Chapter-21

DEVELOPMENT OF PROGRAMS TO MONITOR METHYL-MERCURY EXPOSURE AND ISSUE FISH CONSUMPTION ADVISORIES

Henry A. Anderson[1] and Jeffrey D. Bigler[2]

[1] *MD Chief Medical Officer, Wisconsin Division of Public Health, Madison, WI, USA*
[2] *National Program Manager, National Fish and Wildlife Contamination Program, USEPA, Washington DC, USA*

INTRODUCTION

Regular consumption of fish (1 – 2 meals per week) has been associated with substantial reduction in the risk of death from heart attacks (Daviglus et al., 1997; Albert, 2002). The health benefit attributed to a diet rich in fish and fish oils has led public health authorities to promote a balanced diet containing two meals of fish per week (AHA, 2000). Worldwide, fish and shellfish as a dietary source of protein is rapidly expanding such that fish consumption is estimated to have surpassed other animal dietary protein sources such as beef and fowl. Unlike domesticated beef and fowl that are farm produced for general population consumption, fish and shellfish are primarily harvested from the wild. Aquaculture is rapidly growing in importance but remains limited and currently only provides a small proportion, perhaps 25% of fish and shellfish consumed worldwide. The diet and geographic movement of wild fish harvested for commercial sale can not be controlled. Many sought after fish are large predators at the top of the food chain. Because of their unrestricted movement and opportunistic diet, wild fish are vulnerable to accumulating bio-persistent pollutants circulating in the environment. Methylmercury is one of those chemicals.

It is estimated that anthropogenic sources have contributed to a 2 to 5-fold increase in the global circulating pool of atmospheric mercury. Atmospheric inorganic mercury is deposited in aquatic systems where bacterial methylation converts the inorganic forms of mercury to methylmercury. Biomagnification of methylmercury results in levels in fish that are 10^4 to 10^6 times higher than levels in water (US Environmental Protection Agency, 1997)

Governmental Response to Methylmercury Fish Contamination

Fish and shellfish consumption is the predominant source of methylmercury exposure to humans. Recent epidemiological studies (NRC, 2000) have led to the conclusion that methylmercury is more toxic than previously recognized, especially in-utero exposures which are expressed as later neurodevelopment delay. Utilization of these studies in risk assessments has resulted in the reduction of acceptable human exposures (U.S. EPA, 2001; JECFA, 2003).

Market basket surveys of methyl mercury in commercial foods and surveys to establish population consumption distributions by fish and shellfish species allow exposure assessment analyses. Estimated exposures can then be compared to the target risk thresholds. Human studies of blood or hair mercury distributions in populations have confirmed the exposure assessments and have led governmental scientists to conclude that there is a slim margin of safety for a significant proportion of the population (Mahaffey et al., 2004).

Up until the recent reduction in the acceptable daily or weekly methylmercury exposure, national governments relied upon regulatory approaches to remove the most highly contaminated fish from commerce. In the United States the Food and Drug Administration "action level" has been at 1 ppm methylmercury in fish tissue for several decades. Fish found to exceed that "action level" could be removed from interstate commerce. In the European Union, most fish have a tolerance of 0.5 ppm and initially a small number of less frequently consumed fish were given a 1 ppm tolerance. Increased numbers of commercial fish species, changing catch locations, as well as increased monitoring of fish tissue mercury concentrations have created the need for the European Union (EU) to increase the number of fish species needing a tolerance of 1 ppm to remain on the market. The number of "1 ppm exemptions" has risen to 22 species.

In 2001 the USEPA RfD was reduced from 0.3 ug/kg/day to 0.1 ug/kg/day and in 2004 the EU's provisional tolerable weekly intake (PTWI) was reduced from 3.2 to 1.6 ug/kg/week. These changes required a modification of the current regulatory approach if current commercial fisheries were to remain viable while at the same time excess methylmercury exposures prevented. If individuals consumed the recommended amount of fish per week but chose higher mercury fish, exposures could significantly exceed recommended levels (Knobeloch et al., 1995). The consumer passive regulatory approach could no longer assure that a significant proportion of the general population would not exceed the new toxic thresholds.

National governments have responded to the likelihood that 5-10% or more of their population may be exceeding the hazard threshold for methylmercury with an approach that includes the use of commercial fish consumption advisories. Based upon the epidemiology studies these advisories have generally been targeted to protect the most vulnerable segment of the population, pregnant women and their developing fetus.

Each country has a different mix of subpopulations that are likely to consume more fish than the average. Such groups include commercial fisherman, coastal residents, recreational fisherman, ethnic and indigenous groups with traditional diets high in fish and individuals seeking a high fish diet for the reported heath benefits. For many countries, national consumption advisories appear to have become the principal exposure reduction strategy to protect their citizens from excess methylmercury exposure and toxicity.

Although many commercial species have worldwide markets, other fish are local. Concentrations of pollutants such as methylmercury in the fish tissue may also vary by the location where the fish reside and the size/age of the fish. This variability necessitates consumption advisories tailored to the consumption patterns and fish in commerce in each country.

There is no readily available source to locate all the national fish and shellfish consumption advisories that have been issued, to obtain the advisory development protocols, or to review evaluations of such programs. Table 1 provides a summary of characteristics of examples of such advisories. Most of these can be found on governmental web pages. Not included in the table are the positive statements all advisories include concerning the benefits of fish consumption and the recommendation to include at least 2 fish meals per week.

Eleven of the 12 countries listed in Table 1 address mercury contamination in their advisories.

Only 4 include other contaminants, specifically PCB and Dioxin. Taiwan only addresses PCB in recreational fish skin, liver and eggs. All but Taiwan address commercial fisheries. There is a commonality in the target populations. All countries address women of childbearing age, but there are some differences in how the population of women are defined. Most consistent is the direct mention of pregnant and lactating women. Fewer advisories mention infants or young children. Only three, Sweden, Taiwan and Canada include advice for the general population. All countries issue advice on how frequently fish can be consumed in terms of meals per week or month. Only Finland, Great Britain, Norway, Sweden and the United States include advice to not consume some species. The most commonly mentioned species are swordfish and shark. Nearly all advisories include these species and these are the species most commonly mentioned as "no consumption" for women of reproductive years. Countries whose populations consume whale meat typically include these on there advisories.

Recreational Fisheries

Many countries have a thriving freshwater and or marine recreational fishery that typically is carefully managed and often involves the issuing of recreational licenses and permits to fish specific waters. Such licenses and the regulation pamphlets are a convenient means to inform anglers of advisories. Some segments of the population may also rely upon these locally available fish resources for subsistence. Such groups are indigenous populations or immigrants from countries with a tradition of fish consumption. Six of the countries in Table 1 address recreational fish in their advisories. Countries are just beginning to comprehensively address fish consumption and to explicitly include sport-caught fish as part of their commercial advisory.

Wisconsin, USA: An example of a Comprehensive Fish Consumption Advisory Program

Thirty-five years ago mercury was identified in freshwater sport fish found in many states bordering the Great Lakes (Konrad 1970; Kleinert et al., 1972). From a national perspective, contamination was felt to be limited

Table 1. Worldwide National Fish Consuption Advisories.

Country	Water body Type	Year	Agency	Commercial Recreational	Pollutant	Species	Population of Concern	Meal Advice	Comments
European Union	Marine	2004	EU Commission EU Food Safety Authority (EFSA)	Commercial	Mercury	Swordfish, shark, tuna, pike	Women who might become pregnant, who are pregnant, who are breast-feeding, young children Women of childbearing age	Should not eat more than one small portion (<100g) per week of large predatory fish, such as swordfish, shark, marlin and pike. If they eat this portion they should not eat other fish during this period. Also they should not eat tuna more than twice per week. Consumers should pay attention to any more specific advice from national authorities in light of local specificities. Recommends that women of childbearing age select fish from a wide range of species, without giving undue preference to large predatory fish such as swordfish and tuna	
Denmark	Marine	2004		Commercial	Mercury PCB	Tuna, Halibut, Swordfish, Porbeagle shark, Pike Perch, Zander, Escolar, Ray	Pregnant and lactating women	Pregnant and lactating women should not eat large portions of listed fish All individuals should eat 1-2 meals of fish per week.	One can eat limited amounts of these fish. For example, tuna salad is not harmful, but one should avoid a whole tuna steak. Pregnant and lactating women can eat all other common fish without problems.
Finland	Marine Fresh Water	2004	National Nutrition Council	Commercial Recreational	Mercury PCB, Dioxin	Large Baltic herring and wild caught salmon; Pike and fish from inland waters, Pike from sea, Pike from inland waters	Children, young people, people at fertile age Pregnant women and nursing mothers	Once or twice a month Do not eat	For those who eat fish from inland waters on an almost daily basis should reduce consumption of large perches, pike perches, burbots (due to Hg) Farmed fish low in PCB, Dioxins

Table 1. cont'd.

Country	Water body Type	Year	Agency	Commercial Recreational	Pollutant	Species	Population of Concern	Meal Advice	Comments
Great Britain	Marine waters	2004	UK Food Standards Agency	Commercial	Mercury	Shark, swordfish, and marlin	Pregnant women, women of childbearing age who intend to become pregnant, infants, and children	Avoid eating	
Great Britain						Tuna	Pregnant women, women who are trying to become pregnant	Eat no more than four medium sized cans with a drained weight of 140g per can or up to two fresh tuna steak per week	
Norway	Marine waters	2003	Norway's National Veterinary Institute Scientific Panel	Commercial	Mercury	whale meat	Pregnant women and mothers who are breast feeding	Do not eat	The findings of the scientific panel must be approved by the Norwegian health authorities
Sweden	Marine and fresh waters	2004	National Food Administration	All	Mercury POP	Pike, perch, pike-perch, burbot, eel, large halibut, Baltic - herring, salmon	All	Eat no more than once a week	
Sweden	Marine and fresh waters		National Food Administration	All	Mercury POP	1. Pike, perch, pike-perch, burbot, eel, large halibut, 2. Baltic herring or salmon	Women of childbearing age who intend to become pregnant, infants, and children under 16 years of age	1. Eat no more than once a week 2. Eat no more than once a month	
						1. Pike, perch, pike-perch, burbot, eel, large halibut, 2. Baltic herring or salmon	Pregnant women	1. Do not eat 2. Eat no more than once a month	

Table 1. cont'd.

Country	Water body Type	Year	Agency	Commercial Recreational	Pollutant	Species	Population of Concern	Meal Advice	Comments
Australia and New Zealand	Marine waters	2001	Food Standards Australia and New Zealand (FSANZ)	Commercial	Mercury	shark, ray, swordfish, barramundi, gemfish, orange roughy, ling, and Southern bluefin tuna.	Pregnant women and women considering pregnancy	Limit consumption to four (150 g) meals per week	Pregnant women can eat as much other fish, including salmon, canned salmon and canned tuna as they like
	Fresh-waters			Recreational	Mercury	Freshwater fish caught in geothermal waters	Pregnant women and women considering pregnancy	Limit consumption to four (150 g) meals per week	Pregnant women can eat commercial fish as prescribed
Japan	Marine waters	2003	Health, Labor and Welfare Ministry	Commercial	Mercury	Broadbill swordfish and alfonsino	Pregnant woman	No more than two 60-80g servings per week	Fish tissue data also provided in press release
						Bottlenose dolphin	Pregnant woman	No more than one 60-80g serving every 2 months	Fish tissue data also provided in press release
Japan						Baird's beaked whale, short-finned pilot whale, sperm whale, and shark meat	Pregnant woman	No more than one 60-80g serving per week	Fish tissue data also provided in press release
Taiwan	Fresh-waters	2000	Taiwan EPA	Recreational	PCB	fresh water species	All consumers	Do not eat fish liver, skin, and eggs	There is no official fish advisory in Taiwan; just a soft recommendation
Canada	Marine waters	2002	Health Canada	Commercial	Mercury	shark, swordfish, fresh and frozen tuna	All consumers	Limit consumption of shark, swordfish, and fresh and frozen tuna to one meal per week	Note that this advisory does not apply to canned tuna
Canada	Marine waters	2002	Health Canada	Commercial	Mercury	shark, swordfish, fresh and frozen tuna	Pregnant women, women of childbearing age, young children	Limit consumption of shark, swordfish, and fresh and frozen tuna to one meal per month	Note that this advisory does not apply to canned tuna

Table 1. cont'd.

Country	Water body Type	Year	Agency	Commercial Recreational	Pollutant	Species	Population of Concern	Meal Advice	Comments
United States	Marine & Fresh-water	2004	USEPA and USFDA	Commercial	Mercury	shark, swordfish, king mackerel, tilefish	Women who may become pregnant, pregnant women, nursing mothers, young children	Do not eat	"Do not eat Shark , Swordfish, King Mackerel, or Tilefish because they contain high levels of mercury"
					Mercury	All other fish	Women who may become pregnant, pregnant women, nursing mothers, young children	"Eat up to 12 ounces (2 average meals) a week of a variety of fish and shellfish that are lower in mercury"	"Five of the most commonly eaten fish that are low in Hg are: shrimp, canned light tuna, salmon, pollock, catfish. Another commonly eaten fish, albacore ("white") tuna has more mercury than canned light tuna. When choosing your two meals of fish and shellfish, you may eat up to 6 ounces (one average meal) of albacore tuna per week.
				Recreational	Mercury	All sport caught fish species	Women who may become pregnant, pregnant women, nursing mothers, young children	"Check local advisories about the safety of fish caught by family and friends in your local lakes, rivers, and coastal areas. If no advice is available, eat up to 6 ounces (one average meal) per week of fish you catch from local waters, but don't consume any other fish during that week."	

to local fresh waters and involve recreational fish species rather than commercial species. No national advisories were developed. However because of the importance of consumption of locally caught fish, individual states, including Wisconsin began active fish tissue monitoring programs and state public health authorities linked the test results with consumption frequency advice for sport caught fish. A similar program occurred in the Canadian Province of Ontario. By 2002, 48 states issued advisories for sport-fish consumers. Mercury is the most common contaminant covered by a state advisory (USEPA, 2003). In the United States, states have responsibility for recreational fisheries and the federal government regulates commercial fisheries. Although similar during the 1970s and most of the 1980s, in the 1990s many states and the US federal government began using different methods to assess chemical toxicity and translate it into advice for fish tissue levels of concern (Anderson and Liebenstein, 1989; Anderson et al., 1993). The recently revised mercury toxicity assessments led to a renewed focus on mercury contamination in fish tissue and state recognition that issuing consumption advice only for sport-caught fish while ignoring the exposure contribution from commercially consumed fish did not make sound public health practice. Over the past three to four years, some states began issuing comprehensive fish advisories that included both sport-caught and commercial fish. Currently twelve states include recommendations for commercial fish in their sport fish consumption guidelines.

There is general agreement that a comprehensive fish consumption advisory program should include: 1. Public health surveillance and reporting of mercury poisoning (health care delivery system reporting) and high exposures as measured in whole blood or hair total mercury (laboratory based surveillance); 2. Fish tissue biomonitoring; 3. Advisory development; 4. Advisory evaluation.

Public Health Surveillance

While physician and laboratory reporting is far from comprehensive, case reports are often illustrative of situations that need to be addressed and assist in raising public awareness. Wisconsin has encouraged case reporting and since 1992 has investigated 7 instances of excessive mercury exposure from fish consumption. Cases involved both commercial fish consumption (Knobeloch, 1993) and sport fish. Exposures ranged up to an estimated 100 ug per day of methymercury. With the increased awareness of and concerns for mercury, more hair and blood testing has begun. In the last 2 years there have been three case investigations.

Fish tissue monitoring

Wisconsin has 40,000 miles of rivers and 15,000 lakes. With a limited sample collection capacity and laboratory analysis budget, it was necessary to devise sampling strategies. When in the early 1970s mercury was recognized as a fish contaminant of concern (Konrad, 1970; Kleinert and Degurse, 1972) the Wisconsin Department of Natural Resources (WDNR) been systematically monitoring mercury concentrations in Wisconsin fish (Michaels and Schrank, 2003).

Initially the monitoring strategy focused on rivers receiving effluents from mercury discharging industries. Later, in the 1980s, testing from northern lakes receiving no effluents became the focus when a number of northern Wisconsin lakes had been found to have among the highest mercury concentrations found in predator fish. In the decade of the 1990s monitoring began on a statewide basis using a scheduled rotating basin approach. This strategy involved sampling sites within the major river drainage basins on a five year rotating schedule.

In 1999, a new monitoring strategy called "baseline monitoring" was devised for lakes, wadable, and non-wadable streams and rivers. Fish are being collected for contaminant analysis at a subset of baseline sites where limited or no fish contaminant data exist or where updated information is required. The goal of this strategy is to obtain a statewide distribution of fish contaminant data so the status of contaminants can be determined on a statewide basis versus the previous rotating basin or suspected source impacted sites. Fish are also collected from sites where fish consumption advisories are in place and updated data are required to maintain a 5-year return frequency.

In 2003 the WDNR described the above strategies and summarized all the fish tissue data (Michaels and Schrank, 2003). Figure 1 taken from that report graphically presents 24 years of sampling data. The table represents 12,964 samples from 1,046 locations and 810 unique waterbodies. Of the 183 known native and non-native fish in Wisconsin 54 species were sampled during this time period. These 54 species were sampled because they were targeted by anglers and sportfish consumers or were species valuable for comparisons across sites or over time.

WDNR staff primarily collected the fish using methods dependent on waterbody and species. Tissue samples were prepared using standard procedures (WDNR Field Manual). Preparation of the edible portions of fish involved thawing, measuring length, weighing, and grinding either skin-on fillets (all species except for bullhead, catfish, and sturgeon), skin-off fillets

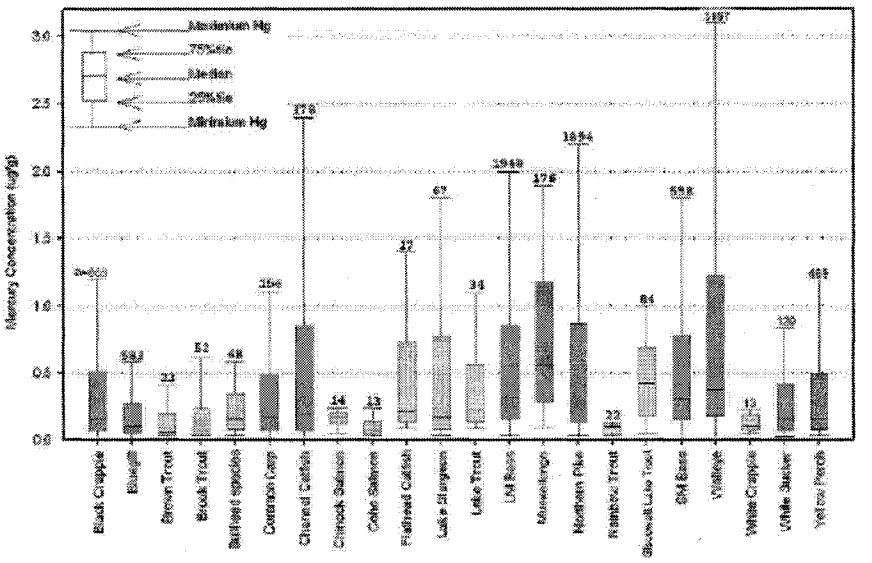


Figure 1. (from Michaels and Schrank, 2003). Mercury for 22 species (1977-2001), all waterbodies. Lighter boxplots denotes limited data (n<100) Mercury concentrations generally increase with size of fish, varies between waterbodies.

(only bullhead, catfish, and sturgeon), or cross-sections of fillets (sturgeon). Over 94% of samples were single fish samples. Figure 1 summaries the data.

The average value of all samples was 0.36 ppm, with a range of below detection to 3.1 ppm and a 75 percentile of 0.48 ppm.

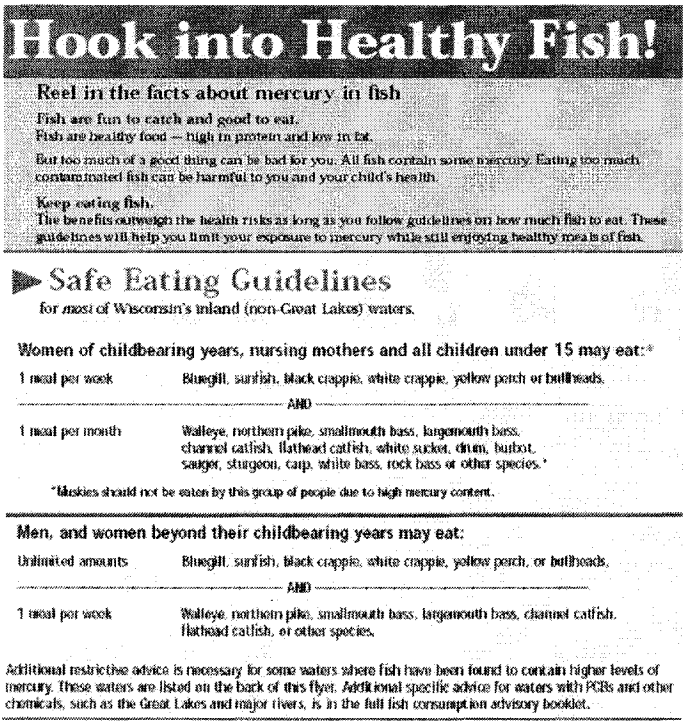
Advisory development

When Wisconsin's sport fish consumption advisory protocol was initiated in the 1970s, the FDA commercial fish action level was applied to sport fish. This provided the angler a qualitative comparison to market fish rather than quantitative, risk assessment based advice. The target audience was primarily anglers and their families. However, as risk assessment procedures advanced and Wisconsin and other states gained the expertise to utilize such procedures some states felt that the advisory should be fully health based rather than utilize the FDA process that included a cost-benefit consideration. During the 1980s and 1990s Wisconsin began to advise the public on how much sport fish was "safe" to eat based upon the type of risk assessment utilized by the USEPA RfD process. Five consumption rate groupings were utilized; "unlimited" (225 11/2lb meals/year), one meal a

week (52 meals/year), one meal a month (12 meals a year), six meals a year and "Do not eat." The advisory grew in complexity as it provided consumption frequency advice by species and size for each specific water body tested. By 2000 the advisory booklet included advice on 340 different water bodies or river segments.

In 1995 the USEPA revised its RfD for methylmercury. This led to considerable controversy and a series of external peer reviews. In 1998 the National Academy of Sciences review panel confirmed the appropriateness of the reduced RfD. In 1999 Wisconsin reviewed its methylmercury advisory protocol applying the new RfD and utilized focus groups to review the existing advisory. It was concluded that a less complex advisory was needed and should include both sport and commercial fish, provide a simple message by species, be consistent with neighboring states and apply to waters not yet tested. In 2000 a new advisory was developed called the "Statewide Safe Eating Guidelines."

Figure 2 provides the new guidelines. The guidelines and other informational materials can be found on the Wisconsin Department of



Hook into Healthy Fish!

Reel in the facts about mercury in fish

Fish are fun to catch and good to eat.
Fish are healthy food – high in protein and low in fat.

But too much of a good thing can be bad for you. All fish contain some mercury. Eating too much contaminated fish can be harmful to you and your child's health.

Keep eating fish.
The benefits outweigh the health risks as long as you follow guidelines on how much fish to eat. These guidelines will help you limit your exposure to mercury while still enjoying healthy meals of fish.

Safe Eating Guidelines

for *most* of Wisconsin's inland (non-Great Lakes) waters.

Women of childbearing years, nursing mothers and all children under 15 may eat:*

1 meal per week	Bluegill, sunfish, black crappie, white crappie, yellow perch or bullheads.
	AND
1 meal per month	Walleye, northern pike, smallmouth bass, largemouth bass, channel catfish, flathead catfish, white sucker, drum, burbot, sauger, sturgeon, carp, white bass, rock bass or other species.*

*Muskies should not be eaten by this group of people due to high mercury content.

Men, and women beyond their childbearing years may eat:

Unlimited amounts	Bluegill, sunfish, black crappie, white crappie, yellow perch, or bullheads.
	AND
1 meal per week	Walleye, northern pike, smallmouth bass, largemouth bass, channel catfish, flathead catfish, or other species.

Additional restrictive advice is necessary for some waters where fish have been found to contain higher levels of mercury. These waters are listed on the back of this flyer. Additional specific advice for waters with PCBs and other chemicals, such as the Great Lakes and major rivers, is in the full fish consumption advisory booklet.

Figure 2.

Natural Resources and the Wisconsin Division of Public Health web pages (URL:http://www.dnr.state.wi.us/org/water/fhp/fish/advisories/ index.htm) - (URL: http://www.dhfs.state.wi. index.htm).

This general advice is augmented with site specific consumption advice developed where fish-monitoring data indicates that more stringent advice is necessary. Only 93 lakes and waters warranted such special advice. Special advice for PCBs is applied to 50 river reaches and lakes. The waters where more stringent advisories are in place are posted with special warnings and the specific advice for that lake.

The new advisory also includes information on both sport and commercial fish. Figure 3 shows the advisory format combining sport and commercial fish into a single advisory Figure 4 is an example of the outreach

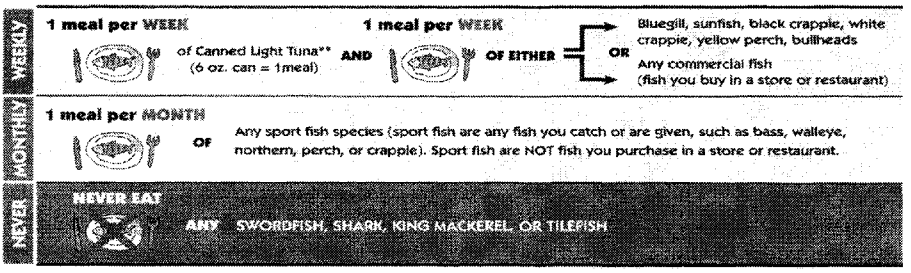


Figure 3. From "A Woman and Child's Guide to Eating Fish from Wisconsin".

materials developed to assist in educating consumers in how to identify fish that are low in methylmercury.

Wisconsin's fish consumption advisory goals remain to a) inform the public about the chemical contaminants contained in some sport-fish, b) educate consumers as to how they can minimize their exposure to contaminants, c)

remind consumers of the health benefits of fish consumption, and d) present advisory information in a manner conducive to maximal voluntary compliance. Because of potential adverse reproductive and developmental effects current advisories make specific consumption frequency recommendations for childbearing-aged women, but also provide advice for the general population. Advisories seek to help individual consumers make informed decisions regarding sport-fish consumption.

Advisory evaluation

Documenting that an advisory is effective is a significant challenge. Too frequently there are insufficient resources to determine the impact of an advisory and to track its penetration over time.

The easiest outcome to assess is awareness of the advisory and increased understanding of the chemical toxicity. However, awareness is only the first step in a successful advisory program.

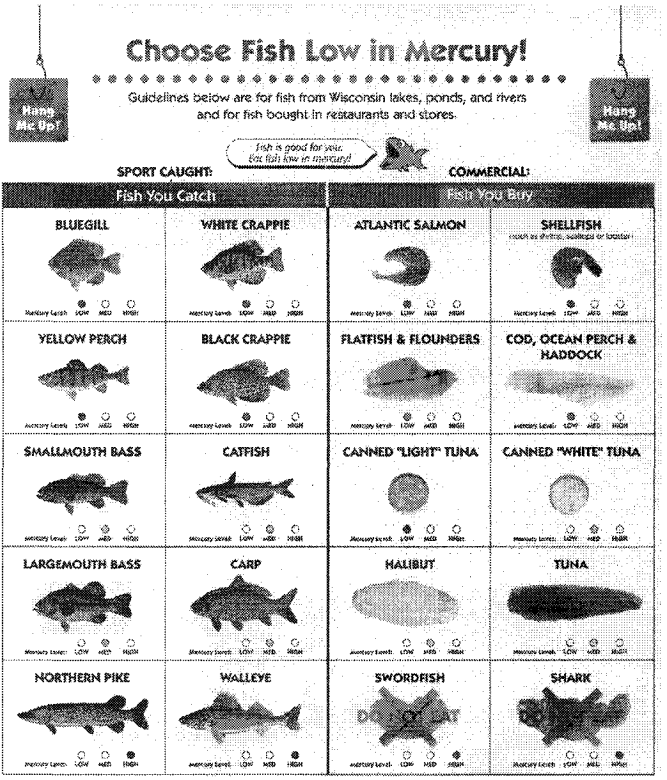


Figure 4.

The goal must be to reduce exposure that can only result from behavior modification.

Wisconsin has conducted several assessments of advisory effectiveness. In 1994-1995 we surveyed adult residents of the Great Lakes Basin (Tilden et al., 1997). That survey found that over 3 million residents were consuming Great Lakes sport fish and that advisory awareness among women,

minorities and low income households was nearly one half that of white males. The results of that study led to significant changes in state advisories with specific outreach to the difficult to reach.

In 2001, before a national USA advisory was being discussed, a consortium of 12 states conducted a telephone survey of 3,015 women aged 18-45.

The twelve states were selected based on their mercury sport fish advisories. Half issue state-wide advisories and half use a site-specific advisories. The states were spread throughout the United States (Figure 5). The goal was to characterize current fish consumption patterns (commercial, all sport-caught fish) and estimate the level of knowledge of mercury, advisory awareness and compliance among consumers of commercial and sport-caught fish (Anderson et al., 2004; Knobeloch et al., 2004).

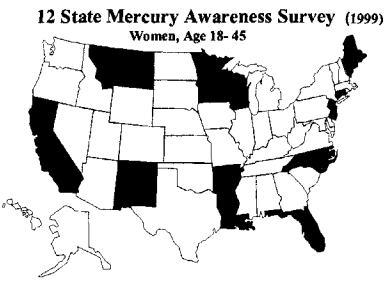


Figure 5. 12 state Hg Awareness Survey (1999).

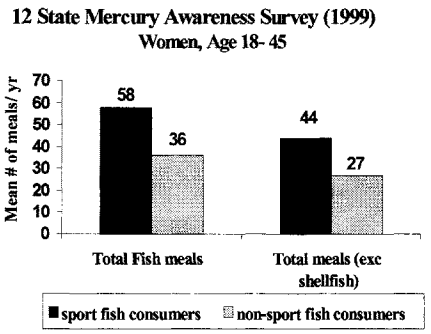


Figure 6. 12 State Mercury Awareness Survey (1999).

We reaffirmed that fish is important in the United States' diet. Only 8% reported no fish or shellfish consumption during the previous 12 months. Included in the 92% who reported some fishmeals were 29% who reported sport-fish consumption (inter-state variability from 14–43%). Ten percent of participants reported consuming two or more fish meals per week. There was an wide range of reported consumption. The maximum reported for commercial fish consumption was 572 meals per year. The maximum for sport fish consumption was 384 meals per year. Of note was the finding that those who consumed sport fish consumed 60% more total fish and shellfish

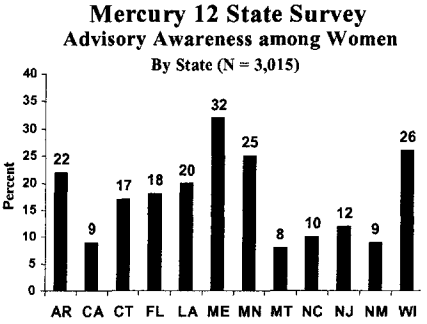


Figure 7. Mercury 12 State Survey.

than those who did not report consuming sport fish (figure 6). This finding supports the need for comprehensive advisories including both sport and commercial fish species.

Although there was considerable consumption of sport fish, awareness of specific state consumption advisories was only 20%, ranging by state from 8-32% (figure 7). Women who were older, had more than a high school education, and had a household member with a fishing license were the most informed about mercury and fish consumption advisories. Most states distributed their advisory with their sport fishing licenses so it was not surprising that households with a license holder would have greater awareness. What was encouraging is that most license holders are men and our survey was of their spouses. Previous research had shown that the men often did not share the advisory information with their wives. In this case there seems to be some improvement in communication.

We found that those aware of the advisory were more informed about the toxicity of mercury. Overall 71% of survey participants recognized that mercury harms a developing child. That rose to 87% among those aware of their state's advisory. Those aware of the advisory were also more likely to understand the characteristics of fish that predicted higher mercury contamination (figure 8).

	Aware of Advisory	Not Aware of Advisory
Harms developing child	87%	67%
Harms ability of muscles	52%	37%
Mercury not reduced by cooking	76%	47%
Higher in older fish	56%	43%
Higher in larger fish	38%	29%
Higher in fish that eat others	23%	18%
Highest in muscle/meat	8%	6%

Significant higher than among those unaware of state advisories ($P<0.01$)

Figure 8.

CONCLUSIONS

Most current methylmercury fish consumption advisories focus on risks to women and their infants. However a word of caution must be interjected to not overlook the potential for toxicity via another mode of action in other vulnerable populations. Studies have associated dietary methylmercury exposure with an increased risk of coronary artery disease and heart attacks in men (Salonen, 1995; Guallar, 2002). While there are also cardiovascular benefits to fish consumption, they may be negated when mercury is high. Fortunately there are fish that are low in mercury but high in beneficial fatty acids. Research on the adult cardiovascular risk warrant increased research

and analysis, before advisories dismiss providing a risk message to older adults, especially men.

If fish consumption advisories are to inform and protect the public, it is important to develop and maintain a comprehensive exposure surveillance program that includes fish tissue and human biomonitoring as well as an advisory effectiveness evaluation strategy. Governments relying on advisories must continuously ask the questions, "Is the message being heard and is it being adhered to?" In most countries just beginning to issue commercial advisories, such strategies are still in the formative stages. The experience of USA states, and Sweden may help inform such efforts.

REFERENCES

AHA (American Heart Association) AHA Dietary Guidelines, revision 2000: A Statement for healthcare professionals from the nutrition committee of the American Heart Association. Circulation; 102, 2296-2311, 2000.

Albert, C.M., Campos, H., Stampfer, M.J., Ridker, P.M., Manson, J.E., Willett, W.C., Ma, J. Blood levels of long-chain n-3 fatty acids and the risk of sudden death. *N. Engl. J. Med.*, 346, 1113-1118, 2002.

Anderson, H.A., Liebenstein, L. Sport fish consumption advisories. *AJPH*, 79, 1434-1435, 1989.

Anderson, H.A., Amrhein, J.F., Shubat, P., Hesse, J. Protocol for a uniform Great Lakes sport fish consumption advisory. Great Lakes Sport Fish Advisory Task Force, Council of Great Lakes Governors, September 1993, Chicago, IL, 1993.

Anderson, H.A., Hanrahan, L.P., Smith, A., Draheim, L., Kanarek, M. Olson, J. The role of sport fish consumption advisories in mercury risk communication: The Role of Sport-fish Consumption Advisories in Mercury Risk Communication: a 1998-1999 12 State Survey of Women age 18-45, *Env. Res.*, 95, 315-324, 2004.

Daviglus, M.L., Stamler, J., Orencia, A.J., Dyer, A.R., Liu, K., Greenland, P., Walsh, M.K., Morris, D., Shekelle, R.B. Fish consumption and the 30-year risk of fatal myocardial infarction. *N. Engl. J. Med.*, 336, 1046-1053, 1997.

WI DNR Field Procedures Manual. PART B: Collection Procedure 1005.1 Fish Contaminant Monitoring Program – Field and Lab Guidelines, Wisconsin Department of Natural Resources, Madison, WI.

Guallar, E., Sanz-Gallardo, M.I., Van't Veer, P., Bode, P., Aro, A., Gomez-Aracena, J., Kark, J.D., Riemersma, R.A., Martin-Moreno, J.M., Kok, F.J. Heavy metals and myocardial infarction study group. Mercury, fish oils, and the risk of myocardial infarction. *N. Engl. J. Med.*, 347, 1747-54, 2002.

JECFA (Joint FAO/WHO Expert Committee on Food Additives). Sixty-first meeting, Rome, 10-19 June 2003. Summary and conclusions. Available from: URL: ftp://ftp.fao. org/es/esn/jecfa/jecfa61sc.pdf.

Kleinert, S., Degurse, P.E. Mercury levels in Wisconsin fish and wildlife. DNR Technical Bulletin No. 52, Madison, WI, 1972.

Knobeloch, L.M., Ziarnik, M., Anderson, H.A., Dodson, V.N. Imported Seabass as a source of Mercury exposure: a Wisconsin case study. *Env. Health Perspect.*, 103, 604-606, 1995.

Knobeloch, L.M., Anderson, H.A., Imm, P., Peters, D., Smith, A. Fish Consumption, Advisory Awareness and Hair Mercury Levels Among Women of Child-bearing Age, *Env. Res.*, 97, 220-227, 2005.

Konrad, J.G. Mercury: new-found threat. *Wisc. Cons. Bull.*, 35, 3-5, 1970.

Mahaffey, K.R., Clickner, R.P., CB Joseph. Blood organic mercury and dietary mercury intake: National Health and Nutrition Examination Survey, 1999 and 2000. *Env. Health Perspect.*, 112, 562-570, 2004.

Michaels, E Schrank, C. Summary of Wisconsin mercury data for edible portions of fish 1977-2001 December 2003, Fisheries Management and Habitat Protection, Wisconsin Department of Natural Resources, Madison, WI.

NRC (National Research Council/National Academy of Sciences), Toxicological effects of methylmercury. Committee on the Toxicological Effects of Methylmercury. Board on Environmental Studies and Toxicology, Commission on Life Sciences. 2000. National Academy Press, Washington DC.

Salonen, J.T., Seppanen, K., Nyyssonen, K., Korpela, H., Kauhanen, J., Kantola, M., Tuomilehto, J., Esterbauer, H., Tatzber, F., Salonen, R. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and any death in eastern Finnish men. Circulation, Feb 1, 91, 645-55, 1995.

Tilden, J., Hanrahan, L.P., Anderson, H.A., Palit, C., Olson, J., MacKenzie, W. and the Great Lakes Consortium. Health advisories for consumers of Great Lakes sport-fish: is the message being received? *Env. Health Perspect.*, 105, 1360-1365, 1997.

USEPA (U. S. Environmental Protection Agency). Mercury Study Report to Congress, Volume III: Fate and transport of Mercury in the environment. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards and Office of Research and Development, EPA-452/R-97-005, 1997.

USEPA (U.S. Environmental Protection Agency), Office of Science and Technology, Office of Water. Water Quality Criterion for the Protection of Human Health: Methylmercury, Final. EPA-823-R-01-001, Washington, 2001.

URL: http://www.epa.gov/waterscience/criteria/methylmercury/document.html.

USEPA (U.S. Environmental Protection Agency). Update: National listing of fish and wildlife advisories. EPA: Pub. No.: EPA-823-F-03-003, Washington DC. 2003.