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MERCURY CONCENTRATIONS IN FISH FROM LAKE MEREDITH, TEXAS: IMPLICATIONS FOR THE ISSUANCE OF FISH CONSUMPTION ADVISORIES

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Abstract. We examined how length of fish is related to mercury concentrations in muscle tissue of seven species of fish from Lake Meredith, Texas and determined how sex and growth rate are related to mercury concentration in walleye (*Sander vitreus*). Flathead catfish (*Pylodictis olivaris*), walleye and white bass (*Morone chrysops*) had the highest concentrations of mercury and channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), river carpsucker (*Carpiodes carpio*) and gizzard shad (*Dorosoma cepedianum*) had the lowest concentrations of mercury. Mercury concentrations were positively correlated with total length (TL) of fish for all species except gizzard shad, which exhibited a negative correlation between mercury concentration and TL. Male walleye grew more slowly than females, and males had higher concentrations of mercury than females. We also assessed the differences in fish consumption advisories that would be issued using Texas Department of State Health Services (DSHS) guidelines versus United States Environmental Protection Agency (USEPA) recommendations. Using DSHS guidelines, no fish species in Lake Meredith would be issued a fish consumption advisory. Nevertheless, DSHS has issued an advisory for walleye in Lake Meredith, possibly due to an inadequate sample size of fish. Using USEPA guidelines, a fish consumption advisory would be issued for the largest size class of flathead catfish but no advisory exists for flathead catfish in Lake Meredith. We suggest that when fish in a lake may be contaminated with mercury, all game fish in the lake should be assessed, and mercury advisories should take fish size into account.

Keywords: fish, fish consumption advisory, mercury

1. Introduction

The primary source of mercury to humans is consumption of mercury-contaminated fish (NRC, 2001). Even low doses of mercury can damage the nervous and cardiovascular systems of humans (NRC, 2001). Fetuses are particularly sensitive to mercury consumed by pregnant women, and prenatal exposure to low levels of mercury can cause developmental and cognitive problems (reviewed in NRC, 2001; USEPA, 2003). To identify the fish species that pose the greatest risk to humans, it is important to understand how mercury concentration varies among fish species.

The largest anthropogenic source of environmental mercury is coal-burning power plants (Jackson, 1997). Power plants release inorganic mercury into the

atmosphere where it resides until it is deposited onto the earth's surface (Jackson, 1997). Inorganic mercury is converted to a highly toxic form, methylmercury, by bacteria in aquatic systems (Morel *et al*., 1998). Methylmercury bioaccumulates in aquatic organisms (Bowles *et al*., 2001) and most of the mercury in fish is methylmercury (Bloom, 1992).

Fish consumption advisories are the primary method of informing the public about the risk of consuming fish with high concentrations of mercury. The United States Environmental Protection Agency (USEPA) makes recommendations about monitoring programs for contaminants in fish. However, fish consumption advisories are generally issued by state public health agencies and these agencies differ in the manner in which they monitor for contaminants (USEPA, 2000), in part because of budgetary limitations or political reasons. The Texas Department of State Health Services (DSHS) is responsible for issuing fish advisories in the State of Texas.

The objectives of this study were to examine how length of fish is related to mercury concentrations in seven species of fish from Lake Meredith, Texas and to determine how sex and growth rate are related to mercury concentration in walleye (*Sander vitreus*). We also assessed the differences in fish consumption advisories that would be issued using DSHS guidelines versus USEPA recommendations.

2. Methods

2.1. Site description

Lake Meredith was formed in 1965 by the construction of Sanford Dam on the Canadian River. The reservoir is located within Hutchinson, Moore, and Potter counties 56 km northeast of Amarillo, Texas. The maximum surface area of Lake Meredith is 6,475 ha with average and maximum depths of 9.1 m and 38.7 m, respectively (Munger, 2003). Lake Meredith is located near Harrington Station, a coal-burning power plant and it is the only reservoir in the Texas Panhandle with a fish consumption advisory for mercury. A fish consumption advisory was issued for walleye by DSHS in 2002 (DSHS, 2005).

2.2. Fish collection

We collected fish with assistance from biologists of the Texas Parks and Wildlife Department (TPWD) in April 2004 using vertical gill nets 38 m long by 2.4 m deep. Gill nets were constructed of monofilament webbing and consisted of 5 panels, 7.6 m in length with bar measures ranging from 25–76 mm. On April 19 and 20, five nets were set in the late afternoon and retrieved the following morning. Fish were placed on ice and transported to a lab where they were weighed and total length (TL) measured. Otoliths were dissected from walleye and sex

was determined by visual inspection of gonads. All fish were frozen until further processing.

2.3. Mercury analysis

Frozen fillets were removed from the freezer, partially thawed and a 100 to 250 Mg piece of skinless tissue was removed from the center of the fillet using a scalpel and forceps that had been rinsed with 50% HNO_3 solution and deionized water. Total mercury analysis was performed with a direct mercury analyzer (DMA-80, Milestone Inc. Monroe, CT USA) that uses thermal decomposition, gold amalgamation and atomic absorption spectrometry (USEPA, 1998). A calibration curve was generated using two reference materials from the National Research Council of Canada Institute for National Measurement Standards: MESS-3 (marine sediment, certified value = 91 ± 9 Ng/g total mercury [dry weight]) and DORM-2 (dogfish muscle, certified value = 4,640 ± 260 Ng/g total mercury [dry weight]). Quality assurance included reference and duplicate samples. Reference samples (MESS-3 or DORM-2) were analyzed every 10 samples and the mean percent recovery was 99% (range = 92–107%; $n = 29$). Duplicate samples were analyzed every 20 samples and the mean relative percent difference was 3.58% (range = 0.09–7.87%; $n = 14$).

Tissue mercury concentrations were determined for 267 fish including 28 flathead catfish (*Pylodictis olivaris*), 95 walleye, 35 white bass (*Morone chrysops*), 20 channel catfish (*Ictalurus punctatus*), 23 common carp (*Cyprinus carpio*), 18 river carpsuckers (*Carpiodes carpio*) and 48 gizzard shad (*Dorosoma cepedianum*). Total mercury was used as a proxy for methylmercury because 95–99% of total mercury in fish tissue is methylmercury (Bloom, 1992).

2.4. Age determination

Walleye exhibit sexual dimorphism in growth rate and mercury concentration (Henderson *et al*., 2003). To determine walleye growth rate, we used otoliths that were broken along a perpendicular plane through the nucleus and polished using sandpaper (Maceina, 1988; D. Buckmeier, TPWD, personal communication). Annuli were counted under a dissecting microscope with a fiber-optic light source. Two readers independently estimated the ages of fish without knowledge of fish length and disagreements were resolved by reexamining otoliths and mutually determining age (Buckmeier *et al*., 2002). To account for growth that occurred prior to the formation of annuli, one year was added to the number of visible annuli.

2.5. Data analysis

Mercury concentration was regressed against TL with SYSTAT (Wilkinson, 2002). A general linear model was used to test for differences in slopes of mercury

concentrations versus TL and TL versus age of male and female walleye. Statistical significance was determined at $p \leq 0.05$.

2.6. Computation of fish consumption advisories

We determined if a fish consumption advisory would be issued for game fish collected in this study (flathead catfish, walleye, white bass and channel catfish) using both DSHS and USEPA methodologies. DSHS assigns advisories based on the analysis of muscle tissue of at least three individual fish per species (AFS, 1999), but apparently fish size class is not taken into account when determining if an advisory should be issued. DSHS issues an advisory if the mean mercury concentration of the fish sampled exceeds an advisory level of 700 Ng/g wet weight (ww).

USEPA (2000) recommends that state agencies issue fish consumption advisories based on the analysis of multiple size classes of fish, and that within each size class, the smallest individual fish should be no greater than 75% of the TL of the largest individual. To form size classes for each fish species, we identified the largest individual collected and then combined it with all individuals within 75% of its TL. After the "large" size class was identified, we repeated the procedure with all remaining individuals. Using this approach, we divided flathead catfish and walleye into three size classes and channel catfish into two size classes. White bass were not divided into multiple size classes.

USEPA suggests that fish consumption advisories be issued when the mean mercury concentration of a size class of fish is significantly greater than the screening value (SV) of 300 Ng/g ww (USEPA, 2001). USEPA recommends using a test statistic (t-value) to determine if the mean mercury concentration is greater than the USEPA recommended screening value (USEPA, 2000). When mercury concentration is determined for a sample of individual fish (as opposed to composite samples), a t-value is calculated as:

$$(\text{mean} - \text{SV})/\text{standard deviation}$$

which has a t-distribution with $n - 1$ degrees of freedom. If the calculated t-value exceeds the critical t-value (one-tailed test), a fish consumption advisory would be issued. USEPA recommends that >10 individual fish be analyzed if the calculated t-value is >0.85. Due to the small sample size and high t-values for some size classes of fish in our study, we set $\alpha = 0.10$ to reduce the probability of making a type II error (accepting a false null hypothesis).

For our analyses, we only considered individual fish of a harvestable size. We defined individuals of a harvestable size as those having a TL greater than the minimum legal length limit (flathead catfish [45.7 cm], white bass [25.4 cm], channel catfish [30.5 cm]) or walleye having a TL of 25 cm or greater.

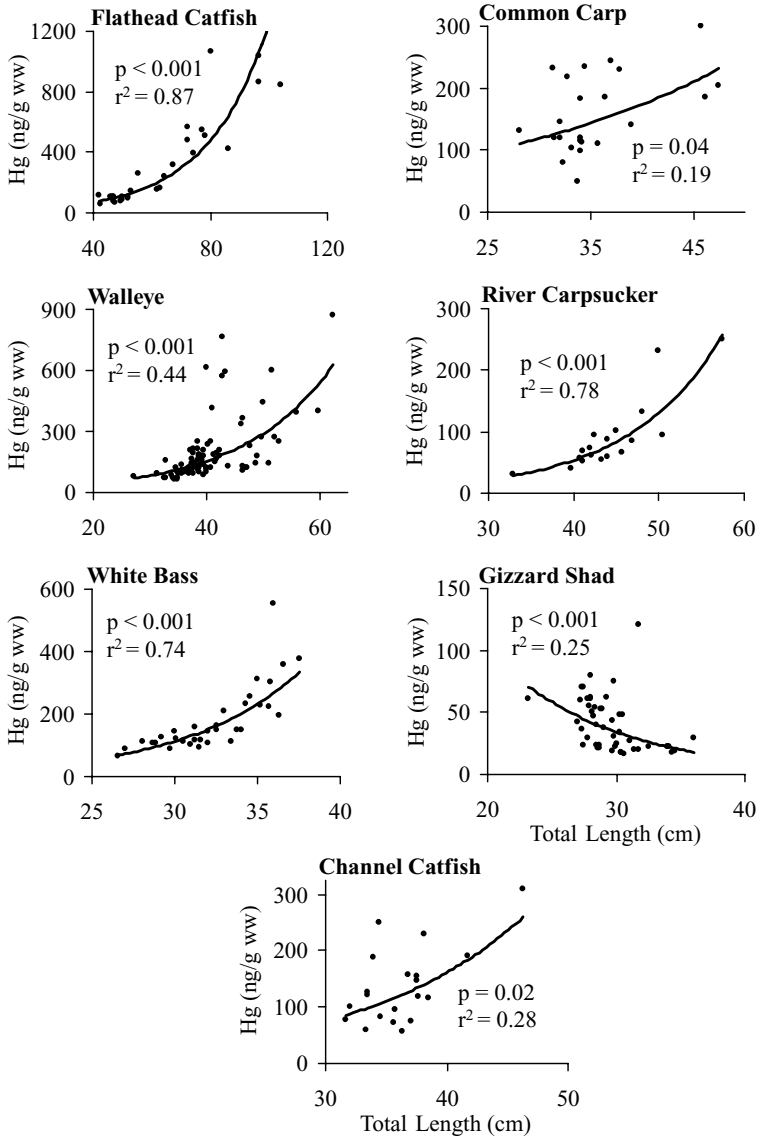

Figure 1. Mercury (Hg) concentration – total length relationships for fish species in Lake Meredith.

3. Results and Discussion

3.1. Species-specific differences in mercury concentration

Fish species in Lake Meredith differed in mercury concentration (Figure 1). Game fish such as flathead catfish, walleye, white bass and channel catfish had the highest

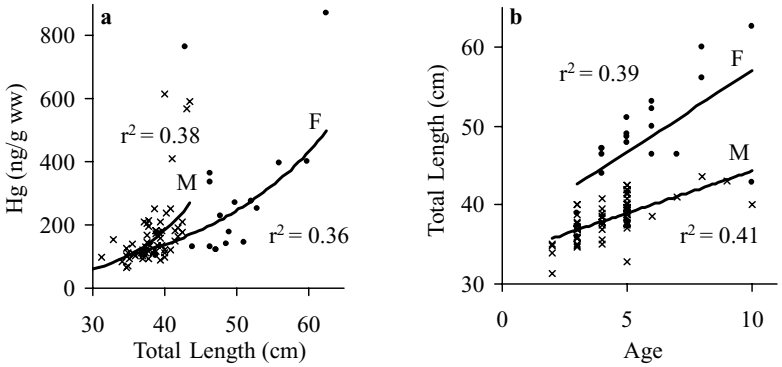

Figure 2. (a). Mercury (Hg) concentration–total length (TL) relationships for male (M) and female (F) walleye. 2(b). TL–age relationships for male and female walleye.

mercury concentrations, with maximum concentrations of 1065, 870, 554 and 309 Ng/g ww, respectively. Non-game fish such as common carp, river carpsucker and gizzard shad had the lowest mercury concentrations, with maximum concentrations of 300, 251 and 120 Ng/g ww, respectively.

The relationships between mercury concentration and TL were best fit by exponential curves and were positive and significant for all species ($p < 0.05$) except gizzard shad, which was negative and significant ($p < 0.001$) (Figure 1). Total length explained from 19 to 87% of the variation in mercury concentration (Figure 1). Correlations were strongest for flathead catfish, white bass and river carpsucker; and weakest for common carp, channel catfish and gizzard shad.

Previous studies have found positive relationships between mercury concentration and fish length, which can be due to an increase in trophic position that occurs as fish increase in size (Bowles *et al*., 2001; Power *et al*., 2002) and because methyl mercury is very slowly eliminated once incorporated into fish flesh (Wiener and Spry, 1996). Like gizzard shad in this study, Branquinha (*Potamorhina latior*), a detritivore from Rio Negro, Brazil, exhibited a decline in mercury concentration with size (Barbosa *et al*., 2003). Gizzard shad diet may change from a higher trophic position to a lower trophic position as they age (Schaus *et al*., 2002). Juvenile gizzard shad feed primarily on zooplankton whereas adult gizzard shad feed more on detritus and algae (Mummert and Drenner, 1986). An alternative hypothesis is that the decline in mercury concentration with gizzard shad length could reflect higher mercury in the muscle of emaciated fish (Cizdziel *et al*., 2002).

3.2. Sexual dimorphism and mercury concentration in walleye

We were able to identify sex in 79 of 95 walleye (20 females and 59 males). We detected a significant difference in the slopes of the mercury-TL relationships for male and female walleye ($p = 0.03$) (Figure 2a) with male walleye having a steeper

slope ($b = 0.11$) than female walleye ($b = 0.06$). Male walleye grew at a slower rate than female walleye ($p = 0.03$) (Figure 2b) and the largest individual we collected was 43.5 cm (TL) compared to a maximum of 62.5 cm (TL) for females. Henderson *et al*. (2003) found sexually dimorphic growth in walleye with males growing slower than females. As we found in Lake Meredith, fish with slower growth rates tend to exhibit size-mercury concentration relationships with steeper slopes than fish with higher growth rates (Doyon *et al*., 1998; Henderson *et al*., 2003).

3.3. Issuance of fish consumption advisories

Using DSHS methodologies or USEPA recommendations would result in differences in fish consumption advisories for Lake Meredith. The mean mercury concentrations of each of the four game fish species we collected were below the DSHS advisory level of 700 Ng/g ww (Figure 3a). Therefore, our data suggest that a fish advisory would not be necessary according to DSHS guidelines. This raises the question of why an advisory currently exists for walleye in Lake Meredith. Only two of the oldest walleye or 2% of all walleye we sampled exceeded the DSHS advisory limit of 700 Ng/g ww. We hypothesize that a small sample size used by DSHS in fish contaminant monitoring programs led to an overly conservative issuance of a fish consumption advisory for walleye. The current walleye consumption advisory warns consumers to limit consumption of all sizes of walleye. This would appear inappropriate considering that 73% of all harvested walleye observed during TPWD creel surveys were below 40.6 cm (Munger, 2003) and that none of the individuals $\leq$40.6 cm that we collected had mercury concentrations higher than the DSHS advisory level.

Following USEPA recommendations would have resulted in the application of a fish consumption advisory for the largest size class of flathead catfish (Figure 3b). Only the largest size class of flathead catfish had a mean mercury concentration significantly greater than 300 ng/g ww ($t = 1.84$, $p = 0.063$). Smaller size classes of flathead catfish and all sizes classes of walleye, white bass and channel catfish had mean mercury concentrations that were not significantly greater than 300 ng/g ww and therefore would not have had an advisory issued according to USEPA recommendations. These results illustrate the discrepancy between state policies and USEPA recommendations for setting fish consumption advisories.

4. Conclusions

USEPA recommends that state agencies examine one predator species (e.g. flathead catfish, walleye, white bass) and one bottom-feeding species (e.g. channel catfish, common carp) in contaminant monitoring studies (USEPA, 2000). Our results indicate that the concentration of mercury is extremely variable even between species within USEPA's functional group designations. If white bass were examined as the

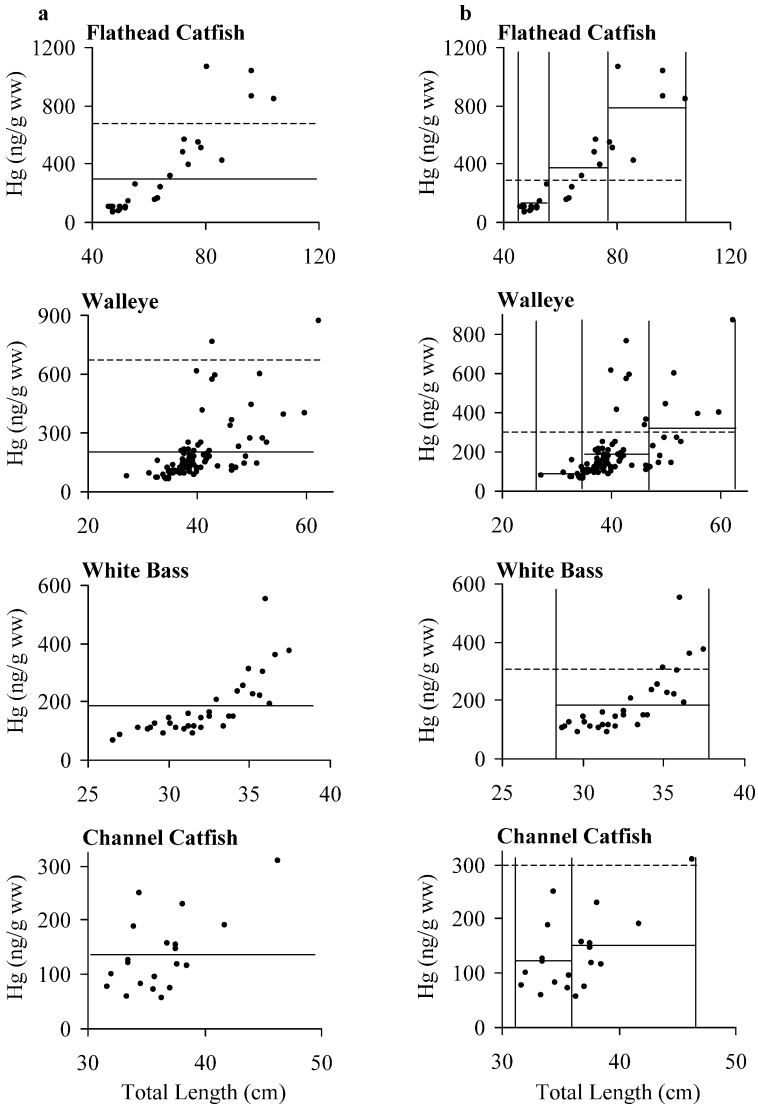

Figure 3. Mercury (Hg) – total length relationships for Lake Meredith game fish species (data from Figure 1). (a). The solid horizontal line represents mean mercury concentration and the dashed line represents the DSHS advisory level of 700 Ng/g ww. (b). Following USEPA recommendations fish were divided into size classes. Solid horizontal lines represent the mean mercury concentration for each size class and the dashed line represents the USEPA screening value of 300 Ng/g ww.

representative predator species, the risk posed to public health by large flathead catfish would be overlooked. We recommend that state agencies examine all game fish species and especially the largest piscivorous species to avoid underestimating risk to public health.

The procedures used by many states to assess the need for fish consumption advisories are different than those recommended by USEPA (AFS, 1999). Many states base advisory decisions on small sample sizes (AFS, 1999) but budgetary limitations may limit the ability of states to perform analyses on adequate sample sizes of fish. DSHS examines a minimum of three fish in contaminant monitoring programs. Mercury concentration is highly variable in some species like the walleye examined in this study. A small sample size is not adequate to characterize the risk posed to public health and could lead to an under- or overestimate of risk. We suggest that state agencies follow USEPA recommendations for determining appropriate samples sizes to minimize this possibility.

In addition to a small sample size, many states do not examine multiple size classes of fish in contaminant monitoring programs (AFS, 1999). However, combining large heavily-contaminated individuals with small less-contaminated individuals results in a lower mean mercury concentration than would be found if size classes are examined as recommended by USEPA. Using our data set from Lake Meredith and following USEPA recommendations, we found that an advisory should be issued for the largest size class of flathead catfish but not flathead catfish smaller than 78 cm (TL). However, if we combine all sizes of flathead catfish and compute the mean mercury concentration, we find that an advisory would not be issued for flathead catfish ($t = -0.99$, $p = 0.17$). Therefore, failure to consider multiple size classes of fish may increase health risks because the public would not be warned about the mercury contamination of the largest and most hazardous fish.

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