

Fish Consumption Patterns and Mercury Advisory Knowledge Among Fishers in the Haw River Basin

Jill E. Johnston, Kate Hoffman, Steve Wing, Amy Lowman

BACKGROUND Fish consumption has numerous health benefits, with fish providing a source of protein as well as omega-3 fatty acids. However, some fish also contain contaminants that can impair human health. In North Carolina, the Department of Health and Human Services has issued fish consumption advisories due to methylmercury contamination in fish. Little is known about local fishers' consumption patterns and advisory adherence in North Carolina.

METHODS We surveyed a consecutive sample of 50 fishers (74.6% positive response rate) who reported eating fish caught from the Haw River Basin or Jordan Lake. They provided information on demographic characteristics, species caught, and the frequency of local fish consumption. Additionally, fishers provided information on their knowledge of fish consumption advisories and the impact of those advisories on their fishing and fish consumption patterns.

RESULTS The majority of participants were male ($n = 44$) and reported living in central North Carolina. Catfish, crappie, sunfish, and largemouth bass were consumed more frequently than other species of fish. Of the fishers surveyed, 8 reported eating more than 1 fish meal high in mercury per week, which exceeds the North Carolina advisory recommendation. Most participants ($n = 32$) had no knowledge of local fish advisories, and only 4 fishers reported that advisories impacted their fishing practices.

LIMITATIONS We sampled 50 fishers at 11 locations. There is no enumeration of the dynamic population of fishers and no way to assess the representativeness of this sample.

CONCLUSIONS Additional outreach is needed to make local fishers aware of fish consumption advisories and the potential health impacts of eating high-mercury fish, which may also contain other persistent and bioaccumulative toxins.

Fish provide numerous nutritional benefits, including protein and omega-3 fatty acids. Omega-3 (n-3) fatty acids in fish are associated with healthy neurological development and with reduced risk of heart disease, stroke, and preterm delivery [1-3]. Based on these health benefits, the American Heart Association recommends the consumption of 2 fish meals per week [4]. In some cultures, fishing and fish consumption are also important contributors to social, mental, and spiritual health. However, fish may contain environmental contaminants that can impair human health.

Although most fish contain a variety of environmental contaminants (eg, polychlorinated biphenyls or dioxins), methylmercury (MeHg) has been the most thoroughly investigated. Inorganic mercury is released to the environment in many ways, such as by combustion of fossil fuels, incineration of medical or municipal waste, and manufacturing processes. This atmospheric inorganic mercury is converted (primarily by microorganisms in the aquatic environment) to MeHg, an organic form of mercury, and MeHg is then biomagnified through aquatic food webs. Higher MeHg concentrations are often found in large and long-lived predator fish species [5], although mercury levels vary geographically. Fish in parts of North Carolina contain some of the highest documented levels of MeHg in the country [6].

People are primarily exposed to MeHg via dietary intake of fish and seafood. Both chronic exposure to MeHg, as well

as the consumption of a single meal of highly contaminated fish, can impair human health [7, 8]. In utero exposure to MeHg may cause neurological damage in fetuses [9], and MeHg exposure among adults has been associated with an increased incidence of acute coronary events, cardiovascular mortality, and neurological symptoms [10, 11]. Consequently, government agencies such as the US Environmental Protection Agency (EPA) and the North Carolina Department of Health and Human Services (DHHS) have issued fish consumption advisories that recommend limiting consumption of fish containing high levels of MeHg.

Fish consumption advisories are voluntary recommendations that seek to inform the public about chemical contaminants and to educate consumers about ways to minimize their exposures to contaminants. However, research suggests that many current efforts to communicate advisories to intended audiences are ineffective [12, 13]. When issuing a fish consumption advisory, DHHS alerts local health departments, issues a statewide press release, and posts the

Electronically published January 13, 2016.

Address correspondence to Dr. Jill E. Johnston, Division of Environmental Health, Keck School of Medicine of USC, 2001 N Soto St, SSB 225Q, Los Angeles, CA 90032 (jillj@usc.edu).

N C Med J. 2016;77(1):9-14. ©2016 by the North Carolina Institute of Medicine and The Duke Endowment. All rights reserved. 0029-2559/2016/77101

advisory on their website [14]. According to the state, recommendations for the number of safe fish meals are based on toxicity data from the Agency for Toxic Substances and Disease Registry, the EPA, and DHHS standard exposure parameters.

The current North Carolina fish consumption advisory recommends that children under 15 years of age, pregnant women, nursing women, and women of childbearing age (15–44 years) avoid fish that are known to be high in mercury and eat a maximum of 2 meals per week of fish that are low in mercury. All other people are advised to eat a maximum of 1 meal per week of fish high in mercury and up to 4 meals per week of fish that are low in mercury (see Table 1).

Limited information is available about the frequency of local fish consumption in North Carolina or about fishers' awareness of consumption advisories for fish from local waters. In the course of research into other persistent, bio-accumulative contaminants in central North Carolina, we conducted a survey of fishers to evaluate consumption of fish from the Haw River Basin and to assess awareness and impact of the mercury advisory.

Methods

We visited fishing locations along the Haw River in Alamance County and Chatham County to identify and survey local fishers. The Haw River is an approximately 110-mile

TABLE 1.
High- and Low-Mercury Freshwater Fish Species

High-mercury fish	Low-mercury fish
Bowfin*	Bluegill sunfish
Black crappie**	Tilapia
Catfish*	Trout
Jack fish*	
Largemouth bass	
Warmouth*	
Yellow perch*	

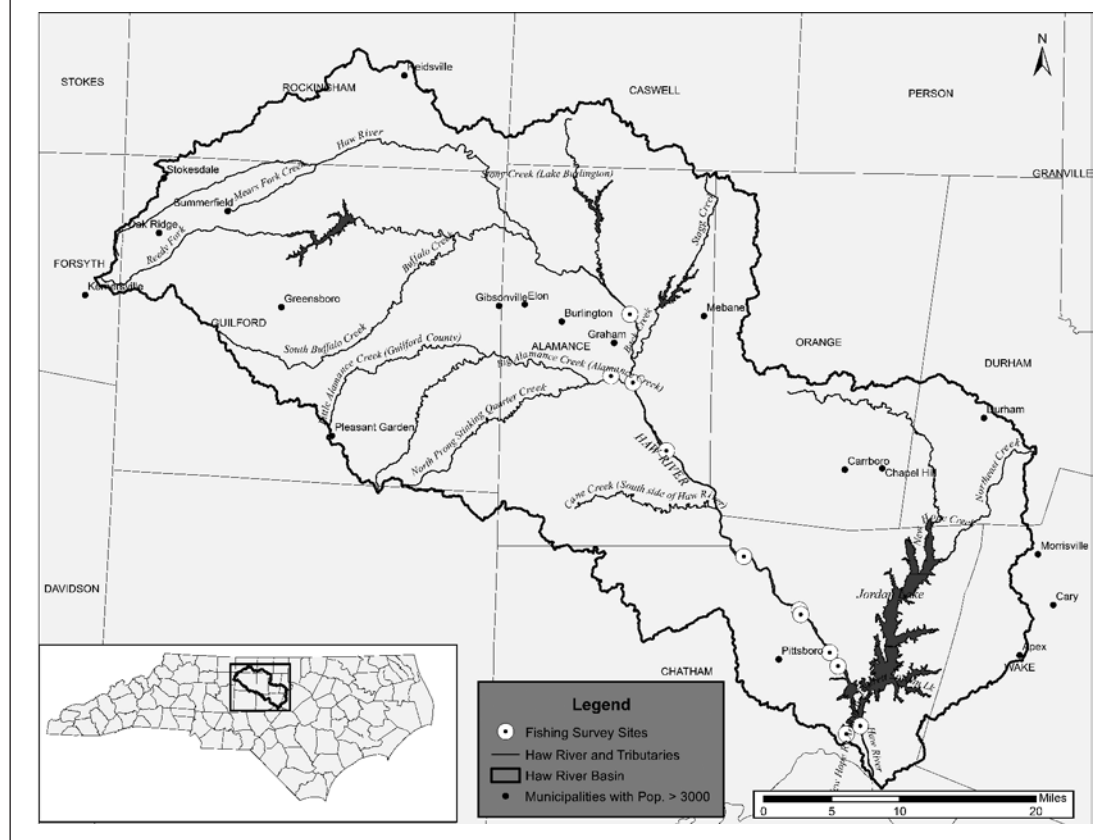
*High mercury levels have been found south and east of Interstate 85.

**High mercury levels have been found in black crappie caught south and east of Interstate 95.

Source: North Carolina Department of Health and Human Services [15].

long tributary of the Cape Fear River that begins in north-east Forsyth County and flows into Jordan Lake. We visited 11 survey locations on 35 days from August to November 2013 (see Figure 1). The survey sites were a convenience sample selected in consultation with the Haw River Assembly, a local nonprofit organization that has been working since 1982 to protect the Haw River, Jordan Lake, and the surrounding watershed communities. The survey sites included fishing sites recommended in the guide "Fishing Access for the Piedmont Region," which is published by the North

FIGURE 1.
Map of Haw River Watershed and Survey Locations



Carolina Wildlife Resources Commission.

Sampling occurred throughout daylight hours; on weekdays, weekends, and holidays; and during morning, afternoon, and evening times. All fishers were approached by research team members and invited to participate in the survey. Fishers were not eligible to participate if they had not eaten fish caught from the Haw River/Jordan Lake during the past year and were not planning on eating the day's catch, if they had already participated in the survey or lived with someone who had already participated, or if they were younger than 16 years of age. Interviews were conducted in Spanish and English.

The interview, designed with advice from the Haw River Assembly, consisted of questions concerning fisher demographic characteristics, catch, consumption patterns of Haw River and Lake Jordan fish over the past year by the interviewee and his or her family, and awareness of local fish advisories. Participants were asked about catching and consuming fish species present in the Haw River and Jordan Lake: bowfin, catfish, crappie, large mouth bass, pickerel (jack), shad, striped bass, sunfish (bream), and yellow perch. Participants were asked about each fish type and were shown pictures to assist in identification. Participants also had the opportunity to name other species that they had caught in the Haw River or Jordan Lake. This research was approved by the institutional review board of the University of North Carolina, and verbal consent was obtained from all study participants. Following the survey, we distributed the fish advisory factsheet entitled "What Fish are Safe to Eat," produced by the North Carolina Division of Public Health.

Results

Fifty recreational and subsistence fishers completed the survey. A total of 78 fishers were approached during the

study in a consecutive sample design; this was a convenience sample in which all accessible subjects were invited to participate. Eleven fishers were ineligible because either a household member had previously completed the survey ($n = 4$) or the fisher reported not eating any fish caught in the past year ($n = 7$). Seventeen fishers refused to participate in the survey, resulting in an overall positive response rate of 74.6%.

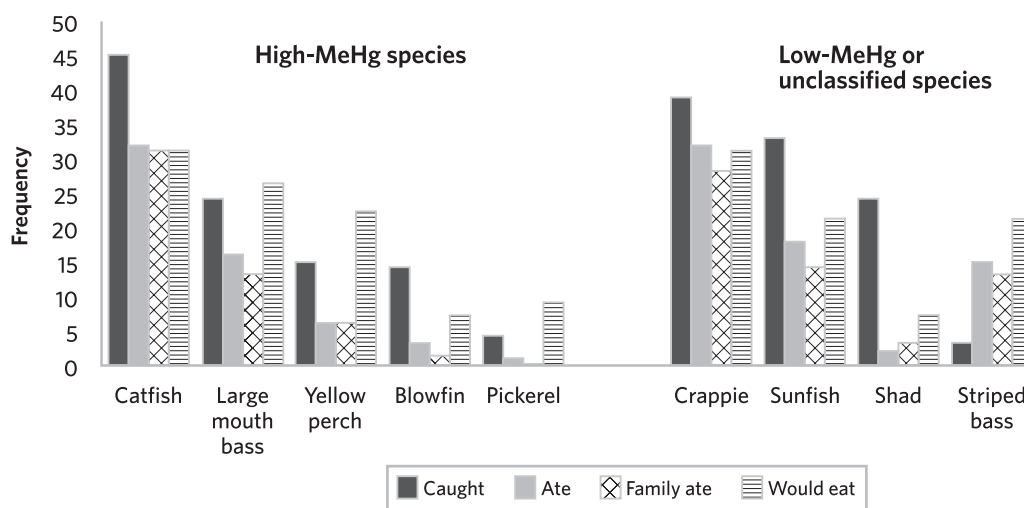
The majority of the participants were male ($n = 44$). Two were aged 16–17 years, 24 were aged 18–44 years, and 24 were 45 years of age or older (mean, 43 years; range, 16–73 years). Twenty of the participants identified as Hispanic/Latino, 17 as Caucasian/white, 7 as African American, and 6 as Asian. Thirty of the interviewees reported being employed. Half of the respondents ($n=25$) reported having earned a high school diploma, 5 held at least a college degree, and 20 had not completed high school. People came to fish on the Haw River or Jordan Lake from 28 different ZIP codes throughout central North Carolina. Eleven fishers reported residing in Sanford.

Fish Species and Fish Meals

The largest numbers of respondents reported eating catfish ($n = 32$), crappie ($n = 32$), sunfish ($n = 18$), and large-mouth bass ($n = 16$). Over half of the participants reported that they would eat catfish ($n = 31$), crappie ($n = 28$), or largemouth bass ($n = 26$) if they caught it, and at least 20 participants said they would eat sunfish, striped bass, or yellow perch (see Figure 2). Forty-seven participants reported sharing their catch with their family and/or members of their household.

Thirty-eight respondents reported having eaten more than 1 species of fish during the past year. Eleven participants reported eating 4 or more species of fish in the past year.

FIGURE 2.
Frequency of Respondents Who Self-Reported Catching or Eating Various Fish Species From the Haw River or Jordan Lake Over the Past Year



Note. MeHg, methylmercury.

TABLE 2.
Key Findings and Recommendations to Increase Awareness of the North Carolina Fish Advisory Among Recreational and Subsistence Fishers in the Haw River Watershed

Key findings	Recommendations
- Fishers are racially and ethnically diverse. - Many fishers are consuming locally caught fish at least once per week. - The majority of fishers eat at least 1 high-mercury fish species. - Knowledge of the statewide fish advisory is limited. - Spanish speakers had the lowest awareness of the fish advisory.	- Post highly visible multilingual advisory signs with pictures of the species of concern. - Present clear information about contaminated species and potential adverse health effects. - Target outreach to the Spanish-speaking community. - Target outreach to pregnant women and women of childbearing age.

On average, interviewees ate 7.5 locally caught fish meals per month (median, 2.5). Fifteen participants reported consuming less than 1 meal of local fish per month, whereas 1 participant reported consuming more than 30 meals of local fish per month. Sixteen of 26 Asian and Hispanic participants reported consuming more than 1 fish meal per week, whereas only 4 of 24 white and African American participants reported consuming more than 1 fish meal per week. Nine participants reported eating 2 or more species of fish at least once per week.

Consumption of Fish High in Mercury

Thirty-six fishers (and their families) ate at least 1 meal of fish high in mercury (bowfin, catfish, jack, largemouth bass, or yellow perch) in the past year. Approximately 45% of total fish consumed by survey respondents was of fish high in mercury. On average, respondents ate 3.5 high-mercury fish meals per month, with a median of 1.5 meals and a range of 0–23 meals.

Of the 20 participants who reported eating a locally caught fish species at least once per week, 5 fishers consumed a high-MeHg species once per week, and 8 consumed a high-MeHg species at least twice per week. The high-MeHg fish species eaten at least once per week by fishers or their families included catfish ($n = 13$), bowfin ($n = 1$), largemouth bass ($n = 1$), and yellow perch ($n = 1$). Two participants ate 3 high-MeHg species at least once per week.

Of the 8 fishers who frequently ate high-MeHg meals, 4 were Hispanic, 3 were Asian, and 1 was white; their average age was 47 years. Two of the 8 were women, and 5 did not have regular employment.

Fish Advisory

The statewide and regional (south or east of Interstate-85) fish advisory for the Haw River Basin and Jordan Lake region is based on MeHg contamination. No other specific fish advisory is in place in either Alamance County or Chatham County.

The participating fishers had limited knowledge of the mercury fish advisory. Thirty-two of the 50 respondents had no knowledge of any local fish advisory. Of the remaining

18 fishers with some knowledge of a North Carolina fish advisory, 2 said they fish less as a result of the advisory, another 2 reported eating less fish, and all others said it had not changed their fishing practices. Spanish speakers had the lowest awareness of fish advisories (1 of 18). In contrast, half of surveyed English speakers (16 of 32) had some knowledge of the fish advisory.

Discussion

Fishing plays an important role in some people's lives, and contaminant levels in fish are a public health concern. Fish consumption is influenced by considerations of cost, availability, taste, cultural traditions, recreational habits, and access to alternative food sources [16]. In this study, we interviewed 50 fishers in the Haw River/Jordan Lake area who reported consuming locally caught fish. Among this sample, some fishers expressed strong preferences for specific species of fish, although these preferences varied by person (eg, some fishers targeted catfish, while others avoided catfish). While the majority of the interviewees were adult males, many fishers reported sharing their fish with other members of their household, which may include children and/or women of childbearing age.

In 2010, North Carolina issued over 1.66 million fishing licenses to residents (approximately 12.3% of the total population) [17]. The proportion of the state's residents who eat locally caught fish is unknown, but one small random sample of women found that 26% of the participants reported having eaten locally caught fish in the past 12 months [18]. National biomonitoring survey data indicate that approximately 8% of women of childbearing age in the United States are exposed to mercury levels that exceed the EPA's recommended reference dose [19, 20].

The reference dose for MeHg (1.0 μg per kilogram of body weight per day) was established based on adverse in utero developmental effects from MeHg exposure; however, a recent review of the literature found evidence that prenatal MeHg exposure below the reference dose could result in childhood neurodevelopmental effects [10]. It is estimated that consuming just 1 or 2 meals of a high-mercury fish species can result in blood mercury levels that exceed

the EPA's current reference dose [5], which suggests the public health importance of the fish advisories for children. In addition, it should be noted that fish contain other contaminants besides mercury—such as other heavy metals, persistent organic pollutants, brominated flame retardants, and radionuclides—that can pose a health risk, and these co-contaminants could contribute to the neurodevelopmental differences seen in children with lower versus higher prenatal MeHg exposure [21, 22].

Local fish consumption advisories should inform the public about the chemical contaminants contained in some species of fish, educate fishers about ways to minimize their exposure to contaminants, remind fishers of the health benefits of fish consumption, and present advisory information in a clear manner. Further, advisories need to be available to fishers who do not have Internet access, and they need to be published in a language that fishers can read. Our finding of limited awareness about fish advisories in North Carolina concurs with previous findings in the state and the country. Awareness of regional fish consumption advisories in the United States is generally low, ranging from an estimated 8% to 32% of the population [18, 23].

In addition to knowing about advisories for consumption, fishers must be able to understand those advisories for them to be effective. We did not directly assess fishers' understanding of risk communication; however, few of the fishers who reported knowing of the fish advisories changed their fishing practices. Other studies have similarly reported that compliance with fish consumption advisories is low [13, 24, 25]. For instance, one study found that 26% of women interviewed in North Carolina reported eating locally caught fish, while only 10% were aware of any fish advisory [5]. In the present study, we did not see any signs or postings about fish advisories at any of the 11 survey sites. Outreach at popular fishing locations, including the posting of multilingual advisory signs, could improve awareness about the advisory (see Table 2). Our findings also suggest the importance of multilingual communication and outreach to the Spanish-speaking community.

Public health officials face many challenges in developing and communicating advisories that will be readily understood by the intended audiences. As we found in our survey along the Haw River, the fishing population is composed of ethnically diverse groups, includes non-English speakers, and often draws individuals from a large geographic area [26]. Studies show that advisories are often ineffective at reaching non-white ethnic groups, individuals with low incomes, and those with low educational levels [12]. Challenges to effective communication include language barriers, educational and literacy status, cultural differences, lack of Internet access, distrust in government, and lack of opportunity to consider long-term health consequences over immediate needs [12, 27, 28]. Research by Burger and colleagues suggests that fishers are willing to change consumption behavior when presented with clear

risk information about specific fish species and potential adverse health effects. The findings conclude that risk communication could be improved by more and brighter signage with pictures of high-MeHg species [29, 30].

Fish advisories need to simultaneously reach those catching the fish (primarily men) and those in susceptible subpopulations (women and children), who may also be consuming the fish. Like many states, North Carolina makes specific consumption recommendations for women of childbearing age due to the potential adverse reproductive and developmental effects of mercury. Although we did not assess the knowledge of fishers' family members about fish advisories, we anticipate that awareness among family members is low, as the vast majority of fishers in our sample reported sharing their catch with others.

Previous research in the United States demonstrates that, while anyone who consumes contaminated fish may be exposed to toxins, low-income individuals and people of color more commonly fish for subsistence, consume local fish, and consume fish species named in advisories. Evidence suggests that these populations are disproportionately affected by contaminated fish [31-34], making this an environmental justice problem that contributes to health disparities. Exposure to contaminated fish among low-income people could be reduced by increased income and the availability of alternative sources of inexpensive, less contaminated protein.

This study is not without limitations. We sampled only a limited number of fishers in the Haw River Basin, and we do not know how well this subsample reflects the broader population of fishers in the watershed. Although we sampled at various times of day, weekdays and weekends, and at various locations, we did not sample locations in the main body of Jordan Lake where fishers use boat ramps (which are not present along most of the Haw River). In addition, there is potential for recall bias when asking about fishing and consumption patterns over the past year. Our assessment of consumption excludes commercial fish or fish caught from other bodies of water, both of which are additional potential sources of MeHg. Also, MeHg levels in fish vary widely even within a single river basin. Within a county or between adjacent counties, MeHg levels can range 10-fold to 100-fold in a single fish species [6]. Our study did not collect any biomarkers of mercury from the fishers or their families, so we could not assess relationships between fish consumption and mercury burdens or clinical effects; however, our findings show that consumption levels are high enough to justify research that includes collecting biomarkers of mercury and possibly other persistent, bioaccumulative contaminants.

Conclusion

During the course of this survey, we identified frequent fish consumers from the Haw River Basin who had limited awareness of any fish advisory. We did not find risk communication about mercury or other contaminants at any of the

frequented fishing sites. Because of the health benefits of fish, advisories should aim to switch fish consumption from high-contaminant to low-contaminant species, rather than simply reduce consumers' total fish intake. There remains the challenge in central North Carolina of providing fishers, especially non-English-speaking populations, with accessible information about fish consumption choices. **NCMJ**

Jill E. Johnston, PhD assistant professor, Division of Environmental Health, Keck School of Medicine, University of Southern California, Los Angeles, California.

Kate Hoffman, PhD research scientist, Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina; visiting assistant professor, Nicholas School of the Environment, Duke University, Durham, North Carolina.

Steve Wing, PhD associate professor, Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

Amy Lowman, MPH project manager, Department of Epidemiology, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

Acknowledgments

Elaine Chiosso, Haw Riverkeeper, helped design the survey and identify fishing locations. We thank Daniel Sebastian for creating the maps included in this manuscript and Christina Cordero for her support in participant recruitment.

Financial support. This work was supported by the University of North Carolina Center for Environmental Health and Susceptibility Pilot Projects Program and NIEHS T32ES007018.

Potential conflicts of interest. All authors have no relevant conflicts of interest.

References

- Mozaffarian D, Rimm EB. Fish intake, contaminants, and human health: evaluating the risks and the benefits. *JAMA*. 2006;296(15):1885-1899.
- Hibbeln JR, Davis JM, Steer C, et al. Maternal seafood consumption in pregnancy and neurodevelopmental outcomes in childhood (ALSPAC study): an observational cohort study. *Lancet*. 2007;369(9561):578-585.
- Uauy R, Dangour AD. Nutrition in brain development and aging: role of essential fatty acids. *Nutr Rev*. 2006;64(5 pt 2):S24-S33.
- Krauss RM, Eckel RH, Howard B, et al. AHA dietary guidelines: revision 2000: a statement for healthcare professionals from the Nutrition Committee of the American Heart Association. *Circulation*. 2000;102(18):2284-2299.
- Anderson H, Hanrahan L, Smith A, Draheim L, Kanarek M, Olsen J. The role of sport-fish consumption advisories in mercury risk communication: a 1998-1999 12-state survey of women age 18-45. *Environ Res*. 2004;95(3):315-324.
- Sackett DK, Aday DD, Rice JA, Cope WG. A statewide assessment of mercury dynamics in North Carolina water bodies and fish. *Trans Am Fish Soc*. 2009;138(6):1328-1341.
- Davidson PW, Myers GJ, Weiss B. Mercury exposure and child development outcomes. *Pediatrics*. 2004;113(4 suppl):1023-1029.
- Ginsberg GL, Toal BF. Development of a single-meal fish consumption advisory for methyl mercury. *Risk Anal*. 2000;20(1):41-47.
- Counter SA, Buchanan LH. Mercury exposure in children: a review. *Toxicol Appl Pharmacol*. 2004;198(2):209-230.
- Karagas MR, Choi AL, Oken E, et al. Evidence on the human health effects of low-level methylmercury exposure. *Environ Health Perspect*. 2012;120(6):799-806.
- Roman HA, Walsh TL, Coull BA, et al. Evaluation of the cardiovascular effects of methylmercury exposures: current evidence supports development of a dose-response function for regulatory benefits analysis. *Environ Health Perspect*. 2011;119(5):607-614.
- Tan ML, Ujihara A, Kent L, Hendrickson I. Communicating fish consumption advisories in California: what works, what doesn't. *Risk Anal*. 2011;31(7):1095-1106.
- Jardine CG. Development of a public participation and communication protocol for establishing fish consumption advisories. *Risk Anal*. 2003;23(3):461-471.
- North Carolina Department of Health and Human Services. Fish consumption advisories. How are fish consumption advisories developed? <http://epi.publichealth.nc.gov/oe/fish/howdeveloped.html>. Updated March 12, 2014. Accessed April 2, 2014.
- North Carolina Department of Health and Human Services (DHHS). Mercury: What Fish Are Safe to Eat? DHHS website. <http://epi.publichealth.nc.gov/oe/mercury/safe/fish.html>. Updated May 28, 2013. Accessed December 7, 2015.
- Oken E, Choi AL, Karagas MR, et al. Which fish should I eat? Perspectives influencing fish consumption choices. *Environ Health Perspect*. 2012;120(6):790-798.
- American Sportfishing Association. Historic fishing license sales data (2014). American Sportfishing Association website. <http://asafishing.org/facts-figures/angler-participation/historic-fishing-license-sales-data/>. Accessed June 28, 2014.
- Knobeloch L, Anderson HA, Imm P, Peters D, Smith A. Fish consumption, advisory awareness, and hair mercury levels among women of childbearing age. *Environ Res*. 2005;97(2):220-227.
- Schober SE, Sinks TH, Jones RL, et al. Blood mercury levels in US children and women of childbearing age, 1999-2000. *JAMA*. 2003;289(13):1667-1674.
- Mahaffey KR, Clickner RP, Bodurov CC. Blood organic mercury and dietary mercury intake: National Health and Nutrition Examination Survey, 1999 and 2000. *Environ Health Perspect*. 2004;112(5):562-570.
- Castoldi AF, Johansson C, Onishchenko N, et al. Human developmental neurotoxicity of methylmercury: impact of variables and risk modifiers. *Regul Toxicol Pharm*. 2008;51(2):201-214.
- Coccini T, Randine G, Castoldi AF, et al. Effects of developmental co-exposure to methylmercury and 2, 2', 4, 4', 5, 5'-hexachlorobiphenyl (PCB153) on cholinergic muscarinic receptors in rat brain. *Neurotoxicology*. 2006;27(4):468-477.
- Glori G, Imm P, Anderson HA, Knobeloch L. Fish consumption and advisory awareness among expectant women. *WMJ*. 2006;105(2):41-44.
- Connelly NA, Knuth BA. Evaluating risk communication: examining target audience perceptions about four presentation formats for fish consumption health advisory information. *Risk Anal*. 1998;18(5):649-659.
- Burger J. Consumption advisories and compliance: the fishing public and the deamplification of risk. *J Environ Plann Manage*. 2000;43(4):471-488.
- Silver E, Kaslow J, Lee D, et al. Fish consumption and advisory awareness among low-income women in California's Sacramento-San Joaquin Delta. *Environ Res*. 2007;104(3):410-419.
- Tilden J, Hanrahan LP, Anderson H, Palit C, Olson J, Kenzie WM. Health advisories for consumers of Great Lakes sport fish: is the message being received? *Environ Health Perspect*. 1997;105(12):1360-1365.
- Kuntz SW, Hill WG, Linkenbach JW, Lande G, Larsson L. Methylmercury risk and awareness among American Indian women of childbearing age living on an inland northwest reservation. *Environ Res*. 2009;109(6):753-759.
- Burger J, Pflugh KK, Lurig L, Von Hagen LA, Hagen S. Fishing in urban New Jersey: ethnicity affects information sources, perception, and compliance. *Risk Anal*. 1999;19(2):217-229.
- Pflugh KK, Lurig L, Von Hagen LA, Von Hagen S, Burger J. Urban anglers' perception of risk from contaminated fish. *Sci Total Environ*. 1999;228(2-3):203-218.
- Derrick CG, Miller JS, Andrews JM. A fish consumption study of anglers in an at-risk community: a community-based participatory approach to risk reduction. *Public Health Nurs*. 2008;25(4):312-318.
- Chess C, Burger J, McDermott MH. Speaking like a state: environmental justice and fish consumption advisories. *Soc Na Resour*. 2005;18(3):267-278.
- Weintraub M, Birnbaum LS. Catfish consumption as a contributor to elevated PCB levels in a non-Hispanic black subpopulation. *Environ Res*. 2008;107(3):412-417.
- Westphal LM, Longoni M, LeBlanc CL, Wali A. Anglers' appraisals of the risks of eating sport-caught fish from industrial areas: lessons from Chicago's Calumet Region. *Hum Ecol Rev*. 2008;15(1):46-62.