Communicating Risk-Risk to the Public: The Case of the Health Benefits and Risks from Eating Seafood

A Ceres® White Paper

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Abstract

Seafood consumption is associated with reduced risk of cardiovascular disease (CVD), but the Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA) have also concluded that consumption of certain types of fish may increase certain health risks for women of childbearing age and their infants and young children because of methylmercury contamination. Communicating this information to consumers in a way that allows them to appropriately balance these two risks has proven difficult. Consumer research conducted over the last two years has demonstrated significant confusion among consumers about the relative benefits and risks of seafood consumption.

This Ceres™ white paper reviews the risk communication challenges for seafood consumption as a case study of the more general problem of risk-risk communication when consumption of a food is associated with a decrease in some risks and an increase in others. We recommend that the case of seafood consumption be used as an opportunity to increase our understanding of effective risk-risk communication to the public about foods. Such an effort could reduce the current confusion among consumers about seafood consumption and provide important new research to shape future risk-risk communication efforts for similar situations.

Communicating Risk-Risk to the Public:
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and Risks from Eating Seafood

Preface

When the World Trade Organization was formed in 1995, the community of member states realized the need for a transparent, science-based system for assessing, managing, and communicating food safety hazards and risks. The Uruguay Round of negotiations established the Sanitary and Phytosanitary agreement (SPS) and the agreement on Technical Barriers to Trade (TBT) that recognized the importance of risk analysis as a process to reduce barriers to trade. Adoption of the risk analysis process thereby provided a structured, science-based approach to ensure a safe global food supply with fewer trade barriers.

As defined by the National Research Council and other authoritative bodies, risk analysis includes risk assessment, risk management, and risk communication. Risk assessment and risk management should incorporate measures of the uncertainty of the analysis, and uncertainty is being incorporated into these models in increasingly sophisticated ways. However, it is less common for risk communication to explicitly discuss the uncertainty identified in risk assessment and risk management.

Risk communication is an iterative, complex process that informs all potential stakeholders including risk managers, food producers, and the public (or segments of the public) about the possible food safety hazards. Risk messages should also be targeted, especially if the risk message(s) are based on complex scientific concepts that are not generally understood. This is especially important as the courts may be engaged to forestall possible complications of communicating risk. For example, on May 12, 2006, the California courts stepped into the debate by noting that a general warning on seafood at the point-of-purchase would cause more harm than good if the warning discouraged fish consumption.

Risk communication is perhaps the most challenging aspect of risk analysis because the scientific issues that surround the problem are not usually or easily put into plain language. Ironically, in April, 2006, the Institute of Medicine Food Forum convened a distinguished panel of experts that simply concluded that they needed to hold more meetings on the topic.[1] In addition, the nuances of terms of art or jargon—such as, “risk” and “safety”—do not adequately explain the potential risk of consuming a particular food or the potential risk of not consuming the same food. Furthermore, most foods provide some health benefits and some health risks, depending on the amount consumed.[2] It is therefore not surprising that clearly and effectively communicating complex risk messages to the general public is so challenging.

The challenges of communicating the risks and benefits of seafood consumption to distinct subpopulations may be acute, but they are not unique to these foods. Moreover, the communication challenges raised by this case should be used as an opportunity to improve our understanding of risk-risk communication when consuming a particular food increases some risks for one sub-population and decreases some risks in another sub-population. A concerted effort by all the stakeholders to learn more about how to communicate with the public, and specific subpopulations, about the benefits (from omega-3 fatty acids) and risks (from methylmercury) of consuming fish and shellfish would provide significant scientific and public health benefits.

Governments should establish a process that considers how risk-risk communication affects consumer behavior, especially in the context of balancing competing risks i.e., the risk of consuming fish vs. the risk of not consuming fish. Government then needs to clarify its position on potential hazards found in foods and target its communications appropriately to the affected population or sub-population. The Food and Agriculture Organization of the United Nations in fact notes that "Communications among risk assessors, risk managers and other interested parties should use language and concepts that are suitable for the intended audience *[emphasis added]*."[3] Risk communication messages should also be routinely evaluated for effectiveness in order to quickly identify misunderstood messages and improve future risk communication efforts. Furthermore, when risk communication fails and unintended consequences occur, government should take corrective action to remedy the situation.

The Case of the Health Benefits and Risks from Eating Seafood

Introduction

With regard to the health benefits associated with fish consumption, there is a growing body of research that the omega-3 fatty acids—eicosapentaenoic acid and docosahexaenoic acid—found in fish are linked with optimal brain function, cognition, and improved eye and skin health. Some studies, furthermore, show that these omega-3 fatty acids may be protective against certain cancers and may have a therapeutic effect on depression and specific autoimmune diseases including lupus erythematosis, psoriasis, and arthritis. Yet, a recent systematic review of the risks and benefits of consuming omega-3 fatty acids on mortality, cardiovascular disease and cancer questioned the health benefits of these fatty acids. The authors suggest that the beneficial effects on stroke, in particular, may be due to selenium or vitamin D, or additional components of fish other than omega-3 fatty acids.[4]

Government policy documents and health professional organizations recommend that Americans eat more fish. The *2005 Dietary Guidelines for Americans* issued by the Department of Health and Human Services (DHHS) and the U.S. Department of Agriculture (USDA) and guidelines from the American Heart Association and the American Dietetic Association recommend consuming two to three servings of fish a week for a total of eight ounces for optimal health.[5] In addition, in 2004, the U.S. Food and Drug Administration (FDA) approved the following qualified health claim:

> *"Supportive but not conclusive research shows that consumption of EPA and DHA omega-3 fatty acids may reduce the risk of coronary heart disease. One serving of [name of food] provides [x] grams of EPA and DHA omega-3 fatty acids. [See nutrition information for total fat, saturated fat and cholesterol content]."*

In spite of the government's policy documents that urge the public to eat fish, in 2004, FDA and the U.S. Environmental Protection Agency (EPA) published a joint advisory on consumption of fish and shellfish that pertains to methylmercury content and its possible health risks for women of childbearing age, pregnant women, nursing mothers, and young children. The advisory also recognized that fish and shellfish are an important component of a healthy diet because they contain high-quality protein and other essential nutrients; are low in saturated fat; and contain omega-3 fatty acids.

Conversely, nearly all fish and shellfish contain trace amounts of mercury. FDA and EPA therefore published an advisory stating that certain subgroups of the population should modify their fish consumption. The advisory stated:

> *"For most people, the risk from mercury by eating fish and shellfish is not a health concern. Yet, some fish and shellfish may contain higher levels of mercury that may harm an unborn baby or young child's developing nervous system. The risks from mercury in fish and shellfish depend on the amount of fish and shellfish eaten and the levels of mercury in the fish and shellfish."*[6]

Furthermore, [the FDA and EPA] risk message advised women of childbearing age, pregnant women, nursing mothers, and young children to avoid <u>some</u> types of fish, such as shark, swordfish, king mackerel, or tilefish, and to eat up to 12 ounces per week of fish and shellfish that are lower in mercury, such as shrimp, canned light tuna, salmon, pollock, and catfish. The advisory does not instruct these subpopulations to avoid all fish.

More than a decade ago, messages from FDA were more straightforward, however.

> *"Consumption advice is unnecessary for the top 10 seafood species, making up about 80 percent of the seafood market--canned tuna, shrimp, pollock, salmon, cod, catfish, clams, flatfish, crabs, and scallops. This is because the methyl mercury levels in these species are all less than 0.2 ppm and few people eat more than the suggested weekly limit of fish (2.2 pounds) for this level of methyl mercury contamination."*
>
> FDA Consumer Magazine, September, 1994

This 1994 message implied a reassuring level of safety, especially for the most commonly consumed fish and shellfish.

Mercury Concentrations in Fish

The World Health Organization (WHO) recently compiled data on mercury concentrations in fish from a number of nations and international organizations. According to the Global Mercury Assessment report, "Moderate consumption of fish (with low mercury levels) is not likely to result in exposures of concern. However, people who consume higher amounts of contaminated fish or marine mammals may be highly exposed to mercury and are therefore at risk."[7]

Consequently, several countries and international organizations have established levels of daily or weekly methylmercury or mercury intakes considered safe, limits/guidelines for maximum concentrations in fish, and fish consumption advisories. The WHO's Global Mercury Assessment of maximum allowed or recommended levels of mercury in fish in various countries are shown in Table 1. These data indicate a fairly consistent and narrow range of maximum or allowed levels of methylmercury in fish and tolerable intake levels of mercury or methylmercury.[8]

Evidence of Methylmercury Toxicity

Mercury is a heavy metal that is found naturally in the environment. Human activity also contributes mercury to the environment through burning coal and other industrial processes. Human exposure to mercury can come from a variety of sources, including occupational and household uses, mercury-containing dental amalgams and vaccines, and consumption of contaminated fish. Bacteria convert inorganic mercury to methylmercury, which is the organic form of the compound. While mercury is poorly absorbed by the body, methylmercury is absorbed easily, passing through the placenta of a pregnant woman and being deposited into the nervous system of her fetus. Methylmercury is a neurotoxicant and high exposures over long periods of time may adversely affect the developing fetal brain and central nervous system.[9]

There are three incidences of severe methylmercury poisonings in humans, two of which were due to almost daily consumption of heavily contaminated fish over long periods of time. The first incidence of methylmercury poisoning dates back about 50 years near Minamata, Japan. A chemical plant discharged untreated mercury compounds into the nearby bay over a 30-year period contaminating the fish, which was the city's primary source of protein. Estimates vary, but it is thought that nearly 3,000 people died or developed severe neurological damage from eating methylmercury-contaminated fish. Twenty-two children with congenital methylmercury poisoning were born to women who had eaten the fish almost daily during pregnancy.[10]

The second incidence of methylmercury poisoning occurred in the 1960s in the Prefect of Niigata, Japan. Once again, untreated mercury from a chemical plant was dumped into the Agano River that supported the area's commercial fishing fleet. As a result of the dumping of untreated chemical waste, a number of babies were born to women who had eaten contaminated fish during their pregnancies. The symptoms of the deformed and neurologically impaired children of Niigata were consistent with those observed in Minamata.

In 1968, the Japanese government finally recognized that Minamata Disease was caused by industrial pollution of waterways leading to severe contamination of the food supply. The fish in Minamata and Niigata had mercury levels that ranged from 9 to 24 parts per million (ppm) with some fish from the Minamata area having as much as 40 ppm. This greatly exceeds the range of 0.1 to 0.5 ppm level in fish commonly eaten in the United States and the FDA action level of 1 ppm.[11]

A third episode of mercury poisoning was linked to consumption of contaminated grain. Wheat seeds that were treated with a mercury-containing fungicide were shipped to Iraqi farmers for planting. But, at that time, the farmers had experienced several poor harvests and had little food. Despite warnings, the farmers fed the contaminated seed to their family members, and that led to several thousand deaths or serious illnesses due to mercury poisoning.

These were three exceptional cases of environmental pollution or significant contamination of a food staple that helped launch further population-based, prospective studies.

Review of Prospective Studies

There are three prospective, longitudinal studies that have examined the health effects of methylmercury on fish-eating populations. The possible effects of methylmercury on neuropsychological and neurophysiological development were examined among young children whose mothers' typical daily diets included fish or other sea mammals. [3]

In these studies, estimates of methylmercury exposure of the mothers and *in utero* exposure of their infants were measured by (umbilical) cord blood mercury and maternal-hair mercury. Hair mercury is a standard used in most studies of this type and it can estimate exposure throughout pregnancy. This measurement is stable and is also known to correlate with brain levels. Cord blood, on the other hand, reflects very recent exposure to methylmercury. It can vary depending on total blood volume and there are no data available to relate cord blood measurement to concentrations in the brain tissue. The results of the following studies conflict and raise additional questions about potential risk associated with exposure to methylmercury from eating seafood.

<u>Seychelles Child Development Study (SCDS)</u>. Seychelles is an independent, archipelago republic situated in the Indian Ocean a thousand miles off the coast of Africa. The Seychellois people typically consume fish at almost every meal and fishing, especially for tuna, is the second largest industry of the nation.

The SCDS is an ongoing, prospective, longitudinal study of more than 700 mother-infant pairs conducted by researchers from the University of Rochester Medical Center in collaboration with the Ministries of Health and Education of the Seychelles republic.[12,13,14] The Seychellois women eat ocean fish about 12 times per week—nearly 10 times more than women in the United States. Furthermore, methylmercury levels of the fish consumed by the Seychellois are comparable to that of similar fish in the United States (roughly 0.3 ppm).

Myers *et al*. measured maternal-hair mercury and carried out mental and motor tests with more than 57 primary endpoints among the children enrolled in the study. The children first were tested at birth, when samples of their mother's hair were taken to determine mercury exposure during pregnancy. The research team conducted the series of psychomotor tests at ages 6, 19, 29, 66, and 107 months (9 years) of age.

After over 9 years of study, the researchers noted only three statistically significant associations with exposure to methylmercury *in utero.* Only one out of 57 associations was negatively associated with prenatal methylmercury exposure. The research team concluded that methylmercury exposure *in utero* does not harm the development of a baby's brain, at least at levels experienced due to almost-daily consumption of ocean fish.

<u>Faroe Islands Study</u>. In contrast to Seychelles, the Faroe Islands are part of the kingdom of Denmark and are situated between the Norwegian Sea and the North Atlantic Ocean. The economy depends almost exclusively on fishing and sea mammals. Whale and its blubber, fish, and mutton are important sources of

protein for the Faroese, with fish and whale constituting 44 and 10 percent of dinner meals, respectively.

A prospective, longitudinal study consisting of more than 900 mother-infant pairs examined neuropsychological and neurophysiological function of children whose mothers were exposed to methylmercury during pregnancy from consumption of pilot whale meat.[15, 16, 17, 18]

Grandjean and his co-workers tested 917 children at 7 years of age to assess possible adverse effects on physical, neurophysiological, and neuropsychological functions due to maternal exposure to methylmercury. The researchers found no association between methylmercury exposure (as measured in maternal hair and cord blood) and physical or neurophysiological test scores. Some neuropsychological endpoints were negatively linked to methylmercury exposure, but the results may be complicated by exposure to PCBs that also accumulate in whale blubber and was consumed by the mothers during pregnancy. Nevertheless, this research team concluded that methylmercury found in seafood adversely affected children's neurological development.

New Zealand Study. Located in the South Pacific, New Zealand's economy is also dependent on fishing and the diet includes many fish and shellfish. Like the Faroese, people in New Zealand tend to consume high amounts of shark and whale blubber. This prospective study found that of over 11,000 babies born in 1978, 73 children had elevated prenatal methylmercury levels. The researchers found a 3-point decrement in the Wechsler Intelligence Scale-Revised (WISC-R) full-scale IQ among children born to women with maternal hair mercury concentrations > 6 µg/g.[19, 20] At 6 years of age, a total of 237 children were assessed on a number of neuropsychological endpoints similar to those used in the Seychelles study. The results suggest that higher hair mercury concentrations were associated with lower WISC-R scores.

None of these studies found symptoms of the severe methylmercury poisoning observed in Japan or Iraq.

Risk Analysis Studies

Eating fish is associated with health benefits and risks. Health benefits, especially heart health benefits, are thought to be conferred by the omega-3 fatty acids found abundantly in oily fish. Some scientists therefore argue that decreased consumption of fish presents a health risk, especially if those at greater risk of coronary heart disease (CHD) reduce intake of fish because of concern about methylmercury.

To understand better the risk-risk trade-off (or competing benefits and risks) associated with consuming fish containing omega-3 fatty acids and trace amounts of methylmercury, the Harvard Center for Risk Analysis conducted a series of quantitative analyses that were published in the *American Journal of Preventive Medicine* in November, 2005. In four studies presented in this journal, the authors conducted quantitative analyses on *1)* fish consumption and coronary heart disease; *2)* fish consumption and stroke; *3)* methylmercury exposure and cognitive development; and *4)* prenatal exposure to omega-3 fatty acids [specifically, DHA] and cognitive development. A fifth paper synthesized the results of the other four in evaluating a risk-risk trade-off that would occur with changes in consumption of fish.

The authors used multiple end points to develop a common metric, quality-adjusted life years (QALY), that accounts for negative health effects in terms of life expectancy and quality of life due to fish consumption, exposure to methylmercury, and consumption of DHA. They then used dose-response relationships that were developed in the other papers to estimate the risk-risk trade-off; that is, the authors compared risk of CHD due to lower omega-3 fatty acid intake versus the risk of diminished cognitive development due to methylmercury exposure.

The authors evaluated five separate scenarios about how the population might respond to FDA/EPA risk messages about fish consumption.[21] Scenario 1 assumed that women of childbearing age fully understood the advisory and substituted fish containing low concentrations of mercury for fish containing 'high' or 'medium' mercury concentrations. In scenario 2, women of childbearing age decreased their fish consumption by 17 percent, a figure based on a study by Oken et al.[22] that examined the response to the FDA's 2001 fish advisory. Scenario 3—the most pessimistic of the assumptions—modeled the consequences of the entire population decreasing fish consumption by 17 percent. Scenario 4 represented the ideal situation in that males and all females not of childbearing age increased fish consumption by 50 percent, and finally, Scenario 5 assumed that women of childbearing age also increased fish consumption. The authors then estimated annual QALY's lost or gained for each of the scenarios.

For Scenario 1, the model estimated a significant improvement in cognitive development and a slight increase in per capita stroke incidence and CHD mortality. The overall impact was a net gain of 49,000 discounted QALYs. If women of childbearing age decreased fish consumption—as modeled in Scenario 2—cognitive development still increased, but the gain was much smaller. The overall impact was a net gain of 9,700 discounted QALYs.

Scenario 3 predicted that the entire population would decrease fish consumption even though the advisory only targeted women of childbearing age, pregnant and lactating women and very young children. In this case, elderly men (ages 75 to 84 years) were most negatively affected as mortality from CHD increased by about 2 in 10,000. The total result was a loss of 41,000 discounted

QALYs—the worst overall outcome of the five scenarios. Conversely, Scenario 4 had the greatest positive impact on elderly men with a reduction in CHD mortality by 5 in 10,000, and the overall impact was a gain of 120,000 discounted QALYs. Scenario 4 had the highest net increase in discounted QALYs.

Lastly, in Scenario 5 (women of childbearing age increase fish consumption similar to the rest of the population), there is a negative effect on cognitive development, but the reduction in CHD deaths and incidence of stroke was decreased similar to that modeled in Scenario 4. Scenario 5 produced a net increase of 90,000 discounted QALYs.

This set of papers suggests if fish consumption is decreased, the negative impacts on health are greater than the potential gain (from lower methylmercury consumption).

The Media and Public Perceptions

While FDA, EPA, and the public health community are working to disseminate advice on seafood consumption, the public is also hearing negative messages about mercury levels in fish and possible risks to unborn babies and young children. Communicated through the mass media, these messages largely come from environmental groups that are pressing for stronger mercury emission standards.[23] These conflicting messages about the benefits and possible risks from mercury in some fish may be confusing the public.

There is some evidence that consumers are misinterpreting the FDA/EPA advisory that specifically targets women of childbearing age, pregnant and nursing women, and young children only. A study commissioned by the Center for Food, Nutrition, and Agriculture Policy at the University of Maryland asked a nationally representative sample of 1,040 adults 18 years of age or older about their perceptions and opinions about fish consumption.

A June, 2005, telephone survey of consumers asked several questions regarding their perceived consumption of fish and shellfish; whether they had heard about the health effects associated with consuming fish; their level of concern about mercury in fish and shellfish; types of fish that are higher and lower in mercury; and people who need to be concerned about mercury. The consumer research study showed that only one male respondent reported eating fish every day and only 17 percent of Americans eat fish twice a week as recommended by the 2005 Dietary Guidelines. In addition, 11 percent of Americans report that they never eat fish whereas almost one-fourth of children do not eat fish. These results are similar to those reported by Tran and coworkers who found that more than 25% of females 16 to 49 years of age consumed no fish in the past 30 days.[24] This suggests that consumption of fish by Americans is considerably less than that of the populations of the Seychelles, Faroe Islands, and New Zealand.

The survey also examined what Americans had heard about the health effects of eating fish. Two-thirds of Americans reported hearing something about the health effects of eating fish with 60 percent hearing positive things and 43 percent hearing something negative. Of those who heard something negative, 35 percent reported that fish was contaminated with mercury. Thirty-one percent of adults reported that they were concerned about mercury content in fish with 39 and 55 percent of Americans saying they are very concerned or somewhat concerned, respectively. Of those who reported concern about mercury content of fish, 55 percent reported that they had changed the type of fish they consume and 43 percent said their concern affected how often they consume fish.

Few Americans are aware of differences in the mercury content of different types of fish. When asked if fish differ in mercury content, 34 percent said they did not know and when asked if they could name the types of fish that were higher in mercury, 68 percent said they did not know. Twelve percent, in fact, erroneously named tuna as a fish that contained higher levels of mercury. In addition, three-fourths of Americans said they did not know which species of fish was lower in mercury.

There is evidence that the public does not understand that the FDA/EPA advisory is targeted to women of childbearing age, pregnant and nursing women, and young children. In the CFNAP study, 45 and 29 percent of Americans said that the elderly and men, respectively, need to pay attention to the amount of mercury in fish.

The CFNAP findings were confirmed by a study commissioned by the Center for Science in the Public Interest (CSPI) conducted in June, 2006. The CSPI study found that "only one in five consumers correctly identified swordfish, shark, or king mackerel as the fish highest in mercury. Confusion over low-mercury containing species was equally evident. While 21 percent of consumers identified salmon as having high mercury levels, another 21 percent believed it has low mercury levels. Salmon, as well as shrimp, catfish, and pollock, contains low levels of mercury."[25]

Conclusions

There are benefits and risks for some subpopulations from eating certain fish and shellfish. The FDA and the EPA have concluded that consumption of certain types of fish above recommended levels may increase neurological health risks for women of childbearing age, pregnant women, nursing mothers, and young children because of methylmercury contamination. At the same time, the *2005 Dietary Guidelines for Americans* issued by DHHS and USDA and guidelines from the American Heart Association and the American Dietetic Association recommend consuming two to three servings of fish a week for optimal health. The conflicting messages have not been effectively communicated to the public, and it appears that some consumers are inappropriately avoiding seafood consumption altogether.

The FDA and EPA advise women of childbearing age, pregnant women, nursing mothers, and young children to modify fish consumption. However, research has suggested that the 2004 FDA and EPA advisory may cause consumers to decrease fish consumption, thus jeopardizing the potential health benefits associated with fish consumption.

CFNAP recommends that FDA, EPA, and other stakeholders initiate two complementary strategies to improve risk communication in these types of situations. The first strategy addresses the immediate communication challenges for seafood consumption that have been identified through consumer research. The second, broader strategy attempts to improve future risk communication through rigorous research on risk communication strategies.

Specific, Immediate Recommendations

Consumer research has shown that there is significant confusion about seafood consumption among consumers in the U.S. Several immediate steps can be taken while a research program on risk communication is being developed and implemented. CFNAP recommends that the following steps be initiated at the same time that the risk communication research program is launched:

1) FDA, EPA, USDA, and NOAA jointly announce a public education campaign to help consumers, health professionals, and the media better understand the benefits and risks of consuming fish and shellfish for different subpopulations. Based on the CFNAP commissioned survey, the public education campaign should focus on improving: a) consumer understanding of the varieties of fish that are most likely to have a high methylmercury concentration and b) the subpopulations that should be most concerned about limiting consumption of methylmercury versus those that should be most concerned about increasing consumption of omega-3 fatty acids.

2) FDA and NOAA collaborate to establish a fee-for-service testing program for fish and shellfish that monitors methylmercury and other contaminants.

3) FDA and NOAA establish a clearinghouse of information to collect data on methylmercury levels of commonly consumed fish and make the information available on the internet.

Research Agenda for Risk-Risk Communication for Foods

The overarching recommendation of this white paper is that public health organizations must invest in research on risk communication in order to improve public health. The FDA and EPA need to work with all stakeholders to invest resources to learn more about effective risk-risk communication. Research in risk communication is especially needed in situations in which consuming a particular food increases some risks and decreases others. Seafood consumption provides an excellent opportunity to learn more about which communication strategies are effective—and which are not—when consumption of a food involves risks and benefits. An integrated research and communication program could reduce the current consumer confusion about seafood consumption and provide valuable insights to improve risk communication in similar cases that will arise in the future.

One of the central questions that the research program should address is how risk communicators can help consumers distinguish between the risk and safety approaches that are used by experts. There are subtle but important differences in these approaches that are not widely appreciated. Risk usually involves a continuous (but not linear) relationship with consumption. The more you consume, the more (or less) risk you face. Safety is usually more like a binary, discrete relationship. If you consume less than a certain amount, then you are safe; otherwise you are “not safe” (but not necessarily at risk).

Is it even possible to successfully communicate with consumers how to moderate consumption to achieve the lowest overall risk associated with consumption of a particular food? Or do consumers only interpret risk messages as identifying a food as “safe” or “not safe”? Our initial belief is that more nuanced communication is possible, but difficult.

The design of the risk communication research program should receive input from many stakeholders, but we offer the following suggestions to begin the conversation. A modified version of the mental models approach could be very effective in this area. [26,27,28] The mental models approach consists of five steps:[29]

1. Create an expert model of the process and develop an influence diagram;
2. Conduct mental models interviews with non-experts based on the interview diagram. Analyze how the interviews correspond to the expert model;
3. Conduct structured interviews with larger groups of non-experts to understand the distribution of beliefs in the target population(s);
4. Develop risk communications based on what has been learned;
5. Evaluate risk communications and refine until satisfied.

Further research will be required to understand how the mental models approach to risk communication is implemented in the behavior of consumers.

Risk communication about seafood consumption has been challenging for all of the reasons discussed in this white paper. However, this challenge creates an opportunity for new research in risk-risk communication that will help governments to better manage future problems of this type.

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The consumer survey discussed in this report was conducted by the Opinion Research Corporation as part of its weekly omnibus CARAVAN telephone survey. The survey questions were developed by the authors.

Table 1

Examples of maximum allowed or recommended levels of mercury (Hg) in fish in various countries and by WHO/FAO

(based on submissions to UNEP, unless otherwise noted).[3]

Country/ Organization	Fish type	Maximum allowed/ recommended levels in fish *1	Type of measure	Tolerable intake levels *1
Australia	Fish known to contain high levels of mercury, such as swordfish, southern bluefin tuna, barramundi, ling, orange roughy, rays, shark All other species of fish and crustaceans and molluscs	1.0 mg Hg/kg 0.5 mg Hg/kg	The Australian Food Standards Code	Tolerable Weekly Intake: 2.8 µg Hg/kg body weight per week for pregnant women.
Canada	All fish except shark, swordfish or fresh or frozen tuna (expressed as total mercury in the edible portion of fish) Maximum allowable limit for those who consume large amounts of fish, such as Aboriginal people	0.5 ppm total Hg 0.2 ppm total Hg	Guidelines/ Tolerances of Various Chemical Contaminants in Canada	Provisional Tolerable Daily Intake: 0.47 µg Hg/kg body weight per day for most of the population and 0.2 µg Hg/kg body weight per day for women of child-bearing age and young children
China	Freshwater fish	0.30 mg/kg	Sanitation standards for food	
Croatia	*Fresh fish* Predatory fish (tuna, swordfish, molluscs, crustaceans) All other species of fish *Canned fish (tin package)* Predatory fish (tuna, swordfish, molluscs, crustaceans) All other species of fish	1.0 mg Hg/kg 0.8 mg methylHg/kg 0.5 mg Hg/kg 0.4 mg methylHg/kg 1.5 mg Hg/kg 1.0 mg methylHg/kg 0.8 mg Hg/kg 0.5 mg methylHg/kg	Rules on quantities of pesticides, toxins, mycotoxins, metals and histamines and similar substances that can be found in the food …..	
European Community *2	Fishery products, with the exception of those listed below. Anglerfish, Atlantic catfish, bass, blue ling, bonito, eel, halibut, little tuna, marlin, pike, plain bonito, Portuguese dogfish, rays, redfish, sail fish, scabbard fish, shark (all species), snake mackerel, sturgeon, swordfish and tuna.	0.5 mg Hg/kg wet weight 1 mg Hg/kg wet weight	Various Commission decisions, regulations and Directives	
Georgia	Fish (freshwater) and fishery products Fish (Black Sea) Caviar	0.3 mg Hg/kg 0.5 mg Hg/kg 0.2 mg Hg/kg	Georgian Food Quality Standards 2001	
India	Fish	0.5 ppm total Hg	Tolerance Guidelines	

Country/ Organization	**Fish type**	**Maximum allowed/ recommended levels in fish** *1	**Type of measure**	**Tolerable intake levels *1**
Japan	Fish	0.4 ppm total Hg/kg 0.3 ppm methylHg (as a reference)	Food Sanitation Law - Provisional regulatory standard for fish and shellfish	Provisional Tolerable Weekly Intake: 0.17 mg methylHg (0.4 μg/kg body weight per day) (Nakagawa *et al*., 1997).
Korea, Republic of	Fish	0.5 mg Hg/kg	Food Act 2000	
Mauritius	Fish	1 ppm Hg	Food Act 2000	
Philippines	Fish (except for predatory) Predatory fish (shark, tuna, swordfish)	0.5 mg methylHg /kg 1 mg methylHg/kg	Codex Alimentarius	
Slovak Republic	Freshwater non-predatory fish and products thereof Freshwater predatory fish Marine non-predatory fish and products thereof Marine predatory fish	0.1 mg total Hg/kg 0.5 mg total Hg/kg 0.5 mg total Hg/kg 1.0 mg total Hg/kg	Slovak Food Code	
Thailand	Seafood Other food	0.5 μg Hg/g 0.02 μg Hg/g	Food Containing Contaminant Standard	
United Kingdom	Fish	0.3 mg Hg/kg (wet flesh)	European Statutory Standard	
United States	Fish, shellfish and other aquatic animals (FDA) States, tribes and territories are responsible for issuing fish consumption advise for locally-caught fish; Trigger level for many state health departments:	1 ppm methylHg 0.5 ppm methylHg	FDA action level Local trigger level	US EPA reference dose: 0.1 μg methylHg/kg body weight per day
WHO/FAO	All fish except predatory fish Predatory fish (such as shark, swordfish, tuna, pike and others)	0.5 mg methylHg/kg 1 mg methylHg/kg	FAO/WHO Codex Alimentarius guideline level	JECFA provisional tolerable weekly intake: 3.3 µg methylHg/kg body weight per week.

Note: **1** Units as used in references. "mg/kg" equals "μg/g" and ppm (parts per million). It is assumed here that fish limit values not mentioned as "wet weight" or "wet flesh" are most likely also based on wet weight, as this is normally the case for analysis on fish for consumers.

2 The European Commission has recently (February 2002) revised the previous maximum limit values for mercury in a small number of specific fish species for consumption (Commission Regulation No 221/2002 of 6 February 2002). These changes are not reflected in the table.

3 Source: "Global Mercury Assessment—Current mercury exposures and risk evaluations for humans."

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[2] In fact, these risk communication challenges are not even unique to food. For example, Europe has experienced outbreaks of mumps and measles after many parents chose to avoid vaccinating their children because of a concern that the vaccine may cause autism. *The New York Times*, "Britain Tries to Quell Fear Over Vaccine for Children," February 11, 2002 and *The New York Times*, "As Vaccination Rates Decline in Ireland, Cases of Measles Soar" February 8, 2003.

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