



Risks and Benefits of Fish Consumption: Yes, Mercury is a Problem



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For

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Executive Summary

Longstanding concerns about the health hazards of methyl mercury, combined with growing evidence that eating fish offers nutritional benefits, have recently amplified debate about food safety aspects of fish consumption. Because of the challenges inherent in communicating with the public about health risks and benefits, many consumers may perceive conflicting messages. Should they eat more fish—since it’s good for the heart? Should they avoid certain fish—because the mercury (and other pollutants) they might contain could be bad for them, for their children or (if they are a mother-to-be) for their baby? The 2004 consumer advisory on mercury in fish issued by the U.S. Food and Drug Administration (FDA) and Environmental Protection Agency (EPA) for the first time mentions limiting consumption of canned tuna (the most heavily eaten fish product in the US), heightening interest even further.

Potential confusion on this subject has been exacerbated by messages from commercially interested parties, most notably, the tuna industry, which has run ads urging people to eat more tuna (fish with low to moderate mercury content). The tuna industry, and other special interest groups, have aggressively promoted the idea that eating fish is completely safe, arguing that the mercury in fish poses no health hazards.^{10,11} Some have also suggested that warnings about health hazards like mercury could make consumers eat less fish, and thereby make them lose benefits of fish consumption.¹²

The self-serving industry message that mercury in fish poses no risk to health is not scientifically defensible. While some have promoted risk-benefit analysis to answer the question of whether consumers should eat fish, that approach is too simplistic. The idea that policy can be based on a trade-off of risks against benefits, when the two are like apples and oranges, is misguided and sends a misleading message to consumers. This is not an either/or choice. By carefully choosing the fish they eat, people can benefit from consuming seafood, while also minimizing their risk from mercury exposure associated with fish in the diet.

This report summarizes the science on both the risks of mercury and the benefits of fish consumption. The truth is, mercury in fish poses health hazards worthy of concern. At the same time, fish consumption offers health benefits. To reap the health benefits while minimizing the risks associated with mercury, consumers need accurate information on which fish may be most beneficial, and which may be harmful and should be consumed less frequently or not at all. Information about risks is not toxic—methyl mercury is toxic.¹³ Information is empowering; people with the facts can make smarter choices at the seafood counter.

Empowering consumers with the information they need to make informed choices is eminently feasible. Some government agencies, non-governmental organizations, and retailers have already begun working together toward the goal of more effective risk communication about exposure risks from eating fish.¹⁴ The goal of all parties in this debate should be to develop and share accurate, balanced, useful information that puts benefits and risks in perspective and helps consumers make informed choices.

Based on a review of the best available information, this report offers the following key findings:

There is enough mercury in certain fish to pose health risks, especially for heavy and moderate fish consumers, women of child-bearing age and children. Multiple lines of evidence clearly demonstrate that methyl mercury in fish represents a real and significant health hazard. Based on the federal definition of “safe” exposure, developed by the EPA, people who eat fish one or more times a week can easily exceed that level, especially if they eat fish varieties that accumulate moderate to high levels of mercury.

- Swordfish contains about 1 part per million (ppm or $\mu\text{g/g}$) of methyl mercury on average.³⁶ One six-ounce serving contains four times the weekly recommended dose of 42 μg for a 130 pound woman.
- A six-ounce can of albacore tuna, at 0.35 ppm,³⁶ gives a person who eats it about 1.5 times the safe weekly dose for a 130 pound woman.
- A 44 pound child has a safe weekly mercury intake of 14 μg .⁵¹ If that child ate one can of albacore tuna per week, her mercury intake would be four times her safe weekly dose.

The EPA definition of “safe” exposure to methyl mercury is not over-protective; more likely, it is not protective enough. EPA applied a 10-fold uncertainty factor to a dose of mercury that caused clear adverse effects on the developing brain, in the best available epidemiological study. Special interests, particularly the tuna industry, have challenged the EPA “reference level” as arbitrary, called the 10-fold “safety factor” excessive, and argued that current exposure to methyl mercury in the United States is safe. However, the safety margin in the EPA reference level is quite narrow when compared with consensus, science-based public-health practices for defining safe exposure to toxic substances.¹⁶ Much larger safety factors, some as high as 1000-fold (or 100 times the factor applied to mercury exposure), have been used by the EPA in setting pesticide exposure limits, for example.¹⁸

Many of the scientific justifications for larger uncertainty factors could have been applied to methyl mercury, but in this case, the EPA settled for a lower safety factor due to countervailing societal interests: the benefits of fish consumption, and the economic impracticalities of achieving a significantly lower exposure target. For decades, it has been accepted that satisfactory definitions of “safe” exposure must include substantial safety margins. The debate should be about whether the 10-fold safety margin applied by the EPA to methyl mercury exposure is adequate, not about the false assertion that exposures just below the harmful level are safe.

Potential health effects associated with mercury, but not considered in the current definition of “safe” exposure, may mean mercury poses wider risks than recognized. Some studies have linked mercury exposure with an increased risk of heart disease,⁵⁴ a decline of neurological functions in the elderly,⁵⁶ and damage to the immune system.⁵⁷ This evidence suggests that mercury in fish may be a concern for everyone, not just women and children, but “safe” exposure in terms of these other hazards cannot be defined since data are limited.

Contrary to alarming industry and media messages, fish consumption in the United States has been steadily increasing and is now at an all-time high. Fears that people might eat less fish if informed of potential health hazards like mercury appear to be substantially unfounded. Fish consumption in the United States has increased 12% since the first FDA mercury advisory was issued in 2001.³⁸ More people are aware of the benefits of eating fish than of the risks from methyl mercury exposure.⁸⁸ Most people are unaware of the government advisories concerning mercury in fish and associated risks.⁸⁶

A study by the Harvard Center for Risk Analysis (HCRA), widely cited as a basis for those alarming messages, has serious methodological weaknesses, and its results have been mischaracterized. HCRA carried out a major analytical study of the benefits and risks of fish consumption, funded largely by the tuna industry.⁹⁰ The study used hypothetical scenarios, based on imagining how consumers might react to dietary advice, to project risks and benefits of changes in fish consumption. Publicity about the study has stressed the theme that “Warnings about hazards in fish may do more harm than good.”⁹² But the study actually concluded that if pregnant women choose low mercury fish over high mercury varieties (as the EPA and FDA recommend), without decreasing their overall fish consumption, there would be enormous public-health benefits from lower mercury exposure, with no loss of nutritional benefits.

One HCRA scenario projected a substantial net negative public health impact if all adult Americans ate much less fish, out of fear of mercury warnings, and lost out on benefits to the heart. This “doomsday” result got the most media attention, but it was based on an extremely unrealistic assumption—all adults would cut back their fish consumption drastically because of mercury warnings. There is actually no credible evidence to support that assumption—it is truly imaginary, and as a result, so are the projected net negative health impacts.

Interestingly, HCRA compared the benefits and risks to the developing brain of its hypothetical changes in fish consumption, and the effects of mercury were three to 10 times greater than the effects of beneficial nutrients in every scenario. However, this conclusion was not publicized by either the authors or the sponsors, nor was it picked up by the media.

People can enjoy the benefits that fish provide and avoid the risks of mercury by choosing low-mercury fish. This common-sense conclusion was strongly supported by the HCRA study. To help women and others meet these goals, dietary advice needs to be more clearly communicated. This can be done effectively at the point of sale.

Recommendations

The best current scientific evidence shows that mercury levels found in some fish pose significant public health hazards, especially for the developing fetus, children and adults who eat a lot of fish, but also that the benefits fish consumption can be achieved while minimizing the risk from mercury, by choosing low-mercury fish. Oceana and the Mercury Policy Project therefore make the following recommendations:

- Heavy fish eaters, women of childbearing age and parents of young children should choose lower-mercury fish to keep their mercury doses within safe limits. Women whose body weights are well below average (say, less than 110 pounds) and parents of young children should exercise even greater care.
- To support the FDA/EPA dietary advisory, grocery stores, should post signs alerting consumers to the varieties of fish the government has issued advisories about.
- FDA should require grocery stores to post signs alerting consumers to the varieties of fish for which the government has issued advisories.
- Consumers who eat fish more than a twice a week, or often eat high-mercury fish, should ask their doctor to get their blood tested for mercury.

Introduction

The human health hazards of methyl mercury in seafood have been well known since an outbreak of mercury poisoning afflicted children born to the fish-eating residents around Minimata Bay, Japan, in the 1950s.¹ Mercury, released in inorganic form from natural sources (e.g., volcanoes, mineral erosion) and human activities (e.g., coal combustion, chlor-alkali production, waste incineration) is converted to an organic form, methyl mercury, by bacteria in freshwater and marine sediments. Methyl mercury is taken up by aquatic organisms and bio-magnified in food webs, and predators high in the food chain can accumulate significant levels.² Fish in the diet is the largest source of most people's mercury exposure, and methyl mercury in fish has been the subject of concerns by government regulatory agencies at least since the 1970s.³

In recent years, several trends have converged to amplify long-standing concerns about the hazards of methyl mercury in fish, and made this food safety issue a focus of renewed public debate. Larger, more sensitive epidemiological studies have refined understanding of the ways methyl mercury harms human health, primarily by affecting the developing brain, and have documented harmful effects at lower doses than were previously thought to cause damage.⁴ Exposure monitoring by the Centers for Disease Control has provided evidence that large numbers of Americans—10 percent of women of childbearing age, a critical at-risk group—have blood mercury levels above the level considered “safe” for the fetus.⁵ Blood mercury levels correlate strongly with fish consumption.⁶ While this evidence of public health risk has accrued, health authorities have simultaneously urged Americans to consume more fish, because of the increasingly well-documented health benefits of fish consumption.⁷ Finally, in the last several years an intense political and economic debate over regulation of mercury emissions from power plants by the U.S. Environmental Protection Agency (EPA) has heightened interest in the potential health hazards of mercury pollution.⁸

This complex debate contains apparently conflicting messages for consumers. Eat more fish—it's good for your heart. No, avoid certain fish—the mercury (and other pollutants) they might contain could be bad for you, or if you are a mother-to-be, for your baby. Add concerns about sustainable fishing practices and depleted species to the mix, and the issue becomes even more convoluted.⁹ Potential consumer confusion on this subject has been exacerbated by messages from commercially interested parties—most notably, the tuna industry, which has run ads urging people to eat more tuna (a fish with low to moderate mercury content), and asserting that there is no evidence that mercury in fish is harmful to health.¹⁰ Special interest groups, opposed to federal regulation of business, have made the same arguments.¹¹ The fishing industry, and others, have also suggested that warning consumers about health hazards like mercury is likely to make them eat less fish, causing them to lose benefits of fish consumption, and damaging their long-term health.¹²

The self-serving message that mercury in fish poses no risk to health has been starkly contradicted by massive amounts of solid, peer-reviewed scientific evidence, which is briefly summarized later in this report, and by the consensus judgments of mainstream expert bodies and regulatory agencies. The simple truth is, mercury in fish poses health hazards worth worrying about. Fish consumption also offers significant health benefits.

Banning the sale of mercury-containing fish is neither feasible nor desirable; consumers instead need information about both benefits and risks of fish consumption. Information about risks is not toxic—methyl mercury is toxic.¹³ Information is empowering; people with the facts can make smarter choices at the seafood counter. The challenge for the public-health community is to develop effective, accurate, balanced messages that will enable consumers to enjoy the benefits of fish consumption, while minimizing their risks from toxic contaminants that accumulate in fish. Those messages also must be clearly disseminated in the face of noise generated by economic interests. This task is feasible with current knowledge, at least for methyl mercury risks. Government agencies, non-governmental organizations, and retailers have already begun working together toward the goal of more effective risk communication on this topic.¹⁴

The remainder of this report examines six critical issues central to the effort to inform consumers about the benefits and risks of eating fish and seafood. The report is in question-and-answer format and summarizes the best available evidence on each point.

Critical Questions and Answers **About Mercury, Fish and Health**

(1) How much methyl mercury in the diet is too much?

Government health advisories to date have focused on warnings that specific groups of people (especially, women of childbearing age) should avoid eating certain fish species that contain high mercury levels.¹⁵ But the problem is more complex than just high levels of mercury in fish. A person's risk from dietary mercury exposure depends on who that person is, how much fish they eat, and which fish they choose to eat. In addition, there is no sharp dividing line between "safe" exposure and "harmful" exposure. Health damage falls on a continuum, and the likelihood and severity of harm increase as methyl mercury doses increase. Safety is relative, and exposures slightly below those that produce overt harm are not safe enough.

One common way to define safe exposure is to begin with data on harmful exposures, then define an acceptable margin of safety. "Safe enough" means more than simply lack of demonstrated adverse effects; it means exposure low enough that we can be sure, with reasonable scientific certainty, that no harm is occurring. To achieve this "reasonable certainty of no harm," government agencies and expert bodies generally incorporate "uncertainty factors" in definitions of safe exposure. When toxicity data come primarily from animal tests, a factor of 10 is applied, in case humans are more sensitive to effects than laboratory animals are. On the other hand, if the primary evidence of harm is from human studies, rather than animal tests, the 10-fold factor for interspecies uncertainty is generally dispensed with. A separate factor of 10 is usually applied to account for the well-documented variability of individual humans in their sensitivity to toxic effects.

The starting point for applying these factors is ordinarily the highest dose that had *no observed adverse effect* in a well-designed animal study. Thus, the typical "reference dose" (a widely used term for the dose that is reasonably certain to cause no harm in humans) is 100-fold lower than a dose that has no observed adverse effect in animal experiments. This standard 100-fold safety margin has for decades been an accepted, consensus approach, widely recognized as necessary to protect public health and solidly founded on scientific principles.¹⁶

When the quantity and quality of available scientific evidence on which to base a risk assessment are limited, and uncertainties are therefore greater, additional safety factors are commonly applied. For instance, sometimes the toxicity data do not indicate a clear no-effect level. In that case, the starting point for application of uncertainty factors is a dose that has a measurable adverse effect, sometimes called a "benchmark" level. Under these circumstances, a wider margin is ordinarily needed to ensure reasonable certainty of no harm, and an additional uncertainty factor of up to 10-fold is often applied.¹⁷

Also, in some cases, evidence that certain sub-populations are extra sensitive to toxic effects has led to the use of more than a 10-fold factor for intra-human variability. The

Food Quality Protection Act, in particular, requires EPA to ensure that the developing brain in the fetus or young child is protected from neurotoxic effects when setting limits for pesticide residues in the diet.¹⁸ The law requires EPA to incorporate an additional uncertainty factor of up to 10-fold to ensure protection of this vulnerable group. In this and other cases, experts may judge that a full 10-fold factor is not required; when such a smaller factor is used, it often is 3 (or roughly, the square root of 10).¹⁹

In summary, standard approaches to defining safe levels of exposure to toxic substances have traditionally incorporated uncertainty factors for multiple reasons, all grounded in scientific evidence. At least four separate factors may sometimes be applied. While it is unusual for all the different scientific reasons to incorporate such factors to apply in any one instance, uncertainty factors of 1,000-fold are relatively common, in reference doses EPA has established for pesticides, for example.

Given that general approach to defining safe exposure, how is the safe dose for methyl mercury exposure, specifically, determined? The starting point is epidemiological studies that have measured the effects of mercury exposure during gestation and after birth on children's neurological development. A number of such studies have been published over the years, and they clearly document the damage done by very large doses of mercury.²⁰ In recent years, more evidence has emerged indicating that lower doses of mercury, in the range that ordinary consumers might be exposed to from fish in their diets, also appear to pose potential hazards to the developing brain. The most extensive and best-designed of these studies has been carried out for the past 18 years in the Faroe Islands, where the diet is rich in fish and whale meat. Investigators identified a cohort of 1,022 pregnant women at the start of the study, measured their mercury exposure by hair analysis, measured the mercury level in their babies' umbilical cord blood at birth, and assessed the children's neurological development as they have grown up. Objective measurements of the speed of nervous signals within the brain and several tests for cognitive abilities have associated lower performance with higher mercury exposure.²¹

The Faroes study is not the only recent evidence on this question. A New Zealand study has found similar evidence of mercury's impairment of brain development,²² while one carried out in the Seychelles Islands, where the population also has a high-fish diet, has reported no firm evidence of adverse effects of mercury on children.²³ Many scientific uncertainties remain (as is typical in environmental health) and researchers continue to debate possible reasons why one study can show clear adverse effects of mercury in a seafood diet, while another study cannot.²⁴ But a review for the EPA by the US National Research Council (NRC) concluded that the Faroes study was methodologically sound, and provides the most appropriate scientific basis for EPA action on this issue.²⁵

When it established a reference level for methyl mercury, the EPA therefore relied on the Faroes study,²⁶ as recommended by the NRC.²⁷ EPA identified the blood mercury level associated with doubling the prevalence of Faroese children with scores in the lowest 5 percent on tests for neuro-development, i.e., an exposure that had a clear adverse effect. That so-called "benchmark" blood mercury level was 58 micrograms of methyl mercury per liter of blood (58 µg/l). EPA then applied a 10-fold uncertainty factor "for intrahuman

toxicokinetic and toxicodynamic variability and uncertainty” to define the reference level as 5.8 µg/l mercury in blood.²⁸

The tuna industry has argued that current US exposure to methyl mercury is safe, because (they assert), no one exceeds the “benchmark level,” 58 µg/l methyl mercury in blood.²⁹ First, that assertion is untrue; some Americans do have blood mercury levels above 58 µg/l (see Section 2, below). And it should be clear from the preceding discussion that doses right up to the level that causes detectable harm clearly cannot be considered safe; that argument is scientifically indefensible. An acceptable definition of “safe” exposure must include a substantial safety margin.

Given the earlier discussion of science-based uncertainty factors typically applied in defining “safe” exposure, it is worth examining EPA’s decision to use only a 10-fold factor in this case. Because the evidence for adverse effects of methyl mercury comes from human data, there is no need to account for interspecies uncertainties. The 10-fold factor that EPA did apply was for intra-human variability.³⁰ But EPA started with a blood mercury level associated with a clear-cut adverse effect, not a no-effect level; typically, this would call for a larger uncertainty factor. Also, mercury affects the developing brain in the fetus and young child, and as it has done when setting reference doses for certain insecticides, EPA could probably have justified applying an additional factor to ensure that the extra-sensitive fetal brain is adequately protected. But neither of these rationales was applied to methyl mercury by EPA.³¹ EPA also assumed that the ratio of mercury in fetal blood to that in maternal blood is 1.0; in fact, it appears to be around 1.7 (range of 1.5 and 2.0), which could mean that the reference level should be correspondingly lower.³² Finally, EPA based its reference level only on effects on the developing brain; it did not try to take into account other toxic effects of mercury, such as cardiovascular damage, that some studies have associated with lower exposures than those that have adverse effects on fetal brain development.³³

In short, EPA’s judgment that 1/10 of a harmful level in the Faroes study is safe enough is certainly subject to challenge as insufficiently conservative. On the other hand, fishing industry interests have vigorously attacked the EPA reference dose as excessively and needlessly precautionary.³⁴ As a practical matter, if EPA had defined “safe” exposure as, say, 10-fold lower than the level it chose, it would have in effect classified most people who eat fish as suffering from excessive mercury exposure (see next section). But a good case can be made that EPA failed to apply uncertainty factors in this case that ordinarily are considered appropriate and necessary to protect public-health.

While debate of its adequacy should continue, the EPA reference level is nevertheless an official definition of safe exposure to methyl mercury, reviewed by the NAS/NRC, and pronounced soundly based on science and appropriately protective of public health. As such, it provides a useful reference point for comparing different people’s actual and potential exposures to methyl mercury and assessing possible associated health risks.

To estimate safe dietary mercury intake, EPA used pharmacokinetic models that describe mercury’s behavior in the body to calculate the dose (the daily dietary intake) of mercury that corresponds to 58 µg/l in blood. That dose, according to EPA, was 1 microgram of

methyl mercury per kilogram of body weight per day (1 µg/kg/day).³⁵ EPA then applied the 10-fold uncertainty factor to derive the so-called “reference dose,” 0.1 µg/kg/day. The reference dose can be used to estimate safe intake of mercury for people of various body sizes. For example, for a 60-kg (130-pound) woman, the safe daily dose is:

$$\begin{aligned} 60 \text{ kg} \times 0.1 \text{ } \mu\text{g/kg/day} &= 6 \text{ } \mu\text{g/day} \\ \text{For a weekly dose, } 7 \times 6 \text{ } \mu\text{g/day} &= 42 \text{ } \mu\text{g/week} \end{aligned}$$

Safe doses for people of other body sizes (such as children) can also be calculated, and provide a standardized, officially-derived definition of “safe exposure.” This definition then can be compared with people’s actual exposure to determine whether anyone is at risk of adverse effects from methyl mercury in their diet (see next section.)

A critical concept here is that someone who gets more than the EPA reference dose has not necessarily been *harmed*. But they are ingesting more mercury than the EPA can say, based on the scientific evidence upon which it relied, is “reasonably certain” to cause no harm. A “gray zone” exists between exposures that we can be relatively confident are safe, and exposures that we can say with conviction are harmful. The goal of public health policy is to keep as many people’s exposure as possible out of that “gray zone,” below a level we are confident is safe. A second, more urgent goal is to keep *everyone’s* exposure below the level that is clearly harmful to health.

Are we meeting those goals? See Question 2.

(2) Who is at risk from mercury in fish?

Several lines of evidence clearly demonstrate that methyl mercury in fish represents a real and significant public health hazard.

The first such evidence is based on comparing amounts of mercury in widely consumed fish species with the EPA reference dose, just described, to assess whether a person who eats a standard-sized portion of those fish would ingest more than the reference dose of mercury. Simple calculations using widely available data on mercury levels in certain fish show that many consumers can easily exceed the EPA reference dose. For example, swordfish contains about 1 part per million (1 ppm, or 1 µg/g) of methyl mercury.³⁶ A six-ounce (170-gram) serving contains 170 µg of methyl mercury—or about four times the reference dose of 42 µg/week for a 60-kg (130-pound) woman. A six-ounce can of albacore tuna, at 0.36 ppm mercury,³⁷ gives a person who eats it 60 µg of mercury, or about 1.5 times the safe weekly dose for that same standard 130-pound woman. In short, people who eat fish one or more times per week can easily exceed a safe level of mercury intake, especially if they choose fish varieties with moderate to high levels of mercury.

How many people eat enough fish to be potentially at risk? Because fish consumption has cardiovascular benefits (see Section 4), health authorities advise us to eat more of it. Many people also have substituted fish for red meat and/or poultry in their diets, either to reduce their saturated fat intake, or for ethical or other reasons. As a result, the average

amount of fish Americans consume each year has increased.³⁸ (See section 5, below.) Not everyone eats a lot of fish, but some individuals clearly eat far more than average amounts of fish and other seafood. Some sub-populations (such as native American and Inuit tribes, and island populations such as in Hawaii and Puerto Rico) have traditional diets that are very rich in seafood. But even outside such groups, many Americans now eat fish far more often than they did in the past.

In developing dietary advisories on mercury in fish and seafood, the US Food and Drug Administration (FDA) has assumed that most people will consume up to 12 ounces of fish in an average week, and advised women of childbearing age to eat no more than that amount of fish weekly.³⁹ But data the FDA used in an analysis of the effects of different policy approaches suggested that several percent of the U.S. population consume more than 12 ounces of fish and seafood per week.⁴⁰ People above the 95th percentile in fish consumption, obviously, would be most likely to ingest excessive amounts of mercury. Since 10 to 20 percent of Americans eat no fish,⁴¹ roughly 12 million people fall in the top 5 percent for fish consumption, and potentially for elevated mercury exposure.

There is also some evidence, albeit anecdotal, that some individuals have a preference for particular kinds of fish, which they consume in large quantities. Lawsuits have been filed, for example, by individuals who said they ate a can of albacore tuna a day, and suffered from mercury poisoning.⁴² Such a claim is biologically plausible; a 130-pound person eating one six-ounce can of albacore tuna every day would ingest 10 times the weekly reference dose of mercury. Such individuals are probably rare, but at least some people do have extreme dietary preferences that can put them at especially high risk of getting mercury exposure far above safe levels.

A third line of evidence that mercury exposure is a serious public-health concern comes from the National Health and Nutrition Examination Survey (NHANES), conducted at intervals by the U.S. Centers for Disease Control and Prevention (CDC). The NHANES survey examines a representative sample of the US population for a variety of health and nutritional indicators. Recent NHANES surveys have included measurements of mercury levels in blood. The 1999-2000 survey found that 8 percent of women of childbearing age in the NHANES sample had blood mercury levels above 5.8 µg/l, the EPA maximum safe level.⁴³ Blood mercury levels correlated strongly with individuals' reported intake of fish.⁴⁴ An updated report of all NHANES blood mercury data, including the most recent 2000-2002 survey, enlarged the sample of women whose blood was tested for mercury, and found elevated mercury levels somewhat less often, in 6 percent, a statistically insignificant change from the earlier survey.⁴⁵ Note, however, that what actually matters is not the mother's blood mercury level but rather that of the fetus, which is not measured in the NHANES survey, and is higher than the maternal level (see below).

It appears that the lower incidence of elevated blood mercury in the 2000-2002 survey compared to the 1999-2000 data reflects differences in the populations sampled between 1999 and 2002, rather than a downward trend in mercury exposure, and the combined 1999-2002 data are more representative of the US population as a whole.⁴⁶ Year-to-year differences aside, the NHANES data indicate unequivocally that significant numbers of

Americans are exposed to mercury above safe levels, primarily because of fish in their diets.

The focus on women of childbearing age in the NHANES data arises from the concern that mercury adversely affects the developing brain. FDA/EPA dietary advisories have also been directed primarily to women of childbearing age. The EPA's Kathryn Mahaffey notes that more than a dozen published studies show that fetal blood contains about 1.6 to 1.8 times as much mercury as maternal blood.⁴⁷ If the health goal is to ensure that fetal blood mercury remains below 5.8 µg/l, then the maternal blood mercury level should be below 3.5 µg/l ($5.8/1.7 = 3.5$).⁴⁸ The 1999-2002 NHANES survey data show 10 percent of women have blood mercury levels above 3.5 µg/l. Therefore, the population of infants exposed prenatally to methyl mercury above the safe level is roughly twice the number of women with blood mercury above 5.8 µg/l.⁴⁹ There are about 4 million births in the US annually; 400,000 babies born every year, according to Mahaffey's analysis, are likely to be exposed during gestation to more mercury than is considered safe.

While the fetus (and by extension, women who are or might become pregnant) is the most thoroughly documented population at risk from mercury exposure, other groups are also of concern. Children's brains develop rapidly up to the age of six years or so, and rapid growth and development increase vulnerability to toxic effects.⁵⁰ Because children also have small body weights, smaller doses of mercury can exceed their safe intake. For example, a 20-kg (44-pound) child has a safe weekly mercury intake of 14 µg.⁵¹ It is not hard at all to exceed this dose: a single tuna sandwich made with three ounces of albacore tuna contains 30 µg of methyl mercury. If that 44-pound child ate two such albacore tuna sandwiches a week, she would get four times her safe weekly dose of mercury. Even if the two sandwiches were made with canned "light" tuna, which contains about 0.12 ppm of mercury on average,⁵² the child's methyl mercury intake would be 20 µg/week, or 143 percent of her safe weekly intake. To prevent children from getting excessive mercury doses, parents need to choose with care the types and amounts of fish their children eat.

A few studies have also linked mercury exposure to an increased risk of heart disease,⁵³ although other studies have failed to find such an association.⁵⁴ While fish consumption is beneficial for the heart (see Section 4, below), the mercury in some fish also appears to be harmful to the heart; in fact, these opposing effects may be linked, i.e., mercury may reduce the cardiovascular benefits.⁵⁵ Additional studies have shown that mercury may cause a loss of neurological function in the elderly, either as a delayed effect of prenatal exposure, as a consequence of adult exposure, or both.⁵⁶ There is also some evidence that mercury adversely affects the immune system.⁵⁷ The accruing evidence of these possible additional risks suggests that mercury in fish may well be a concern for everyone, not just for women and children. However, there is not enough evidence yet to precisely define a maximum safe mercury exposure level with respect to heart disease, adult neurological damage or immune effects.

The final line of evidence that mercury in fish poses health hazards is probably the most compelling: Several published studies now have reported elevated mercury exposure and some evidence of mercury toxicity in Americans who have high-fish diets. For example, Hightower and Moore⁵⁸ reported on 116 patients with elevated blood mercury levels and

symptoms consistent with mercury poisoning, whose only documented source of mercury exposure was their seafood-rich diet; some of the patients reported eating fish more than 10 times per week. Four patients' blood mercury levels exceeded 50 µg/l; the highest was 85 µg/l. Most of the patients with symptoms, though, had less than 20 µg/l blood mercury when tested.⁵⁹ Four other studies have reported similar findings in groups that include commercial fishermen and their families, patients at a neurological rehabilitation clinic, island and coastal populations.⁶⁰ Further research focused on populations with high-fish diets is needed to confirm and expand evidence of high mercury exposure and associated adverse health effects.

In summary, there is ample evidence that mercury in fish poses a significant public-health risk. People who eat relatively large amounts of fish, or even moderate amounts of certain mercury-accumulating fish, are at risk of excessive exposure. The developing fetal brain is considered the most sensitive target of mercury toxicity, and the fish intake of women of childbearing age is therefore a critical concern. But young children, whose brains are growing and developing rapidly, and the population at large, because mercury exposure may increase the risk of heart disease and other adverse effects, also warrant concern.

The question is not whether this risk exists—it clearly is a real, and significantly large, public health risk. The question is not, when will well-designed research demonstrate beyond any scientific doubt that people are being harmed. Such research would be very costly and could take decades to complete, and it is ethically unacceptable to wait for conclusive proof of widespread harm, before acting to protect health. Instead, the most critical question is, what actions can be taken *now* to manage and reduce this risk. Risk communication, in the form of information on mercury in different varieties of fish and advice on reducing mercury intake by choosing low-mercury fish, is an important part of effective risk management strategies.

(3) Which fish contain mercury? Which fish are safe?

Data on the mercury content of various fish and seafood choices have been collected by the FDA, and published on the FDA web site.⁶¹ Table 1 lists 41 varieties in descending order by mercury content, based on those FDA data.⁶² The table, originally prepared by Consumers Union in 2003, also indicates how many *three-ounce* servings of each fish variety can be consumed safely, i.e., without exceeding the EPA reference dose of methyl mercury, in a week by a 60-kg (130-pound) woman and a 20-kg (44-pound) child.

The EPA/FDA advisory on mercury in fish specifically advises women of childbearing age to avoid eating the four fish varieties with the highest mercury content in the table (tilefish, swordfish, shark and king mackerel).⁶³ The advisory also urges women to limit their intake of canned albacore tuna, a very widely-consumed product, to no more than 6 ounces per week. To minimize mercury exposure, consumers, and parents choosing fish for their children, should most often choose low-mercury fish and seafood (those with a mercury content of 0.1 ppm or less).

Three factors are important for people trying to minimize their mercury intake: Which fish they choose, how much of the fish they eat (how often, and serving size); and what they weigh, since ingested dose of mercury is a function of body weight.⁶⁴ Most people probably eat fish servings larger than three ounces (the official USDA “serving size”), and should reduce the “safe” numbers of servings suggested in Table 1 accordingly. Women with relatively small body weights and parents choosing fish for their children should choose low-mercury fish and eat (or serve children) smaller portions. People who eat more than 12 ounces of fish per week, i.e., those in the top few percent in per capita fish consumption, should be especially focused on choosing low-mercury varieties.

Choosing fish and seafood requires considering more than mercury content. Some fish also accumulate other pollutants, such as PCBs, dioxins, brominated flame retardants and pesticides, from the environment. However, among all these toxic contaminants, methyl mercury appears to pose by far the greatest risks.⁶⁵ Scattered data are available on some of these pollutants in some fish varieties, but it is not currently feasible to give systematic advice on how to minimize intake of all these contaminants simultaneously; advice that comprehensive must await further research. The sustainability of fisheries and other fish-producing methods is also a concern when choosing which fish to consume; for example, see the Blue Ocean Institute’s guide to “ocean-friendly” seafood choices.⁶⁶

The following fish and seafood choices are low in mercury, “ocean-friendly,” and not currently subject to advisories for other contaminants: Farmed clams, mussels, oysters, bay scallops; Alaska salmon; American lobster; squid; Pacific soles; farmed catfish; U.S. farmed shrimp; U.S. farmed tilapia; king crab. People who wish to avoid mercury, then, have a relatively large number of popular, widely available seafood choices that are both low in mercury and support environmentally sound fishing practices.

TABLE 1. FISH AND SEAFOOD SPECIES LISTED BY MERCURY CONTENT

<i>Acceptable number of 3-oz servings per week for a 60-kg (130 lb) woman</i>	<u>Fish Species and average mercury level</u>	<i>Acceptable number of 3-oz servings per week for a 20- kg (44 lb) child</i>
0 Servings	Tilefish, 1.45 ppm Swordfish, 1.00 ppm Shark, 0.96 ppm King Mackerel, 0.73 ppm Red Snapper, 0.60 ppm Moonfish, 0.60 ppm* Orange Roughy, 0.58 ppm* Saltwater Bass, 0.49 ppm*	0 Servings
1 serving	Marlin, 0.47 ppm Grouper (Mycteroperca), 0.43 ppm Freshwater Trout, 0.42 ppm Fresh Tuna, 0.32 ppm Canned Tuna, white/albacore, 0.35 ppm American Lobster, 0.31 ppm Bluefish, 0.30 ppm* Croaker, 0.28 ppm Sea Trout, 0.27 ppm Grouper (Epinephelus), 0.27 ppm	
2 servings	Halibut, 0.23 ppm Sablefish, 0.22 ppm Pollock, 0.20 ppm Cod, 0.19 ppm Mahi Mahi, 0.19 ppm Ocean Perch, 0.19 ppm Dungeness Crab, 0.18 ppm Haddock, 0.17 ppm Blue Crab, 0.17 ppm	
3 servings	Whitefish, 0.16 ppm* Herring, 0.15 ppm* Tanner Crab, 0.15 ppm Spiny Lobster, 0.13 ppm* Canned Tuna, light, 0.12 ppm	1 serving
4 or more servings	King Crab, 0.09 ppm Catfish, 0.07 ppm Scallops, 0.05 ppm Flounder/Sole, 0.04 ppm Salmon, ND Oysters, ND Shrimp, ND Tilapia, ND* Clams, ND*	2 servings 3 servings 4 or more servings

* Indicates species for which FDA has fewer than 10 samples in its database

(4) What are the health benefits of consuming fish and seafood?

Several large, well-designed epidemiological studies have associated a decreased risk of cardiovascular disease with high-fish diets.⁶⁷ While some studies have failed to find a statistically significant association between fish consumption and cardiovascular health benefits, the expert consensus is that the benefit is real, and substantial, and consumers are now advised by most health authorities to eat more fish.⁶⁸ A recent review of this evidence concluded that people who eat fish once a week have a 17 percent lower risk of coronary heart disease, and each additional fish serving per week reduces this risk by an additional 3.9 percent.⁶⁹ (The calculated benefit applies only within the range of numbers of fish meals per week consumed by large numbers of people in the available studies, i.e., up to three or four. It cannot be inferred, for example, that eating fish 23 times per week would eliminate the risk of coronary heart disease altogether, setting mercury risk aside.)

Fish consumption may benefit cardiovascular health both indirectly and directly. The indirect benefits come not from anything in the fish itself, but rather from the substitution effect; if people eat more fish, they probably eat less red meat, lowering their saturated fat intake and the associated cardiovascular risk. The direct benefits appear to come from the omega-3 fatty acids, polyunsaturated fatty acids that are in rich supply in fish oils (as well as in certain other foods). Controlled clinical trials in which patients took omega-3 fish oil supplements have shown reductions in cardiovascular risk as great as or greater than those associated with a high-fish diet.⁷⁰

But like most issues involving diet and health, this one is more complicated than it may seem from simple messages like “eat more fish.” Fish are not all alike. Just as different species of seafood contain different amounts of mercury, different fish contain greater or lesser amounts of omega-3 fatty acids. Some species that are relatively rich in omega-3s include salmon, herring, whitefish, bluefin and albacore tuna, mackerel, rainbow trout, bluefish and sardines.⁷¹ Heavily-consumed seafood items that are relatively low in these desirable nutrients include “light” tuna, cod, clams, catfish, shrimp, perch, oysters, sole, flounder, halibut and king crab.⁷² The variation in apparent benefits in studies that have sought to link “fish consumption” with cardiovascular health may reflect insufficient specificity as to which fish are consumed.⁷³ Better definition of the benefits of eating fish may require studies that narrow the focus to consumption of particular types of fish, just as more precise assessments of risks of mercury exposure could be supported by studies focused on intake of specific fish varieties.

Fish consumption appears to have additional health benefits, beyond its cardiovascular effects. Several studies have linked fish consumption with a reduced risk of stroke.⁷⁴ The omega-3 acids are also important nutrients that the body uses when forming nerve cells;⁷⁵ fish consumption therefore appears to benefit the developing brain, although the data on this point are less clear-cut than for the heart and stroke benefits.⁷⁶ As with heart disease, eating certain fish may both offer benefits and pose risks to brain development, and these opposing effects may be interlinked in studied populations, making each type of outcome harder to measure.

An obvious question that arises is, how large are the benefits of fish consumption? And how do they compare with the substantial risks from mercury in fish? Fishing industry sources, and others, have argued that the benefits are much larger than the risks.⁷⁷ Their implication is that the risks are therefore acceptable, or should be ignored, because fish consumption offers a net health benefit. A recent analysis by the Harvard Center for Risk Analysis, funded by fishing interests, attempted to quantify and compare the risks and benefits of fish in the diet,⁷⁸ and has been widely cited in this context. (See also Section 6, below.) Risks and benefits of seafood consumption is also the subject of an ongoing study by the Institute of Medicine/National Research Council, and is receiving increased attention from scientific, government and commercial organizations.⁷⁹

But the argument that policy should be based on an apples-and-oranges comparison of risks and benefits is mistaken. This is not an either/or choice. People can benefit from consuming fish and seafood, while also minimizing their risk from mercury exposure associated with fish in the diet, by carefully choosing which fish they eat. The value of risk/benefit analysis is its systematic approach. The best strategies for managing risks of mercury in fish must consider the benefits of fish consumption, as well as other factors, such as the need for sustainable fish production. Arguments that emphasize only benefits and pay minimal attention to risks (or the reverse) should be rejected in favor of a more balanced approach.

(5) Do warnings about mercury make people eat less fish?

A question that currently appears most to concern fishing industry interests is “How can we promote the benefits of eating seafood?” This seems to be in reaction to perceptions that information about fish-related risks, such as mercury, may lead consumers to eat less fish.⁸⁰ A substantial decrease in seafood consumption could threaten industry markets, and such a dietary shift might also reduce the health benefits that Americans could get from fish consumption. But little concrete evidence exists to indicate that warnings about contaminants in fish will cause significant changes in fish consumption; in fact, evidence shows that recent US fish consumption has increased markedly, despite the warnings.

One study⁸¹ examined the fish-eating behavior of women before and after the first FDA advisory on mercury in fish. Diets of 2,235 women in a large Boston ob-gyn practice were monitored before and for 11 months after FDA issued its warning that women who were or might become pregnant should avoid consuming four specific high-mercury fish, in March 2001.⁸² The women surveyed reduced their overall fish intake from 7.7 to 6.4 meals per month after the advisory, a 17 percent decrease. Most of their total reduction (0.8 meals/month) came from eating less canned tuna, their most heavily consumed fish product, and one that often contains moderate mercury levels, although it was not one of the varieties singled out for warnings in the 2001 FDA advisory. The women also ate 0.2 fewer meals per month of “dark meat fish,” a group including swordfish, a high-mercury species. Consumption of “white meat fish,” which generally are lower in mercury, also dropped by 0.2 meals/month. Intake of shellfish, generally the lowest in mercury among seafood choices, did not change.

In short, the group of women studied substantially decreased their intake of types of fish known to be significant sources of mercury exposure; they also cut down their intake of some varieties not generally associated with mercury risk, to a smaller extent. Although these changes in eating patterns happened after FDA issued its 2001 advice, other factors (such as price, availability, advice from their doctors) also could have influenced dietary choices the women made, and a strict cause/effect relationship between the advisory and the women's decreased fish consumption cannot be inferred.

In 2004, FDA and EPA issued their current joint advisory, which conveys more balanced information.⁸³ The new advisory stresses the benefits of eating fish and lists low-mercury fish to choose, as well as high-mercury fish to avoid. FDA and EPA were aware of Oken et al.'s study and explicitly aimed to avoid unintended consequences of their advice when developing the new advisory.⁸⁴

Data on annual per capita fish consumption, compiled by the National Marine Fisheries Service,⁸⁵ show that American consumers are eating more fish, not less. Consumption increased 24 percent from 1980 through 1989, then leveled off in the 1990s, fluctuating around 15 pounds per capita per year. Consumption dropped slightly from 15.2 pounds per capita in 2000 to 14.8 pounds per capita in 2001; while some might interpret this (2.6 percent) decrease as a response to mercury concerns, it is hard to distinguish the change in 2001 from background year-to-year variation. Similar decreases in consumption of 0.2 to 0.4 pounds per capita occurred three times in the preceding 10 years, suggesting that factors other than concern about mercury are probably also involved.

Since 2001, US per capita fish consumption has increased steadily, from 14.8 pounds per person per year in 2001, to 15.6 in 2002, 16.3 in 2003, and 16.6 in 2004, a net increase of 12 percent over the four-year period. The 16.6 pounds consumed per capita in 2004 is the highest ever recorded. Americans are apparently getting the message that fish is good for their health, and eating more fish. The fact that a historical high-water mark in per capita fish consumption has been reached during a period when publicity about methyl mercury in fish has also been intense suggests that mercury warnings are just one of many factors, and not the one given greatest weight, in consumers' decisions about eating fish.

Some studies have also attempted to find out what consumers know about the benefits and risks of eating fish, and what factors influence their decisions in the marketplace. In December 2004, Oceana commissioned a public-opinion survey to assess consumers' awareness of and desire for information about mercury in fish.⁸⁶ The results showed that only 34 percent knew that mercury in swordfish and tuna can be a problem. Recently, a study from the University of Maryland⁸⁷ found 31 percent of Americans are concerned about mercury in seafood. Taken together, these surveys suggest that two-thirds or more of US adults are unaware of either the dietary advisories or more general concerns about mercury in fish and seafood. A study of New Jersey consumers⁸⁸ found that more people (94 percent) were informed about the benefits of eating fish than had heard about risks in general (73 percent). While 53 percent recalled hearing some warnings about tuna, only 31 percent were aware of the (2001) FDA advisory, and only 13 percent knew that the advisory included a warning about shark and swordfish. It appears from the limited data, therefore, that Americans are not generally well enough informed about mercury in fish

to justify the assumption that they are reducing their fish consumption to avoid potential mercury hazards. Furthermore, myriad advisories about mercury in sport-caught fish have been issued by state health departments, targeted at anglers and other at-risk groups. A primary concern of state and federal risk communicators (and documented in the literature) is that advisories that reach these groups are often ignored.⁸⁹

In summary, current industry efforts to promote eating fish for its health benefits seem to stem at least in part from fears that consumers may “get the wrong message” or make poorly-informed decisions about the fish they consume, not from credible evidence that risk information affects consumers this way. In fact, the available evidence suggests that such fears are unjustified; fish consumption has increased substantially at the same time that warnings about mercury in fish have been published. Fear is a poor basis for policy, and messages that overstress the benefits of fish consumption, while they ignore or play down the risks, are inappropriate. The goal of all interested parties in this debate should be to develop accurate, balanced, useful information that puts both benefits and risks in perspective and helps consumers make informed choices.

(6) What did the recent study by the Harvard Center for Risk Analysis *really* say?

A major analytical study of the benefits and risks of fish consumption was carried out by the Harvard Center for Risk Analysis (HCRA), and was published in October 2005 in the *American Journal of Preventive Medicine*.⁹⁰ The study was funded largely by the fishing industry, and has been widely publicized, both by Harvard and by the affected industries, which have put their own “spin” on the results. The lead investigator, Joshua T. Cohen, has stated his opinion that fear of mercury and other hazards in fish may make people eat less fish, and thus lose out on (what he perceives as) potentially greater health benefits associated with fish consumption.⁹¹ The theme of most media coverage of the study has been that “warnings about hazards in fish may do more harm than good.”⁹²

The HCRA study, however, cannot be reduced to simplistic sound bites. It was a large and complex endeavor, with diverse and nuanced conclusions. Moreover, it was a first attempt at an important, innovative, comprehensive look at this problem; and like most first attempts, it is subject to many methodological criticisms. In the interest of helping future studies develop sounder analytical approaches, and to put some of the inaccurate press accounts of the study in perspective, it is worth examining the study, its principal conclusions, and its strengths and weaknesses, in some detail.

The study actually consisted of six separate papers: An introduction and overview;⁹³ four separate papers that reviewed the literature and developed dose-response relationships for the associations between fish consumption and heart disease,⁹⁴ stroke,⁹⁵ mercury-related damage to the developing brain,⁹⁶ and omega-3 related benefits to the developing brain;⁹⁷ and an assessment that constructs scenarios based on hypothetical consumer responses to dietary advice and projects and compares risks and benefits, based on the dose-response analyses just listed.⁹⁸ Included in the journal’s package, but not part of the HCRA study, were two commentaries: One, by senior Harvard nutritionist Walter Willett, warns of an impending public-health disaster that he blames on information about toxic pollutants in

fish.⁹⁹ The other, a broad look at ecological and social-justice aspects of possible trends in fish consumption, asks what may happen to global fisheries, and to fish consumption among the poor here and abroad, if well-to-do and well-educated Americans follow the advice now being offered by nutritional experts and eat more fish.¹⁰⁰

There are three components to the study: Its *scientific* elements; its *speculative* elements; and the way it has been publicized. Each component is subject to different criticisms, so the varied elements are evaluated separately here, with emphasis on the first two.

Scientific Elements: As scientific analysis, the four dose-response papers are useful and reasonably well done. They attack important and interesting questions and creatively try to apply innovative analytical techniques to shed light on them. Nevertheless, there are several important methodological weaknesses, some particular to individual sub-studies and some common to all four studies.

For example, the two analyses of positive effects (of the omega-3s) and negative effects (of mercury) on the developing brain used increase or decrease in IQ, respectively, as the outcome measures. While IQ, a numerical index, facilitates comparisons of benefits and harm, IQ is not necessarily the best (nor the most sensitive) measure of cognitive effects of prenatal mercury exposure. In fact, mercury effects on IQ were not measured in the Faroe Islands study; HCRA analysts instead estimated likely IQ effects in that study by using available correlations between IQ and some of the cognitive outcomes that actually were measured. Such correlations may be imprecise, and IQ has not been correlated with all of the actual effects detected in the Faroese children, so the HCRA analysis does not accurately capture the effects mercury had in that study.

As another example, the analysis that looked at beneficial effects of omega-3s in fish on the developing brain relied on eight studies, seven of which involved adding omega-3s to infant formula; only one of the eight studies involved supplementing the maternal diet with omega-3s during gestation. In other words, seven of the eight studies relied on did not examine the effect being modeled—prenatal benefits of fish in the mother's diet. The data on infants are the best data available, but major uncertainties remain as to whether a dose-response relationship derived from infant feeding can accurately represent how the fetal brain would respond to omega-3's in the maternal diet.

Another methodological problem associated with any analysis of such breadth is its focus on aggregate impacts. The dose-response relationships derived, for example, are averages from multiple studies. While this approach considers a large amount of available data, it excludes some studies on each topic because their results were not suited for this type of analysis. That is, the studies relied upon may be those judged best to meet the needs of the analysis, rather than those that provide the best evidence on the questions tackled.

A separate problem related to aggregation is the way results are expressed, not only in the four dose-response papers, but also in the integrated analysis of benefits and risks. Most of the outcomes are examined for either all women of childbearing age, or the entire US adult population. IQ effects, for example, are expressed as total IQ points lost or gained by all the babies born in a year. The average effect is less than 0.1 IQ point per capita, in

either direction. While estimates of aggregate impacts do suggest overall societal costs, they also obscure much more variable individual impacts. The effects on people at the “tails of the curve” often matter more than effects on the average person. For instance, mercury damage to the developing brain would probably be concentrated among babies of mothers who had the highest mercury exposure, not evenly distributed over all babies born in a year. Impacts on affected individuals (a few percent of all children) would be far larger than 0.1 IQ point, and the social costs of those effects would be substantial.¹⁰¹

In addition to their insensitivity to distinctions among sub-populations that might be differentially affected, the HCRA analyses all treat “fish consumption” in the aggregate, as if the risks and benefits of consuming any and all varieties of fish were the same. The authors acknowledge that this is not the case; both omega-3 intake and mercury exposure are likely to vary substantially, depending on which kinds of fish people eat. But for the most part, such real-world variability was too complex to be modeled in the analyses by HCRA, seriously limiting the usefulness of the results.

Speculative Elements: The keystone analysis of the package, the comparison of risks and benefits, is explicitly an examination of *hypothetical scenarios*. Cohen et al. acknowledge that there is very little actual evidence to tell us how consumers will respond to various messages about seafood—either warnings to avoid mercury-containing fish, or advice to eat more fish. They therefore made some assumptions about how people *might* respond, and developed five scenarios:

- Scenario 1 considered only women of childbearing age, and assumed that they would correctly follow the EPA/FDA advisory and substitute low-mercury fish for higher mercury fish, without reducing their overall fish consumption.
- Scenario 2 assumed that women of childbearing age would misunderstand mercury advisories and would not specifically eliminate high-mercury fish from their diets but would instead reduce their overall fish intake by 17 percent.
- Scenario 3 assumed that all adults (not just women of childbearing age) would react to mercury warnings by reducing their overall fish consumption by 17 percent.
- Scenario 4 assumed that everyone *except* women of childbearing age would increase their fish consumption by 50 percent, in response to dietary advice to eat more fish.
- Scenario 5 assumed that everyone, including women of childbearing age, would eat 50 percent more fish.

The analysis then projected the outcomes of these hypothetical changes in national eating patterns, in terms of the beneficial effects of fish consumption and the adverse effects of mercury exposure.

Scenario 1 projected substantial health benefits with essentially no adverse public health impacts; the authors called this their “win/win” outcome. That is, if the current EPA/FDA dietary advisory is properly understood and followed by all women of childbearing age, they will avoid mercury damage without losing other health benefits of fish consumption. Scenario 2 also produced a small net health benefit, but with less gain in terms of avoided mercury damage, and some offsetting loss of other benefits associated with the decrease in overall fish consumption. Scenario 3 projected a substantial negative national public health impact, as population groups assumed to be less at risk from mercury exposure (in particular, elderly men) lost out on cardiovascular benefits by decreasing their fish intake.

Scenario 4 produced a large public health benefit. So did Scenario 5, but the benefit was partially offset by increased mercury damage associated with higher fish consumption among women of childbearing age.

The results of these scenarios are interesting, and it is useful to imagine what the future might be like, in order to assess the possible consequences of current interventions. But one must keep in mind, first, that scenarios are not predictions, and the impulse to treat them as “future facts” needs to be strongly resisted. Second, a scenario is only as good as the assumptions it is founded upon, and some of the assumptions made by Cohen et al. certainly invite challenge.

In particular, the critical assumption in Scenarios 2 and 3 is that women’s (in Scenario 2) or everyone’s (in Scenario 3) overall fish consumption will decrease 17 percent because of misunderstanding of government warnings about mercury in fish. That assumption is highly suspect since it is based on a single study, by Oken et. al., discussed in Section 5, above.¹⁰² Oken et al.’s findings presumably reflect reactions to the FDA’s 2001 mercury warning, not to the current, more balanced, 2004 EPA/FDA advisory. Further, the women in that group did decrease their fish consumption by 17 percent in the 11 months after the 2001 FDA advisory was issued; but, as noted above, they selectively ate less canned tuna and swordfish, among other varieties, and reduced their consumption of low-mercury fish and shellfish far less dramatically. But for their Scenarios 2 and 3, Cohen et al. assumed an across-the-board reduction in intake of all fish. Cohen et al. also seem to have failed to consider actual data on US fish consumption from 2001 through 2004 (discussed in Section 5), which show that per capita fish consumption increased 12 percent over that four year span.¹⁰³

For all these reasons, it therefore seems quite tenuous to assume, first, that all American women will respond to the 2004 advisory, over extended periods, the same way a group of women in Boston responded for 11 months to the earlier FDA warning. Second, it defies all logic to assume that elderly men and the rest of the adult population, on whom the Oken et al. study offers no evidence whatsoever, will respond to the current advisory the same way those Boston women responded to a simpler, scarier message four years ago. Two-thirds or more of US adults appear to be unaware of concerns about mercury in fish, despite the FDA’s and EPA’s efforts to disseminate their latest advisory. Cohen et al.’s assumed 17 percent drop in everyone’s fish consumption therefore appears to be an unrealistic worst-case scenario, contradicted by most of the available evidence.

This is far from the only debatable assumption upon which the HCRA scenarios rest, but it is the Achilles heel of the study. It is the single driving assumption that leads to all the negative health consequences in scenarios 2 and 3—which are the basis for the featured conclusions that “warnings can do more harm than good.” The plain fact is, there is little or no credible basis for assuming that warnings about mercury will lead to a substantial or lasting decrease in overall fish consumption by the entire adult population.

Publicity: One problem with complex scientific studies is that most people never read the actual research reports; they just read the media accounts. As noted at the beginning of this section, news reports about this study did not convey an accurate or balanced picture

of its methods and findings. Most of the coverage focused on Scenario 3, which predicts a large net negative effect on public health. Scenario 1—which projects that the current FDA/EPA advice could greatly reduce mercury damage with almost no offsetting loss of nutritional benefits—attracted far less attention. The point that Scenario 3 is based on an assumption—that all adults would reduce their fish consumption by 17 percent—which in turn is based on a single study that did not address that issue at all—was not picked up by the news media. Harvard’s press release did not help matters much, either. It did note that only one study exists concerning how “women” react to “advisories,” but then stated “...nor is it difficult to imagine that other adults, not targeted by the advisory, cut back on fish, based on misperceptions about the risks.”¹⁰⁴ Their word choice is apt: The assumed reduction in fish consumption is *imaginary*. The problem is that the study’s authors and many of those publicizing it have treated it as if it were real.

An additional aspect of the HCRA study warrants critical comment. A prominent theme of recent industry statements, especially from the tuna industry, has been that the benefits of fish consumption for children’s developing brains vastly outweigh the risks posed to brain development by the mercury in fish.¹⁰⁵ Four of HCRA’s five scenarios explicitly compared the positive and negative effects of fish consumption on brain development, and in all four cases, the effect of mercury (whether seen as IQ points gained by reducing mercury exposure, or IQ points lost due to increased fish consumption) exceeded the effect of omega-3 intake (seen as IQ points gained from increased intake, or IQ points lost when fish consumption was reduced), by a wide margin. In Scenario 1, the mercury damage avoided outweighed the benefits of omega-3 intake by almost 10-to-1. In both Scenarios 2 and 3, the gain from reduced mercury exposure was 3 times greater than the loss from reduced omega-3 intake, and in Scenario 5, the loss of IQ points from increased mercury exposure was 3 times the gain in IQ from increased omega-3 intake. (Scenario 4 excluded pregnant women, so these two effects were not considered there.)

In short, this industry-funded study powerfully contradicts one of the main themes of the fishing industry’s current campaign to neutralize economic impacts of mercury warnings. But this central conclusion of the study was publicized neither by the Harvard authors nor by any of the commercial interests that have sought to call attention to the study.

Overall, the HCRA study attempted an interesting and useful analysis on an important topic, but was hamstrung by lack of data on many critical aspects, by some questionable or untenable assumptions leading to unrealistic hypothetical scenarios, and by strictures of the analytical framework, such as the need to consider only aggregate indices, which limit the value of the results. The greatest value this study may have be to highlight areas in which there are too few data to answer key questions. By doing that, the HCRA study could spur other investigators to gather better data and carry out sounder analyses of the benefits and risks of fish consumption.

References and Notes

- ¹ Huddle, N., M. Reich and N. Stisman (1987), *Island of Dreams: Environmental Crisis in Japan*. Rochester, VT: Schenkman Books, Inc.; 2nd Edition.
- ² The US EPA has compiled extensive information on the environmental behavior of mercury; for example, see <http://www.epa.gov/mercury/faq.htm#1>.
- ³ The US FDA first established an action level for mercury in fish in 1975. Numerous state governments and the US EPA have issued, collectively, hundreds of consumer advisories warning about mercury in fish from contaminated waters (see <http://www.epa.gov/mercury/advisories.htm>).
- ⁴ Grandjean, P., et al. (1997), Cognitive deficit in 7-year-old children with prenatal exposure to methyl mercury. *Neurotoxicol Teratol* **19**:417-428; National Research Council (2000), *Toxicological Effects of Methylmercury*. Washington, DC: National Academy Press.
- ⁵ Analysis by K.R. Mahaffey, US EPA, presented at the 2005 Fish Forum, September 19, 2005; available at http://epa.gov/waterscience/fish/forum/2005/presentations/Monday%20Slides%200919/afternoon/Mahaffey_Fish%20Forum%202005%20-%20Mahaffey%20Final.ppt. CDC report of NHANES data: see Jones, R.L., et al. (2004), Blood Mercury Levels in Young Children and Childbearing-Aged Women—United States, 1999-2002. *Morbidity and Mortality Weekly Reports* **53**(43):1018-1020, November 5, 2004. US Centers for Disease Control and Prevention.
- ⁶ Schober, S.E., et al. (2003), Blood Mercury Levels in US Children and Women of Childbearing Age, 1999-2000. *JAMA* **289**(13):1667-1674.
- ⁷ US Department of Agriculture (2004), Dietary Guidelines for Americans: 2005. Available on USDA web site at <http://www.healthierus.gov/dietaryguidelines/>.
- ⁸ For example, see Gayer, T. and R.W. Hahn (2005), Regulating mercury: What's at stake? (letter), *Science* 8 July, p. 244; Zeller D. and S. Booth (2005), Costs and Benefits of Regulating Mercury (letter), *Science*, 4 November, pp. 777-779.
- ⁹ See for example <http://www.blueoceaninstitute.org/seafood/>.
- ¹⁰ Many examples of denial of the evidence of mercury hazards and promotion of increased fish (and specifically, tuna) consumption are accessible on the US Tuna Foundation web site. For example, see http://www.tunafacts.com/news/eat_more_fish_081505.cfm.
- ¹¹ For example, see Swarc, S., Fishy Advice: The Politics of Methylmercury in Fish and Mercury Emissions, Competitive Enterprise Institute, December, 2004; Schwartz, J., "Clear Foolishness," American Enterprise Institute, March 2005; Soon, W., "More on Eating More Fish," Annapolis Center for Science-Based Public Policy, available at <http://acsh.org>.
- ¹² For example, see "Study Finds Government Advisories on Fish Consumption and Mercury May Do More Harm Than Good," Press Release, Harvard School of Public Health, October 19, 2005. Available at <http://www.hsph.harvard.edu/press/releases/press10192005.html>.
- ¹³ Information may, however, be hazardous to the sale of certain products. The tuna industry has sued the State of California in an attempt to block a state requirement that the mercury content of certain fish (tuna among them) be disclosed to consumers at the point of sale. See press release posted on BusinessWire, 9:41 PM October 19, 2005, "Tuna Canners Take Attorney General to Task; Opening Statements Given in Trial That Could Determine the Future of Healthy Eating In California."
- ¹⁴ See for example Oceana press release, "Concerned Moms Urge Supermarkets to Post Warning Signs for Mercury-Tainted Seafood," November 17 2005; also, Heckman, C., "Grocery chains post fish warnings," Seattle Post-Intelligencer, October 20, 2005; Galehouse, M., "All Safeways to carry mercury warnings," The Arizona Republic, October 20, 2005.
- ¹⁵ See "What You Need to Know About Mercury in Fish and Shellfish," the current FDA/EPA advisory; available at <http://www.epa.gov/waterscience/fishadvice/advice.html>. Also see state advisories, available through the EPA web site (see Note 3, above).
- ¹⁶ For a discussion of the history and application of "safety factor" and "uncertainty factor" approaches, see National Research Council (1994), *Science and Judgment in Risk Assessment*. Washington, DC: National Academy Press, pages 30-31 and 60-63.
- ¹⁷ NRC 1994, *ibid*.
- ¹⁸ The use of an additional safety factor is specifically required by the Food Quality Protection Act, passed in 1996, which provides for EPA's regulation of pesticide residues in foods. For a discussion of the FQPA, its requirements, and the basis for them, see Benbrook, C.M., E. Groth, et al. (1996), *Pest Management at the Crossroads*. Yonkers: NY: Consumers Union of US, Inc.
- ¹⁹ See Stern, A. (2005), A Fresh Look at the Uncertainty Factor Adjustment in the Methylmercury RfD. Presentation at the EPA Fish Forum, September, 2005.
- ²⁰ The NRC (note 4 above) has reviewed this literature; see NRC (2000) for references.
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- ²² Kjellstrom, T., et al. (1989), Physical and Mental Development of Children with Prenatal Exposure to mercury from Fish. Stage 2: Interviews and Psychological Tests at Age 6. National Swedish Environmental Board, Solna, Sweden.
- ²³ Myers, G.J., et al. (2003), Prenatal methylmercury exposure from ocean fish consumption in the Seychelles child development study. *Lancet* **361**:1686-1692.
- ²⁴ For example, see Clarkson, T.M., L. Magos and G.J. Myers (2003), The Toxicology of Mercury—Current Exposures and Clinical Manifestations. *N Engl J Med* **349**(18):1731-1737. Also, Grandjean, P., S. Cordier, T. Kjellstrom, P. Weihe, and E. Budtz-Jørgensen (2005), Health Effects and Risk Assessments. Chapter 22, pp. 499-523 in: Pirrone, N. and K.R. Mahaffey, eds., *Dynamics of Mercury Pollution on Regional and Global Scales: Atmospheric Processes and Human Exposures Around the World*. Nrowell, MA: Springer.
- ²⁵ NRC (2000), Note 4 above, page 6.
- ²⁶ Rice, D.C., R. Schoeny and K. Mahaffey (2003), Methods and rationale for derivation of a reference dose for methylmercury by the US EPA. *Risk Anal.* **23**(1):107-115.
- ²⁷ NRC (2000), Note 4, above, page 6.
- ²⁸ Rice et al. (2003), Note 26 above.
- ²⁹ For example, see "Eat More Fish!" at http://www.tunafacts.com/news/eat_more_fish_081505.cfm

- ³⁰ Rice, D.C. (2004), The US EPA Reference Dose for methylmercury: Sources of uncertainty. *Environ Res.* **95**(3):406-413.
- ³¹ Ibid.
- ³² Rice et al. (2003), Note 26, above.
- ³³ Ibid.
- ³⁴ “Eat More Fish!,” Note 29, above.
- ³⁵ Rice et al. (2003), Note 26, above.
- ³⁶ For FDA data on mercury levels in fish; see <http://www.cfsan.fda.gov/~frf/sea-mehg.html>.
- ³⁷ Ibid.
- ³⁸ National Marine Fisheries Service (2005), Fisheries of the United States, 2004. Page 79, Per Capita Consumption. Silver Spring, MD: National Ocean and Atmospheric Administration. The referenced table contains data on per capita fish consumption since 1910. Per capita consumption rose from 12.5 to 15.5 pounds per year during the 1980s, fluctuated around 15 pounds per year from 1990 to 2001, and has risen for the last three years to 16.6 pounds per capita in 2004. The NMFS statistical report is available at http://www.st.nmfs.gov/st1/fus/fus04/fus_2004.pdf.
- ³⁹ See FDA/EPA joint dietary advisory on mercury in fish and seafood, Note 15, above.
- ⁴⁰ Carrington, C.D., and P.M. Bolger (2004), An intervention analysis for the reduction of exposure to methylmercury from the consumption of seafood by women of child-bearing age. College Park, MD: U.S. Food and Drug Administration.
- ⁴¹ Carrington, C.D. and P.M. Bolger (2002), An exposure assessment for methylmercury from seafood for consumers in the United States. *Risk Anal.* **22**:689-699.
- ⁴² The author knows of one such lawsuit, filed in Alabama, based on a personal communication from the plaintiff’s lawyer, who mentioned other cases.
- ⁴³ Mahaffey, K.R., R.P. Clickner, and C.C. Bodurow (2004), Blood Organic Mercury and Dietary Mercury Intake: National Health and Nutrition Examination Survey, 1999 and 2000. *Environ Health Perspect* **112**: 562-570.
- ⁴⁴ Ibid. See also Schober et al. (2003), Note 6 above.
- ⁴⁵ See Jones, et al. (2004), Note 5, above.
- ⁴⁶ Mahaffey (2005) presentation at Fish Forum, Note 5, above.
- ⁴⁷ Mahaffey (2005), *ibid.*, summarizes findings of 13 studies on this topic.
- ⁴⁸ Mahaffey (2005), *ibid.*; also Mahaffey presentation at 2004 Fish Forum, “Methylmercury: Epidemiology Update”, at <http://www.epa.gov/waterscience/fish/forum/2004/presentations/monday/mahaffey.pdf>.
- ⁴⁹ Mahaffey (2005), *ibid.*
- ⁵⁰ See National Research Council (1993), *Pesticides in the Diets of Infants and Children*. Washington, DC: National Academy Press, for a discussion of the vulnerability of the developing nervous system.
- ⁵¹ Based on the EPA reference dose: 20 kg x 0.1 µg/kg/day x 7 days = 14 µg.
- ⁵² FDA data, see <http://www.cfsan.fda.gov/~frf/sea-mehg.html>.
- ⁵³ Salonen, J.T., et al. (1995), Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular and any death in eastern Finnish men. *Circulation* **91**:645-655. Also, Rissanen, T., et al. (2000), Fish-oil derived fatty acids, docosahexaenoic acid and docosapentaenoic acid, and the risk of acute coronary events: The Kuopio ischaemic heart disease risk factor study. *Circulation* **102**:2677-2679. Also, Guallar, E., et al. (2002), Mercury, fish oils and the risk of myocardial infarction. *N Engl J Med* **347**:1755-1760. Also, Grandjean, P. et al. (2004), Cardiac Autonomic Activity in Methylmercury Neurotoxicity: 14-Year Follow-Up of a Faroese Birth Cohort. *J. Pediatr.* **144**:169-176.
- ⁵⁴ For reviews of this literature, see Stern, A.H. (2005), A review of the studies of the cardiovascular health effects of methylmercury with consideration of their suitability for risk assessment. *Environ Res* **98**:133-142; also, Konig, A., et al. (2005), A Quantitative Analysis of Fish Consumption and Coronary Heart Disease Mortality. *Am J Prev Med* **29**(4):335-346.
- ⁵⁵ See Stern’s review, cited in Note 54, above.
- ⁵⁶ For example, Yokoo, E.M., et al. (2003), Low level methylmercury exposure affects neuropsychological function in adults. *Environmental Health: A Global Access Science Source* **2**:8. Also, Newland, C.M. and E.B. Rasmussen (2003), Behavior in Adulthood and During Aging Is Affected by Contaminant Exposure in Utero. *Current Directions in Psychological Science* **12**(6):212-217. Also see Rice et al. (2003), Note 26, above, for discussion.
- ⁵⁷ NRC 2000; Note 4, above.
- ⁵⁸ Hightower, J.M. and D. Moore (2003), Mercury Levels in High-End Consumers of Fish. *Environ Health Perspect* **111**:604-608.
- ⁵⁹ Hightower and Moore (2005), *ibid.* The median blood mercury level was 14 µg/l, and 81 percent had less than 20 µg/l.
- ⁶⁰ See Mahaffey (2005), Note 5, above, for a summary of these studies.
- ⁶¹ For FDA data on mercury levels in fish; see <http://www.cfsan.fda.gov/~frf/sea-mehg.html>.
- ⁶² This table appeared originally in a Statement by Consumers Union Of U.S., Inc., Regarding Federal Dietary Advice on Methyl Mercury in Fish and Seafood, presented by Edward Groth III, PhD., Senior Scientist, Consumers Union, at an FDA/EPA “Stakeholders Meeting,” College Park, MD, July 30, 2003. Available at <http://www.consumersunion.org/pdf/mercury-FDA.pdf>.
- ⁶³ EPA/FDA advisory; see Note 15, above.
- ⁶⁴ “Mercury calculators” that indicate how much of a given fish with a given mercury content can safely be consumed by a person with any given body weight are available on the Internet. See, for example, one by the Mercury Policy Project, available at <http://www.mercuryproject.org/calculator/>.
- ⁶⁵ Cohen, J.T., et al. (2005), A Quantitative Risk-Benefit Analysis of Changes in Population Fish Consumption. *Am J Prev Med* **29**(4):325-334.
- ⁶⁶ Available at <http://www.blueoceaninstitute.org/seafood/>.
- ⁶⁷ Kris-Etherton, P., W.S. Harris and L.J. Appel (2002), Fish Consumption, Fish Oil, Omega-3 Fatty Acids, and Cardiovascular Disease. An American Heart Association Scientific Statement. *Circulation* **106**:2747-2757. See also Konig et al. (2005), Note 69, below.
- ⁶⁸ For example, see US Department of Agriculture (2004), Dietary Guidelines for Americans: 2005. Available at <http://www.healthierus.gov/dietaryguidelines/>.

- ⁶⁹ Konig, A., et al. (2005), A Quantitative Analysis of Fish Consumption and Coronary Heart Disease Mortality. *Am J Prev Med* 29(4):335-346.
- ⁷⁰ Reviewed by Konig et al. (2005), *ibid*.
- ⁷¹ *Consumer Reports*, Omega-3 oil: Fish or Pills? July, 2003, pp. 30-32.
- ⁷² *Ibid*.
- ⁷³ For discussion, see Mahaffey, K.R. (2004), Fish and shellfish as dietary sources of methylmercury and the omega-3 fatty acids, eicosahexaenoic and docosahexaenoic acid: risks and benefits. *Environ Res.* 95(3):414-428.
- ⁷⁴ Bouzan, C., et al. (2005), A Quantitative Analysis of Fish Consumption and Stroke Risk. *Am J Prev Med* 29(4):347-352.
- ⁷⁵ Helland, I.B., et al. (2003), Maternal supplementation with very long-chain n-3 fatty acids during pregnancy and lactation augments children's IQ at 4 years of age. *Pediatrics* 111:e39-34.
- ⁷⁶ Cohen, J.T., D.C. Bellinger, W.E. Connor and B.A. Shaywitz (2005), A Quantitative Analysis of Prenatal Intake of n-3 Polyunsaturated Fatty Acids and Cognitive Development. *Am J Prev Med* 29(4):366-374. The authors review eight controlled clinical trials on this topic, noting that results are "inconsistent" from study to study. Also, seven of the eight studies involved supplementation of infant formula; only one trial tested for effects of maternal (prenatal) supplementation.
- ⁷⁷ For example, see http://www.tunafacts.com/news/eat_more_fish_081505.cfm. Also, in a news story about the tuna industry's California lawsuit, industry sources are quoted as saying that "...warnings on canned tuna would create harm for Californians by discouraging consumption of a healthy and safe food," and "...canned tuna provides enormous benefits for the people who eat it. As our expert toxicologist will testify, the only warning that would be appropriate for canned tuna would be: Warning, not eating enough of this product could be hazardous to your health."
- ⁷⁸ The HCRA study is reviewed in Section 6.
- ⁷⁹ For a description of the IOM study, see <http://www.iom.edu/project.asp?id=23788>. See also description of a major conference at <http://www.seafoodandhealth.org/>.
- ⁸⁰ For example, a press release from the National Fisheries Institute, issued October 20, 2005, said that advisories warning about the effects of mercury exposure from fish "could be misinterpreted by the general population, resulting in a decrease in consumption of fish and seafood." Industry sources have been stating this fear for many years; now that the HCRA study (which they funded) has said much the same thing, the industry is citing Harvard as an authoritative source for its risk perception.
- ⁸¹ Oken, E., et al. (2003), Decline in Fish Consumption Among Pregnant Women After a National Mercury Advisory. *Obstet Gynecol.* 102:346-351.
- ⁸² "An important message for pregnant women and women of childbearing age who may become pregnant about the risks of mercury in fish." US FDA, March 2001.
- ⁸³ "What You Need to Know About Mercury in Fish and Shellfish," the current (2004) EPA/FDA advisory, available at <http://www.epa.gov/waterscience/fishadvice/advice.html>.
- ⁸⁴ This issue was discussed extensively at a December 10, 2003 meeting of the FDA's Food Advisory Committee (transcript available at <http://www.fda.gov/ohrms/dockets/ac/cfsan03.html>). It was addressed in written comments submitted by industry groups and by Consumers Union (Note 62, above), among others.
- ⁸⁵ See Note 38, above. All data in this section from Fisheries of the United States, 2004.
- ⁸⁶ Oceana (2005), Mercury in Seafood: Shoppers Have A Right to Know. Discusses survey. Available at http://www.oceana.org/fileadmin/oceana/uploads/mercury/1081.MercuryPollingReport_HI-RES.pdf.
- ⁸⁷ The study has been reported in press accounts (see IntraFish, at <http://www.intrafish.no/global/archive>, "Survey: 31 percent of consumers concerned over mercury in seafood," October 17, 2005; see also, Beth Daley, "Fish warnings taken too far," *The Boston Globe*, October 24, 2005.) The survey was conducted by the Center for Food, Nutrition and Agriculture Policy at the University of Maryland, but a search of the university web site could not locate the survey itself, nor any indication that it has been published.
- ⁸⁸ Burger, J. (2004), Fishing, fish consumption, and knowledge about advisories in college students and others in central New Jersey. *Environ Res* 98:268-275.
- ⁸⁹ *Ibid*; also see also "National Risk Communication Conference Proceedings Document" EPA conference May 2001, available at: <http://www.epa.gov/ost/fish/forum/riskconf.pdf>.
- ⁹⁰ The published package included eight separate papers (see notes 93 through 100, below). See also "Did NFI, tuna foundation money influence Harvard seafood mercury study?" Ben DiPietro. Intrafish. October 21, 2005.
- ⁹¹ Cohen is quoted in the HSPH press release as follows: "Fish are an excellent source of omega-3 fatty acids, which may protect against coronary heart disease and stroke, and are thought to aid in the neurological development of unborn babies. If that information gets lost in how the public perceives this issue, then people may inappropriately curtail fish consumption and increase their risk for adverse health outcomes." He is also quoted in the same release as saying that, while it is not known how people react to fish advisories, "Depending on how the population reacts, that impact could very well be negative."
- ⁹² The headline of Harvard's press release used almost those exact words (see release at <http://www.hsph.harvard.edu/press/releases/press10192005.html>.) The Boston Globe headlined its article the next day, "Fish warnings taken too far." Other stories had much the same tone and emphasis.
- ⁹³ Teutsch, S.M. and J.T. Cohen (2005), Health Trade-offs from Policies to Alter Fish Consumption. *Am J Prev Med* 29(4):324.
- ⁹⁴ Konig, A., et al. (2005), A Quantitative Analysis of Fish Consumption and Coronary Heart Disease Mortality. *Am J Prev Med* 29(4):335-346.
- ⁹⁵ Bouzan, C., et al. (2005), A Quantitative Analysis of Fish Consumption and Stroke Risk. *Am J Prev Med* 29(4):347-352.
- ⁹⁶ Cohen, J.T., D.C. Bellinger and B.A. Shaywitz (2005), A Quantitative Analysis of Prenatal Methyl Mercury Exposure and Cognitive Development. *Am J Prev Med* 29(4):353-365.
- ⁹⁷ Cohen, J.T., D.C. Bellinger, W.E. Connor and B.A. Shaywitz (2005), A Quantitative Analysis of Prenatal Intake of n-3 Polyunsaturated Fatty Acids and Cognitive Development. *Am J Prev Med* 29(4):366-374.
- ⁹⁸ Cohen, J.T., et al. (2005), A Quantitative Risk-Benefit Analysis of Changes in Population Fish Consumption. *Am J Prev Med* 29(4):325-334.
- ⁹⁹ Willett, W.C. (2005), Fish: Balancing Health Risks and Benefits. *Am J Prev Med* 29(4):320-321.
- ¹⁰⁰ McMichael, A.J. and C.D. Butler (2005), Fish, Health and Sustainability. *Am J Prev Med* 29(4):322-323.

¹⁰¹ Trasande, L., P.J. Landrigan and C. Schechter (2005), Public Health and Economic Consequences of Methyl Mercury Toxicity to the Developing Brain. *Environ Health Perspect* **113**(5):590-596.

¹⁰² Oken et al. (2003), Note 81, above.

¹⁰³ NMFS data, Note 38, above.

¹⁰⁴ Press release, "Study Finds Government Advisories on Fish Consumption and Mercury May Do More Harm Than Good," Harvard School of Public Health, October 19, 2005. Note 12, above. Available at <http://www.hsph.harvard.edu/press/releases/press10192005.html>.

¹⁰⁵ In an October 20 news release related to the industry's lawsuit against California labeling requirements, a spokesman for the tuna industry said: "Seafood, especially species that are rich in omega-3 fatty acids like canned tuna, has been shown in numerous studies to have overwhelming health benefits. Recent scientific studies, including a just-released report by Harvard researchers, have praised seafood for its benefits in aiding childhood development...According to the government's advisory,...young children should eat up to 12 ounces a week of these types of fish." The statement fails to mention that the industry paid for the Harvard study, omits mention that the Harvard study found that damage done to the brain by methyl mercury far outweighed the benefits from omega-3 intake in every scenario, and makes factually inaccurate statements about the FDA/EPA advisory (it says children should eat smaller portions, not up to 12 ounces per week) and the omega-3 content of canned tuna (bluefin and albacore tuna are good sources of omega-3's; "light" tuna, the dominant variety on the market, is quite low in omega-3s.)