MERCURY CONCENTRATIONS IN LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*), WHITE BASS (*MORONE CHRYSOPS*), AND WHITE CRAPPIE (*POMOXIS ANNULARIS*) FROM SIX DALLAS-FORT WORTH AREA RESERVOIRS

by

JACOB MICHAEL WADLINGTON

Bachelor of Science, 2009

Lipscomb University

Nashville, Tennessee

Submitted to the Graduate Faculty of the

College of Science and Engineering

Texas Christian University

in partial fulfillment of the requirements

for the degree of

Masters of Science

May 2011

ACKNOWLEDGEMENTS

Dr. Matthew Chumchal has been an extremely helpful thesis advisor and friend throughout my research and I thank him earnestly for his involvement in my education and life. I would also like to thank my thesis committee members Dr. Ray Drenner and Dr. Amanda Hale. Dr. Drenner has given me his time, use of his laboratory, and great advice for my research and career. Dr. Hale's help in statistics has allowed me to succeed in and out of the classroom with my research and her help has strengthened my education considerably.

I would also like to thank my fellow TCU biology graduate students who assisted me in my studies and were great friends. Michelle Fernando was instrumental in processing fish in the laboratory. I would also like to thank the TPWD fishery biologists Rafe Brock and Tom Hungerford for their help in collecting fish and for their hospitality. The TCU Biology department provided supported through a teaching assistantship during this study. The TCU Biology Department, TCU Adkin and RCAF grants funded this research.

Lastly, I would like to thank my family for their support, visits, and encouragement as I attended graduate school. My wife, Sara, has given me tremendous support and has made me happy. I appreciate her dedication and love for me as I spent these past two years at TCU. Also, I would like to thank God because He has continued to bless me more than I deserve.

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Introduction

Mercury (Hg) is a neurotoxin that accumulates in food webs. Hg levels have increased in the environment because of anthropogenic activities, including the burning of coal for electricity generation, metal production, and waste incineration (Driscoll et al. 2007). These anthropogenic activities emit several forms of inorganic Hg to the atmosphere that are transported variable distances before being deposited onto the earth's surface (Driscoll et al. 2007). In aquatic ecosystems, inorganic Hg is converted to methylmercury (MeHg). Methylmercury biomagnifies in aquatic food chains and fish have MeHg concentrations approximately 1 to 10 million times greater than dissolved MeHg concentrations found in surrounding waters (US EPA 2001). Humans are exposed to Hg, when they consume Hg-contaminated fish (NRC 2001). When fish are contaminated with Hg, the economic, nutritional, and cultural values of fishery resources are diminished (Wiener et al. 2003).

The growing awareness of environmental Hg contamination has led to increasing efforts to survey Hg concentrations of fish, producing information that has, in turn, prompted issuance of advisories concerning the consumption of fish (Wiener et al. 2003). In Texas, the Department of State Health Services (DSHS) issues species-specific fish consumption advisories for water bodies having fish with high concentrations of Hg in their tissues. The Department of State Health Services assigns advisories based on the analysis of muscle tissue; if the mean Hg concentration of fish muscle tissue exceeds the advisory level of 700 µg/kg wet weight (WW) (~3,500 µg/kg dry weight [DW]) a consumption advisory is issued (DSHS 2008). In most cases, DSHS advises that adults limit consumption of fish to two meals (not exceeding eight ounces of fish tissue each) per month. Women who are nursing, pregnant, or who may become pregnant and children under twelve years old are advised not to consume species of concern from the water body (DSHS 2008).

The Department of State Health Service does not monitor all fish species from a reservoir before making a decision to issue a fish consumption advisory. As a result the risk posed to consumers from eating some species of fish are assessed while others are not. For example, largemouth bass (*Micropterus salmoides*) were surveyed in 87% of the 46 monitored reservoirs in Texas (Appendix A). Other sport fish are monitored less frequently but may be more frequently consumed by Texas anglers than largemouth bass (R. Brock, TPWD, personal communication). For example, white crappie (*Pomoxis annularis*) and white bass (*Morone chrysops*) were sampled in 28% and 32%, respectively, of the 46 monitored reservoirs (Appendix A) but are the third and fifth most preferred fish species in Texas (TPWD 2010). If other sport fish are contaminated with Hg and are not monitored, anglers will not be warned about potential risk. The purpose of this study was to survey Hg concentrations in largemouth bass, white bass, and white crappie from six Dallas-Fort Worth area reservoirs. Hg concentrations in largemouth bass, a species that is frequently monitored, were compared to Hg concentrations in white bass and white crappie two species that are not frequently monitored, but are frequently consumed by Texas anglers.

Methods

Largemouth bass, white bass, and white crappie were collected from Benbrook Lake, Eagle Mountain Lake, Grapevine Lake, Lake Lewisville, Joe Pool Lake, and Lake Ray Hubbard. The average size of these reservoirs is 5,179 hectares (range 1,471-11,976 hectares) (Figure 1).

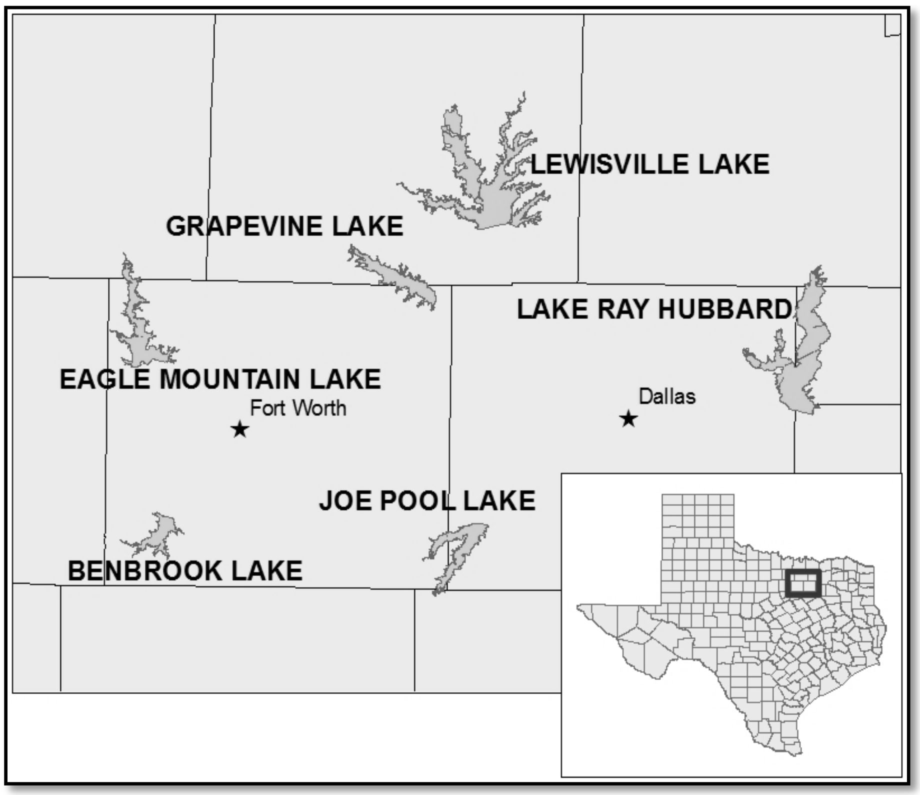

Figure 1. Six study reservoirs in the Dallas-Fort Worth area of North Texas.

Largemouth bass, white bass, and white crappie can generally be categorized as piscivores as adults but each species has a unique diet. Adult largemouth bass adults feed heavily on fishes including threadfin shad, gizzard shad, various minnows, sunfishes, and darters, while continuing to consume aquatic insects. Adult white bass feed mainly on fishes, yet aquatic insects are important in diet during the spring. Adult white crappie adults eat insects and forage fish (Thomas 2007). Of the three species, largemouth bass have the fastest growth rate and reach the largest total length (TL) while white crappie have the slowest growth rates and shortest average TLs (Thomas 2007).

Fish were collected between 2009 and 2010 with fishery biologists from TPWD using a boat-mounted electroshocking unit, and trap nets, and with fishing guides using rod and reel, resulting in a total of 159 largemouth bass, 86 white bass, and 80 white crappie. After collection, fish were placed on ice and transported to a lab where TL (cm) and weight (g) were determined. Samples were dried in an oven at 60^{o}C for at least 48 hours prior to analysis.

Total Hg concentrations (µg/kg dry weight [DW]) in fillet muscle tissues were analyzed using a direct Hg analyzer (DMA-80; Milestone) that uses combustion atomic absorption spectrometry (US EPA 1998). Total Hg was analyzed as a proxy for MeHg because MeHg is the primary form of Hg found in fish (Bloom 1992). For Hg analyses, a calibration curve using three reference materials from the National Research Council of Canada Institute for National Measurement Standards: DOLT-3, DORM-2, and MESS-3 were generated. Reference samples of DOLT-3 and MESS-3 were analyzed approximately every 10 samples and the average percent recovery was 100% (range = 90.4-110%; n=46). Duplicate samples were analyzed approximately every 20 samples and the average relative percent difference was 5.99% (range 2-17%; n=18).

A series of analysis of covariance (ANCOVA) (SPSS Inc., version 11.5.0,) models were used to explore the effect of species, TL, and reservoir on Hg concentrations in fish. For each species, Hg concentration was significantly different between reservoirs (ANCOVA: $df = 5, 309$; $f = 20.5$ $p < 0.001$) therefore, fish were analyzed from each reservoir separately in subsequent analyses. Differences in Hg concentrations observed between reservoirs in this study are consistent with the results of previous surveys of Hg in Texas reservoirs (Drenner et al. in review), but a more in-depth discussion of this issue is beyond the scope of this paper. Within reservoirs a significant interaction between species and TL was observed (ANCOVA: $p < 0.001$). Therefore, main effects of fish species and the covariate were tested for with the interaction term included in the model. The Wilcox procedure (Quinn and Keough, 2002) was performed to determine the range of the covariate (TL) for which a significant effect of fish species exists (WILCOX, version 3.2, Constable, 1989).

Results and Discussion

Largemouth bass were collected from all six reservoirs, where as white bass and white crappie were collected from four and five reservoirs, respectively (Table 1). Within each species, Hg concentration was significantly and positively correlated with total length (ANCOVA $p<0.001$ in all cases), a finding that is consistent with other studies (e.g., Weiner et al., 2003, Chumchal and Hambright, 2009). Three individuals were above the DSHS advisory limit; two white bass and one white crappie from Grapevine Lake but most fish and the average Hg concentrations for each species from each reservoir were below DSHS advisory levels.

Table 1. Descriptive statistics for species examined in each reservoir, including average total length, range of total length, and average Hg concentration

	Largemouth bass			White bass			White crappie		
Reservoir	N	TL avg (range)	Avg Hg conc (± SE)	N	TL avg (range)	Avg Hg conc (± SE)	N	TL avg (range)	Avg Hg conc (± SE)
Benbrook	10	32.9 (27.3-43.1)	526.8 (93)	0	---	---	18	28.9 (23.7-32.7)	276.5 (35)
Eagle Mountain	32	29.4 (24.4-48.0)	123.9 (30)	36	31.6 (14-41)	830.0 (108)	0	---	---
Grapevine	43	30.6 (11.6-42.9)	1051.6 (56)	14	29.9 (25.2-36.1)	1413.5 (336)	8	29.6 (25-34.8)	1259.4 (512)
Joe Pool	17	31.3 (25.3-43.0)	956.6 (144)	21	25.4 (19.8-28.1)	467.6 (23)	20	22.5 (17.3-26)	216.7 (19)
Lewisville	29	29.1 (16.8-50.0)	975.8 (52)	15	31 (26.6-38)	1008.2 (211)	22	27.5 (24.7-32.6)	359.3 (36)
Ray Hubbard	28	29.8 (11.8-42.7)	392.8 (40)	0	---	---	12	26.6 (23.4-34.5)	105.8 (17)

Between species differences in Hg concentrations within reservoirs were observed. In three of four reservoirs in which both white bass and largemouth bass were collected there was a range of sizes in which white bass Hg concentrations were not significantly different than largemouth bass Hg concentrations (Figure 2). All size classes of white bass had significantly higher Hg concentrations than largemouth bass in one reservoir. In three of five reservoirs that white crappie and largemouth bass were both collected, there was a range of sizes in which white crappie Hg concentrations were not significantly different than largemouth bass Hg concentrations (Figure 2). In two of five reservoirs all size classes of white crappie were significantly lower than largemouth bass Hg concentrations.

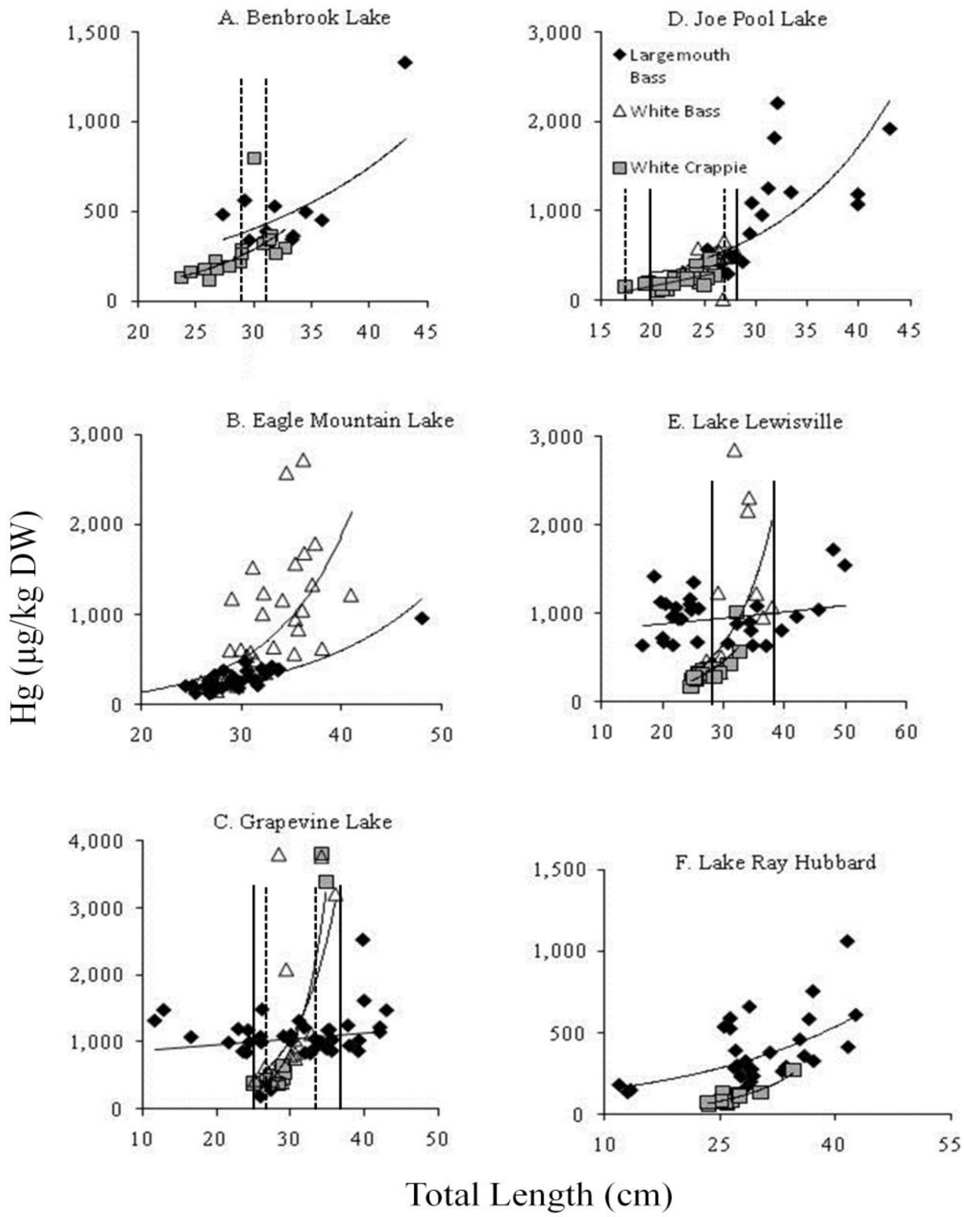

Figure 2. Relationship between TL and total Hg in largemouth bass, white bass, and white crappie in (A) Benbrook, (B) Eagle Mountain Lake, (C) Grapevine Lake, (D) Joe Pool Lake, (E) Lake Lewisville, and (F) Lake Ray Hubbard. Areas between dashed lines are the range of total length in which white crappie and largemouth bass Hg concentrations

were not significantly different. Areas between solid lines were the range of total length in which white bass and largemouth bass Hg concentrations are not significantly different. If no lines are present then Hg concentrations were significantly different between species.

In this study some size classes of largemouth bass, white bass, and white crappie had similar Hg concentrations (Figure 2); this is likely because all three species are piscivorous to varying degrees (Green and Murphy 1971 and Thomas 2007). However, in some cases white bass Hg concentrations were higher than largemouth bass Hg concentrations where as white crappie was sometimes lower. Although all three species can be broadly classified as piscivorous their diets still differ (Thomas 2007) and they have different growth rates (Thomas 2007), two factors known to strongly influence Hg concentrations (Chumchal and Hambright 2009).

Consumption advisories are issued to warn anglers that fish may be harmful if consumed. For fish consumption advisories to effectively assess risk, it is essential to characterize Hg concentrations in fish species consumed by humans (Lepak et al. 2009). White bass and white crappie are often consumed but are more difficult to monitor than largemouth bass because methods of capture are more labor intensive (i.e. hook and line, trap netting). These data suggest that Hg concentrations in largemouth bass may be representative of Hg concentrations in white bass and white crappie of equivalent size and that largemouth bass may be an appropriate indicator species for Hg monitoring programs. When DSHS is not able to assess risk in all species of game fish it may be appropriate to issue advisories for all species if largemouth bass are found to contain Hg concentrations above advisory levels.

REFERENCES

Bloom, N. S. 1992, On the chemical form of mercury in edible fish and marine invertebrate tissue, *Can. J. Fish. Aquat. Sci.* 49, 1010–1017.

Chumchal, M. M. & Hambright, K. D. 2009. Ecological factors regulating mercury contamination of fish from Caddo Lake, Texas, USA. *Environmental Toxicology and Chemistry,* 28**,** 962-972.

Davis JA, Greenfield BK, Ichikawa G, Stephenson M. 2008. Mercury in sport fish from the Sacramento–San Joaquin Delta region, California, USA. *Sci Total Environ* 391:66–75.

Drenner, R.W. M.M. Chumchal, S.P. Wente, M. McGuire*, and S.M. Drenner**. Landscape-level patterns of mercury contamination of fish in North Texas. *In review at Environmental Toxicology and Chemistry.*

Driscoll, C. T., Han, Y. J., Chen, C. Y., Evers, D. C., Lambert, K. F., Holsen, T. M., Kamman, N. C. & Munson, R. K. 2007. Mercury contamination in forest and freshwater ecosystems in the Northeastern United States. *Bioscience,* 57**,** 17-28.

Greene, D.S. and C.E. Murphy. 1971. Food and feeding habits of the white crappie (*Pomoxis annularis* Rafinesque) in Benbrook Lake, Tarrant County, Texas. J. Tex. Acad. Sci. 25(1):35-51.

Lepak, J.M., Shayler, H. A., Kraft, C. E. & Knuth, B. A. 2009. Mercury Contamination in Sport Fish in the Northeastern United States: Considerations for Future Data Collection. *Bioscience,* 59**,** 174-181.

NRC (National Resource Council). 2001, *Toxicological Effects of Methylmercury*. National Academy Press, Washington D.C.

Texas Department of State Health Services. 2008. Characterization of potential health risks associated with consumption of fish from Lake Madisonville. Austin, TX, USA.

Texas Department of State Health Services (DSHS): 2004, Listing of water bodies with advisories or bans and areas where no advisory was issued. *TDH Bureau of Food and Drug Safety: SeafoodSafety Division Web site*, www.tdh.state.tx.us/bfds/ssd/fiscount.html.

Thomas C., Bonner T.H., &Whiteside B.G. 2007. Freshwater Fishes of Texas. Texas A&M Press. http://www.bio.txstate.edu/~tbonner/txfishes/index.htm.

US EPA (U.S. Environmental Protection Agency). 2001. Mercury Update: Impact on Fish Advisories. USEPA, Washington, D.C. Available: http://www.epa.gov/waterscience/fish/advice/mercupd.pdf .

US EPA (U.S. Environmental Protection Agency). 1998. Method 7473: Mercury in solids and solutions by thermal decomposition, amalgamation, and atomic absorption spectrophotometry. Washington, DC. Available: http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/7473.pdf

Wiener J.G., Krabbenhoft D.P., Heinz G.H., & Scheuhammer A.M. 2003. Ecotoxicology of mercury. In Hoffman DJ, Rattner BA, Burton GA Jr, Cairns J Jr, eds, *Handbook of Ecotoxicology*, 2nd ed. Lewis, Boca Raton, FL, USA, pp 409–463.

APPENDIX

Appendix A. Texas reservoirs surveyed by DSHS including species surveyed and advisory status

Reservoir	Species surveyed	Species issued an advisory
Alan Henry Reservoir	blue catfish, flathead catfish, crappie, largemouth bass and spotted bass	blue catfish, flathead catfish, crappie, largemouth bass and spotted bass
B.A. Steinhagen Reservoir	blue catfish, channel catfish, freshwater drum, largemouth bass, spotted bass, smallmouth buffalo, and white bass	freshwater drum, hybrid striped bass, largemouth bass, and white bass
Big Cypress Creek and Caddo Lake	black crappie, bowfin, chain pickerel, channel catfish, common carp, flathead catfish, freshwater drum, largemouth bass, and white bass	freshwater drum and largemouth bass
Bouton Lake	blue catfish, bowfin, largemouth bass, and spotted gar	none
Boykin Springs	largemouth bass and white crappie	none
Brakes Bayou	blue catfish, common carp, flathead catfish, smallmouth buffalo, and southern flounder	none
Brandy Branch Reservoir	black crappie and largemouth bass	none
Canyon Lake	blue catfish, flathead catfish, largemouth bass, longnose gar, striped bass, and white bass	longnose gar and striped bass
Cement Creek Lake	black bullhead and largemouth bass	none
Clear Creek	blue catfish, blue crab, channel catfish, common carp, smallmouth buffalo, southern flounder, and white crappie	none
Clear Lake	alligator gar, blue catfish, channel catfish, common carp, flathead catfish, largemouth bass, longnose gar, and smallmouth buffalo	bowfin, freshwater drum, and largemouth bass
Como Lake	channel catfish, common carp, and largemouth bass	none
Daingerfield Lake	catfish and largemouth bass	largemouth bass
Delta Lake	channel catfish, freshwater drum, and tilapia aurea	none
Forest Park Lake	largemouth bass	none
French lake	largemouth bass and warmouth	none
Hills Lake	bowfin, flathead catfish, freshwater drum, largemouth bass, and smallmouth buffalo	freshwater drum and largemouth bass
Joe Pool Lake	common carp, largemouth bass, and yellow	none

	bullhead	
Lake Conroe	channel catfish, flathead catfish, freshwater drum, largemouth bass and white crappie	none
Lake Houston	black crappie, blue catfish, channel catfish, freshwater drum, largemouth bass, white bass, and white crappie	none
Lake Isabell	black crappie, largemouth bass, and spotted gar	largemouth bass
Lake Kimball	channel catfish, flathead catfish, largemouth bass, and spotted gar	all species
Lake Livingston	blue catfish, channel catfish, flathead catfish, largemouth bass, white bass, and white crappie	none
Lake Madison	channel catfish, largemouth bass and white crappie	none
Lake Madisonville	Largemouth bass	largemouth bass
Lake Meredith	black crappie, blue catfish, channel catfish, flathead catfish, largemouth bass, walleye, white bass, warmouth, and white crappie	walleye
Lake Nacogdoches	channel catfish and largemouth bass	none
Lake O' the Pines	channel catfish, common carp, largemouth bass, and redear sunfish	none
Lake Palestine	blue catfish, hybrid striped bass, freshwater drum, largemouth bass , white bass, and white crappie	none
Lake Raven	channel catfish and largemouth bass	none
Lake Tawakoni	black crappie, blue catfish, channel catfish, freshwater drum, striped bass, and white bass	none
Lake Timpson	channel catfish, largemouth bass, and white crappie	none
Lake Wright Patman	channel catfish, flathead catfish, freshwater drum, largemouth bass, white bass	none
Martin Creek Reservoir	black crappie, blue tilapia, channel catfish, common carp, flathead catfish, largemouth bass and white crappie	none
Moss Lake	channel catfish, freshwater drum, largemouth bass, spotted bass, spotted gar, white bass, and white crappie	none
O.H. Ivie Reservoir	black crappie, channel catfish, common carp, freshwater drum, and largemouth bass	none
Pruitt Lake	bigmouth buffalo, black crappie, bowfin, common carp, flathead catfish, largemouth bass, longnose gar, and spotted gar	all species
Ratcliff Lake	blue catfish, channel catfish, largemouth, and river carpsucker	largemouth bass
Red Bluff Reservoir	channel catfish, common carp, hybrid striped bass, and smallmouth buffalo	none

Sam Rayburn Reservoir	blue catfish, channel catfish, crappie, flathead catfish, freshwater drum, hybrid striped bass, and largemouth bass	freshwater drum and largemouth bass
Taylor Bayou	black crappie, bowfin, largemouth bass, smallmouth buffalo, spotted gar, and white bass	none
Toledo Bend Reservoir	channel catfish, flathead catfish, freshwater drum, hybrid striped bass, largemouth bass, white bass, and white crappie	freshwater drum and largemouth bass
Town Lake	common carp, gizzard shad, largemouth bass, longear sunfish, redear sunfish, redbreast sunfish, rio grande cichlid, shad, striped bass, and warmouth	none
Twin Lake	blue catfish, green sunfish, and largemouth bass	none
Waco lake	blue catfish, channel catfish, flathead catfish, largemouth bass, white bass, and white crappie	none
Welsh Reservoir	black crappie, channel catfish, common carp, flathead catfish, largemouth bass, and spotted gar	none

Data from http://www.dshs.state.tx.us/seafood/survey.shtm and from DSHS databases (Kirk Wiles, personal communication)

VITA

Personal Background	Jacob Michael Wadlington Cadiz, Kentucky Son of Timothy Wade Wadlington and Frances Jeanette Wadlington Married Sara Elizabeth Green, June 20, 2009
Education	Diploma, Trigg County High School, Cadiz, Kentucky, May 2005 Bachelor of Science, Biology, Lipscomb University, Nashville, Tennessee, May 2009 Master of Science, Biology, Texas Christian University, Fort Worth, Texas, May 2011
Experience	2009-2011 Teaching Assistant Texas Christian University
Professional Memberships	Texas Chapter of American Fisheries Society Texas Academy of Science Sigma Xi Vanderbilt Chapter

ABSTRACT

SURVEY OF MERCURY CONCENTRATIONS IN LARGEMOUTH BASS (*MICROPTERUS SALMOIDES*), WHITE BASS (*MORONE CHRYSOPS*), AND WHITE CRAPPIE (*POMOXIS ANNULARIS*) FROM SIX DALLAS-FORT WORTH AREA RESERVOIRS

by Jacob Wadlington, M.S., 2011
Department of Biology
Texas Christian University

Thesis Advisor: Matt M. Chumchal, Assistant Professor of Biology

Largemouth bass (*Micropterus salmoides*) are routinely monitored for mercury (Hg) in Texas reservoirs. Other piscivorous game-fish that may have high concentrations of Hg, such as white bass (*Morone chrysops*) and white crappie (*Pomoxis annularis),* are monitored less frequently because they are difficult to capture. I examined Hg concentrations in largemouth bass, white bass, and white crappie from six Dallas-Fort Worth area reservoirs: Benbrook Lake, Eagle Mountain Lake, Grapevine Lake, Lake Lewisville, Joe Pool Lake, and Lake Ray Hubbard. Fish were collected using electroshocking, trap nets and hook and line. For all species Hg concentrations were positively correlated with total length. Hg concentrations of each species were significantly different between reservoirs, indicating that some reservoirs were more contaminated with Hg than others. In the majority of reservoirs Hg concentrations in largemouth bass did not differ from Hg concentrations in white bass and white crappie. These data suggest that Hg concentrations in largemouth bass may be representative of Hg concentration in other piscivorous game-fish and is an appropriate target species for monitoring studies.