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Methylmercury risk and awareness among American Indian women of childbearing age living on an inland northwest reservation ☆

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ABSTRACT

American Indian women and children may be the most overrepresented among the list of disparate populations exposed to methylmercury. American Indian people fish on home reservations where a state or tribal fishing license (a source of advisory messaging) is not required. The purpose of this study was to examine fish consumption, advisory awareness, and risk communication preferences among American Indian women of childbearing age living on an inland Northwest reservation. For this cross-sectional descriptive study, participants ($N = 65$) attending a Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) clinic were surveyed between March and June 2006. An electronic questionnaire adapted from Anderson et al. (2004) was evaluated for cultural acceptability and appropriateness by tribal consultants. Regarding fish consumption, approximately half of the women surveyed (49%) indicated eating locally caught fish with the majority signifying they consumed medium- and large-size fish (75%) that could result in exposure to methylmercury. In addition, a serendipitous discovery indicated that an unanticipated route of exposure may be fish provided from a local food bank resulting from sportsman's donations. The majority of women (80%) were unaware of tribal or state fish advisory messages; the most favorable risk communication preference was information coming from doctors or healthcare providers (78%). Since the population consumes fish and has access to locally caught potentially contaminated fish, a biomonitoring study to determine actual exposure is warranted.

1. Introduction

Exposure to methylmercury is recognized as a critical and emerging public health issue with fetuses and children at highest risk (Woodruff et al., 2003; US EPA, 2007a). This pervasive neurotoxin targets the brain in developing organisms, is linked to neurobehavioral testing disorders including deficits in attention span, fine motor function, language, visual–spatial ability and memory even at low exposure levels (Budtz-Jorgensen et al., 2002; Debes et al., 2006; Grandjean et al., 1997, 1998, 1999, 2001), and is also associated with increased blood pressure in exposed children (Sorensen et al., 1999).

According to the United Nations Environment Program (UNEP) and the United States Environmental Protection Agency (US EPA), the primary source of exposure to methylmercury occurs through the consumption of fish contaminated from a variety of anthropogenic sources but principally from atmospheric emissions from coal-fired power plants (UNEP, 2002; US EPA, 2007a). Inorganic mercury released into the atmosphere through combustion of fossil fuels can travel great distances before depositing in aquatic systems and bioaccumulating as methylmercury in the food chain (Clarkson, 2002; National Research Council (NRC), 2000; US EPA, 1997a, b).

Once this toxicant is in the food chain, balancing the public health risks and nutritional benefits of consuming fish presents a complex challenge (Burger and Gochfeld, 2009; Knuth et al., 2003). The primary method of protecting women of childbearing age from unknowingly exposing an unborn child to methylmercury is through education and the distribution of fish advisory messages based on the potential for local exposure (Mahaffey et al., 2008). This paper summarizes the results of a survey conducted with clients of the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) on the Flathead Reservation (Confederated Salish and Kootenai Tribes [CSKT]) in northwest Montana. The goals of the study were to examine fish consumption, advisory awareness, and risk communication preferences among American Indian women of childbearing age.

☆ *IRB Approval*: This study complies with requirements of the US human subject and research regulations and was reviewed and approved by the Montana State University Institutional Review Board for Protection of Human Subjects on March 4, 2006. A tribal council letter of approval to conduct research on the target reservation was received on 20-12-05.

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1.1. National tracking of mercury body burden

The National Center for Health Statistics, a division of the Centers for Disease Control and Prevention (CDC), conducts the National Health and Nutrition Examination Survey (NHANES) to monitor the health and nutrition status of the US population (CDC, 2007). Body burden of mercury in women of childbearing age (16–49 years) is monitored annually through examination of dietary histories and analysis of blood mercury concentrations. Children born to women with blood mercury concentrations above 5.8 parts per billion are determined to be at increased risk. EPA's reference dose (RfD) for methylmercury maternal intake is set at 0.1 μg/kg/day which corresponds to 5.8 parts per billion mercury in blood (Rice, 2004; Rice et al., 2003; US EPA, 2001).

American Indian women and children may be the most overrepresented among the list of disparate populations exposed to methylmercury. An assessment of the 1999–2001 NHANES data focused on the racial/ethnic groups classified as "other" in the survey (Asians, Pacific Islanders, and Native Americans/Alaska Natives). Researchers found that this group was three times more likely to have elevated blood mercury levels than all other racial/ethnic participants of the survey (Hightower et al., 2006). Studies from coastal, Great Lakes, and Canadian indigenous populations have documented fish consumption patterns (Dellinger, 2004; Morrissette et al., 2004; Muckle et al., 2001a, b; Arquette et al., 2002; McKeown-Eyssen et al., 1983). In addition, Jewett and Duffy (2007) noted subsistence consumption rates of specific fish species among Alaskan Natives. As early as 1997, Harris and Harper identified fish consumption characteristics of indigenous subsistence lifestyle in the Lower Columbia River Basin on the Umatilla reservation and estimated a potential exposure scenario. More recently, the impact of fish contaminant burden coupled with the cultural and economic significance of fish for the Confederated Tribes (Cayuse, Umatilla, and Walla Walla) was examined to recommend risk-based action levels for the population with high consumption of contaminated fish species (Harper and Harris, 2008).

1.2. Fish consumption advisories

Fish advisories are critical to populations who eat certain species and amounts of commercial and sport-caught fish (Silver et al., 2007). Advisories are intended to alert consumers to potential risks and are based on fish sampling in specific water bodies (US EPA, 2004). The National Research Council (2000) scientific review of risk evidence summarized the toxicological effects of methylmercury on vulnerable populations and recommended improving the characterization of risk and regional differences of methylmercury exposure in the US population. The federal government through EPA's National Listing of Fish Advisories (NLFA), maintains a database of states, tribes, and territories issuing fish advisories and safe-eating guidelines. In 2006, 48 states (including Montana), the District of Columbia, two of four territories, and five of 562 federally recognized American Indian tribes (US Federal Register, 2002) issued fish consumption advisories (US EPA, 2007b).

Prior to 2003, Montana officials utilized site-specific fish consumption advisories by listing fish species with concentrations of methylmercury or polychlorinated biphenyls (PCBs) found in sampled fish in specific lakes and streams. In 2003 Montana adopted a statewide advisory system to alert anglers of potential hazards (US EPA, 2004). Fish advisory information is disseminated through fishing license brochures, fishing access postings, on websites sponsored by Montana Fish, Wildlife, and Parks (MT FWP) and Montana Department of Public Health and Human Services (MT DPHHS) Food and Consumer Safety. Locally, the CSKT follow the state advisories and publish fish consumption guidelines in the tribal license brochure. Fish advisory messages target the 220,000 resident and 50,000 non-resident anglers who purchase state or tribal fishing licenses (MT FWP, 2007). This population does not necessarily include American Indian anglers who often fish on home reservations where a state or tribal license is not required. It is assumed that tribes as sovereign nations take responsibility for informing tribal residents about potential dangers related to fish consumption (Anderson et al., 2004). There is, however, little evidence of tribal members receiving or acting on fish advisories on tribal lands.

1.3. Flathead Lake ecosystem

Flathead Lake is the largest freshwater lake in the western US with a maximum length of 27 miles, a width of 15 miles, and depth of 386 feet. The lake is fed by two major rivers, the Flathead and Swan that flow from the Bob Marshall and Great Bear wilderness areas and Glacier National Park (University of Montana Biological Center, 2009).

The Flathead Lake and River System is uniquely important to people of the Confederated Salish and Kootenai Tribes (CSKT) by contributing ecological, cultural, spiritual, and economic benefits to the people. Native fish are significant to the survival of native people. The Salish, Pend O'reille, and Kootenai elders state that native people are merely the stewards of the land, while depending upon the fish, wildlife, water, plants, and air to remain in balance, which is significant to their cultural integrity (CSKT and MT FWP, 2001, p. 8).

Of the 25 species of fish commonly found in the Flathead River–Lake Ecosystem, 10 are native fish and 15 are non-native. Two species, lake trout and lake whitefish, have drastically increased in abundance since 1970 with the lake trout identified as directly responsible for a severe decline in native fish, primarily the bull trout. To rebalance the ecosystem, the predatory lake trout population management strategies include recreational angling incentives during a yearly spring and fall Mack Days fishing contest (CSKT and MT FWP, 2006). Creel surveys from 2000 to 2009 suggest a slow decline in lake trout even with annual harvest goals set at 60,000 fish and contest prizes worth approximately $40,000 per semi-annual event (CSKT and MT FWP, 2009).

2. Materials and methods

2.1. Survey design

This study complied with requirements of the US human subject and research regulations and was reviewed and approved by the Montana State University Institutional Review Board for Protection of Human Subjects on March 4, 2006. A tribal council letter of approval to conduct research on the target reservation was received on December 20, 2005. Each participant received a letter from the investigators explaining the purpose of the study. Verbal informed consent was obtained from participants prior to the survey. Respondent anonymity was maintained throughout the data collection period.

This cross-sectional research was conducted from March through June, 2006 during a 2-day a week WIC clinic located at one site on the Flathead Reservation. The clinic serves both American Indian and non-Indian clients who meet the federal poverty guidelines, are pregnant, breastfeeding, and/or have children under the age of five. WIC clinics are open to all qualifying clients regardless of race/ethnic group. For this study, surveys obtained from American Indian women 18–55 years, were analyzed ($N = 65$). To accommodate potential differences in reading level and computer literacy among participants and to expedite data entry, a tribal research assistant was trained to administer an electronic questionnaire using Snap survey software. The WIC case manager informed each client of the opportunity to participate and receive a $10 gift card to be used at a local department store. All clients were assured that accepting or declining participation in the survey would not affect their WIC benefits. Approximately 80% of the clients

arriving for their scheduled appointment consented to participate. The tribal research assistant distributed an educational brochure to each participant, created by Montana Fish, Wildlife, and Parks and the Montana Department of Public Health and Human Services Consumer Safety Division (2004) after survey completion. The electronic questionnaires were submitted by the research assistant to a secure Montana State University website and the data were downloaded to SPSS 14.0 for analysis (SPSS for Windows (Statistical Package for the Social Sciences), 2005).

2.2. Survey development

Prior to beginning the project, permission to adapt a telephone survey was granted by researchers from the Wisconsin 12-state fish consumption advisory project (Anderson et al., 2004). After two tribal consultants reviewed the tool for cultural acceptability and appropriateness, the survey was shortened and wording was modified to accommodate the educational and cultural needs of the local population. For instance, instead of the term "sport-caught fish" wording was changed to "locally caught fish" since few American Indian women are sport anglers. The survey was then re-examined for clarity and appropriateness by a diverse group of state health officials and tribal health professionals. Following revisions, the survey was published as an electronic questionnaire and tested for time burden by five clinic participants who found the average time for completion to be approximately 10 min. The adapted survey included 36 questions and collected information regarding commercial and locally caught fish consumption, knowledge and advisory awareness, risk communication preferences, and demographics.

Fish consumption questions required dietary recall of frequency (number of fish meals per month), differentiated commercially purchased from locally caught fish consumption, and asked the participant to identify primary fishing sites on the reservation (lake, streams), and size of fish consumed. To help respondents identify commercial tuna choices (light or albacore), a can of each type of tuna was displayed. In addition, information was collected regarding reasons an individual might avoid eating fish altogether.

To determine if fish advisories had reached this particular population, a series of questions estimating the participant's knowledge of advisories (Likert scale responses ranged from "a lot" to "nothing at all"). To determine familiarity with a statewide brochure, participants were prompted by a picture of the fish consumption guideline that appeared on the computer screen. Mercury, fish, and health knowledge within the statewide/tribal advisory were tested in a series of questions. For those indicating familiarity with fish advisories, questions were asked to determine the source of advisory message information.

Generally, little is known about preferred risk communication modes among American Indian women. Survey questions queried participants to better understand the most trusted sources of information and preferences in terms of a messenger. What types of messages are most respectful of American Indian values and world views and what is the concept of "risk"? Where, when, and how should risk information be communicated? Are fish advisories most likely or least likely to be heeded if they emanate from a tribal fish and wildlife agency or a tribal health agency?

2.3. Data analysis

Missing data from the survey were imputed via SPSS algorithms. Descriptive statistics (frequencies and means) were generated for the variables of interest. Chi square was used to compare the relationship between groups.

3. Results

3.1. Demographic characteristics of participants

Consistent with a population receiving WIC services, all participants were low-income (185% poverty), young (88% <36 years of age), and 57% were married or a member of an unmarried couple. Educational level was moderate with less than one-third indicating having less than a high school education. The majority of women were not currently working for pay. Among participants, one-fourth of the women were pregnant and those who were not pregnant were not planning on becoming pregnant in the next year. Only 15 participants (23%) indicated that someone in the household held a Montana fishing license (see Table 1).

Table 1
Sample description.

	n	%
Age		
Under 18	5	7.7
18–25	29	44.6
26–35	20	30.8
36–45	7	10.8
46–55	4	6.2
Marital status		
Single	24	36.9
Married	15	23.1
Divorced	1	1.5
Separated	3	4.6
Member of an unmarried couple	22	33.8
Working for pay		
Yes	23	35.4
No	42	64.6
Education		
Less than high school	21	32.3
Completed high school	20	30.8
More than high school	24	36.9
Currently pregnant		
Yes	17	26.2
No	48	73.8
Participant or family member possessing a Montana fishing license		
Yes	15	23.1
No	50	76.9

3.2. Fish consumption

Over half of the sample stated that they consumed less than one fish meal per month although 35% reported two to four meals and about 9% indicated they ate five to eight meals per month. None reported eating nine or more fish meals per month. The participants were more likely to eat light tuna rather than albacore tuna. Shellfish, fish fillets, fish stick, and fish sandwiches were also popular choices. Overall, half of the subjects in the sample reported eating locally caught fish with the majority of this group indicating they consumed medium-sized fish measuring 15–17 in. or larger. Of the group of respondents, 56 (86.2%) indicated they had "very little" or "no knowledge at all" about mercury contaminants in fish (see Table 2).

One additional finding bears mentioning. In addition to traditional sources of fish (purchased or locally caught), the WIC population may acquire fish from the local food bank. This possible exposure route was discovered serendipitously from a dietary history conducted by a WIC employee. Because the research team's awareness of this source of fish was raised only after the research study was underway, no data were collected on the prevalence of this source of fish among study participants.

3.3. Fish knowledge and advisory awareness

Basic awareness of Montana's fish advisory among the research subjects was modest with just 20% ($n = 13$) stating that they were aware of a state or tribally issued fish advisory. In order to understand risk communication patterns, we asked the 13 participants with some awareness of Montana's fish advisory, where they received their information. Participants were able to select multiple sources of information with "talking to people you know" the most frequently used source. Other advisory information sources included "talking with doctors/health professionals," "television news," and "fish and game regulations with license purchase." No participants chose "WIC office," "radio,"

Table 2
Fish consumption amounts and types.

	n	% Sample
During the average month, about how many meals of fish do you eat including all types of freshwater and saltwater fish either purchased or caught in local waters?		
Less than one meal per month	36	55.4
2–4 meals per month	23	35.4
5–8 meals per month	6	9.2
9 or more	0	0
Types of purchased fish eaten in the last 12 months		
Shellfish (shrimp, lobster, clams, crab, crayfish, imitation shellfish)	40	61.5
Fish fillets, fish sticks, fish sandwiches	41	63.1
Light tuna	50	76.9
Albacore tuna	25	38.5
Do you or your family ever eat locally caught fish?		
Yes	32	49.2
		% of 'yes' above
When you eat locally caught fish, are they generally		
Small (less than 14 in.)	8	25.0
Medium (15–17 in.)	18	56.3
Large (18 in. or greater)		
How much do you know about mercury contaminants in fish?		
A lot	1	1.5
Some	8	12.3
Very little	28	43.1
Nothing at all	28	43.1

Table 3
Fish advisory awareness.

	n	% Sample
Some states issue consumption advice for fish contaminated with mercury. Do you know if Montana or (this) reservation issues an advisory on eating locally caught fish?		
Yes	13	20.0
No	52	80.0
		% of 'yes' above
Where did you learn about Montana's fish advisory? (13 participants responding)		
TV shows	1	7.7
TV news	3	23.1
Radio	0	0.0
Magazines	0	0.0
Newsletters/brochures sent to home	2	15.4
Talking to doctors/health professionals	5	38.5
Talking to people you know	9	69.2
Government agencies/representatives	1	7.7
Signs or posters	1	7.7
WIC office	0	0.0
Fish and game regulation booklet with fishing license purchase	2	15.4
School	0	0.0
Internet	0	0.0

Table 4
Detailed awareness of Montana fish consumption guidelines ($N = 13$).

How much would you say you know about the following risk of mercury exposure guidelines?	A lot	Some	Only a little	Nothing at all
Fish species	0	0	6 (46.2)	7 (53.8)
Fish size	0	1 (7.7)	5 (38.5)	7 (53.8)
Fishing location	0	1 (7.7)	5 (38.5)	7 (53.8)
Consumption frequency	0	0	6 (46.2)	7 (53.8)

"magazines," "school," or "Internet" as the sources of fish advisory awareness (see Table 3).

Finally, in order to understand whether participants with basic awareness had more detailed understanding of Montana's fish advisories, the women were asked to rate their level of knowledge about fish species, fish size, fishing locations, and consumption frequency (see Table 4). None of the 13 participants with basic awareness rated their level of knowledge across all four categories of response as "a lot," and only a single participant stated she knew "some" about fish size and fishing locations(see Table 4). Overall, over half of the women with basic awareness of fish advisories indicated they knew "nothing at all" about the details of the fish advisory. The balance of participants stated they only knew a little about the topics presented. Two species of Flathead Lake fish are of particular concern. Women of childbearing age and children are advised to "not eat" large lake trout (28–39 in. in length) and eat just one meal a month of lake trout (18–27 in.) and lake whitefish (14–19 in.) (see Table 5).

3.4. *Risk communication preferences*

Among the 10 possible risk communication preferences listed in Fig. 1, "talking with doctors/healthcare providers" and "newsletters or brochures" received the most favorable responses with most indicating that these sources were very useful. Responses related to the other sources of health information were generally homogenous with the exception of some evidence that respondents felt that government, newspapers and television, and tribal officials were the least useful.

4. Discussion

Three major findings emerged from this study related to fish consumption, fish advisory awareness/knowledge, and risk communication preferences among American Indian women of childbearing age living on the Flathead Reservation in the inland Northwest. First, most American Indian women of childbearing age who participated in this study included locally caught and/or commercial fish in their diet. Second, 80% ($n = 52$) of study participants were unaware of local or statewide fish advisories. Those that had heard of the advisories had little specific knowledge of the health effects of eating fish contaminated with methylmercury. This level of awareness is slightly less than statewide results found on the Montana Behavioral Risk Factor Surveillance System (BRFSS) survey. The Montana Department of Public Health and Human Services added the following question to the statewide BRFSS in 2005: "Are you aware of Montana's sport-fish consumption guidelines?" Among Montana women (aged 18 to 65+), 70% ($n = 2025$) were unaware of the fish consumption guidelines (MT DPHHS, 2005). Finally, since advisory messages are intended for the general population as well as specific vulnerable groups, this study reveals important population-specific risk communication preferences among this sample of American Indian study participants not addressed in previous studies. These findings could contribute to improving the effectiveness and distribution of fish advisories to this population.

Fish consumption data collection requires consideration of a number of variables such as serving size (Silver et al., 2007), species and size of fish, and participant dietary recall regarding number of servings per month, per 3 months or per year (Anderson et al., 2004; Knobeloch et al., 2005). While average

Table 5
Concentrations of mercury and PCBs (μg/g) in fish length groups (in.) and recommended consumption for people eating fish from Flathead Lake over the entire year.

Fish species	Length (in.)	Mercury (μg/g)	PCB (ng/g)	Meal (0.5 lbs) guidelines for annual use
Lake trout	18–27	0.3–0.4	Less than 0.1	Adults—1 meal/week Women (child bearing years)—1 meal/month Children—1 meal/month
	28–39	0.6–0.9	0.1–0.4	Adults—1 meal/month Women (child bearing years)—don't eat Children—don't eat
Lake whitefish	11–14	0.1	ND	Adults—unlimited Women (child bearing years)—1 meal/week Children—1 meal/week
	14–19	0.2	ND	Adults—1 meal/week Women (child bearing years)—1 meal/month Children—1 meal/month

Source: Confederated Salish and Kootenai Tribes and Montana Fish, Wildlife, and Parks Co-Management Plan (2001).

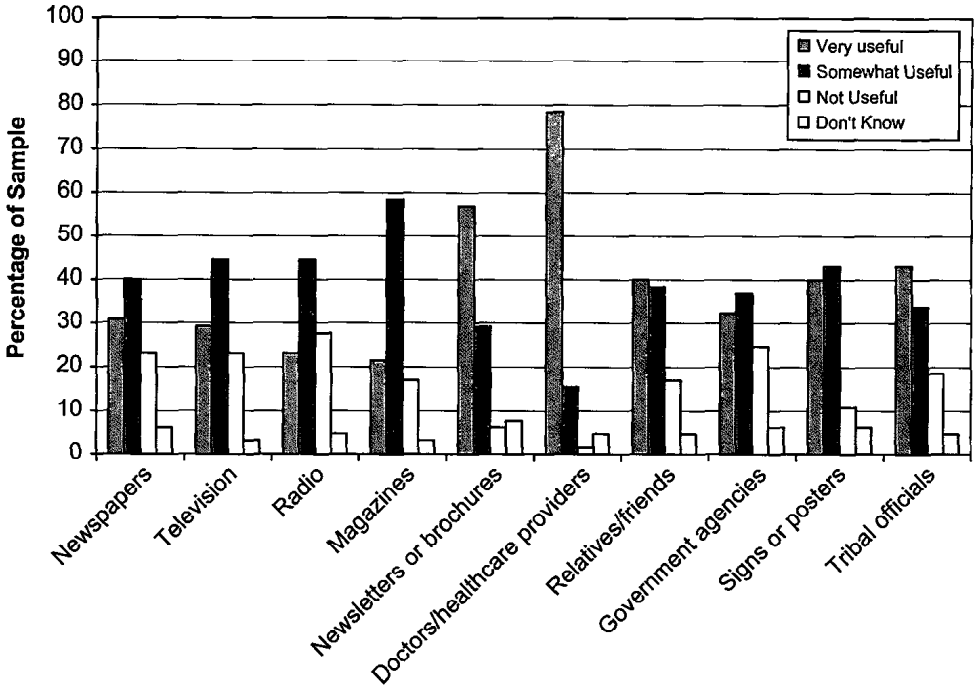

Fig. 1. Risk communication preferences.

fish consumption rates among American Indians was previously reported in the 12-state survey conducted by Anderson et al. (2004), the study sample included a small subset of American Indians ($n = 51$, 1.6%) with just six of the 51 participants representing Montana. In addition, results reported by state name three states with the highest sport-fish consumption rates: Louisiana (43%), Montana (42%), and Minnesota (41%). Our study focused on lower socioeconomic American Indian women in one local area and found that childbearing-age women do consume both commercial and locally caught fish at a rate exceeding the rate reported in the 12-state survey for Montana. Silver et al. (2007) collected fish consumption data (1 month recall) from 500 WIC clients in California including a small number of American Indians ($n = 11$) and found overall higher rates in the entire ethnically diverse population for commercial (91%, $n = 457$) and sport-caught fish consumption (16%, $n = 80$) than reported for California in the Anderson et al. (2004) 12-state study. American Indians in the California study consumed sport-caught fish at a rate 27% above the FDA/EPA advisory limit (Silver et al., 2007). Participants in our study who consume locally caught fish could be at increased risk for exposure to methylmercury, depending on the fish species and the water body where fish are caught.

Our findings suggest that advisory messages may not be reaching or impacting the childbearing women participating in this study. Indigenous populations in Montana have demonstrated reliance on natural resources including dependence on fish and wildlife for sustenance. Indian people hunt and fish on home reservations free of licensing requirements so likely miss this primary information source, the fish and wildlife licensing brochure advisory messages. Locally, the WIC population often access food resources through the local food pantry. During the course of this study WIC personnel found that women reported fish consumption based on fish donated to the food pantry. When questioned further, it was discovered that a large supply of lake trout had been donated to the food pantry as a result of the Mack Days fishing contest. A recent biological study of lake trout confirmed high levels of mercury in tissues of older and larger fish between 0.3 and 0.9 μg/g (Stafford et al., 2004). In 2006 approximately 4403 lake trout were caught during this popular fishing contest and in 2007 the number increased to 7904 fish

with much of the catch filleted and donated to food pantries in the region. The generosity associated with providing this important source of protein to low income women may inadvertently and unintentionally have caused increased risk of exposure to methylmercury in pregnant and/or breastfeeding women and children since children often reflect the consumption patterns of their mothers (Imm et al., 2007). Since this source of fish was not specifically listed in the survey, our results might underestimate fish consumption by limiting the range of acquisition to two choices. Fish obtained from food banks are neither locally caught nor commercially purchased. Future surveys involving low income women should include "food bank/food pantry" as an acquisition option or otherwise inquire about fish sources not listed as options within the measurement scheme.

American Indians in the Silver et al. (2007) study had the highest level of advisory awareness among ethnic groups (36%) as did the American Indians in the Anderson et al. (2004) study (31%). Our study, however, found just 20% of study participants were aware of advisory messages issued by the state or tribe. In contrast to our study, American Indians were not the focus of either the Anderson or Silver studies but were included as a subsample within the larger population; 2% of the study sample ($n = 11$) in the Silver et al. (2007) study and just 1.6% in the Anderson et al. (2004) study. Of the "aware" group in our study, most stated they learned about the advisory by talking to acquaintances (69%) or health care providers (38%), however, over half said they had no knowledge of advisory-specifics in terms of species, size, fishing location, or recommended consumption frequencies. Due to the small sample size of the advisory "aware" group, no variables were significant predictors of fish advisory awareness or fish consumption patterns including level of education. In contrast, Silver et al. (2007) and Knobeloch et al. (2005) found ethnicity and increasing age related to higher fish consumption rates and years of education predictive of advisory awareness.

Approximately 49% of the study participants said they consumed locally caught fish of medium to large size and since advisories in fishing licenses may not reach American Indians fishing on home reservations, there is a need to identify more effective and reliable information distribution points among this population. Indigenous communities are often strikingly different from the dominant culture in their approach to decision-making and communication of important messages. Risk communication assessment in tribal communities requires flexibility, collaboration, and respect for points of view that might come from elders or other community members rather than scientific experts (ATSDR, 2000; Bird, 2002; Cajete, 1994; Colomeda-Lambert, 1999). Although mistrust of health care providers by American Indians and other ethnic groups has been a dominate theme in some studies (Devlin et al., 2006) participants in our study indicated health information from a doctor or health care provider would be the most useful followed by newsletters or brochures, and "talking with people I know." The small group of participants who indicated advisory awareness said they learned about the advisory from people they knew (69%) followed by doctors/healthcare providers (38%) as their source of information. This finding suggests the need to adapt the risk communication message to accommodate the preferred mode of the population at risk. Public participation in designing fish consumption advisories is critical to achieving regional and cultural appropriateness and should include 14 guiding principles for not only setting communication messages but also evaluating the message effectiveness after they are posted (Jardine, 2003). Additionally, warning and advisory messages can be made more effective by monitoring actual human exposure (Suk et al., 2004). Although fish consumption was relatively high and advisory awareness was low in the population, actual exposure is unknown. Knobeloch et al. (2005) reported difficulty in assessing exposure levels in minority women including American Indians who declined hair sampling. Since hair is culturally symbolic, future studies should be developed with a trusted tribally affiliated research partner who can explain the procedure as well as the cultural implications to participants.

Strengths of this study include the focus on American Indian women in one specific community thereby improving the characterization of risk, regional, and local potential for exposure to methylmercury. Reliance on an instrument adapted from Anderson et al. (2004) by tribal consultants, improved the ability to ask culturally appropriate and significant questions about the potential for methylmercury exposure. Although this research was academically initiated, the entire project was made possible from start to completion with the help of tribal consultants (Holkup et al., 2009). Limitations of this study include a small sample size and the fact that all participants were primarily from one tribe thereby preventing generalizability. The cross-sectional study design, while appropriate for the study aims, lacks the potential to capture trends or change in knowledge, attitudes, or behavior over time. In addition, the participation incentive ($10 gift card) may have increased the number of participants willing to commit to the 10 min survey but might have also influenced responses in unknown ways. Memory associated with diet recall may be another limiting factor since individuals may have difficulty remembering dietary specifics and might tend to guess or provide any answer in order to complete the survey.

In conclusion, improved risk messages should be developed and disseminated especially related to the Mack Days fishing contest since the population not only consumes fish but also has access to locally caught fish including lake trout and lake whitefish. The 2009 CSKT/FWP co-management plan specifically mentions information and education activities to improve fish consumption advisory awareness. In light of the availability of fish with high levels of mercury with this particular group, a biomonitoring study of American Indian women is warranted to determine actual exposure. Ultimately, reduction of mercury emissions to improve the quality of available food is necessary but until environmental controls are in place, education, biomonitoring, and carefully crafted risk communication messages are needed to reduce exposure to this environmental hazard. Larger and longitudinal studies are needed to better understand both the risks and resources of vulnerable American Indian populations.

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