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Exposure assessment and initial intervention regarding fish consumption of tribal members of the Upper Great Lakes Region in the United States☆,☆☆

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Abstract

The Ojibwe Health Study (OHS) has concluded 10 years of data collection and exposure assessment. Eight hundred and twenty-two participants from tribes in the states of Wisconsin, Michigan, and Minnesota (USA) completed fish consumption and environmental risk perception questionnaires. Many participants provided hair and blood samples for mercury and polychlorinated biphenyl (PCB) residue analyses as body burden indicators of these persistent environmental pollutants. Fish were collected by the tribal organizations and contaminants were analyzed for numerous tribal reports and professional environmental journal articles, these data were used by the Great Lakes Indian Fish and Wildlife Commission to produce tribal-specific geographic information systems maps as part of a public health intervention strategy. These maps are currently available at www.glifwc.org for six Wisconsin tribes that regularly harvest walleye. To determine the health impacts (if any) of pollutants on cancer, diabetes, and reproduction, it was necessary to know the recent trends in key indicators such as cancer mortality ratios and birth gender ratios. The Great Lakes Inter-Tribal Council provided the OHS and each participating tribe in Wisconsin and Michigan with a health profile. Total fish consumption (estimated by recall) for 720 tribal participants was self-reported as 60 g/day, but the highest actual consumption was measured as 11.2 g/day in one of the tribal groups. The highest blood concentrations in tribal participants were 18.6 ppb total serum PCBs and 11.8 ppb total blood mercury. Ninety percent of the participants had less than 3.8 ppb total serum PCBs and 2.6 ppb total blood mercury. Compared to other studies of subsistence fishing populations, these exposures were only moderately elevated and not high enough to warrant widespread restrictions on diets. Furthermore, the benefits of eating a fish diet must be continually emphasized. However, sport fishermen and their families who consume larger and more contaminated fish should abide by their state fish consumption advisories to minimize their health risks.

Keywords: Methylmercury; Polychlorinated biphenyls; Native Americans; Fish; GIS mapping

1. Introduction

Recently, the Wisconsin Department of Natural Resources (WDNR) lowered its mercury in fish action level by a factor of 10× to 0.05 ppm based upon subtle alterations in neurodevelopment in children born to mothers who eat large amounts of fish (WDNR, 2002). This reduction causes piscivorous fish (e.g., walleye) from all bodies of water in Wisconsin to exceed the advisory limit for most women and all young children. Until recently, most states, federal agencies, and the tribes used 0.50 ppm mercury as the fish consumption advisory limit (ATSDR, 1999).

Women are discouraged ("…may eat…" p. 9, WDNR, 2002) from eating more than one fish meal containing walleye per month. Therefore, when the tribal nutritionist was asked recently what advice she gives to expecting mothers regarding eating fish, she responded that she tells them, "Don't smoke, don't

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☆☆The opinions and conclusions made in this report are solely those of the author and not necessarily shared by the sponsor, collaborators, or tribal participants.

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drink, and don't eat fish'' (Risingson, personal communication). After learning about the mercury data provided on the Great Lakes Indian Fish and Wildlife Commission's (GLIFWC) geographic information systems (GIS) maps (Fig. 1), She no longer includes fish in the same category as smoking and drinking. Now, Ms. Risingson advises tribal women to eat fish but to ''choose wisely''. This report examines the issue of balancing the risks versus the benefits of fish consumption by summarizing the ongoing 10-year research program aimed at determining the health risks to tribal members from the eating of their traditional diet of fish from the upper Great Lakes region of the United States.

The Great Lakes region has long been known for its abundant natural resources and enormous freshwater lakes. These lakes provide considerable recreational and nutritional importance to 25% of Canadians and 10% of the US citizens, and the health consequences of pollution were a concern for the Agency for Toxic Substances and Disease Registry (ATSDR) (Hicks et al., 2000). ATSDR initiated the Great Lakes Human Health Effects Research Program in 1992, and the Ojibwe Health Study (ATSDR/OHS) was initiated to conduct an exposure assessment on this traditionally subsistence fishing Native American culture.

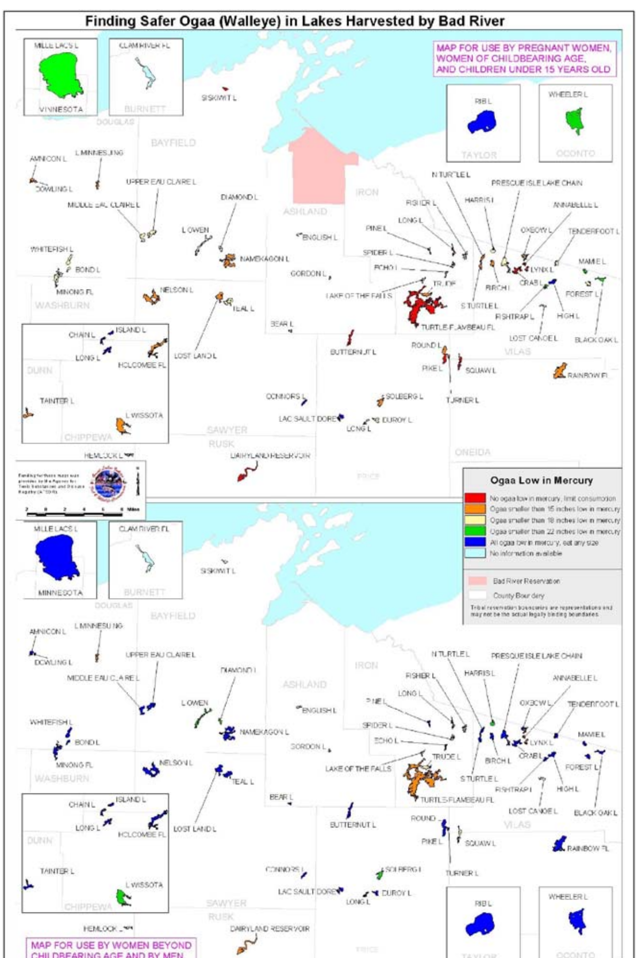


Fig. 1. Bad River GLIFWC mercury map (GLIFWC, 2003) reprinted with Bad River Tribal Health Clinic permission (LeCapitaine, personal communication).

The Ojibwe tribes of the upper Great Lakes region of the United States have a long history of relying upon fish as a major part of their diets, of using fish for commercial fisheries, and of valuing fish for their cultural and social importance. Our earlier papers have described one Ojibwe tribe and characterized the contaminants commonly found in the diets of the Ojibwe people. The initial study was funded by the Great Lakes Protection Fund (GLPF) with Dellinger as the principal investigator between 1990 and 1992 (see Gerstenberger et al., 1997).

Methylmercury is known to be a neurotoxicant, and the developing fetus is the most susceptible human cohort (Clarkson, 2002; ATSDR, 1999). The adverse developmental effects of methylmercury were first recognized in the 1970s due to the epidemic in Minamata, Japan (Tsubaki and Takahashi, 1986) and shortly thereafter an even larger outbreak in Iraq (Bakir et al., 1973). Both epidemics highlighted just how severely acute, high doses of the heavy metal could permanently affect the development of the nervous system in the fetus.

Polychlorinated biphenyls (PCBs) are a mixture of 209 congeners of chlorinated biphenyl rings that can cause adverse health effects ranging from developmental effects to an increased risks for cancer (ATSDR, 2000). PCBs were first identified as a serious health risk in the 1960s in Japan (see the review in Masuda, 1994) and again in the 1970s in Taiwan (see the review by Hsu et al., 1994). In both Asian epidemics, rice-bran cooking oils were contaminated with PCBs during processing; the recent longitudinal follow-up of the Taiwan cohort (Lai et al., 2001) concluded that the children born to exposed mothers experienced long-term adverse effects on their cognitive development. More recent than the Asian epidemics, beginning in the 1990s a series of reports by Jacobson et al. (1990) demonstrated that consumption of PCB-contaminated Great Lakes fish resulted in altered growth and development in children.

Both methylmercury and PCBs are considered to be significant human health risks (primarily through the aquatic food chain), and they are as ubiquitous and as much of a global concern today as they were when the International Joint Commission listed them as 2 of the 11 ''targeted'' persistent pollutants of concern in the Great Lakes over a decade ago (GLWQB, 1987). While there are numerous other persistent organic pollutants (POPs) of concern in the fish diets of people residing in the Great Lakes, mercury and PCBs are the most widely characterized, are frequently used to help estimate the health risks associated with eating fish, and are often the basis of fish consumption advisories (WDNR, 2002).

Furthermore, the relative contributions of these contaminants and other POPs vary depending upon fish species, geographical location, and, most importantly, fish size. Piscivorous fish bioaccumulate these and other POPs and they biomagnify the pollutants to significantly higher concentrations than are found in the water in which they swim.

2. Materials and methods

The ongoing ATSDR/OHS project expanded the initial cohort from 89 participants in the GLPF study to 822 tribal members from several Ojibwe reservations and the Menominee reservation located in the upper Great Lakes region (Michigan, Minnesota, and Wisconsin). The majority of the participants were recruited at tribal health fairs. Some were recruited at *powwows*, Women, Infant, and Child (WIC) (a public health program) program meetings, Head Start Round-ups (a US government program for early childhood education), and other tribal functions. No efforts were made to either randomly select or exhaustively sample entire tribal families. Many participants willingly volunteered for additional pilot study projects and follow-up sampling. Tribal health fairs are normally annual events that frequently correspond with other more traditional tribal gatherings. *Powwows* are gatherings that are roughly similar to a large family reunion in the nontribal communities of the midwestern USA. However, *powwows* emphasize more traditional art, music, dance, and spiritual rejuvenation. Normally all these activities (health fairs and *powwows*) occur in the summer and early fall.

This report describes the overall study and summarizes the basic contaminant results for both human and fish data, including the basic demographic and fish consumption information for each of five tribal groupings based upon diet and geographical location (Fig. 2). The report compares the 822 ATSDR/OHS participants' fish consumption patterns and the contaminants in their fish to our original GLPF study and to specific dietary/geographical tribal groupings. It also characterizes the tribal blood concentrations of total PCBs and total Hg in preparation for more specific analyses and reports to follow.

This report summarizes GLIFWC's initial intervention strategy (funded in part by ATSDR/OHS) using GIS to map mercury contamination in walleye and communicate and to reduce the health risks to tribal members eating contaminated fish (Fig. 1).

2.1. *"Self-reported" fish consumption and medical questionnaire data collection*

Volunteers were solicited at local tribal health fairs and *powwows* from 1993 to 2000. Each participant received a colorful tribally designed and culturally relevant tee shirt for completing the extensive questionnaire and/or for allowing hair and blood samples to be collected. A smaller cohort completed a brief environmental risk perception portion of the questionnaire and received a colorful button (Fig. 3). The logo on the tee

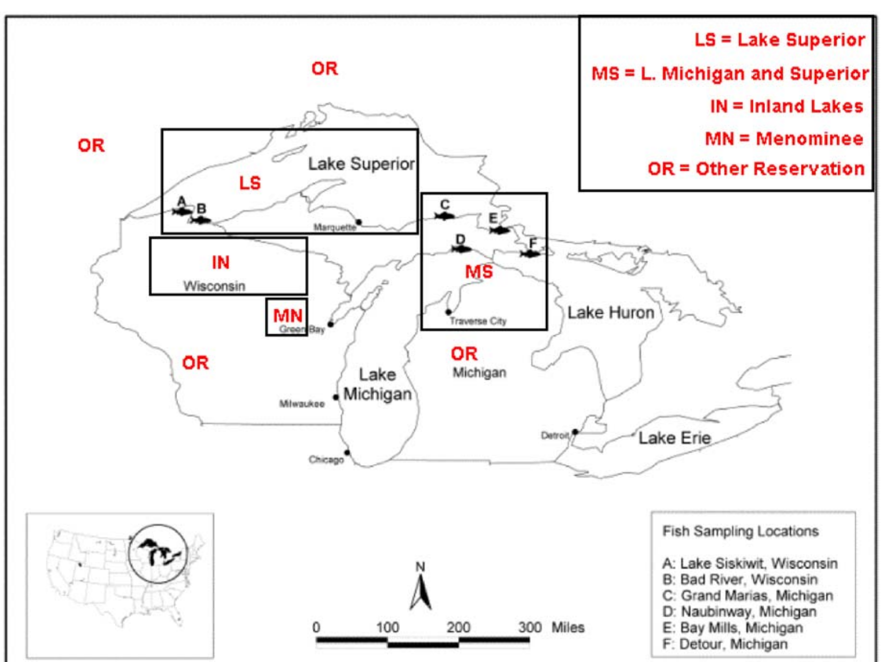


Fig. 2. An overlay of the four primary tribal groupings over our most recently published tribal fish contaminant sampling (adapted from Gerstenberger and Dellinger, 2002).

Fig. 3. Logo for Ojibwe Health Study teeshirts and buttons designed by a Native American student at Fond du Lac Community College, Duluth, MN, USA.

shirt and the button was created by an Ojibwe community college student at Fond du Lac (MN, USA). No other monetary payment was necessary to recruit participants.

The identification cover sheets and copies of the voluntary consent forms were removed from the questionnaires and replaced with an alphanumeric code to insure that data entry and reporting would be blinded and that all data would be kept confidential. All questionnaires were entered into the CDC Epi Info (2002) statistical analysis program for epidemiological analyses and data reporting.

2.2. Prospectively quantifying of "actual" fish consumption by tribal families

GLIFWC, with partial support from the ATSDR/OHS project, conducted a priori fish consumption studies to compare "actual" weighed and recorded consumption by tribal families to the self-reported data collected weeks or months later by the ATSDR/OHS project at health fairs. These studies included 10–12 families per year over a 5-year period from 1997 to 2002. As part of the tribal family's normal routine of harvesting and distributing walleye from the spring spearfishing season, they were asked by GLIFWC to weigh and record their actual consumption of all fish. Each family was provided a small scale to weigh the portions of fish being prepared. During 1999 through 2002, a total of 147 members from 32 families at 11 reservation sites participated in the data gathering. GLIFWC provided the ATSDR/OHS project with the results of those studies in a final technical report (GLIFWC, 2003), and those results are briefly summarized in this report.

2.3. Chronic disease mortality data for tribes

In 1994, it became apparent that there were not tribally specific mortality and morbidity data that could be used to determine baseline values for each of the participating tribes. The ATSDR/OHS project required baseline chronic disease and reproductive health data for each tribe. To determine the health impacts (if any) of pollutants on cancer, diabetes, and reproduction, it was necessary to know the recent trends in key indicators such as cancer mortality ratios and birth gender ratios. In collaboration with The Great Lakes Inter-Tribal Council (GLITC), we recovered the mortality data from the State of Wisconsin and prepared the first chronic disease report specifically for Wisconsin tribes (Dellinger and Malek, 1995); with subcontract funding provided by ATSDR/OHS, we expanded the data acquisition to include the appropriate Minnesota and Michigan tribes. Those early efforts have resulted in the production of biannual Community Health Profiles for approximately 36 tribes and urban Indian health clinics that are and updated annually for each Great Lakes state with subsequent funding by the Indian Health Service (GLITC, 2002).

Data for these Community Health Profiles are compiled by GLITCs EpiCenter from the US Census Bureau, state departments of public health, state WIC programs, Tribal Health centers, and the Indian Health Service. Report formats are generally similar to those reported for the national statistics by the US Public Health Service under the title *Trends in Indian Health* (PHS, 1994).

2.4. Biological sample analyses

The tribal biological samples reported here were all analyzed by the Centers for Disease Control and Prevention (CDC) National Center for Environmental Health (NCEH). Additional biological samples were analyzed and summarized in our earlier preliminary report (Dellinger et al., 1996). Hair samples were analyzed by two laboratories for both total and organic mercury. In order to more completely discuss those results, they will be reported separately, but the hair results do not significantly alter the conclusions based upon the blood mercury results reported here.

2.4.1. Blood mercury measurements

Whole-blood specimens were analyzed for both total mercury and inorganic mercury. Specimens were analyzed using automated cold-vapor atomic-absorption spectrophotometry by the Division of Laboratory Sciences at the NCEH. The detection limit was 0.14 μg/L for total mercury and 0.4 μg/L for inorganic mercury. Mercury was measured by Flow Injection Mercury System 400 (Perkin–Elmer, Shelton, CT) with an AS-91 autosampler. All solutions were made of analytical-grade chemicals. Ultrapure water at 3–18 MΩ (Milli-QTM, Millipore Corp. Bedford, MA, USA) was used for solution preparation. Matrix-matched calibration methods were used. All blood samples were kept frozen from the time of aliquoting until the analysis. The total blood mercury analysis utilized a Maxidigest MX 350 (Prolabo, Fontenay-sous-Bois, Cedex, France) in-line microwave digester connected to the FIMS-400 system. The inorganic mercury analysis utilized stannous chloride as the reducing agent, and the total mercury analysis utilized sodium borohydride as the reducing agent. The blood mercury analysis required 0.2 mL of blood for the total and an additional 0.2 mL of blood for the inorganic analysis.

For both total and inorganic mercury measures, National Institute of Standards Technology Standard Reference Material (NIST SRM 966) was used as a bench quality-control material as well as three levels of in-house blood pools traceable to NIST SRM 966 for daily quality control. One of two different levels of a blind quality-control material was inserted in every analytical group of samples for an additional quality-control check. All quality-control specifications were met in the analyses of the samples.

2.4.2. Serum analyses for PCBs

Serum samples from the ATSDR/OHS project were submitted to the NCEH for analysis using isotope-dilution mass spectrometry (IDMS). Our preliminary comparison indicates that the new IDMS method provides profiles very similar to that reported for the GLPF project (Gerstenberger et al., 1997). This report will focus on total PCBs and one single congener, the hexa-chlorinated congener normally referred to as International Union of Pure and Applied Chemistry (IUPAC) Congener No. 153 (see Tables 4–5 in ATSDR, 2000).

Briefly, the differences between the serum organochlorine methods for our GLPF study and the CDC NCEH analyses were as follows: The GLPF project used 10 mL of serum from 61 participants to quantify 93 peaks for 126 congeners using Hewlett–Packard (Palo Alto, CA, USA) Model 5880A with a DB-5 capillary column and electron-capture detection (ECD) following the basic modified methods of Mullin as published in Gerstenberger et al. (1997, 2000).

For the ATSDR/OHS project, 307 participants' (included 38 nontribal spouses and nonnative tribal employees for comparison purposes) serum samples were shipped to the NCEH for analysis using the IDMS method described earlier by Burse et al. (1996). PCBs were analyzed using high-resolution gas chromatography/isotope-dilution high-resolution mass spectrometry. Serum samples were spiked with $^{13}C_{12}$-labeled internal standards, and the analytes of interest were isolated using either a C_{18} solid-phase extraction or a liquid–liquid extraction procedure followed by a multicolumn automated clean-up and enrichment procedure. The analytes were chromatographed on a DB-5 MS capillary column (30 m × 0.25 mm × 0.25 μm film thickness) using selected ion monitoring at a 10,000 resolving power using either a Micromass Autospec ULTIMA or Finnigan MAT95 mass spectrometer in the EI mode. The concentration of each analyte was calculated from an individual standard linear calibration. Each analytical run was conducted blind and consisted of three unknown serum samples, a method blank, and a quality control sample. After all data were reviewed using comprehensive quality assurance/quality control procedures, the analytical results were reported on both a whole-weight and lipid-adjusted basis. Serum total lipids were determined using an enzymatic "summation" method (Atkins et al., 1989). Detection limits, on a whole-weight basis and a lipid-adjusted basis, were reported for each sample and corrected for sample weight and analyte recovery. All human serum specimens were handled using universal precautions (MMWR, 1987). A recent and more complete description of the method can be found in the paper by Turner et al. (1997). The results included quatifications of 36 congener peaks: IUPAC Abs. (in elution order) 18, 28, 52, 49, 44, 74, 66, 101, 99, 87, 110, 118, 105, 151, 149, 146, 153, 138/158, 128, 167, 156, 157, 178, 187, 183, 177, 172, 180, 170, 189, 201, 196/203, 195, 194, 206, and 209 and 11 other organochlorine residues [HCB (hexachlorobenzene), β-HCCH (β-hexachlorocyclohexane), γ-HCCH, H.Epox. (heptachlor epoxide), oxychlor, *t*-Nona (*trans*-nonachlor), *p,p′*-DDE, Dieldrin, *o,p′*-DDT, *p,p′*-DDT, and Mirex). The analysis of the specific congeners (other than IUPAC No. 153) and the other organochlorine residues will not be discussed in this report.

At the University of Illinois–Urbana/Champaign, Dr. Larry Hansen's laboratory used DB-5 capillary-column gas chromatography with ECD to quantify 26 individual congeners, including 8, 18, 28, 44, 47/48, 49, 52, 66/95, 70, 74, 101, 105, 77/110, 118 126, 128, 138, 153, 170, 180, 187, 195, 200, 206, and 209 (Gerstenberger, 1996). These methods were used to analyze 144 participants for the ATSDR/OHS project and will be reported separately in more detail. Those results were not included in the summary statistics in this report (Table 1).

2.5. Fish contaminant analyses

Fish were harvested by tribal members and submitted to GLIFWC or collected directly by GLIFWC or the Inter-Tribal Fisheries Assessment Program (ITFAP) personnel to determine the contaminants in fish routinely eaten by the tribes. These collections included species and sizes deemed appropriate for each location. For example, the tribes on the shores of Lake Michigan and Lake Superior (MS group) tended to focus sampling on lake trout (*Salvelinus namaycush*) and whitefish (*Coregonus clupeaformis*), whereas the Inland lakes

Table 1
Average and maximum blood results by tribal/dietary grouping

Group	N	Age in years, average SD	Females[a] (%)	Fish[a] meals/year, average SD	Fish[a] g/day, average SD	Blood Hg, ppb, average (max)	Total serum PCBs[b], ppb wet weight, average (max)	Congener No. 153[c] ppb, lipid weight, average (max)
Lakes Huron, Michigan, and Superior (MS)	271	40 (15)	68%	95 (135)	62 (102)	1.1 (5.0)	3.1 (18.6)	91 (834)
Lake Superior (LS)	346	41 (13)	64%	104 (149)	60 (105)	1.6 (11.8)	2.1 (11.4)	67 (471)
Inland lakes (IN)	63	40 (12)	78%	74 (110)	46 (72)	2.0 (7.0)	1.4 (5.9)	34 (87)
Menominee (MN)	66	39 (12)	65%	47 (56)	34 (41)	2.0 (8.0)	1.4 (5.6)	36 (134)
Other reservations (OR)	76	43 (13)	49%	118 (192)	87 (223)	1.4 (4.0)	2.3 (6.8)	68 (475)
All tribal participants	822	41 (14)	65%	95 (140)	60 (113)	1.6 (11.8)	2.3 (18.6)	65 (834)
Totals analyzed	—	—	—	$N = 724$	$N = 720$	$N = 311$	$N = 269$	$N = 269$

[a] Based on all 822 participants completing questionnaires and post hoc recall of fish consumption.
[b] Based on 269 NCEH samples only using isotope-dilution high-resolution mass spectroscopy. MANCOVA tests for overall group (controlled for age) $F(4,263) = 5.132$; $P < 0.001$; $N = 269$. Contrasts IN versus MS, $P < 0.006$; LS versus MS, $P < 0.006$; MN versus MS, $P < 0.001$.
[c] MANOVA test for group (controlled for age) for Congener No. 153 serum concentrations (lipid weight), $F(4,304) = 5.886$; $P < 0.0001$; $N = 269$. Contrasts MS versus LS, $P < 0.048$; MS versus MN, $P < 0.001$; MS versus IN, $P < 0.002$; LS versus MS, $P < 0.012$.

tribes (IN group) focused almost exclusively on walleye (*Stizostedion vitreum*). The Menominee (MN groups) tribe is not known as a fishing-tribe. Their sampling covered a much wider range of possible species, and this sampling allowed us to create more comprehensive profiles across several species for this comparison tribe.

In all tribal grouping cases, the sampling matched the preferences reported by the tribal members of each group and summarized in Fig. 4. This report focuses primarily on the total mercury and PCBs results, but our laboratories analyzed most fish samples for several specific congeners and many other organochlorines (Dellinger et al., 1996; Gerstenberger and Dellinger, 2002). Due to the focus on mercury and PCBs in both the fish eaten and the human biological sampling, only the mercury and PCB methods are described here.

Fish collected and submitted from the Menominee tribe and by GLIFWC were analyzed at the University of Wisconsin's Lake Superior Research Institute under the direction of Larry Brooke (Brooke et al., 2001). For the Lakes Michigan and Superior tribal grouping, whitefish and lake trout were analyzed by the ITFAPs subcontractor, the Department of Fisheries and Oceans (DFO) in Burlington, Ontario (Canada). Also, a small number of walleye were submitted by ITFAP, allowing us to compare this one important species across all five tribal groups. In all cases, fish were collected and filleted by tribal fishermen using standard methods for skin-on or skin-off according to their preference (Dellinger et al., 1995).

2.5.1. Menominee fish collection

Samples of 10 fish species (103 fish total) were collected by the Menominee Indian tribe of eastern Wisconsin to characterize the fish normally eaten by the MN grouping. The 10 species included for the Menominee were northern pike (*Esox lucius*), walleye (*S. vitreum*), largemouth bass (*Micropterus salmoides*), brown trout (*Salmo trutta*), yellow perch (*Perca flavescens*), bluegill (*Lepomis macrochirus*), lake sturgeon (*Acipenser fulvescens*), white suckers (*Catostomus commersoni*), brook trout (*Salvelinus fontinalis*), and Kokenee salmon (*Oncorhynchus nerka*). Fish of similar sizes were homogenized to prepare 30 composite samples and are reported as separate data points.

2.5.2. Mercury in fish

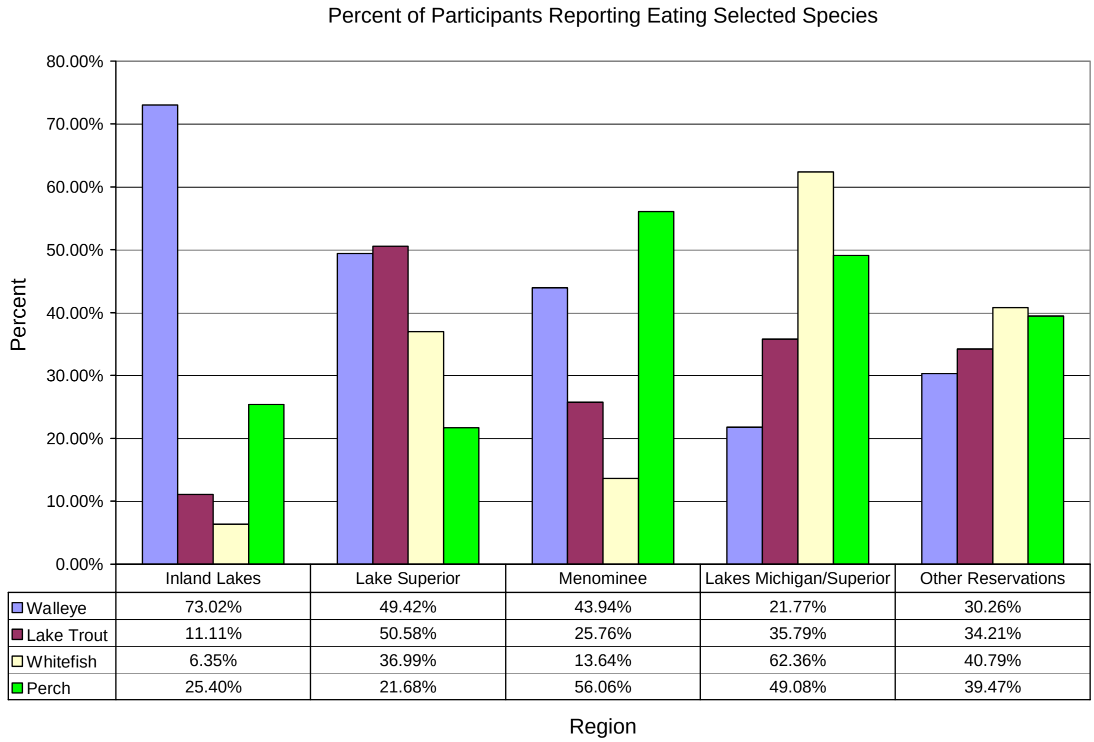
Composite samples of fish from GLIFWC and the Menominee were analyzed for total mercury using cold-vapor atomic absorption on a Varian, Inc. (Palo Alto, CA, USA) SpectroAA200 as described in Dellinger et al. (1995).

2.5.3. PCBs in fish

The Menominee and GLIFWC composite fish samples were also analyzed for PCBs and other organochlorines using a total-Arochlor-mixture method by En Chem. Inc. (Madison, WI, USA) on a Hewlett–Packard 5890 ECD with a detection limit of 50 μg/kg (ppb) (Brooke et al., 2001). For the Menominee composite samples, all 10 species (30 composite samples) were below the detection limits for total PCBs and are not reported in the results or figures.

2.5.4. Inter-tribal fisheries assessment program fish analysis for mercury and PCBs

ITFAP, as part of their normal assessments, and with partial support of the ATSDR/OHS project, provided analytical data for lake trout and whitefish between 1995



	Inland Lakes	Lake Superior	Menominee	Lakes Michigan/Superior	Other Reservations
Walleye	73.02%	49.42%	43.94%	21.77%	30.26%
Lake Trout	11.11%	50.58%	25.76%	35.79%	34.21%
Whitefish	6.35%	36.99%	13.64%	62.36%	40.79%
Perch	25.40%	21.68%	56.06%	49.08%	39.47%

Fig. 4. Reported fish species consumed by tribal groupings.

and 2001. Alternating between Lakes Superior, Huron, and Michigan, ITFAP collected 12 lake trout and 12 whitefish for each of four size groups ranging from 17 to 25 in (Group 1, 17–19 in; Group 2, 19.1–21.0 in; Group 3, 21.1–23.0 in; and Group 4, 23.1–25.0 in) each year for analysis. Fish were weighed, measured and inspected for ulcerations, lamprey wounds, tags, clips, or other assessment markings. Scales were collected for aging unless a wire code tag was present, and in that case the head was removed for later aging. The fish were wrapped in solvent, prerinsed aluminum foil (if for organochlorine analyses or directly into plastic if for mercury analysis) and then placed in plastic bags for freezing and shipping to DFO in Burlington, Ontario, Canada for subsequent analyses.

The results of those analyses were provided to the ATSDR/OHS project to help characterize the contaminants in the fish commonly eaten by the tribes near the Upper Peninsula of Michigan the (MS grouping). Although the DFO laboratory provided the tribes with data on lipids and many other organochlorines (including dioxins on the largest fish), only PCB and mercury results are being reported here. ITFAP annually prepares administrative reports with the complete analyses and provides them to the tribes (ITFAP, 2001).

2.6. Statistical analyses

The questionnaire data from Epi Info (2002) were summarized into Microsoft Excel spreadsheet database files and combined with the biological data (hair/blood mercury and serum organochlorine). Statistical Package for the Social Sciences (SPSS) crosstabs were used to summarize the variables for each tribal dietary/region grouping. Descriptive statistics and graphing of averages with either standard deviations (SD) or maximum values were used to characterize the five tribal groups. Inferential statistics used SPSS MANOVA to test for the difference between tribal groups for total PCBs (wet weight) and IUPAC Congener No. 153 (lipid corrected). The lipid-weight congener results were compared with a recent summary report by Fangstrom et al. (2002). The descriptive data were used to validate the groupings for subsequent and more detailed statistical and epidemiologic analyses.

3. Results

Fig. 4 summarizes the percentage of respondents who recalled eating four major species. While the questionnaire included far more species, we focused on the four most commonly consumed species: walleye, lake trout, whitefish, and perch. Fig. 5 depicts the months in which the tribal members ate the fish (based on member recall). Clearly, the IN group ate primarily walleye in the spring spearfishing season, with a peak harvest in April. The Lake Superior-only (LS) group ate as much lake trout as walleye and a moderate amount of whitefish across the months of March and the summer. The LS consumption

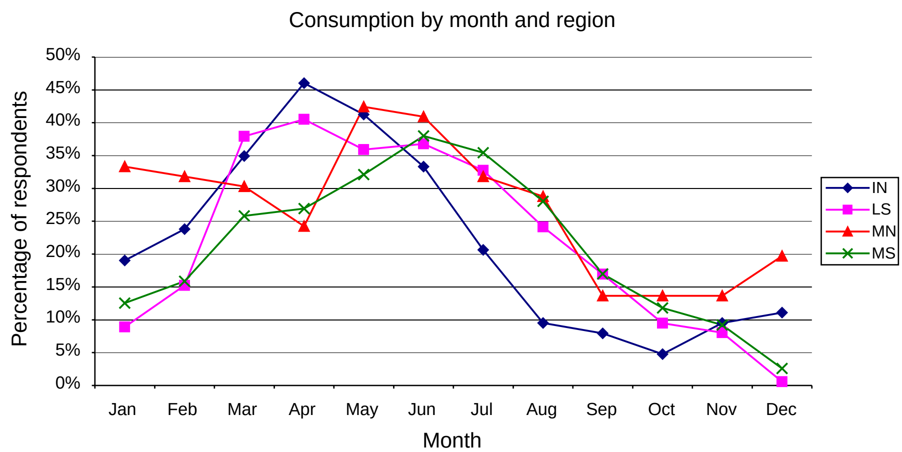


Fig. 5. Percentage of respondents reporting (based upon recall) fish consumption by month by tribal geographical regions.

pattern was very similar to that we reported for the GLPF study tribe, which also was located on the shores of Lake Superior. The MN group reported less consumption of each fish species but more perch than all other groups except the MS group. Menominee tribal members appeared to have two peaks in harvesting activity: the first during the winter ice-fishing period in January and the second during the spring opening of the fishing season starting in May. The MS group reported eating predominantly whitefish and perch, and their consumption peaked in the late summer when they harvested eastern Lake Superior, northern Lake Michigan, and Western Lake Huron. The other reservations (OR) group showed no clear preference for any of the four species, and their temporal consumption pattern was very similar to that of the LS group (not shown).

Similar to the findings of our earlier reports (Dellinger et al., 1996; Gerstenberger and Dellinger, 2002), organochlorines, like the PCBs, tended to accumulate in the larger piscivorous fish from the Great Lakes more so than in those from the inland lakes or the rivers harvested by the IN or MN groups (Fig. 6). The highest concentrations of PCBs were found in Lakes Huron and Michigan lake trout. In general, Lake Superior fish (especially whitefish) were very low in organochlorine residues. This was expected, since whitefish are not a piscivorous fish.

Mercury bioaccumulation was the greatest concern, but it was predictable regarding species and size (Figs. 7 and 8). Walleye in particular, due to their shallow water (polluted bays) feeding and spawning habits, tended to bioaccumulate the most mercury in even the more pristine-looking lakes such as Lake Superior and the smaller inland lakes. However, the average walleye had less than 0.5 ppm mercury. Not shown was that walleye, similar to all of the other species that we tested, had equal amounts (0.5 ppm) of selenium in the fillets (Groetsch et al., 2002). This may be important when one considers that selenium may be protective against

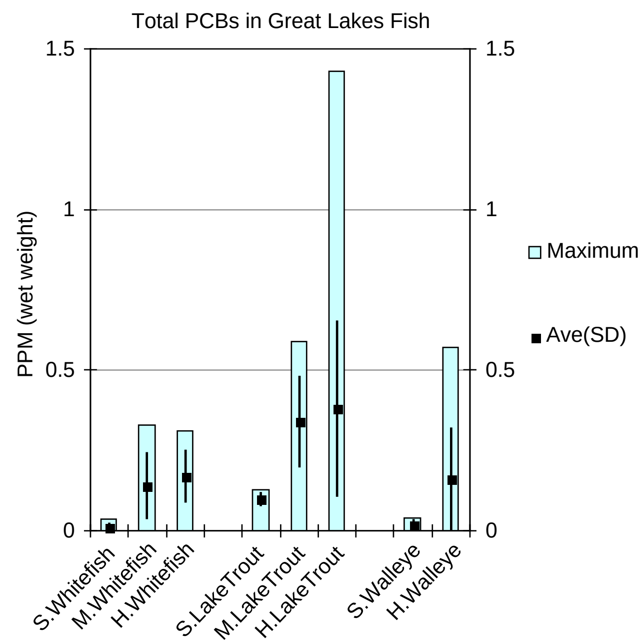


Fig. 6. PCBs in walleye, lake trout and whitefish (average with 1 SD and the highest concentration found, $N = 12$ per whitefish and lake trout groups; $N = 10$ for S. walleye; $N = 15$ for H. walleye). S., Lake Superior; M., Lake Michigan; H., Lake Huron.

some of the adverse effects of mercury (Lourdes et al., 1991). Fig. 7 summarizes only the larger walleye (>15 in) to compare the different tribal groupings because mercury (unlike selenium) accumulates in higher concentrations in the larger, older fish (Groetsch et al., 2002).

Results of the past decade of mercury analyses for the walleye of tribally harvested lakes were provided to the tribes via the GIS maps, routinely updated, and distributed to each tribe by GLIFWC (Fig. 1). The top map used the action level of 0.5 ppm for women who were of childbearing age or for children (<15 years), and the bottom map was based upon a level of 1.0 ppm

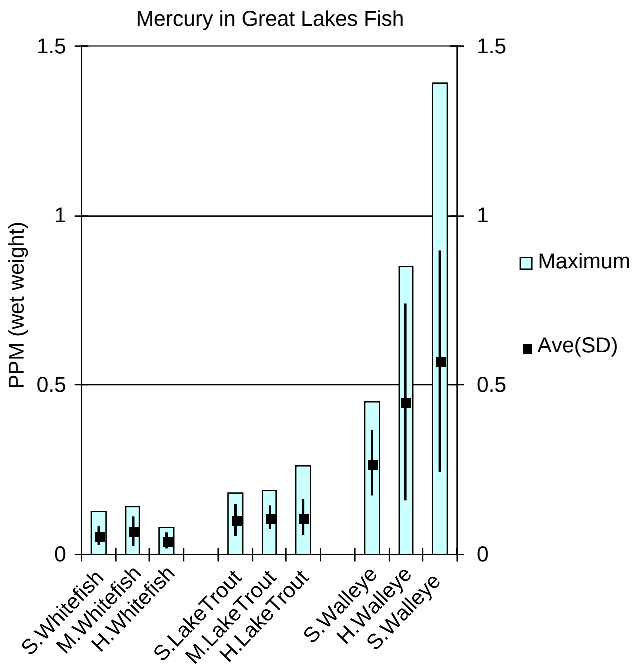


Fig. 7. Hg in walleye, lake trout and whitefish (average with 1 SD and the highest concentration found, $N = 12$ for whitefish and lake trout groups; $N = 10$ for S. walleye; $N = 15$ for H. walleye; $N = 24$ for S. walleye). S., Lake Superior; M., Lake Michigan; H., Lake Huron.

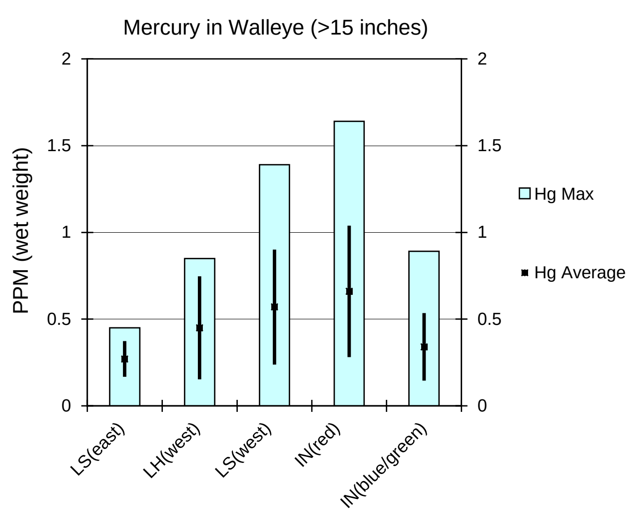


Fig. 8. Mercury in Walleye for LS(east), the eastern Lake Superior ITFAP sample group ($N = 10$); for LH(west), the Western Lake Huron ITFAP sample group ($N = 15$); for LS(west), the Western Lake Superior GLIFWC sample group ($N = 24$); for IN(red), the red lakes on GLIFWC maps ($N = 73$); for IN(blue/green), the blue and green-coded lakes on GLIFWC mercury maps ($N = 68$).

for adult men and women beyond childbearing years. These limits were based upon the earlier WDNR and US Food and Drug Administration (FDA) advisory limits for men (ATSDR, 1999). Red lakes on the GLIFWC maps indicated lakes where walleye should not be consumed, and walleye from dark blue and green lakes (hereafter referred to as "blue/green" lakes) were relatively low in mercury contamination and therefore safer to consume.

Fig. 8 also depicts how use of the GIS maps can significantly reduce the average concentrations of mercury ingested. The "red" and "blue/green" concentrations were based upon averages of only those walleye greater than 15 in in length from lakes with those color codes on the top maps (women/children, 0.5 ppm). Clearly, by following the tribally specific advisory, the tribal members can lower their average intake of mercury below 0.5 ppm and to the current US Environmental Protection Agency (EPA) advisory for human consumption of fish (0.3 ppm). Our other reported results indicate that these smaller and less contaminated walleye had the same amount of selenium, 0.5 μg Se/g, regardless of their size (Groetsch et al., 2002).

GLIFWC also collected 11 sturgeon from Lake Superior for analysis in June 1998 (Groetsch, 2002). The sturgeon ranged from 19 in (49.4 cm) to 39 in (99.4 cm) in length and from 3 to 7 years of age. The average mercury concentrations were 0.069 μg Hg/g (ppm), with a maximum of 0.133 ppm for these 11 fish. These young sturgeon were quite low in mercury. To compare the tribal fish to market canned tuna, four cans were purchased at a local market by GLIFWC and summarized in the Groetsch (2002) report as Lot No. TG KBSKB F227J, Can No. 1, 0.089 μg Hg/g, and Can No. 2, 0.066 μg Hg/g; Lot No. TG KSBKA F222J, Can No. 3, 0.404 μg Hg/g; and Lot No. TB KSBOCF266H, Can No. 4, 0.405 μg Hg/g. Wild rice samples were collected by GLIFWC from six lakes in 1995 and submitted for selenium analyses. The selenium was low, averaging 0.0089 μg Se/g (range of 0.0034–0.21 μg Se/g). The sample analyses for selenium in 24 walleye from Lake Superior (same fish as LS Superior in Fig. 7) resulted in an average of 0.618 μg Se/g (range of 0.486–0.713 μg Se/g) (Groetsch, 2002). Obviously, the walleye were an excellent source of dietary selenium.

The Menominee tribe, although not traditionally as reliant upon fish as the Ojibwe, have an excellent choice of relatively low-mercury fish species available for harvest and consumption (Fig. 9). This figure is for the 30 fish composite samples of various size groups (plotted separately). Therefore, tribal members should select the smallest northern pike and walleye for the women and children, but they may be relatively comfortable with consuming their traditional fish diets. Concurring with the GLIFWC sampling, the three Menominee sturgeon averaging 28 in. (71 cm) in length were relatively low in mercury.

The body burden indicators of mercury and organochlorines, hair and blood biological sampling, yielded moderately elevated concentrations that were not as high as those seen in earlier studies with Canada's aboriginal people. The highest concentrations in tribal

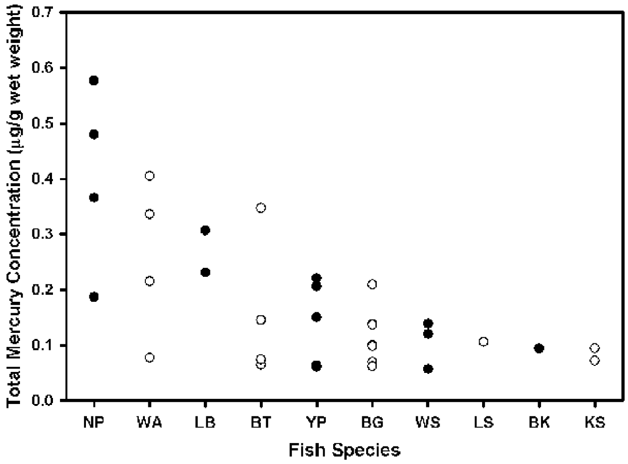


Fig. 9. Total mercury concentration in composite fillet samples of various species of fish captured during the autumn of 2000 by the Menominee Indian tribe. NP = northern pike; WA = walleye; LB = largemouth bass; BT = brown trout; YP = yellow perch; BG = bluegill; WS = white sucker; LS = lake sturgeon; BK = brook trout; and KS = Kokanee salmon (Brooke et al., 2001).

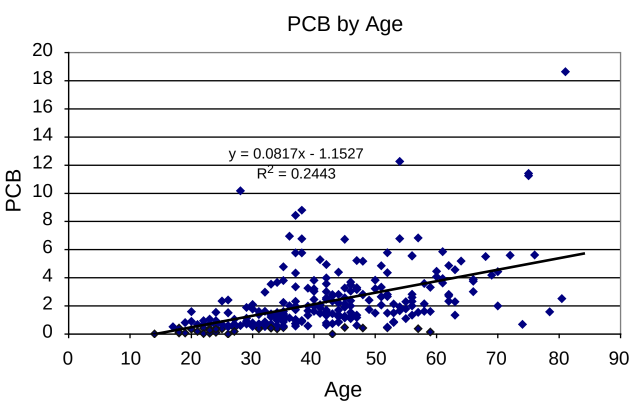


Fig. 10. Total serum PCBs by age.

participants were 18.6 ppb total PCBs and 11.8 ppb total blood mercury. Ninety percent of the participants had less than 3.8 ppb total PCBs and 2.6 ppb total blood mercury.

Fig. 10 is a plot of the NCEH IDMS results for total serum PCB concentrations versus age. Our GLPF study clearly indicated that age was a significant confounder, and the $R^2 = 0.24$ indicates a similar trend in the ATSDR/OHS data. When the single Congener No. 153 (usually the largest single PCB peak) was analyzed in a MANOVA with age as a covariate, the tribal groupings yielded significant differences between the groups on a wet weight basis (Table 1 contains the lipid-weight basis). The largest significant difference was between the MS and MN groups ($F_{(1,304)} = 14.274$; $P < 0.0001$). The MS versus OR and LS versus MN were also significantly different ($P < 0.006$ and $P < 0.049$, respectively). The differences between the MS versus OR, LS versus IN, LS versus OR, MN versus IN, MN versus OR, and IN versus OR were not significant ($P > 0.05$). The difference in the diet of Great Lakes fish versus of predominantly inland (non-Great Lakes) fish contributes the most to these differences, as expected, considering the contaminants in the fish in Figs. 6–9.

As expected, the diet-group contrasts for these differences were significant whether on a total PCBs (wet-weight) or on a Congener No. 153 (lipid-weight) basis. The lipid-corrected values (and MANOVA F ratios) are shown in Table 1 for Congener No. 153 (in ppb) for direct comparisons (see Section 4) to the Faroe Island, northern Quebec, Latvia, and Sweden data (in ppm) as published in Fangstrom et al. (2002).

Blood mercury correlated better than hair mercury (not shown) with reported fish consumption and matched the tribal dietary/region groupings (Fig. 4). Therefore, blood mercury is reported in Table 1. However, unlike our GLPF study, the total mercury values did not correlate with the dental amalgams (Fig. 11). Therefore, subsequent analyses will not use dental amalgams as a confounder. The highest blood mercury value recorded was 11.8 ppb, and 90% of the samples were less than 2.6 ppb. The overall average for all participants was 1.6 ppb, with the highest average of 2.0 ppb for both the IN and MN groups.

In Table 1, females represent 65% of the tribal participants, with the IN having more females (78%) and the OR having slightly more males (51%). The groupings resulted in broad ranges of ages with approximately the same average age (41 years ± 14 SD). Fish consumption based upon meals per year averaged 95 meals for all tribal members, with OR consuming an average of 118 meals per year and the Menominee averaging only 47 meals per year. Fish consumption (based upon recall) averaged 60 g/day, with a high of OR consuming 87 g/day and MN consuming only 34 g/day. These estimates had large standard deviations. The estimated grams per meal for the groups was 230 g/meal, which matched relatively

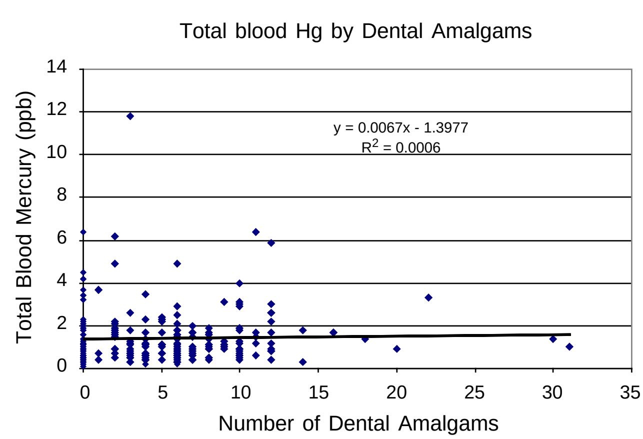


Fig. 11. Total blood mercury versus dental amalgams.

Table 2
"Actual" fish consumption by tribal members by dietary/geographical region

Group	Families/sites	Individuals	Average (g/day)	Highest[a] (g/day)	Meals/year (maximum)
Lakes Huron, Michigan, and Superior (MS)	2/1	12	4.2	4.2	12 (12)
Lake Superior (LS)	6/3	28	11.2	21.7	34 (70)
Inland lakes (IN)	10/4	54	8.2	17.5	26 (78)
Other reservations (OR)	14/3	53	7.6	13.0	14 (25)
Totals	32/11	147	8.2	50.0[b]	21.5 (78)

Source: GLIFWC (2003).
[a] The mean and highest values for several sites within a group.
[b] The highest value reported by GLIWC for any family of the 32 families (regardless of site) was 653 oz/person/year.

Table 3
Summary statistics for self-reported chronic disease (standardized per 100)

Group	Diabetes	Cancer	COPD	High blood pressure	Heart disease	Infertility	Kidney	Liver	Thyroid
Lakes Huron, Michigan, and Superior (MS)	10.0	2.6	3.0	21.0	5.5	2.2	0.4	0.4	4.1
Lake Superior (LS)	15.1	4.4	6.4	17.5	5.8	0.9	1.5	1.5	6.0
Inland lakes (IN)	19.0	4.8	6.3	14.3	4.8	0.0	5.6	0.0	6.0
Menominee (MN)	8.5	4.2	2.8	11.3	1.4	1.4	0.0	0.0	4.2
Other reservations (OR)	10.3	2.6	3.9	16.9	2.6	0.0	2.6	5.2	3.9
All tribal participants	12.7	3.6	4.7	17.8	5.0	1.2	1.3	1.2	5.0
Cases reported	$N = 105$	$N = 30$	$N = 39$	$N = 147$	$N = 41$	$N = 10$	$N = 11$	$N = 10$	$N = 41$

closely the value measured in our GLIFWC prospective study of 221 g/meal (GLIFWC, 2003). Both values were very comparable to the Wisconsin Division of Health estimate of 8.0 oz or 227 g per meal.

The prospective study conducted by GLIFWC for 1999–2002 resulted in the average tribal family member actually eating 1.8 fish meals per month for a total of 8.2 g/day per person (GLIFWC, 2003). The highest group average (based upon actual consumption) was the 11.2 g/day measured for the LS group (Table 2). The average meal size was quantified as 7.8 oz (221 g) when calculated for a total of 184 participants (including family members and guests).

Table 2 summarizes the "actual" consumption of fish by 32 families (147 tribal members) according to four of the tribal groupings. The Menominee tribe was not a part of this subproject. On average, the LS group (recorded by 6 families at three sites) consumed the most fish by averaging 11.2 g/day (highest site average of 21.7 g/day) in 34 meals. The IN group (recorded by 10 families at four sites), with the highest walleye consumption, consumed 8.2 g/day (highest site average of 17.5 g/day) in 26 meals. The lowest measured consumption (only 2 families from one site for this group) was for the MS group, with 4.2 g/day in 12 meals. Therefore, actual fish consumption averaged 8.2 g/day and ranged from a low of 4.2 g/day to a maximum of 21.7 g/day, which at the maximum measured is three times less than the recall values in Table 1. Even the maximum family average was 50 g/day and less than the overall recall average in the ATSDR/OHS.

In Table 3 the differences in self-reported chronic diseases are summarized. Regardless of the small numbers and the uneven distributions of participants, there were a few notable patterns. Diabetes ranged from 8.5 cases/100 for MN to 19% for the IN group. Interestingly, these two groups were very similar in Table 1 statistics. Cancer ranged from 2.6% for the MS and OR groups to a high of 4.8% for the IN group. This was the reverse of the expected trend if PCBs in fish were expected to increase cancer. However, chronic obstructive pulmonary disease (COPD defined by the respondent as persistent cough, emphysema, or chronic bronchitis) was also high in both the IN and LS groups, where cancer was highest. Therefore, it was more likely that smoking was responsible for the excess cancer rates for these two groups. The MS group reported the highest blood pressure and infertility problems. Kidney disease was most commonly reported (5.6%) by the IN group, and liver disease was most commonly reported by the OR group (5.2%), which also had the highest ratio of male participants (51%).

4. Discussion

The data provided in Figs. 4–8 support our earlier published composite samples for Great Lakes fish and inland walleye. They also provide chemical contaminant characterizations that allow comparisons to species eaten (Fig. 4) and the body burden indicators found in Table 1. For example, the IN and LS groups would be expected to have the higher accumulation rates for mercury rather than the organochlorines since they ate more walleye, the walleye being highest in mercury, and the Lake Superior fish were less contaminated with PCBs. That trend was noticeable, plus the MN group was eating fish low in PCBs and also accumulating the least amount of PCBs. In contrast, the MS group would be expected to accumulate the highest amounts of PCBs and the least amounts of mercury, and this indeed was the trend when we compared blood mercury to serum PCBs.

The range and maximum values for the PCBs reported in Table 1 were similar to those reported for 192 Wisconsin anglers who had a mean of 2.2 ppb with a maximum of 27.1 ppb (Fiore et al., 1989). A specific comparison of the single Congener No. 153 on a lipid-weight basis to Fig. 3 in Fangstrom et al. (2002) illustrated that the PCB serum concentrations in the ATSDR/OHS were considerably less than those published for the Faroe Islands, Northern Quebec, and Latvia. Our highest value for IUPAC No. 153 of 834 ppb in the MS group was approximately equal to that found in the Northern Quebec and Latvia groups, but still well below the mean of the Faroe Islands moderate/high-consumers (two to eight meals per month) group of 1500 ppb.

Overall, the LS group closely matched the consumption and contaminant (both fish and human) results reported earlier for our GLPF study, and this was expected since the former reservation was colocated with the ATSDR/OHS LS group reservations. Also, the GLPF study provided data that diabetes was a major concern, and similarly we observed an increased prevalence for diabetes in the ATSDR/OHS LS and IN groups. In fact, the GLITC Community Health Profile for the Minnesota, Wisconsin, and Michigan tribal region found that in a medical chart review, over 95% of the tribal members had had diabetes screening. Approximately 20% of those screened had greater than a 9.5% on the hemoglobin A1c test, which is indicative of poor blood sugar control and diagnostic for diabetes (GLITC, 2002). Therefore, the range of 8.5–19.0% reported by ATSDR/OHS respondents was expected. This diabetes indicator confirms that diabetes is a major health concern for this study population. We reported earlier that Wisconsin Native Americans experienced 107 diabetes-related deaths between 1986 and 1995, and this was an excess of 70 deaths over nonnative people of Wisconsin for the same time period (Tavris et al., 1999).

The data in Table 3 indicates that the Menominee tribe was less affected by chronic disease (other than cancer) morbidity than the other groups. One must be cautious about this assumption because the data collection at most tribal sites was limited to those who attended tribal health fairs. Local tribal health officials may have recruited a broader segment of the population while gathering Menominee data at tribal powwows only and not at health fairs. Last, there were less than 100 participants for the MN, IN, and OR groups.

The trends in these small samples of participants provide evidence that the biggest health concerns for the tribes revolve around diabetes and high blood pressure (Table 3). Smoking and obesity are well known to increase the risk of heart disease and diabetes, respectively. Meanwhile, fish consumption is thought by many to decrease the risk of heart disease, especially in traditional tribal diets such as that of the James Bay Cree (Dewailley et al., 2002). The LS and the IN groups have high COPD and diabetes problems that would tend to take precedence over concern for the adverse health effects from eating fish at or below the FDA advisory level. The FDA advises women to limit the consumption of fish with up to 0.5 ppm Hg to 14 oz per week or with up to 1.0 ppm Hg to 7 oz per week (ATSDR, 1999). Clearly, canned tuna and other market fish can contain amounts of mercury similar to that found in their traditional diet of walleye. By following the GLIFWC GIS maps, these tribal members can reduce their mercury intake to well below the usual action level of 0.5 μg Hg/g (Fig. 8).

The ATSDR Minimal Risk Level (MRL) of 0.3 μg/kg/day for long-term chronic ingestion of methylmercury-contaminated fish is an appropriate benchmark for tribal women and children since it is based upon subtle neurodevelopmental effects in children (ATSDR, 1999). This MRL is midway between the EPA reference dose (RfD) of 0.1 μg/kg/day and the WHO criteria of 0.47 μg/kg/day (ATSDR, 1999; WHO, 2000; Clarkson, 2002). Assuming the worst-case scenario for methylmercury exposures of the IN tribal members (78% female) eating only walleye with an average consumption rate of 46 g/day, the average 70-kg tribal member would consume 0.6 μg/kg/day if the fish were at 1 ppm. At a more realistic fish mercury concentration of 0.5 ppm, the overall approximate average for all walleye groups (shown in Figs. 7–8), the average tribal member would consume 0.3 μg/kg/day, which is equivalent to the ATSDR MRL for methylmercury. By consuming only from the blue/green lakes a woman or child could further reduce her or his average exposure to 0.15 μg/kg/day.

Therefore, the consumption rates and contaminant levels determined from the questionnaires in the

ATSDR/OHS do not exceed the MRL for methylmercury if the tribal members follow the GLIFWC GIS mercury maps. If one makes the same calculations based upon the actual consumption numbers in Table 2 of 8.2 g of fish per day and 1.8 meals per month (21.5 meals/year) (GLIFWC, 2003), the consumption rate drops to well below even the current EPA RfD of 0.1 μg/kg/day. The ratio of recall fish consumption to actual consumption (60 g/day versus 8.2 g/day) was similar to that reported by Loranger et al. (2002), who reported that anglers in Quebec actually ate six times less than their recall estimates.

The only group eating above the ATSDR MRL (based upon estimated recall in the ATSDR/OHS project, Table 1) were the OR group individuals, for whom a higher proportion of males were reported to eat 118 meals per year (approximately 2.5 meals per week). The OR group will exceed the advisory limit for methylmercury if they eat only very large walleye at 1 ppm, and they should restrict themselves to the more conservative 0.5 ppm advisory limit if they eat a large quantity of walleye or similarly contaminated fish species.

Therefore, the beneficial effects of omega-3 fatty acids and the protective effects of selenium provide healthy benefits that should be weighed against the increased risk of exceeding the MRL for methylmercury. The average ATSDR/OHS participant was self-reporting that he/she eats 95 meals per year (approximately 2 meals/week), or eight times the WDNR advisory recommended 1 meal per month if the fish is walleye and/or sturgeon. The tribes are not experiencing a large body burden of either mercury or PCBs, as indicated by blood residues. However, the adverse health consequences due to obesity, diabetes, and heart disease due to further departure from their traditional fish diet makes switching to a market-based diet a risky health adventure. The small sample of canned tuna (four cans) analyzed by GLIFWC yielded a range from 0.066 to 0.405 μg Hg/g of tuna. Thus, switching to 1 canned tuna meal per week (as "allowed" by the WDNR) may not be better than the fish that they would traditionally eat.

The OR group, which was reportedly eating 2.5 meals per week, was reporting less heart disease, less cancer, and less diabetes than the other groups. Therefore, in this limited study, there was no evidence that exceeding the MRL places them at a higher risk than the other groups. The exception for this group was liver disease, but a higher proportion of males and a higher intake of alcohol may explain that difference. The increased kidney disease and diabetes for the IN group indicate that these are major issues for the tribes but are unlikely related to their fish consumption. Diabetes especially, is a confounding issue of major importance to these tribes (Tavris et al., 1998). Subsequent analyses of this data set should examine the associations (if any) between chronic disease indicators (self-reported and GLITC profile data) and body burden indicators (e.g., mercury and PCBs, separately and together).

4.1. Limitations of this study

The data collection at tribal health fairs led to more female participants and, perhaps, people who were having more health problems. The low and unbalanced sample size could affect the statistical testing and subsequent interpretations.

Although not a random sampling (female biased), the research was deemed relevant because the major concern was female health and the development of the unborn fetus.

5. Conclusions

The tribal dietary/region groupings clearly delineate the differences in fish species eaten, Hg/PCB concentrations in biological samples, and differences in self-reported chronic disease. The Menominee and Inland groups had very similar dietary exposures and body burdens, but very different chronic disease profiles. Future analyses or studies will provide data indicating whether these differences are due to genetics, lifestyle, or environmental factors. The tribal dietary/region groupings will be used in subsequent and more detailed analyses of the data for epidemiology, exposure assessments, and risk analyses. Those future analyses will include interactions between body burden indicators and chronic disease indicators. This report concentrated only on the risk associated with mercury exposures because that was the basis for lowering of the WDNR fish consumption advisory and because some tribal groups were consuming large amounts of walleye. PCB fish concentrations in both the fish and the tribal members were low but must be examined more closely from a risk assessment point of view.

While tribal members were moderately high fish consumers, they are not currently exhibiting high blood mercury or PCB concentrations in their biological samples compared to those of other past and similar studies. Selenium from two traditional diet sources (wild rice, with low amounts, and fish, with an average of approximately 0.5 ppm) may mitigate the adverse effects of mercury and may be a natural buffer.

Compared to other studies of subsistence fishing populations, these exposures were only moderately elevated and not high enough to warrant widespread restrictions of diets. Furthermore, the benefits from eating a fish diet must be continually emphasized. Fish is lower in fat and provides more omega-3 fatty acids and other nutrients compared to alternative protein sources. The tribes may elect to consume the traditional fish diet at or above the MRL if the other beneficial factors described here outweigh the risks from the contaminants. Meanwhile, every effort must be made to reduce persistent organic pollutants (POPs), especially regarding anthropogenic emissions of mercury so that the tribal fisheries are less threatened and so that the tribe members can return to a more healthy and traditional diet.

As part of this investigation, the health profile for each Native American community, including the risks for excess morbidity and mortality from heart disease, cancer, diabetes, and other serious chronic illnesses, is being studied relative to the dietary exposures to POPs in the fish diet. Furthermore, there are other social and cultural values regarding traditional diets of fish and game that should be considered. Fishing is a family and community bonding experience that could provide the social stability (Wheatley, 1996) that will prolong life beyond the extent that the POPs will shorten it.

By collecting and measuring the concentrations of these pollutants in the fish normally eaten, one can develop risk management strategies to limit the uptake through the human diet. This does not necessarily mean that the fish need to be eliminated from the diet of the tribal members. In fact, a comprehensive risk assessment must take into consideration the beneficial effects of consuming traditional fish diets versus the alternative "market" diet (Egeland and Middaugh, 1997). In many cases the traditional fish diet (including the known contaminants) may in fact be healthier than the alternative store-bought (market) diet, which is known to be higher in less healthy saturated fats and lower in omega-3 fatty acids and to contain other undocumented contaminants (Kuhnlein et al., 2000). These traditional diets with their higher omega-3 fatty acid content may in fact contribute to a reduced risk of cardiovascular disease (Dewailley et al., 2002). Heart disease is the largest mortality category for excess Native American deaths for Wisconsin Native Americans (Tavris et al., 1999).

Therefore, publishing health hazard warnings based solely upon contaminants in the diet without considering the benefits is dangerous and should be avoided (Wheatley and Paradis, 1996). Many Canadian and Alaskan studies have addressed these issues in the past regarding aboriginal people, their diets, the health benefits/risks of traditional diets, and the social impacts of fish consumption advisories (Egeland and Middaugh, 1997; Wheatley and Wheatley, 2000; Kuhnlein et al., 2000; Dewailley et al., 2002).

In general, the continental USA seems to be focused on restricting dietary exposures without regard to the cultural/social issues that are so important to the tribes. For example, the recently promulgated fish consumption advisory for the state of Wisconsin, lowering the advisory criteria by 10-fold, placed All Wisconsin waters under the advisory (WDNR, 2002). "Women of childbearing years, nursing mothers and all children under 15 may eat..." (WDNR, 2002, p. 9) one meal per month of walleye or sturgeon (both are traditional and culturally important tribally harvested species). Simultaneously, the advisory allows the consumption of one can of tuna per week. While this advisory may be appropriate for Wisconsin sport anglers such as those characterized by Fiore et al. (1989), it is very difficult for tribal members to follow this advice and continue to consume fish in the traditional amounts, as measured in our earlier studies (Gerstenberger et al., 1997).

Therefore, this study has assisted the tribes in weighing the risks versus the benefits of traditional fish consumption practices, and it has provided specific harvesting advice by helping to fund the GLIFWC tribally specific GIS maps (Fig. 1). The data presented in this report demonstrate that the GLIFWC intervention strategy can help substantially limit exposure while maintaining fish as an important dietary source of protein and of important nutrients such as the omega-3 fatty acids.

Tribal members should "choose wisely" by following the WHO advice. The strict adherence to WDNRs advisory may lead to other health risks by diverting individuals to highly processed supermarket diets instead of more traditional fish diets. The GLIFWC GIS mercury maps are an excellent method for helping the Inland lake walleye consumers choose wisely and cut their intake of mercury nearly in half (comparing IN(red) to IN(blue/green) in Fig. 8). However, sport fishermen and their families who consume larger and more contaminated fish should abide by their state fish consumption advisories to minimize their health risks.

In summary, we must not forget what Paracelsus taught us in the 16th century: "What is there that is not poison? All things are poison and nothing (is) without poison. Solely the dose determines that a thing is not a poison" (Klassen, 2001). Fish can be considered within the clinical concept of a therapeutic window. Eating some fish is an important component of a healthy diet, but like everything else, moderation can be prudent.

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