Affordability influences nutritional quality of seafood consumption among income and race/ethnicity groups in the United States

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ABSTRACT

Background: The 2020 US Dietary Guidelines for Americans recommend that the US population consume more seafood. Most analyses of seafood consumption ignore heterogeneity in consumption patterns by species, nutritional content, production methods, and price, which have implications for applying recommendations.

Objectives: We assessed seafood intake among adults by socioeconomic and demographic groups, as well as the cost of seafood at retail to identify affordable and nutritious options.

Methods: NHANES 2011–2018 dietary data (n = 17,559 total, n = 3285 eating seafood) were used to assess adult (≥20 y) intake of seafood in relation to income and race/ethnicity. Multivariable linear regression assessed the association between seafood consumption and income, adjusted for age, sex, and race/ethnicity, and the association between nutrients and seafood price, using Nielsen 2017–2019 retail sales data, adjusted for sales volume.

Results: Low-income groups consume slightly less seafood than high-income groups [low income: mean 120.2 (95% CI: 103.5, 137.2) g/wk; high income: 141.8 (119.1, 164.1) g/wk] but substantially less seafood that is high in long-chain n–3 (ω-3) PUFAs [lower income: 21.3 (17.3, 25.5) g/wk; higher income: 46.8 (35.4, 57.8) g/wk]. Intake rates, species, and production method choices varied by race/ethnicity groups and within race/ethnicity groups by income. Retail seafood as a whole costs more than other protein foods (e.g., meat, poultry, eggs, beans), and fresh seafood high in n–3 PUFAs costs more (P < 0.002) than fresh seafood low in n–3 PUFAs. Retail seafood is available in a wide range of price points and product forms, and some lower-cost fish and shellfish were high in n–3 PUFAs, calcium, iron, selenium, and vitamins B-12 and D.

Conclusions: New insights into the relation between seafood affordability and consumption patterns among income and ethnicity groups suggest that specific policies and interventions may be needed to enhance the consumption of seafood by different groups. *Am J Clin Nutr* 2022;116:415–425.

Keywords: affordability, diet, fish, NHANES, n–3, PUFA, seafood

Introduction

Identifying dietary patterns that are nutritious, affordable, and sustainable is critical for human and planetary health (1, 2) and for achieving several UN Sustainable Development Goals (3). Seafood (i.e., fish, shellfish, crustaceans, etc.) can be an important part of healthy and sustainable diets based on their

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Supplemental Figures 1–3 and Supplemental Tables 1–4 are available from the "Supplementary data" link in the online posting of the article and from the same link in the online table of contents at https://academic.oup.com/ajcn/.

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Abbreviations used: CVD, cardiovascular disease; FNDDS, Food and Nutrient Database for Dietary Studies; FPED, Food Patterns Equivalents Database; IPR, income-to-poverty ratio; USDGs, US Dietary Guidelines for Americans.

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nutritional properties and environmental impacts (4, 5). Many dietary patterns associated with positive health outcomes, such as the Mediterranean diet and the new Nordic diet, include seafood (2, 6, 7). Evidence continues to accumulate that healthy diets often cost more than unhealthy diets (8–12), and because seafood is expensive (8), affordability remains a barrier to access among low-income populations (13, 14).

The US Dietary Guidelines for Americans (USDGs) recommend that adults consume 227–283 g per week of a variety of seafood to achieve an average consumption of 250 mg/d of EPA and DHA. These long-chain n–3 PUFAs are associated with a reduced risk of cardiovascular disease (CVD) and mortality (15). Women who are pregnant or breastfeeding are recommended to consume at least 227 and up to 340 g/wk to improve infant and pregnancy-related health and development outcomes (15). One recent study suggests that CVD benefits from fish may be limited to those fish rich in n–3 PUFAs (16), but health benefits of fish are not limited to n–3 PUFAs and include benefits from micronutrients (17). Protein from animal source foods, including seafood, has a more balanced amino acid profile than that from most plant sources (18).

Most Americans (90%) do not consume recommended amounts of seafood (15). USDGs recommend to increase general consumption from the seafood category rather than of specific types of seafood, except for pregnant and lactating women and children younger than 11 y who should avoid fish species high in mercury (19). Many existing analyses of seafood consumption in the US population do not make distinctions about seafood type or apply only simple categories, such as high compared with low n–3 content (20–22), and reducing the complexity of seafood in this way may have advantages for communicating recommendations to the public. However, seafood is a heterogeneous product that comes from many different sources (23–25) with a wide range of price points and nutritional characteristics. A more nuanced understanding of seafood consumption patterns within the US population, one that recognizes heterogeneity of the commodity, can inform efforts to address dietary and nutritional gaps within subpopulations in the United States and will also have more general interest as many other countries face similar challenges.

This study explores how socioeconomic factors and affordability may influence seafood consumption overall and choices related to specific seafood items. By linking national data sets along the seafood value chain to consumption, this study aims to *1*) describe consumption patterns of major types of seafood by income and race/ethnicity, *2*) assess the affordability of different types of seafood, and *3*) quantify the cost of nutrients available in different categories of seafood.

Methods

Description of data sets and data processing

National seafood intake.

The NHANES day 1 dietary recall data set was analyzed for adults (≥20 y) in year cycles 2011–2012 to 2017–2018, which contained 17,559 total adult respondents, including 3285 individuals who reported consuming seafood. The 2011–2012 cycle was selected as the start date because it was the first cycle in which Asian was included as a separate race group. NHANES data were joined with the USDA Food Patterns Equivalents Database (FPED) to convert protein foods consumed by NHANES respondents from gram weights into ounce-equivalents (26). All NHANES analyses accounted for the complex sampling design using primary sampling units, strata, and survey weights to construct nationally representative estimates of food consumption.

Study characteristics and sample sizes are presented in **Table 1**. The sample was split into 3 income-to-poverty ratio (IPR) groups (<185%, 185–399%, and ≥400%), which were referred to as “income groups,” and 4 race/ethnicity groups defined by NHANES and self-identified by participants (non-Hispanic white, non-Hispanic black, Hispanic, and non-Hispanic Asian). IPR is the ratio of family income to federal poverty guidelines. Income groups were developed with recognizable cut-points used in federal poverty guidelines and were roughly equally weighted across the US population (**Supplemental Figure 1**). IPR of 185% is the upper bound of eligibility for some forms of federal food assistance programs (i.e., National School Lunch Program) (27). IPR of 400% is the upper bound of eligibility for federal tax credits and federally managed health care plans (28). In 2021, IPRs of 185% and 400% equate to a monthly, 2-person household income of $2700 and $5800, respectively.

The per capita consumption of total seafood, seafood groups high and low in long-chain n–3 PUFAs, and other protein foods (e.g., red meat, processed meat, poultry, eggs, nuts and seeds, legumes, soy) was calculated by race/ethnicity and income. Seafood intake was also calculated as the percentage of total consumed by species group and by seafood production methods. Species groups ($n = 44$) were defined by the NHANES 24-h dietary recall questionnaire. Two popular species (pollock and pangasius) were notably absent from the NHANES questionnaire, which is a limitation. Seafood production methods and habitats were determined using production and trade data. NHANES was linked to production and trade data using species name as a matching term to estimate the shares of marine fisheries, inland fisheries, marine aquaculture, and inland aquaculture consumed by race/ethnicity and IPR group. Creating the linking term required a name regularization step for species groups in the NHANES and production/trade data sets.

National retail seafood sales.

National-level sales projections were based on data reported by NielsenIQ through its Scantrack Service for protein food categories for the period starting January 2017 and ending December 2019. Data before 2017 were not available to the study team. Nielsen data used the national market and xAOC channel (eXtended All Outlet Combined), according to the NielsenIQ standard product hierarchy. Methods for analysis have been previously described (29). Briefly, retail sales volumes were converted to kilograms from ounces, adjusted revenue ($), and unit price ($/kg). Weights included seafood and added ingredients such as breading. One kilogram equals 35.27 ounces or 2.2 pounds. Missing weights were imputed using the average unit price of a similar item and matched using a concatenation

TABLE 1 Characteristics of study population of NHANES respondents for year cycles 2011–2012 to 2017–2018

		Income-to-poverty ratio group (% of unweighted sample)			
Characteristic	*n*	<185%	185–399%	≥400%	NA
All NHANES participants					
US adults (+20)	17,559	45	29	26	0
Race/ethnicity					
Non-Hispanic white	6985	41	29	30	0
Non-Hispanic black	3909	50	30	20	0
Hispanic	4001	57	28	15	0
Non-Hispanic Asian	2018	28	30	42	0
Other	646	49	30	20	0
NHANES seafood consumers[1]					
US adults (+20)	3285	40	29	31	0
Race/ethnicity					
Non-Hispanic white	972	33	26	40	0
Non-Hispanic black	861	47	30	23	0
Hispanic	648	52	29	19	0
Non-Hispanic Asian	696	30	30	40	0
Other	108	43	24	33	0

[1]Seafood consumers were considered participants who ate any seafood product during the day 1 dietary recall survey. NA, not available.

term. Data were deflated using the Consumer Price Index (CPI-U series) and adjusted to 2019 for annual inflation. Nielsen retail sales were summarized for each protein food group and within the seafood category. Nielsen retail sales were linked to production and trade data using seafood species name as a linking term to calculate the weighted average unit price of fresh, frozen, and shelf-stable seafood products by their production methods and habitat. Creating the linking term required a name regularization step for species groups in the production/trade and Nielsen data sets. A complete list of retail prices for seafood and other protein foods is provided in **Supplemental Tables 1** and **2**.

Seafood nutrients.

The Food and Nutrient Database for Dietary Studies (FNDDS) was used as the source of nutrient values for seafood (30). New variables were added for species name and product form (raw, canned, preserved, etc.) and used along with selected nutrients, including protein, calcium, EPA, DHA, iron, selenium, zinc, and vitamins A, B-12, and D. These nutrients were selected due to the relatively high nutrient content of certain species of seafood and their public health importance. These data were linked to retail sales and trade, using species name as the linking term to assess the influence of price and seafood habitat on nutrient values. Creating the linking term required a name regularization step for species groups in the FNDDS and Nielsen data sets. Nutrient values were based on raw product forms without added ingredients or cooking methods, and prices were for fresh and frozen products. FNDDS did not routinely report production methods (aquaculture or fisheries) alongside seafood nutrients, which is a limitation and prevented the use of production method as a variable in nutrient analyses. A list of species high and low in n–3 PUFAs, as defined by FPED, is presented in **Supplemental Table 3**.

Seafood production methods and habitat.

The starting point for this analysis was seafood production and trade data. To estimate production method and habitat associated with traded aquatic foods, we first identified species groups by their trade code, which is a unique 6-digit number used to classify products (HS 2012 version). We converted bilateral trade data from BACI (31) to the live-weight equivalent based on live-weight conversion factors provided by the European Market Observatory for Fisheries and Aquaculture Products. We then estimated the species mix within each trade code proportionally to production of the species falling within the code from the exporting country based on FAO production data (32). Similarly, we assumed the production method and habitat to be proportionate to the reported production method and habitat of each species group in the exporting country. Nonfood items (i.e., baitfish and fish meal) were removed from the data set. Production methods and habitat for the terms *fish* and *seafood* refer to global averages of all fish and seafood (fish + mollusks + crustaceans + other), respectively.

Analytical methods

Data analyses and plots were made using R (v 4.0.2; R Core Team, 2021) and RStudio (v. 1.3). Data linkages are provided as a flowchart in **Supplemental Figure 2**. Multivariable linear regression models were used to explore associations between seafood consumption and income and race/ethnicity, adjusted for age and sex as potential confounders (13). Weighted average retail prices of product types were compared across years using ANOVA and Tukey multiple comparison test for 3 or more groups and *t* tests for 2 groups. The χ^2 test assessed whether the distribution of species or production methods was significantly different among high- compared with low-income groups. Multivariable linear regression models were used to explore associations between retail seafood price and each

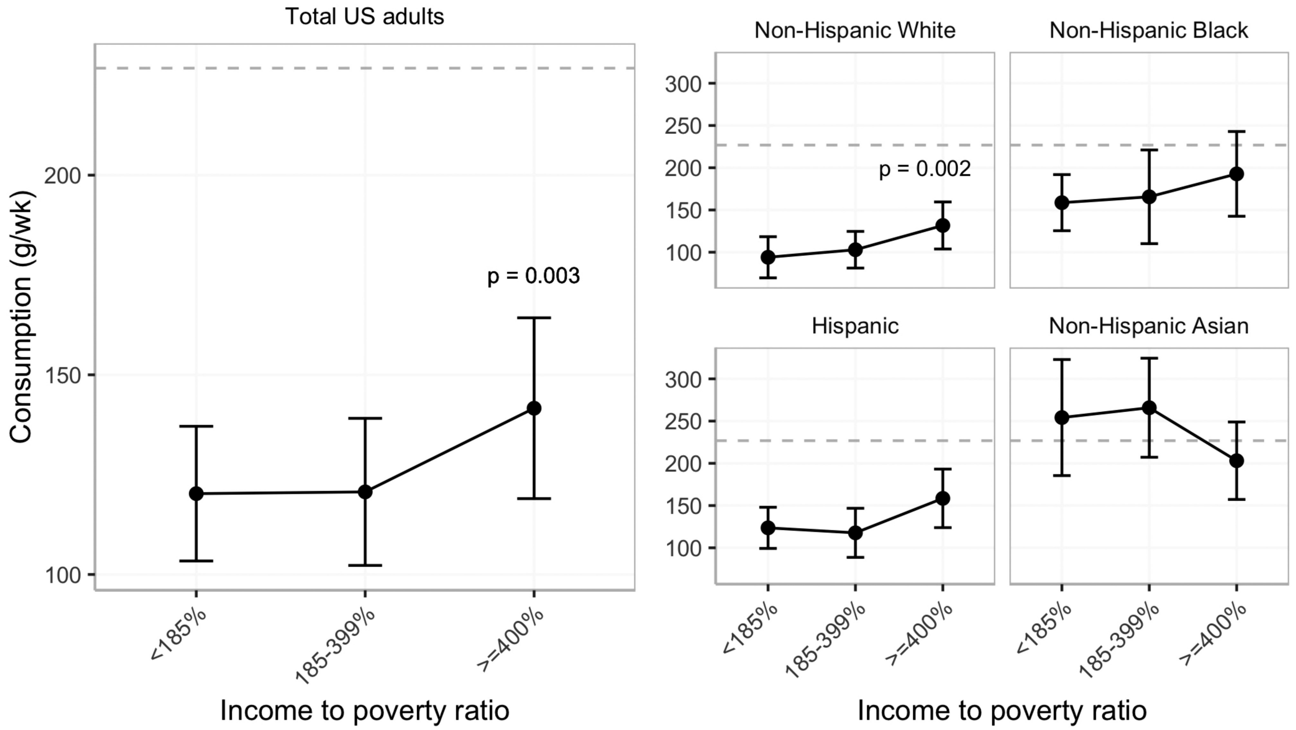

FIGURE 1 Per capita seafood consumption by US adults by race/ethnicity and income groups, 2011–2018 NHANES. A multivariable regression for associations between seafood consumption and income as a continuous variable, controlling for age, sex, and race/ethnicity (for total United States only). Significant *P* values for total US adults and non-Hispanic white adults but not other groups, with 95% CIs reported. Dashed line at 227 g/wk represents the minimum seafood intake recommended in the US Dietary Guidelines for Americans. Sample sizes by income group reported in Table 1. One gram equals 0.035 oz.

nutrient, weighted for the retail sales volume. Significance was set at an α of 0.05 for all analyses.

Results

Seafood intake by income and race/ethnicity

In the NHANES data, lower incomes were associated with less intake of seafood among all US adults ($P = 0.003$) (**Figure 1**). The low-income group consumed 120.2 (95% CI: 103.5, 137.2) g/wk, which was 21.6 g/wk (18%) less than the high-income group (141.8; 95% CI: 119.1, 164.1) g/wk ($P = 0.03$). Lower incomes were also associated with less intake of nuts and seeds ($P < 0.001$), soy ($P < 0.001$), and all protein foods ($P < 0.001$) in US adults, whereas income was not associated with intake of red meat, processed meat, poultry, eggs, or legumes (**Supplemental Figure 3**), suggesting that associations between income and intake are not generalizable to all protein foods.

By race/ethnicity, lower incomes were associated with less intake of seafood among non-Hispanic white adults ($P = 0.002$) but no other groups, perhaps due to higher within-group variability (Figure 1). Seafood intake rates were significantly lower among non-Hispanic white adults than non-Hispanic black ($P = 0.001$) or non-Hispanic Asian ($P < 0.001$) adults. Non-Hispanic Asian adults routinely met USDG targets of 227 g/wk but interestingly had a different response to income than other race/ethnicity groups. Among non-Hispanic Asian adults, seafood intake appeared to drop among the high-income group ($P = 0.087$, not statistically significant).

Retail price and intake of seafood high in n–3 PUFAs

In NHANES, lower income was associated with less intake of seafood high in n–3 PUFAs among all US adults ($P < 0.001$) and non-Hispanic white adults ($P < 0.001$) (**Figure 2**). Seafood high in n–3 PUFAs made up 18%, 28%, and 33% of all seafood intake for low-, middle-, and high-income groups (**Supplemental Table 4**). As a quantity, low-income and high-income groups consumed 21.3 (95% CI: 17.3, 25.5) g/wk and 46.8 (95% CI: 35.4, 57.8) g/wk of seafood high in n–3 PUFAs. Intake of seafood low in n–3 PUFAs was not associated with income among all US adults or any race/ethnicity group (Figure 2).

Using national retail sales data, **Figure 3**A presents the weighted average price of species high and low in n–3 PUFAs. The average price of fresh seafood high in n–3 PUFAs was \$22.33/kg ± \$0.42/kg, which was significantly more expensive (32% more) than fresh seafood low in n–3 PUFAs ($P < 0.002$). There were no significant differences in the price of high compared with low n–3 PUFA products in either frozen or shelf-stable forms. Across all forms (fresh, frozen, and shelf stable), however, there were larger retail sales volumes of seafood low in n–3 PUFAs compared with high in n–3 PUFAs.

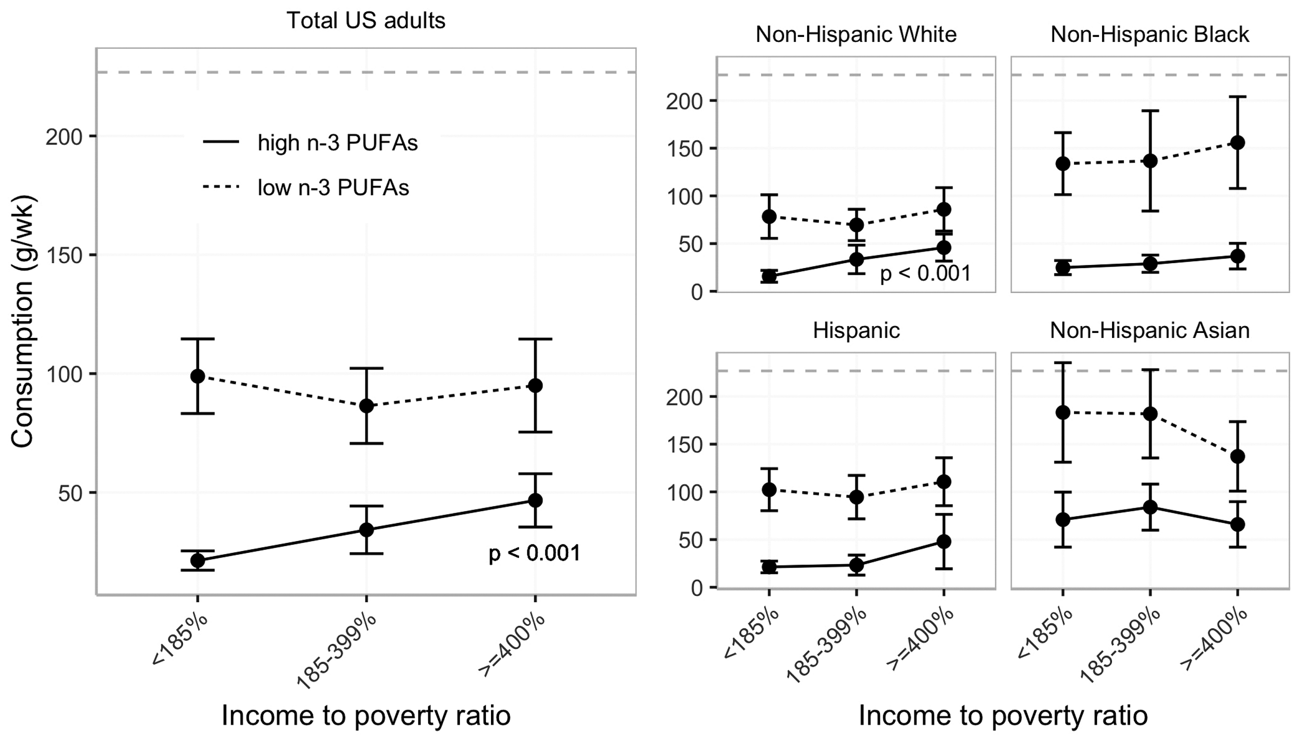

FIGURE 2 Per capita consumption of species high and low in long-chain n–3 PUFAs by US adult race/ethnicity and income groups, 2011–2018 NHANES. Multivariable regressions for associations between seafood consumption and income and race/ethnicity, adjusting for age and sex as potential confounders. Significant *P* values for total US adults and non-Hispanic white adults consuming high long-chain n–3 PUFAs. There were no significant differences in low long-chain n–3 PUFAs for each group, with 95% CIs reported. Dashed line at 227 g/wk represents minimum US Dietary Guidelines for Americans recommended seafood intake. Sample sizes by income group reported in Table 1. One gram equals 0.035 oz.

Retail price and intake of top seafood species

Figure 4 presents the top seafood species consumed by US adults. National averages mask differences in species preferences by income groups. The distribution of species consumed was significantly different among high- compared with low-income groups for total US adults ($P < 0.001$), non-Hispanic white adults ($P < 0.001$), non-Hispanic black adults ($P < 0.001$), and Hispanic adults ($P < 0.001$) but not non-Hispanic Asian adults. As incomes rise, all groups appear to add salmon to the diet. For example, in all US adults, salmon made up 7% of seafood intake for low-income groups and 21% of seafood intake for high-income groups. Salmon is high in n–3 PUFAs and contributes to overall higher n–3 PUFA intake among high-income groups.

At retail outlets, salmon is relatively expensive compared with other seafood and protein foods. The main product form for salmon is fresh (29), which has an average retail price of $22.71/kg. Fresh salmon was 170%, 340%, and 860% more expensive than all fish, chicken, and beans, respectively (Supplemental Table 3). Lower-priced seafood products include tilapia ($7.94/kg frozen), tuna ($11.66/kg canned), catfish ($10.74/kg frozen), cod ($13.34/kg frozen), and shrimp ($17.59/kg frozen), reported as the most common product forms (29). Retail prices of protein foods and the top 50 seafood species are provided in Supplemental Table 4.

Retail price and intake of fisheries and aquaculture products

Seafood species were grouped by production methods and habitat to better relate consumer choices with food production practices (**Figure 5**). Using this approach, it was estimated that seafood consumption among US adult income groups comes from marine fisheries (46–48%), marine aquaculture (25–34%), inland aquaculture (16–24%), and a limited amount from inland fisheries (3–4%). The distribution of production methods was significantly different among high- compared with low-income non-Hispanic black adults ($P = 0.01$) but not other groups (Figure 5). This findings suggests that as incomes rise, non-Hispanic black adults replaced less expensive inland aquaculture products with more expensive marine fisheries products (Figure 3B).

At retail outlets, inland fisheries and aquaculture products were significantly less expensive than marine fisheries and aquaculture products (Figure 3B). For example, the weighted average price of fresh inland aquaculture products was $11.13/kg, which was 185% and 174% less expensive than fresh marine aquaculture ($P < 0.001$) and fresh marine fisheries ($P < 0.001$) products, respectively. Frozen forms cost less than fresh, but the price difference between inland and marine sources remained. For example, frozen inland aquaculture products were $8.66/kg, which was 200% and 183% less than the price of frozen marine aquaculture ($P < 0.001$) and frozen marine fisheries ($P < 0.001$) products, respectively.

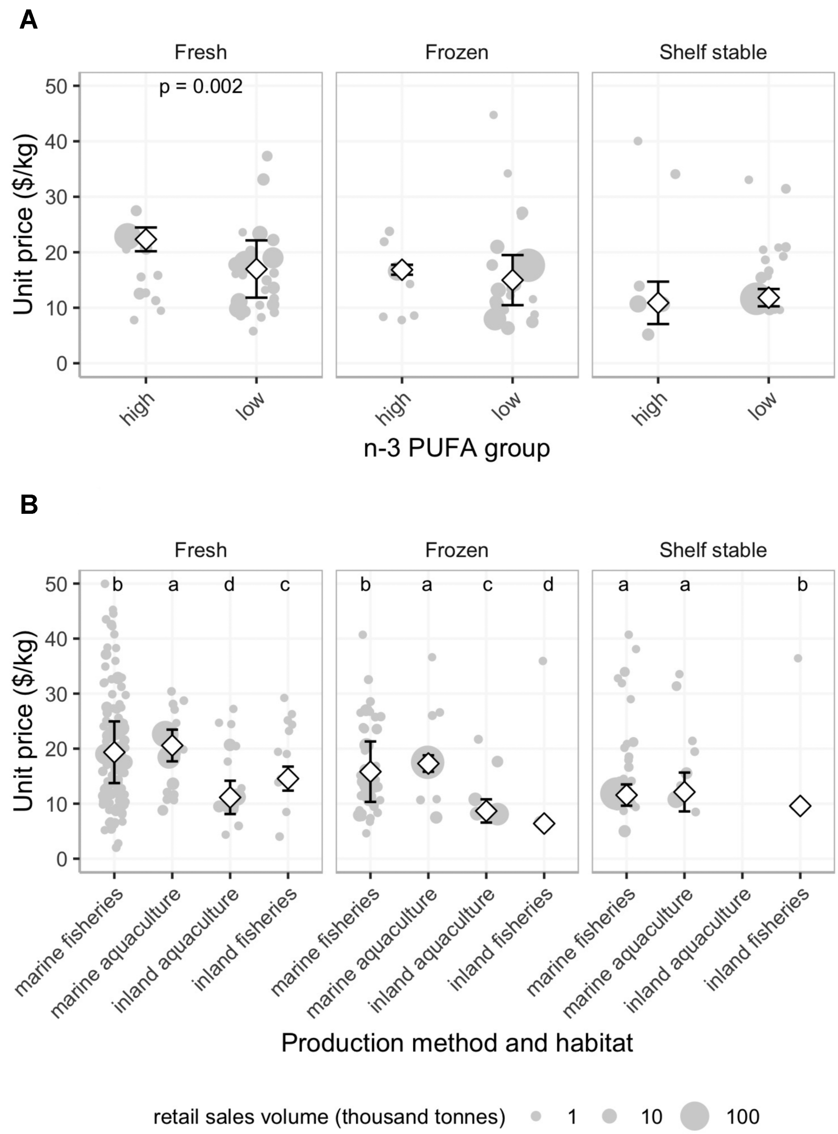

FIGURE 3 US retail fresh, frozen, and shelf-stable seafood prices for (A) species high and low in long-chain n–3 PUFAs and (B) production methods and habitat, Nielsen, 2017–2019. Each dot represents a species group. Dot size equals retail sales volume (thousand tonnes). Diamonds are weighted means ± SDs. (A) A *t* test for high compared with low n–3 PUFA unit price, with no significant difference in high compared with low groups sold as frozen or shelf-stable forms. Sample size (N = species; n = products): high n–3 PUFAs (fresh, $N = 11$, $n = 19{,}863$; frozen, $N = 7$, $n = 2082$; shelf-stable, $N = 6$, $n = 3822$); low n–3 PUFAs (fresh, $N = 28$, $n = 49{,}336$; frozen, $N = 23$, $n = 16{,}140$; shelf-stable, $N = 16$, $n = 4{,}900$). (B) ANOVA ($P < 0.01$ for all plots) and Tukey multiple comparison test (letters for significant differences). Sample size (N = species; n = products): marine fisheries (fresh, $N = 114$, $n = 34{,}948$; frozen, $N = 47$, $n = 5728$; shelf-stable, $N = 26$, $n = 7283$); marine aquaculture (fresh, $N = 17$, $n = 34{,}061$; frozen, $N = 8$, $n = 11{,}957$; shelf-stable, $N = 8$, $n = 1556$); inland aquaculture (fresh, $N = 13$, $n = 8315$; frozen, $N = 5$, $n = 1958$; shelf-stable, $N = 0$, $n = 0$); inland fisheries (fresh, $N = 12$, $n = 1097$; frozen, $N = 2$, $n = 225$, shelf-stable, $N = 2$, $n = 55$). One kilogram equals 2.2 lbs.

There is a diversity of species sold at retail (each dot in Figure 3B represents a species group). Fresh and frozen marine fisheries are the most diverse categories, whereas aquaculture is made up of fewer species (e.g., farmed salmon, shrimp, tilapia, and catfish) with large market shares. This diversity in species provides a wide variety of nutrients.

Retail price of seafood-associated nutrients

Figure 6 presents seafood-associated nutrients and retail prices for 34 top species. Retail prices were not associated with nutritional density for any of the nutrients analyzed using multilinear regressions for price and nutrients as continuous variables (Figure 6). There were, however, several lower-priced nutritious options. For example, mackerel and herring were half the price of salmon but higher in EPA and DHA. There were also lesser-consumed species that were highly nutritious. Eel was exceptionally high in vitamins A and D, octopus was high in iron and vitamin B-12, lobster and perch were high in calcium (as is eating small whole fish and fish bones), fresh tuna was high in selenium, and oysters and mussels were high in iron, vitamin B-12, and zinc.

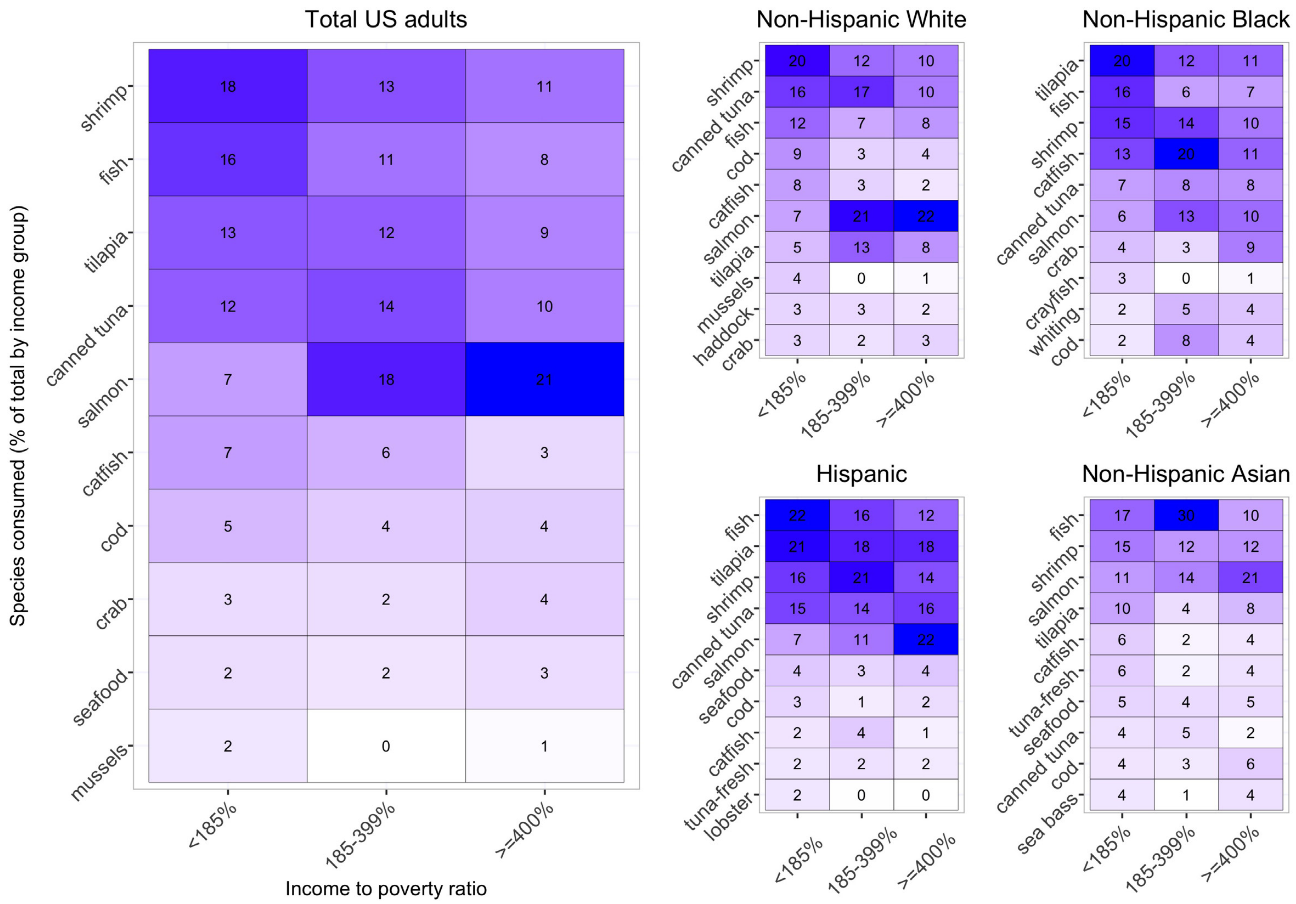

FIGURE 4 The percentage of top species consumed by US adult race/ethnicity and income groups, 2011–2018 NHANES. Top 10 species are reported, which sum to the following by race/ethnicity and income group: total US adults: 86%, 82%, 73% (<185%, 185–399%, ≥400% income to poverty ratio); non-Hispanic white: 87%, 82%, 71%; non-Hispanic black: 88%, 89%, 75%; Hispanic: 94%, 90%, 92%; non-Hispanic Asian: 81%, 78%, 75%. Sample sizes by income group reported in Table 1. The χ^2 tests for the distribution of species between highest compared with lowest income groups. Significance was found for total US adults ($P < 0.001$), non-Hispanic white adults ($P < 0.001$), non-Hispanic black adults ($P < 0.001$), and Hispanic ($P < 0.001$) adults but not non-Hispanic Asian adults.

Discussion

Our study found that in the US, lower-income groups consume slightly less seafood than higher-income groups but substantially less seafood that is high in n–3 PUFAs. This is partly due to the price of seafood. Findings from the present study agree with others that seafood as a whole costs more than other protein foods (e.g., meat, poultry, eggs, beans) (8), seafood from marine habitats costs more than seafood from inland habitats (33), and the present study also found fresh seafood high in n–3 PUFAs costs more than fresh seafood low in n–3 PUFAs. Previous work indicates that low-income groups consume lower-cost and lower-quality diets (34) and are sensitive to food prices (35, 36). In a systematic review of Western countries, consumers reported that price is the main barrier to increasing seafood consumption (13). Cost is also a barrier for including seafood in federal nutrition assistance programs and school lunches (37, 38). Low intake of fish rich in n–3 PUFAs among many lower-income groups poses a challenge for meeting USDG recommendations of 250 mg/wk of EPA and DHA from seafood. Nutritional interventions and messaging should consider the affordability of seafood as a barrier for lower-income groups and potentially highlight affordable, nutrient-dense options. Investments in healthy diets, including subsidies for healthy foods and taxes for unhealthy foods, could be an important way of reducing health disparities between lower and higher socioeconomic status groups (39), but the higher cost of healthier diets raises concerns about barriers to widespread adoption.

Preferences for seafood varied widely among and within race/ethnicity groups. For example, there was more than a 2-fold difference between the highest (non-Hispanic Asian) compared with the lowest (non-Hispanic white) consuming race/ethnicity groups. Preferences for higher-priced marine fisheries products shifted as a function of income among non-Hispanic black adults. There were also wide within-group differences in seafood intake among non-Hispanic Asian adults, for example. The non-Hispanic Asian group includes a mix of origins from China, India, Indonesia, and across South and Southeast Asia, with many different cultures, religions, and food preferences. Notably, Asian adults appeared to decrease seafood intake at the highest income level, which was different from other race/ethnicity groups. This may be a function of high-income Asian adults consuming more vegetarian diets or

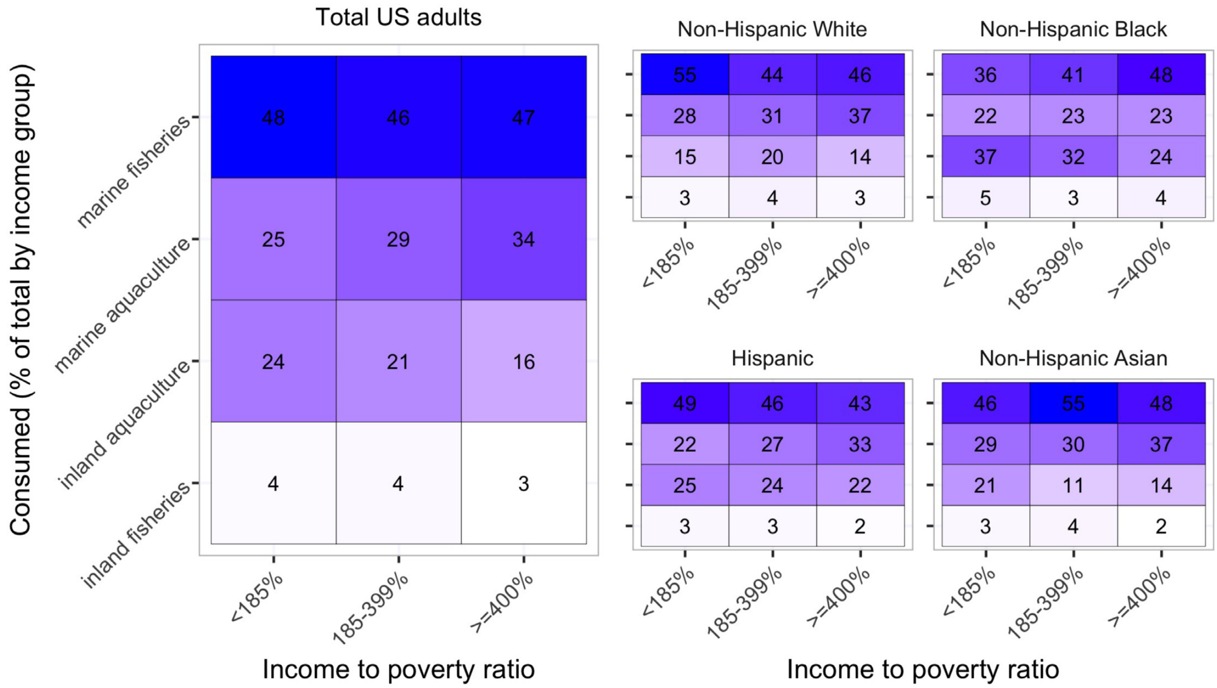

FIGURE 5 The percentage of seafood consumed by production method and habitat for US adult race/ethnicity and income groups, 2011–2018 NHANES. Columns sum to 100%. Sample sizes by income group reported in Table 1. The χ^2 test for the distribution of production methods between highest compared with lowest income groups. Significance was found for non-Hispanic black adults ($P = 0.01$) but not other race/ethnicity groups or total US adults.

acculturation, which others found was associated with lower seafood intake among all Asian Americans and East Asian Americans (40). The US is heterogeneous with respect to seafood intake, and seafood itself varies widely by species, form (fresh, frozen, canned), and prices available at retail (29). For dietary interventions to be most effective, they must be sensitive to these differences.

Seafood is a diverse and heterogeneous food category, which is often not fully appreciated in the US or leveraged for human nutrition. There are nearly 3000 taxa of aquatic foods with a wide range of fatty acid, macronutrient, and micronutrient levels, and nutrient composition data are becoming more available (17, 23, 41). Over the past century, the ratio of n–3 PUFAs to n–6 PUFAs has decreased over time with potential adverse implications for human health (42). Seafood represents an opportunity to enhance the overall dietary quality given high micronutrient and n–3 PUFA content and the potential to substitute for less-healthy red and processed meat (43).

This study found that seafood currently consumed by Americans is a mixture of farmed and wild-caught, and the majority comes from marine habitats. This study showed that seafood harvested by different production methods and habitats has different retail prices, but there are also differences in nutritional quality and food safety. Marine wild-caught shark, swordfish, king mackerel, and tilefish can bioaccumulate methylmercury, and wild-caught oily fish can sequester dioxin and dioxin-like polychlorinated biphenyls at higher rates, which could limit human dietary intake (44). Aquacultured fish are distinct nutritionally and ecologically from their wild-caught counterparts as they consume feed supplemented with crop and animal meals, vegetable oils, and animal fats (45–47). Switching from fishmeal to plant-based feeds for sustainability has decreased n–3 PUFA concentrations in Norwegian salmon by 60% from 2005 to 2020 (48), but farmed salmon remains very high in n–3 PUFAs (2–3 g/100 g). Production methods also vary widely in environmental impacts (4, 49), yet dietary guidelines rarely incorporate these factors. These studies suggest there is an untapped opportunity offered by recognizing and understanding the importance of production methods and environment for nutrition.

There are multiple opportunities to better implement interventions that enhance the nutrition and health of the US population within the food system. At the federal level, the Federal Supplemental Nutrition Assistance Program is a promising opportunity to introduce affordable domestic seafood into American diets, for instance, through bulk purchases of canned wild caught pink salmon, canned wild caught tuna, wild caught Alaska pollock, and farmed catfish (38). Coastal communities in Alaska, California, Maine, Massachusetts, and Oregon have leveraged funds from the National School Lunch Program and other sources to serve culturally appropriate, local seafood at schools (37, 50). The Federal Prohibited Species Donation Program allows prohibited catch of Alaskan groundfish and salmon that would be dumped overboard to be donated to food assistance programs (51). At retail, frozen seafood products appear to be a good entry point for low-income consumers (29), and frozen products can be prepared with less food waste than fresh seafood (52). Eating seafood purchased at retail and prepared at home is more affordable and healthier than at most restaurants (53, 54), and seafood portion sizes at restaurants are often smaller than home meals (55), although some consumers lack confidence preparing seafood at home (52).

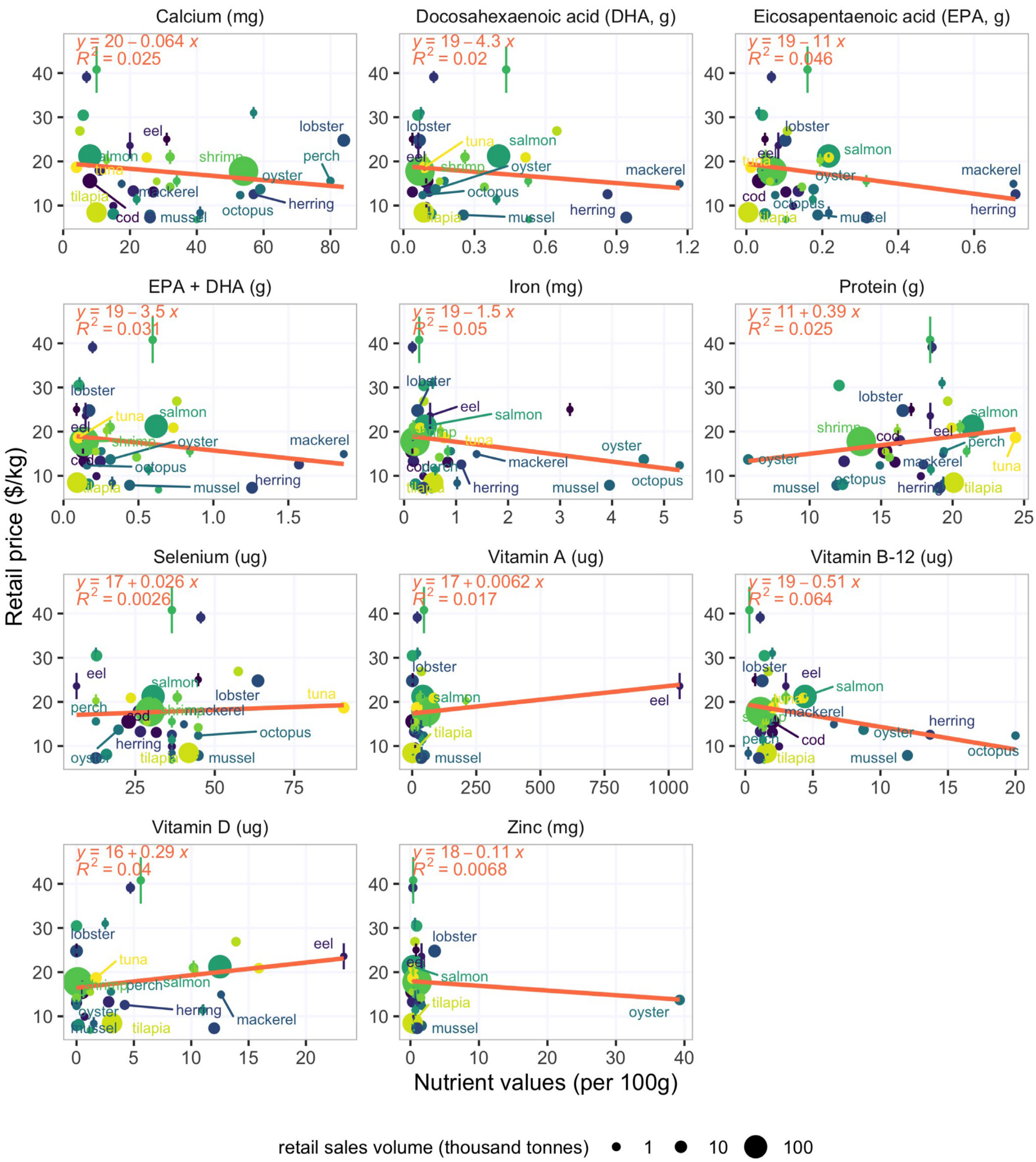

FIGURE 6 US retail price ($/kg, ± SD error bars) and nutrient density (per 100 g) for seafood species. Based on raw product nutrient values (n = 1–2 per species) and fresh/frozen retail unit prices for 34 seafood species groups with available data, Nielsen 2017–2019 and USDA Food and Nutrient Database for Dietary Studies. Dot size equals retail sales volume (thousand tonnes). Select species names provided. Colors are used to differentiate species. Multilinear regression for association between nutrients and seafood price weighted for the retail sales volume. None of the tests were statistically significant. The slope equation and R^2 values reported. Sample size for retail unit prices: shrimp (25,352), salmon (16,721), cod (4481), tilapia (3954), lobster (2809), tuna (2557), scallop (2325), oyster (2140), trout (1978), haddock (1197), whitefish (1156), herring (1130), flounder (1128), swordfish (1111), halibut (1109), snapper (1046), squid (1005), pollock (990), crawfish (956), mussel (934), sea bass (641), perch (578), mackerel (410), octopus (342), shark (230), croaker (152), pompano (102), pike (88), mullet (79), sturgeon (53), eel (51), surfperch (22), abalone (7), and scup (5). One kilogram equals 2.2 lbs.

By comparing seafood prices and nutrients, our study found that retailers do not set prices for seafood products based on their nutrient content. This is consistent with economic literature that indicates attributes such as quality, origin, and ecolabeling are what consumers value most (56, 57). At retail, over a third of seafood products are purchased fresh as random-weight items (e.g., from the seafood counter at supermarkets) (55), which is required to have labeling for country of origin and production method but not for nutrients; therefore, many consumers may be unaware of the nutrient content of different seafood products. Lower-priced species with favorable nutrient profiles do exist (e.g., mackerel, herring, mussels, octopus, and eel), but they may not be widely available, and some Americans may be unaccustomed to eating a diversity of aquatic animals beyond shrimp, salmon, canned tuna, tilapia, and cod (29, 53). The high (compared with low) n–3 PUFA group was more expensive, in part, because salmon makes up a large share of intake within the high n–3 PUFA group and is more expensive than many other fish.

Our study has a number of limitations. To maximize the sample size for demographic subgroups in the NHANES analysis, we pooled data across multiple cycles, and therefore our findings may not capture the changes in consumption that may have occurred over time within those groups. The use of 1 d of NHANES data rather than 2 d would not influence mean estimates but would tend to overestimate variance/confidence intervals and the percentage of the population at the tails of the distribution. NHANES and Nielsen measured seafood in a slightly different way; dietary intake data report the cooked weight of seafood eaten, whereas retail are raw weights, including added ingredients. Raw values for nutritional content in our analyses were selected because they match the unit prices of raw seafood, although this could be seen as a limitation because different types of seafood may be prepared and cooked in different ways, with important implications for the nutrient content and bioavailability of the final consumed product. We relied on the broad categories for ethnicity used in the NHANES, and there could be substantial variation within these categories, including by factors that could strongly influence dietary patterns.

In conclusion, the 2020 USDGs recommended that the population increase consumption of seafood. This study helps fill an important gap by describing the seafood consumption patterns of groups of different incomes and ethnicities in the United States. This information is needed to *1*) design and implement policy and interventions that aim to enhance seafood consumption among specific income and race/ethnic groups and *2*) identify and promote sustainable and affordable diets crucial for planetary health.

The authors' responsibilities were as follows—DCL, ALT-L, ZC, JAG, FA, and EMN: designed the research; JAG, ZC, DG-S, AM, and DCL: contributed data sets; DCL: analyzed the data; DCL, ALT-L: wrote the manuscript; DCL, ALT-L, ZC, JAG, FA, DG-S, AM, EMN, and MWB: provided critical review and feedback and read and approved the final manuscript; and all authors: have read and approved the final version.

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Data Availability

Data described in the manuscript and analytic code will be made available upon request.

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