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Results of a national survey of high-frequency fish consumers in the United States☆

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ABSTRACT

Exposure to contaminants in fish may be associated with adverse health outcomes even as fish consumption is generally considered beneficial. Risk assessments conducted to support regulatory analyses rely on quantitative fish consumption estimates. Here we report the results of a national survey of high-frequency fish consumers (n = 2099) based on a survey population statistically representative of ~17.6 million U.S. individuals consuming three or more fish meals per week. The survey was conducted during 2013 using an on-line survey instrument. Total fish consumption averaged 111 g/day from market, restaurant and self-caught sources. Depending on the season, the incidence of individuals reporting consumption of self-caught species ranged between 10–12% of our high-frequency fish consuming demographic, averaging approximately 30 g/day and comprising 23% of total fish consumption from all sources of fish. Recreational or self-caught consumption rates vary regionally and are poorly understood, particularly for high-frequency consumers, making it difficult to support national-scale assessments. A divergence between sport-fishing and harvesting of fish as a food-staple is apparent in survey results given differences in consumption patterns with income and education. Highest consumption rates were reported for low income respondents more likely to harvest fish as a food staple. By contrast, the incidence of self-caught fish consumption was higher with income and education although overall consumption rates were lower. Regional differences were evident, with respondents from the East-South Central and New England regions reporting lowest consumption rates from self-caught fish on the order of 12–16 g/day and those from Mountain, Pacific and Mid-Atlantic regions reporting highest rates ranging from 44 to 59 g/day. Respondent-specific consumption rates together with national-level data on fish tissue concentrations of PCBs, MeHg, and PFOS suggest that 10–58% of respondents reporting self-caught fish consumption are exposed to concentrations of these contaminants that exceed threshold levels for health effects based on a target hazard index of one, representing 2.3 M to 19 M individuals. The results of this nationwide survey of high-frequency fish consumers highlights regional and demographic differences in self-caught and total fish consumption useful for policy analysis with implications for distributional differences in potential health impacts in the context of both contaminant exposures as well as protective effects.

1. Introduction

Bioaccumulative contaminants such as methylmercury (MeHg), polychlorinated biphenyls (PCBs) and poly and perfluoroalkyl substances (PFASs) are commonly detected in fish from United States (U.S.) (US EPA, 2009, 2013a). These contaminants have been associated with a suite of adverse health outcomes such as negative neurodevelopmental outcomes in children (Oken et al., 2008; Orenstein et al., 2014; Shayler, 2008), cardiovascular health (Karagas et al., 2012; Roman et al., 2011) as well as endocrine disruption, metabolic disorders, and cancer (Stahl et al., 2011; Suja et al., 2009; Blum et al., 2015). In the U.S., only the highest level fish consumers consistently exceed safety thresholds for MeHg and PCB exposures (Mahaffey et al., 2004, 2009). Data on these high-frequency consumers are limited and site-specific dietary recall surveys cannot be extrapolated because they are not statistically representative of a census region or demographic group (Karimi et al., 2012; 2014; Mayfield et al., 2007; Tsuchiya et al., 2008). Exploring and developing national consumption rates of high-frequency

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fish consumers can benefit regulatory analyses, for example, for deriving ambient water quality criteria (US EPA, 2000) or the Mercury and Air Toxics Standards (US EPA, 2011a).

We developed a nationwide survey of high-frequency fish consumers (defined as individuals consuming three or more fish meals per week, approximately equivalent to the 95th percentile of fish consumption as reported in the National Health and Nutrition Examination Survey or NHANES (US EPA, 2011b; Birch et al., 2014)) to better understand reported consumption patterns and species preferences. This study further characterizes recreational and self-caught fish consumption based on and in the context of this nationally-representative survey of high-frequency fish consumers. We use the term "fish" for all types of finfish and shellfish.

Recreational anglers represent an important component of frequent fish consumers and their self-caught fish consumption rates are known to vary regionally (U.S. EPA, 2013b; Schaefer et al., 2014; Moya et al., 2008; Moya, 2010). Those studies that have evaluated both self-caught and overall fish consumption have all focused on specific regions as opposed to a national overview (Angert, 2013; Moya et al., 2008; Burger, 2000, 2002, 2013; Dong et al., 2015; Lincoln et al., 2011; Mayfield et al., 2007; Perkinson et al., 2016; Polissar et al., 2012; Weintraub and Birnbaum, 2008). A subset of respondents to this survey reported consuming self-caught fish and we focus on these respondents for specific analyses as recreational or self-caught fish consumption in the context of overall fish consumption is rarely examined (Burger, 2013).

In addition, these survey data provide an opportunity to estimate respondent-specific back-calculated risk-based concentrations of PCBs, MeHg, and PFASs in recreationally-caught fish tissue, which can then be compared to fish tissue data from national monitoring programs (EPA 2016; Wathen et al., 2015; Stahl et al., 2009, 2014). Individuals consuming fish integrate exposure over varying temporal and spatial scales. Given the national scale of this survey and the statistical approach to fish sampling by the EPA (US EPA, 2013b, 2016), we combine consumption preferences from the survey with fish concentration data to identify the percentage of recreational fish consumers whose risk-based back-calculated tissue concentrations fall below the mean of the national distribution for each contaminant for self-caught species.

We provide descriptive statistics and an exploratory analysis of fish consumption preferences and patterns based on a nationwide survey of high-frequency fish consumers with a particular emphasis on those respondents who indicated consuming self-caught fish in addition to commercially-sourced fish. Respondent-specific self-caught fish consumption rates are used to develop risk-based back-calculated fish concentrations, which we compare to nationwide monitoring data. Finally, we discuss the implications of these data for risk-based decision making more broadly.

2. Methods

2.1. Study population and survey design

Working with an established online survey research firm, we recruited a cross-sectional cohort (n = 2099) of U.S. individuals that reported consuming three or more fish meals per week. This corresponds to the 90–95th percentile seafood consumer in the National Health and Nutrition Examination Survey (NHANES). Cross-sectional data were collected in April (n = 685), July (n = 689), and September (n = 725) of 2013 to account for seasonal variability in fish consumption. Participants were selected to be statistically representative of the U.S. Census from a panel maintained by GfK Knowledge Networks (GfK), a professional organization specializing in survey research (Callegaro and DiSogra, 2011; Yeager et al., 2011) augmented by non-panel respondents to ensure sufficient sample sizes (DiSogra et al., 2012a, 2012b). Research protocols, consent procedures and the survey instrument were reviewed and approved by the Harvard T.H. Chan School of Public Health Human Subjects Committee prior to recruitment. Details of recruitment methods and survey design can be found in the Supplemental Material S1 and Li et al. (2016). In short, the web-based survey was administered by GfK and included one-month and three-month recall periods. Survey participants were asked to recall their overall seafood meal frequency over the past one and three months as well as meal sizes prompted by visual cues and fish preparation methods. They were also asked to identify where they obtained their fish (e.g., self-caught, commercial market, restaurant) and the magnitudes and quantities of individual types of species-specific seafood consumed. Recall was aided by a list of commonly consumed fish species based on data reported in Mahaffey et al. (2011). Respondents were also asked to identify fish species not specifically listed in the survey.

2.2. Contaminants in fish tissue

Data on contaminants in fish fillets were obtained from the National Study of Chemical Residues in Lake Fish Tissue and the National Rivers and Streams Assessment Fish Tissue Study, the first national assessments of freshwater fish contamination in the United States for which sampling sites were selected according to a statistically-based design (http://www2.epa.gov/fish-tech/studies-fish-contamination) for lakes, rivers, and streams. We extracted data for PCBs (Stahl et al., 2009; US EPA, 2009, 2016; Batt et al., 2017; Scott et al., 2009), PFASs (expressed as PFOS as this represented > 95% of PFASs detected in fish tissue nationwide) (Stahl et al., 2014; US EPA, 2009, 2016; Ye et al., 2008; Delinsky et al., 2010), and MeHg (Peterson et al., 2007; US EPA, 2009, 2016; Wathen et al., 2015).

2.3. Data analysis

We develop descriptive statistics for overall survey respondents and self-caught anglers to compare them to data from the U.S. Census. We explore species preferences and estimated g/day annualized consumption rates and g/kg-day consumption rates to compare to published results from other surveys. We develop these for overall fish consumption from all sources as well as just the amount reflecting self-caught fish consumption for all survey respondents. A further set of descriptive statistics and analyses focus on the subset of exclusively self-caught anglers (e.g., those respondents reporting 100% of fish consumption as self-caught).

Fish consumption frequency is converted into a fish consumption rate (g/d) using the reported meal sizes and frequencies reported by each respondent. A general fish consumption rate (FCR) is calculated based on overall reported fish consumption. A species-specific FCR is calculated as the sum of FCRs across all species as well as only the self-caught species. Since over reporting is consistently observed for species-specific consumption rates (Björnberg et al., 2005; Lincoln et al., 2011), we corrected and scaled values for individual species using overall fish consumption rates.

We back-calculate risk-based PCB, PFOS, and MeHg concentrations in fish for each individual reporting self-caught fish consumption using his or her individual intake rate and body weight, an assumption of exposure over 26 years per US EPA guidance (US EPA, 2014), and a target hazard quotient as shown in Eq. (1). The target hazard quotient is a risk management decision defined by the regulatory context and is generally based on 1.0 for individual contaminants or may be adjusted to account for multiple and cumulative exposures (see, for example, guidance under the US EPA Superfund program recommending THQs of 1.0 and 0.1; https://www.epa.gov/risk/regional-removal-management-levels-rmls-users-guide). Toxicity values were expressed as Reference Doses (RfD) in mg/kg-day as published by the U.S. EPA (www.epa.gov/iris) for each contaminant. PCB toxicity was expressed in terms of Aroclors, the commercial mixture sold and released into the environment and the basis of published toxicity values.