An Intervention Analysis for the Reduction of Exposure to Methylmercury from the Consumption of Seafood by Women of Child-bearing Age

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Abstract

A previously developed exposure model was used (Risk Analysis 22:689-699, 2002) to assess the effectiveness of various advisory scenarios on minimizing mercury (Hg) blood levels via the consumption of commercial seafood, both finfish and shellfish. This exposure model was developed to predict levels of Hg in blood in women of child-bearing age in the US based on the frequency of seafood consumption, the amount of seafood consumed per serving, and the types of seafood consumed. Steady-state relationships that employed descriptive statistics to account for toxicokinetic variation were used to predict levels of Hg in blood. The model incorporates an uncertainty dimension that is intended to represent the range of plausible interpretations of the data. The predictability of the model was confirmed via the use of National Health and Nutrition Examination Survey (NHANES) blood Hg data. In the present analysis, the model was used to predict the impact of limitations in the amount or types of seafood consumed on blood Hg levels. Specifically, simulations for various advisory scenarios were developed on the basis of limitations on total consumption of seafood, elimination of the consumption of certain species altogether, and/or a combination of both. In the baseline model, the median (uncertainty) estimates for the 50^{th}, 95^{th}, and 99^{th} per capita population percentiles were 1.25, 8.2, and 16.1 ppb blood Hg, respectively. After restriction of seafood consumption to no more than 12 oz per week, the median (uncertainty) estimates for the 50^{th}, 95^{th}, and 99^{th} per capita population percentiles were 1.22, 6.8, and 10.6 ppb blood Hg, respectively. Elimination of MeHg species, with average concentrations above 0.6 ppm, resulted in very modest decrements in Hg blood levels, in comparison to either the baseline or the reduced consumption scenarios. These results suggest that strategies to reduce MeHg exposure by reducing the amount of fish consumed (e.g., 12 oz/week) are more effective at eliminating the high end of the exposure distribution than are strategies intended to change the types of fish consumed.

Introduction

Methylmercury (MeHg) is a well known environmental toxicant found in the aquatic ecosystem. Inorganic mercury originates from anthropogenic and natural sources. Once in the ecosystem inorganic mercury is converted to methylmercury primarily through bacterial activity and accumulates in fish and other marine species to varying degrees, particularly in long-lived, predators which are at the top of the marine food-chain. Depending on the level of exposure MeHg can cause mild to severe neurological symptoms, such as paresthesia, ataxia, dysarthyria, hearing defects, visual disturbances and death. Levels of exposure seen in some fish-eating populations have been reported to be associated with developmental delays in children whose mothers were exposed during pregnancy. While high-level poisoning episodes in Minimata and Nigata, Japan and in Iraq demonstrated pronounced MeHg-induced neurological deficits there is also concern that MeHg can cause more subtle developmental delays or other neurological effects at lower levels of exposure more consistent with the usual patterns of fish consumption seen in the U.S. (JECFA, 2003; NRC, 2000).

As part of its efforts to minimize the risks associated with such outcomes the U.S. Food and Drug Administration issued a new advisory in 2001 that provided recommendations concerning the consumption of certain fish species and for fish in general by pregnant women. The FDA advised these women to avoid the consumption of four species of fish; namely King mackerel, shark, swordfish and tile fish. In addition, it was recommended that they include up to 12 oz of a variety of other fish species over the course of a week. In order to better understand and define what a variety of fish means a series of exposure assessments of various fish consumption scenarios were performed that were constructed to be consistent with the consumption of 12 oz of a variety of fish. The scenarios differed in how “variety” of fish was defined. In these assessments several thresholds of safety (e.g., Minimal Risk Level (ATSDR, 1999), Provisional Tolerable Weekly Intake (JECFA, 2003), Reference Dose (USEPA, 2001)) were used as measures of the effectiveness of the consumption/exposure scenarios in keeping weekly MeHg exposures of women who followed the specific advise scenario below the threshold of safety.

Methodology

The Baseline Model

The model employed in the present analysis is a modified version of a model described previously (Carrington and Bolger, 2002). These modifications are as follows:

- The number of fish categories for which distributions were developed was expanded from 24 to 42. (see Table 1). Tuna was broken into three categories, corresponding to 1) light canned tuna, 2) albacore canned tuna, and 3) fresh/frozen tuna steaks.
- Mercury concentration data was obtained for additional species, which are identified in Table 2. For tuna steaks, this data was used to construct an empirical distribution. For the

remaining species for which additional data was obtained, modeled distributions were developed by fitting the distributions to the portions of the cumulative distribution above the levels of detection. A battery of ten distributions were fit to each data set and the four that provided the best fit were used to construct a probability tree (see Figure 1 for an example and Carrington, 1996 for further description of the methodology).

- A range of 0.1 to 0.2 ppb was added to blood Hg levels in order to represent contributions from sources other than fish. This range reflected the levels at the low end of the National Health and Nutrition Examination Survey (NHANES; CDC, 2003). Since virtually everyone in the NHANES survey had a blood mercury level above zero, yet 10-20% of the NHANES survey population reported no seafood consumption, this suggests that there are contributions to blood Hg levels from other sources (e.g., dental amalgams) other than seafood. Since the present model is intended to represent methylmercury exposure, a range with an uncertainty bound including zero was introduced to acknowledge the possibility of minor exposures from sources other than seafood.
- A correction factor (listed in Table 1) was applied to reflect water loss during food preparation. The values were based on water loss of 11% for fried seafood, 21% for poached or steamed seafood, and 25% for baked or broiled seafood (EPA, 2000). Group-specific correction factors were calculated based on the frequency of use of different food preparation (e.g. baking, steaming, or frying) within each group, based on the CSFII survey (USDA, 1998). A default value of 0.8 was used for categories not represented in the CSFII survey. These are listed in Table 1. No correction factors were applied for canned-tuna since the MeHg concentration values, expressed as total Hg, were obtained after cooking and draining of water or oil from the can.
- The model parameters used to extrapolate long-term frequency of consumption from short-term records were chosen to be consistent with the 30 day seafood consumption data collected by NHANES (see Figure 2). The percentage of consumers was also changed from 70-90% to 85 to 95% in order to be consistent with the NHANES survey.
- The fraction of the annual seafood diet estimated from the individual dietary survey, as opposed to market share, was treated as an individual variable rather than as a population uncertainty. Also, instead of using a range of 20 to 80%, the fraction of seafood meals falling within a single category was used to represent range of individual repetitiveness (i.e. the extent to which a short-term survey can be expected to represent the range of species consumed). This distribution was derived from the NHANES survey, by calculating the fraction of total seafood consumption in the seafood category with the highest number of eating occasions for the 403 adult women who consumed seafood on 4 or more occasions (see Figure 3)

Scenarios

In order to simulate the impact of consumer seafood advisories for women of child bearing age who become pregnant, several scenarios were developed that are intended to predict the expected impact of the advisory on mercury blood. All the scenarios presumed full compliance with the advisory. Seafood species were divided into three groups, as listed in Table 2.

Using these groups, the following advisory scenarios were modeled:

- *Total Seafood Consumption Limits* (see Table 3). The consumption of seafood is limited to 6, 12, or 18 oz without regard to species.
- *Species Consumption Limits* (see Table 4). There is no limit on how much fish may be consumed. Seafood consumption is limited to either the middle or low groups (No High Hg), or the low group only (Low Hg Only). In either case, seafood from the restricted group(s) is replaced by a random selection from a market-share distribution of low mercury species.
- *Total Seafood and Species Limit Combinations* (see Table 5).
  - *12 oz No High* Consumption of seafood is limited to 12 oz per week, high mercury fish are replaced with low mercury fish.
  - *12 oz Variety.* Seafood consumption is limited to 12 oz per week, with no more than 6 oz from the Middle Hg group. High Hg fish (shark, swordfish, and mackerel) and Middle Hg fish in excess of 6 oz are replaced with Low Hg fish.
  - *12 or 6 Albacore.* Same as 12 oz variety. In addition, for the purposes of calculating the 12 oz limit, albacore portions are doubled. As a result, the maximum amount of seafood that may be consumed is reduced by an amount equal to the amount of albacore consumed. For example, if 3 oz of albacore is consumed per week, then the total amount of seafood that may be consumed is 9 oz. As the most extreme example, if 6 oz of albacore is consumed per week, then no additional seafood may be consumed.
  - *12 Low or 6 oz Middle.* Seafood consumption is limited to 12 oz per week, High Hg fish (shark and swordfish) are replaced with Low Hg fish. For the purposes of calculating the 12 oz limit, seafood portions from the Middle group are doubled. As a result, the maximum amount of seafood that may be consumed is reduced by an amount equal to the amount of seafood from the middle group consumed. For example, if 3 oz of Middle Group seafood is consumed per week, then the total amount of seafood that may be consumed is 9 oz. As the most extreme example, if 6 oz of Middle Group seafood is consumed per week, then no additional seafood may be consumed.
  - *12 oz Low.* Seafood consumption is limited to 12 oz, high and mid Hg fish are replaced with low Hg fish.

Results

Comparison of Baseline Model to NHANES

The results from the blood mercury exposure model were compared to survey mercury blood values from the NHANES survey population between 1999 and 2000 (see Figure 4). The values are in very close agreement.

Intervention Scenarios

The impact of various consumer advisories on mercury blood levels is presented in Tables 3, 4, and 5. In each case, the impact of each advisory is compared to current baseline blood mercury values.

Total Seafood Consumption Limits

Table 3 shows the expected reduction in mercury blood levels following the introduction of consumption limits ranging from 6 to 18 oz per week. While a limit of 18 oz only slightly reduces the level of exposure at the extreme tail (i.e. above the 99th percentile), more aggressive limits reduce exposure for a greater range of consumers and provide a greater reduction at the tail.

Advisories Concerning Specific Species

Table 4 shows the expected reduction in mercury blood levels following the elimination of certain species, with either particularly high mercury levels or any species with above average mercury levels. Although the reductions on mercury exposure are not as dramatic, the reductions in exposure may be noted across the entire distribution.

Advisories Combining Limits on Amount and Species

Table 5 shows the expected reduction in blood mercury levels with several different scenarios where the advisory includes some combination of limitation on the amount of seafood consumed with additional limitations on the types of seafood consumed In the first scenario, which reflects the current FDA advisory avoiding the consumption of high methylmercury species and limiting seafood consumption to no more than 12 oz per week will eliminate the occurrence of blood mercury values that are higher than 5 times the average. The simulations indicate that more aggressive limits on what species are consumed would result in greater reductions across the entire distributions of blood mercury values, but only provide minor, further (in comparison with advisories that only limit the amount of fish consumed) reductions in those consumers with the highest levels of exposure.

Conclusions

The purpose of this analysis was to assess the impact of a variety of fish consumption advisory scenarios on modeled distributions of blood mercury levels in a population of women of child-bearing age. This population group was identified to be the subpopulation group of greatest concern because of MeHg induced fetal effects (NRC, 2000). As stated previously it was assumed that adherence to each advisory would be complete. In a previous analysis (Carrington and Bolger, 2002) the blood mercury estimates were within a factor of two across the distributional range. The model used in the present analysis was revised in a number of ways. The most significant adjustments were 1) incorporating additional data on mercury levels in seafood, 2) adjusting for water loss during food preparation, and 3) revising the population distributions for frequency of seafood consumption. As a result of these changes, the model results are in much closer agreement with NHANES survey data for mercury in blood. While this does not prove beyond any possible doubt that the model is entirely correct in every respect, the comparison does indicate that the results of the model are plausible.

In general, reducing overall fish consumption appears to have more impact on the overall population distributions than reducing or eliminating levels of high level mercury species only. This may be largely attributed to the fact that the fish with higher levels of mercury tend to have a smaller market share. Nonetheless, the scenarios do indicate that curtailing consumption of high level fish can reduce the number of individuals with unusually high blood levels.

Comparison of the scenario distributions with various safety standards (see Figure 5) indicates that a scenario (12 oz of low Hg fish only) may be devised to reduce the blood Hg levels of the entire population of women aged 16 to 49 years below any of a wide range of proposed standards. However, it is difficult to gauge the utility of any of the advisory scenarios by comparing the results to safety standards for several reasons. First, none of the standards can be equated to a level of absolute zero risk, since it can never be established that some imperceptible effect does not occur with a given dose. Second, at the tails of the population distributions, there are likely to be some (albeit different) fraction of the total population above the safety standard regardless of which is chosen. Third, because none of the standards serve as a dose-response function, a safety standard based analysis does not provide information about the extent of the very small adverse effects that might be anticipated if the standard is exceeded or perhaps even if it is not. For the purpose of comparing mercury risks to other costs and benefits, more information could be provided by combining the present exposure assessment with a dose-response function (e.g. Carrington and Bolger, 2000).

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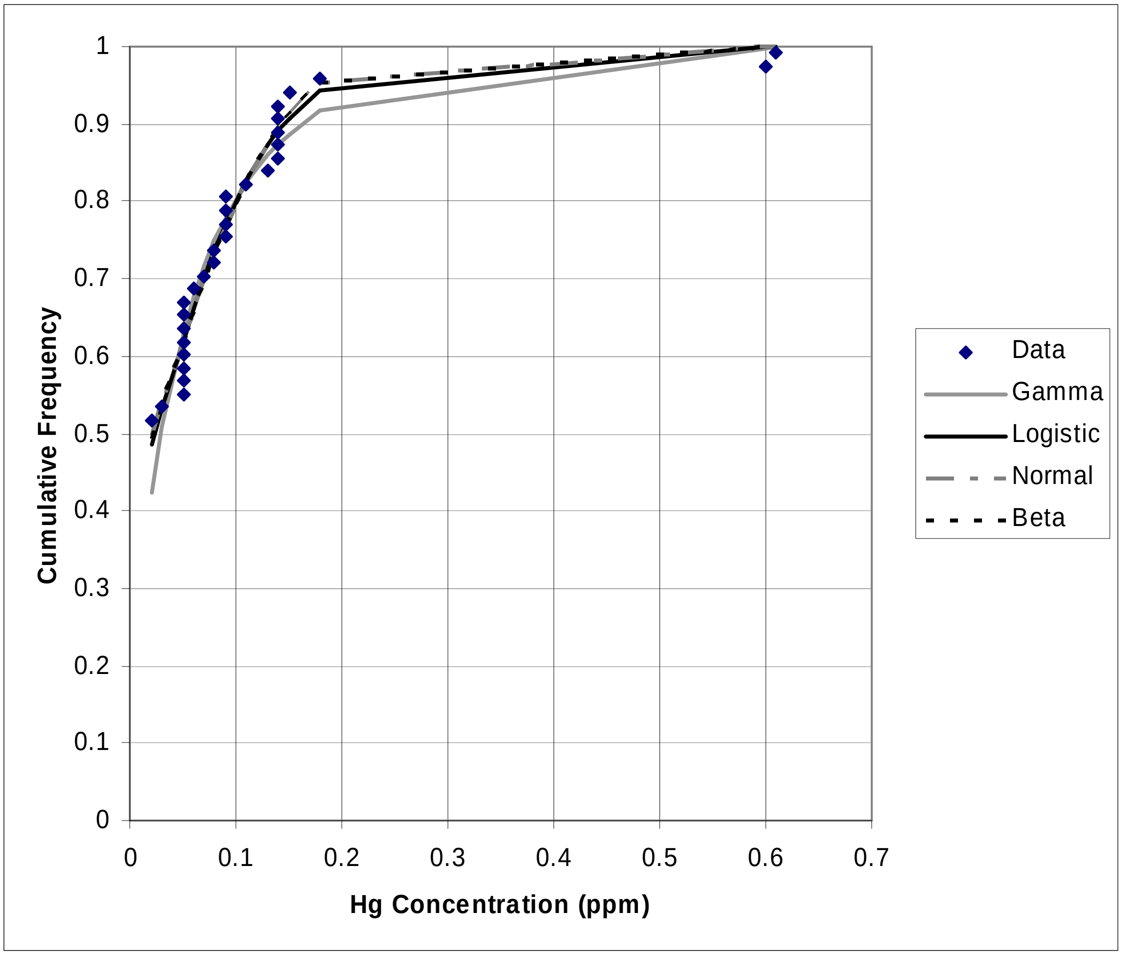
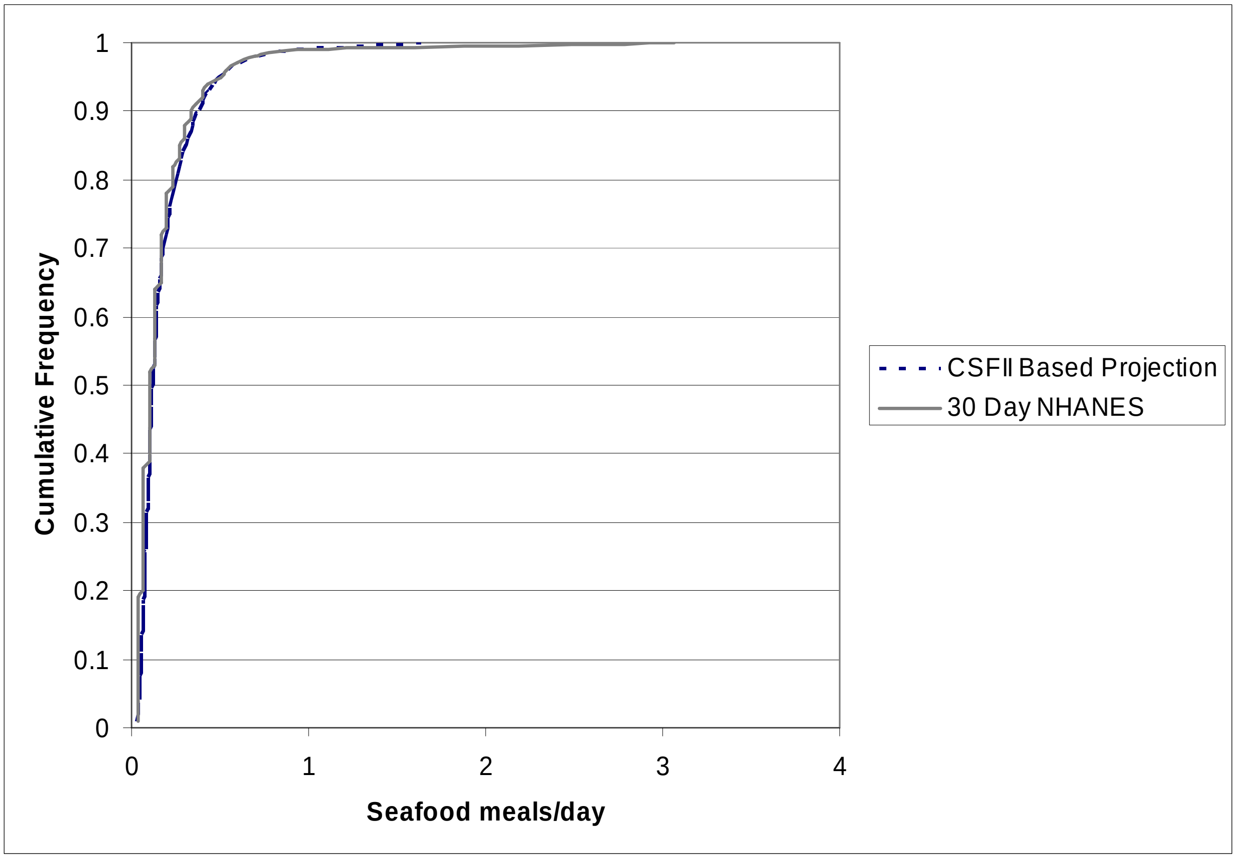
Figure 1: Fitted Distributions for Hg in Crab Meat



An example of a fitted distribution. 10 different distributions were fit to the sample Hg data for Crabs. The four best models were used to create a probability tree that describes the frequency distribution with a representation of model uncertainty. The primary advantage of using distributions to describe the data is that they can be used to extrapolate the concentration in the samples that are below the level of detection – which comprise about 50% of the crab samples.

Figure 2: Long-Term Frequency Extrapolation for Consumption



The CSFII based projection employed the exponential function described in Carrington and Bolger (2002b), using values of 0.696 and 0.356 for the alpha and beta parameters, respectively. These parameters were obtained by fitting the projected frequency distribution to 30 day survey data obtained from NHANES III (CDC, 2003).

Figure 3: Major Category Ratio Distribution

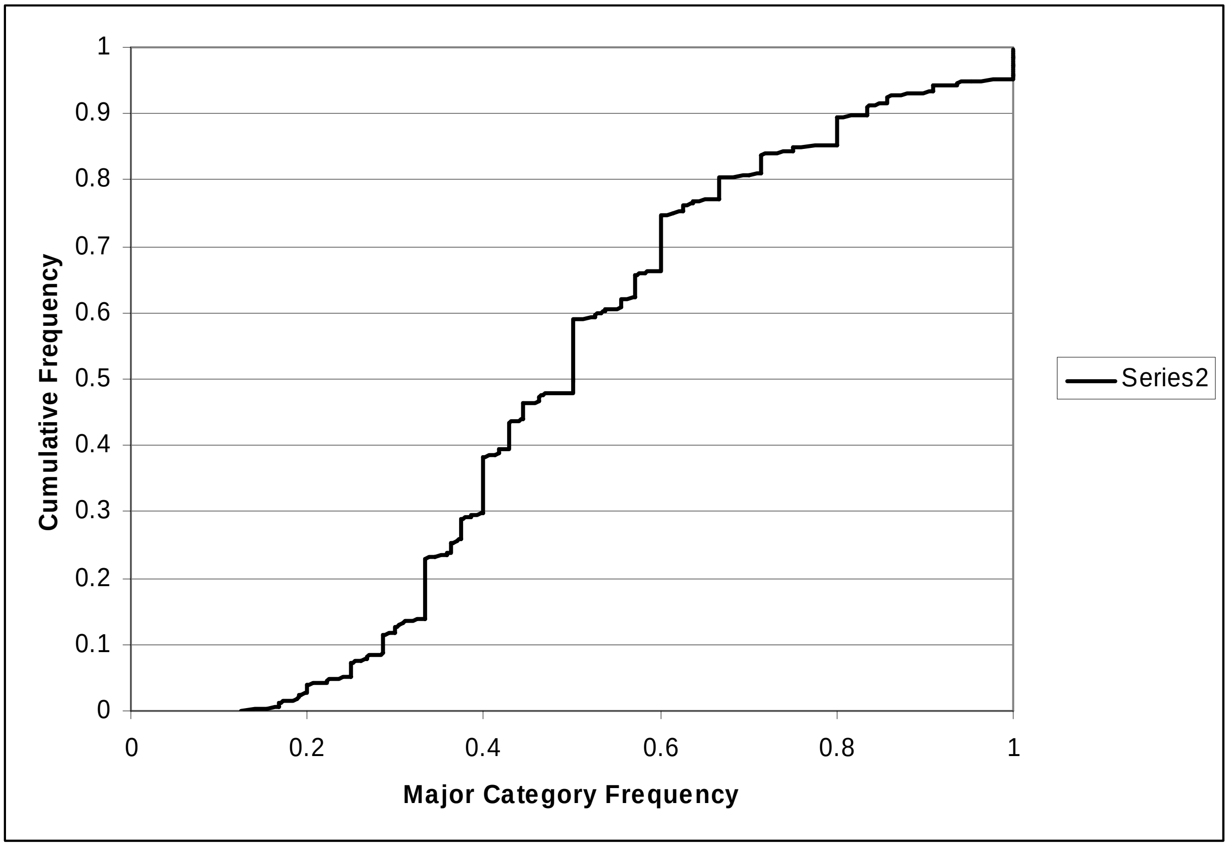


Figure 4: Quantile-Quantile Comparison of Simulation and Survey Blood Hg Values

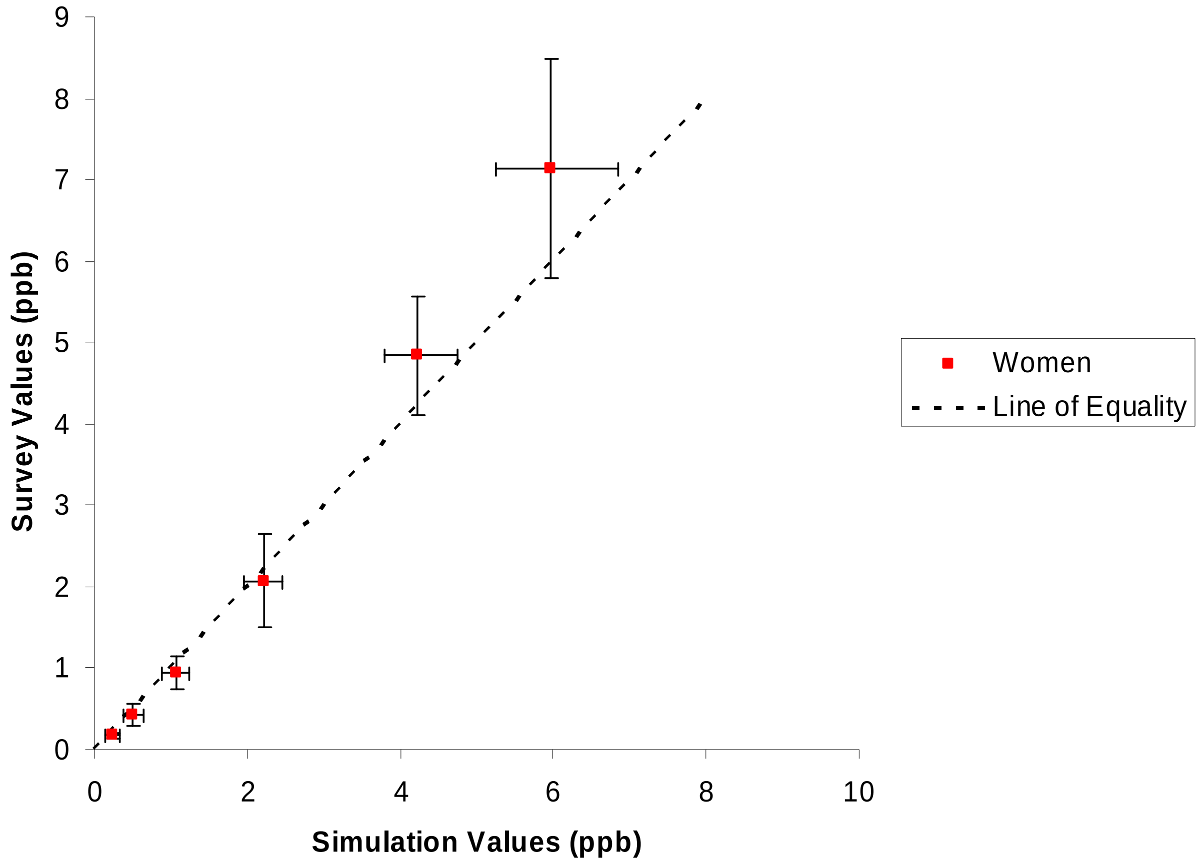
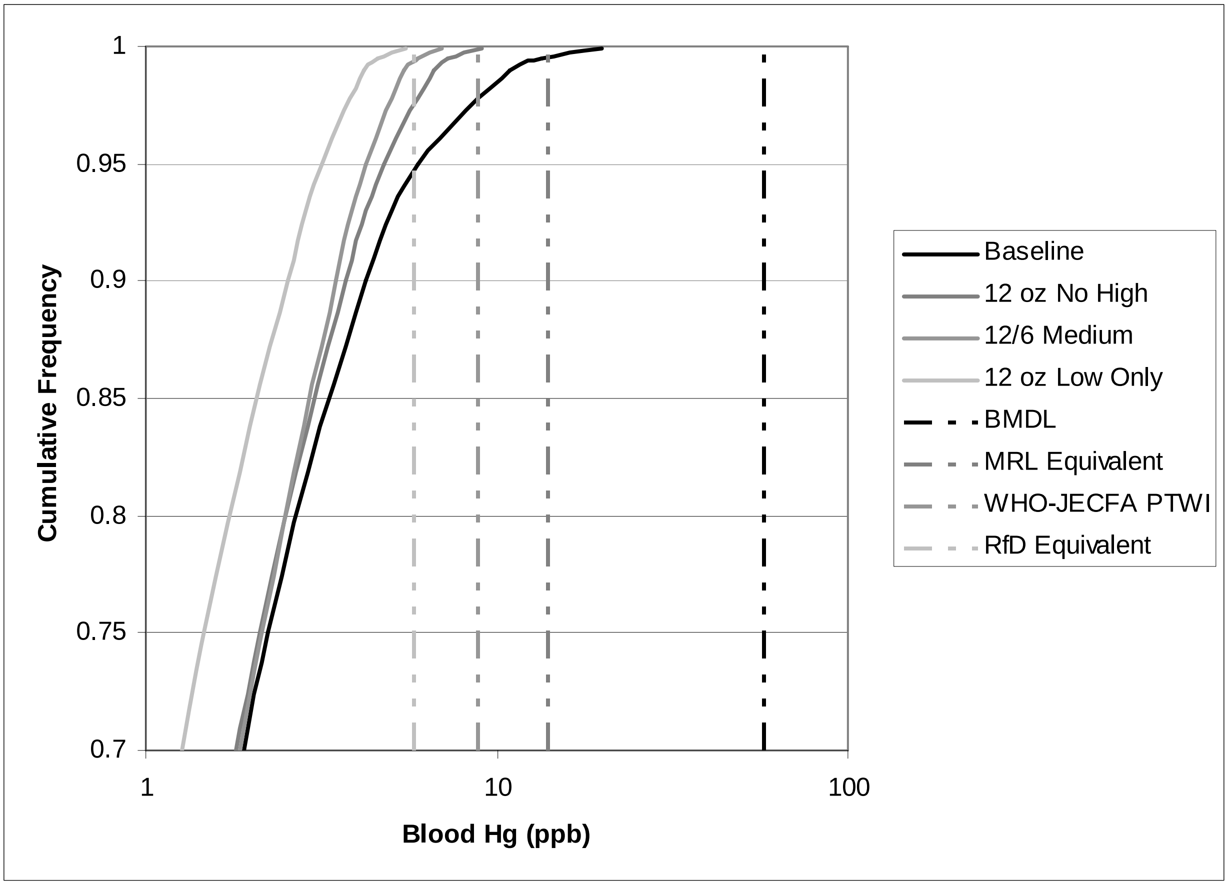


Figure 5: Comparison of Scenario Outcomes to Various Safety Standards



12 oz – no restriction of fish from low or medium Hg group; 12/6 Medium – 12 oz low or 6 oz medium Hg fish; 12 oz of low Hg fish; BMDL – Bench Mark Dose Lower Confidence Limit; WHO-JECFA PTWI – World Health Organization-Joint Expert Committee on Food Additives Provisional Tolerable Weekly Intake. RfD Equivalent – steady state blood level equivalent to oral Reference Dose; MRL – Minimal Risk Level. As an alternative to distinguishing the shade for each scenario or target level, the lines may be identified by noting that the top to bottom order in the figure legend corresponds to the right to left order in the figure.

Table 1: Seafood Hg data

SPECIES	MERCURY CONCENTRATION (PPM)[1] MEAN	MEDIAN	MIN	MAX	n	Source[2]	MARKET[3]
ANCHOVIES	0.04	NA	ND	0.34	40	NMFS 1978	0.5%
BASS (Saltwater)[4]	0.27	0.15	0.06	0.96	35	FDA 1990-03	0.6%
BLUEFISH	0.31	0.30	0.14	0.63	22	FDA 2002-03	0.1%
BUFFALOFISH	0.19	0.14	0.05	0.43	4	FDA 1990-02	0.0%
BUTTERFISH	0.06	NA	ND	0.36	89	NMFS 1978	0.1%
CARP	0.14	0.14	0.01	0.27	2	FDA 1990-02	0.0%
CATFISH	0.05	ND	ND	0.31	22	FDA 1990-02	4.8%
CLAMS	ND	ND	ND	ND	6	FDA 1990-02	1.7%
COD	0.11	0.10	ND	0.42	20	FDA 1990-03	4.7%
CRAB [3]	0.06	ND	ND	0.61	59	FDA 1990-02	4.7%
CRAWFISH	0.03	0.03	ND	0.05	21	FDA 2002-03	0.6%
CROAKER (Atlantic)	0.05	0.05	0.01	0.10	21	FDA 1990-03	0.3%
CROAKER WHITE (Pacific)	0.29	0.28	0.18	0.41	15	FDA 1990-03	0.0%
FLATFISH [5]	0.05	0.04	ND	0.18	22	FDA 1990-02	3.6%
GROUPER	0.55	0.44	0.07	1.21	22	FDA 2002-03	0.2%
HADDOCK	0.03	0.04	ND	0.04	4	FDA 1990-02	0.6%
HAKE	0.01	ND	ND	0.05	9	FDA 1990-02	0.3%
HALIBUT	0.26	0.20	ND	1.52	32	FDA 1990-02	0.9%
HERRING	0.04	NA	ND	0.14	38	NMFS 1978	2.5%
JACKSMELT	0.11	0.06	0.04	0.50	16	FDA 1990-02	0.0%
LOBSTER (Northern/American)	0.31	NA	0.05	1.31	88	NMFS 1978	1.3%
LOBSTER (Spiny)	0.09	0.14	ND	0.27	9	FDA 1990-02	0.8%
MACKEREL ATLANTIC (N. Atlantic)	0.05	NA	0.02	0.16	80	NMFS 1978	0.3%
MACKEREL CHUB (Pacific)	0.09	NA	0.03	0.19	30	NMFS 1978	0.2%
MACKEREL KING	0.73	NA	0.23	1.67	213	GULF 2000	0.1%
MACKEREL SPANISH (Gulf of Mexico)	0.45	NA	0.07	1.56	66	NMFS 1978	0.0%
MACKEREL SPANISH (S. Atlantic)	0.18	NA	0.05	0.73	43	NMFS 1978	0.0%
MARLIN	0.49	0.39	0.10	0.92	16	FDA 1990-02	0.0%
MONKFISH	0.18	NA	0.02	1.02	81	NMFS 1978	0.4%
MULLET	0.05	NA	ND	0.13	191	NMFS 1978	0.2%
ORANGE ROUGHY	0.54	0.56	0.30	0.80	26	FDA 1990-03	0.2%
OYSTERS	ND	ND	ND	0.25	34	FDA 1990-02	0.8%
PERCH (Freshwater)	0.14	0.15	ND	0.31	5	FDA 1990-02	0.0%
PERCH OCEAN	ND	ND	ND	0.03	6	FDA 1990-02	0.5%
PICKEREL	ND	ND	ND	0.06	4	FDA 1990-02	0.1%
POLLOCK	0.06	ND	ND	0.78	37	FDA 1990-02	11.1%
SABLEFISH	0.22	NA	ND	0.70	102	NMFS 1978	0.3%
SALMON (Canned)	ND	ND	ND	ND	23	FDA 1990-02	0.9%
SALMON (Fresh/Frozen)	0.01	ND	ND	0.19	34	FDA 1990-02	7.9%
SARDINE	0.02	0.01	ND	0.04	22	FDA 2002-03	1.2%
SCALLOPS	0.05	NA	ND	0.22	66	NMFS 1978	0.8%
SCORPIONFISH	0.29	NA	0.02	1.35	78	NMFS 1978	0.9%
SHAD (American)	0.07	NA	ND	0.22	59	NMFS 1978	0.0%
SHARK	0.99	0.83	ND	4.54	351	FDA 1990-02	0.1%
SHEEPSHEAD	0.13	NA	0.02	0.63	59	NMFS 1978	0.0%
SHRIMP	ND	ND	ND	0.05	24	FDA 1990-02	15.1%
SKATE	0.14	NA	0.04	0.36	56	NMFS 1978	0.3%
SNAPPER	0.19	0.12	ND	1.37	25	FDA 2002-03	0.5%
SQUID	0.07	NA	ND	0.40	200	NMFS 1978	1.0%
SWORDFISH	0.97	0.86	0.10	3.22	605	FDA 1990-02	0.4%
TILAPIA	0.01	ND	ND	0.07	9	FDA 1990-02	1.9%
TILEFISH (Atlantic)	0.15	0.10	0.06	0.53	17	FDA 2002-03	0.0%
TILEFISH (Gulf of Mexico)	1.45	NA	0.65	3.73	60	NMFS 1978	0.0%
TROUT (Freshwater)	0.03	0.02	ND	0.13	17	FDA 2002-03	0.7%
TUNA (Canned, Albacore)	0.35	0.34	ND	0.85	179	FDA 1990-03	5.3%
TUNA (Canned, Light)	0.12	0.08	ND	0.85	131	FDA 1990-03	13.4%
TUNA (Fresh/Frozen)	0.38	0.30	ND	1.30	131	FDA 1990-02	1.8%
WEAKFISH (Sea Trout)	0.25	0.16	ND	0.74	27	FDA 1990-03	0.1%
WHITEFISH	0.07	0.05	ND	0.31	25	FDA 1990-03	0.2%
WHITING	ND	ND	ND	ND	2	FDA 1990-02	4.1%

1 - Mercury was measured as Total Mercury and/or Methylmercury. ND - mercury concentration below the Level of Detection (LOD=0.01ppm). NA - data not available.

2 - Source of data: FDA Surveys 1990-2003, "National Marine Fisheries Service Survey of Trace Elements in the Fishery Resource" Report 1978 , "The Occurrence of Mercury in the Fishery Resources of the Gulf of Mexico" Report 2000

3 - Market share calculation based on 2001 National Marine Fisheries Service published landings data.

4 - Includes: Sea bass/ Striped Bass/ Rockfish

5 - Includes: Flounder, Plaice, Sole

6 - Includes: Blue, King, and Snow crab

Table 2: Methylmercury Distributions for Various Species

Species	Market Share[1]	Mean Hg (ppm)	Distribution Type[2]	Concentration Factor[3]	Advisory Group
Tilefish, Gulf	0.01%	1.450	Analog	0.839	High
Shark	0.13%	0.988	Empirical	0.758	High
Swordfish	0.42%	0.969	Empirical	0.75	High
Mackerel, King	0.05%	0.73	Analog	0.8	High
Grouper	0.17%	0.549	Modeled	0.823	Medium
Orange Roughy	0.20%	0.540	Modeled	0.809	Medium
Marlin	0.02%	0.489	Modeled	0.8	Medium
Tuna, Fresh	1.79%	0.378	Empirical	0.8	Medium
Mackerel, Spanish	0.05%	0.368	Analog	0.8	Medium
Tuna, Albacore Canned	5.29%	0.352	Empirical	1	Medium
Bluefish	0.09%	0.324	Modeled	0.839	Medium
Bass, Freshwater	0.00%	0.318	Modeled	0.791	Medium
Lobsters, American	1.29%	0.31	Analog	0.758	Medium
Croaker, Pacific	0.00%	0.303	Modeled	0.871	Medium
Lingcod and Scorpionfish	0.92%	0.286	Analog	0.802	Medium
Sablefish	0.25%	0.273	Analog	0.839	Medium
Trout, Saltwater	0.06%	0.269	Modeled	0.77	Medium
Bass, Saltwater	0.61%	0.263	Modeled	0.797	Medium
Halibut	0.90%	0.217	Modeled	0.761	Medium
Carp and Buffalofish	0.02%	0.203	Modeled	0.871	Medium
Haddock, Hake, and Monkfish	5.35%	0.17	Modeled	0.802	Medium
Perch, Freshwater	0.04%	0.162	Modeled	0.785	Medium
Cod	4.71%	0.143	Modeled	0.809	Medium
Snapper, Porgy, and Sheepshead	0.54%	0.141	Modeled	0.812	Medium
Skate	0.34%	0.137	Analog	0.758	Medium
Tuna, Light Canned	13.35%	0.124	Empirical	1	Low
Tilefish, Atlantic	0.03%	0.123	Modeled	0.839	Low
Lobsters, Spiny	0.82%	0.121	Modeled	0.758	Low
Smelt	0.00%	0.092	Modeled	0.867	Low
Mackerel, Chub	0.17%	0.088	Analog	0.8	Low
Squid	1.03%	0.07	Analog	0.818	Low
Whitefish	0.22%	0.068	Modeled	0.752	Low
Pollock	11.05%	0.067	Modeled	0.794	Low
Catfish	4.77%	0.066	Modeled	0.8	Low
Crabs	4.70%	0.063	Modeled	0.775	Low
Flatfish	3.61%	0.059	Modeled	0.761	Low
Butterfish	0.14%	0.0580	Analog	0.839	Low
Pike	0.10%	0.056	Modeled	0.75	Low
Croaker, Atlantic	0.30%	0.055	Modeled	0.871	Low
Anchovies, Herring, and Shad	3.06%	0.05	Analog	0.737	Low
Mackerel, Atlantic	0.29%	0.049	Analog	0.8	Low
Mullet and Perch, Ocean	0.69%	0.04	Analog	0.809	Low
Trout, Freshwater	0.69%	0.030	Modeled	0.752	Low
Salmon	8.24%	0.028	Modeled	0.77	Low
Crawfish	0.56%	0.027	Modeled	0.773	Low
Tilapia	1.87%	0.02	Modeled	0.8	Low
Clams	1.69%	0.017	Modeled	0.764	Low
Oysters and Mussels	1.24%	0.017	Modeled	0.782	Low
Scallops	0.80%	0.017	Modeled	0.793	Low
Sardines	1.23%	0.016	Modeled	0.75	Low
Shrimp	15.14%	0.012	Modeled	0.776	Low

1 – As a result of species not included in the list, the sum of the market share values is about 99%.
2 - *Empirical* – Direct sampling of data set, used for large data sets with very few values below the limit of detection. *Fitted* – Modeled distribution with uncertainty about model form (see text for additional explanation). Used for data sets with a limited number of observations, often with many values below the level of detection. *Analog* – Two generic distributional forms (lognormal or gamma) were employed, with a mean value from 1978 National Marine Fisheries Survey, and a shape parameter shape derived from distributions for other species (see Carrington and Bolger, 2002 for additional explanation). This technique was used when only mean values are

available.

3 – These values reflect weight after food preparation as a percentage of initial weight. Mercury concentrations for seafood as eaten were calculated by dividing initial concentration by the correction factor. No correction factor was applied for canned tuna, since the mercury measurements were made after cooking. .

Table 3: Effect of Advisories Based on Seafood Consumption Limits on Estimated Hg Blood Levels

Scenario	Baseline	18 oz/week	12 oz/week	6 oz/week
Average	1.8 (1.7, 2.0)	1.7 (1.6, 1.9)	1.6 (1.5, 1.8)	1.3 (1.2, 1.4)
Perc 0.10	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)
Perc 0.25	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)
Median	1.1 (0.9, 1.2)	1.1 (0.9, 1.2)	1.1 (0.9, 1.2)	1.1 (0.9, 1.2)
Perc 0.75	2.2 (2.0, 2.5)	2.2 (2.0, 2.4)	2.2 (2.0, 2.4)	1.9 (1.8, 2.1)
Perc 0.90	4.2 (3.8, 4.8)	4.1 (3.7, 4.6)	3.9 (3.5, 4.2)	2.7 (2.6, 2.9)
Perc 0.95	6.0 (5.3, 6.8)	5.7 (5.1, 6.4)	4.9 (4.6, 5.4)	3.2 (3.0, 3.5)
Perc 0.99	10.6 (8.9, 13.8)	8.5 (7.6, 9.7)	6.8 (6.3, 7.5)	4.2 (3.8, 4.6)
Perc 0.995	13.1 (10.4, 17.5)	9.7 (8.4, 11.2)	7.5 (6.8, 8.6)	4.7 (4.2, 5.2)
Perc 0.999	18.7 (13.8, 31.4)	12.0 (10.1, 15.3)	9.2 (8.0, 12.7)	6.0 (4.9, 8.4)

All units are µg Hg/L in blood with uncertainty bounds expressed as 5^{th} and 95^{th} confidence limits in parentheses.

Table 4: Effect of Advisories Based on Species Selection on Estimated Hg Blood levels

Scenario	Baseline	No High	Low Only
Average	1.8 (1.7, 2.0)	1.8 (1.6, 2.0)	1.1 (1.0, 1.3)
Perc 0.10	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.1, 0.3)
Perc 0.25	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.4 (0.3, 0.5)
Median	1.1 (0.9, 1.2)	1.1 (0.9, 1.2)	0.7 (0.6, 0.8)
Perc 0.75	2.2 (2.0, 2.5)	2.1 (1.9, 2.4)	1.3 (1.2, 1.5)
Perc 0.90	4.2 (3.8, 4.8)	4.1 (3.6, 4.5)	2.5 (2.2, 2.8)
Perc 0.95	6.0 (5.3, 6.8)	5.7 (5.0, 6.6)	3.5 (3.0, 4.0)
Perc 0.99	10.6 (8.9, 13.8)	10.4 (8.5, 14.0)	6.1 (4.6, 8.3)
Perc 0.995	13.1 (10.4, 17.5)	12.3 (9.9, 18.1)	7.5 (5.6, 10.9)
Perc 0.999	18.7 (13.8, 31.4)	17.7 (12.8, 32.2)	10.4 (7.3, 19.6)

All units are μg Hg/L in blood with uncertainty bounds expressed as 5^{th} and 95^{th} confidence limits in parentheses.

Table 5: Effect of Advisories with Species and Consumption Limits on Estimated Hg Blood Levels

Scenario	Baseline	12 oz No High	12 oz Variety	12 or 6 Albacore	12 or 6 Medium	12 oz Low
Average	1.8 (1.7, 2.0)	1.6 (1.4, 1.7)	1.6 (1.4, 1.7)	1.5 (1.4, 1.7)	1.5 (1.3, 1.6)	1.1 (1.0, 1.2)
Perc 0.10	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.2, 0.3)	0.2 (0.1, 0.3)
Perc 0.25	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.5 (0.4, 0.6)	0.4 (0.3, 0.5)
Median	1.1 (0.9, 1.2)	1.0 (0.9, 1.2)	1.0 (0.9, 1.2)	1.0 (0.9, 1.2)	1.1 (0.9, 1.2)	0.7 (0.6, 0.9)
Perc 0.75	2.2 (2.0, 2.5)	2.1 (1.9, 2.4)	2.1 (1.9, 2.4)	2.1 (1.9, 2.4)	2.1 (1.9, 2.4)	1.4 (1.3, 1.6)
Perc 0.90	4.2 (3.8, 4.8)	3.7 (3.4, 4.1)	3.7 (3.4, 4.2)	3.7 (3.3, 4.0)	3.5 (3.2, 3.7)	2.5 (2.3, 2.8)
Perc 0.95	6.0 (5.3, 6.8)	4.8 (4.4, 5.1)	4.7 (4.3, 5.2)	4.6 (4.2, 4.9)	4.2 (3.9, 4.5)	3.2 (2.9, 3.5)
Perc 0.99	10.6 (8.9, 13.8)	6.5 (6.0, 7.2)	6.4 (5.8, 7.1)	6.0 (5.6, 6.6)	5.4 (5.1, 5.9)	4.2 (3.8, 4.6)
Perc 0.995	13.1 (10.4, 17.5)	7.3 (6.5, 8.2)	7.1 (6.3, 7.8)	6.6 (6.1, 7.4)	5.9 (5.5, 6.6)	4.6 (4.0, 5.3)
Perc 0.999	18.7 (13.8, 31.4)	8.8 (7.7, 11.9)	8.3 (7.2, 9.7)	7.8 (6.9, 11.6)	6.8 (6.1, 8.2)	5.4 (4.5, 6.8)

All units are μg Hg/L in blood with uncertainty bounds expressed as 5^{th} and 95^{th} confidence limits in parentheses.