THE FLIP SIDE OF MERCURY

Mercury and selenium levels in fish from Madison, Wisconsin

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a project of the Center for Consumer Freedom

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BACKGROUND

Levels of mercury in commercially available fish have become the subject of intense campaigning by environmental activist groups, often resulting in statements about food safety that stretch the bounds of good science and truthful advocacy. While scientists and regulators generally aim to protect the public's health with advisories and warnings about trace levels of mercury in fish, such measures are often out of proportion with a health risk that remains entirely theoretical.

As a result, much of the public misunderstands the hypothetical nature of health risks from mercury. No U.S. cases of fish-related mercury poisoning can be found in the medical literature.[1] Yet a July 2006 national survey conducted by Opinion Research Corporation found 40 percent of Americans mistakenly believe at least 10,000 childhood cases of mercury poisoning are documented by scientists each year.[2]

In addition, very little publicity has followed scientific studies demonstrating that selenium—an element present in hundreds of common foods and plentiful in most fish—protects the human body against mercury exposure. Scientists first documented this phenomenon in 1967,[3] and innovative research continues.[4] Today, the U.S. Environmental Protection Agency describes selenium as an element that is "antagonistic to the toxic effects of mercury."[5]

It is increasingly clear that talking only about mercury levels in fish—and ignoring selenium's protective effects—misses half the story.[6] Yet environmental advocates and government regulators (at the state and federal level) generally fail to mention selenium when warning the public about trace amounts of mercury in fish.

In an index of 1,111 commonly consumed foods, the U.S. Department of Agriculture reports that 17 of the top 25 sources of dietary selenium come from seafood.[7] This is important since a higher selenium-to-mercury ratio in fish indicates a greater likelihood that tiny traces of mercury will have no measurable impact on human health.[8]

Overblown mercury warnings, along with a lack of public understanding about the protective effects of selenium, can have negative public health consequences if consumers react by steering clear of fish and its many well documented health benefits. Studies have shown that consuming omega-3 fatty acids (which are also plentiful in fish) can help prevent or inhibit numerous medical conditions including cardiovascular disease,[9] breast[10] and prostate cancer,[11] kidney disorders,[12] Alzheimer's disease,[13] stroke,[14] and bipolar disorder.[15]

In November 2005 testimony before a California Superior Court, former U.S. Health and Human Services Secretary Dr. Louis Sullivan outlined a relationship between fish warnings, declining fish consumption, decreased consumption of omega-3s, and a substantial increase in premature births.[16] The infant mortality rate of the United States ranks a disappointing 27th among industrialized countries,[17] and the March of Dimes estimates that 75 percent of infant deaths in the first month of life involve preterm births.[18]

A greater understanding of how selenium protects the human body from mercury will help Americans overcome their growing (but irrational) fear of fish. And the public health benefits of increased fish consumption in general cannot be denied.

"The administration of selenium compounds to animals protects against the toxic effects of methylmercury."

— World Health Organization, International Programme on Chemical Safety, "Environmental Health Criteria 101" (1990)

"From all the reports we had seen about mercury and its impact on development, we thought we would be able to show how bad it was for children. But we didn't find it at all."

— University of Rochester Pediatrics Professor Dr. Philip Davidson, telling *The Medical Post* about his study of heavy fish-eaters in the Seychelle Islands (2006)

INTRODUCTION

Because of the negative health consequences that may result from the public's growing fear of eating fish, the nonprofit Center for Consumer Freedom (CCF) sought to examine the mercury and selenium levels of commercially available fish in a single region of the United States. The city of Madison, Wisconsin was chosen because it was the planned site of the Eighth International Conference on Mercury as a Global Pollutant, scheduled for August 2006.[19]

In May 2006, the Center for Consumer Freedom collected 142 fish samples from 38 retail locations in the Madison area. The fish included canned tuna, sushi, store-bought fresh fish, and cooked restaurant fish. In addition to two types of canned tuna, 17 different fish species were sampled.

Frontier GeoSciences Inc., an independent laboratory in Seattle, performed scientific tests to determine the concentrations of mercury and selenium in the samples. Individual mercury levels ranged from 0.001 parts per million in a fresh catfish sample to 3.480 parts per million in cooked swordfish. Selenium levels were "undetectable" (less than 0.1 parts per million) in many catfish samples, and as high as 3.215 parts per million in cooked walleye.

Even before accounting for selenium, a careful reading of the Food and Drug Administration's description of its mercury "Action Level" indicates that **no fish sampled in this study is unsafe to eat.**

The FDA has written that its Action Level (currently set at 1.0 part per million) "was established to limit consumers' methyl mercury exposure to levels 10 times lower than the lowest levels associated with adverse effects."[20]

Adjusting for this 1,000-percent cushion, 10.0 (ten) parts per million is actually the minimum level that the FDA believes might represent a health concern for the fish-buying public.

The highest mercury level measured in this study was less than 35 percent of what the FDA describes as "the lowest level associated with adverse effects" to human health. And since health risks from trace levels of mercury in fish are hypothetical—and predicted only after a lifetime of exposure—consumers in the Madison area should be reassured that the fish in their community is safe to eat.

These results are similar to those reported by a number of environmental organizations during the past year, none of which has identified a single fish whose mercury level represents an actual human health hazard.

And the rich presence of selenium in most fish should make consumers even more confident about including seafood in their diets. **On average, every fish species we tested (and over 97 percent of the individual fish samples) contained more selenium than mercury, providing consumers with adequate protection from any theoretical mercury-related harm.** (See "One to One," page 6.)

TESTING METHODOLOGY

Over a three-day weekend (May 5–7, 2006), 142 fish samples were collected from the Madison, Wisconsin region. Fish species were selected based on their availability at Madison-area restaurants, grocery stores, and fish markets. They included 25 cans of tuna; 44 specimens of fresh, store-bought fish; 28 samples of sushi and sashimi; and 45 orders of cooked restaurant fish.

A reasonable effort was made to purchase fish from stores in a diverse range of communities throughout the Madison region. The fish came from 38 locations, including 24 restaurants and 14 grocery stores and specialty seafood shops.

No attempt was made to seek out specific species of fish. The goal was to gather a representative sample of what was available from Madison-area restaurants and grocers. Accordingly, the number of samples of each species varies.

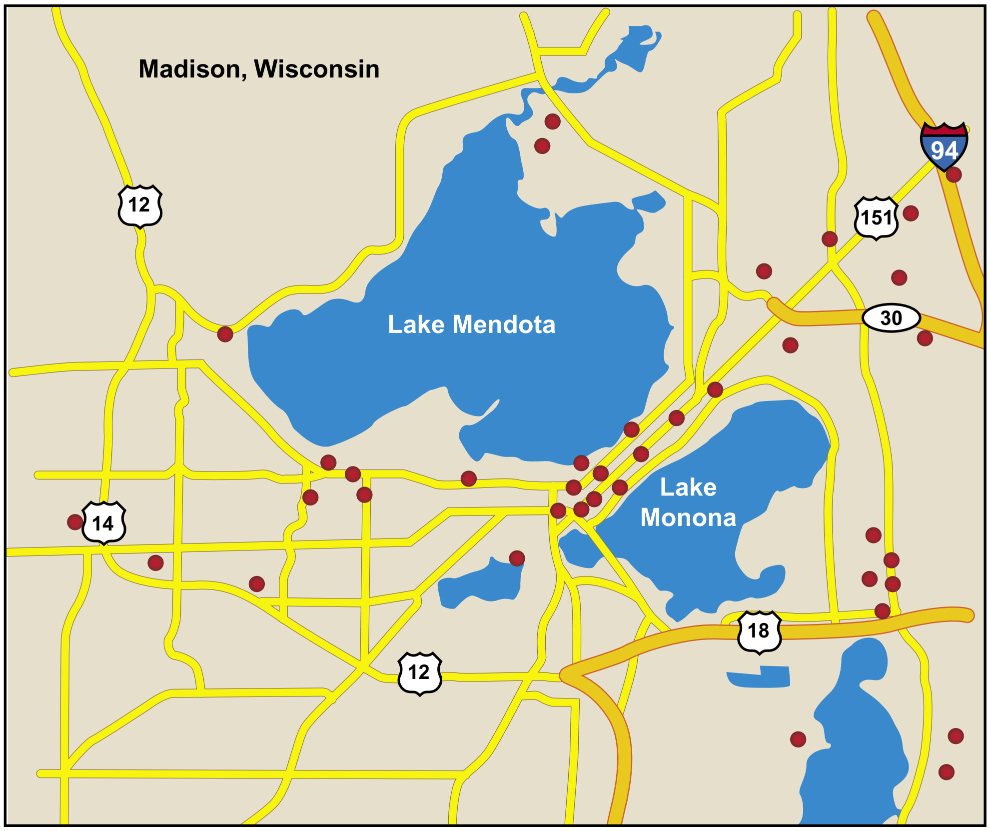
Cooked fish and sushi were purchased as part of typical carry-out orders placed in person or by telephone. Fresh fish was purchased as fillets or steaks. Cooked fish samples were allowed to cool for one hour in their carry-out packaging prior to being sealed in specimen jars.

Canned tuna samples included 25 varieties from 17 different brands, including two varieties sold in plastic pouches. No individual variety of canned tuna was sampled more than once.

Aside from canned light and albacore tuna, the fish species included catfish, cod, haddock, halibut, mackerel, mahi-mahi, orange roughy, perch, red snapper, striped bass, swordfish, tilapia, trout, walleye, whitefish, yellowfin ('ahi) tuna, and yellowtail.

All fish samples were sealed in lab-supplied specimen jars, kept cool with ice packs, and shipped overnight to Frontier GeoSciences Inc.[21] in a climate-controlled cooler. Frontier GeoSciences tested the fish for total mercury and selenium content, and re-tested ten samples for quality control. (See Appendix D for technical details.) Fourteen fish samples, representing statistical outliers for either mercury or selenium, were also re-tested for confirmation.

Figure 1: Geographic distribution of sampled retailers



> “Commercial ocean fish are uniformly rich in selenium and therefore protect humans from any mercury toxicity [from fish consumption].”
>
> — University of North Dakota scientist Dr. Nicholas Ralston, talking to *Environment News Service* (2005)

WHY SELENIUM?

In scientific terminology, selenium has an unusually high “binding affinity” for mercury. Translated into layman’s terms, when the two elements are found together, they tend to connect and form a new substance. Mercury’s potentially toxic effects appear to be cancelled out when it “binds” (connects) with selenium in brain cells. But when this happens, the selenium is also no longer available to perform its normal essential functions.

Scientists are still exploring exactly how selenium neutralizes mercury, but most researchers accept one of two competing explanations.

The conventional theory sees selenium as a sort of “mercury magnet.” This idea assumes that selenium present in the body can render mercury harmless by binding with it. But if sufficient selenium isn’t available, the mercury is free to cause harm.

A more recent hypothesis proposes that mercury seeks out selenium (instead of the other way around) and takes it out of

One to One

Nearly 40 years of scientific experiments have demonstrated that selenium tends to diminish the impact of mercury in humans and animals. And while there are several competing theories about just why that happens, the weight of scientific evidence indicates that it does.[22]

But how much selenium is enough?

There’s good reason to believe that the typical state of things in mammals is a nearly one-to-one ratio of selenium and mercury atoms. Scientists have found this ratio in dolphins,[23] seals and toothed whales,[24] and other marine mammals.[25]

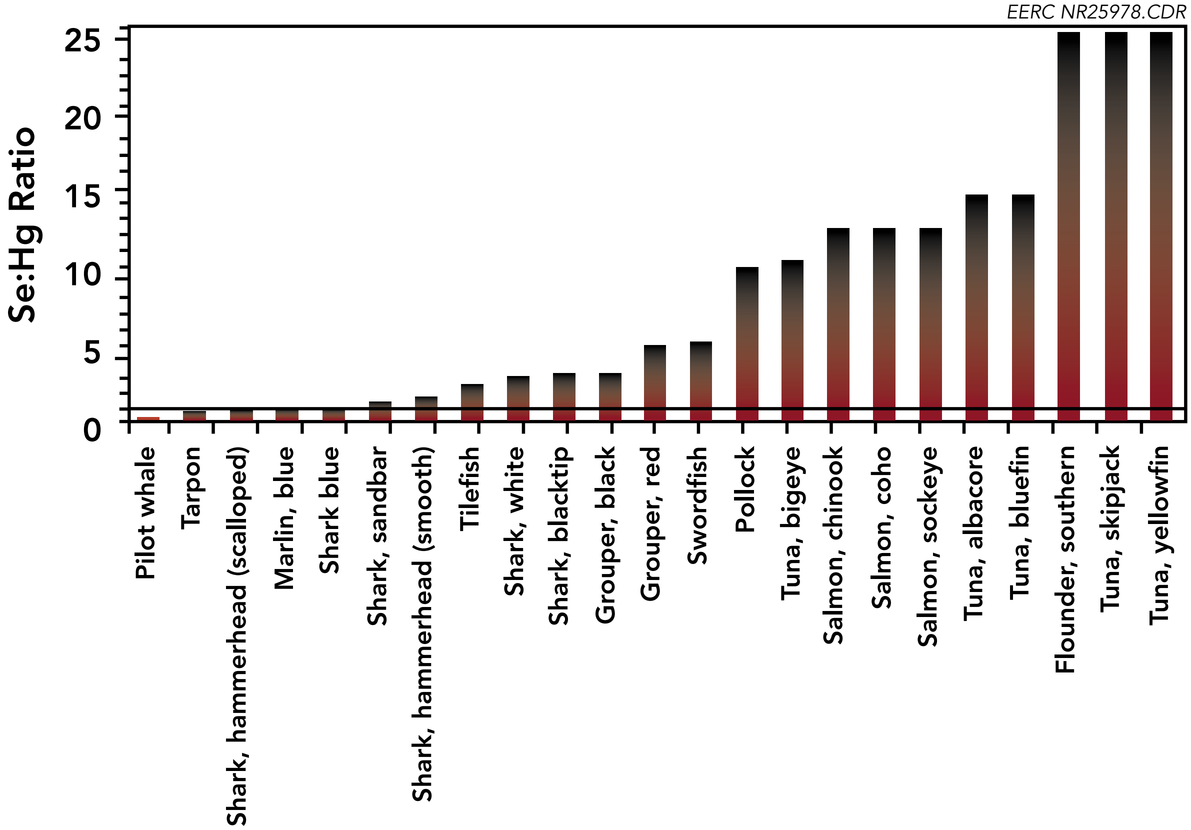
This ratio has also been measured in human organs during autopsies of large numbers of European mercury miners,[26] Swedish dental employees,[27] and members of the general population in Germany.[28] Brain cells appear to regulate selenium in a way that keeps their levels slightly above those of mercury, regardless of how much mercury they’ve been exposed to.[29]

A Japanese scientific team demonstrated in 1997 that even in the presence of toxic levels of mercury, equal parts (one-to-one) selenium and mercury will form new molecules in the bloodstream,[30] rendering both elements unavailable to be absorbed by brain cells and other tissues.

Scientists are still studying just how the human body processes selenium so efficiently, and how this makes it available to interact with mercury. But it’s reasonable to conclude that eating foods containing far more selenium than mercury will help the former to effectively cancel out the latter.

And what if the reason mercury is toxic at high doses is related to its ability to keep selenium from doing its job? All the more reason to make sure any dietary mercury is accompanied by an even larger dose of selenium—which every fish species tested in this study provides.

Figure 2: Selenium (Se) relative to mercury (Hg) in ocean fish



Molar ratios from "Mercury and Selenium Relationships in Seafood" (Dr. Nicholas Ralston, University of North Dakota Energy and Environmental Research Center). Used with permission.

circulation. This idea suggests that mercury's theoretical health impacts might arise if it steals too much selenium from brain cells. This would prevent these cells from creating certain essential enzymes which depend on selenium to perform their functions.

Enzymes are special proteins that control various steps in all the chemical reactions on which human life depends. Without enough selenium-based enzymes, the functions of brain cells can be impaired.

So problems can only occur if we don't get enough selenium to counteract the trace amounts of mercury that have always been present in the fish we eat. But fish are so rich in selenium that this is not likely to happen. The fish in this study, for instance, averaged far more selenium than mercury.

As early as 1978, researchers at the National Oceanic and Atmospheric Administration showed that very few ocean creatures in the human diet (pilot whale, tarpon, blue marlin, and several shark species) contain more mercury than selenium.[31] But all the fish in a typical American diet—including tuna, salmon, and the much-maligned swordfish—are far more selenium-rich.

> "It appears that selenium levels in fish are high enough to give protection against mercury toxicity."
>
> — Drs. Lourdes Cuvin-Aralar and Robert Furness, writing in the journal *Ecotoxicology and Environmental Safety* (1991)

SELENIUM SCIENCE

It's ironic that until the 1960s selenium was known only as a poison. (Anything, including water, can be poisonous in high enough doses.) But it is now understood that selenium plays a vital role in the normal function of the human body. And research continues to support theories about how selenium protects us from mercury.

- Selenium was first shown to reduce the toxicity of mercury given to rats in 1967.[32] During the following four years, a flurry of other published studies confirmed this basic but important finding.

- Five years later, the journal *Science* published the results of a study in which the selenium in canned tuna protected Japanese quail from mercury toxicity.[33] This study found that samples of tuna with higher mercury levels also contained higher levels of selenium. Cornell University scientists reinforced this in 1974 by feeding controlled amounts of both methyl mercury and selenium to the same species of birds, finding that selenium at various doses "gave complete protection" from mercury.[34]

- By 1978, scientists from Sweden were reporting that "mercury is accompanied by selenium in all investigated species of mammals, birds, and fish," adding that it "seems likely that selenium will exert its protective action against mercury toxicity in the marine environment."[35]

- In that same year, scientists at Virginia Commonwealth University learned that by feeding swordfish to lab rats, they could prevent the negative effects of methyl mercury injections.[36] They concluded that the selenium, present in the swordfish at twice the level of mercury, was responsible. (Some fish species in the current Madison, Wisconsin survey had a selenium-to-mercury ratio of over 100-to-1.)

- Also in 1978, the *American Journal of Clinical Nutrition* published a New Zealand study that documented a nationwide selenium deficiency among children. The authors attributed it to the low selenium content of New Zealand's native soil, which resulted in low-selenium food crops.[37] A 1998 New Zealand study later claimed to document mercury toxicity *without* taking selenium into account.[38]

- In 1989, Swedish scientists reported that adding selenium to a lake over a three-year period lowered the mercury levels in the native fish by over 75 percent.[39] (In 2000, a Tennessee study found that limiting the amount of selenium discharged into a quarry actually *increased* the mercury levels in bass more than 30-fold.[40])

- In 1990, the U.S. Fish and Wildlife Service published the results of its National Contaminant Biomonitoring Program from 1976 to 1984. This program measured the concentrations of seven chemicals (including mercury and selenium) in 315 whole fish caught at 109 different locations nationwide.[41] No sample in this broad survey had a selenium-to-mercury ratio of less than 1.46-to-1. On average, selenium was 28 times more abundant than mercury.

- A helpful 1991 review of selenium-and-mercury interactions provided an explanation for how a surplus of selenium could protect against mercury, suggesting that the two chemical elements may "compete for the same receptors located in animal tissue."[42]

- In 1999, a Danish team described laboratory experiments in which lake trout were given mercury injections along with dietary selenium. Compared to other fish that received only the mercury, the selenium-injected fish excreted much more of the mercury from their bodies.[43]

- The following year a group of Greenland scientists published the results of mercury and selenium tests performed on the muscles and organs of healthy fish, shellfish, birds, seals, whales, and polar bears. They found that "selenium was present in a substantial surplus compared to mercury in all animal groups and tissues."[44]

- In 2001[45] and again this year,[46] researchers at Laurentian University in Ontario reported that selenium deposits (from metal smelters) into lake water greatly reduced the absorption of mercury by microorganisms, insects, and small fish.[47]

- Also in 2006, two McGill University researchers have documented how feeding selenium and vitamin E to rats lowered the impact of dietary mercury. "Antioxidant nutrients" like selenium, they wrote, "may alter methyl mercury's reproductive and developmental toxicity."[48]

What's a Molar Ratio?

A "mole" is a unit that helps chemists count huge numbers of atoms in a sample of mercury, selenium, or any other chemical substance. Since different chemical atoms weigh different amounts, just comparing the weight of two chemical samples doesn't give an accurate picture of how many *atoms* there are in each.

At the microscopic scale on which chemical reactions take place, all chemicals (including mercury and selenium) react with each other one atom at a time. Establishing their "molar ratio"—comparing them mole-for-mole—is a reliable way to determine how many atoms of each are available for these reactions.

MERCURY AND SELENIUM LEVELS

For tables of all reported raw data, see Appendix A.

Generally speaking, scientific research suggests that a "molar ratio" greater than one-to-one indicates a protective effect provided by selenium against mercury toxicity. (see "One to One," page 6)

Mercury and selenium levels are in parts per million.

Yellowfin ('ahi) tuna – 19 samples

Average mercury level:	0.408
Average selenium level:	0.676
Average selenium-to-mercury molar ratio:	7.902

Canned light tuna – 13 samples

Average mercury level:	0.093
Average selenium level:	0.770
Average selenium-to-mercury molar ratio:	30.336

Canned albacore tuna – 12 samples

Average mercury level:	0.364
Average selenium level:	0.649
Average selenium-to-mercury molar ratio:	4.700

Walleye – 11 samples

Average mercury level:	0.114
Average selenium level:	0.648
Average selenium-to-mercury molar ratio:	37.566

Cod – 8 samples

Average mercury level:	0.094
Average selenium level:	0.290
Average selenium-to-mercury molar ratio:	44.684

Trout – 8 samples

Average mercury level:	0.028
Average selenium level:	0.322
Average selenium-to-mercury molar ratio:	32.630

Catfish – 8 samples*

Average mercury level:	0.010
Average selenium level:	0.184
Average selenium-to-mercury molar ratio:	17.661

Red snapper – 7 samples

Average mercury level:	0.078
Average selenium level:	0.526
Average selenium-to-mercury molar ratio:	142.307

Tilapia – 6 samples

Average mercury level:	0.024
Average selenium level:	0.290
Average selenium-to-mercury molar ratio:	69.423

Mackerel – 5 samples

Average mercury level:	0.048
Average selenium level:	0.400
Average selenium-to-mercury molar ratio:	21.613

Halibut – 5 samples

Average mercury level:	0.188
Average selenium level:	0.363
Average selenium-to-mercury molar ratio:	6.408

Swordfish – 5 samples

Average mercury level:	2.086
Average selenium level:	0.815
Average selenium-to-mercury molar ratio:	1.141

Perch – 5 samples

Average mercury level:	0.103
Average selenium level:	0.641
Average selenium-to-mercury molar ratio:	21.543

Yellowtail – 5 samples

Average mercury level:	0.182
Average selenium level:	0.444
Average selenium-to-mercury molar ratio:	6.229

Whitefish – 5 samples

Average mercury level:	0.065
Average selenium level:	0.477
Average selenium-to-mercury molar ratio:	31.875

Striped bass – 4 samples

Average mercury level:	0.047
Average selenium level:	0.361
Average selenium-to-mercury molar ratio:	81.611

* Selenium was below 0.100 ppm (the detection limit) in six of the eight catfish samples. "Average selenium level" and "molar ratio" were calculated from the two remaining samples with measurable selenium.

MERCURY AND SELENIUM LEVELS (continued)

Mahi-mahi – 4 samples

Average mercury level:	0.544
Average selenium level:	0.429
Average selenium-to-mercury molar ratio:	2.190

Orange roughy – 3 samples

Average mercury level:	0.511
Average selenium level:	0.608
Average selenium-to-mercury molar ratio:	3.657

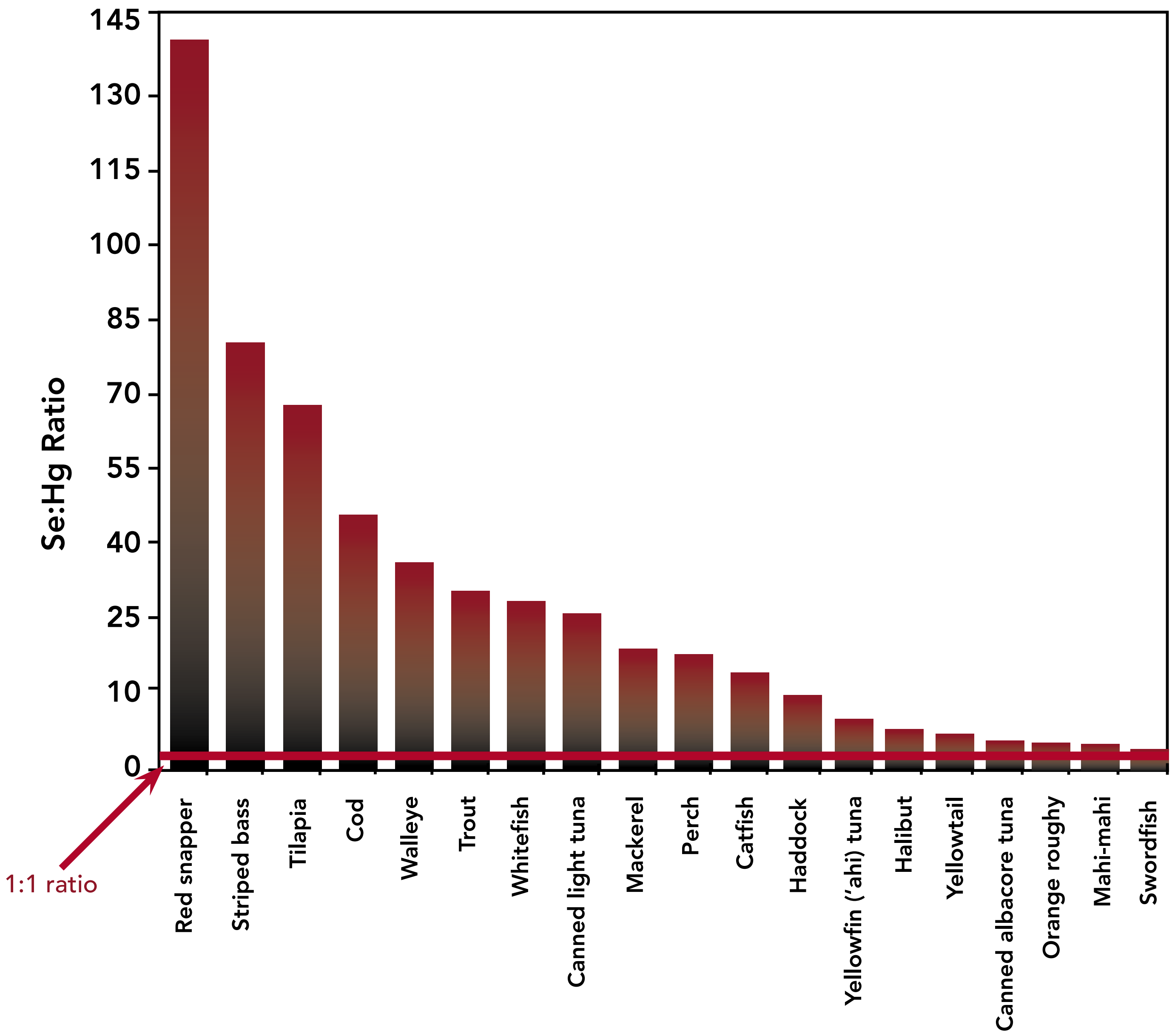
Haddock – 3 samples

Average mercury level:	0.062
Average selenium level:	0.261
Average selenium-to-mercury molar ratio:	11.419

OVERALL – 142 samples

Average mercury level:	**0.241**
Average selenium level:	**0.531**
Average selenium-to-mercury molar ratio:	**31.415**

Figure 3: Selenium-to-mercury ratios in Madison, Wisconsin fish



> "Measuring the amount of mercury present in the environment or food sources may provide an inadequate reflection of the potential for health risks if the protective effects of selenium are not also considered."
>
> — Dr. Laura J. Raymond and her colleagues, writing in the *Seychelles Medical and Dental Journal* (2004)

TEN-FOLD SAFETY FACTORS AND THE "REFERENCE DOSE"

Trace levels of mercury in fish have become the subject of intense debate in scientific and advocacy circles. Some activists, journalists, and regulators have issued fearsome statements about mercury toxicity from fish without taking into account the significant safety margins built into government advisory levels.[49]

The FDA's 1.0 part-per-million mercury Action Level is not the only advisory benchmark with a wide, built-in margin of safety. The Environmental Protection Agency's "Reference Dose" for mercury—which represents that agency's judgment of the highest "safe" daily intake over a person's entire lifetime—also includes a 10-fold safety cushion.[50]

In calculating its mercury Reference Dose, the EPA first decided on a "Benchmark Dose Lower Limit" (BMDL), which corresponds to the lowest level of daily exposure (over a lifetime) that may bring negative health effects. This BMDL—not the Reference Dose—represents the EPA's theoretical harm threshold. (At levels up to the BMDL, "harm" is likely to be undetectable in individuals.[51]) The mercury Reference Dose is simply one-tenth of the BMDL.

Even so, considerable scientific disagreement exists concerning whether the BMDL itself was set too low. When the EPA determined how much mercury is "too much," it relied primarily on a study of the population of the Faroe Islands (in the North Atlantic Ocean).[52] But the Faroese may not be an appropriate model for mercury intake in the United States, because they supplement their diets with large amounts of pilot whale.[53] This whale meat and blubber is contaminated with a wide variety of toxins including dioxins, PCBs,[54] and cadmium.[55] Pilot whale meat is also a very poor source of selenium. In the Faroe Islands, it's difficult to determine if mercury by itself is responsible for any negative health outcomes—especially when those outcomes are few[56] and largely irrelevant to individuals.[57]

In another ongoing study of heavy fish-eaters, in the Seychelles Islands (a tiny Indian Ocean republic), researchers have found no negative health effects from the naturally occurring trace levels of mercury in fish.[58] This assessment includes 16 years of tracking more than 700 children (now teenagers) whose mothers' mercury levels were elevated during pregnancy.[59] Seychelles natives eat approximately ten times as much fish as typical Americans,[60] but pilot whale is not a part of their diets. The EPA's failure to emphasize this study's findings when determining a BMDL for mercury remains unexplained.

Given the ten-fold safety factor built into the mercury Reference Dose (and accounting for the possibility that the EPA's decision to ignore the Seychelles research may have rendered the BMDL artificially low), the upper limit of "safe" consumption levels for all species of fish should be understood as ten times higher than what published EPA advisories suggest.

For example, mercury levels in the 13 cans of light tuna sampled in this study averaged 0.094 parts-per-million (ppm). Adjusting for the ten-fold safety factor in the EPA's Reference Dose, **a woman of average weight living in Madison, WI can safely consume over 183 ounces of canned light tuna (that's more than 30 cans) every week for the rest of her life before risking any theoretical negative health effects.**

Both the BMDL and the hyper-precautionary Reference Dose are meant to be lifetime consumption guidelines. In a 2004

Refereeing the Great Mercury Debate

The biggest unanswered question in the Great Mercury Debate of our time isn't whether or not fish is a health food. It's which of the most talked-about studies of mercury in the human diet is "right." Long-term studies of large groups of people have resulted in conflicting verdicts, and each study has its share of loyalists in the scientific community.

One research team in the Seychelle Islands found that elevated mercury levels during pregnancy have no impact on the long-term development of children. Another group in the Faroe Islands found very subtle differences among children whose mothers' hair contained various levels of mercury during their pregnancies. And scientists behind a third (much smaller) study in New Zealand also claimed to identify a connection between mercury exposure and lower scores on some children's developmental tests.[61]

Selenium levels in seafood may explain how these three studies generated such different results.

Pilot whale meat, a staple of the Faroese diet, contains nearly four times as much mercury as selenium, by molar weight.[62] (See "What's a Molar Ratio," page 9.) But ocean fish—unlike marine mammals like dolphins and whales—average between eight and ten times as much selenium as mercury.[63]

Among seafood in the human diet, pilot whale has the greatest documented mercury content relative to selenium. (See figure 2, page 7.) So while a fish-heavy diet (*e.g.*, that of the Seychellois) would contain adequate protective selenium, a diet whose mercury comes mainly from whale meat (*e.g.*, that of the Faroese) would be selenium-deficient. Any study of mercury levels among heavy whale-eaters might expect to find mercury-related health consequences which would not show up in other populations.

Similarly, the well-documented low selenium content of New Zealand soils contributes to the selenium-deficient diet of that nation's children.[64] Studying New Zealanders' mercury levels without considering the impact of low selenium levels may have generated misleading results.

Selenium measurements have not been a regular feature of the ongoing study of Seychelle Islands children. But a 2004 study of 16 fish species common to the Seychellois diet found more than 10 times as much selenium as mercury.[65]

On average, mothers whose children enrolled in the Seychelle study had higher mercury levels than their counterparts in the Faroes. But the abundance of selenium in Seychelle-caught fish—and the lack of selenium in the unusually whale-heavy Faroe Islands diet—could explain why one group of children appear to perform somewhat better than the other.

The University of North Dakota's Energy & Environmental Research Center writes that "contrasting observations" in the Faroe and Seychelle Islands "may be related to differences in mercury exposure relative to selenium in the foods consumed by their respective study populations."[66]

joint advisory, the EPA and FDA conceded that "one week's consumption of fish does not change the level of methyl mercury in the body much at all."[67]

The FDA is aware that health advice based on the mercury Reference Dose can lead consumers to fear a nonexistent harm. In 2004, FDA Chief Medical Officer Dr. David Acheson acknowledged: "We know there will be people above the Reference Dose, above the tenfold safety factor. But not far above it. They will be in the zone of safety."[68]

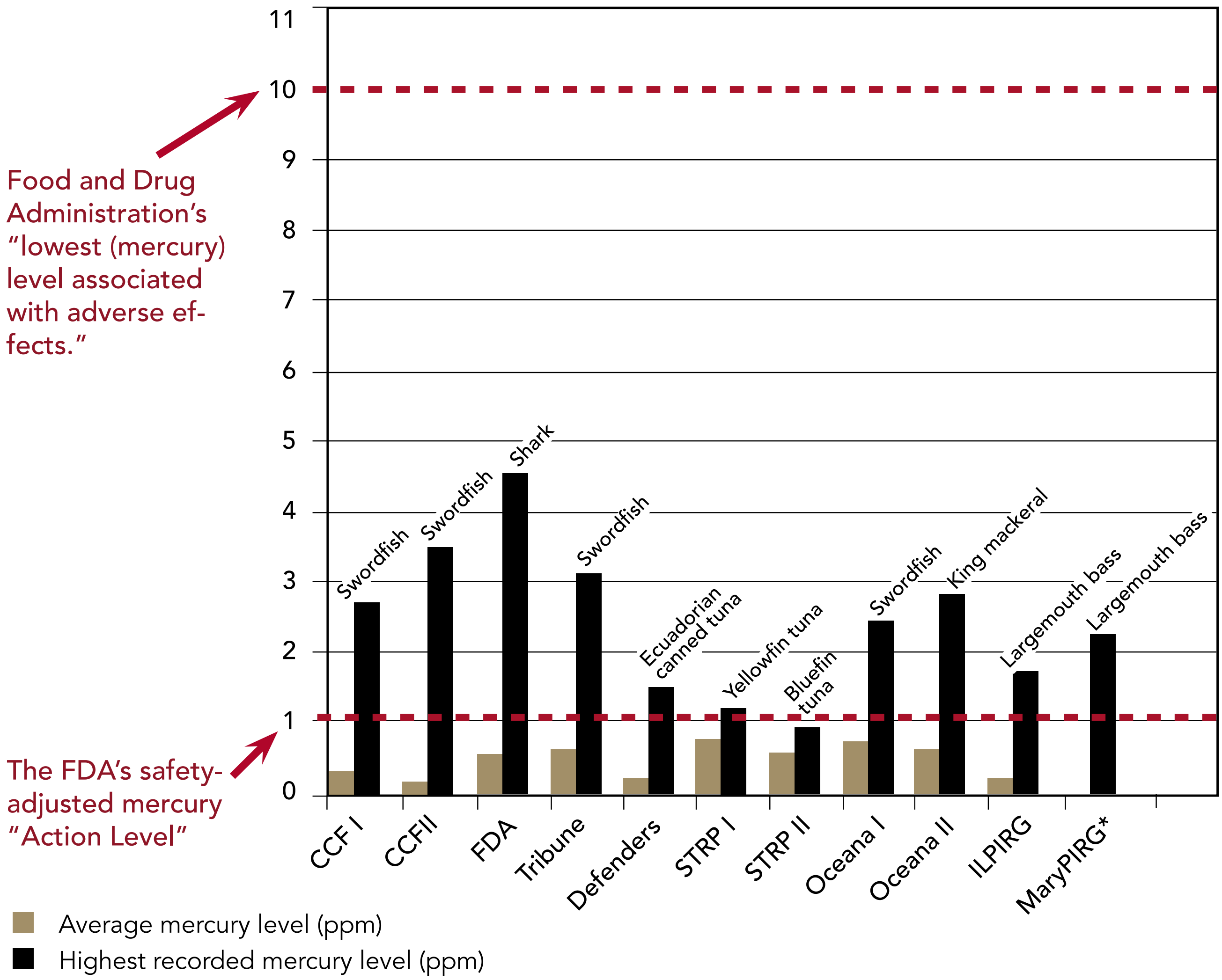
And during a 2002 joint FDA/EPA meeting, FDA Contaminants Branch chief Dr. Michael Bolger remarked that "ninety-two percent of women of child-bearing age already consume below the Reference Dose … the remaining women, approximately the top 8 percentile, still have a margin of safety of about eight-fold."[69]

OTHER RECENT FISH SURVEYS

The mercury-testing results from this survey are comparable to long-term data made publicly available by the Food and Drug Administration.[70] **Based on the FDA's own description of its mercury Action Level, the agency has not identified any fish whose mercury levels represent a genuine health risk. This report found similarly safe levels in all tested fish.**

The Center for Consumer Freedom's June 2006 *Safe Fish* report detailed mercury levels found in 142

Figure 4: Recent fish-mercury tests fall far short of the theoretical harm threshold



CCF I: Center for Consumer Freedom (142 samples, June 2006)
CCF II: Center for Consumer Freedom (142 samples, August 2006)
FDA: Mercury Concentrations in Fish: FDA Monitoring Program (3,272 samples, 1990-2004)
Tribune: *The Chicago Tribune* (144 samples, December 2005)
Defenders: Defenders of Wildlife (164 samples, July 2006)
STRP I: Sea Turtle Restoration Project (12 samples, March 2006)
STRP II: Sea Turtle Restoration Project (20 samples, May 2006)
Oceana I: Oceana (55 samples, September 2005)
Oceana II: Oceana (190 samples, February 2006)
ILPIRG: Illinois Public Interest Research Group (827 samples, April 2006)
MaryPIRG: Maryland Public Interest Research Group (1,939 samples, April 2006)

* MaryPIRG data average was not published

Mercury Mumbo-Jumbo

Action Level: The Food and Drug Administration's advisory limit (1 part per million) for mercury in fish, equal to just one-tenth of what the FDA calls "the lowest levels associated with adverse effects."

Benchmark Dose Lower Limit (BMDL): The Environmental Protection Agency's best estimate of how much dietary mercury (over a lifetime of exposure) *might* cause a negative health impact. Recent data from the Centers for Disease Control and Prevention indicate that no Americans test anywhere near the mercury BMDL.

Methyl mercury (MeHg): An "organic" form of mercury that is produced when microorganisms in water or soil digest an oxidized form of "elemental" mercury (the slick silvery stuff in thermometers). Most scientific surveys have found that the level of methyl mercury in ocean fish has remained constant (or even declined) during the past 25 to 100 years.

Reference Dose (RfD): The EPA's lifetime-mercury-dose advice, calculated by applying a 1,000-percent safety cushion to the BMDL (see above).

For more information about trace amounts of mercury in your diet, visit **www.mercuryfacts.org.**

samples of fresh fish and canned tuna purchased in the Washington, DC area. The samples included canned light and albacore tuna, fresh yellowfin ('ahi) tuna, swordfish, salmon, Chilean sea bass, and rockfish. In these Washington samples, the average mercury level across all species was 0.399 parts per million (ppm), and the highest level was a 2.85-ppm swordfish steak. In the current Madison study, the overall mercury average was 0.241 ppm. The highest level was, again, a swordfish sample—this time measuring 3.48 ppm.

Our results are similar to those published in 2005 and 2006 by the *Chicago Tribune*; three environmental activist groups (Oceana, the Sea Turtle Restoration Project, and Defenders of Wildlife); and at least six U.S. television news departments. These other reports, however, entirely ignored the impact of built-in safety margins, claiming incorrectly that fish samples exceeding the FDA's mercury Action Level were inherently unsafe to eat. They also failed to consider the likely impact of selenium.

According to the *Tribune*, the highest mercury reading in its survey was a swordfish whose concentration was 3.07 ppm.[71] Considering the Action Level's built-in safety factor, this is less than one-third of the mercury level that might be harmful. No other species averaged above 1.0 ppm. And despite a later editorial complaining about "Tuna Roulette," the *Tribune* was unable to find a single sample of tuna that exceeded the mercury Action Level.

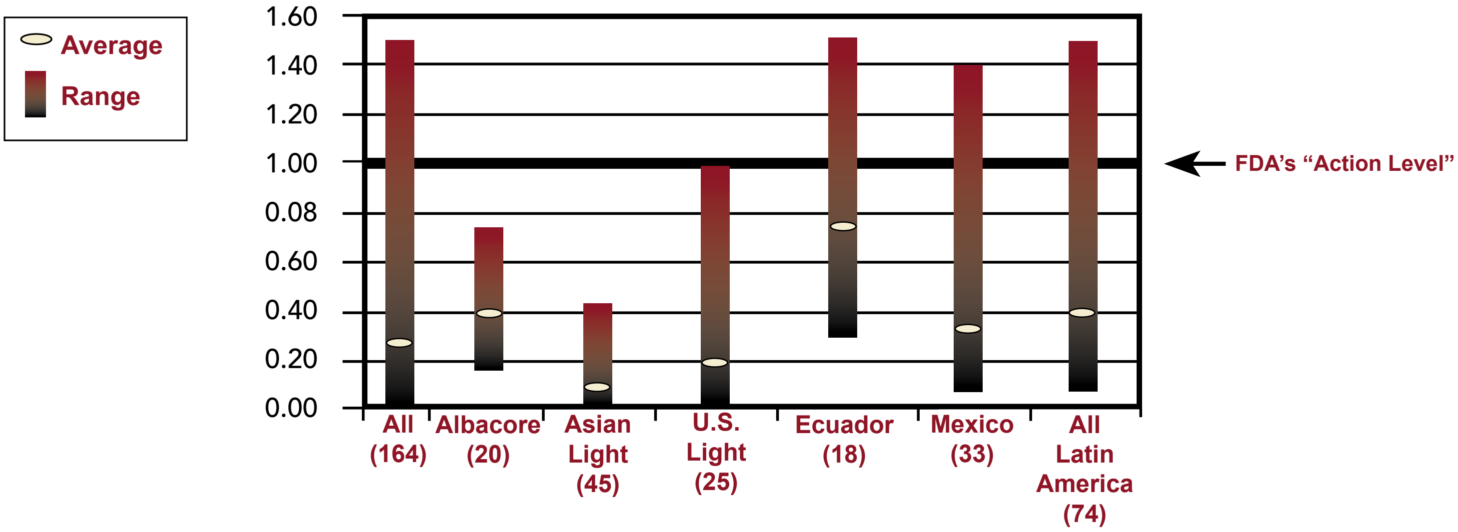
Despite Oceana's call for warning labels and signs in grocery stores, its own 2005 survey of tuna and swordfish concluded with similar results.[72] No sample of tuna in Oceana's survey approached the FDA's mercury Action Level (the highest measurement was 0.684 ppm). And while half of Oceana's swordfish samples exceeded the Action Level, none approached the actual level of health concern, which is ten times greater. The highest mercury level Oceana reported in swordfish, 2.328 ppm, is less than one-fourth of what might constitute a health risk.

Oceana's other recent data, published in February 2006, consisted of mercury levels from 190 fish caught during a July 2005 Gulf of Mexico fishing tournament.[73] Across all 30 species sampled, the average mercury level was 0.53 ppm, or barely half the FDA's Action Level. Put another way, the average mercury concentration in this study was barely five percent of the level that might be harmful. The highest mercury level was a 3.97-ppm king mackerel, which still provides a 250-percent safety margin.

The Sea Turtle Restoration Project's 2006 surveys of tuna sushi in Los Angeles[74] and San Diego[75] restaurants are particularly problematic. Based on a total of 12 pieces of fish from Los Angeles, the organization claimed in March 2006 that "women and children should not eat tuna served as sushi or sashimi." Yet the highest mercury level in this survey was 1.01 ppm, representing barely one-tenth of the level that would justify such alarm.

The group's May 2006 survey of San Diego sushi restaurants—carried out in cooperation with KGTV News—included 20 pieces of tuna, and its results were equally skewed. Despite the fact that it found

Figure 5: Mercury concentrations in canned tuna, as reported by Defenders of Wildlife (2006)



no tuna with mercury levels above the FDA's Action Level (the highest sample was 0.967 ppm), the Sea Turtle Restoration Project seemingly invented its own food-safety standard and claimed that 20 percent of the sampled fish were "unsafe for women and children to consume."

A July 2006 report from Defenders of Wildlife (issued in conjunction with the Mercury Policy Project and the Center for Science in the Public Interest)[76] tested 164 samples of canned tuna. The groups documented a small difference between mercury levels in domestic (U.S.-caught) and imported fish, but they failed to identify any samples that were unsafe to eat. The report complained about "unacceptably high" mercury levels in canned tuna and warned that "nearly one in every 20 cans of light tuna exceeded the 1.0 ppm FDA Action Level." Its authors, however, apparently couldn't find room (in a 39-page manuscript) to discuss the ten-fold safety cushion that helps *define* that Action Level.

In addition, North Carolina's Neuse River Foundation,[77] the Illinois Public Interest Research Group,[78] and the Maryland Public Interest Research Group[79] have each published data in 2006 indicating "unsafe" or "dangerous" levels of mercury in freshwater fish.

These three groups based their claims about the healthfulness of fish on the EPA's "Ambient Water Quality Criterion" (AWQC), a measurement intended to determine water pollution levels, not food safety.[80] The AWQC is currently set at 0.3 ppm. This is 70 percent lower than the FDA's more appropriate Action Level—which itself already includes a considerable safety factor.

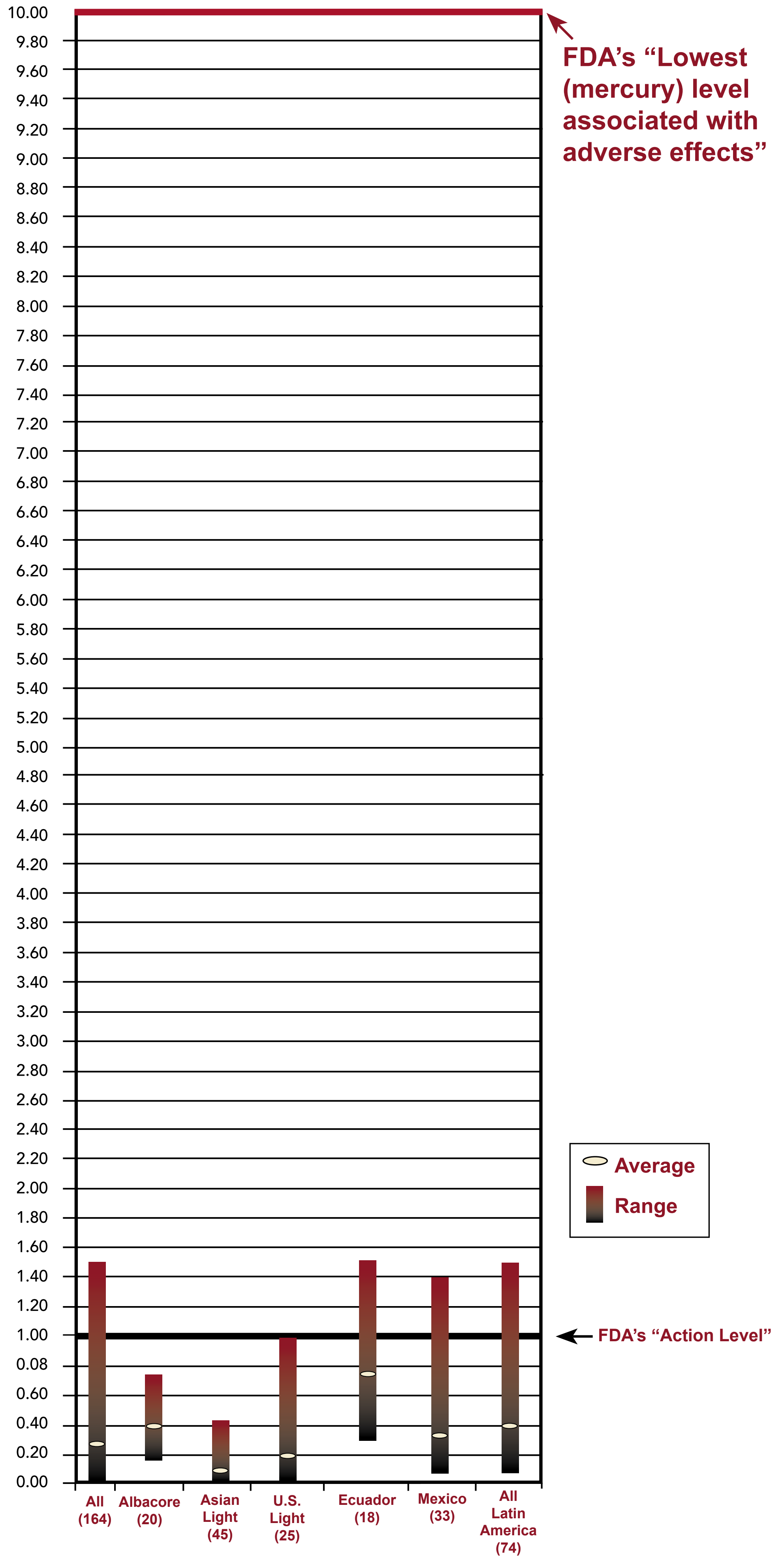
The bottom line: No fish tested in any of these studies is unsafe to eat.

Maryland PIRG found only two species of fish (out of 36) that tested above the FDA's mercury Action Level. The highest measurement, in a largemouth bass whose mercury level was 2.08 ppm, would provide an angler with a 481-percent safety margin.

Similarly, Illinois PIRG found a sample of only one fish species (out of 32) that exceeded the Action Level. The highest mercury reading, in a largemouth bass whose mercury concentration was 1.40 ppm, is 714 percent lower than a level that would justify health concerns.

The Neuse River Foundation has not released its test results, stating only that 16 out of 81 fish exceeded the EPA's AWQC level of 0.3 ppm. It is unlikely that any fish in this survey actually contained enough mercury to pose a health risk to fishermen or their families.

Figure 6: Mercury concentrations in canned tuna, as Defenders of Wildlife should have reported



A different presentation of the Defenders of Wildlife tuna-mercury data. The red line above represents a realistic harm threshold, which the Food and Drug Administration describes as the "lowest [mercury] level associated with adverse effects."

"Most of us should be eating more fish. It's an excellent source of protein and it contains essential vitamins and minerals, such as selenium and iodine."

— The United Kingdom's Food Standards Agency (2005)

Mercury Fears on the Small Screen

At least six local television news teams (in Cincinnati, Cleveland, Dallas, New York City, St. Louis, and Washington) have reported commissioning their own fish-mercury testing during the first half of 2006:

- A St. Louis reporter said a "nationally accredited lab" tested eight samples of tuna sushi, and "did not find any measurable levels of mercury."[81]
- In Dallas, a TV station tested 12 boxes of frozen fish sticks and reported that only five showed measurable levels of mercury, ranging from 0.07 to 0.01 parts per million (ppm).[82]
- The Washington report included eight swordfish steaks and warned that "more than half" tested above the FDA's mercury Action Level, with two samples testing "double" the Action Level.[83]
- New Yorkers saw a report describing the highest of "several" tuna and mackerel samples as 0.77 ppm and 0.675 ppm, respectively.[84]
- A Cincinnati news broadcast reported on single samples of canned light tuna (0.11 ppm), canned albacore tuna (0.23 ppm), and fresh albacore (0.26 ppm). The station noted that fresh and farmed salmon had "lower levels of mercury than the tuna," as did frozen pollock fish fillets. One sample of swordfish tested "50 percent higher" than the FDA's Action Level (presumably 1.50 ppm).[85]

No fish described in any of these television reports is unsafe to eat. A consumer who eats swordfish containing 2.0 ppm mercury is still protected by a 500-percent safety factor. Yet viewers were not told about the ten-fold safety cushion built into the FDA's mercury Action Level.

The Cincinnati broadcast reported that mercury in fish "can hurt you and your family." The New York City reporter incorrectly said that several sushi samples contained mercury amounts "over acceptable levels."

The St. Louis station suggested that its zero-mercury tuna samples might have come from younger fish. But its reporter still gave the activist Sea Turtle Restoration Project a platform to suggest that eating tuna was a form of "Russian Roulette" and describe avoiding all tuna fish as a "common sense precaution."

Washington viewers were told, in error, that 1.0 ppm is "the lowest level at which adverse effects could occur in adults." (That number, according to the FDA, is ten times higher.) And despite mercury readings that were near or at zero, the Dallas report ended by advising viewers to "limit the servings" of fish sticks "to about one a week."

Appendix A: Individual Mercury and Selenium Test Results

Mercury (Hg) and Selenium (Se) measurements in parts-per-million (ppm) were provided by Frontier GeoSciences. Molar weight was calculated by dividing by the atomic weight of each element. Molar ratios are simple proportions.

In theory, selenium-to-mercury molar ratios greater than 1.0 indicate that mercury has been adequately "sequestered" by selenium, affording the human body sufficient protection.

Species / sample type	ppm Mercury (Hg)	ppm Selenium (Se)	Nanomoles Hg per gram of fish	Nanomoles Se per gram of fish	Molar ratio (Se/Hg)
YELLOWFIN TUNA					
fresh	0.051	0.340	0.253	4.309	17.008
fresh	0.068	0.608	0.338	7.701	22.770
sushi	0.070	0.576	0.350	7.304	20.861
cooked	0.113	0.858	0.564	10.869	19.286
fresh	0.117	0.574	0.584	7.270	12.458
cooked	0.149	0.420	0.743	5.323	7.163
sushi	0.202	0.480	1.007	6.084	6.038
sushi	0.294	0.450	1.466	5.703	3.890
fresh	0.306	0.983	1.526	12.460	8.164
sushi	0.338	0.684	1.686	8.666	5.141
fresh	0.459	0.853	2.289	10.806	4.720
fresh	0.527	0.784	2.628	9.935	3.780
sushi	0.536	0.440	2.673	5.578	2.087
sushi	0.655	0.966	3.267	12.246	3.749
fresh	0.660	0.646	3.292	8.185	2.486
cooked	0.683	1.248	3.407	15.811	4.641
fresh	0.792	0.771	3.950	9.774	2.474
sushi	0.861	0.703	4.294	8.913	2.076
sushi	0.866	0.460	4.319	5.830	1.350
CANNED LIGHT TUNA					
canned	0.029	0.616	0.143	7.807	54.475
canned	0.033	0.669	0.165	8.483	51.262
canned	0.035	0.763	0.172	9.670	56.149
canned	0.043	0.803	0.213	10.178	47.707
canned	0.049	0.531	0.246	6.728	27.341
canned	0.062	0.664	0.311	8.416	27.060
canned	0.090	1.093	0.449	13.848	30.876
canned	0.091	0.998	0.452	12.655	28.024
canned	0.103	1.336	0.511	16.929	33.107
canned	0.103	0.641	0.514	8.129	15.805
canned	0.148	0.319	0.737	4.043	5.489
canned	0.163	0.331	0.813	4.199	5.163
canned	0.266	1.245	1.325	15.781	11.908

Individual Mercury and Selenium Test Results (continued)

Species / sample type	ppm Mercury (Hg)	ppm Selenium (Se)	Nanomoles Hg per gram of fish	Nanomoles Se per gram of fish	Molar ratio (Se/Hg)
CANNED ALBACORE TUNA					
canned	0.269	0.590	1.343	7.474	5.565
canned	0.269	0.662	1.343	8.389	6.246
canned	0.288	0.677	1.435	8.578	5.976
canned	0.305	0.760	1.522	9.633	6.328
canned	0.314	0.456	1.564	5.779	3.696
canned	0.351	0.703	1.751	8.913	5.091
canned	0.379	0.734	1.892	9.309	4.921
canned	0.415	0.627	2.069	7.947	3.841
canned	0.419	0.616	2.090	7.812	3.739
canned	0.441	0.747	2.198	9.474	4.310
canned	0.444	0.622	2.216	7.888	3.560
canned	0.479	0.590	2.387	7.472	3.130
WALLEYE					
cooked	0.026	3.215	0.130	40.747	314.484
cooked	0.065	0.450	0.325	5.703	17.550
cooked	0.067	0.539	0.337	6.837	20.316
cooked	0.096	0.192	0.479	2.432	5.082
cooked	0.105	0.534	0.523	6.774	12.948
fresh	0.109	0.322	0.545	4.081	7.488
fresh	0.111	0.370	0.555	4.689	8.452
cooked	0.121	0.641	0.605	8.127	13.428
cooked	0.123	0.184	0.615	2.327	3.783
cooked	0.135	0.380	0.673	4.816	7.155
cooked	0.300	0.299	1.494	3.787	2.534
COD					
cooked	0.003	0.447	0.014	5.664	391.202
fresh	0.025	0.208	0.126	2.640	20.892
cooked	0.045	0.209	0.227	2.654	11.697
cooked	0.051	0.228	0.252	2.892	11.463
cooked	0.057	0.202	0.282	2.561	9.083
cooked	0.061	0.228	0.305	2.895	9.492
fresh	0.066	0.250	0.331	3.174	9.583
cooked	0.071	0.400	0.354	5.070	14.309
cooked	0.135	0.320	0.672	4.056	6.033
cooked	0.180	0.380	0.898	4.816	5.363
cooked	0.339	0.321	1.689	4.062	2.405

Individual Mercury and Selenium Test Results (continued)

TROUT

Species / sample type	ppm Mercury (Hg)	ppm Selenium (Se)	Nanomoles Hg per gram of fish	Nanomoles Se per gram of fish	Molar ratio (Se/Hg)
fresh	0.015	0.146	0.075	1.844	24.538
fresh	0.018	0.400	0.089	5.070	56.961
cooked	0.019	0.410	0.095	5.196	54.848
fresh	0.022	0.168	0.112	2.132	19.094
fresh	0.025	0.430	0.125	5.450	43.531
cooked	0.041	0.340	0.204	4.309	21.167
cooked	0.042	0.400	0.209	5.070	24.315
cooked	0.044	0.285	0.218	3.610	16.585

CATFISH*

fresh	0.001	<.100	0.005	N/A	N/A
fresh	0.002	<.100	0.010	N/A	N/A
cooked	0.003	<.100	0.015	N/A	N/A
cooked	0.004	<.100	0.018	N/A	N/A
fresh	0.004	<.100	0.019	N/A	N/A
fresh	0.010	<.100	0.051	N/A	N/A
cooked	0.026	0.236	0.128	2.996	23.446
fresh	0.028	0.133	0.141	1.679	11.875

RED SNAPPER

sushi	0.002	0.512	0.008	6.493	800.647
sushi	0.004	0.197	0.018	2.501	142.073
sushi	0.010	0.223	0.048	2.826	58.361
sushi	0.010	0.310	0.052	3.929	75.580
fresh	0.063	0.543	0.315	6.877	21.835
cooked	0.115	1.079	0.574	13.674	25.829
cooked	0.201	0.614	1.002	7.781	7.766
fresh	0.222	0.732	1.108	9.272	8.367

TILAPIA

fresh	0.004	0.311	0.020	3.935	201.234
cooked	0.005	0.116	0.024	1.473	60.275
cooked	0.008	0.217	0.039	2.753	70.654
fresh	0.008	0.196	0.039	2.482	63.103
fresh	0.016	0.227	0.079	2.882	36.502
fresh	0.016	0.236	0.080	2.992	37.581
cooked	0.111	0.727	0.554	9.209	16.613

* Selenium was below 0.100 ppm (the laboratory detection limit) in six of the eight catfish samples. Molar calculations were performed on the two remaining samples with measurable selenium.

Individual Mercury and Selenium Test Results (continued)

Species / sample type	ppm Mercury (Hg)	ppm Selenium (Se)	Nanomoles Hg per gram of fish	Nanomoles Se per gram of fish	Molar ratio (Se/Hg)
MACKEREL					
sushi	0.039	0.430	0.193	5.450	28.202
sushi	0.041	0.330	0.204	4.183	20.483
sushi	0.045	0.390	0.227	4.943	21.796
sushi	0.049	0.370	0.246	4.689	19.099
sushi	0.055	0.450	0.273	5.703	20.866
sushi	0.057	0.430	0.283	5.450	19.230
HALIBUT					
cooked	0.104	0.520	0.521	6.591	12.649
fresh	0.140	0.480	0.696	6.084	8.740
fresh	0.170	0.510	0.848	6.464	7.618
fresh	0.239	0.192	1.190	2.432	2.044
cooked	0.285	0.111	1.421	1.408	0.991
SWORDFISH					
fresh	1.370	0.980	6.833	12.421	1.818
cooked	1.420	0.860	7.082	10.900	1.539
fresh	1.800	0.790	8.978	10.013	1.115
fresh	2.360	0.514	11.771	6.517	0.554
cooked	3.480	0.930	17.357	11.787	0.679
PERCH					
fresh	0.054	0.701	0.269	8.887	33.000
cooked	0.062	1.204	0.308	15.257	49.607
cooked	0.113	0.470	0.565	5.957	10.544
fresh	0.125	0.330	0.622	4.183	6.722
cooked	0.161	0.498	0.805	6.314	7.841
YELLOWTAIL					
sushi	0.141	0.221	0.702	2.806	3.999
sushi	0.166	0.410	0.829	5.196	6.266
sushi	0.181	0.850	0.905	10.774	11.908
sushi	0.196	0.360	0.977	4.563	4.668
sushi	0.224	0.380	1.119	4.816	4.303

Individual Mercury and Selenium Test Results (continued)

Species / sample type	ppm Mercury (Hg)	ppm Selenium (Se)	Nanomoles Hg per gram of fish	Nanomoles Se per gram of fish	Molar ratio (Se/Hg)
WHITEFISH					
fresh	0.021	0.520	0.105	6.591	62.532
cooked	0.024	0.440	0.120	5.577	46.633
fresh	0.048	0.460	0.242	5.830	24.106
cooked	0.068	0.506	0.338	6.410	18.949
sushi	0.163	0.460	0.815	5.830	7.155
STRIPED BASS					
sushi	0.003	0.358	0.017	4.537	273.608
sushi	0.040	0.490	0.201	6.210	30.943
sushi	0.065	0.410	0.326	5.196	15.934
sushi	0.079	0.186	0.396	2.360	5.957
MAHI MAHI					
cooked	0.390	0.459	1.945	5.823	2.994
cooked	0.470	0.593	2.347	7.511	3.201
fresh	0.656	0.324	3.270	4.108	1.256
fresh	0.660	0.340	3.294	4.309	1.308
ORANGE ROUGHY					
fresh	0.235	0.556	1.170	7.047	6.024
fresh	0.596	0.550	2.973	6.969	2.344
fresh	0.701	0.718	3.496	9.099	2.602
HADDOCK					
cooked	0.048	0.303	0.237	3.840	16.193
fresh	0.058	0.238	0.291	3.010	10.333
fresh	0.080	0.244	0.400	3.091	7.733

Appendix B: Restaurants and Grocery Stores Sampled

RESTAURANTS

Angelo's Pizzeria
5801 Monona Drive
Madison, WI 53716

Avenue Bar
1128 East Washington Avenue
Madison, WI 53703

Blue Marlin
101 North Hamilton Street
Madison, WI 53703

Captain Bill's
2701 Century Harbor Road
Madison, WI 53562

Christy's Landing
2952 Waubesa Avenue
Madison, WI 53711

Crandall's Carry-Out
5696 Monona Drive
Madison, WI 53716

Edo Garden
6309 Monona Drive
Madison, WI 53716

Edo Japanese Restaurant
532 South Park Street
Madison, WI 53715

Ginza of Tokyo
122 State Street
Madison, WI 53703

Great Dane
123 East Doty Street
Madison, WI 53703

Green Lantern
4412 Siggelkow Road
Madison, WI 53558

Joey's Seafood & Grill
6602 Mineral Point Road
Madison, WI 53705

Madison's
119 King Street
Madison, WI 53703

Mariner's Inn
5339 Lighthouse Bay Drive
Madison, WI 53704

Nau-ti-Gal
5360 Westport Road
Madison, WI 53704

Ocean Grill
117 Martin Luther King Jr. Blvd.
Madison, WI 53703

Orpheum Theatre
216 State Street
Madison, WI 53703

Red Lobster
4502 East Towne Boulevard
Madison, WI 53703

Restaurant Muramoto
106 King Street
Madison, WI 53703

Rossario's
6001 Monona Drive
Madison, WI 53716

Sushi Box
2433 University Avenue
Madison, WI 53726

Takara
315 State Street
Madison, WI 53703

Wasabi Japanese Restaurant
449 State Street, Suite G
Madison, WI 53703

GROCERY STORES

Aldi
3925 Lien Road
Madison, WI 53704

Capitol Centre Foods
111 North Broom Street
Madison, WI 53703

Copps Food Center
2502 Shopko Drive
Madison, WI 53704

Copps Food Center
3650 University Avenue
Madison, WI 53705

Cub Foods
4141 Nakoosa Trail
Madison, WI 53714

Hughes Seafood
8210 Watts Road
Madison, WI 53719

Jenifer Street Market
2038 Jenifer Street
Madison, WI 53704

Magic Mill Natural Foods
2862 University Avenue
Madison, WI 53705

Metcalfe's Sentry
726 North Midvale Boulevard
Madison, WI 53705

Pick 'n Save
5709 Highway 51
McFarland, WI 53558

Seafood Center
712 South Whitney Way
Madison, WI 53711

Whole Foods Market
3313 University Avenue
Madison, WI 53705

Williamson Street Grocery Coop
1221 Williamson Street
Madison, WI 53703

Woodman's Food Market
3817 Milwaukee Street
Madison, WI 53714

Appendix C: About Frontier GeoSciences Inc.

Frontier GeoSciences Inc. (FGS) is a leading environmental analytical laboratory that specializes in the determination of trace metals at ultra-low levels.

FGS has been instrumental during the past decade in developing the ultra-clean sampling techniques, analytical methods, and sound scientific procedures used all over the world to measure trace metals levels.

Located in Seattle, FGS provides quality analytical data to federal agencies including the Environmental Protection Agency, the U.S. Geological Survey, the National Oceanic & Atmospheric Administration, and the Department of Energy. FGS also contracts with state departments of health in Washington and New York, focusing on trace metal levels in surface water, plant and animal tissue, and soil and sediments.

FGS is staffed by over fifty scientific professionals, and its analytical methods have been rigorously tested and certified by the National Environmental Laboratory Accreditation Program.

Appendix D: Technical Information from Frontier GeoSciences Inc.

One hundred forty-two (142) fish tissue samples were submitted for total mercury analysis using cold vapor atomic fluorescence spectrometry (CVAFS). In addition to mercury analysis, all samples were submitted for the analysis of total selenium.

Samples for selenium analysis were analyzed initially by inductively coupled plasma–mass spectrometry (ICP-MS). After analysis, samples that were below the reporting limit for ICP-MS were analyzed via hydride generation–atomic fluorescence spectroscopy (HG-AFS). A total of thirty-seven (37) samples required analysis of selenium via HG-AFS.

All samples were received on May 9, 2006 in a sealed cooler with a temperature below 3.0°C. All samples were logged in according to Frontier's protocols on the day of receipt and placed in a secure freezer until sample processing occurred.

Samples were processed using ultra-clean sample handling techniques in laminar flow clean areas known to be low in atmospheric trace metals. Reagents, gases, and de-ionized water are all reagent or ultra-pure grade, and previously analyzed for trace metals to ensure very low blanks.

Daily analytical runs were begun with a 5 point standard curve, spanning the entire analytical range of interest, with additional standards run every 10 samples. The daily standard curves were calculated using the blank-corrected initial standards, a linear regression forced through zero. For each analytical set one matrix duplicate, two matrix spikes, and at least three method blanks were co-processed and analyzed in exactly the same manner as ordinary samples.

Sample preparation. Samples were thoroughly homogenized on an acid-cleaned Teflon surface using fresh razor blades for each sample. Following homogenization, approximately 0.25 grams of sample was digested with 10-milliliter concentrated nitric acid and brought to a final volume of 25 milliliters with reagent water. The digest was split and analyzed for mercury via CV-AFS.

Total mercury analysis. Digested samples were analyzed for total mercury (Hg) in accordance with the standard operating procedures described in the Frontier Geosciences Quality Assurance manual. Aliquots of each digest (100 milliliters for whole water) were reduced in pre-purged double-distilled water to Hg^o with $SnCl_2$, and then the Hg^o purged onto gold traps as a pre-concentration step. The Hg contained on the gold traps was then analyzed by thermal desorption into a cold vapor atomic fluorescence detector (CVAFS) using the dual amalgamation technique. Peak heights were measured by chart recorder and recorded on bench sheets in "chart units" to the nearest 0.2 unit.

ICP-MS selenium analysis. Sample digestates were analyzed for selenium by inductively coupled plasma–mass spectrometry (ICP-MS) on a Perkin Elmer ELAN 6100 ICP-MS. Internal standardization with ^{6}Li, ^{74}Ge, ^{115}In, and ^{195}Pt was utilized. The daily calibration standard curves were calculated using linear regression forced through zero (ELAN software). The ICP-MS software performs most calculations automatically, and outputs hardcopies with results in mg/kg as received (wet weight basis; AR) into an MS-Access database where blank corrections are performed. All sample results are reported instrument blank corrected.

HG-AFS selenium analysis. Sample digestates were analyzed for selenium (Se) via hydride generation–atomic fluorescence spectroscopy (HG-AFS). An aliquot of the digestate was boiled with 40% hydrochloric acid (HCl) and potassium persulfate ($K_2S_2O_8$) to reduce all inorganic and organic Se to Se(IV). Reaction of the sample with sodium borohydride ($NaBH_4$) releases gaseous hydrides that are carried by an argon stream into a hydrogen-fueled flame placed in the path of an atomic fluorescence detector. Peak height results are produced and concentrations are calculated using an MS-Access database. All samples were corrected for the instrument and 40% hydrochloric acid (HCl) blanks.

There were no analytical difficulties experienced with these samples. All blanks, standard reference materials, matrix spikes and matrix spike duplicate samples were within established quality control limits.

References

1. During the 1950s and 1960s, Japan saw thousands of severe mercury-poisoning cases in Minamata and Niigata, respectively, following massive industrial dumping of mercury into fishing waters. These incidents, while tragic, offer little insight into the effects of mercury at the comparatively tiny levels found in the contemporary fish supply.

2. Opinion Research Corporation. Nationally representative telephone survey of 1,011 Americans, conducted at the direction of the nonprofit Center for Consumer Freedom. July 13-16, 2006.

3. Parizek et al. "The protective effect of small amounts of selenite in sublimate intoxication." *Experientia*. 1967 Feb 15;23(2):142-3.

4. Among the most interesting is the work being carried out at the University of North Dakota's Energy and Environment Research Center, to whose scientific investigators we are grateful for their advice and guidance.

5. United States Environmental Protection Agency. "Mercury Update: Impact on Fish Advisories." June 2001. Accessed at http://www.epa.gov/ost/fishadvice/mercupd.pdf.

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Notes

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