Developing Statewide Consumption Guidelines for Iowa Sport Fish

Research Study 7064 Completion Report
Federal Aid to Sport Fish Restoration
Iowa Fisheries Research

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Executive Summary

The Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) recommend eating fish weekly as part of a healthy diet. Iowa-caught fish are safe to consume for a majority of the population. The at-risk population (ARP) of people (i.e., pregnant women, women wanting to become pregnant, are breastfeeding, and those under 12 years of age) should monitor their consumption of fish containing methyl mercury. Elemental and inorganic mercury from natural and anthropogenic sources are deposited in lakes. Bacteria found in anaerobic sediments convert these two forms of mercury into methyl mercury. Methyl mercury bioaccumulates in animals found in lakes and rivers including fish and the highest concentrations can be found in top level predators. Angler surveys in Iowa have shown people would consume more Iowa-caught fish if they knew they were safe to eat. Current procedures post fish consumption advisories for individual lakes and river reaches. The application of statewide fish consumption advisories would be less confusing for consumers and encompass all waterbody types. Two Iowa studies were conducted to provide the ARP with consumption advisories for Iowa-caught fish.

Cashatt (2017) and this study were designed to improve the understanding of where high concentrations of methyl mercury in Iowa-caught fish are located and provide recommendations for statewide length-based fish consumption advisories for commonly consumed fish species. Fish length is positively correlated with mercury concentrations in most species (i.e., as fish length increases for an individual so does methyl mercury concentration) and fish length is an easy to understand variable that any angler can determine on their own. In fact, most Iowa anglers are already accustomed to measuring fish length as it is commonly used by anglers as a measure of success (i.e., proximity of their catch to eating size or trophy size) and because many species are managed with length-based harvest regulations. Top-level predators (i.e., Muskellunge and Largemouth Bass) typically have higher mercury concentrations than prey species (i.e., Bluegill and Yellow Perch). Some environmental variables (i.e., watershed size and land use) are also correlated with methyl mercury concentration levels in fish. However, in both studies fish species and length explained most of the variation in methyl mercury concentration, confirming that these two variables could be used to set statewide consumption advisories for Iowa. Cashatt (2017) significantly improved the understanding of waterbodies that contain fish with high methyl mercury concentrations in Iowa. Information from that study was used to design the current study and ultimately provide length-based advisories for Iowa-caught fish.

Management Recommendations

- Iowa-caught sport fish are safe to eat for most people.
- Predator species (i.e., Largemouth Bass, Walleye, Northern Pike, Flathead Catfish, Muskellunge) had higher levels of mercury in their tissue than other species (i.e., Bluegill, Crappie Spp., Perch, Trout, Channel Catfish, and Common Carp).
- These consumption advisories are conservative recommendations for the ARP. Many of the samples collected in this study were targeted to collect samples containing mercury levels close to or above the 0.3 mg/kg advisory level. Therefore, these samples don't represent the true average of mercury concentrations in fish populations statewide.

Suggested citation format, American Fisheries Society Style Guide:

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Approach 1: Measure mercury concentration in sport fish species caught in Iowa lakes and rivers

INTRODUCTION

Iowa anglers consumed an estimated 4.59 million meals of Iowa-caught fish in 2018 (Responsive Management 2019). This survey also noted 52% of anglers that were not currently eating fish would consume fish if they felt consumption was safe. In Iowa, very few contaminants negatively affect fish consumption. Methyl mercury is the primary contaminant of concern with the angling population. Results from six consecutive cycles of the National Health and Nutrition Examination Survey (1999-2010) showed lower blood mercury concentrations and increased fish consumption 2009-2010 compared to 1999-2000 in women between 16 and 49 years of age (Cusack et al. 2017). These results suggest eating fish as part of a healthy diet can be accomplished by consuming species with low mercury concentrations. Inorganic and elemental mercury can be found in the environment (i.e., air, soil, and water) occurring naturally and from anthropogenic sources. Bacteria found in anerobic sediments convert the inorganic mercury deposited in a lake or river into a toxic organic form called methyl mercury, hereafter referred to as mercury. Mercury concentrations in Iowa waterbodies vary due to many environmental and species-specific factors (McMurtry et al. 1989, Selch et al. 2007, Weber and Cashatt 2020). Cashatt (2017) found that most Iowa fish had low levels of mercury contamination. Of all the fish analyzed during that study, 30% were below the detection limit of 0.05 mg/kg, and 90% were below the advisory level of 0.3 mg/kg (i.e., one-meal-per-week advisory) and the advisory level of 1.0 mg/kg (i.e., do-not-eat advisory). Mercury concentrations were highest in predator species (e.g., Muskellunge *Esox masquinongy*, Walleye *Stizostedion vitreum*, Largemouth Bass *Micropterus salmoides*, Smallmouth Bass *M. dolomieu*, Northern Pike *E. lucius*) and lowest in omnivorous and planktivorous species (e.g., Black Crappie *Pomoxis nigromaculatus*, White Crappie *P. annularis*, Bluegill *Lepomis macrochirus*, Channel Catfish *Ictalurus punctatus*), and positively related to fish length and age in all species. These relationships were stronger for predator species. Based on these results, the Iowa DNR drafted consumption advisories to protect at-risk population (ARP). The ARP for fish consumption regarding mercury concentrations is pregnant women, women wanting to become pregnant, are breastfeeding, and those under 12 years of age. Unfortunately, after this study was completed, a follow-up QAQC study determined that results from Iowa's State Hygienics Laboratory (i.e., the laboratory used for mercury analyses for Cashatt 2017) were 21% lower than two other laboratories that perform this type of analysis in the Midwest (Krogman 2019). Although Cashatt (2017) substantially improved our understanding of mercury contaminants in Iowa-caught fish, additional research was necessary to confirm the proposed statewide consumption advisories were based on accurate information.

The goal of Research Study 7064, Developing Statewide Consumption advisories for Iowa Sport Fish, was to create length-based consumption advisories for the ARP consuming Iowa-caught fish. Fish length is a variable that is positively related to mercury concentrations (Sackett et al. 2013). The two advisory levels, (i.e., 0.3 mg/kg and 1.0 mg/kg) were determined appropriate by the U.S. Food and Drug Administration to set one-meal-per-week and do-not-eat advisories, these advisory levels were adopted by the Iowa Department of Public Health and the Iowa DNR (USFDA 2022). Results from Cashatt (2017) were used to develop the methods section for Research Study 7064 (Krogman 2019). Analysis of data collected by Cashatt (2017) suggested lower mercury levels were found in more productive lake systems (i.e., shallow, lower Secchi depth, and higher algal densities; Krogman 2019). Results from river data showed there may be important spatial variation in mercury levels and length of fish explained a significant amount of variability for multiple species. This document summarizes tissue sample results collected by Cashatt (2017) and sample results collected between 2019 and 2021 as part of Research Study 7064.

METHODS

Research Study 7064

Samples collected between 2019 and 2021 don't represent the average mercury concentration values found throughout Iowa. Targeted sampling was completed in areas that had the greatest chance of collecting individual fish with mercury concentrations above the ≥0.3 mg/kg advisory level. The goal of this study was to create statewide length-based fish consumption advisories, therefore selecting lakes and rivers most likely to contain fish species with elevated mercury levels was necessary to make conservative recommendations.

Waterbodies were broken into the following five types: impoundments (manmade lakes with earthen built dams), large rivers (Mississippi River and Missouri River), natural lakes (lakes occurring naturally on the landscape and are often times shallow basins with small watersheds), rivers (all rivers within the state boundaries excluding the Mississippi River and

Missouri River), surface mines (excavated areas with small watersheds that are often connected to groundwater sources), and reservoirs (large impoundments with large watersheds and used for flood control). Sample sites were selected based on species abundance, fishery popularity (from Responsive Management 2019), waterbody type, and watershed characteristics. Study sites included some of the same systems from Cashatt (2017) for comparison, as well as new waterbodies not previously sampled (e.g., surface mines and impoundments in Community Fishing Program areas). Fish were collected using standard Iowa DNR sampling protocols (Schultz 2008). Proposed number of samples by species was selected based on the analysis completed by Krogman (2019), but were modified based on the results from FY2020 and FY2021 sampling efforts (Table 2). Results from Weber and Cashatt (2020) suggested detection of mercury in Largemouth Bass and Walleye could be accomplished by collecting larger fish and using 10-fish sample sizes in lakes. Bluegill and Crappie tissue samples from Cashatt (2017) were below the one-meal-per-week advisory level of 0.3 mg/kg; therefore, only a small sample size was collected to verify these results. New species added to this study (e.g., Shovelnose Sturgeon *Scaphirhynchus platorynchus* and Paddlefish *Polyodon spathula*) were sampled at a reduced sample size of 40 fish and across a broad range of length bins to determine if more sampling was necessary. Size of collected fish focused on length bins near the 0.3 mg/kg advisory level for each species (Krogman 2019). Collected fish were euthanized, wrapped in aluminum foil, frozen and stored in a -10°C freezer until mercury analysis was completed. The frozen fish were thawed in a laboratory and tissue plugs were removed from the fish to quantify mercury concentration in the tissue. Tissue plug samples processed in the field and the laboratory produced similar results to whole fillets, therefore all samples between 2019 and 2021 were collected using a 5 mm biopsy punch (Stahl et. al 2019). All tissue samples were skinless and removed from the dorsal axial muscle from each fish. Each tissue sample had a minimum weight of 0.2 g. Tissue samples were removed while wearing disposable gloves. Cross-contamination of samples was avoided by replacing gloves between fish and using a new biopsy punch for each fish. Fish tissue samples were stored in a -10°C freezer until transported to a laboratory for analysis. Tissue samples were kept in a cooler and on ice during transportation periods.

Fish of similar lengths and collected from the same waterbodies for both studies were analyzed for differences in mercury concentrations and fish length, this analysis was the only instance where results from Cashatt (2017) and Research Study 7064 were separated. Cashatt (2017) sampled random waterbodies and a wide range of length bins for each species. Research Study 7064 sampled a truncated number of length bins near the break point where mercury concentrations were ≥0.3 mg/kg advisory level. Tissue samples biased towards higher mercury concentrations were included in the analysis because the objective of this study was to determine statewide length-based consumption advisories instead of advisories for specific waterbodies. Length bins with mean values and 95% confidence intervals (CI) were used to determine maximum length for consumption of each fish species. The length bin with 95% CI closest to, but not exceeding the 0.3 mg/kg advisory level was recommended as the maximum size of fish to be consumed. Samples from both studies were used in the individual species analysis to determine length-based consumption advisories. Samples from Cashatt (2017) were analyzed at multiple laboratories. One of the laboratories used different methodology to process the tissue samples; analysis suggested data from the State Hygienics Laboratory (SHL) was precise but not accurate.

Cashatt (2017)
Tissue samples collected by Cashatt (2017) were analyzed to determine if the results could be combined with results from the 2019-2021 samples. Tissue sample results from the laboratory were tested in the models prepared by Krogman (2019). Natural lakes and impoundments were analyzed together. Surface mines were analyzed separately for some species based on analysis from Krogman (2019). When determining length-based consumption advisories, length bins of interest had a 95% probability of exceeding the 0.3 mg/kg advisory level. Mercury sample concentration results were combined for individual species analysis when all sample results were below the 0.3 mg/kg advisory level.

The consumption advisory template was provided by the EPA. Statewide length-based advisories were designed to communicate potential risks in eating Iowa-caught fish using a portion size of 6-7 oz. Best, Good, and Avoid categories were used to define the three fish consumption choices for the ARP. The Best category were fish species with no consumption limit for the ARP, the Good category were fish species that are recommended to be eaten once per week by the ARP, and the Avoid category were fish species the ARP should not consume.

RESULTS AND DISCUSION

Research Study 7064 and Cashatt (2017)

T-tests were used to find significant differences between mercury concentration results for fish species sampled in this study and results from Cashatt (2017; Table 5); Turkey-Kramer tests were used to find significant differences between sample results from three laboratories used to process tissue samples from Cashatt (2017). Tukey-Kramer tests comparing the "slope" parameters for each lab indicated no significant difference between the USEPA Laboratory (EPA) and Minnesota Department of Agriculture (MDA) ($P=0.486$), a significant difference between USEPA and SHL ($P<0.0001$), and a significant difference between MDA and SHL ($P<0.0001$) (Iowa DNR unpublished data, April 2, 2018). When detectable, mercury concentration estimates from SHL were 21% lower than quality assurance results from MDA and EPA. Therefore, a correction factor of 21% was applied to the SHL sample results so results were comparable to those from Research Study 7064 (Krogman 2019). The total number of samples collected for Research Study 7064 and corrected from Cashatt (2017) was 2,329 and 2,747, respectively (Table 2). These studies sampled impoundments (N=34), natural lakes (n=11), reservoirs (n=4), and surface mines (n=9). Lakes (i.e., impoundments, reservoirs, and natural lakes) ranged in size from 2 ac to 15,000 ac.

Fish Consumption Advisory

Although length is positively correlated with mercury levels in fish, there are other fish variables (i.e., age and sex) and environmental variables (i.e., water chemistry, lake basin morphology, and watershed characteristics) known to influence mercury levels in fish. Recent studies showed similarities among fishes and systems throughout Iowa (Mills 2016; Milles et al. 2018). The proposed consumption advisories in this document were conservative, length based, and designed to provide information for the ARP regarding Iowa-caught fish (Table 3). General results were presented first and followed by species-specific analysis.

Mean mercury concentrations were highest in rivers and lowest in reservoirs for most species. Natural lakes had the most variability between individual sample results. The Upper Iowa River had higher levels of mercury than any other waterbody for all species sampled. Therefore, the statewide fish consumption advisories will need to be more conservative to protect anglers that may harvest fish from this resource (i.e., results from the Upper Iowa River lowered the safe length and number of species in the best choice category; Table 3). Specifically, the Upper Iowa River results moved Shorthead Redhorse *Moxostoma macrolepidotum* from the Best Choice to the Good Choice category; and reduced the acceptable size of Smallmouth Bass, Walleye, and Northern Pike in the Best Choices category. Sampling locations for Research Study 7064 were selected based on the goal of creating statewide recommendations, therefore river stretches or lakes were selected to identify issues similar to those detected in the Upper Iowa River with the idea that erring on the side of being more conservative was necessary to protect ARP.

Results for predator species found higher mercury concentrations than prey species and increased length was positively correlated with increased mercury concentration. This research also showed increased length of predator species increased the chance of sampling Largemouth Bass or Walleye that contain mercury concentrations >0.3 mg/kg. Longer fish required fewer samples to detect mercury levels >0.3 mg/kg, often times a sample of 10 fish was adequate. Consumption advisories were determined for individual species (Table 3). Some species (e.g., Hybrid Striped Bass and White Bass) are difficult to identify for the average angler. The length-based consumption recommendation was different for each of these species. Combining these species was overly conservative for the ARP consuming Hybrid Striped Bass but it would protect those who misidentify a White Bass.

Weber and Cashatt (2020) found that environmental factors, (e.g., percentage of grassland in the watersheds) can be an indicator of high or low mercury levels in Iowa sport fish species. Elevated mercury levels were also found in prey species collected from an impoundment that had a recent water-level drawdown. This may suggest drought conditions or a lake draw down may temporarily impact the availability of mercury in the water column. Drawdowns can occur naturally during drought conditions or artificially as a management tool to increase fish size structure in lakes. The consumption advisories recommended by this study were selected to protect ARP, even if they harvest fish from waters that could be influenced by these and other environmental factors.

Largemouth Bass

Largemouth Bass were sampled in impoundments (N=28), natural lakes (N=5), reservoirs (N=4), large rivers (N=1), and surface mines (N=9). Tissue samples collected for both studies from the same sites were not significantly different (Table 5). Natural Lake samples had the highest median mercury concentration of all waterbody types and impoundments had the highest individual mercury concentration level (Figure 1). The minimum value was 0.010 mg/kg and maximum value was 0.992 mg/kg (Figure 2). Using a 95% confidence level for each length bin Largemouth Bass <350 mm didn't require a consumption advisory for the ARP (Figure 3).

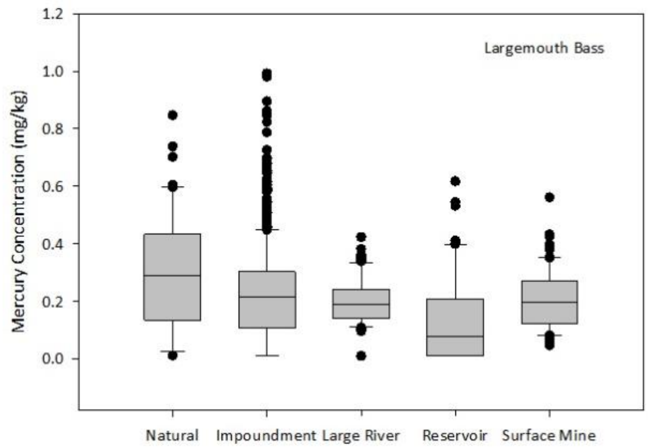

Figure 1. Largemouth Bass median mercury concentrations for five waterbody types with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

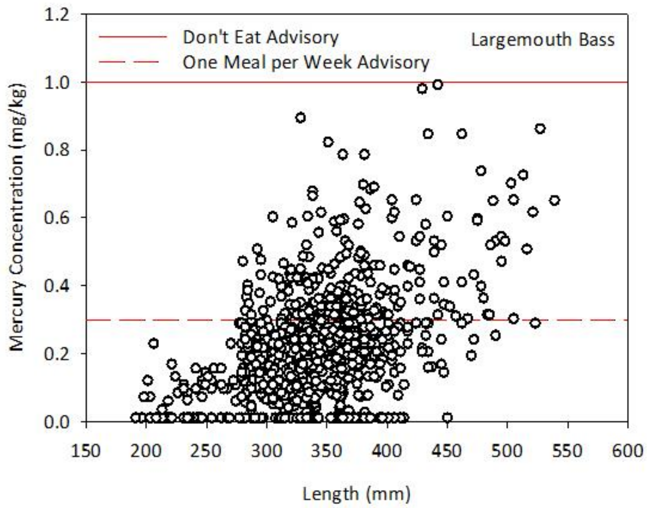

Figure 2. Mercury concentration results for Largemouth Bass (N=919) with 0.30 mg/kg and 1.0 mg/kg advisory levels.

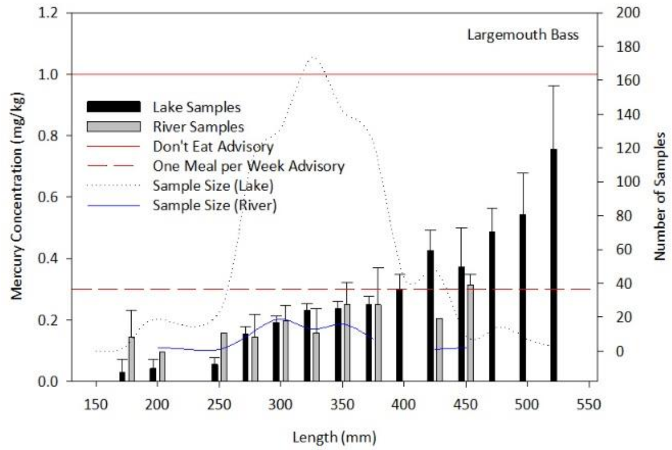

Figure 3. Largemouth Bass average mercury concentrations with error bars representing the 95% confidence level (α=.05), sample size per length bin, and advisory levels at 0.3 mg/kg and 1.0 mg/kg.

Smallmouth Bass

Smallmouth Bass (N=393) were sampled at 14 sites on 9 rivers and the maximum mercury concentration was 1.041 mg/kg (Figure 4). Mercury concentration results for fish collected from the same sites during both studies were significantly different (Table 5). Mercury concentrations collected from Cashatt (2017) had a higher mean concentration than this study. Sites sampled in both studies were from river stretches where fish can migrate. The Upper Iowa River Upstream collection site had the highest mercury concentrations, with one sample result exceeding the 1.0 mg/kg advisory level (Figure 5). A 95% confidence level was used to determine ARP could consume Smallmouth Bass <350 mm without exceeding the advisory level of 0.3 mg/kg (Figure 6). The Upper Iowa River upstream site drove the highest mercury concentration values for Smallmouth Bass.

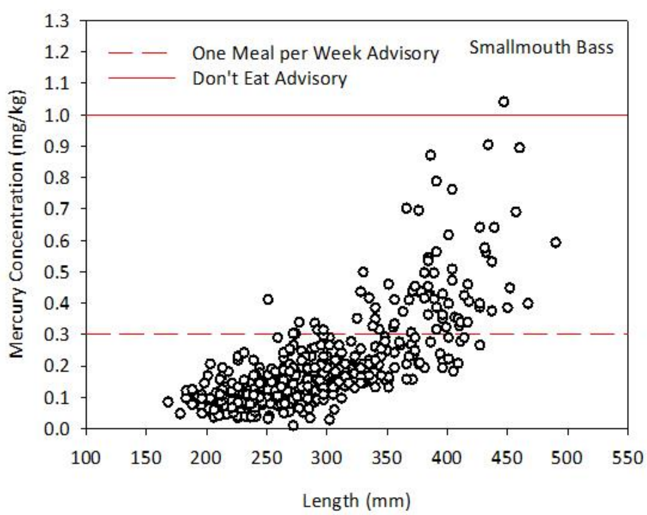

Figure 4. Mercury concentration results for Smallmouth Bass tissue samples collected in Iowa rivers with 0.3 mg/kg and 1.0 mg/kg advisory levels.

It is worth noting that black bass (i.e., Largemouth, Smallmouth, and Spotted Bass) are managed by a statewide minimum length limit of 381 mm in lakes and 305 mm in rivers; and exceptions to these statewide regulations are generally more restrictive (e.g., 457 mm minimum length limit or catch and release only regulation). Therefore, in most cases, black bass that are safe to eat for ARP are not legal to harvest from public lakes and the range of black bass that are legal to harvest and safe to eat is only 305 mm to 350 mm on public rivers. However, substantial Largemouth Bass harvest occurs on private ponds that are not regulated by these length limits and illegal harvest does occur on public waters. Therefore, a consumption advisory was still set to protect ARP in these and other situations that may result in harvest from Iowa's black bass fisheries.

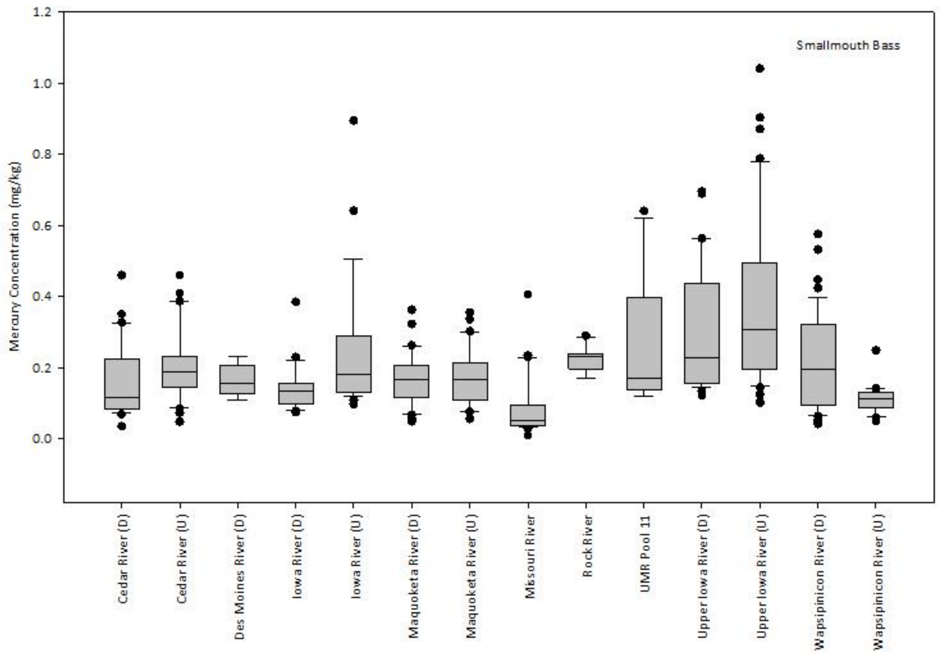

Figure 5. Smallmouth Bass median mercury concentrations for 14 sites on 9 rivers (upstream "U" and downstream "D") with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

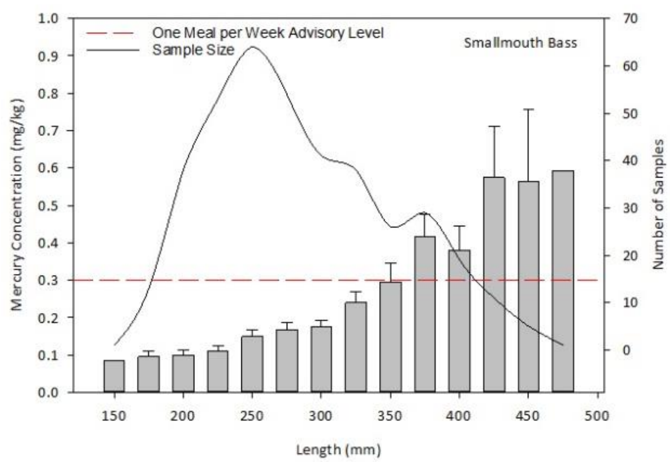

Figure 6. Smallmouth Bass average mercury concentrations with error bars representing the 95% confidence level (α= .05), sample size per length bin, and advisory level at 0.3 mg/kg.

Bluegill

Bluegill (N=397) were sampled in impoundments (N=19), natural lakes (N=5), reservoirs (N=4), large rivers (N=1), and surface mines (N=4). Mercury concentration results for fish collected from the same sites during both studies were significantly different (Table 5). All Bluegill samples collected during Cashatt (2017) were below the detection level, therefore the *SD* for mercury concentration was 0.0 mg/kg. The maximum mercury concentration for all samples was 0.339 mg/kg. During Cashatt (2017) when the entire length range was sampled from each lake, only 0.004% of fish exceeded 0.3 mg/kg (after increasing sample results by 21%). During this study, when sample collection was intentionally biased towards size ranges with expected higher mercury concentrations, only five samples were collected that were above the 0.3 mg/kg advisory level (Figure 7). These five individual fish were collected from a surface mine and an impoundment (Figure 8). Krogman (2019) suggested using a simple proportion estimator to determine sample size because tissue samples collected by Cashatt (2017) were all below the 0.3 mg/kg advisory level after the 21% increase. Therefore, Bluegill samples collected for mercury tissue analysis were placed in length bins, a 95% confidence level was used to determine length bins below 0.3 mg/kg advisory level, and results suggested consumption advisories were not necessary for the ARP (Figure 9).

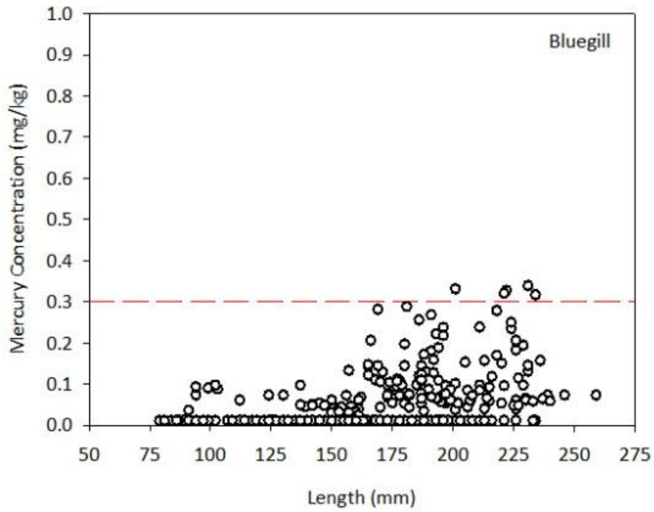

Figure 7. Mercury concentration for Bluegill tissue samples collected in Iowa rivers with advisory level at 0.3 mg/kg.

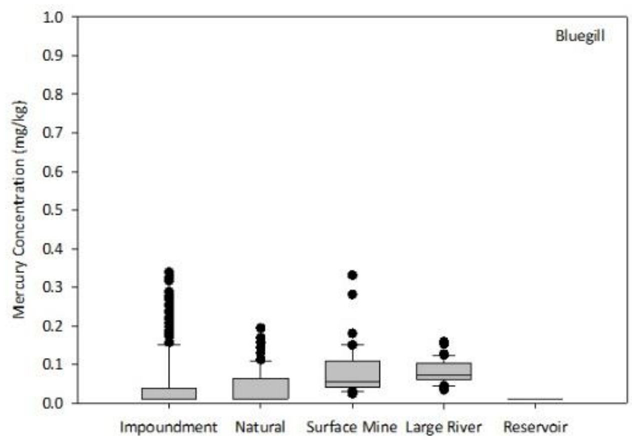

Figure 8. Bluegill median mercury concentrations for 35 sites in 5 waterbody types with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

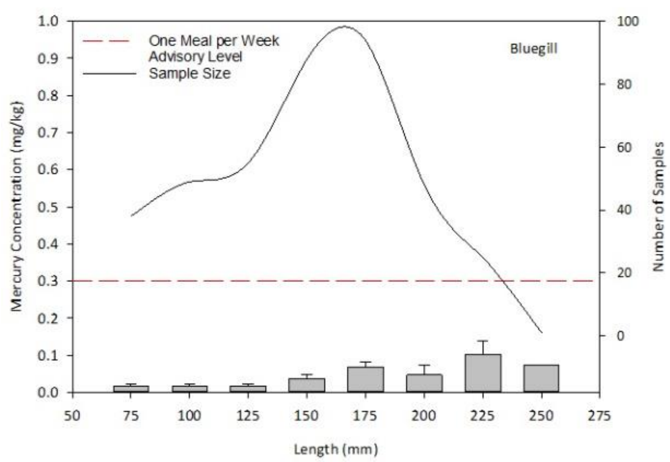

Figure 9. Bluegill average mercury concentrations with error bars representing the 95% confidence level (α= .05), sample size per length bin, and advisory level at 0.3 mg/kg.

Walleye

Tissue samples from Walleye (N=867) were collected in impoundments (N= 5), large rivers (N=1), natural lakes (N=9), reservoirs (N=4), and interior rivers (N=8) (Figure 10). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were not significantly different (Table 5). The highest individual mercury concentrations were found in rivers and the lowest mean concentrations were found in impoundments (Figure 11). The Upper Iowa River had a significantly higher mercury concentration than other rivers and lakes (Figure 12). The maximum mercury concentration for all samples was 1.690 mg/kg (Figure 13). Mercury concentration was found to have a strong correlation with length in top level predators (Krogman 2019). Therefore, using length bins with error bars representing a 95% confidence level were used to determine the consumption advisory for the ARP could be a Best Choice <475 mm and a one meal per week ≥475 mm (Figure 11).

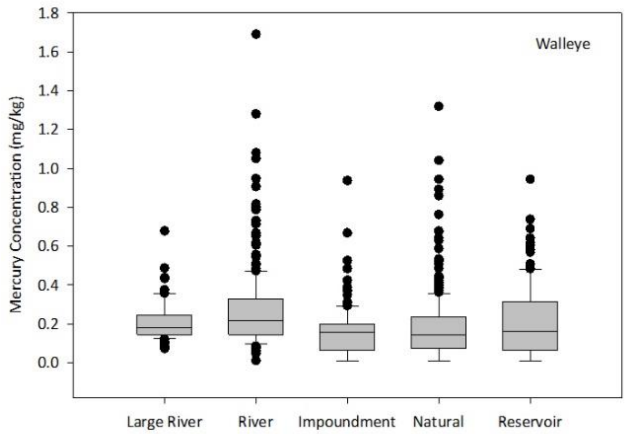

Figure 10. Walleye median mercury concentrations for 35 sites in 5 waterbody types with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

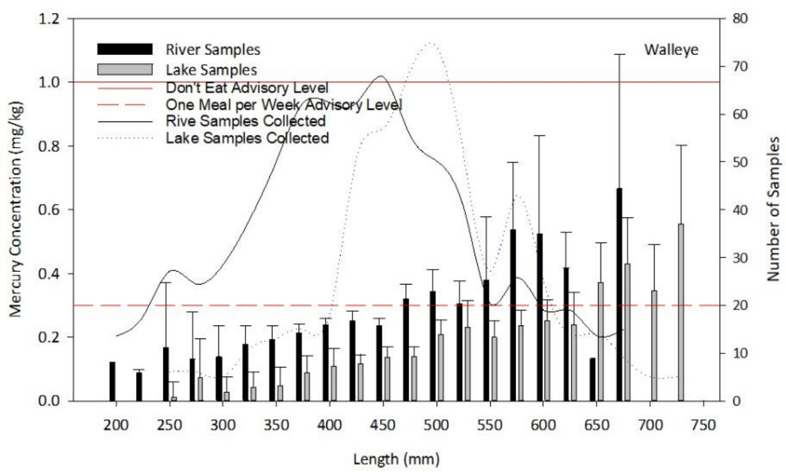

Figure 11. Walleye mean mercury concentrations with error bars representing the 95% confidence level (α=.05), sample size per length bin, and advisory level at 0.3 mg/kg and 1.0 mg/kg. Lake samples include reservoirs, surface mines, impoundments and natural lakes. River samples included both rivers and large rivers.

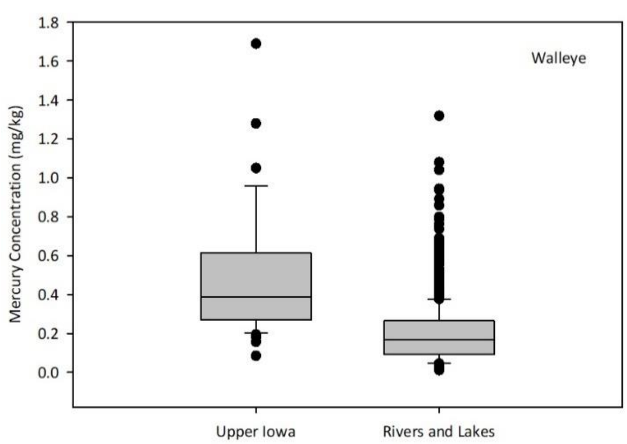

Figure 12. Walleye median mercury concentrations for 2 sites with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

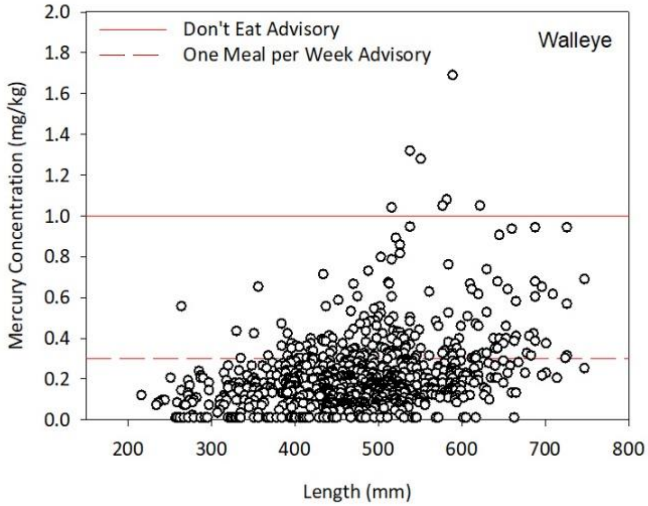

Figure 13. Mercury concentration for Walleye tissue samples collected in 5 waterbody types with advisory level at 0.3 mg/kg and 1.0 mg/kg.

Paddlefish

Paddlefish (N=21) were collected from the Missouri and Mississippi Rivers (Figure 14). These two locations represent a majority of the locations where this species can be caught by anglers. Mean mercury concentration was .088 mg/kg with a maximum value of 0.166 mg/kg. Lengths of collected individuals represent sizes caught by anglers. No advisory for the ARP is necessary for Paddlefish. If additional sampling is conducted it should target larger-sized individuals from other pools in the Mississippi River and additional reaches of the Missouri River that weren't previously sampled.

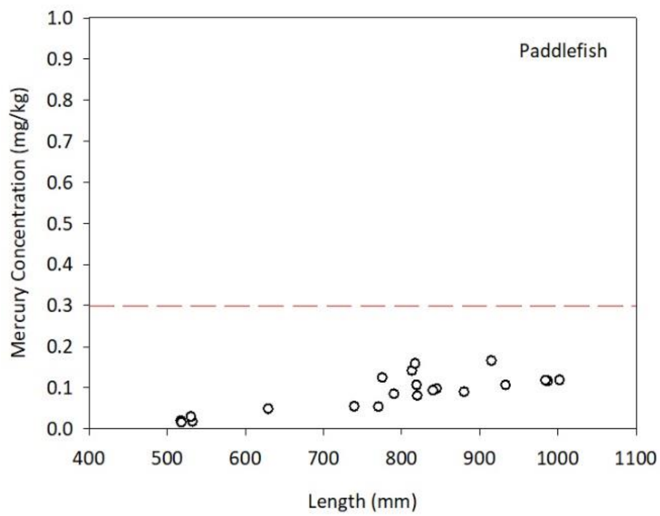

Figure 14. Mercury concentration in Paddlefish tissue samples collected in 2 large rivers and a 0.3 mg/kg advisory level.

Shovelnose Sturgeon

Shovelnose Sturgeon (N=46) were sampled in rivers (N=2) and large rivers (N=1). The mean mercury concentration was 0.032 mg/kg with a maximum value of 0.197 mg/kg (Figure 15). Collected fish represent the range of sizes anglers can capture. None of the collected samples were above the one meal per week advisory level of 0.3 mg/kg. Eye-to-fork in the tail length measurements for all samples were between 373 mm and 734 mm. A mercury consumption advisory for the ARP is not necessary for Shovelnose Sturgeon.

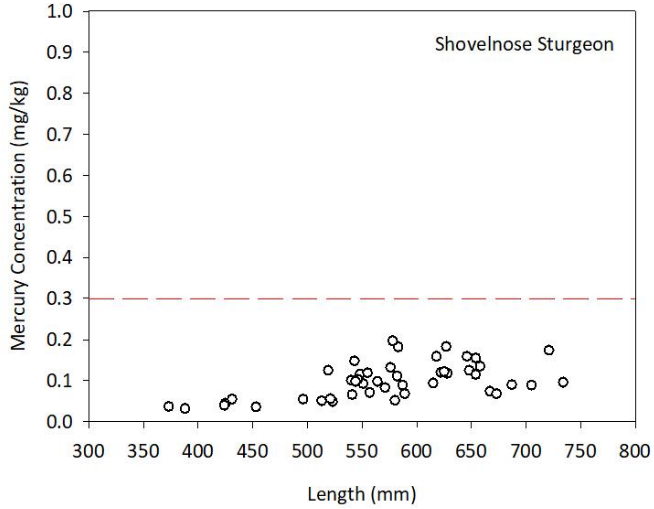

Figure 15. Individual mercury concentrations for Shovelnose Sturgeon tissue samples collected in 2 rivers and 1 large river, the 0.3 mg/kg advisory level is also highlighted.

Crappie Spp.

Black, White and Hybrid Crappie were collected in impoundments (N=14), large river (N=1), natural lakes (N= 7), reservoirs (N=4), and surface mines (N=5; Figure 16). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were significantly different (Table 5). This suggests there are more variables than just length associated with mercury concentrations in fish tissue. The maximum mercury concentration in crappie spp. was 0.386 mg/kg. All large river crappie samples were below the 0.3 mg/kg advisory level (Figure 17). Crappie sampled in other waterbody types had a smaller mean size than large rivers and individual samples tested above the advisory level of 0.3 mg/kg. Black Crappie had a mean mercury concentration of 0.061 (SD, 0.069) mg/kg and White Crappie had a mean concentration of 0.034 (SD, 0.051) mg/kg. Of the 447 crappie samples collected 6 were >0.3 mg/kg advisory level; these samples were collected from impoundments, natural lakes and surface mines. Crappie samples collected for mercury tissue analysis were placed in length bins, a 95% confidence level was used to determine length bins below 0.3 mg/kg advisory level, and results suggested consumption advisories are not necessary for ARP (Figure 18).

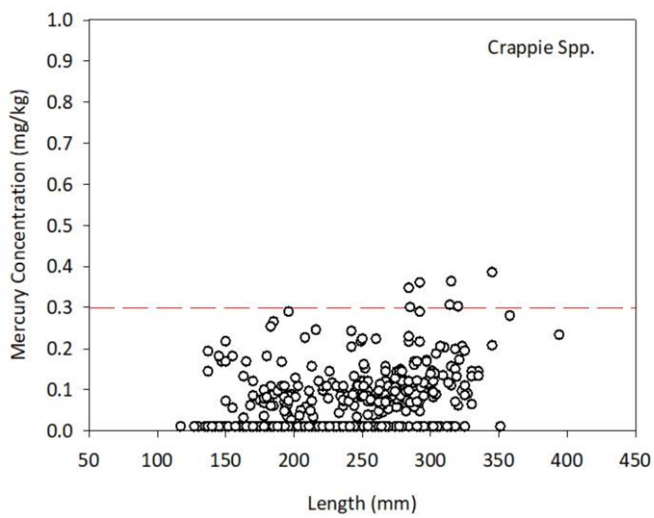

Figure 16. Individual mercury concentrations and the 0.3 mg/kg advisory level for crappie spp. tissue samples collected in 5 waterbody types.

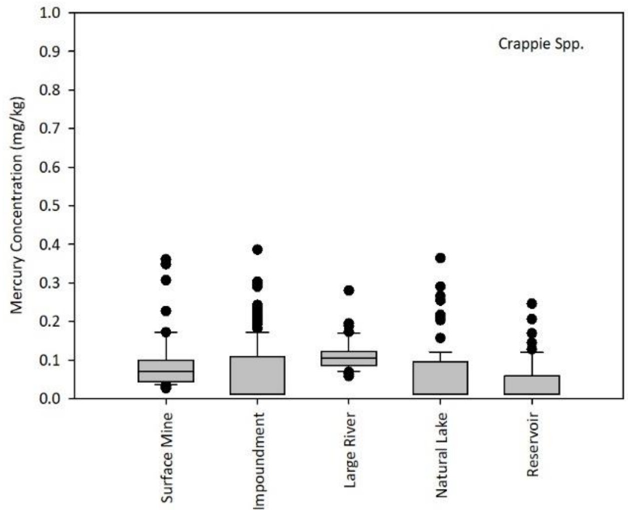

Figure 17. Crappie spp. median mercury concentrations for 5 waterbody types with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

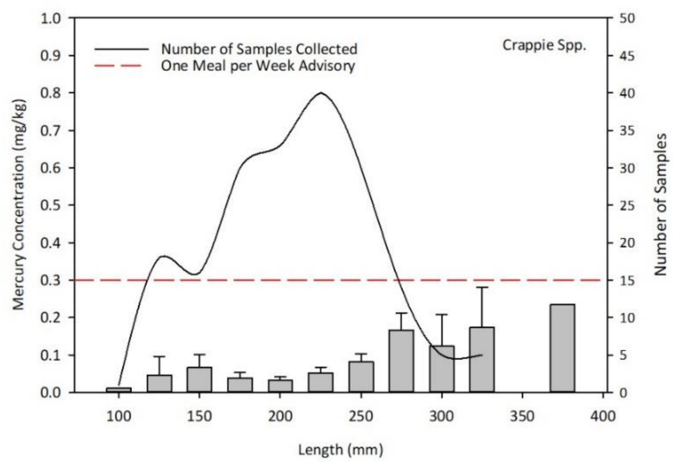

Figure 18. Crappie spp. mean mercury concentrations with error bars representing the 95% confidence level (α=.05), sample size per length bin, and advisory level at 0.3 mg/kg.

Flathead Catfish

Flathead Catfish *Pylodictis olivaris* (N=293) were sampled in 2 large rivers, 7 rivers, and 3 reservoirs. Mercury concentration results for fish of the same size range and collected from the same sites during both studies were significantly different even though length was not significantly different (Table 5). The maximum mercury concentration for Flathead Catfish was 0.98 mg/kg. Sample results exceeded the 0.3 mg/kg advisory level and were below the 1.0 mg/kg advisory level (Figure 19). Flathead Catfish mercury concentration results suggest this species is similar to other top-level predators in that increased length is positively associated with higher mercury concentration. Mercury concentrations in Flathead Catfish tissue samples were highest in rivers but tissue samples from length bins >550 mm were lacking in reservoirs (Figure 20). Additional samples in reservoirs and rivers could improve the precision in larger length bins. Sampling for this study was centered around the length bins where samples were most likely to increase above the 0.3 mg/kg advisory level. The recommended advisory for the ARP is one-meal-per-week for fish ≥475 mm (Figure 21).

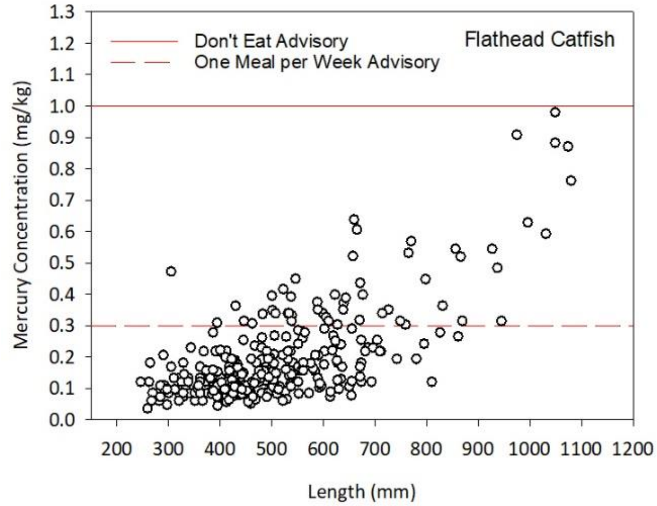

Figure 19. Mercury concentration for Flathead Catfish tissue samples collected in reservoirs, rivers and large rivers with 0.3 mg/kg and 1.0 mg/kg advisory levels.

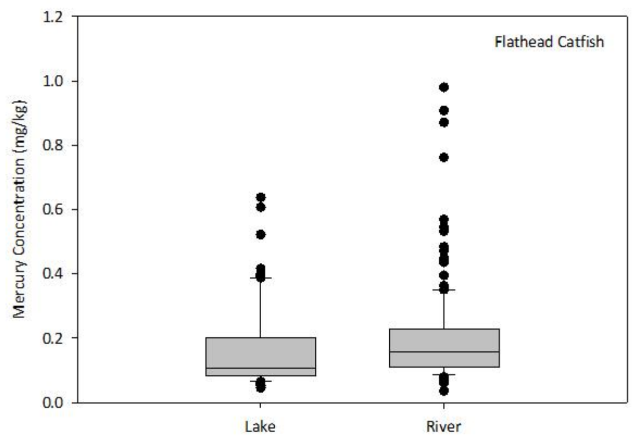

Figure 20. Flathead Catfish median mercury concentrations for lakes(reservoirs) and rivers (rivers and large rivers) with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

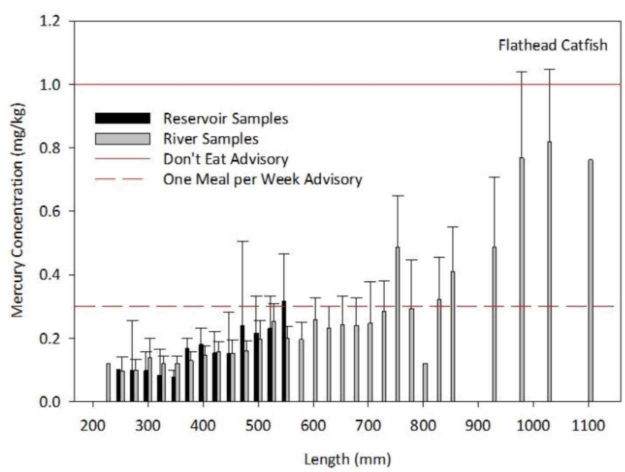

Figure 21. Flathead Catfish mean mercury concentrations with error bars representing the 95% confidence level (α= .05) and advisory levels at 0.3 mg/kg and 1.0 mg/kg.

Channel Catfish

Channel Catfish tissue samples (N=397) were collected from surface mines (N=4), impoundments (N=3), rivers (N=8), and large rivers (N=2). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were not significantly different (Table 5). The maximum mercury concentration for all Channel

Catfish samples was 0.714 mg/kg (Figure 22). River samples had the highest mercury concentrations and surface mines had the lowest (Figure 23). Of the 22 samples above 0.3 mg/kg only one was from an impoundment. The recommended statewide advisory for the ARP is one-meal-per-week for fish ≥625 mm in total length (Figure 24).

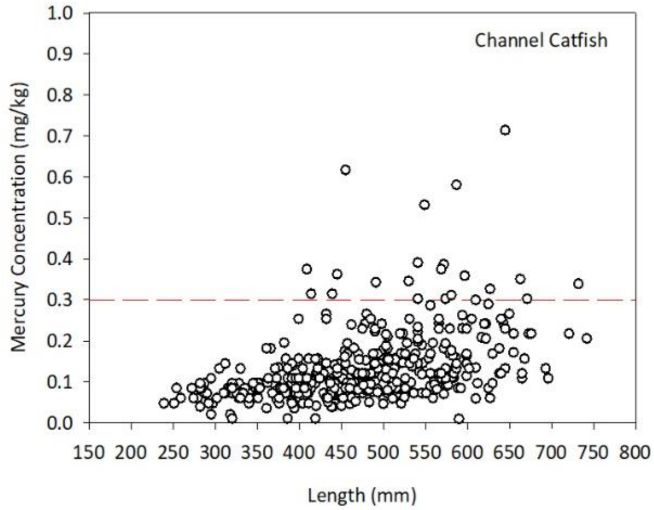

Figure 22. Mercury concentration for Channel Catfish tissue samples collected in reservoirs, rivers and large rivers with advisory levels at 0.3 mg/kg.

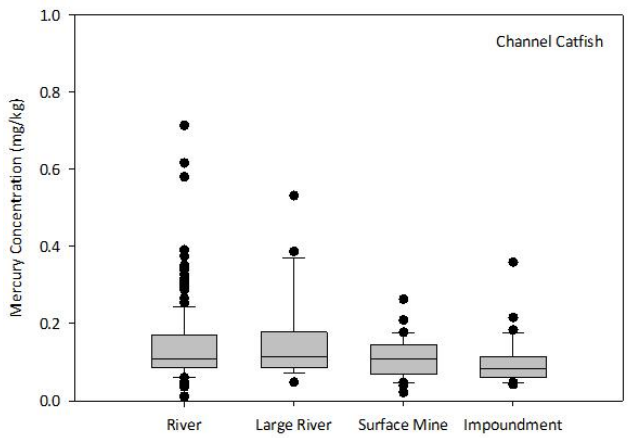

Figure 23. Channel Catfish median mercury concentrations for rivers, large rivers, surface mines and impoundments with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

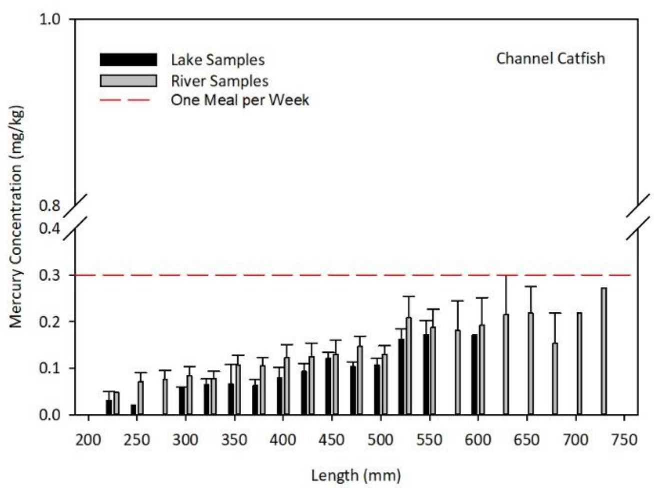

Figure 24. Channel Catfish mean mercury concentrations with error bars representing the 95% confidence level (α=.05) and advisory level at 0.3 mg/kg.

Common Carp

Common Carp *Cyprinus carpio* tissue samples (N=70) were collected from 2 rivers, 1 impoundment, and 1 natural lake. All of the tissue samples tested below 0.3 mg/kg advisory level (Figure 25). The mean mercury concentration was 0.082 mg/kg. An advisory for the ARP is not necessary for Common Carp.

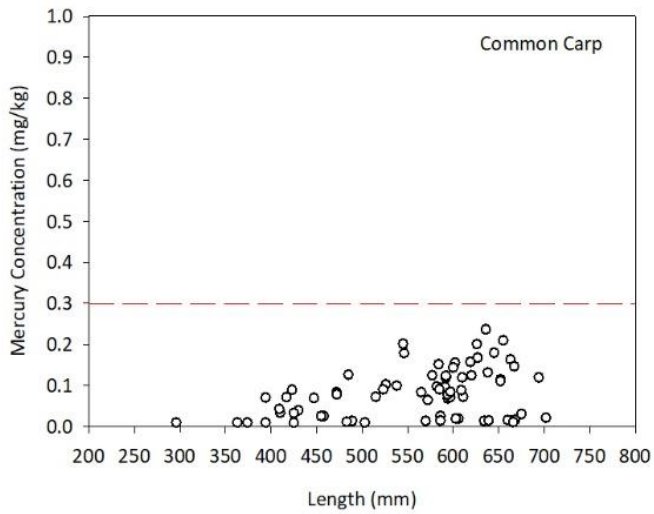

Figure 25. Mercury concentration for Common Carp tissue samples collected in impoundments, rivers and large natural lakes with an advisory level of 0.3 mg/kg.

Sucker Spp.

Shorthead Redhorse tissue samples (N=40) were collected in 4 rivers (Figure 26). The mean mercury concentration was 0.145 mg/kg and the Upper Iowa River had the highest concentration of 0.425 mg/kg (Figure 27). The ARP should follow the one-meal-per-week advisory recommendations when consuming Shorthead Redhorse.

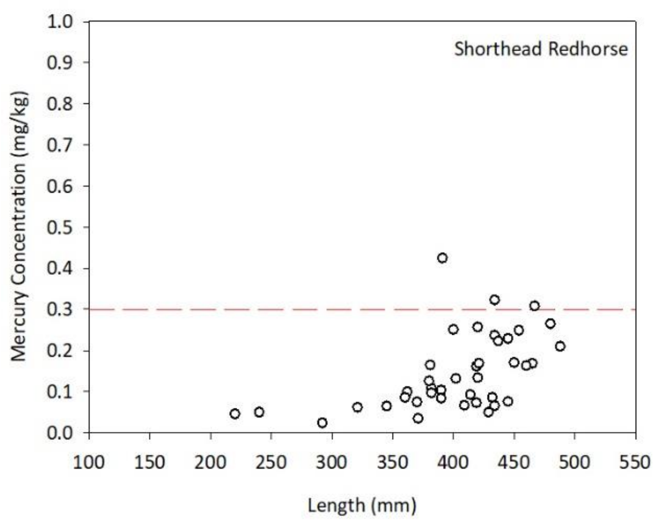

Figure 26. Mercury concentration for Shorthead Redhorse tissue samples collected in 4 rivers with an advisory level of 0.3 mg/kg.

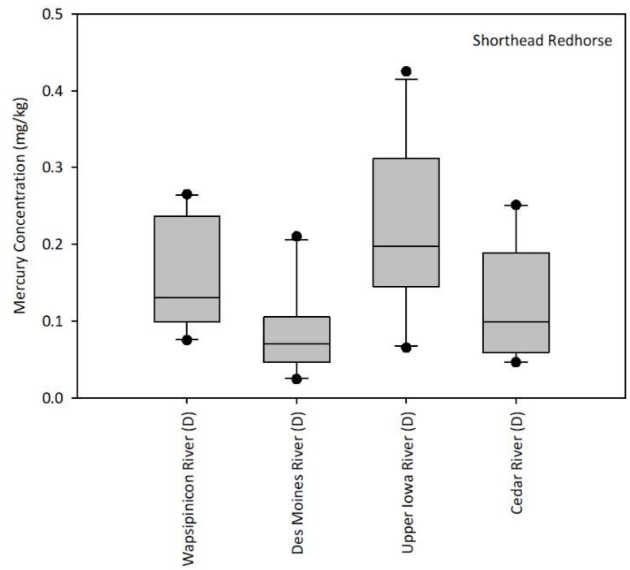

Figure 27. Shorthead Redhorse median mercury concentrations for 4 river sites with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

Hybrid Striped Bass

Hybrid Striped Bass *Morone saxatilis* x *M. chrysops* tissue samples (N=135) were collected from surface mines (N=2), reservoirs (N=3), natural lakes (N=1), impoundments (N=4). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were significantly different (Table 5). The maximum mercury concentration for Hybrid Striped Bass was 0.452 mg/kg (Figure 28). Of the 9 sample results >0.3 mg/kg, 8 were from a single surface mine. Hybrid Striped Bass are also difficult to differentiate from White Bass *Morone chrysops* of the same size, therefore, these species were combined and the more conservative White Bass advisory was used. The advisory for the ARP is one-meal-per-week for Hybrid Striped Bass ≥525 mm (Figure 29).

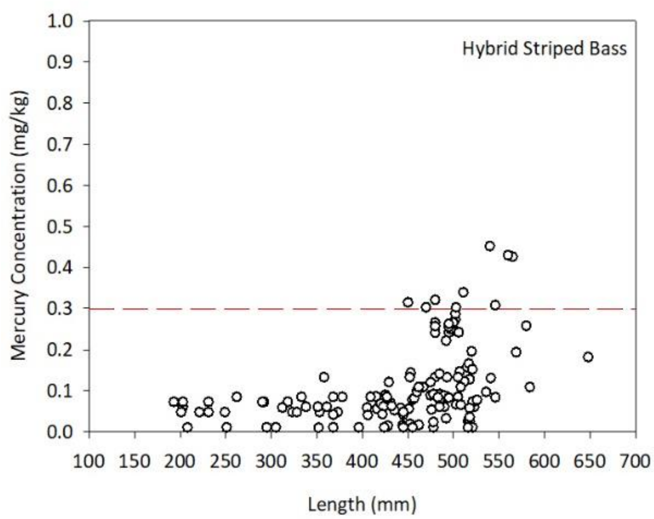

Figure 28. Mercury concentration for Hybrid Striped Bass tissue samples collected in impoundments, natural lakes, reservoirs, and surface mines with an advisory level of 0.3 mg/kg.

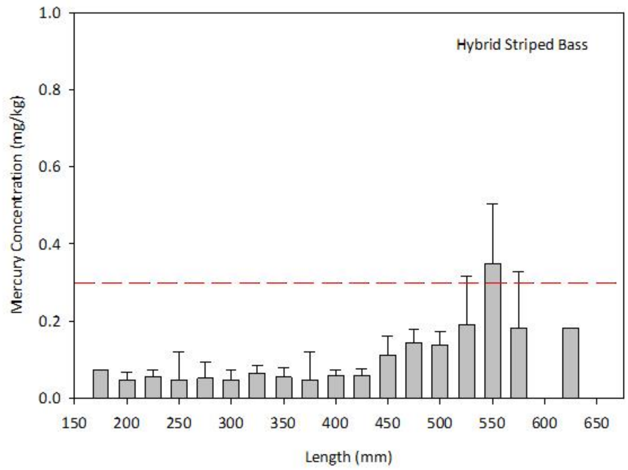

Figure 29. Hybrid Striped Bass mean mercury concentrations with error bars representing the 95% confidence level (α= .05) and advisory level at 0.3 mg/kg.

White Bass

White Bass tissue samples (N=136) were collected in natural lakes (N=1), rivers (N=4), large rivers (N=1), reservoirs (N=2), and impoundments (N=1; Figure 30). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were not significantly different (Table 5). The maximum mercury concentrations for White Bass was 0.511 mg/kg. Of the 10 sample results collected that were over 0.3 mg/kg, 4 were from the Maquoketa River. A one-meal-per-week advisory for the ARP was suggested for White Bass >400 mm (Figure 31). Combining Hybrid Striped Bass and White Bass made the one-meal-per-week advisory >400 mm for ARP.

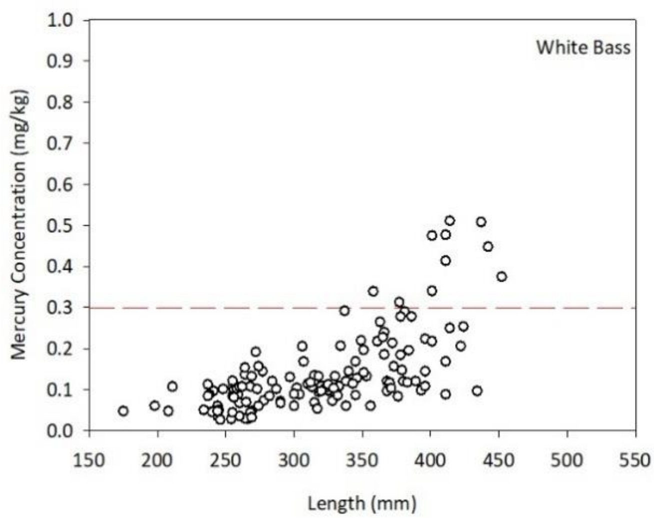

Figure 30. Mercury concentration for White Bass tissue samples collected in impoundments, natural lakes, reservoirs, large rivers, and rivers with an advisory level of 0.3 mg/kg.

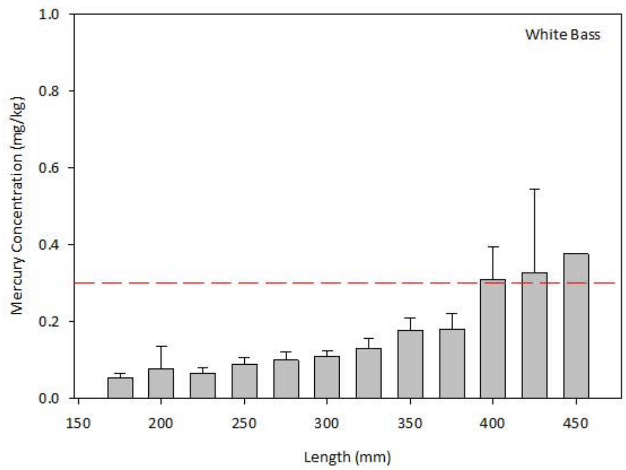

Figure 31. White Bass mean mercury concentrations with error bars representing the 95% confidence level (α= .05) and advisory level at 0.3 mg/kg.

Sauger

Sauger *Sander canadense* tissue samples (N=96) were collected from 2 large rivers. Mercury concentration results for fish of the same size range and collected from the same sites during both studies were significantly different (Table 5). The maximum mercury concentration was 0.556 mg/kg (Figure 32). The recommended advisory for ARP is one-meal-per-week of Sauger >400 mm (Figure 33).

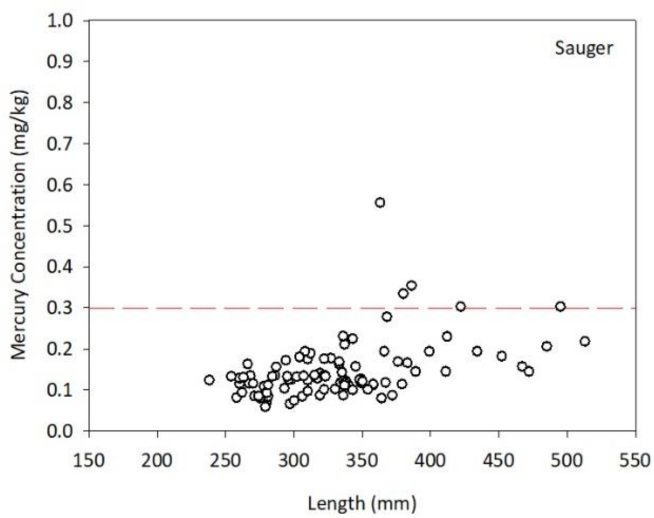

Figure 32. Mercury concentration for Sauger tissue samples collected in impoundments, natural lakes, reservoirs, large rivers, and rivers with an advisory level of 0.3 mg/kg.

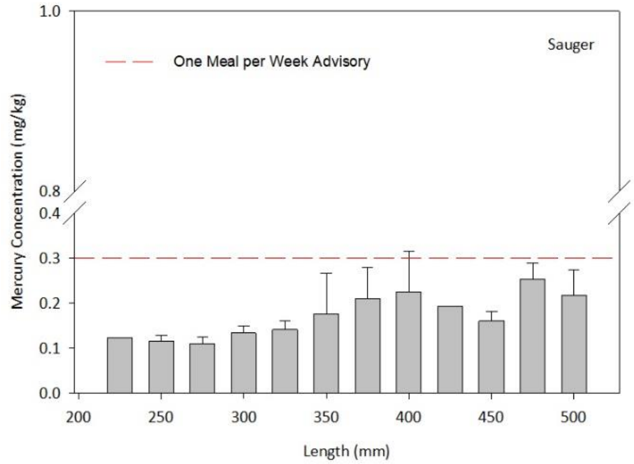

Figure 33. Sauger mean mercury concentrations with error bars representing the 95% confidence level (α=.05) and advisory level at 0.3 mg/kg.

Muskellunge

Muskellunge tissue samples (N=96) were collected from impoundments (N=2) and natural lakes (N=3) (Figure 34). The maximum mercury concentration was 3.049 mg/kg. Muskellunge are regulated with a 1016 mm minimum length limit in Iowa and the mean mercury concentration for fish >1016 mm was 0.853 mg/kg. Therefore, Muskellunge were identified as the only species with a do-not-eat advisory (i.e., mercury concentration ≥1.0 mg/kg) for the ARP.

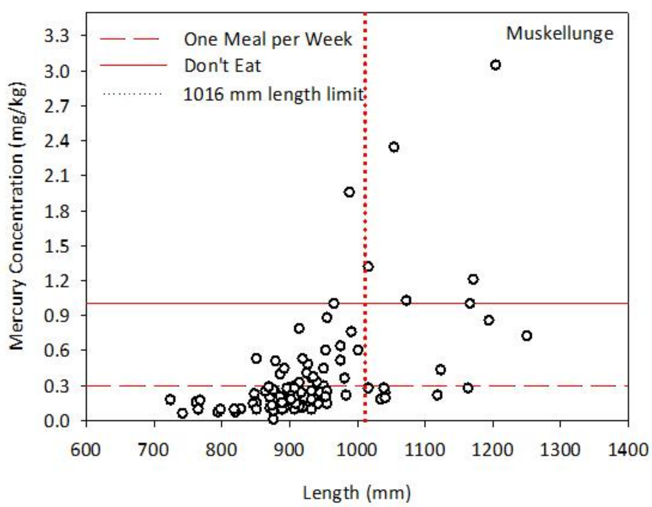

Figure 34. Mercury concentration for Muskellunge tissue samples collected in impoundments and natural lakes with advisory levels 0.3 mg/kg and 1.0 mg/kg.

Yellow Bass

Yellow Bass *Morone mississippiensis* tissue samples were collected in natural lakes (N=3) and impoundments (N=1). The maximum mercury concentration was 0.254 mg/kg. All samples were below the advisory level of 0.3 mg/kg (Figure 35). A consumption advisory was not necessary for the ARP consuming Yellow Bass.

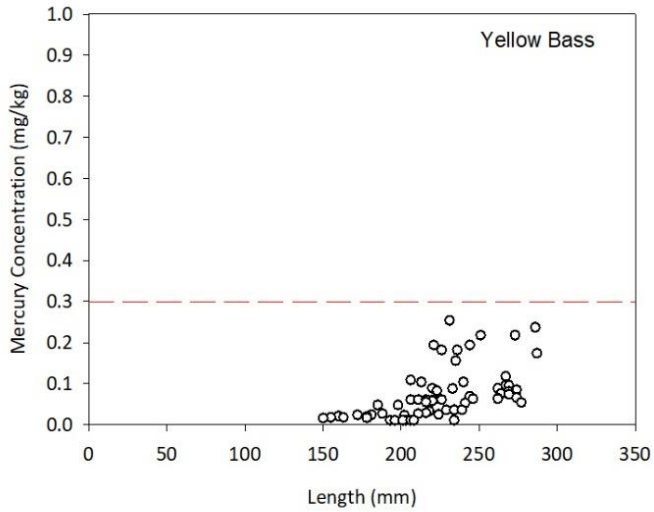

Figure 35. Mercury concentration for Yellow Bass tissue samples collected in impoundments and natural lakes with an advisory level of 0.3 mg/kg.

Trout

Brook Trout *Salvelinus fontinalis* (N=20), Brown Trout *Salmo trutta* (N=31), and Rainbow Trout *Oncorhynchus mykiss* (N=20) were collected in 5 trout streams and 1 hatchery in Northeast Iowa (Figure 36). The maximum mercury concentration for all samples was 0.181 mg/kg. All samples were below the 0.3 mg/kg advisory level. Therefore, an advisory for ARP was not necessary.

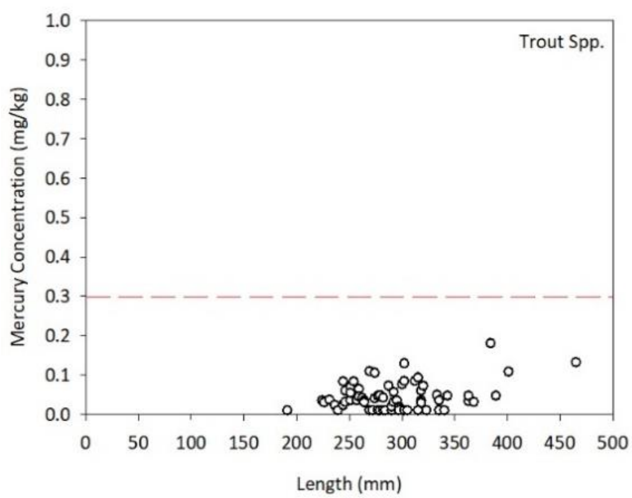

Figure 36. Mercury concentration for Brook, Brown, and Rainbow Trout tissue samples collected in a Northeast Iowa fish hatchery and 5 trout streams with an advisory level of 0.3 mg/kg.

Yellow Perch

Yellow Perch *Perca flavescens* tissue samples (N=143) were collected from natural lakes (N=5), impoundments (N=2), and large rivers (N=1) (Figure 37). The maximum mercury concentration was 0.242 mg/kg. All samples were below the 0.3 mg/kg advisory level. Yellow Perch can be consumed at any length, and an advisory for the ARP was not necessary for this species.

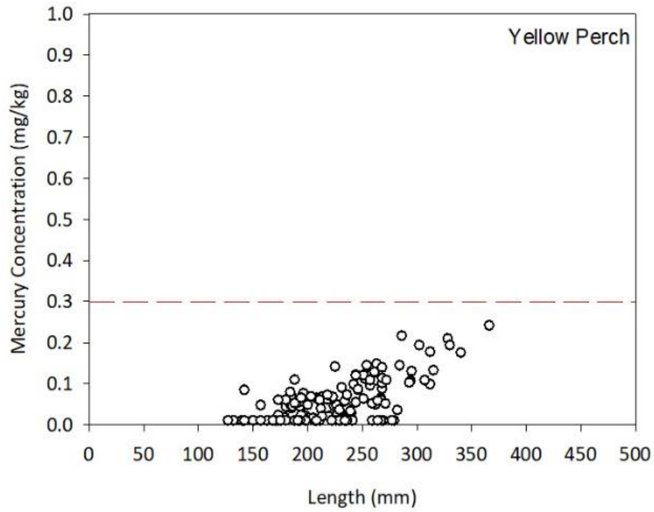

Figure 37. Mercury concentration for Yellow Perch tissue samples collected in natural lakes, impoundments, and large rivers with an advisory level of 0.3 mg/kg.

Freshwater Drum

Freshwater Drum *Aplodinotus grunniens* (N=114) were sampled in three pools of the Upper Mississippi River (Figure 38). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were significantly different (Table 5). The maximum mercury concentration for Freshwater Drum was 0.793 mg/kg (Figure 39). These fish can also be found in surface mines, other rivers and some natural lakes such as West Okoboji. Future sampling should be conducted to include these waterbody types. Until then, a conservative advisory for the ARP of one-meal-per-week for fish ≥450 mm was recommended (Figure 40).

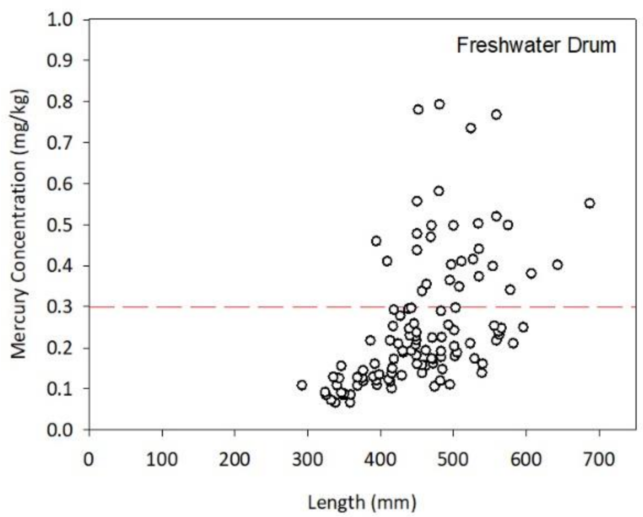

Figure 38, Mercury concentration for Freshwater Drum tissue samples collected from 3 pools in the Upper Mississippi River with an advisory level of 0.3 mg/kg.

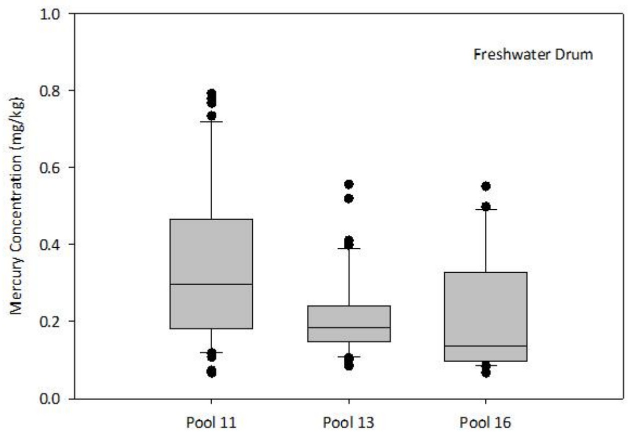

Figure 39. Freshwater Drum median mercury concentrations for 3 Upper Mississippi River pools with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

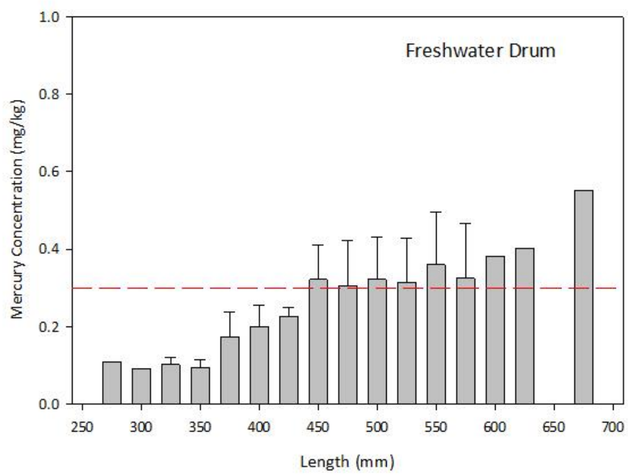

Figure 40. Freshwater Drum mean mercury concentrations with error bars representing the 95% confidence level (α= .05) and advisory level at 0.3 mg/kg.

Northern Pike

Northern Pike tissue samples were collected from natural lakes (N=6), rivers (N=6), large rivers (N=1), and surface mines (N=1) (Figure 41). Mercury concentration results for fish of the same size range and collected from the same sites during both studies were significantly different (Table 1 and Table 5). The maximum mercury concentration for Northern Pike was 0.787 mg/kg. Impoundments had the highest individual sample concentration and surface mines had the highest median value (Figure 42). The advisory for ARP is one-meal-per-week for Northern Pike ≥475 mm (Figure 43). Additional samples could be collected from East and West Okoboji Lakes to monitor changes in mercury level concentrations. Additional samples could also be collected on the Upper Mississippi River pools to monitor higher than average values in the UMR pools (Figure 44).

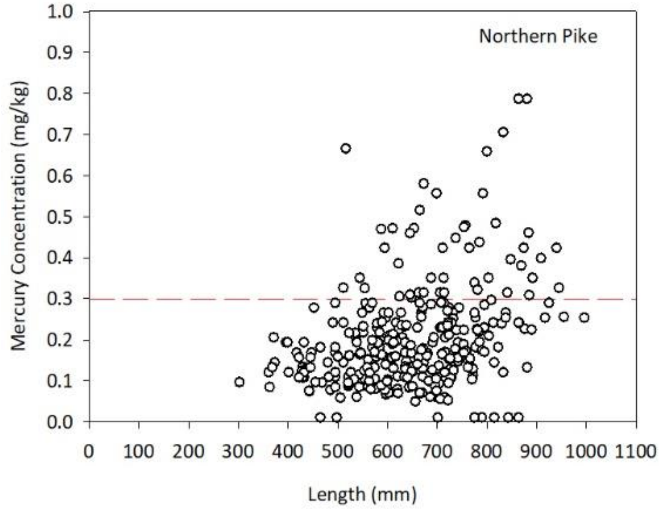

Figure 41. Mercury concentration for Northern Pike tissue samples collected from natural lakes, rivers, large rivers, and surface mines with an advisory level of 0.3 mg/kg.

Table 1. Mean total length and mercury concentration for Northern Pike collected at two different time periods in East and West Okoboji lakes student t-test results, *P* values < .05 were considered significant.

Collection Period	mean Total Length (mm)	mean Hg conc (mg/kg)
Study 7044 (N=22)	639	0.259
Study 7064 (N=21)	648	0.115
P Value	0.826	<.001

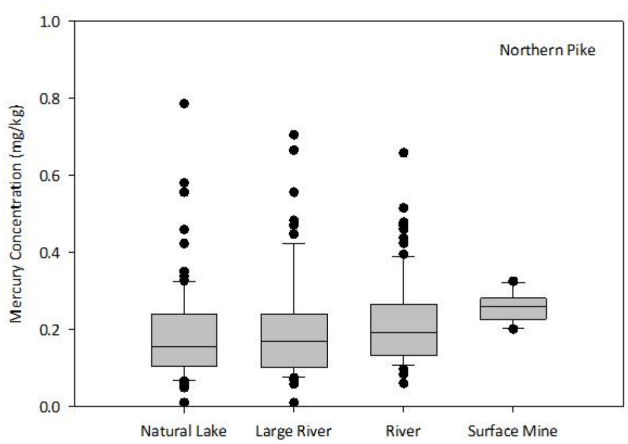

Figure 42. Northern Pike median mercury concentrations for natural lakes, large rivers, rivers, and surface mines. Upper Mississippi River pools with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

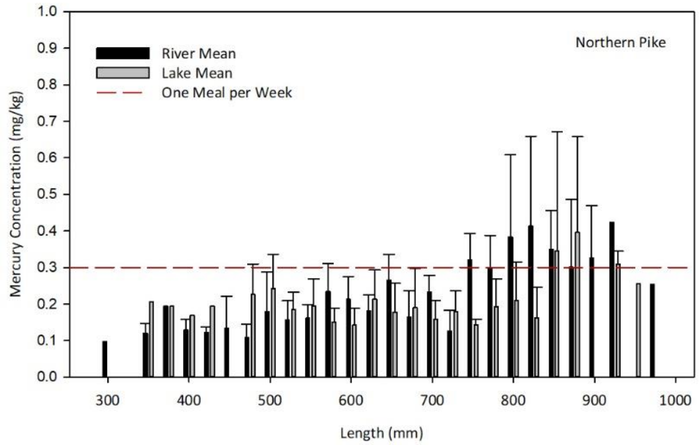

Figure 43. Northern Pike mean mercury concentrations with error bars representing the 95% confidence level (α=.05) and advisory level at 0.3 mg/kg.

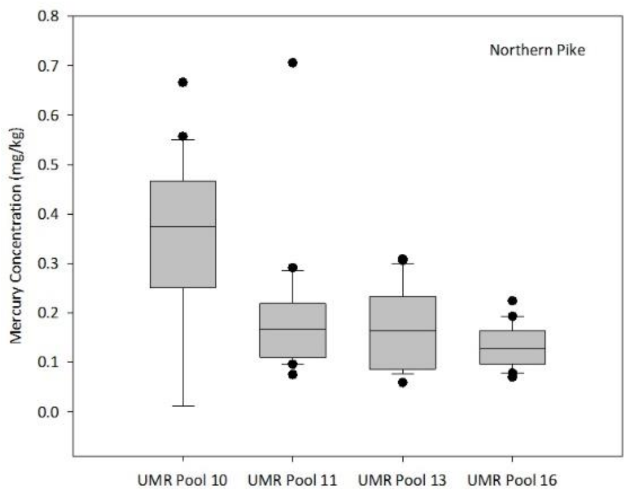

Figure 44. Northern Pike median mercury concentrations for 4 pools in the Upper Mississippi River. Upper Mississippi River pools with the ends of the boxes displaying the 25th and 75th percentile and error bars defining the 10th and 90th percentiles.

Management Recommendations

- Iowa-caught sport fish are safe to eat for most people.
- Predator species (i.e., Largemouth Bass, Walleye, Northern Pike, Flathead Catfish, Muskellunge) had higher levels of mercury in their tissue than other species (i.e., Bluegill, Crappie Spp., Perch, Trout, Channel Catfish, and Common Carp).
- These consumption advisories are conservative recommendations for the ARP. Many of the samples collected in this study were targeted to collect samples containing mercury levels close to or above the 0.3 mg/kg advisory level. Therefore, these samples don't represent the true average of mercury concentrations in fish populations statewide.

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TABLE AND FIGURES

Table 2. Species and number of sport fish collected and analyzed for mercury contamination in tissue, species listed in descending order of angler preference with Largemouth bass being the most preferred (FY20-FY22).

Common Name	Scientific Name	River Sample	Lake Sample	Surface Mine
Largemouth Bass	*Micropterus salmoides*	60	211	100
Walleye	*Sander vitreus*	147	191	
Bluegill	*Lepomis macrochirus*	40	40	40
Crappie spp.	*Pomoxis spp.*	40	40	50
Channel Catfish	*Ictalurus punctatus*	90	28	40
Flathead Catfish	*Pylodictis olivaris*	61	70	
Smallmouth Bass	*Micropterus dolomieu*	204		
Trout spp.	*Salmonid spp.*	40		
Yellow Perch	*Perca flavescens*	40	40	
Sauger	*Stizostedion canadense*	71		
Northern Pike	*Esox lucius*	97	71	10
Muskellunge	*Esox masquinongy*		25	
Hybrid Striped Bass	*Morone saxatilis* x *M. chrysops*		35	40
White Bass	*Morone chrysops*	51	40	
Yellow Bass	*Morone mississippiensis*		40	
Common Carp	*Cyprinus carpio*	30	40	
Freshwater Drum	*Aplodinotus grunniens*	100		
Sucker spp.	*Catastomide spp.*	40		
Shovelnose Sturgeon	*Scaphirhynchus platorynchus*	46		
Paddlefish	*Polyodon spathula*	21		
	Total	1178	871	280

Table 3. Suggested statewide fish consumption advisories for the at-risk population consuming fish caught in Iowa lakes and rivers.

Best Choices EAT 2-3 SERVINGS A WEEK	
Largemouth Bass ≤ 13"	Channel Catfish ≤ 24"
Smallmouth Bass ≤ 13"	Common Carp
Bluegill	White Bass ≤ 15"
Walleye ≤ 19"	Freshwater Drum ≤ 17"
Paddlefish	Hybrid Striped Bass ≤ 20”
Shovelnose Sturgeon	Yellow Bass
Crappie Spp.	Trout Spp.
Sauger ≤ 15”	Yellow Perch
Flathead Catfish ≤ 18"	

Good Choices EAT 1 SERVING A WEEK	
Largemouth Bass > 13"	White Bass > 15"
Smallmouth Bass > 13"	Hybrid Striped Bass > 20”
Walleye > 19"	Freshwater Drum > 17"
Flathead Catfish > 19"	Shorthead Redhorse
Channel Catfish > 24"	Northern Pike

Choices to Avoid HIGHEST MERCURY LEVELS
Muskellunge

www.iowadnr/fishadvice

STATE OF IOWA DEPARTMENT OF Health AND Human SERVICES

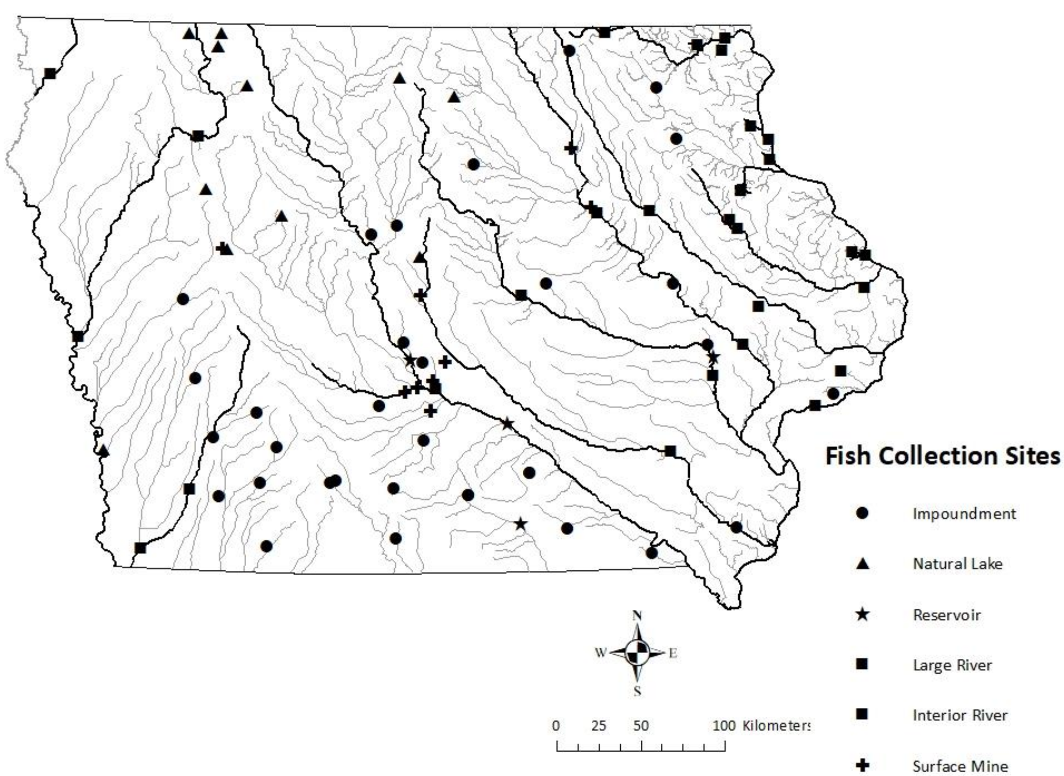

Figure 45. Locations of sample sites for fish tissue samples collected for fish consumption advisories.

Table 4. Site names and waterbody types sampled.

Site Name	DNR Code	Waterbody Type	X-Coord	Y-Coord
Ankeny Lake (DMACC)	ANK77	Impoundment	449512	4617135
Badger Creek Lake	BAC61	Impoundment	423894	4591432
Beeds Lake	BEE35	Impoundment	480056	4735292
Big Creek Lake	BIC77	Impoundment	438321	4629479
Briggs Woods Lake	BWO40	Impoundment	434799	4698625
Brushy Creek Lake	BRC94	Impoundment	419317	4693494
Cold Springs Lake	CSP15	Impoundment	325247	4573271
Lake Ahquabi	AHQ91	Impoundment	450319	4571146
Lake Anita	ANI15	Impoundment	351184	4587776
Lake Geode	GEO44	Impoundment	636088	4519879
Lake Hendricks	HEN45	Impoundment	536797	4802512
Lake Icaria	ICA02	Impoundment	353124	4545986
Lake Macbride	MAC52	Impoundment	619078	4628229
Lake Meyer	MEY96	Impoundment	588587	4780856
Lake Miami	MIA68	Impoundment	512953	4551707
Lake of the Hills	LTH82	Impoundment	693799	4599252
Lake of Three Fires	TFI87	Impoundment	357231	4508111
Lake Sugema	SUG89	Impoundment	585661	4504194
Lake Wapello	WAP26	Impoundment	535776	4518715
Little River Watershed Lake	LRI27	Impoundment	434102	4512932
Marina Cove	MIA68	Impoundment	512953	4551707
Mormon Trail Lake	MTR01	Impoundment	363054	4566934
Pleasant Creek Lake	PLC57	Impoundment	598200	4664126
Prairie Lakes North	RHA59	Impoundment	477089	4538562
Prairie Rose Lake	PRO83	Impoundment	315023	4608076
Red Haw Lake	RHA59	Impoundment	477089	4538562
Three Mile Lake	THM88	Impoundment	397911	4547597
Twelve Mile Creek Lake	TMI88	Impoundment	394548	4546017
Union Grove Lake	UGR86	Impoundment	522800	4664064
Viking Lake	VIK69	Impoundment	329002	4538071
Volga Lake	VOL33	Impoundment	600341	4750281
West Lake (Osceola)	WOS20	Impoundment	432377	4543058
Yellow Smoke Park Lake	YSM24	Impoundment	307776	4655290
Missouri River	RMR78	Large River	697954	4612222
UMR Pool 10	UMR10	Large River	655064	4749599
UMR Pool 11	RMR22	Large River	655985	4737777
UMR Pool 13	RMR49	Large River	713008	4680823
UMR Pool 16	RMR70	Large River	682997	4591858
Big Spirit Lake	SPL30	Natural	329967	4812894
Blackhawk Lake	BHA81	Natural	333592	4684764
Clear Lake	CLE17	Natural	468224	4775663
Crystal Lake	CRY44	Natural	435752	4786527

Site Name	DNR Code	Waterbody Type	X-Coord	Y-Coord
East Okoboji Lake	EOK30	Natural	328395	4805142
Lake Manawa	MAN78	Natural	260203	4565635
Little Wall Lake	LWA40	Natural	447509	4679896
Lost Island lake	LIS74	Natural	345237	4781981
North Twin Lake	NTW13	Natural	366058	4704862
Silver Lake (Dickinson)	SIL30	Natural	310997	4813089
Storm Lake	STL11	Natural	320724	4720590
West Okoboji Lake	EOK30	Natural	328395	4805142
Coralville Reservoir	COR52	Reservoir	622294	4620498
Rathbun Reservoir	RAT04	Reservoir	507934	4521817
Red Rock Reservoir	RRO63	Reservoir	500001	4581032
Saylorville Reservoir	SAY77	Reservoir	442685	4618589
Big Mill Creek	TBM49	River	704699	4682593
Cedar River (U)	RCR07	River	553557	4706183
Cedar River (D)	RCR16	River	639956	4627789
Des Moines River (D)	RDR89	River	457456	4601676
Des Moines River (U)	RDR77	River	457456	4601676
East Nishnabotna River (D)	REN36	River	282164	4507273
East Nishnabotna River (U)	REN69	River	311476	4542087
Fountain Springs	TFS28	River	638639	4719344
French Creek	TFR03	River	627633	4802344
Iowa River (D)	RIR52	River	622229	4609708
Iowa River (U)	RIR64	River	508658	4657393
Little Sioux River (U)	RLS11	River	316584	4751679
Little Sioux River (D)	RLS43	River	245262	4632381
Manchester Fish Hatchery	MNH01	River	631870	4702267
Maquoketa River (U)	RMR28	River	636388	4696604
Maquoketa River (D)	RMR49	River	712122	4661938
North Cedar Creek	TNC22	River	644451	4757794
Pine Creek	TPI03	River	613053	4805823
Rock River	RRR84	River	228638	4788330
Skunk River	RSR92	River	596775	4564380
Upper Iowa River (D)	RUI03	River	629719	4809687
Upper Iowa River (U)	RUI096	River	558315	4812722
Wapsipinicon River (D)	RWR53	River	649311	4650310
Wapsipinicon River (U)	RWR10	River	584223	4707149
Ada Hayden Heritage Park Lake	AHL85	Surface Mine	448174	4657208
Arrowhead Lake	ARR81	Surface Mine	330912	4684794
Banner Lake (North)	BLN91	Surface Mine	454077	4588169
Blue Heron Lake	RRP77	Surface Mine	439021	4599899
Copper Creek	COC77	Surface Mine	455930	4605980
George Wyth Lake	GWY07	Surface Mine	549305	4709368
Grays Lake	GRL77	Surface Mine	446620	4602227

Site Name	DNR Code	Waterbody Type	X-Coord	Y-Coord
Lake Petocka	BOL77	Surface Mine	463217	4617300
Plainfield Lake	PLA09	Surface Mine	537455	4744520

Table 5. Descriptive statistics and T-test results comparing mercury concentration and total fish length for 12 species where fish were collected for both study 7064 and Cashatt (2017) with significant P values, α=.05, in bold text.

Species	Variable	Study	N	Mean	Std Dev	Range	Max	Min	Median	T	P Value
Largemouth Bass	Length (mm)	7064	121	341	33	155	437	282	340	13285	**<0.001**
		Cashatt	186	369	33	147	434	287	373		
	Hg Conc.	7064	121	0.203	0.124	0.613	0.646	0.033	0.174	17425.5	0.112
		Cashatt	186	0.214	0.134	0.642	0.653	0.011	0.23		
Bluegill	Length (mm)	7064	10	187	12	36	213	177	184	-0.0948	0.931
		Cashatt	4	188	10	23	196	173	191		
	Hg Conc.	7064	10	0.0863	0.0369	0.107	0.144	0.037	0.081	-6.453	**0.002**
		Cashatt	4	0.011	0	0	0.011	0.011	0.011		
Walleye	Length (mm)	7064	245	475	45	360	645	285	474	78387	0.429
		Cashatt	409	479	98	358	645	287	480		
	Hg Conc.	7064	245	0.206	0.209	1.678	1.69	0.012	0.16	76350	0.096
		Cashatt	409	0.209	0.164	1.308	1.319	0.011	0.182		
Crappie Spp.	Length (mm)	7064	37	261	34	136	318	182	259	0.98	0.336
		Cashatt	59	254	36	142	325	183	251		
	Hg Conc.	7064	37	0.14	0.0724	0.311	0.364	0.053	0.112	2591.5	**<0.001**
		Cashatt	59	0.0458	0.0612	0.279	0.29	0.011	0.011		
Channel Catfish	Length (mm)	7064	70	496	47	190	610	420	490	2013	0.711
		Cashatt	38	495	52	190	612	422	483		
	Hg Conc.	7064	70	0.145	0.0766	0.381	0.391	0.01	0.121	2079	0.962
		Cashatt	38	0.157	0.107	0.569	0.617	0.048	0.133		
Flathead Catfish	Length (mm)	7064	40	495	76	254	634	380	501	692.5	0.539
		Cashatt	23	483	73	241	627	386	462		
	Hg Conc.	7064	40	0.196	0.0868	0.381	0.449	0.068	0.171	595.5	**0.045**
		Cashatt	23	0.16	0.0772	0.254	0.327	0.073	0.133		
Freshwater Drum	Length (mm)	7064	35	462	47	190	540	350	471	0.878	0.396
		Cashatt	11	482	71	183	559	376	483		
	Hg Conc.	7064	35	0.174	0.0474	0.21	0.298	0.088	0.173	-3.477	**<0.001**
		Cashatt	11	0.325	0.142	0.412	0.557	0.145	0.29		
Hybrid Stripped Bass	Length (mm)	7064	44	486	39	213	565	352	487.5	1.393	0.119
		Cashatt	23	467	59	216	569	353	478		
	Hg Conc.	7064	44	0.161	0.126	0.442	0.452	0.01	0.0965	628	**0.042**
		Cashatt	23	0.105	0.111	0.328	0.339	0.011	0.073		
Northern Pike	Length (mm)	7064	50	688	95	432	955	523	696	-2.937	**0.004**
		Cashatt	52	750	115	409	945	536	758		
	Hg Conc.	7064	50	0.149	0.0549	0.255	0.322	0.067	0.141	1871.5	**<0.001**
		Cashatt	52	0.277	0.196	0.776	0.787	0.011	0.26		

Species	Variable	Study	N	Mean	Std Dev	Range	Max	Min	Median	T	P Value
Smallmouth Bass	Length (mm)	7064	174	295	64	262	450	188	284	30283	0.186
		Cashatt	169	304	66	264	452	188	295		
	Hg Conc.	7064	174	0.203	0.15	0.862	0.904	0.042	0.152	32004	**0.001**
		Cashatt	169	0.231	0.15	1.005	1.041	0.036	0.194		
Sauger	Length (mm)	7064	34	320	37	123	383	260	332	-0.151	0.87
		Cashatt	11	323	44	135	389	254	323		
	Hg Conc.	7064	34	0.126	0.0812	0.497	0.556	0.059	0.115	349.5	**0.011**
		Cashatt	11	0.141	0.0316	0.109	0.194	0.085	0.133		
White Bass	Length (mm)	7064	51	313	53	174	414	240	312	1870	0.186
		Cashatt	38	328	51	170	411	241	336		
	Hg Conc.	7064	51	0.125	0.0851	0.45	0.477	0.027	0.107	1818.5	0.37
		Cashatt	38	0.131	0.0732	0.303	0.339	0.036	0.121		