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Demographic and geographic patterns of cetacean-based food product consumption and potential mercury exposure within a Caribbean whaling community

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ABSTRACT

Exposure to mercury (Hg), especially methylmercury (MeHg), through the consumption of seafood is a major public health concern. St. Vincent & the Grenadines (Eastern Caribbean) supports two related whaling operations, which produce food from cetaceans for human consumption. Recent data suggest that Hg concentrations in cetacean tissue samples exceed recommended consumption limits. Our objective was to determine the role of cetacean-based food products in the diet of the Vincentian population as a proxy for exposure to MeHg using interview surveys ($n = 921$). Based upon provisional tolerable weekly intake (PTWI) guidelines for MeHg from the Food and Agricultural Organization (FAO) and the World Health Organization (WHO), we determined safe weekly consumption amounts for specific cetacean-based food products, based upon reported consumption patterns. We found cetacean-based food products to be included in the diet of 77.4% of respondents. Respondents' gender and geographical home region are the most important factors influencing cetacean consumption. Frequency and amount of consumption vary, but generally exceed calculated safe weekly limits. The consumption of cetacean-based food products may represent a public health risk, as a large portion of the population may be exposed to high MeHg concentrations.

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Introduction

Mercury (Hg) contamination in seafood is a major public health concern, and risk assessments are critical to efforts to manage rates of exposure (Kojadinovic et al. 2006; Grandjean 2013; Olmedo et al. 2013). Due to the biomagnification of methylmercury (MeHg) in marine food webs, high trophic-level marine organisms with long lifespans—including tunas, billfish, sharks, and cetaceans—have the potential to contain high Hg levels (Wagemann et al. 1997; Kehrig et al. 2002; Kojadinovic et al. 2006). Cetacean-based food products are consumed globally at varying levels, and their consumption has been increasing in several regions around the world during recent years (Clapham and Van Waerebeek 2007; Robards and Reeves 2011). In some cases, this increase is in response to food shortages exacerbated by climate change and other human impacts (Alter et al. 2010). Studies have confirmed the increasing risk related to the consumption of cetacean-based food products due to the presence of high contaminant levels, particularly Hg (e.g., Simmonds et al. 2002; Endo and Haraguchi 2010).

The archipelagic Caribbean nation of St. Vincent & the Grenadines (SVG; Figure 1) supports two distinct, yet related, whaling operations, both of which produce food for human consumption. The first, based on the island of Bequia, holds an International Whaling Commission (IWC)-sanctioned aboriginal subsistence whaling quota to take up to four humpback whales (*Megaptera novaeangliae*) per year (Adams 1971; Ward 1995). The second, based in the town of Barrouallie on the main island of St. Vincent, takes short-finned pilot whales (*Globicephala macrorhynchus*) and other small cetaceans not managed by the IWC (Gillespie 2001). These include Atlantic spotted dolphins (*Stenella frontalis*), false killer whales (*Pseudorca crassidens*), Fraser's dolphins (*Lagenodelphis hosei*), killer whales (*Orcinus orca*), Risso's dolphins (*Grampus griseus*), and spinner dolphins (*Stenella longirostris*) (Adams and Higman 1973; Caldwell and Caldwell 1975; Fielding 2018). The two whaling operations in SVG produce meat that is consumed fresh, dried (often then rehydrated), or “doved” (cooked and stored in its own oil); blubber, which is consumed after having been “rendered” or heated until it expresses—and is then fried in—its own oil; and oil itself, which is bottled and used as a health tonic and treatment for colds.

Whaling was introduced to the Eastern Caribbean through interaction with the New England-based “Yankee Whaler” fleet during the 19th century (Romero and Cresswell 2005). Both the humpback whale-focused operation on Bequia and the operation targeting small cetaceans from the main island of St. Vincent grew out of this introduction. Historically, food produced from small cetaceans was a last resort for the poor—considered relatively unpalatable—and was one of the least expensive local protein options (Adams 1980). Today, the consumption of cetacean meat has also become a cultural signifier, or an expression of Vincentian identity (Zane 1999; Fielding 2018).

Food products derived from small cetaceans are distributed through formal and informal networks within the main island of St. Vincent. This consists mainly of established vendors selling dried meat or cooked blubber from stalls at the island's major fish markets and mobile vendors traveling throughout the island and setting up temporary stalls or tables on street corners from which to sell small cetacean products, but other methods of acquisition exist, particularly for food products derived from internal organs

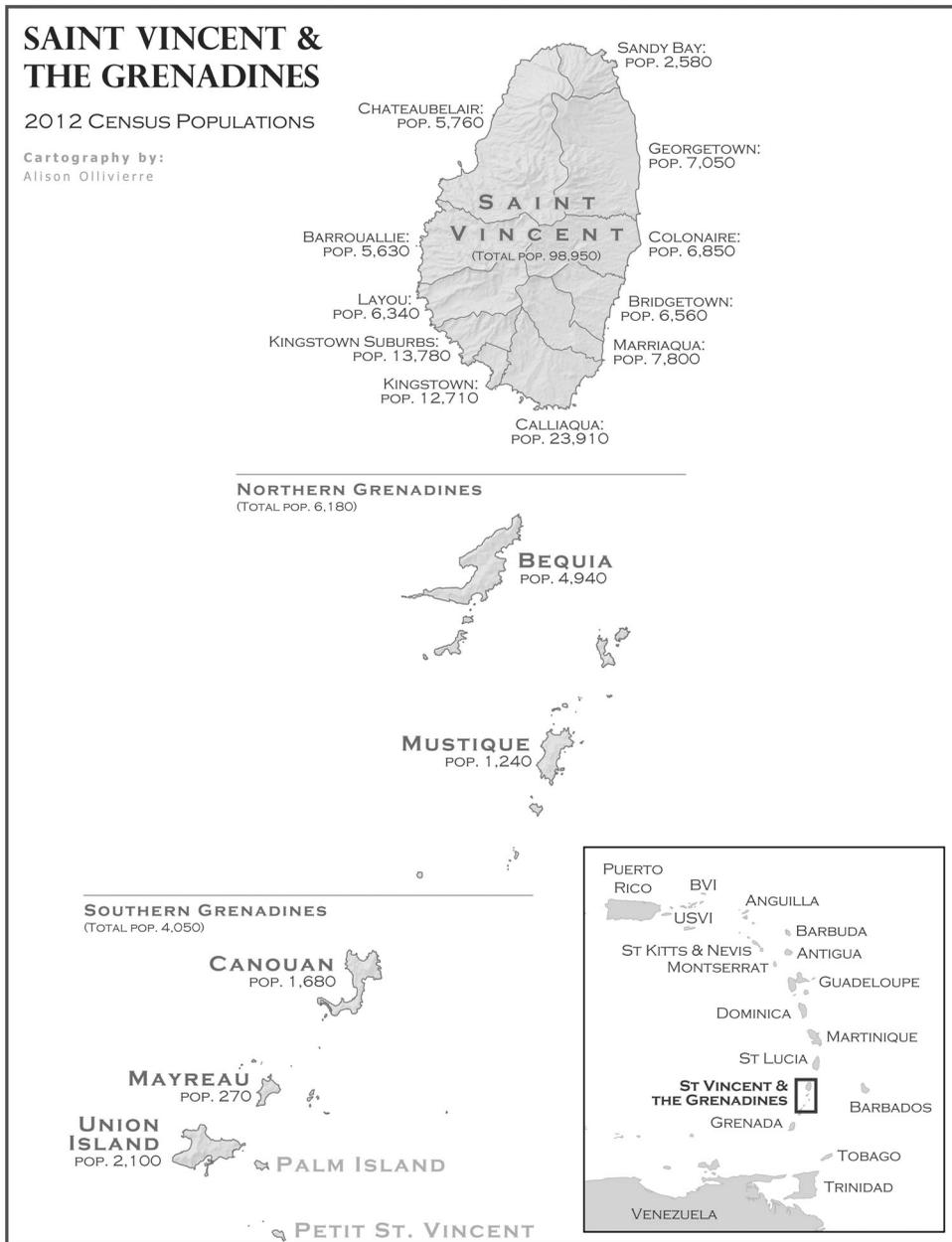


Figure 1. The study site, with 2012 population by census region (Ministry of Finance 2019).

such as liver and kidney (Fielding 2014, 2018). The Grenadines rely more upon informal distribution networks (e.g., a family member bringing products from St. Vincent) for small cetacean products, although during periods of increased supply, St. Vincent-based vendors will occasionally travel by ferry throughout the Grenadines. Food products derived from humpback whales are distributed immediately following the catch of a whale—which occurs a maximum of four times per year. The primary distribution occurs in Bequia, but humpback whale products are distributed secondarily, mainly

through informal family-based networks, throughout St. Vincent and the rest of the Grenadines. The prices of cetacean-based food products remain accessible: EC\$2.50 (approx. US\$1.00) per bundle for meat from small cetaceans and EC\$5.00 (approx. US \$2.00) per pound for meat from humpback whales (IWC 2015).

As long-lived and high trophic-level marine predators, the small cetaceans taken in the Barrouallie operation are subject to high concentrations of Hg. Recent analysis by McCormack et al. (2020) suggests that mean concentrations of total mercury (THg) in muscle, blubber, and internal organs (liver and kidney) from five species taken in Barrouallie (See Table S1) far exceed the advisory level for human consumption of 1.0 $\mu\text{g/g}$ wet-weight determined by the United Nations Food & Agriculture Organization and the World Health Organization (FAO/WHO 2011). Tissue samples from humpback whales caught in Bequia have not been analyzed for contaminant levels, concentrations of which are known to vary widely by region in this species (Wise et al. 2018; Wise, Wise, et al. 2019; Wise, Croom-Perez, et al. 2019).

The use of cetaceans as a local food source in SVG potentially exposes human consumers to high Hg concentrations (Fielding 2018; McCormack et al. 2020). The degree to which individuals are exposed to Hg is based, in part, upon individual rates of consumption of cetacean-based food products. In order to determine the demographic and geographic patterns to the consumption of cetacean-based food products in SVG, we undertook an interview-based survey of local dietary habits across the major, inhabited islands of the archipelago. Previous seafood-related dietary surveys have been conducted in SVG (e.g., Adams 1980; Josupeit 2011) and studies have measured, in human tissue, the concentrations of Hg and other contaminants known to be absorbed through the consumption of marine foods (Forde and Dewailly 2012, 2015; Forde et al. 2014a, 2014b). Our study is the first, however, to focus explicitly on the consumption of cetacean-based food products and the first designed specifically to measure and map the potential exposure to public health risks presented by environmental contaminants concentrated therein. Our use of dietary data as a proxy for Hg exposure—as opposed to the collection of human tissue samples for direct Hg analysis—is in compliance with a directive from the SVG Ministry of Health, Wellness & the Environment (Ministry of Health), which oversees all human health research in SVG. While the Ministry of Health has undertaken previous campaigns associated with improving nutrition, these efforts have focused largely on enhancing food security in a nation in which approximately 48% of residents are categorized as poor or vulnerable to falling into poverty, and 5% of the population is considered “undernourished”. The SVG government acknowledges that the “rapid growth of the informal food service sector has outstripped the capacity of the Public Health Department to monitor and regulate food safety and sanitation” and that “pesticide/chemical residue analysis in food receives little or no attention nationally” (Government of St. Vincent and the Grenadines 2014, 38–39).

Materials and methods

Data collection

During July and August 2018, we conducted in-person individual interviews with 921 adults (≥ 18 years) living in SVG. This human-subject research was approved by the

Institutional Review Board at the University of the South under permit 18-13. The study sample constitutes 1.3% of the country's adult population, according to the most recent census estimates (Ministry of Finance 2019). Our interviews were conducted on four of the country's eight inhabited islands: St. Vincent, Bequia, Mayreau, and Union Island. More important to determining the geographic patterns of consumption than the interview locations, however, were the hometowns that our respondents reported; we interviewed individuals claiming 69 hometowns throughout SVG, which we then grouped into geographical regions. The sparsely inhabited interior of the main island (Fielding and Ollivierre 2017) was not included in our survey.

Participants were recruited through various methods including encounters in public spaces, personal introductions through our local contacts, and a snowball sampling method (Coleman 1958). Our sample represents the country's demographics reasonably well (Table 1). We distinguished ages at the upper end of the range differently than the census (80–89 and 90–99 in our survey, as opposed to 80–84 and 85+ in the census). For comparison purposes, we have collapsed both ranges into the 80+ category in Table 1. Our age-specific analysis does not include data from respondents for whom we have no age information, nor from respondents in the oldest age category (90–99 years), owing to the low sample size ($n = 2$) in that range.

As for occupational categories, we based our distinctions upon the 2008 *International Standard Classification of Occupations* (ISOC-08) published by the United Nations' International Labor Office (ILO 2012) with some modifications. Owing to the presence of unemployed or retired respondents, as well as students, we added these categories to the list. Respondents who reported being retired from a specific occupation were categorized in that occupation. Those who simply reported being retired and did not elaborate were categorized only as "retired." A 2019 International Monetary Fund report found

Table 1. Demographic data from the 2012 SVG Census, compared to this study's sample.

Category	Criteria	Census percentage	Survey percentage
Gender	Female	49.1%	39.5%
	Male	50.1%	60.5%
Age range	18–29	27.4%	17.6%
	30–39	20.2%	17.5%
	40–49	19.2%	21.2%
	50–59	15.2%	17.5%
	60–69	8.7%	14.5%
	70–79	5.9%	8.0%
	80+	3.5%	2.8%
	No Data	0.0%	0.7%
Occupation	Managers	4%	6.8%
	Professionals	11%	4.6%
	Technicians and associate professionals	7%	1.3%
	Clerical support workers	6%	1.5%
	Service and sales workers	26%	11.0%
	Skilled agricultural, forestry and fishery workers	13%	15.0%
	Craft and related trades workers	13%	7.4%
	Plant and machine operators, and assemblers	5%	5.5%
	Elementary occupations	13%	6.0%
	Military	–	0.2%
	Students	–	0.8%
	Retired	–	5.6%
	Unemployed	–	5.6%
Not Stated	1%	33%	

the unemployment rate in SVG to be greater than 20% (James et al. 2019). In our sample, 5.6% of respondents reported being unemployed, but a much larger subset (264 individuals, i.e., 28.7% of the sample) chose not to state their occupation.

Food products derived from a variety of small cetaceans in the Barrouallie operation are all sold under the local name, “blackfish,” without reference to the species of origin (Fielding 2014). Consumers are almost never aware of which species they are consuming. As such, we did not distinguish beyond this designation in our interviews; rather, we used the term “blackfish” to refer to the entire suite of small cetaceans taken in the Barrouallie operation, and “whale” to refer only to the humpback whales taken in Bequia, again following local usage of the term. Cooked blubber was referred to using the local term, “crisps” (pronounced with the first “s” silent, as *crisps*). When respondents referred to other food products with unfamiliar local terms, we transcribed the terms phonetically and consulted with our local collaborators to determine the precise food product(s) being discussed.

Interviews were semi-structured in format and conversational in tone. They were conducted by teams, each consisting of two US-based undergraduate students and one local collaborator. Each interview included key questions about the respondent’s identity and regular diet. Because whaling is a contentious issue (Fielding 2018), we did not set out to conduct interviews *about* the consumption of cetacean-based food products. Rather, we discussed respondents’ diets broadly, without drawing unnecessary attention to the food products in which we were most interested.

Within this framework, we obtained demographic and dietary data, including details such as whether the respondent consumes food products derived from cetaceans at all (distinguishing between the small cetaceans taken in Barrouallie and the humpback whales taken in Bequia), which products the respondent consumes (meat, blubber, and oil), quantity of consumption per unit of time, and reasons why cetacean-based food products are not consumed (by respondents who report not consuming them). The study was designed to avoid the various response biases common to dietary surveys, such as the production of “demand characteristics” in which respondents, being reminded of the unhealthiness of certain foods, downplay their own consumption of those foods (e.g., Nichols and Maner 2008). As such, we did not ask respondents about their knowledge of Hg or other foodborne contaminants. During each interview, interviewers took handwritten notes, which we transcribed into a Microsoft Excel spreadsheet at the end of each day as part of an iterative debriefing process which allowed continuous refinement of questions in response to results.

Data analysis

Data with identifiable personal information removed were analyzed with six primary variables collected for each of the 921 individuals included in the final study. Consumption of food products derived from small cetaceans and from humpback whales were each analyzed separately as primary outcomes. Respondents’ age category, gender, home region, and occupational category were included as primary explanatory variables. Likelihood ratio tests were conducted to determine the overall significance of each factor and Akaike information criteria (AIC) values were used to compare model

fit and guide final model selection. Given the binary outcome under consideration—whether a person does or does not consume food products derived from small cetaceans or humpback whales—logistic regression was used to generate estimated adjusted odds ratios and 95% confidence intervals for the increased or decreased odds of consumption based on the explanatory variables included in the best-fitting model. For all models, values of $p < 0.05$ were considered statistically significant. Statistical analyses were conducted in R with models estimated as generalized linear models with the `glm()` function and a logit link function (R Core Team 2016).

Determination of safe weekly consumption amounts

To minimize negative health effects resulting from the ingestion of contaminated food products, the FAO/WHO provides estimates of the provisional tolerable weekly intake (PTWI). The PTWI equates to the amount of a contaminant per unit of the consumer's body weight that can be ingested weekly without adverse health effects. For MeHg, the PTWI is currently 1.6 μg per kilogram of body weight (JECFA 2006). McCormack et al. (2020), who first presented the current THg concentrations for small cetaceans in SVG, estimated the amount of muscle, blubber, liver, and kidney that could be consumed weekly by a 60 kg person so as not to exceed the PTWI. That study estimated these values according to the mean wet weight THg concentration for all species combined for each tissue type and the amount of MeHg present in each tissue based on one tissue-specific MeHg percentage taken from the literature. While this resulted in a coarse estimation, it did not account for variation among species; however, because consumers in St. Vincent are generally not aware of the species they are consuming, the coarse estimation was appropriate given the scope of that study.

To account for variability in both THg concentrations and the percentage MeHg within and among species, we estimated the amount of each tissue type that could be consumed weekly without exceeding the PTWI using a more detailed approach. Using the data from McCormack et al. (2020), for each tissue sample, the amount of MeHg was estimated by species, based upon a range of tissue-specific MeHg percentages taken from the literature (Gaskin et al. 1974; Arima and Nagakura 1979; Itano et al. 1984; Palmisano et al. 1995; Storelli et al. 1998, 1999; Cardellicchio et al. 2002; Chen et al. 2002; Bustamante et al. 2003; JMHLW 2003; Ruelas-Inzunza et al. 2003; Endo et al. 2005, 2006; Capelli et al. 2008; Fielding and Evans 2014; Sakamoto et al. 2015). If values were not found for a specific tissue, the mean percent MeHg of other species was applied. The maximum amount of MeHg (in μg) that a 60 kg person can ingest (96 μg) each week without exceeding the PTWI was then divided by the concentration of MeHg in each sample to determine the amount of tissue that can safely be consumed per week.

Results

Cetacean-based food products are highly popular among consumers in SVG, with 77.4% of all respondents indicating that they do consume at least one of the following products: small cetacean meat, small cetacean blubber, small cetacean oil, humpback whale

meat, humpback whale blubber, or humpback whale oil. The popularity of cetacean-based food products varies, however, across demographic categories and geographic areas (Tables S2 and S3, Figure 2). When determining which characteristics correlate with increased consumption of food products derived from small cetaceans, gender ($\chi^2 = 15.21$, $p < 0.001$, $df = 1$) and home region ($\chi^2 (13, n = 921) = 94.99$, $p < 0.001$) proved to be highly significant predictors. Occupational category ($\chi^2 (9, n = 921) = 16.71$, $p = 0.054$) was determined to be an important precision variable and included in the final model even though not significant at the $p < 0.05$ level. Age ($\chi^2 (8, n = 921) = 5.79$, $p = 0.67$) proved not to be predictive and, therefore, not included in our final model. For the consumption of food products derived from humpback whales, home region ($\chi^2 (13, n = 921) = 219.82$, $p < 0.001$) is the primary predictor with gender ($\chi^2 (1, n = 921) = 9.00$, $p = 0.003$) also highly significant. Occupational category ($\chi^2 (9, n = 921) = 16.04$, $p = 0.066$) was marginally significant whereas age ($\chi^2 (8, n = 921) = 5.83$, $p = 0.67$) again was not. Within these categories, variation in likelihood of consumption exists both directionally (higher versus lower odds of consumption) and in magnitude (how much the odds of consumption change).

Demographic patterns

Certain segments of the Vincentian population are more likely to consume cetacean-based food products than others. For example, male respondents reported higher levels of consumption than female respondents with 82.8% of male respondents reporting that they consume at least one of the six cetacean-based food products compared to 69.2% of female respondents. The relative rates of consumption vary slightly when analyzed by individual food product (meat, blubber, and oil; each from small cetaceans and humpback whales) but maintain the overall trend toward higher consumption rates among male respondents than among female respondents for all products. Overall, male respondents are 2.2 times more likely ($p < 0.001$) to consume food products from small cetaceans, and 2.4 times more likely ($p < 0.001$) to consume food products from humpback whales, than female respondents.

We found that the age of the respondent offered little to no influence on the consumption of cetacean-based food products. None of the seven age categories significantly differed from the rest in terms of consumption rates.

With regard to the effect of occupational category, as a proxy for socioeconomic class, we found lower consumption rates of food products derived from small cetaceans were associated only with respondents with occupations in Category 8 (Plant and machine operators) ($p = 0.004$), and for products derived from humpback whales only with respondents in Category 4 (Clerical workers) ($p = 0.025$).

Across all demographics, meat is a more popular food product than blubber or oil, whether from small cetaceans or humpback whales. Meat from small cetaceans is consumed by 59.7% of all respondents, while 30.3% of respondents reported consuming meat from humpback whales. This may be compared to the results for consumption of blubber and oil, which are 37.7% and 29.4%, respectively, for small cetaceans and 17.7% and 22.0%, for humpback whales.

Spatial variation

Cetacean-based food products are more popular in some parts of SVG than in others (Figure 2). Food products derived from small cetaceans are more popular than those derived from humpback whales in all regions of the main island, as well as on the Grenadine island of Mayreau, while the opposite is true on Bequia and Union Island. Respondents who claimed hometowns outside of SVG tended to prefer small cetacean-based food products to those derived from humpback whales and those for whom we had no hometown data had mixed results. Overall, cetacean-based food products are most popular in the regions where they are produced: respondents from Barrouallie are 7.4 times more likely ($p < 0.001$) to consume food products derived from small cetaceans than respondents from other regions. Correspondingly, respondents from Bequia are 2.7 times more likely ($p < 0.001$) to consume food products derived from humpback whales than respondents from other regions.

Rates of small cetacean-based food product consumption generally decrease in regions progressively further from Barrouallie. Meat from small cetaceans is consumed by 65.1% and 70.5% of respondents in regions immediately adjacent to Barrouallie (North Leeward and South Leeward, respectively) but by 54.9% of respondents in the North Windward region, the furthest region on the main island—by road—from Barrouallie. Similarly, food products derived from humpback whales are more popular among respondents from Bequia, where they are produced, with humpback whale meat, blubber, and oil consumed by 73.9%, 53.7%, and 61.1% of respondents in that region, respectively. Rates of humpback whale-based food product consumption are generally higher within the Grenadines than on the main island. For example, meat from humpback whales is consumed by 35.7% and 29.1% of respondents from the other two Grenadine islands surveyed—Mayreau and Union Island, respectively—as compared to rates ranging from 5.4% to 27.1% across the main island's nine regions, averaging to a rate of 14.2% for the island of St. Vincent as a whole.

Other attributes of cetacean-based food product consumption follow geographically defined patterns. For example, a respondent's preferred whaling operation—the small-cetacean operation at Barrouallie or the humpback whale operation at Bequia—can be predicted geographically. Specifically, the majority (68.3%) of those who consume cetacean-based food products choose products that come from only one of the country's two whaling operations. This preference is stronger among consumers of small cetacean products than consumers of products derived from humpback whales. Among consumers of small cetacean products, 66.1% do not consume humpback whale products, while 35.1% of consumers of humpback whale products do not consume products from small cetaceans.

Frequency and amount of consumption

Results indicate that, among those who do consume cetacean-based food products, the most common frequency for products derived from small cetaceans is greater than once per month but less than once per week (27.7% of respondents who consume). For products derived from humpback whales, the most common frequency is greater than once per year but less than once per month (19.2% of respondents who consume) (Figure 3).

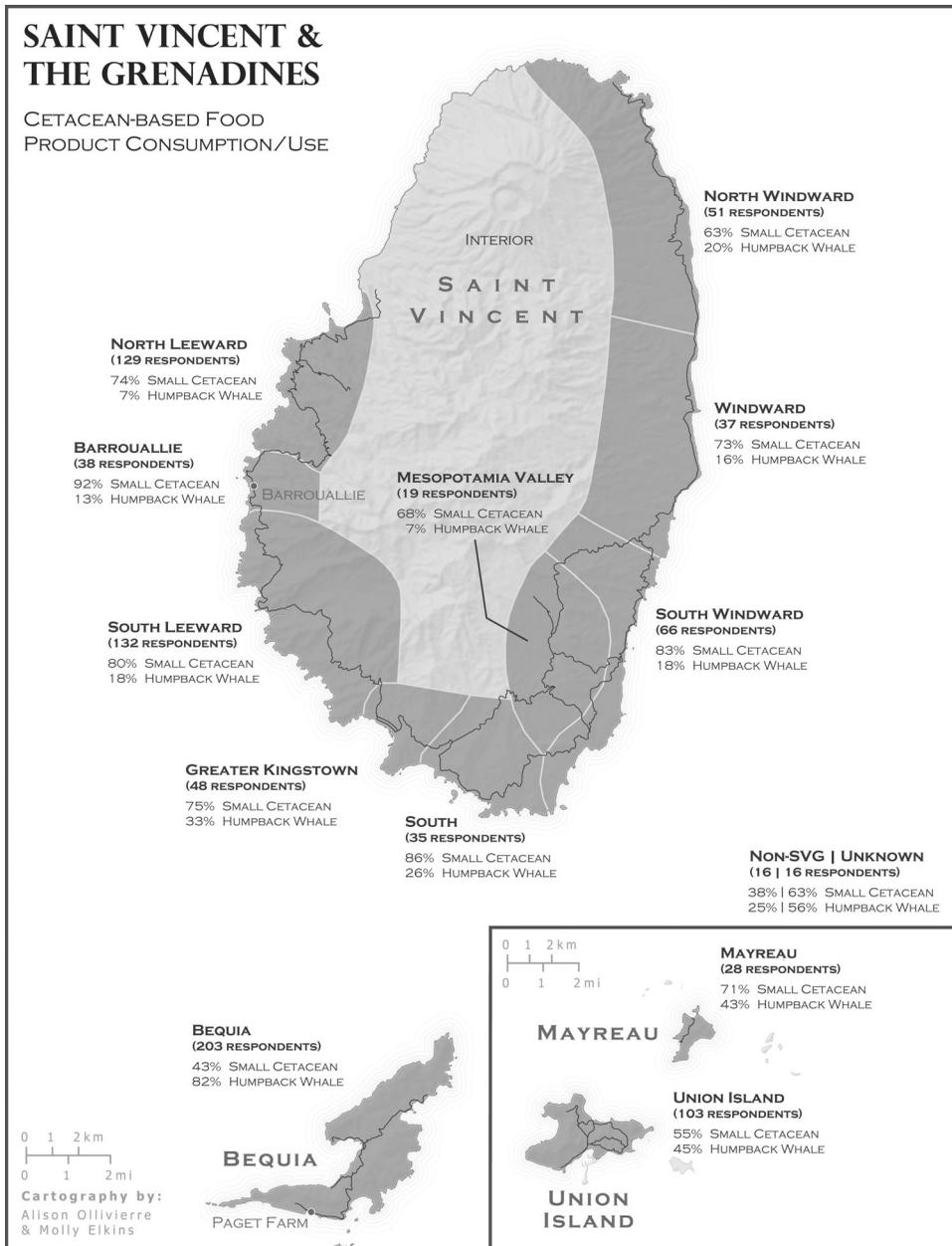


Figure 2. Geographical patterns of consumption of cetacean-based food products in SVG.

A minority (5.1%) of respondents reported a perceived seasonality regarding cetacean-based food product availability, but were not in agreement as to when the seasons of relative abundance or scarcity occurred.

The amount of small cetacean tissue by individual species and all species combined that can be consumed each week without exceeding the PTWI is shown in [Figure 4](#) and [Table 2](#). Using the mean percent MeHg for all species combined, on average, blubber can be consumed in the highest quantity without exceeding the PTWI (1331 g), followed

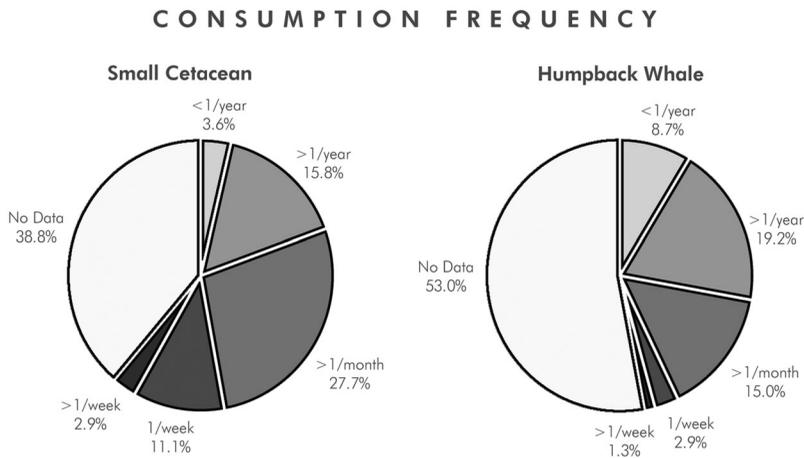


Figure 3. Frequency of consumption of cetacean-based food products in SVG.

by kidney (364 g), liver (104 g), and muscle (52.1 g). There was significant interspecies variability in the amount of each tissue that can be consumed per week.

Reasons for not consuming

We received a wide range of descriptive responses to our questions about reasons why cetacean-based food products were not consumed by those who reported not consuming them and categorized these responses into thirteen broad rejection categories (Table 3). The most common reason for rejection of cetacean-based food products was simple personal preference (38.7% of rejections of small cetacean-based food products and 35.1% rejections of humpback whale-based food products). Respondents whose rejections fell into this category remarked that the appearance, smell, taste, or texture of the food products was unappealing. Following preference, availability and religion are the next most common reasons for the rejection of cetacean-based food products from both small cetaceans (21.6% for both reasons) and humpback whales (25.1% and 19.9%, respectively). Certain religious traditions (primarily the Rastafarian and Seventh-Day Adventist faiths) forbid the consumption of cetacean-based food products and the products are not available to the same degree in all parts of the country.

Following these top three, rejections due to perceptions of the unhealthiness of the food products (6.8% of small cetacean rejections and 4.7% of humpback whale rejections) were the next most common. We understand the perception of “unhealthiness” to be based upon characteristics of the food products other than Hg contamination, as this issue was not widely known at the time of our fieldwork—indeed, it remains so at the time of writing.

Other reasons for rejection included abstention because cetaceans are mammals (3.1% of small cetacean rejections and 3.7% of humpback whale rejections), the belief that cetaceans menstruate (3.1% of small cetacean rejections and 2.1% of humpback whale rejections), perceptions about the unsanitary nature of the relevant food-production methods (2.1% of small cetacean rejections but not mentioned for humpback whales),

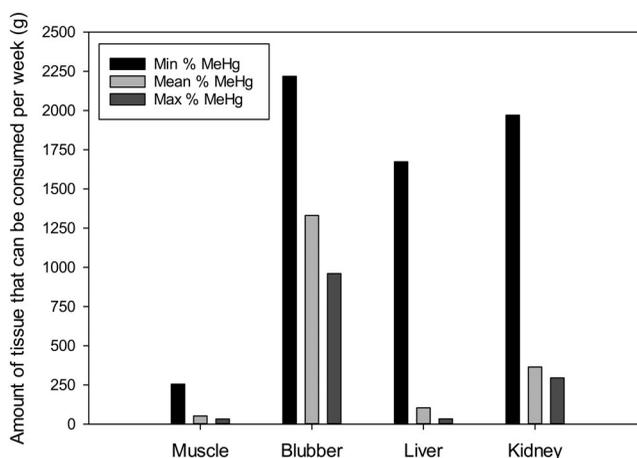


Figure 4. The mean amount (g) of small cetacean muscle, blubber, liver, and kidney that can be consumed weekly without exceeding the provisional tolerable weekly intake (PTWI) of $1.6 \mu\text{g MeHg/kg}$ body weight/week for a 60-kg person. All species are combined. The tissue-specific minimum, mean, and maximum percentage MeHg values are reported in [Table 2](#).

the ethics of whaling (3.1% of humpback whale rejections but not mentioned for small cetaceans), and the food products not fitting within the respondent's chosen diet (2.1% of humpback whale rejections but less than 1.0% for small cetaceans). Less common reasons for rejection, all given by less than 1.0% of those who rejected a particular cetacean-based food product, included the prohibitive cost of the food products, the decision not to eat fish (coupled with the belief that cetaceans *are* fish), and the belief that whaling is illegal.

The spatial variation to reasons for rejection is illustrated in [Figure 5](#). Availability is most commonly given as a reason for non-consumption in regions geographically distant from the regions of origin for the respective food products: Barrouallie for small cetaceans and Bequia for humpback whales. For example, the highest rates of small cetacean rejection for the reason of availability are found in the Grenadines (41.1% on Bequia, 40.0% on Mayreau, and 15.9% on Union Island), along with the North Windward region of St. Vincent (35.0%). Availability also drives the rejection of food products derived from humpback whales: Bequia saw the lowest incidence of this reason at just 4.5%. Pockets of frequency appear for other rejection reasons, such as the high prevalence of religious rejections in Bequia (11.1% for small cetaceans and 27.7% for humpback whales), the Mesopotamia Valley (83.3% for small cetaceans and 40.0% for humpback whales) and the South Windward region (41.2% for small cetaceans and 40.0% for humpback whales).

Discussion

While cetacean-based food products are highly popular among the Vincentian public, distinct demographic and geographic patterns define this popularity, indicating that risks presented by the contaminants in these food products are unevenly distributed within the population.

Table 2. The amount of small cetacean tissue (g) that can be consumed weekly by a 60 kg person without exceeding the provisional tolerable weekly intake (PTWI) of 1.6 µg MeHg/kg body weight/week.

Species	Tissue	n	Min % MeHg				Mean % MeHg				Max % MeHg			
			% MeHg	Mean (g)	SD	Range (g)	% MeHg	Mean (g)	SD	Range (g)	% MeHg	Mean (g)	SD	Range (g)
Combined (all species)	Muscle	59	12.7	255	260	3.7–1105	62.2	52.1	53.1	0.76–226	100	32.4	33.1	0.48–140
	Blubber	36	4.2	2218	3121	300–18253	7.0	1331	1873	180–10952	9.7	960	1351	130–7903
	Liver	17	0.48	1673	1702	18.4–4992	7.7	104	106	1.1–311	24.2	33.2	33.7	0.36–99.0
Killer whale	Kidney	10	3.4	1970	3212	4.3–9630	18.4	364	594	0.79–1780	22.7	295	481	0.64–1442
	Muscle	12	ND	ND	ND	ND	71.0	8.0	5.6	0.67–20.8	ND	ND	ND	ND
	Blubber	6	ND	ND	ND	ND	7.0*	420	401	178–1218	ND	ND	ND	ND
False killer whale	Liver	5	ND	ND	ND	ND	1.9	262	558	5.2–1261	ND	ND	ND	ND
	Kidney	2	ND	ND	ND	ND	3.4	29.1	ND	4.3–53.9	ND	ND	ND	ND
	Muscle	21	ND	ND	ND	ND	36.0	142	109	10.3–390	ND	ND	ND	ND
Short-finned pilot whale	Blubber	5	ND	ND	ND	ND	7.0*	625	240	233–876	ND	ND	ND	ND
	Liver	2	ND	ND	ND	ND	7.7*	4.1	ND	1.1–7.1	ND	ND	ND	ND
	Kidney	2	ND	ND	ND	ND	18.4*	49.1	48.7	4.6–93.5	ND	ND	ND	ND
Risso's dolphin	Muscle	21	12.7	219	191	4.1–834	49.9	55.7	48.7	1.0–212	81.0	34.3	30.0	0.64–131
	Blubber	23	ND	ND	ND	ND	5.4	2075	2729	548–14197	ND	ND	ND	ND
	Liver	9	0.48	2353	1385	108–4213	5.1	221	130	10.2–396	9.8	115	67.9	5.3–206
Stenella spp.	Muscle	3	44.0	88.1	96.0	7.7–194	60.8	63.7	69.5	5.6–141	75.9	51.1	55.6	4.4–113
	Blubber	1	ND	ND	ND	ND	7.0*	5083	ND	ND	ND	ND	ND	ND
	Muscle	2	35.0	97.1	ND	63.1–131	69.9	48.6	ND	31.6–65.6	100	34.0	ND	22.1–45.9
Liver	Blubber	1	4.2	603	ND	ND	7.5	337	ND	ND	9.7	261	ND	ND
	Liver	1	1.6	586	ND	ND	9.7	96.6	ND	ND	24.2	38.7	ND	ND
	Kidney	1	7.6	13.3	ND	ND	24.8	4.1	ND	ND	45.0	2.2	ND	ND

Mean, standard deviation (SD), and range values have been calculated for the minimum, mean, and maximum percentage of THg that is speciated as MeHg (% MeHg) based on literature values. Values have been provided by species and for all species combined. ND = not determined due to small sample size or only one mean % MeHg was found in the literature.

*% MeHg values could not be found for the species and, therefore, the mean % MeHg for all species combined was used.

Table 3. Reasons for not consuming cetacean-based food products, measured across the entire study area.

Rejection reason category	Explanation	Percent of small cetacean product rejections	Percent of humpback whale product rejections
Availability	Considers cetacean-based food products to be unavailable in respondent's hometown	21.6%	25.1%
Cost	Considers cetacean-based food products to be too expensive	0.7%	–
Diet	Cetacean-based food products are not part of respondent's chosen diet (vegetarian, vegan, etc.)	0.7%	2.1%
Ethics	Considers whaling to be unethical	–	3.1%
Fish	Does not consume fish, and considers cetaceans to be fish	0.7%	–
Health	Considers cetacean-based food products to be unhealthy	6.8%	4.7%
Legality	Believes whaling to be illegal	–	1.0%
Mammal	Does not consume meat from mammals	3.1%	3.7%
Menstruation	Believes cetaceans menstruate and does not consume them because of this (see discussion below)	3.1%	2.1%
Other	Uncategorized	1.0%	3.1%
Preference	Does not like the appearance, smell, taste, or texture of cetacean-based food products	38.7%	35.1%
Religion	Considers the consumption of cetacean-based food products to violate respondent's religion	21.6%	19.9%
Sanitation	Considers cetacean-based food products to be produced, sold, or stored in unsanitary conditions	2.1%	–

Demographic patterns

We found a gender-based preference for cetacean-based food products, with male respondents consuming more than female respondents. Within SVG, 39% of households are headed by women (Ministry of Finance 2019) and women, regardless of whether they are considered the heads of their households, are the primary planners of household meals (Young 1993). These sociological factors may indicate that dietary guidelines, if established, would have a good chance of protecting the population from pollution-associated negative health effects, owing to the likelihood of their adherence by women in planning not only their own meals but the meals consumed by the other members of their households.

Age is not a significant factor affecting cetacean-based food product consumption. This challenges the common conception that whaling—and, by extension, the consumption of food products derived from whaling—is a declining way of life globally and specifically in the Caribbean (Gillespie 2005; Fielding 2013). A 2013 study conducted in SVG found that 64% and 55% of respondents ($n=211$, ages 16–25, mean 18.0 years) consumed meat and blubber, respectively, from small cetaceans (Fielding 2013). Our findings indicate that cetacean-based food products remain popular with Vincentian youth and that their popularity neither increases nor decreases significantly with the age of the consumer.

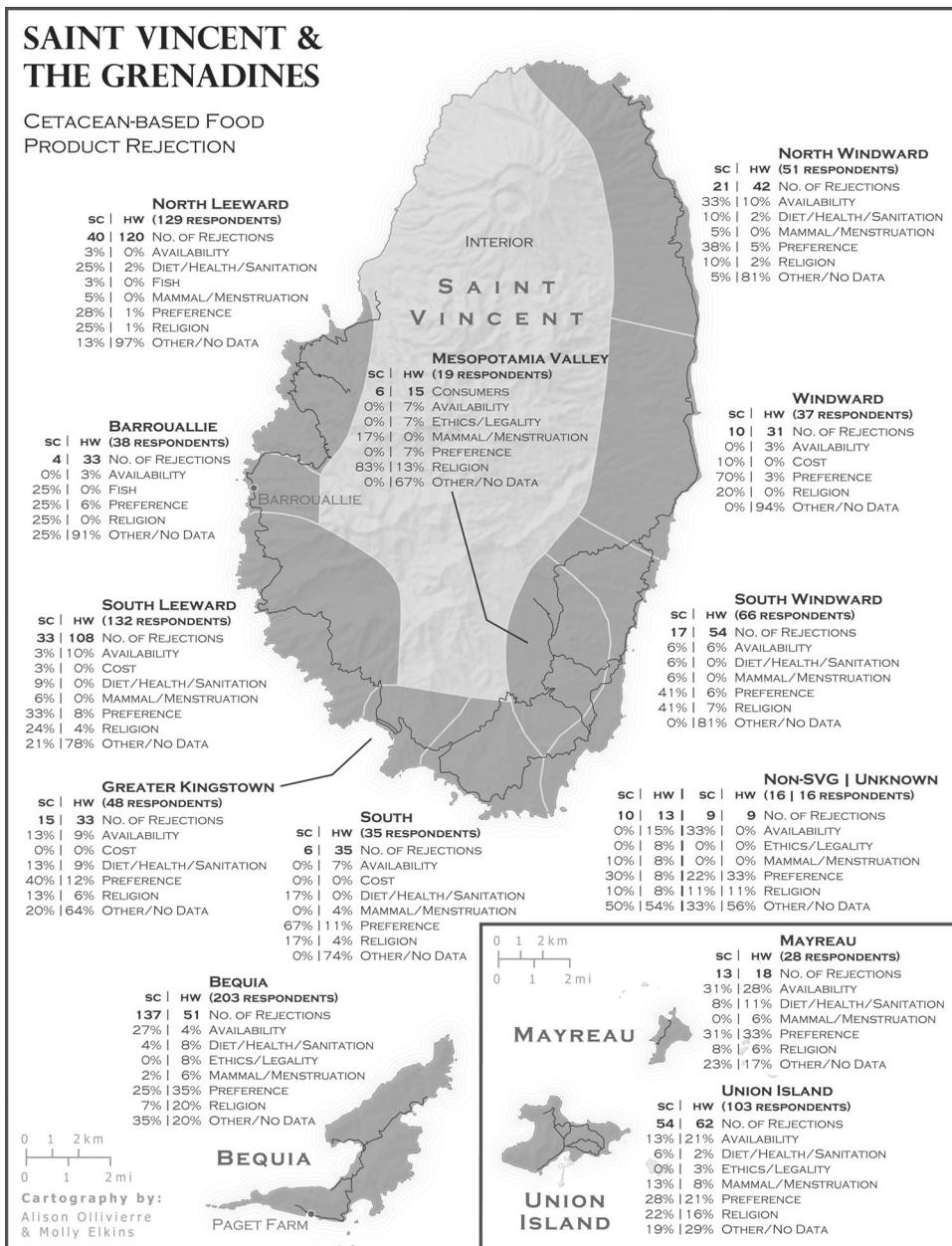


Figure 5. Geographical patterns of reasons given for not consuming cetacean-based food products in SVG. SC = small cetacean, HW = humpback whale.

Our analysis of consumption data organized by occupational categories (as a proxy for socioeconomic class) contradicts previous studies. Adams (1980, 25) found that small cetacean meat was occasionally consumed in SVG by what he termed “low income informants,” and hardly at all by those of higher socioeconomic standing. By contrast, we found no significant preference for cetacean-based food products among those of lower socioeconomic classes (occupational categories 6–9), nor among respondents who reported being unemployed at the time of the survey. While our findings did

show some significance in predicting consumption among respondents representing occupational categories 4 and 8 (Clerical workers and plant and machine operators), the prediction in both of these cases was toward *lower* than average rates of consumption. These results may indicate either that our data benefit from a larger sample size and stronger partnership with local collaborators than previous studies, or that dietary patterns have changed during the intervening decades. If the latter is the case, the change is likely driven by the increased availability of imported meats, resulting in cetacean-based food products no longer being “much cheaper than any other source of animal protein on the island” (Adams 1980, 72).

Spatial variation

The two regions in which Vincentian whaling operations are based—Barrouallie and Bequia—are home to the highest rates of consumption of the products derived from those operations. Each of these regions also represent a nadir of consumption of the “other” cetacean-based food product (small cetacean products in Bequia and humpback whale products in Barrouallie). This spatial pattern could be due to the availability of products: local demand is sufficiently high and transportation logistics are complicated or expensive to the point that it often makes sense for vendors to distribute food products close to their point of origin. Indeed, with a few exceptions, our results suggest that consumption rates strongly correlate with proximity to the whaling centers of Barrouallie and Bequia. A general association of small cetacean-based food products with the main island of St. Vincent and humpback whale-based food products with the Grenadines confirms this trend. Within the Grenadines, only the tiny island of Mayreau (pop. 270, $n = 28$) hosts a population whose demand for small cetacean-based food products matches that of any region on the main island. No region on St. Vincent exceeds any Grenadine island in terms of humpback whale meat, blubber, or oil consumption but the region in which these products are most popular is the South—the closest region, geographically, to the Grenadines. Simple availability does not fully account for the low rate of small cetacean product consumption in Bequia and the similarly low rate for humpback whale products in Barrouallie. Rather, the pattern explained by proximity to whaling centers is likely punctuated by specific regional pride and loyalty to local products within each of the whaling centers.

Frequency and amount of consumption

In other whaling communities where health authorities have advised the public on reducing their exposure to environmental contaminants, dietary recommendations typically have been designed to limit the frequency of consumption. For example, the first dietary recommendations in the Faroe Islands in the North Atlantic, issued in 1977, suggested the general population limit its consumption of small cetacean meat and blubber to no more than one meal per week. Over the following decades, as concentrations of Hg and other contaminants in whale tissue continued to increase, Faroese health authorities issued increasingly strict dietary guidelines, culminating in the controversial 2008 recommendation that “the pilot whale ... no longer [be] used for human

consumption” (Weihe and Joensen 2012). During the 31 years that elapsed between the first dietary advice and the 2008 recommendation to discontinue consumption, health authorities were able to inculcate the Faroese public to the nature of the risk and the associated need for mitigation (Fielding 2018). Owing to the higher levels of Hg found in cetaceans taken in SVG, relative to those in the Faroe Islands, the Vincentian population is unlikely to have the luxury of such a long process of acclimatization.

Among nutrition researchers, portion size is a difficult datum to gather accurately (Cypel et al. 1997). With regard to small cetacean meat and blubber, specifically, our analysis might have been aided by the fact that these food products are typically sold in single-serving bundles. A comparison of small cetacean meat bundles, however, found that they varied by more than 100 g, ranging from 113 g to 227 g, even though prices were equal among portions of all sizes (Fielding 2010). This makes our respondents’ statements on portion size such as “five dollars’ worth every week,” or “a bundle a day,” less useful in terms of actual portion size analysis. Most of our respondents provided detailed information on the frequency with which they consumed cetacean-based food products but could not specify their typical portion size in a meaningful way. In the absence of reliable data on portion sizes, we will assume a bundle of dried meat weighing 170 g—the midpoint of the range presented by Fielding (2010)—as an estimate for average portion size until future research provides more specific data.

The amounts that can be safely consumed per week, based upon the MeHg PTWI (JECFA 2006), can be instructive in terms of dietary advice and public health advocacy. Given that the species identity of the cetacean being consumed is not reliably known for products resulting from the operation targeting small cetaceans in Barrouallie (Fielding 2014), we shall address here only two measures: the mean amount that can be consumed per week for all small cetacean species combined and the same value for all species combined, excluding killer whales. We included calculations for all species excluding killer whales because among species, killer whales had the highest THg concentrations recorded in McCormack et al. 2020. For both measures, we estimated values according to mean MeHg percentages taken from the literature. In the current system, with all species combined, a 60 kg adult can consume slightly less than a third (31%) of an average-weight bundle (170 g) of small cetacean meat per week and remain within the guidelines provided by the FAO/WHO. When we remove killer whales from the analysis, the tissue ranking remains the same, but a 60-kg adult could safely consume 13.7% more blubber, 8.7% more liver, 7.1% more kidney, and 21.5% more muscle per week.

Large intraspecies and interspecies variability occurs in the amount of tissue that could be consumed without exceeding the PTWI. This variability is likely a result of the large variability in THg concentrations and the percent present as MeHg, which is further confounded by the fact McCormack et al. (2020) did not speciate for MeHg and we, therefore, had to rely on values taken from the literature. As a result, we cannot make specific recommendations as to the safest species to consume, particularly for muscle, but suggest that the most conservative interpretation would be to focus upon the minimum amount of tissue calculated based upon the highest percentage MeHg (the low end of the range presented in each row of the right-most column in Table 2). While the greatest amount of blubber could be consumed without exceeding the PTWI,

consumers should still be cautious because this estimation is only based on MeHg and does not include lipophilic organic contaminants such as PCBs and pesticides, which are often found in cetacean blubber (Dam and Bloch 2000). Finally, it is also important to consider that consumers may eat different tissues, or tissues from various species, within a week and these values are based on the consumption of a single tissue.

Reasons for not consuming

We identified a number of factors affecting the rejection of cetacean-based products. An analysis of the reasons for *not* consuming cetacean-based food products illuminates the existence of certain barriers that, if removed, would likely result in greater rates of consumption in SVG. Of particular interest is the spatial pattern of rejections due to lack of availability.

Lack of availability limits the consumption of humpback whale products, especially in regions of St. Vincent, and the same is a major reason for the lack of small cetacean product consumption in the Grenadines, as well as in the North Windward region of St. Vincent. Going by road, North Windward is the region of the island that is the most difficult and time-consuming to reach from Barrouallie; it seems that the travel is not worth the reward to many of the island's small cetacean product vendors. The necessity of a long and expensive ferry trip (> 6 h to cover the 65 km from St. Vincent to Union Island, at EC\$100 [US\$37] for a round-trip fare, based upon the available ferry options in 2018) certainly contributes to the reduced availability of small cetacean products in the Grenadines as well.

Some respondents perceive a “seasonality” regarding cetacean-based food product availability. While the Bequia whaling operation does, in fact, rely upon the seasonal migrations of humpback whales between the Eastern Caribbean and North Atlantic (Martin et al. 1984; Stevick et al. 1999, 2018), the Barrouallie-based small cetacean operation shows no clear seasonal variation except for the short-term breaks in whaling activity during certain holidays and periods of unfavorable weather (Adams and Higman 1973; Fielding 2018).

Among consumers of small cetacean products, 62.8% do not consume humpback whale products, while only 31.9% of consumers of humpback whale products do not consume products from small cetaceans. This is likely an indication not only of the relative ubiquity of products derived from small cetaceans but also of their tendency to replace humpback whale meat when the latter is unavailable. At the time of our study, the Bequia operation had successfully landed only one humpback whale during the previous three years (2015, 2016, and 2017). Rejections for lack of availability indicate that unmet demand for cetacean-based food products likely exists in some parts of SVG. Specifically, if more whaling were to occur, and if distribution networks were expanded to reach currently underserved areas, the products would likely find ready consumers. The Bequia humpback whale operation is limited to a maximum of four whales per year by the IWC. The Barrouallie small cetacean operation, however, is not limited by Vincentian domestic law or by any international treaty to which SVG is party (Fielding 2018). In theory, the operation acts as an open-access resource institution and—if cetacean populations can sustain the increased pressure—could potentially expand to fulfill

demand for cetacean-based food products in places where availability is currently limited. This underscores the pressing need for future research to understand the size and dynamics of local cetacean populations. It also illustrates the need for future policy action, specifically the establishment of whaling quotas or another system of limited entry to regulate the take of small cetaceans by Vincentian whalers.

Rejection of cetacean-based food products for religious reasons is largely associated with two specific religious groups: adherents to the Rastafarian and Seventh-Day Adventist faiths. Both traditions proscribe the consumption of sea creatures lacking “fins and scales” in keeping with their interpretation of the Levitical dietary laws given in the Bible. In the 2012 census, 11.6% of Vincentians self-identified as Seventh-Day Adventists, while 1.1% identified themselves as Rastafarians. Rejections by Adventists dominate the religious rejection of cetacean-based food products. Of all the rejections for religious reasons, 71.4% of small cetacean product rejections and 73.7% of humpback whale product rejections are by respondents who cited their Adventist faith; 11.1% and 7.9% are from those who cited their Rastafarian faith, and 17.5% and 18.4% are for unspecified religious adherence.

We found more religious rejections of small cetacean products than of humpback whale products along with the occurrence—absent in the small cetacean product rejections—of ethics and legality as a category of reasons not to consume humpback whale meat. The Bequia-based whaling operation has attracted more international scrutiny than the small cetacean operation in Barrouallie. This is, in part, due to the fact that humpback whales are internationally protected and are strictly managed by the IWC. Under current IWC rules, every six years the government of SVG must submit a “need statement” to the IWC, laying out the cultural and nutritional benefit of maintaining its aboriginal subsistence whaling quota (IWC 2012, 2015). The operation targeting small cetaceans falls only under the jurisdiction of the Government of SVG because small cetaceans in the Caribbean region are not managed internationally (Gillespie 2001; Reeves 2005). The differential management of the two whaling operations may give Vincentian consumers the impression that Bequia’s operation targeting humpback whales is more ethically and legally ambiguous than the Barrouallie operation, since the former requires international oversight and the latter does not.

Although rejection for “menstruation” is mentioned only infrequently in our surveys (3.1% and 2.1% for small cetacean and humpback whale products, respectively), it warrants discussion here for its unusual nature. Specifically, a belief exists among some members of the Vincentian public that female cetaceans menstruate and that this constitutes a valid reason to eschew their consumption. To be clear, cetaceans do not menstruate, although certain odontocetes, including killer whales and short-finned pilot whales, do experience a reduction and eventual loss of fertility with age (Marsh and Kasuya 1984, 1986)—a phenomenon that some scholars have compared to menopause in humans (McAuliffe and Whitehead 2005). While the origins of this unfounded belief remain unknown, it calls to mind the general menstrual taboos long described by anthropologists (e.g., Kamsler 1938; Stephens 1961; Young and Bacdayan 1965; Montgomery 1974) and in particular, the interactions between the menstrual taboo and hunting traditions (Kitahara 1982). The important difference between the cases analyzed by Kitahara and the Vincentian case is that the former considers only human

menstruation as a taboo during hunting, while the latter projects this characteristic upon the non-human quarry.

Previous research has found that cetacean-based food products are largely viewed as healthy in SVG. A 2013 study found that 68% of survey respondents ($n = 211$) believed small cetacean meat to be healthy (Fielding 2013). A further 19% of respondents in that study answered that they did not know whether it was healthy or not. Only 8% responded that small cetacean meat was not healthy. In our surveys, a minority of respondents—6.8% and 4.7%—cite health as their reason for not consuming small cetacean meat and humpback whale meat, respectively. Even when all of the marginally health-related categories of reasons for rejection (diet, fish, health, mammal, and sanitation) are taken together, only 13.4% and 10.5% of respondents reject small cetacean products and humpback whale products, respectively, for this inclusive reason of health. Considering the findings of McCormack et al. (2020), it is clear that this public perception is misaligned with the reality of environmental contamination.

Conclusions

Our findings indicate a high rate of consumption of cetacean-based food products, at a time when global Hg emissions (Pirrone et al. 2010; UNEP 2013; Pacyna et al. 2016; Streets et al. 2019), as well as Hg concentrations in Caribbean-caught cetaceans (Gaskin et al. 1974; Fielding and Evans 2014; McCormack et al. 2020), have been shown to have increased during recent decades. These high atmospheric and biospheric Hg concentrations, coupled with the high rates of cetacean-based food product consumption shown here by our research, indicate the likelihood of a human health risk in SVG.

McCormack et al. (2020) advised that their study warranted further investigation, owing to the *potential* human health risk uncovered therein. We would go further, recommending that, given the high concentration of environmental contaminants and the high degree of popularity of these food products, the Government of SVG should embark upon a demographically and geographically targeted intervention campaign by establishing and communicating dietary recommendations based upon the most recent information available. Our analysis of the demographic and geographic patterns of the consumption of cetacean-based food products will allow an information campaign to be directed toward those members of the population with the greatest risk of exposure. Given the variation in Hg concentrations reported by species, we would also recommend that species-specific whaling quotas be considered as a way to eliminate the most contaminated food products from the local Vincentian food system.

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Data availability statement

The datasets produced and analyzed for this study are available from the corresponding author (Fielding) upon reasonable request.

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