total weight (±1.00 g), sexual identification, and aging structures (otoliths) were recorded before collecting a ~30.00 g tissue sample. Skin-off tissue samples were taken on the left side anterior to the dorsal fin, while rolling the knife blade down the rib cage to limit bones from entering the tissue sample all while using a clean stainless-steel fillet knife. Additionally, diet contents were samples and preserved in 95% EtOH. Prey items were identified and taken to species. Tissue samples were rinsed with distilled and deionized water, weighed (wet weight) to the nearest 0.01 g, and placed in a clean sterile Whirl-Pak plastic bag. Whirl-Paks were labeled with Lake, Fish ID #, and gender. Tissue samples were transferred to a freezer (−20 °C) to be stored until lyophilization and homogenization. Tissue samples were lyophilized with a Harvest Right stainless-steel freeze dryer; approximately 24 hours of run time from frozen to a freeze-dried sample. Each sample was homogenized using porcelain mortar and pestles, weighed (± 0.01 g) for wet vs. dry weight conversions, and placed in 100 mL amber Boston vial.

Samples were analyzed using a Milestone TriCell Dual Beam Direct Mercury Analyzer (DMA-80evo) following EPA protocol 7473 (US EPA 2007). A 3-point calibration curve was developed using a serial dilution of a 1000 mg/kg Hg solution in 3% nitric acid. With the three standard solutions at concentrations of 0.9868, 0.09387, and 0.00958 mg/kg. The R^2 value of the calibration curve was found to be 0.9990. One DORM-4 sample, was used to verify EPA method 7473. All sample concentrations were converted from dry weight concentration to wet weight concentrations. Sample boats were brushed clean of ash and ran back through the DMA-80evo for sterilization after each sample run and stored in a new zip-sealed bag.

Following mercury analyzation linear regression analysis based on AIC scoring (Sakamoto et al. 1986) was completed to determine the affect the variables of age, length, weight, gender, and lake had on total mercury concentrations.

III. RESULTS

Average total mercury was 0.1248 mg/kg (SD = 0.0717) in Cass Lake, 0.1022 mg/kg (SD = 0.0352) in Lake Winnibigoshish, and 0.0435 mg/kg (SD = 0.0176) in Bad Medicine Lake (Figure 1). Of the 29 burbot captured 17 were sampled from Cass Lake (2 females, and 15 males), 4 were sampled from Lake Winnibigoshish (2 females and 2 male), and 7 from Bad Medicine Lake (2 females and 5 males). AIC scores were calculated using total mercury as a function of age, length, lake, sex, and weight. As a result, 10 models were constructed based on a combination of these variables. AIC scores ranged from -95.85 and -61.46 with a maximum ΔAIC value of -34.39. Furthermore, R^2 values ranged from 0.000 to 0.7951 (Table 1). An additive model where mercury as a function of changes of lake, age, weight, and length produced the best AIC score and explained 79.51% of the variation in Hg concentration variability (Figure 2).

TABLE 1. MODELS USED TO PREDICT Hg CONCENTRATIONS IN BURBOT FROM BAD MEDICINE LAKE, CASS LAKE, AND LAKE WINNIBIGOSHISH.

Model	AIC	ΔAIC	R^2
Hg~Length+Weight+Lake+Age	-95.9	0	0.795
Hg~Age+Length	-92.3	-3.57	0.712
Hg~Length	-91.4	-4.45	0.681
Hg~Length+Weight+Lake	-91.1	-4.80	0.739
Hg~Length+Weight+Age	-90.4	-5.50	0.712
Hg~Length+Weight	-89.8	-6.03	0.685
Hg ~Weight	-87.9	-7.99	0.637
Hg~Age	-81.4	-14.5	0.543
Hg~Lake	-75.7	-20.1	0.479
Hg~Gender	-61.7	-34.2	0.199
Hg ~ 1	-61.5	-34.3	0.000

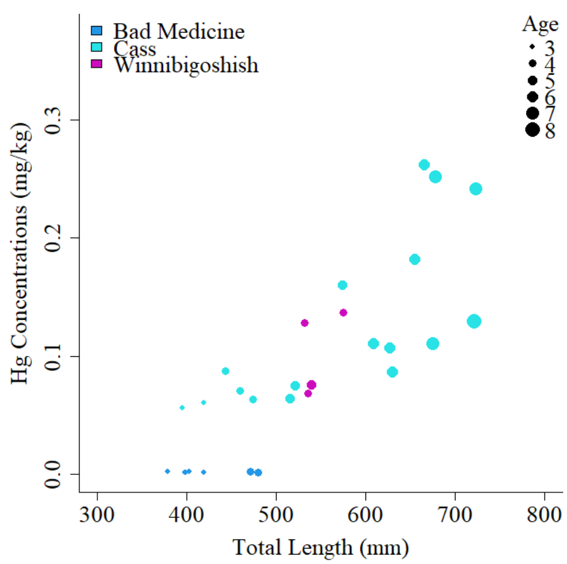

Fig. 1. Mercury concentrations (mg/kg) as a function of length (mm) from Bad Medicine Lake (blue), Cass Lake (green), and Lake Winnibigoshish (violet). Point sizes are weighted based on the age of individual burbot, larger points are older individuals. Burbot ages range from 3 to 8 years.

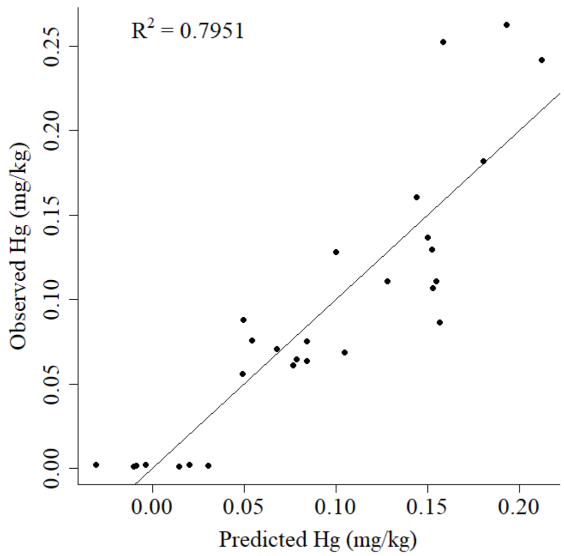

Fig. 2. Predictive model used to estimate Hg in burbot from Bad Medicine Lake, Cass Lake, and Lake Winnibigoshish. An additive model with four different variables length, age, weight, and lake was used to estimate Hg concentrations.

IV. DISCUSSION

The condition of burbot showed to be a major factor in total mercury accumulation. As burbot grew older, to longer lengths, and to heavier weights mercury concentrations increased dramatically. Fish require more calories and prey items to grow to these larger sizes which may contribute to mercury bioaccumulation leading to biomagnification (Kidd et al. 2012). Findings from the diet study suggested that prey items for burbot were low sources of mercury. Primary food sources were found to be crayfish, *Faxonius* sp. and other macroinvertebrates which are low in total mercury (Karmi et al. 2016). This allows for higher prey consumption with low risk of mercury accumulation for burbot. Besides diet and condition there may be other variables that also contribute to mercury accumulation in burbot.

Additionally, changes in the aquatic system had a significant effect on total mercury concentrations and bioaccumulation in burbot. Mercury is a biogeochemical that has a total maximum daily load of 0.2 mg/kg in fish tissue (MNPCA 2007). Two systems that were sampled within this study, Winnibigoshish and Cass are also connected by the Mississippi river which may contribute to possible mercury loading and lead to increased bioaccumulation. This is due to mercury being trapped in the sediment, and when the sediment is moved down stream during high water events sediment will load in exorheic systems. Furthermore, another discrepancy that may be affecting a difference in aquatic system is that the food web in each system may be slightly different at the benthic level. Burbot in all three systems may be selecting specific prey items more heavily than others resulting in different rates of bioaccumulation.

In contrast, this study suggests there is a drastic difference in mercury concentrations when compared to other Minnesota gamefish. More specifically when compared to mercury concentrations in northern pike *Esox lucius* and walleye *Sander vitreus*. For a point of reference, average mercury concentration in walleye with an average length of 380 mm was 0.268 mg/kg, and northern pike with an average of 560 mm had a mercury concentration of 0.320 mg/kg (MNPCA 2017). When these concentrations are compared to burbot at 533 mm average length mercury concentration were found to be 0.091 mg/kg. Based on these baseline averages northern pike had 3.5 times more mercury and 2.9 times more mercury in walleye. This makes burbot an excellent species for eating within mercury risk groups more specifically young children and pregnant women.

REFERENCES

[1] Bentzen, R., J. M. Castellini, R. Gerlach, C. Dykstra, and T. O’Hara. 2016. Mercury concentrations in Alaska Pacific halibut muscle relative to stable isotopes of C and N and other biological variables. Marine Pollution Bulletin 113:110–116.

[2] Clarke, E. O., C. A. Harms, J. M. Law, J. R. Flowers, V. N. Williams, B. D. Ring, A. S. McGinty, M. Hopper, and C. V. Sullivan. 2012. Clinical and pathological effects of the polyopisthocotylean monogenean, *Gamacallum macroura* in white bass. Journal of Aquatic Animal Health 24:251–257.

[3] Fitzgerald, W. F. and T.W. Clarkson. 1991. Mercury and mono- methylmercury: present and future concerns. Environmental Health Perspective 96:159–166.

[4] Karimi, R., C. Y. Chen, and C. L. Folt. 2016. Comparing nearshore benthic and pelagic prey as mercury sources to lake fish: the importance of prey quality and mercury content. The Science of The Total Environment 565:211–221.

[5] Kidd, K., M. Clayden, and T. Jardine, 2012. Bioaccumulation and biomagnification of mercury through food webs. In: Liu, G., Y. Cai, and N. O’Driscoll, eds, Environmental Chemistry and Toxicology of Mercury. Hoboken, NJ, John Wiley & Sons.

[6] Le Croizier, G., A. Lorrain, J. E. Sonke, S. Jaquemet, G. Schaal, M. Renedo, L. Besnard, Y. Cherel, and D. Point. 2020. Mercury isotopes as tracers of ecology and metabolism in two sympatric shark species. Environmental Pollution 265:114931.

[7] McPhail, J. D., and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Bulletin of the Fisheries Research Board of Canada 173:295–300.

[8] MNPCA (Minnesota Pollution Control Agency). 2017. March. Minnesota statewide Mercury Total Maximum Daily Load. https://www.pca.state.mn.us/ sites/default/files/wq-iw4-01b.pdf.

[9] Morway, E. D., R. M. Hirsch, A. P. Paul, M. Marvin-DiPasquale, and C. E. Thodal. 2023. Long-term mercury loading and trapping dynamics in a western North America reservoir. Journal of Hydrology: Regional Studies 50:101566.

[10] Orgon, T. J., A. W. Hafs, C. W. Isaacson, and S. E. Bowe. 2023. Spatial and temporal variability of mercury in Upper and Lower Red Lake walleye. Ecotoxicology 32:811–823.

[11] Rice, K. M., M. E. Walker, M. Wu, C. Gillette, and R. E. Blough, 2014. Environmental mercury and its toxic effects. Journal of Preventive Medicine and Public Health 47:74–83.

[12] Sakamoto, Y., M. Ishiguro, and G. Kitagawa, 1986. Akaike Information Criterion statistics, Tokyo, KTK Scientific Publishers.

[13] Scudder, B. C., L.C. Chasar, D.A. Wentz, N. J. Bauch, M. E Brigham, P. W. Moran, and D. P. Krabbenhoft. 2009. Mercury in fish, bed sediment, and water from streams across the United States, 1998–2005. USGS, Scientific Investigation Report 2009-5109, 1-74.

[14] Stapanian, M. A., V. L. Paragamian, C. P. Madenjian, J. R. Jackson, J. Lappalainen, M. J. Evenson, and M. D. Neufeld. 2010. Worldwide status of burbot and conservation measures. Fish and Fisheries 11:34–56.

[15] Ullrich, S. M., T. W. Tanton, and S. A. Abdrashitova. 2001. Mercury in the aquatic environment: A review of factors affecting methylation. Critical Reviews in Environmental Science and Technology 31:241–293.

[16] US EPA (United States Environmental Protection Agency). 2000. Quality assurance project plan for analytical control and assessment activities in the national study of chemical residues in lake fish tissue. Report No. EPA-823-R-02-006.

[17] Walther, E. J., D. E. Arthur, A. Cyr, M. K. Fraley, T. Cubbage, E. Hinkle, J. McMahon, and H. A. P. Westley. 2022. Ecotoxicology of mercury in burbot (*Lota lota*) from interior Alaska and insights towards human health. Chemosphere 298: 13427.