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Expanding perceptions of subsistence fish consumption: Evidence of high commercial fish consumption and dietary mercury exposure in an urban coastal community ☆,☆☆

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ABSTRACT

Through collaborative partnerships established between current researchers and The Moton Community House (a local community center), African American women (ages 16–49 yrs) from the Southeast Community of Newport News, Virginia, USA were surveyed to assess the reproducibility and consistency of fish consumption patterns (ingestion rates, exposure frequencies, weight, and fish consumption rates) derived from a community-specific fish consumption survey. Women were also surveyed to assess the reliability of the survey responses, and to estimate daily mercury intake. Fish consumption patterns were reproducible and the survey responses were reliable. Comparison between years revealed that fish consumption patterns remained consistent over time. In addition, the high fish consumption rate estimated in 2008 (147.8 g/day; 95% CI: 117.6–185.8 g/day) was confirmed with a rate (134.9 g/day; 95% CI: 88–207 g/day) not materially different and still considerably higher than mean fish consumption rates reported for U.S. women. Daily mercury intake rates were estimated using consumption data from 2008 and three consumption scenarios (canned white, canned light, and no tuna) due to confirmed differences in mercury concentration between canned white and light tuna. Arithmetic mean daily mercury intake rates were 0.284 μg/kg bw/day (95% CI: 0.229–0.340 μg/kg bw/day) using canned white tuna, 0.212 μg/kg bw/day (95% CI: 0.165–0.259 μg/kg bw/day) using light tuna, and 0.197 μg/kg bw/day (95% CI: 0.151–0.243 μg/kg bw/day) using no tuna. Approximately 58%–73% of the daily mercury intake rates for African American women in the Southeast Community exceeded US EPA's oral reference dose (RfD) of 0.10 μg/kg bw/day for mercury. In addition, 2% of the rates exceeded a level (1.00 μg/kg bw/day) documented to produce adverse health effects. Past and current investigations confirmed that even though women in this community were not subsistence fishers, they are subsistence fish consumers.

1. Introduction

The estimation of finfish and shellfish (further referred to as fish) consumption and contaminant exposure in US subpopulations (e.g. subsistence fishers, ethnic minorities, or recreational anglers) can be greatly influenced by an assessor's perception and the selection of parameter values used to estimate exposure; especially, in subpopulations where peer reviewed publications and exposure data are limited, and an assessor is left to their own "best" judgment. Due to limited exposure data for certain US subpopulations (e.g., ethnic minorities), Federal and State default values are often used when estimating fish consumption and contaminant exposure (e.g. mercury, polychlorinated biphenyls, or endocrine disrupters) in these populations. However, more thought and consideration needs to be given when selecting such values because they typically are not reflective of many US subpopulations and are based on both consumers and non consumers of fish as opposed to only fish consumers (National Environmental Justice Advisory Council (NEJAC), 2002). For Federal and State assessors, narrowly held perceptions of certain subpopulations could lead to incorrect assumptions of fish consumption and contaminant exposure that in turn could result in environmental policies and standards that do not effectively protect these subpopulations.

Subsistence fishers are generally defined as those that rely on non-commercially caught fish as a major source of protein to their diet (US

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Environmental Protection Agency (US EPA), 2000a, 2000b). In the US, subsistence fishers represent subpopulations that are potentially highly exposed to contaminated fish and exhibit the highest fish consumption rates reported, as suggested by US EPA's default consumption rate for subsistence fishers (142.4 g/day) and peer reviewed publications (Toy et al., 1996; Sechena et al., 1999, 2003; Duncan, 2000; Judd et al., 2004). The high fish consumption rates exhibited by subsistence fishers strongly support the use of the adjective "subsistence" in describing their fish consumption patterns; although, subsistence fish consumers are often only thought of as individuals with high consumption rates who "fish" for, instead of "purchase," fish. This perception of subsistence fish consumers (and consumption), currently held by many exposure and risk assessors, stymies the use of the adjective "subsistence" to also describe subpopulations that do not fish but whose consumption of fish provides a major source of protein to their diet, is commercially purchased, and is comparable to that of subsistence fishers. Recently we suggested that currently held perceptions of subsistence fish consumers (and consumption) be broadened to include other subpopulations populations with comparable subsistence fish consumption patterns and contaminant exposures (Holloman and Newman, 2010). We define subsistence fish consumers broadly as those who rely on noncommercially caught or commercially purchased fish as a major source of protein in their diets (Holloman and Newman, 2010).

In 2004, the US EPA and Food and Drug Administration (US FDA) jointly developed fish consumption advice for one specific contaminant, mercury (US EPA/FDA, 2004). This joint effort reflected an understanding that human exposure to mercury contaminated fish involves the consumption of both commercial and noncommercial items. Mercury poses a human-health risk because of the adverse neurodevelopmental effects that have been linked with exposure. Methylmercury (MeHg), the predominant form of mercury associated with fish, is known for its neurotoxicity and developmental toxicity (National Research Council (NRC), 2000; Castoldi et al., 2008). In addition, some studies have linked methylmercury exposure from fish consumption to cardiovascular toxicity (Salonen et al., 1995; Guallar et al., 2002; Virtanen et al., 2005; Roman et al., 2011) while others have found no associations (Ahlqwist et al., 1999; Hallgren et al., 2001; Yoshizawa et al., 2002; Mozaffarian 2009; Mozaffarian et al., 2011). To protect humans against chronic and developmental mercury toxicity, US EPA developed an oral reference dose (RfD) of 0.10 μg/kg bw/day, an estimate of a daily oral exposure that is likely to be without an appreciable risk of adverse health effects over a lifetime (US EPA, 2001a, 2001b).

In the US, African Americans represent a subpopulation whose dietary mercury exposure may potentially be underestimated due to misperceptions about subsistence fish consumption. Numerous studies continue to report that African Americans have higher fish consumption rates and associated contaminant exposures than the general US population or other subpopulations such as recreational anglers (e.g., Burger et al., 1999, 2001; Mahaffey et al., 2004; Gibson and McClafferty, 2005; Derrick et al., 2008; Shilling et al., 2008; Mahaffey et al., 2009; McGraw and Waller, 2009; Holloman and Newman, 2010; Shilling et al., 2010). However, peer-reviewed publications remain limited regarding African American fish consumption patterns and contaminant exposures (Weintraub and Birnbaum, 2008; Derrick et al., 2008; McGraw and Waller, 2009; Holloman and Newman, 2010) and cultural and lifestyle factors influencing such exposures (Beehler et al., 2001; Cecelski, 2001; Weintraub and Birnbaum, 2008).

Through collaborative partnerships established between current researchers and a local community center (The Moton Community House), a community-based participatory research (CBPR) approach was used to explore fish consumption and dietary mercury exposure for African American women of childbearing age (ages 16–49 yrs) residing in the Southeast Community of Newport News, Virginia, USA. During April and May 2008, we administered a community-based fish consumption survey to African American women (n = 95) for the purpose of estimating fish consumption patterns (Holloman and Newman 2010). Our results suggest that even though African American women in this community are not subsistence fishers, they are subsistence fish consumers and that their consumption of commercially purchased items is high enough to warrant concerns of dietary mercury exposure (Holloman and Newman, 2010).

The goals of the present investigation were to confirm that the consumption survey used to estimate fish consumption patterns was reproducible and to estimate dietary mercury exposures for African American women (ages 16–49 yrs) residing in the Southeast Community of Newport News, Virginia. Specific objectives were to: 1) assess the reproducibility of the East End Fish Consumption Survey, 2) quantify the reliability of the responses used to estimate fish consumption rates, 3) assess the consistency of fish consumption patterns in the community, 4) determine mercury concentrations in commonly consumed fish items, and 5) generate deterministic (point) estimates of daily mercury intake. We hypothesized that fish consumption rates for African American women in the Southeast Community were greater than US EPA default values. We also hypothesized that daily mercury exposures, as well as percentage of the population exceeding US EPA's oral RfD for mercury, for African American women in this community were higher than reported estimates and exceedances for general US women.

2. Materials and methods

2.1. Survey design

The 2010 East End Fish Consumption Survey was based on the consumption survey administered during April and May 2008 (Holloman and Newman, 2010). The East End Fish Consumption Survey was designed to estimate the ingestion rate (IR, g/meal), exposure frequency (EF, meals/year), and consumption rate (CR, g/day) of individual fish (finfish and shellfish) items consumed by, and the body weight (Wgt, kg) of, low-income African American women residing in the Southeast Community of Newport News, Virginia, USA. Methods previously published (Holloman and Newman, 2010) were used in determining IR, EF, and CR for the current survey. All questions asked in the 2008 survey were included in the 2010 version of the East End Fish Consumption Survey.

Changes in the 2010 version of the East End Fish Consumption Survey included the use of different visual aids, clarification of cooking methods, and an additional question used to quantify reliability of responses. It was noted that the validity of the estimates (i.e., Wgt, IR, EF, and CR) was important but was not quantified due to limited resources. In the current survey, 68 new individual fish items were vacuum sealed and used based on visual aid methods previously published (Holloman and Newman, 2010). For clarification of cooking methods, the same questions asked in 2008 were asked in the current survey but separately for fish and shellfish. To assess the reliability of the responses given by the participants, they were asked initially to state consumption information for all fish items they listed. Then at the end of the survey, they were asked to restate consumption information pertaining specifically to the first fish item listed. A measure of concordance between the two responses (beginning and end) was determined and used as a relative measure of reliability in responses given by the participants.

2.2. Sample size and recruitment

The number of women used to assess the consistency of fish consumption and reproducibility of the East End Fish Consumption Survey was based on confidence interval precision using SAS PROC POWER (Version 9.2 software; SAS Institute Inc, Cary, NC). We were interested in confidently detecting a difference between 2010 estimates for IR, EF, and Wgt that was at most, 30% of the 2008 mean estimates. Because of the nonnormality in the IR, EF, and Wgt distributions obtained in 2008, log transformed data were used in the calculation of sample size. Sample sizes for IR, EF, and Wgt were calculated and the results of the three variables compared. It was determined that 12 women would be sufficient to achieve the desired precision. A total of 12 participants were conveniently recruited throughout the Southeast community of Newport News, Virginia. Inclusion criteria for participation were that participants (1) resided in the Southeast community of Newport News, VA, (2) considered themselves an African American or Black woman between the ages of 16–49 years, and (3) consumed fish. None of the selected women had participated in the 2008 survey.

We attempted to assess reproducibility by administering the survey to the same 12 women, four separate times during February 2010–June 2010. This time frame was selected because we also wanted to simultaneously examine seasonality of fish consumption, representing winter/spring (February/April 2010) and spring/summer (May/June 2010) consumption. However, the number of participants (12) needed to confidently achieve the desired precision for assessing reproducibility was only attained during May 2010. In June 2010, the month with the next highest number of participants, only nine out of the 12 women were able to take the survey. Therefore, subsequent analysis for reproducibility only focused on data collected during May and June 2010 for nine women (with the understanding that differences in 2010 less than 30% of the 2008 estimates may not confidently be detected), and seasonality was not analyzed. To assess the consistency of fish consumption patterns (IR, EF, and CR), the 12 women in the current study were surveyed during a time (the month of May) comparable to when women in 2008 were surveyed (Holloman and Newman, 2010), and data between the two were compared.

2.3. Determination of mercury concentrations

2.3.1. Sample collection

A total of 39 different types of fish were listed as items consumed by women in the Southeast Community of Newport News, Virginia (Holloman and Newman, 2010); however, all items were not analyzed for mercury due to time, availability, and resources. Out of the 39 items listed, a total of 24 fish items were selected for mercury determination (Table 1). Fish items selected were based on: 1) ten or more women surveyed in 2008 (Holloman and Newman, 2010) consuming a particular item (n = 19), 2) the potential of an item having elevated mercury concentrations due to species' trophic ecology and availability of the item in local grocery stores and fish markets (n = 2), and 3) three randomly selected fish items consumed by 9 or less of the women (n = 3).

For each of the 24 fish items, ten samples were selected from local grocery stores and fish markets. Grocery stores and fish markets were selected for sampling because 93% of fish items consumed by women in 2008 came from stores and markets whereas only 4% of items consumed were self-caught (Holloman and Newman, 2010). Selection of the store or market to purchase the item was based on the cumulative probability of all stores and markets listed by women in 2008 (Holloman and Newman, 2010). For one of the items (lobster), in addition to being purchased at a grocery store/fish market, four out of the ten samples were selected from a local restaurant because of the high probability of lobsters being consumed at restaurants. Also for trout (n = 19), the only species available in the selected stores and markets was sea trout which was why trout (sea) (n = 3) was denoted with an asterisk in Table 1. Once at the store or market, all of the different brands and types (fresh, frozen, canned) of the particular item were listed and a random number table was used to select an item from this list. If a store or market did not carry the particular fish item, another store/market was selected as previously mentioned and the process repeated.

2.3.2. Sample preparation and analysis

Once collected, individual items were cut in half. One half of the item was processed and analyzed in its unprepared (raw or straight out of the can with no further preparation required) state; the other was cooked, processed, and analyzed in its prepared (further preparation required) state. Based on cooking and cleaning methods previously determined (Holloman and Newman, 2010) all cooked finfish was breaded (with skin on) and pan/deep fried, and all cooked shellfish was boiled/steamed and the shell removed before homogenizing. The halves were homogenized and placed into tared acid washed (10% HNO_3) polypropylene bottles. The sample bottle was reweighed and the weight of the bottle with the sample recorded. The unprepared and prepared halves were freeze-dried to constant weight and then wet: dry weight ratios calculated.

Total mercury concentrations (mg/kg, ppm) of dried samples were determined using a Milestone DMA-80 Direct Mercury Analyzer (Shelton, CT). The method detection limit (MDL) and limit of quantification (LOQ) for the DMA-80 were 0.0001 and 0.0005 mg/kg for 0.05 g of tissue, respectively. Results were converted to a wet weight concentration (mg/kg) by dividing the dry weight concentration by the wet: dry ratio. All mercury concentrations used in determining mercury exposure were the converted wet weight concentrations (mg/kg, ppm).

2.3.3. Quality control and quality assurance

Standard curves were generated using different amounts of DORM-3, certified standard reference material from the National Research Council of Canada. To assess analytical quality of each analytical session, the certified standard reference material TORT-2 was used to establish

Table 1
List of commonly consumed fish items (finfish and shellfish) and the frequency of women consuming the items. Items with an asterisk (*) refer to the fish items selected for total mercury analysis (24 out of 39 items).

	Common names of fish items consumed	Number of women consuming items (n = 95)
1.	Whiting*	79
2.	Shrimp*	77
3.	Tuna*	77
4.	Snow crab legs*	70
5.	Blue crab*	65
6.	Croaker*	61
7.	Scallops*	43
8.	Spot*	40
9.	Mackerel cake*	35
10.	Salmon cake*	35
11.	Tilapia*	25
12.	Crab cake*	21
13	Trout*	19
14.	Flounder*	18
15.	Oysters*	18
16.	Catfish*	16
17.	Clam*	16
18.	Sardines*	12
19.	Lobster*	11
20.	Mussels	7
21.	Black bass*	5
22.	Butterfish*	4
23.	Salmon steak	4
24.	Perch*	3
25.	Striped bass*	3
26.	Trout (Sea)*	3
27.	Dungeness crab	2
28.	King fish	2
29	Monk fish	2
30.	Porgy*	2
31.	Bluefish	1
32.	Clam strips	1
33.	Crab meat	1
34.	Fish sticks	1
35.	Largemouth bass	1
36.	Mackerel salad	1
37.	Puppy drum	1
38.	Shad	1
39.	Sushi	1

control charts in which four replicates of the reference material (two in the beginning, one in the middle, and one at the end) were analyzed during each session. Based on the planned use of the data (i.e., estimating daily mercury intake), a recovery of ±6% for the TORT-2 reference material was deemed acceptable as the control chart upper and lower limits. Mean mercury concentrations (wet weight, mg/kg,) for all fish items analyzed were well above the method detection limit (0.0001 mg/kg) and limit of quantification (0.0005 mg/kg; Table 3). For the entire analytical process, the mean percent recovery for the certified standard reference material, TORT 2, was 103% (±2%).

2.4. Daily mercury intake

A deterministic (point) estimate of daily mercury intake (mg/kg bw/day) was generated for low income African American women (ages 16–49 yrs) in Southeast Newport News, Virginia using consumption data generated from women surveyed in 2008 (Holloman and Newman, 2010) along with mercury data generated from the current investigation. Other mercury data were obtained from the peer reviewed literature (Peles et al., 2006; Sunderland, 2007; Lowenstein et al., 2010) and federal databases (US FDA, 2011a, 2011b). Specifically, fish consumption rates (g/day converted to kg/day) were multiplied by mean mercury concentrations (mg/kg) yielding an amount of mercury consumed (mg/day) for individual fish items listed. For each of the 95 women, the amounts of mercury consumed for individual fish items listed were summed yielding a total (summed) amount which was then divided by the woman's weight (kg). Because only 93 out of the 95 women reported their weight, 93 daily mercury intake rates (mg/kg bw/day) were estimated and ranked. Transformed ranks (Blom, 1958) and cumulative proportions of daily mercury intake (mg/kg bw/day) were plotted. In addition, because canned tuna (not differentiating between type of canned tuna) was the only type of tuna that the women stated consuming in 2008 (Holloman and Newman, 2010) and known differences exist in mercury concentrations between types of canned tuna (white and light; Burger and Gochfeld, 2004), three estimates of mercury intake were generated. These three estimates represented the consumption of fish that included either canned “white”, “light”, or “no” tuna.

2.5. Statistical analysis

SAS 9.2 (SAS Institute Inc, Cary, NC) was used for all statistical analyses and probability values less than 0.05 were deemed significant. Data from the 2010 East End Fish Consumption Survey were not normally distributed. Therefore, a nonparametric Kendall τ procedure was used to assess correlations between demographic variables (age, income, education, and body weight) and total number of fish items listed, summed ingestion rate (IR, g/meal), summed exposure frequency (EF, meals/year), and summed fish consumption rate (CR, g/day). In addition, geometric estimates for means, standard deviations, and 95% confidence intervals were determined for summed IR, EF, and CR, and for body weight.

Data from the nine out of 12 women surveyed in May and June 2010 were compared to assess the reproducibility of the consumption survey to estimate IR, EF, CR, and body weight (kg, Wgt) for African American women (ages 16–49 yrs) in the Southeast Community. A nonparametric two sample Wilcoxon Rank Sum test (two-sided) was performed using NPAR1WAY SAS procedures to generate a rank sum statistic (W_{RS}) along with associated p-values. Significant probabilities suggested that the underlying distributions of IR, EF, CR, and Wgt differed significantly between May and June surveys and that the survey could not reproduce such estimates.

For consumption information requested twice within the survey, a measure of concordance between responses was determined and used to quantify the reliability of survey responses (i.e., for meal size, meals/year, and portion size) used to estimate IR, EF, CR, and Wgt. The validity of the estimate itself (i.e., IR, EF, CR, and Wgt) was not quantified. Because the response data was not normally distributed, nonparametric procedures were employed and the Kendall τ–b coefficient was generated. This statistic was used as the quantitative measure of reliability for responses used to estimate IR, EF, CR, and Wgt.

To assess the consistency of fish consumption patterns (IR, EF, and CR) for African American women (ages 16–49 yrs) in the Southeast Community, data from 2008 (Holloman and Newman, 2010) was compared with current May 2010 data. A nonparametric two sample Wilcoxon Rank Sum test (two-sided) was also performed using NPAR1WAY SAS procedures to generate a rank sum statistic (W_{RS}) and associated probabilities (p-values). Significant probabilities suggested that the underlying distributions of IR, EF, CR, and Wgt differed significantly between years and that the fish consumption patterns for African American women in the Southeast were not consistent through time. Fish consumption patterns for African American women in the Southeast Community were also compared to US EPA default values for the general population, recreational anglers, and subsistence fishers and the higher estimate was determined.

Mercury concentration data was not normally distributed; therefore, difference in mercury concentrations between raw and cooked samples were also analyzed using nonparametric procedures. A Wilcoxon signed rank test was performed using PROC UNIVARIATE to estimate the signed ranked statistic (W_{SR}). The hypothesis that the median difference between raw and cooked samples is equal to zero was rejected for all items with significant probability values thus suggesting that the underlying distributions between raw and cooked samples differed.

Nonparametric methods were used to compare the three daily mercury intake rates (white tuna, light tuna, or no tuna). A Kruskal–Wallis test was performed and a χ^2 statistic generated using the NPAR1WAY SAS procedure to determine if a difference among the intake rates existed. A probability value less than 0.05 was deemed significant and suggested that a difference among the three intake rates existed. Cumulative proportions of daily mercury intake rates were plotted and compared to US EPA's oral reference dose (RfD) for mercury (0.10 μg/kg bw/day). The percentage of intake rates exceeding the oral RfD was determined and compared to national estimates of exceedances.

3. Results

3.1. Reproducibility, reliability, and consistency of fish consumption patterns

Fish consumption data (IR, EF, CR, and Wgt) for the nine out of 12 participants who took the survey during May and June 2010 were used to assess the reproducibility of the consumption survey. Comparisons revealed no significant difference ($p>0.05$) in underlying distributions of IR ($W_{RS}=87$, $p=0.93$), EF ($W_{RS}=91$, $p=0.70$), CR ($W_{RS}=92$ $p=0.60$), and Wgt ($W_{RS}=86$, $p=1.00$) between May and June 2010 for the nine participants. Measures of concordance (Kendall τ–b) used to assess the reliability of participant survey responses were high (Kendall τ–b>0.80) for May ($n=12$) and June ($n=9$) 2010. For May 2010, Kendall τ–b coefficients were 0.92 (95% CI: 0.76–1.00) for meal size, 0.95 (95% CI: 0.85–1.00) for meals/year, and 1.0 (95% CI: 1.00–1.00) for portion size. For June 2010, Kendall τ–b coefficients were 1.00 for meal size, meals/year, and portion size.

Data used to assess the consistency of fish consumption patterns was obtained during May 2010, a time similar to that for the 2008 survey (April and May). All of the women ($n=12$) surveyed in 2010 had completed high school, GED or vocational training and had household incomes of $0–$20,000. There was no significant association ($p>0.05$) between demographic variables (age, income, education, and weight) and total number of fish items listed (Kendall $\tau=0.12$, 0.28, −0.10,

−0.08 respectively; $p = 0.62$, 0.30, 0.71, and 0.72 respectively) and summed IR (Kendall $\tau = 0.14$, 0.33, 0.26, 0.17 respectively; $p = 0.53$, 0.19, 0.31, and 0.45 respectively). There was a significant association between the demographic variable age and summed EF (Kendall $\tau = 0.5$; $p = 0.02$), and summed CR (Kendall $\tau = 0.46$; $p = 0.04$); however, there was no significant association between the other demographic variables (income, education, and weight) and summed EF (Kendall $\tau = 0.19$, −0.21, −0.02 respectively; $p = 0.47$, 0.41, and 0.94 respectively) and summed CR (Kendall $\tau = 0.33$, 0.17, 0.24 respectively; $p = 0.19$, 0.52, and 0.30 respectively).

Fish consumption data were not normally distributed therefore, geometric means for Wgt and the sums of IR, EF, and CR were reported (Table 2). Comparison between years for fish consumption data (Fig. 1A–D) revealed no significant difference ($p < 0.05$) in underlying distributions of IR ($W_{RS} = 653$, $p = 0.96$), EF ($W_{RS} = 519$, $p = 0.21$), CR ($W_{RS} = 561$ $p = 0.40$), and Wgt ($W_{RS} = 599$, $p = 0.71$) between 2008 and 2010.

3.2. Mercury concentration of commonly consumed fish items

Mercury concentrations ranged between 0.001–0.327 mg/kg for unprepared (raw or straight from the can) items and 0.012–0.177 mg/kg for prepared (cooked) items. In general, prepared items were higher in concentration than unprepared items. Out of the 20 fish items in which a comparison of median differences between prepared and unprepared concentrations could be made, median differences were significantly greater than zero for 14 of the items (Table 3). Median differences were significantly greater than zero for shrimp croaker, blue crab, whiting, salmon cake, scallops, tilapia, flounder, crab cake, catfish, lobster, black bass, and butterfish. For sea trout, the median difference was significantly greater than zero with a borderline p value (0.049).

3.3. Deterministic estimates of daily mercury intake

For women surveyed in 2008, arithmetic mean daily mercury intake rates were 0.284 µg/kg bw/day (95% CI: 0.229–0.340) using canned white tuna, 0.212 µg/kg bw/day (95% CI: 0.165–0.259) using light tuna, and 0.197 µg/kg bw/day (95% CI: 0.151–0.243) using no tuna. The mean ranks of daily mercury intake rates were significantly different among the choice of tuna used ($\chi^2 = 8.60$; $p = 0.01$). For approximately 58%–73% of the cases, daily mercury intake rates for low income African American women in Southeast Newport News, VA, would exceed US EPA's oral reference dose (RfD) of 0.10 µg/kg bw/day for mercury (Fig. 2). In addition, for approximately 2% of cases, women in this community would exceed a level (10*RfD for mercury; 1.00 µg/kg bw/day) documented to produce adverse health effects (Fig. 2).

Table 2
Geometric mean, standard deviation, and 95% confidence interval for ingestion rate, exposure frequency, fish consumption rate, and body weight of women surveyed in 2008 and 2010 (present study).

	N	Mean	SD	95% CI
East End Fish Consumption Survey 2010				
May				
Ingestion rate (IR, g/meal)	12	1366	1.46	1074–1737
Exposure frequency (EF, meal/year)	12	269	1.57	201–358
Fish consumption rate (CR, g/day)	12	135	1.96	88–207
Weight (kg)	12	71	1.16	64–78
June				
Ingestion rate (IR, g/meal)	9	1427	1.59	997–2042
Exposure frequency (EF, meal/year)	9	249	1.59	174–356
Fish consumption rate (CR, g/day)	9	128	1.86	79–206
Weight (kg)	9	70	1.11	64–76
East End Fish Consumption Survey 2008				
Ingestion rate (IR, g/meal)	95	1288	1.75	1149–1443
Exposure frequency (EF, meal/year)	95	259	2.39	259–370
Fish consumption rate (CR, g/day)	95	148	3.08	118–186
Weight (kg)	93	73	1.25	69–76

4. Discussion

4.1. East end fish consumption survey

In the field of nutritional epidemiology, there are numerous methods to assess the validity and reproducibility of estimates derived from fish consumption surveys (Shatenstein et al., 1999; Mina et al., 2007; Birgisdottir et al., 2008). We understand the importance of validating estimates (IR, EF, CR, and Wgt) derived from the East End Fish Consumption Survey; however, due to limited resources we were only able to assess the reproducibility of the estimates and the reliability of the responses used to generate the estimates. For reproducibility, results revealed no difference in the underlying distributions of IR, EF, CR, and Wgt between May and June 2010 for the nine women surveyed thereby implying that the survey was able to reproduce the estimates. A difference between May and June estimates may have existed but, was not detected because the number of participants ($n = 12$) needed to confidently detect such difference (at most 30% of the 2008 estimates) was not achieved. However, if such a difference existed, it would be marginal in comparison to the more illuminating differences between estimates for African American women in the Southeast Community and US. EPA default values for the general population and recreational anglers. Thus, even with the possibility of the estimates between May and June being different, such a difference still does not overshadow the fact that the survey was able to reproduce the substantially higher estimates exhibited by women in this community.

Reliability of the responses used to generate the fish consumption estimates was not assessed in 2008; however, data collected in 2010 (May and June) did suggest that responses used in generating estimates were highly reliable and similar to the responses given 2008 (Holloman and Newman, 2010). For both May and June, the measures of concordance (Kendall τ–b) were 0.92 and 1.00 respectively for meal size, 1.00 respectively for portion size, and 0.95 and 1.00 respectively for meals/year. Such high measures of concordances (>0.80) strongly implies that responses in 2010 were reliable and that the same may have been true for responses given in 2008; thus for our purposes we assumed that responses given in 2008 were reliable as well.

Comparisons of estimates between the years (2008 and only May 2010) strongly suggest that fish consumption patterns of African American women in the Southeast were consistent through time. Seasonality was not able to be addressed but can play a significant role in fish consumption for women in this community. Both of the surveys were administered during late spring (April and May) and therefore may only be reflective of consumption during that season. Thus, because the current and past (Holloman and Newman, 2010) investigations assumed regular and consistent consumption, fish consumption estimates generated for African American women in the Southeast are potentially overestimated.

As noted earlier, the validity of IR, EF, CR, and Wgt should be investigated and could be addressed by using dietary records or recalls in which consumption estimates generated by the survey are compared with estimates generated by the records or recalls (Masson et al., 2003). The use of biomarkers (e.g. hair and blood mercury) could also be used to assess the validity of estimates derived from fish consumption surveys. Biomarkers provide a more accurate estimate of actual fish consumption as well as a method free from errors associated with dietary records (e.g. food consumption diaries) or recollections, e.g. 24 h recall (Mina et al., 2007).

The lack of validating IR, EF, CR, and Wgt potentially means that the estimates may not be accurate and precise reflections of fish consumption for African American women in this community. However, based on current conclusions that: 1) the survey consistently estimated

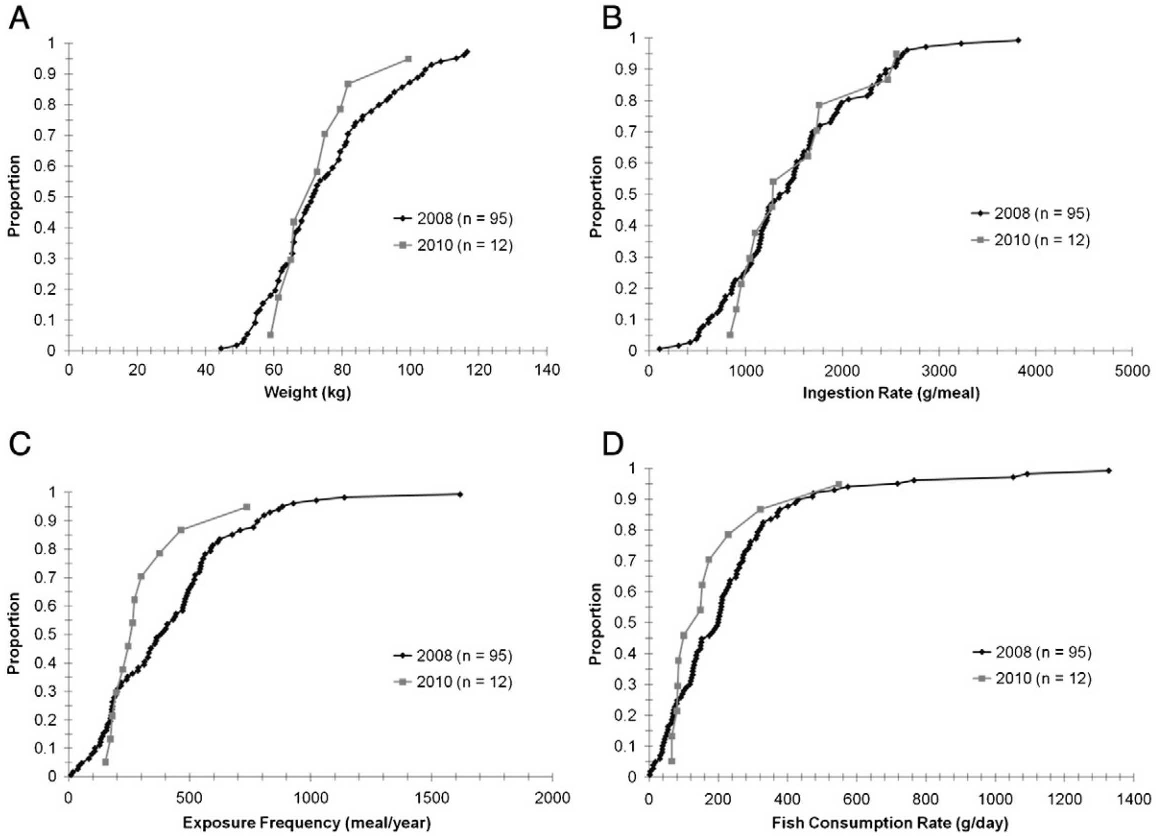

Fig. 1. A–D. Comparison of fish consumption patterns estimated using data collected in 2008 and 2010: A) Weight (Wtg, kg), B) Ingestion rate (IR, g/meal). C) Exposure Frequency (EF, meal/year), and D) Fish Consumption rate (CR, g/day).

ingestion rate (g/meal), exposure frequency (meal/year), fish consumption rate (g/day), and body weight (kg), 2) the responses used to generate such estimates were highly reliable, and 3) estimates derived from the survey were reproducible, we assumed the estimates generated in 2008 and currently were reasonable reflections of fish consumption patterns during late spring and early summer for African American women in the Southeast Community.

4.2. Evidence of high subsistence fish consumption

The high fish consumption rate (147.8 g/day) obtained in 2008 for African American women residing in this urban costal community (Holloman and Newman, 2010) was also confirmed with results of the current investigation. The mean fish consumption rate of women surveyed in the current investigation (134.9 g/day) was not materially different from women surveyed in 2008; however, it was considerably higher than US EPA default values reported for the general population and recreational angler (17.5 g/day), and more similar to the default value for subsistence fishers (142 g/day).

In estimating ingestion rates, a necessary adjustment was made based on the understanding that the total amount ingested for a particular item was not only the portion size (g/meal), but also how many individual portions (meal size) were consumed during one meal setting (Holloman and Newman, 2010). Such an adjustment should be considered when estimating ingestion rates and was calculated by multiplying the portion size selected by the number of individual portions consumed during one meal setting (Holloman and Newman, 2010). For African American women in this community, not making this adjustment would result in underestimation of ingestion rates and is potentially one of the reasons why consumption rates were higher.

Additionally, as noted in an earlier publication (Holloman and Newman, 2010), the manner in which rates were calculated (using individual differences in exposure frequencies and ingestion rates instead of averages) likely contributed to the higher consumption rate estimates. For each individual surveyed in 2008, the IR for each item listed was summed and used to represent a summed ingestion rate (g/meal) for the individual. Thus, the IR reported in Table 2 is the mean of the summed ingestion rates for the 95 individuals surveyed in 2008 (Holloman and Newman, 2010) and not the mean of mean ingestion rates which, explains why this estimate seems extremely high. Women surveyed in 2008 and 2010 could list up to 11 fish items and on average listed 8 items for both years. To get a rough estimate of mean ingestions rates, the summed ingestion rates could be divided by the average number of fish items listed (e.g., the mean of summed IR for 2008 (1366 g/meal)/mean # of items listed (8) = 171 g/meal).

It has been suggested that not taking into account species specific differences in fish consumption potentially biases estimates downward (Burger et al., 1999). On the other hand, others have suggested that such a "species specific" approach tends to overestimate fish consumption patterns (Lincoln et al., 2011). For May 2010, consumption rates (CR, g/day) based on a question specific to fish meals consumed within seven days of taking the survey were generated and compared to the mean summed CR generated from the listing of all fish consumed. Comparisons revealed that the estimate based on the seven day question was lower (84 g/day; 95% CI: 32–219 g/day) than the mean summed CR estimate (134 g/day; 95% CI: 88–207 g/day); however, not significantly lower. Similar to work highlighting this difference (Lincoln et al., 2011), we believe that true fish consumption for women in this community lies somewhere between the two estimates (7 day CR and summed CR).

Based on the women surveyed in 2008, African American women (ages 16–49 yrs) from this urban coastal community would not be considered subsistence fishers (hence subsistence fish consumers) because 65% of the women surveyed did not fish and 93% of the fish items

Table 3
Arithmetic mean (± standard deviation) and median mercury concentrations (mg/kg) and for unprepared (raw/ straight out of the can) and prepared (fried or steamed) fish items. (*) refers to items with a median difference between unprepared and prepared that was significantly greater than zero.

Fish Items (finfish and shellfish)	Unprepared			Prepared		
	N	Mean (±SD)	Median	N	Mean (±SD)	Median
Whiting*	10	0.046 (±0.029)	0.034	10	0.066 (±0.038)	0.054
Shrimp*	9	0.021 (±0.014)	0.016	10	0.023 (±0.017)	0.018
Canned tuna (white)	5	0.327 (±0.072)	0.361			
Canned tuna (light)	5	0.056 (±0.052)	0.035			
Snow crab legs	10	0.103 (±0.056)	0.077	10	0.114 (±0.057)	0.086
Blue crab*	9	0.053 (±0.021)	0.053	10	0.057 (±0.022)	0.057
Croaker*	10	0.079 (±0.029)	0.080	10	0.127 (±0.059)	0.134
Scallops*	10	0.012 (±0.005)	0.013	10	0.018 (±0.009)	0.020
Spot	10	0.021 (±0.013)	0.014	10	0.022 (±0.011)	0.018
Mackerel cake	10	0.043 (±0.011)	0.041	10	0.047 (±0.010)	0.046
Salmon cake*	10	0.022 (±0.008)	0.019	10	0.027 (±0.011)	0.025
Tilapia*	10	0.012 (±0.014)	0.002	10	0.012 (±0.014)	0.002
Crab cake*	10	0.033 (±0.025)	0.020	10	0.045 (±0.025)	0.035
Trout (sea)*	10	0.119 (±0.103)	0.088	10	0.134 (±0.111)	0.108
Flounder*	10	0.069 (±0.048)	0.056	10	0.081 (±0.051)	0.071
Oysters	10	0.025 (±0.014)	0.021			
Catfish*	10	0.015 (±0.021)	0.006	10	0.020 (±0.029)	0.006
Clam	10	0.001 (±0.004)	0.009			
Sardines	10	0.029 (±0.013)	0.032			
Lobster*	6	0.072 (±0.016)	0.067	10	0.092 (±0.026)	0.090
Black bass*	10	0.115 (±0.032)	0.101	10	0.161 (±0.038)	0.149
Butterfish*	10	0.072 (±0.010)	0.072	10	0.100 (±0.027)	0.099
Ocean perch	10	0.175 (±0.124)	0.108	10	0.177 (±0.142)	0.107
Striped bass	4	0.109 (±0.043)	0.101	4	0.135 (±0.046)	0.126
Porgy	10	0.122 (±0.026)	0.122	10	0.133 (±0.037)	0.138

consumed came from grocery/fish markets (Holloman and Newman, 2010). However, the women consumed fish at a rate (147.8 g/day; Holloman and Newman, 2010) comparable to rural subsistence fishing population such as the Squamish Indian Tribe (213.9 g/day; Duncan, 2000), Asian and Pacific Islanders in King County, Washington (117.2 g/day; Sechena et al., 1999), and Native Alaskans (109 g/day; Nobmann et al., 1992). In addition, 83% of the women surveyed had consumed fish within seven days of being interviewed (Holloman and Newman, 2010). Such fish consumption patterns were also confirmed with results of the current investigation in which 75% (95% CI: 46–100%) of the women surveyed in 2010 did not fish and 90% of the items consumed came from grocery stores (53%; 95% CI: 43–63%) and fish markets (37%; 95% CI: 27–47%). Sixty-seven percent (95% CI: 35–98%) of the women had consumed fish seven days prior to being interviewed. Collectively, this evidence strongly suggests that African American women from the Southeast Community of Newport News are subsistence fish consumers and rely on commercially caught fish as a major source of protein in their diets (Holloman and Newman, 2010).

4.3. Preparation of fish and mercury concentration

Mean mercury concentrations for the fish items analyzed were comparable to other mean estimates reported for commercial fish items (Sunderland, 2007; McKelvey et al., 2010; US FDA, 2011a, 2011b). The higher mercury concentrations (statistically significant in many cases) for items prepared (cooked) versus unprepared (raw) were similar to differences reported in the literature (Morgan et al., 1997; Burger et al., 2003). Noting the difference in mercury concentration between cooked versus raw fish items, it has been suggested that food preparation factors be used in estimating mercury exposure (Morgan et al., 1997; Burger et al., 2003). Preparation factors (mercury concentration in cooked item/mercury concentration in raw item; Burger et al., 2003) for the current investigation ranged from 1.1 (perch) to 1.6 (croaker) for fish and from 1.2 (snow crab legs) to 1.5 (crab cake) for shellfish, compared to 1.5 to 1.8 for largemouth bass (Burger et al., 2003) and 1.3 to 1.6 for walleye and lake trout (Morgan et al., 1997). Factors obtained in the current investigation also coincided with the suggestion that a preparation conversion factor of 2 would be a suitable, protective default value (Burger et al., 2003). As highlighted by Burger et al. (2003), the process of cooking fish (particularly deep frying) causes moisture loss, but no mercury loss which results in an increase in mercury concentration in the cooked fish relative to the raw fish sample. This is the most plausible explanation as to why mercury concentrations were higher in cooked fish items than in raw items.

No adjustments were made using a preparation food conversion factor to estimate mercury intake because amount consumed and mercury concentrations were based on cooked items. Burger et al. (2003) warned that assessors who do not take cooking methods into account, but use raw fish contaminant data, may be overestimating safe consumption levels and underestimating actual exposure. Thus, the lack of clearstatements as to what type of data (prepared/cooked data) were used to generate consumption estimates and mercury concentrations can create serious risk communication issues. For the current investigation, estimates of meal size and amount consumed were based on cooked items except for canned tuna, clams, oysters, and sardines in which estimates were based on how the items are normally consumed in this community, unprepared (straight from the can with no further cooking preparation). Mercury concentrations were also based on cooked items except for canned tuna, clam, oysters, and sardines in which concentrations were based on no further preparation (i.e. frying). As noted earlier, if fish consumption estimates are based on cooked items but, an assessor calculates exposure based on raw fish contaminant data, such estimates would underestimate actual exposure (Burger et al., 2003). For the current investigation, because the estimation of fish consumption and mercury exposure were based on cooked items, it was believed that calculated exposure estimates were more reflective of the actual daily mercury intake for women in the community.

4.4. Daily mercury intake: evidence of high exposure

The mean mercury consumption per day (mg Hg /day;) using white tuna (0.02 mg Hg/day), light tuna (0.015 mg Hg/day), and no tuna (0.014 mg Hg/day) was similar to means reported for minority anglers from California's Central Valley Delta (African American: 0.02 mg Hg/day; Southeast Asian: 0.02 mg Hg/day; Asian/Pacific Islander: 0.02 mg

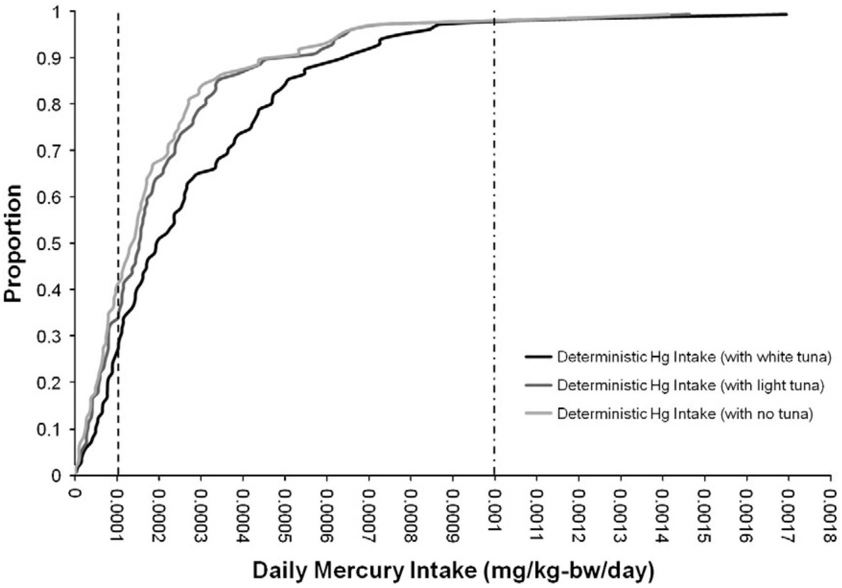

Fig. 2. Proportion of deterministic daily mercury intake rates (mg/kg bw/day) using canned white tuna, light tuna, and no tuna. Dashed line = US EPA's oral reference dose for mercury (0.0001 mg/kg bw/day). Dashed/dotted line = intake estimate that has resulted in measurable health effects (0.001 mg/kg bw/day).

Hg/day; Hispanic: 0.01 mg Hg/day; Native American: 0.02 mg Hg/day) (Shilling et al., 2010). Daily mercury intake rates for no, light, and white tuna consumption (0.197, 0.212, and 0.284 μg/kg bw/day respectively) were significantly higher than national estimates reported for general US women (0.02 μg/kg bw/day; 95% CI: 0.02–0.03 μg/kg bw/day; Mahaffey et al., 2004) and for non-Hispanic Black women (0.05 μg/kg bw/day; 95% CI: 0.01–0.09 μg/kg bw/day; Mahaffey et al., 2004). However, current mercury intake rates more closely resembled the median rates of fishing populations such as fluvial lake fish eaters in Canada (0.80 and 0.14 μg/kg bw/day; Abdelouahab et al. 2008), and mean rates of subsistence fishing populations such as the Tulalip native population in Washington State, US (0.11–0.20 μg/kg bw/day), the Squaxin Island native population in Washington State, US (0.11–0.22 μg/kg bw/day) , and the Suquamish native population in Washington State, US (0.16–0.25 μg/kg bw/day; Mariën and Patrick, 2001). This evidence strongly supports earlier conclusions that African American women in the Southeast Community of Newport News, Virginia are subsistence fish consumers (Holloman and Newman, 2010) and suggests that dietary mercury exposure among these women is high.

Exposure to mercury from the consumption of fish can produce both chronic and developmental toxicity effects in humans (US EPA 2001a, 2001b). To protect humans against such mercury toxicity, US EPA developed an oral reference dose (RfD) of 0.10 μg/kg bw/day, an estimate of a daily oral exposure that is likely to be without an appreciable risk of adverse health effects over a lifetime (US EPA, 2001a, 2001b). This RfD was based on cord blood measurements and is associated with a blood mercury (BHg) concentration of 5.8 μg/l (NRC, 2000; US EPA, 2001a, 2001b). The percentage of women exceeding US EPA's oral RfD was high for all three estimates (white, light, and no tuna) with more than 50% of the estimates exceeding this threshold. These exceedances were approximately 2–3 times higher than what was reported in general (29%) and specifically for African American (36%), Hispanic (25%), Asians (42%) and Native American (27%) low income women in California's Sacramento-San Joaquin Delta (Silver et al., 2007). These exceedances were also considerably greater than recent national BHg exceedances for general US women (ages 16–49 yrs, 4.7%; Mahaffey et al., 2009) and for African American women (4.1%; Mahaffey et al., 2009).

The oral RfD, 0.10 μg/kg bw/day, is a conservative estimate meant to be protective of all components of populations including susceptible subgroups and is not associated with measureable health effects. However, ten times the oral RfD for mercury is an intake estimate that has resulted in measurable health effects (US EPA, 2001a, 2001b). The percentage of women exceeding this estimate (1.00 μg/kg bw/day) was approximately 2% for the current investigation. This was comparable to the 5% of consumers found to be exceeding this estimate in California's Central Valley Delta (Shilling et al., 2010). Collectively, the estimates of daily mercury intake and the proportion of women exceeding US EPA's oral RfD provide strong evidence that African American women in the Southeast Community of Newport News, Virginia might be highly exposed to mercury through the consumption of fish.

5. Conclusions

It is erroneous to compare mean fish consumption of fish consumers with means of general populations that includes both consumers and non consumers of fish; however, many Federal and State agencies use default values based on such *per capita* estimates to describe fish consuming populations as well as setting environmental standards and policies to protect them (NEJAC, 2002). Assessors need to be more aware of their perceptions associated with certain subpopulations and their selection of parameter estimates used to characterize fish consumption in these populations, especially when exposure data is limited. Narrow perceptions and incorrect assumptions of fish consumption and contaminant exposure for many US subpopulations has lead to serious issues of environmental injustices regarding risk management and communication whereby non protective standards and polices have been implemented (and communicated), and the burden of exposure reduction has placed solely on the individual and population (NEJAC, 2002).

Through the collaborative partnership established between our research team and the Moton Community House, critical insights were gained about fish consumption patterns and dietary mercury exposure for low income African American women residing in the Southeast Community of Newport News, Virginia. One critical insight was that fish consumption rates for women in this community were the highest rates reported for African American women and supported the evidence that fish consumption among women of this ethnicity was high compared to general population. Another insight was that the sources of the fish items consumed by women in this community were mainly from commercial sources (grocery store or fish market), not noncommercial sources (fishing).

Results from the past (Holloman and Newman, 2010) and current investigations confirmed that, even though women in this community are not subsistence fishers, they consume fish at a subsistence fisher rate. It is conceivable how a lifestyle factor such as subsistence fish consumption would have significant impacts on dietary mercury exposure and results from the current investigation confirms this to be true for women in this community. Noteworthy is the potential environmental injustice issue arising from current perceptions of subsistence fish consumption held by many charged with assessing and regulating exposure to contaminated fish. Assessors viewing subsistence fish consumption only in relation to items fished for, instead of purchased, may unintentionally overlook or make incorrect assumptions about populations who are not subsistence fishers, but nonetheless, consume commercial fish at a subsistence rate. African American women residing in the urban costal community of Southeast Newport News, Virginia is one example of such a population.

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References

Abdelouahab N, Vanier C, Baldwin M, Garceau S, Lucotte M, Mergler D. Ecosystem matters: fish consumption, mercury intake and exposure among fluvial lake fisheaters. Sci Total Environ 2008;407(1):154–64.

Ahlqwist M, Bengtsson C, Lapidus L, Gergdahl IA, Schutz A. Serum mercury concentration in relation to survival, symptoms, and diseases: results from the prospective population study of women in Gothenburg, Sweden. Acta Odontol Scand 1999;57:168–74.

Beehler G, McGuinness BM, Vena JE. Polluted fish, sources of knowledge, and the perception of risk: contextualizing African American anglers' sport fishing practices. Hum Organ 2001;60:288–97.

Birgisdottir BE, Kiely M, Martinez JA, Thorsdottir I. Validity of a food frequency questionnaire to assess intake of fish in adults in three European countries. Food Control 2008;19:648–53.

Blom G. Statistical Estimates and Transformed Beta Variables. New York: John Wiley & Sons, Inc.; 1958.

Burger J, Gochfeld M. Mercury in canned tuna: temporal trends. Environ Res 2004;96:239–49.

Burger J, Stephens WL, Boring S, Kuklinski M, Gibbons JW, Gochfeld M. Factors in exposure assessment: ethnic and socioeconomic difference in fishing and consumption of fish caught along the Savannah River. Risk Anal 1999;19:427–38.

Burger J, Gaines KF, Gochfeld M. Ethnic differences in risk from mercury among Savannah River fisherman. Risk Anal 2001;21:533–44.

Burger J, Dixon C, Boring CS. Effect of deep-frying fish on risk from mercury. J Toxicol Environ Health 2003;66:817–28.

Castoldi AF, Johansson C, Onishchenko N, Coccini T, Roda E, Vahter M, et al. Human developmental neurotoxicity of methylmercury: impact of variables and risk modifiers. Regul Toxicol Pharmacol 2008;51:201–14.

Cecelski DS. The Waterman's song: Slavery and freedom in maritime North Carolina. Chapel Hill, NC: University of North Carolina Press; 2001.

Derrick CG, Miller JSA, Andrews JM. A fish consumption study of anglers in an at-risk community: a community- based participatory approach to risk reduction. Public Health Nurs 2008;25(4):312–8.

Duncan M. Fish consumption survey of the Squamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region. The Suquamish Tribe, Port Madison Indian Reservation, fisheries department, Suquamish, WA, USA; 2000.

Gibson Joshua C, McClafferty JA. Identifying populations at risk for consuming contaminated fish in three regions of concern. CMI-HDD-05-01. Blacksburg, VA: Chesapeake Bay Program and Conservation Management Institute; 2005.

Guallar E, Sanz-Gallardo MI, van't Veer P, Bode P, Aro A, Gomez-Aracena J, et al. Mercury, fish oils, and the risk of myocardial infarction. N Engl J Med 2002;347(22):1747–54.

Hallgren CG, Hallmans G, Jansson JH, Marklund SL, Huhtasaari F, Schu¨tz A, et al. Markers of high fish intake are associated with decreased risk of a first myocardial infarction. Br J Nutr 2001;86:397–404.

Holloman EL, Newman MC. A community-based assessment of fish consumption along the lower James River, Virginia, USA: potential sources of dietary mercury exposure. Environ Res 2010;110:213–9.

Judd N, Griffith W, Faustman E. Consideration of cultural and lifestyle factors in defining susceptible populations for environmental disease. Toxicology 2004;198:121–33.

Lincoln AR, Shine JP, Chesney EJ, Vorhees DJ, Grandjean P, Senn DB. Fish consumption and mercury exposure among Louisiana recreational anglers. Environ Health Perspect 2011;119(2):245–51.

Lowenstein JH, Burger J, Jeitner CW, Amato G, Kolokotronis SO, Gochfeld M. DNA barcodes reveal species-specific mercury levels in tuna sushi that pose a health risk to consumers. Biol Lett 2010;6(5):692–5.

Mahaffey K, Clickner R, Boduro C. Blood organic mercury and dietary mercury intake: national health and nutrition examination survey 1999–2002. Environ Health Perspect 2004;112:562–70.

Mahaffey KR, Clicker RP, Jeffries RA. Adult women's blood mercury concentrations vary regionally in the United States: associations with patterns of fish consumption (NHANES 1999–2004). Environ Health Perspect 2009;117(1):47–53.

Mariën K, Patrick GM. Exposure analysis of five fish consuming populations for overexposure to methylmerucry. J Expo Anal Environ Epidemiol 2001;11(3):193–206.

Masson LF, McNeil G, Tomany JO, Simpson JA, Peace HS, Wei L, et al. Statistical approaches for assessing the relative validity of a food-frequency questionnaire: use of correlation coefficients and the kappa statistic. Public Health Nutr 2003;6(3):313–21.

McGraw Sr JE, Waller DP. Fish ingestion and congener specific polychlorinated biphenyl and p, p′-dichlorodiphenyldichloroethylene serum concentrations in a great lakes cohort of pregnant African American women. Environ Int 2009;35:557–65.

Mckelvey W, Chang M, Arnason J, Jeffery N, Kricheff J, Kass D. Mercury and polychlorinated biphenyls in Asian market fish: a response to results from mercury biomonitoring in New York City. Environ Res 2010;110(7):650–7.

Mina K, Fritschi L, Knuiman M. A valid semiquantitative food frequency questionnaire to measure fish consumption. Eur J Clin Nutr 2007;61:1023–31.

Morgan J, Berry MR, Graves RL. Effects of commonly used cooking practices on total mercury concentration in fish and their impact on exposure assessments. J Expo Anal Environ Epidemiol 1997;7:119–34.

Mozaffarian D. Fish, mercury, selenium and cardiovascular risk: current evidence and unanswered questions. Int J Environ Res Public Health 2009;6:1894–916.

Mozaffarian D, Shi P, Morris JS, et al. Mercury exposure and risk of cardiovascular disease in two U.S. cohorts. N Engl J Med 2011;364:1116–25.

National Environmental Justice Advisory Council (NEJAC). Fish Consumption and Environmental Justice; 2002.

National Research Council (NRC). Toxicological Effects of Methylmercury. Washington, DC: National Academy Press; 2000.

Nobmann ED, Byers T, Lanier AP, Hankin JH, Jackson MY. The diet of Alaska native adults: 1987–1988. Am J Clin Nutr 1992;55:1024–32.

Peles JD, Glenn TC, Brant HA, Wall AK, Jagoe CH. Mercury concentration in largemouth bass (Micropterus Salmoides) from five South Carolina reservoirs. Water Air Soil Pollut 2006;173:151–62.

Roman HA, Walsh TL, Coull BA, et al. Evaluation of the cardiovascular effects of methylmercury exposures: current evidence supports development of a dose–response function for regulatory benefits analysis. Environ Health Perspect 2011;119:607–14.

Salonen JT, Seppänen K, Nyyssönen K, Korpela H, Kauhanen J, Kantola M, et al. Intake of mercury from fish, lipid peroxidation, and the risk of myocardial infarction and coronary, cardiovascular, and any death in Eastern Finnish men. Circulation 1995;91(3):645–55.

Sechena R, Nakano C, Liao S, Polissar N, Lorenzana R, Truong S, et al. Asian and Pacific Islander fish consumption study. Seattle, WA: EPA Office of Environmental Assessment; 1999.

Sechena R, Liao S, Lorenzana R, Nakano C, Polissar N, Fenske R. Asian American and Pacific Islander seafood consumption — a community-based study in King County, Washington. J Expo Anal Environ Epidemiol 2003;13(4):256–66.

Shatenstein B, Kosatsky T, Nadon S, Lussier-Cacan S, Weber JP. Reliability and relative validity of fish consumption data obtained in an exposure assessment study among Montreal-Area sportfishers. Environ Res A 1999;80:S71–86.

Shilling FM, Sommer S, Leonelli L, Shimoum D. Community-based strategies to reduce mercury exposure in Delta fishing communities. Report for the California Department of Public Health and the Central Valley Regional Water Quality Control Board; 2008.

Shilling F, White A, Lippert L, Lubell M. Contaminated fish consumption in California's central valley delta. Environ Res 2010;110:334–44.

Silver E, Kaslow J, Lee D, Lee S, Tan ML, Weis E, et al. Fish consumption and advisory awareness among low-income women in California's Sacramento–San Joaquin Delta. Environ Res 2007;104:410–9.

Sunderland EM. Mercury exposure from domestic and imported estuarine and marine fish in the United States fish market. Environ Health Perspect 2007;115(2):235–42.

Toy KA, Polissar NL, Liao S, Mittelstaedt GD. A Fish Consumption Study of the Tulalip and Squaxin Island tribes of the Puget Sound region. Marysville, WA: Tulalip Tribes, Department of Environment; 1996.

United States Environmental Protection Agency (US EPA). Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories. EPA-823/B-00-007. Fish Sampling and AnalysisWashington, DC: Office of Water; 2000a.

United States Environmental Protection Agency (US EPA). Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories. EPA-823/B-00-008. Risk Assessment and Fish Consumption LimitsWashington, DC: Office of Water; 2000b.

United States Environmental Protection Agency (US EPA). Integrated Risk Information System (IRIS). Methylmercury; 2001a. [Available from URL:]http://www.epa.gov/iris/subst/0073.htm. [Accessed: 11/1/2005].

United States Environmental Protection Agency (US EPA). Water Quality Criterion for the Protection of Human Health: Methylmercury. EPA-823/R-01-001. Washington D.C: Office of Water; 2001b.

United States Food and Drug Administration (US FDA). Mercury Concentrations in Fish: FDA Monitoring Program (1990–2009). Washington, DC: Food and Drug Administration; 2011a [Available:]http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Fish/FoodbornePathogensContaminants/Methylmercury/ucm191007.htm [Accessed: 2/23/2011].

United States Food and Drug Administration (US FDA). Mercury levels in commercial fish and shellfish. Washington, DC: Food and Drug Administration (1990–2009); 2011b [Available:]http://www.fda.gov/Food/FoodSafety/Product-SpecificInformation/Fish/FoodbornePathogensContaminants/Methylmercury/ucm115644.htm [Accessed: 2/23/2011].

US EPA/FDA. What You Need to Know About Mercury in Fish and Shellfish. EPA-823-R-04-005; 2004.. [Online. Available:]http://www.epa.gov/waterscience/fishadvice/advice/html.. [or]http://www.cfsan.fda.gov/~dms/admehg3.html.. [Accessed: 2/18/2011].

Virtanen JK, Voutilainen S, Rissanen TH, et al. Mercury, fish oils, and risk of acute coronary events and cardiovascular disease, coronary heart disease, and all-cause mortality in men in eastern Finland. Arterioscler Thromb Vasc Biol 2005;25:228–33.

Weintraub M, Birnbaum LS. Catfish consumption as a contributor to elevated PCB levels in a non-Hispanic black subpopulation. Environ Res 2008;107:412–7.

Yoshizawa K, Rimm EB, Morris JS, Spate VL, Chung-cheng H, Spiegelman D, et al. Mercury and the risk of coronary heart disease in men. N Engl J Med 2002;347:1755–60.