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Reported fish-consumption patterns and modelled fish-derived nutrient contributions among school-going adolescents in Sylhet, Bangladesh: a cross-sectional survey

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Abstract

Background

Fish is central to Bangladeshi diets, but the species consumed may influence its nutrient contribution. This study described reported fish-consumption patterns among school-going adolescents in Sylhet Sadar and explored modelled fish-derived contributions under explicit serving-size assumptions, including variation by self-reported household financial condition.

Methods

A cross-sectional, school-based survey was conducted among 398 adolescents in Classes 6–10. An 11-item questionnaire assessed fish-consumption status, frequency, species and preparation methods. Reported frequency was linked to published species-specific nutrient-composition values using a 75 g edible-portion base case; deterministic 50 g and 100 g serving-size scenarios were also examined. Protein and micronutrient contributions were compared with selected age- and sex-relevant reference values. EPA + DHA was reported in mg/d and compared descriptively with 250 mg/d. Associations were examined using chi-square tests, exploratory regression models and concentration indices.

Results

Fish consumption was reported by 87.0% of participants. The most frequently reported species were Rohu (52.5%), Hilsa (41.9%), Tilapia (39.7%), Catla (34.9%) and Pangas (29.1%). Reported frequency differed across household financial-condition categories ($\chi^2 = 49.0$, $p < 0.001$). Under the 75 g base case, median modelled daily contributions among consumers were 4.96 g protein, 0.27 mg iron, 0.25 mg zinc, 43.1 mg calcium, 4.7 µg vitamin A, 0.53 µg vitamin B_{12} and 136 mg EPA + DHA. Across the 50–100 g scenarios, modelled contributions of iron, zinc, calcium and vitamin A remained comparatively low. Higher financial condition was associated with more frequent reported consumption (OR 4.07, 95% CI 2.57–6.45), and modelled contribution thresholds were generally concentrated among participants reporting higher financial condition; these analyses were exploratory and did not account for school/class clustering.

Conclusions

Fish consumption was commonly reported in the participating schools, but modelled nutrient contributions varied by nutrient and serving-size assumption. The estimates represent potential fish-derived contributions, not directly measured total dietary adequacy or biochemical deficiency. Quantitative dietary studies are needed to confirm the findings and assess their broader relevance.

Background

Adolescence (10–19 y) is a window of exceptional nutritional vulnerability. Linear growth, lean-mass accretion, sexual maturation and neurocognitive development collectively impose nutrient demands second only to those of the first 1,000 days of life [1]. Yet adolescents remain comparatively under-represented in nutrition information systems, dietary surveillance and policy across low- and middle-income countries (LMICs) [2]. In South Asia in particular, where stunting, anaemia and micronutrient deficiencies coexist with rapid food-system change, granular evidence on what adolescents actually eat - and what their diets deliver in nutritional terms - is scarce.

Bangladesh provides an instructive setting in which to interrogate this gap. Fish has long been the dominant animal-source food in Bangladeshi diets, contributing roughly 60% of animal protein nationally and embedded in cultural identity through the 'fish-and-rice' food complex [3]. Per-capita fish consumption rose from 7.6 kg/y in 1990 to over 24 kg/y today, driven almost entirely by an aquaculture sector that has expanded eight-fold since 1990 [3, 4]. Aquaculture now supplies 58% of total fish production in Bangladesh, dominated by farmed major carps, tilapia and pangasius [4, 5].

This expansion has been celebrated as a food-security success, but national analyses have also raised concerns about nutrient quality. Bogard et al. (2017), using nationally representative household surveys spanning 1991–2010, reported that despite a 30% increase in total fish consumption, estimated iron and calcium intakes from fish declined, with no improvement in zinc, vitamin A or vitamin B_{12}[3]. Small indigenous species (SIS), often consumed whole with bones and viscera, can provide substantially more iron, calcium and vitamin A than commonly farmed large species [6, 7, 8]. These findings suggest that changes in species composition may influence the nutrient contribution of fish, although species availability, preparation and edible portion also matter.

Whether similar species patterns are present among adolescents has been less well described. Existing Bangladeshi studies have often relied on household-level apparent-consumption data, which cannot directly describe individual adolescent intake or intra-household allocation [3, 9]. A recent study of adolescent girls in coastal aquaculture eco-zones documented agro-ecological variation in whole-blood omega-3 status [10], but did not estimate the fish-derived contribution of several micronutrients in a mixed-sex school sample. The present survey therefore provides local, exploratory evidence rather than a nationally representative dietary assessment.

The present study combined a cross-sectional school survey of 398 adolescents in Sylhet Sadar with published species-level composition values. Because portion size and species-specific frequency were not directly measured, the nutrient component was treated as model-based estimation with a prespecified base case and alternative serving-size scenarios. The study addressed three questions:

1. What fish-consumption frequencies, species and preparation methods were reported by adolescents attending the participating schools?
2. Under a prespecified base case and alternative serving-size scenarios, what potential contribution could reported fish consumption make to selected nutrient reference values?
3. How were reported consumption frequency and modelled contribution thresholds associated with self-reported household financial condition, sex and age?

The analysis was informed by a food-systems perspective in which species mix, edible portion and consumption frequency are potentially important determinants of the nutrient contribution of aquatic foods [3, 6, 8].

Methods

Study design and setting

A school-based, cross-sectional survey was conducted in Sylhet Sadar upazila, Sylhet division, north-eastern Bangladesh. Data were collected between 28 August 2025 and 15 September 2025. Sylhet Sadar is a mixed urban / peri-urban sub-district with a high density of government and non-government secondary schools and a long tradition of fish consumption derived from the surrounding haor (wetland) ecosystem. Data were collected during one academic term (Classes 6–10).

Participants and sampling

The target population comprised school-going adolescents aged 11–18 y enrolled in Classes 6–10. A pragmatic two-stage recruitment approach was used. Schools were grouped by type (government vs non-government) and approached based on accessibility and willingness to participate; within participating schools, intact classes were invited. This was not a probability sample of schools or adolescents. Eligibility criteria were (i) enrolment in a participating school and class, (ii) presence on the survey day, and (iii) provision of assent and, where required, parental consent.

Sample size. The initial target was estimated using the Naing et al. (2022) prevalence formula [11]: $n_0 = Z^2p(1 - p)/d^2$, with $Z = 1.96$, $p = 0.50$ and $d = 0.05$, giving $n_0 \approx 384$. A design-effect inflation of 1.5 and 10% non-completion allowance produced an aspirational target of approximately 635. In the field, 442 questionnaires were distributed and 398 were complete. Because schools were recruited pragmatically and the planned target was not reached, conventional precision calculations should not be interpreted as design-based population precision.

Data collection

Data were collected using an 11-item paper-based, self-administered questionnaire developed in English and translated into Bangla by bilingual researchers. Minor wording adjustments were made after pilot

testing among students not included in the main analysis. Items were informed by published instruments on adolescent fish consumption [12, 13] and local dietary practice. The questionnaire captured socio-demographic characteristics, self-reported household financial condition, fish-consumption status and categorical frequency, species reported, preparation methods, size preference and reasons for non-consumption. Trained research assistants supervised classroom completion without teacher influence. The instrument did not collect weighed portions, repeated 24-hour recalls, total dietary intake or a separate consumption frequency for each selected species.

Species-level nutrient composition database

A species-level nutrient-composition database (per 100 g edible portion) was compiled from peer-reviewed sources prioritising Bangladeshi or geographically proximate fish. Primary values were taken from Bogard et al. (2015) [6] and Bogard et al. (2017) [3], with cross-checking against Roos et al. (2003) [7], Byrd et al. (2021) [8], Hossain et al. (2014) [14] and Mohanty et al. (2019) [15]. Nutrients were protein, EPA + DHA, iron, zinc, calcium, vitamin A (RAE) and vitamin B_{12}. Whole-fish values were used for SIS when reported; for larger species, edible-portion values were retained as defined in the source publication. Because source studies did not use fully uniform definitions of edible portion, production system, season or cooking state, composition values should be interpreted as representative inputs rather than participant-specific measurements.

Estimation of nutrient intake from fish

For each respondent, weekly fish-derived nutrient contribution was modelled by linking reported frequency, selected species and a prespecified 75 g edible portion to species-level nutrient density. Frequency was converted to servings per week as follows: every day = 7; 2–3 times/week = 2.5; once/week = 1; rarely = 0.25; non-consumer = 0. Daily values were calculated as weekly values divided by seven. When multiple species were selected, their nutrient densities were averaged equally because species-specific frequencies were unavailable. For the fewer than five consumers who reported no species, Rohu was used as the base-case proxy. These rules define a modelled base case and do not represent directly measured individual intake. Because the questionnaire did not provide measured portion size or species-specific frequency, alternative frequency mappings and species-allocation weights were not empirically identifiable and were not numerically modelled.

Reference values and descriptive contribution thresholds

The adolescent focus was considered in light of Bangladesh's rapid reduction in undernutrition over recent decades [16] and the demographic importance of this age group; people aged 10–19 years represented about one fifth of the national population in 2020 [17]. Protein and micronutrient contributions were compared with selected age- and sex-relevant reference values from World Health Organization/Food and Agriculture Organization (WHO/FAO) sources, including the 2004 vitamin and

mineral report and the WHO/FAO/UNU protein report [18, 25]. Iron comparisons assumed 10% bioavailability and zinc comparisons assumed moderate bioavailability. EPA + DHA was reported primarily in mg/d. Because FAO did not establish a quantitative EPA + DHA recommendation for children aged 2–18 y, 250 mg/d was used only as a descriptive adult comparison value and not as an adolescent RNI [26]. Thresholds of 25% and 50% were retained as descriptive fish-contribution cut-points; crossing them was not interpreted as total dietary adequacy.

Statistical analysis

Continuous variables were summarised as mean ± SD or median (IQR); categorical variables as n (%). Associations between reported consumption frequency and self-reported household financial condition were examined using chi-square with Cramér's V. Exploratory multivariable models included (i) logistic regression of reported fish consumption on financial condition, sex and age; (ii) ordered logistic regression of reported frequency among consumers on financial condition, sex and age; and (iii) logistic regression of descriptive 25% contribution thresholds for protein, vitamin B_{12} and EPA + DHA (the latter relative to the 250 mg/d comparison value) on financial condition, sex and age. Results are reported as odds ratios with 95% confidence intervals.

Income-related inequality was explored using Erreygers-corrected concentration indices for binary contribution-threshold outcomes [19]. Positive values indicate concentration among adolescents reporting higher household financial condition and negative values indicate concentration among those reporting lower financial condition. Because financial condition had only three self-reported categories, these indices were treated as exploratory summaries rather than precise measures of household income inequality.

All analyses were conducted in Python 3.12 using pandas (1.5.3), numpy (1.26), statsmodels (0.14.2) and scipy (1.13). Two-sided $p < 0.05$ was used as a conventional significance threshold. School- and class-level identifiers were unavailable for analysis; consequently, the reported confidence intervals were not recalculated with cluster-robust methods and should be interpreted as exploratory. The analysis code and de-identified dataset are available from the corresponding author on reasonable request.

Ethics

Ethical approval

was obtained from Sylhet Agricultural University (approval code ARP2026073). Written permission was obtained from participating school authorities; written informed consent was obtained from parents or guardians, and written assent was obtained from each adolescent. Participation was voluntary, no identifying information was recorded, and the study was conducted in accordance with the Declaration of Helsinki (2013).

Results

Sample characteristics

Of 442 distributed questionnaires, 398 were fully complete (completion proportion 90.0%). The mean age was 14.2 ± 1.4 y (median 15, IQR 14–15); 240 (60.3%) participants were male and 158 (39.7%) female. Most respondents described their household financial condition as middle (309; 77.6%); 50 (12.6%) selected low and 37 (9.3%) high, while two mixed responses (0.5%) were excluded from stratified analyses (Table 1).

Table 1
Socio-demographic characteristics of adolescent respondents, Sylhet Sadar, Bangladesh (n = 398).

Characteristic	**n (%) or mean ± SD**
Sex	
Male	240 (60.3)
Female	158 (39.7)
Age (years)	14.2 ± 1.4
Median (IQR)	15 (14–15)
Class	
Class 6	62 (15.6)
Class 7	58 (14.6)
Class 8	67 (16.8)
Class 9	117 (29.4)
Class 10	94 (23.6)
School type	
Government	98 (24.6)
Non-government	300 (75.4)
Household financial condition	
Low	50 (12.6)
Middle	309 (77.6)
High	37 (9.3)
Mixed (excluded from stratified analyses)	2 (0.5)

Fish consumption prevalence and frequency

Most adolescents (346; 87.0%) reported consuming fish; 52 (13.0%) did not. Among consumers, 50.6% reported fish 2–3 times/week, 25.7% every day, 10.1% once/week and 13.6% rarely. Frequency differed across categories of self-reported household financial condition ($\chi^2 = 49.0$, df = 6, $p < 0.001$, Cramér's V = 0.27): low-condition respondents more often reported rare consumption (32.6%) and less often daily consumption (10.9%), whereas 66.7% of high-condition consumers reported daily consumption (Fig. 1). In the exploratory ordered logistic model, each one-category increase in financial condition was associated with higher odds of a more frequent category (OR 4.07; 95% CI 2.57–6.45; Table 2).

Table 2

Exploratory logistic and ordered logistic models of reported fish consumption, frequency and modelled contribution thresholds (n = 396 after exclusion of two mixed financial-condition responses).

Outcome / predictor	OR (95% CI)	p	Reference
Logistic: reports fish consumption = yes			
High financial condition	0.58 (0.24–1.43)	0.239	Middle
Low financial condition	1.75 (0.59–5.15)	0.310	Middle
Male	0.89 (0.48–1.66)	0.723	Female
Age (per year)	1.20 (0.95–1.52)	0.125	-
Ordered logit: reported frequency category (consumers, n = 344)			
Financial condition (per category)	4.07 (2.57–6.45)	< 0.001	-
Male	1.08 (0.71–1.63)	0.723	Female
Age (per year)	1.05 (0.90–1.22)	0.563	-
Logistic: modelled protein contribution ≥ 25% reference			
High financial condition	4.11 (2.03–8.32)	< 0.001	Middle
Low financial condition	0.35 (0.12–1.01)	0.053	Middle
Male	0.88 (0.53–1.46)	0.618	Female
Age (per year)	1.05 (0.86–1.27)	0.650	-
Logistic: modelled EPA + DHA contribution ≥ 25% comparison*			
High financial condition	1.89 (0.88–4.06)	0.101	Middle
Low financial condition	0.65 (0.36–1.18)	0.159	Middle
Male	0.88 (0.58–1.34)	0.559	Female

Outcome / predictor	OR (95% CI)	p	Reference
Logistic: reports fish consumption = yes			
Age (per year)	0.97 (0.83–1.13)	0.692	-
Logistic: modelled vitamin B_{12} contribution ≥ 25% reference			
High financial condition	2.00 (0.99–4.05)	0.053	Middle
Low financial condition	0.59 (0.31–1.12)	0.109	Middle
Male	0.99 (0.65–1.49)	0.947	Female
Age (per year)	1.08 (0.93–1.26)	0.322	-

OR, odds ratio; CI, confidence interval. Models adjust for the other listed covariates. EPA + DHA threshold models use 25% of a descriptive 250 mg/d comparison value, not an adolescent RNI. Confidence intervals were not adjusted for school/class clustering and should be interpreted as exploratory.

Species and preparation profile

The five most frequently reported species were Rohu (Rui; 209/398, 52.5%), Hilsa (Ilish; 167/398, 41.9%), Tilapia (158/398, 39.7%), Catla (139/398, 34.9%) and Pangas (116/398, 29.1%) (Fig. 2A). Other species—including Pabda, Koi, Boal and prawn/shrimp—were each reported by ≤ 9 respondents (combined 5%). No respondent named a specific SIS such as mola, dhela, kachki or puti in the open “other species” response. Most respondents (59.5%) reported eating both small and large fish; 33.7% preferred large fish only and 6.0% small fish only.

Preparation most often included fried fish (273/398, 68.6%) and fish curry (202/398, 50.8%); vorta (mashed fish) was reported by 80 (20.1%), and only one respondent reported a steamed/baked preparation such as paturi (Fig. 2B).

Reasons for non-consumption

Among the 52 non-consumers, the reported counts were 30 for dislike of taste, 21 for fear of bones, 13 for unpleasant smell, three for family non-cooking practice, and one each for allergy and vegetarianism (Fig. 3). Using the consistent denominator of 52, these correspond to 57.7%, 40.4%, 25.0%, 5.8%, 1.9% and 1.9%, respectively. Responses were multi-select.

Species-level nutrient density

Under the assumed 75 g edible portion, published species-level nutrient densities varied substantially (Fig. 4). SIS provided 27.6% of the selected iron reference, 54.8% of calcium and 35.6% of vitamin A. Hilsa provided 12.6% of the iron reference and 11.8% of calcium; therefore, it did not cross the 25% iron threshold. Rohu and Catla provided 6.0% of the iron reference and 13.6–15.5% of calcium, while Tilapia and Pangas provided < 4% for iron, calcium and vitamin A. EPA + DHA is shown as mg per 75 g serving rather than as a percentage of an adolescent RNI.

Estimated daily fish-derived nutrient intake

Under the 75 g base-case model, median (IQR) daily fish-derived contributions among consumers were: protein 4.96 g (3.3–10.5); iron 0.27 mg (0.16–0.59); zinc 0.25 mg (0.13–0.55); calcium 43.1 mg (24.7–93.7); vitamin A 4.7 µg RAE (1.8–9.9); vitamin B_{12} 0.53 µg (0.27–1.30); and EPA + DHA 136 mg (80–340) (Fig. 5). These are modelled contributions, not directly measured dietary intakes.

In the 75 g base case, 21.4% of adolescents crossed the descriptive 25% protein contribution threshold and 44.5% crossed the vitamin B_{12} threshold; 29.3% crossed the 50% vitamin B_{12} threshold. For iron, zinc, calcium and vitamin A, ≤ 0.5% crossed the 25% contribution threshold. Median EPA + DHA was 136 mg/d; 58.3% crossed 25% of the descriptive 250 mg/d comparison value. These thresholds describe the estimated contribution of fish only and do not establish total dietary adequacy (Table 3, Fig. 6).

Table 3
Base-case modelled daily fish-derived nutrient contribution among consumers (n = 346).

Nutrient	Mean modelled daily contribution	Median modelled daily contribution	Mean % of selected reference/comparison	% below 50% reference/comparison
Protein (g)	6.40	4.96	14.3	100
Iron (mg)	0.41	0.27	3.1	100
Zinc (mg)	0.33	0.25	3.5	100
Calcium (mg)	62.1	43.1	4.8	100
Vitamin A (µg RAE)	8.4	4.7	1.4	100
Vitamin B_{12} (µg)	0.98	0.53	44.0	66.5
EPA + DHA (mg)	237.3	136.1	**94.9***	**48.8***

Protein and micronutrient percentages use selected age-/sex-relevant reference values. Iron assumes 10% bioavailability and zinc moderate bioavailability. *EPA + DHA percentage and threshold values use 250 mg/d as a descriptive comparison, not an adolescent RNI.

Serving-size sensitivity analysis

To examine one major assumption without constructing unobserved respondent data, base-case mean and median contributions were proportionally recalculated for 50 g and 100 g portions while holding reported frequency, species allocation and composition values constant. This deterministic analysis isolates serving-size uncertainty only.

Table 3

A. Deterministic serving-size sensitivity analysis among consumers (n = 346). Each cell reports mean; median; and, where applicable, mean percentage of the selected reference value.

Nutrient	50 g scenario	75 g base case	100 g scenario
Protein	Mean 4.27; median 3.31 g/d; mean 9.5% reference	Mean 6.40; median 4.96 g/d; mean 14.3% reference	Mean 8.53; median 6.61 g/d; mean 19.1% reference
Iron	Mean 0.3; median 0.2 mg/d; mean 2.1% reference	Mean 0.4; median 0.3 mg/d; mean 3.1% reference	Mean 0.5; median 0.4 mg/d; mean 4.1% reference
Zinc	Mean 0.2; median 0.2 mg/d; mean 2.3% reference	Mean 0.3; median 0.2 mg/d; mean 3.5% reference	Mean 0.4; median 0.3 mg/d; mean 4.7% reference
Calcium	Mean 41.4; median 28.7 mg/d; mean 3.2% reference	Mean 62.1; median 43.1 mg/d; mean 4.8% reference	Mean 82.8; median 57.5 mg/d; mean 6.4% reference
Vitamin A	Mean 5.60; median 3.13 µg RAE/d; mean 0.9% reference	Mean 8.40; median 4.70 µg RAE/d; mean 1.4% reference	Mean 11.20; median 6.27 µg RAE/d; mean 1.9% reference
Vitamin B_{12}	Mean 0.65; median 0.35 µg/d; mean 29.3% reference	Mean 0.98; median 0.53 µg/d; mean 44.0% reference	Mean 1.31; median 0.71 µg/d; mean 58.7% reference
EPA + DHA	Mean 158.2; median 90.7 mg/d; no adolescent RNI applied	Mean 237.3; median 136.1 mg/d; no adolescent RNI applied	Mean 316.4; median 181.5 mg/d; no adolescent RNI applied

Because nutrient estimates scale linearly with assumed portion size, this analysis quantifies the effect of portion magnitude but does not validate the underlying model. Under the 100 g scenario, mean contributions remained 4.1% of the iron reference, 4.7% of zinc, 6.4% of calcium and 1.9% of vitamin A. Mean vitamin B_{12} contribution increased proportionally from 29.3% at 50 g to 44.0% at 75 g and 58.7% at 100 g; mean EPA + DHA likewise increased from 158.2 to 237.3 and 316.4 mg/d. Frequency coding, equal species weighting, cooking retention and nutrient-composition variability were not numerically sensitivity-tested and remain sources of uncertainty.

Income-related inequality in modelled fish-derived contribution thresholds

Erreygers-corrected concentration indices were positive for the modelled protein, vitamin B_{12} and EPA + DHA contribution thresholds, indicating that threshold crossing was more concentrated among adolescents reporting higher household financial condition (Fig. 7, Table 4). Point estimates were + 0.110 for protein ≥ 25%, + 0.144 for vitamin B_{12} ≥25% and + 0.110 for EPA + DHA ≥ 25% of the descriptive comparison value. At the 50% thresholds, the indices were + 0.161 for vitamin B_{12} and + 0.134 for EPA + DHA. The index for reported fish consumption status was small and negative (− 0.032). These exploratory indices do not establish causal income effects.

Table 4
Exploratory concentration indices for self-reported household financial condition and modelled fish-derived contribution thresholds (n = 396).

Outcome	Mean proportion	Standard CI	Erreygers-corrected CI
Protein ≥ 25% reference	0.215	+ 0.129	+ 0.110
EPA + DHA ≥ 25% comparison*	0.586	+ 0.047	+ 0.110
Vitamin B_{12} ≥25% reference	0.447	+ 0.081	+ 0.144
EPA + DHA ≥ 50% comparison*	0.447	+ 0.075	+ 0.134
Vitamin B_{12} ≥50% reference	0.293	+ 0.138	+ 0.161
Reports fish consumption (yes/no)	0.874	−0.009	−0.032

Multivariable analysis of modelled contribution thresholds

In exploratory models adjusted for sex and age, the largest financial-condition association was observed for the protein 25% contribution threshold: high versus middle aOR = 4.11 (95% CI 2.03–8.32; $p < 0.001$) and low versus middle aOR = 0.35 (95% CI 0.12–1.01; $p = 0.053$). For vitamin B_{12}, the corresponding aORs were 2.00 (0.99–4.05; $p = 0.053$) and 0.59 (0.31–1.12; $p = 0.109$). For EPA + DHA relative to the descriptive comparison threshold, they were 1.89 (0.88–4.06; $p = 0.101$) and 0.65 (0.36–1.18; $p = 0.159$). Sex and age were not statistically significant in these models. Because modelled nutrient contributions were constructed partly from reported frequency, the previous claim that frequency “mediated” the financial-condition association was removed; no formal causal mediation analysis was performed (Fig. 8).

Discussion

This study directly describes reported fish-consumption patterns in participating schools and secondarily models the potential nutrient contribution of those patterns. Fish consumption was common (87.0%), but frequency differed across self-reported household financial-condition categories. Under the

75 g base case, modelled contributions were relatively greater for vitamin B_{12} and EPA + DHA than for iron, zinc, calcium and vitamin A. The serving-size sensitivity analysis preserved this relative pattern: even at 100 g, mean contributions for iron, zinc, calcium and vitamin A remained below 7% of their selected reference values. These findings are local and model-based; they do not establish total dietary adequacy, biochemical deficiency or effects of national aquaculture policy.

Interpretation in the context of the Bangladesh aquaculture transition

The reported species profile was dominated by Rohu, Hilsa, Tilapia, Catla and Pangas, broadly consistent with the prominence of major carps and introduced farmed species in Bangladesh [3, 4, 5]. No respondent named a specific SIS in the open-response category. Published composition data indicate that whole-eaten SIS can provide substantially more calcium and vitamin A per edible portion than many larger fish [6, 7, 8, 20]. However, the survey did not measure actual portion size, bone consumption, species-specific frequency or cooking retention, so the nutrient-density comparison should be viewed as a hypothesis-generating contrast rather than evidence that individual adolescents consumed or lacked a particular nutrient.

Reported consumption frequency and several modelled contribution thresholds were more favourable in higher financial-condition categories. The ordered-logistic estimate remained after adjustment for sex and age, but the cross-sectional design, self-reported three-category socioeconomic measure, pragmatic school sample and lack of cluster-adjusted reanalysis limit causal interpretation. In particular, the data do not show that financial condition causes the observed pattern or that frequency formally mediates nutrient contribution. The results are consistent with the possibility that affordability, access and household food practices influence frequency, but these mechanisms were not directly measured [3, 21].

Comparison with prior literature

The 87.0% prevalence of reported fish consumption was higher than that reported in some adolescent studies from other settings, including a Polish school sample [12]. Direct numerical comparison is limited because questionnaires, recall periods, serving definitions and cultural food environments differ. Taste, smell and fear of bones were nevertheless similar to barriers described in the broader seafood-consumption literature [13, 22], supporting further local work on acceptability rather than assuming that a single product strategy will transfer across settings.

The base-case median EPA + DHA contribution was 136 mg/d. This estimate cannot be interpreted as an adolescent adequacy prevalence because no quantitative FAO recommendation was established for children aged 2–18 y [26]. The biomarker findings reported by Grieve et al. (2023) in Bangladeshi adolescent girls [10] provide relevant context, but they do not validate the present model because the populations, exposure measures and outcomes differ. Hilsa had a high published EPA + DHA density, yet the survey did not record the frequency or portion of Hilsa separately; therefore, the manuscript no longer labels Hilsa a population “nutritional buffer.”

The low modelled contributions of iron, zinc, calcium and vitamin A are directionally consistent with national analyses showing that greater aggregate fish availability does not necessarily produce proportional gains in every micronutrient [3]. The present study adds a school-based species-reporting perspective, but it cannot extend household apparent-consumption estimates to measured individual intake because all nutrient values remain modelled.

Potential implications and research priorities

The findings suggest three areas for further evaluation rather than immediate national policy prescriptions.

First, future nutrition-sensitive aquaculture and food-environment studies could compare the affordability, availability and adolescent acceptability of nutrient-dense small fish with commonly consumed larger species [23]. The current data do not determine what proportion of SIS production should be targeted or whether changing production would improve adolescent nutrient status.

Second, product-development research could test low-bone or bone-softened fish formats because fear of bones and sensory concerns were commonly reported among non-consumers. Fish balls, patties, nuggets or vorta-style products are plausible prototypes, but their nutrient retention, safety, cost and acceptability require direct evaluation before programme recommendations are made.

Third, the financial-condition gradient indicates that equity and affordability should be considered in future intervention studies. The present concentration indices do not demonstrate that school provision, cash transfers or subsidies would be effective; such options should be tested prospectively with measured dietary and nutritional outcomes.

Strengths and limitations

Strengths include a high completion proportion among distributed questionnaires, species- and preparation-level reporting, integration of several peer-reviewed composition sources, and explicit separation of directly observed survey findings from modelled nutrient contributions. The serving-size sensitivity analysis also makes one major modelling assumption visible rather than presenting the 75 g estimate as a measured portion.

Several limitations are important. First, schools were recruited pragmatically in one upazila, non-government schools were over-represented, and school/class clustering was not incorporated in the analysis; population generalisability and inferential precision are therefore limited. Second, frequency was self-reported and the questionnaire did not collect weighed portions, repeated recalls, total dietary intake or species-specific frequency. The 50–100 g sensitivity analysis addresses only serving-size uncertainty; it cannot resolve frequency coding, equal species weighting, nutrient-composition variability or cooking retention. Third, the estimates concern fish-derived contribution only and cannot classify total dietary adequacy or micronutrient deficiency. Fourth, biomarkers were not measured. Fifth, composition values vary by season, geography, production system, edible portion and preparation, and the current

model uses representative published values. Sixth, self-reported household financial condition is an ordinal proxy rather than measured income. Finally, the cross-sectional design precludes causal or mediation conclusions.

Future directions

Future studies should prioritise repeated quantitative dietary assessment, ideally with a validation subsample using weighed portions or repeated 24-hour recalls; record species-specific frequency and preparation; include school/class identifiers for clustered analysis; and, where feasible, link intake estimates with biomarkers. Mixed-methods work can assess the acceptability and affordability of nutrient-dense fish products before any school- or community-level trial.

Conclusions

Among adolescents attending the participating schools in Sylhet Sadar, fish consumption was commonly reported, although frequency varied by self-reported household financial condition. Model-based estimates under 50 g, 75 g and 100 g serving assumptions suggested that the reported fish pattern could contribute more vitamin B_{12} and EPA + DHA than iron, zinc, calcium or vitamin A. The serving-size analysis did not resolve uncertainty from frequency coding, equal weighting of selected species, nutrient-composition values or cooking retention. Accordingly, the results should be interpreted as potential fish-derived contributions—not total dietary adequacy, biochemical deficiency, causal income effects or nationally representative evidence. The study supports further quantitative dietary assessment and evaluation of acceptable, nutrient-dense fish options for adolescents.

Abbreviations

aOR
adjusted odds ratio
CI
confidence interval
DHA
docosahexaenoic acid
ECI
Erreygers-corrected concentration index
EPA
eicosapentaenoic acid
FAO
Food and Agriculture Organization
FFQ
food-frequency questionnaire
IQR

interquartile range
LMIC
low- and middle-income country
OR
odds ratio
RAE
retinol activity equivalents
RNI
recommended nutrient intake
SD
standard deviation
SIS
small indigenous species
WHO
World Health Organization.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from Sylhet Agricultural University (approval code ARP2026073). Written permission was obtained from participating school authorities; written informed consent was obtained from parents or guardians, and written assent was obtained from each adolescent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Authors' information

Not applicable.

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Author Contribution

H.R.K., M.R. and S.J. conceptualized the study. H.R.K., M.R., A.H.S. and S.J. contributed to the methodology and study design. M.R., M.A. and J.M. conducted data collection. H.R.K. and S.J. performed data analysis. H.R.K. prepared the original manuscript draft. S.J. and S.N. contributed to interpretation of results and manuscript refinement. All authors reviewed and edited the manuscript and approved the final version.

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Availability of data and materials

The datasets and analysed during the current study are available from the corresponding author on reasonable request.

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Figures

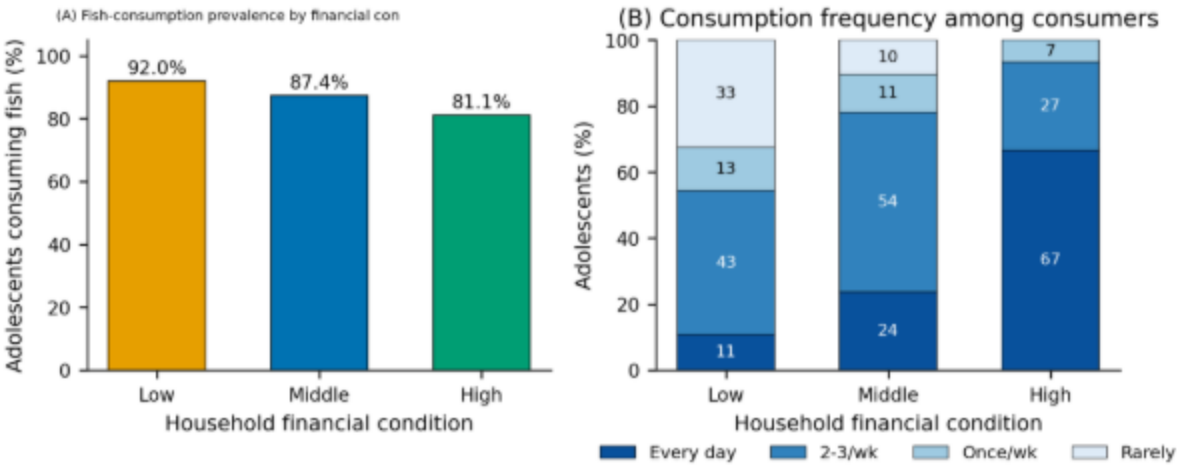


Figure 1

Reported fish-consumption prevalence and frequency by self-reported household financial condition among participating adolescents. Numbers within stacked bars are within-stratum percentages.

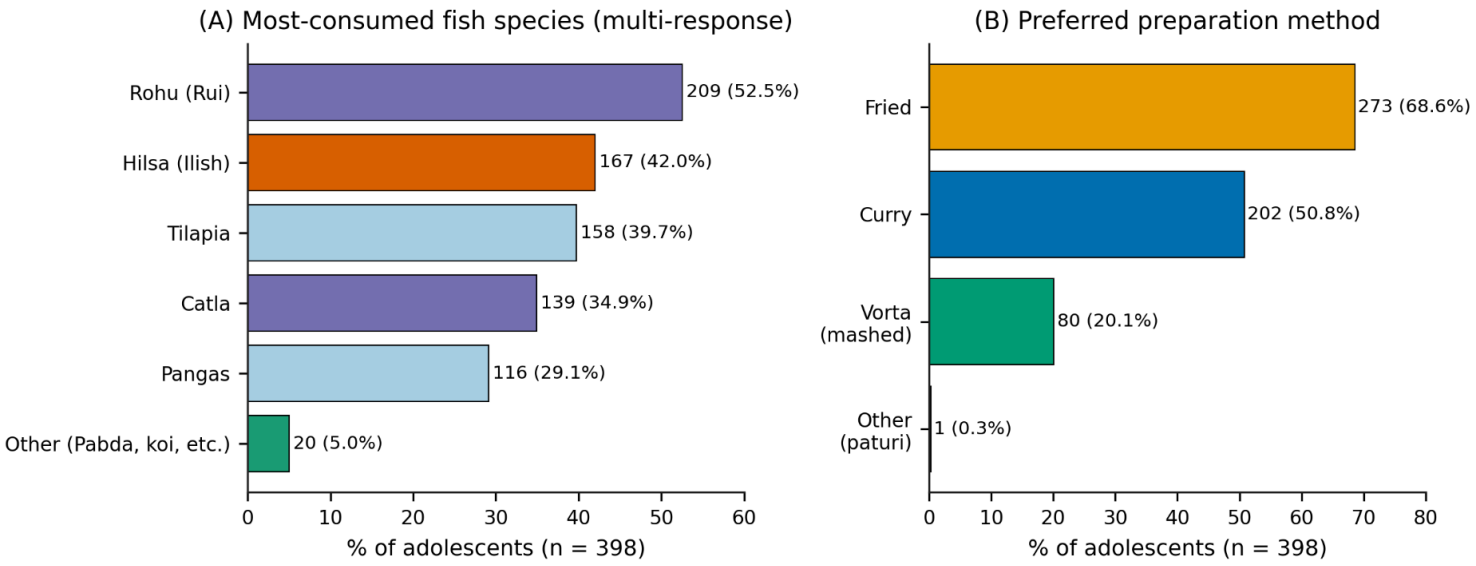


Figure 2

Species and preparation methods reported by participating adolescents (n = 398; multi-response). (A) Most frequently reported species. (B) Preparation methods.

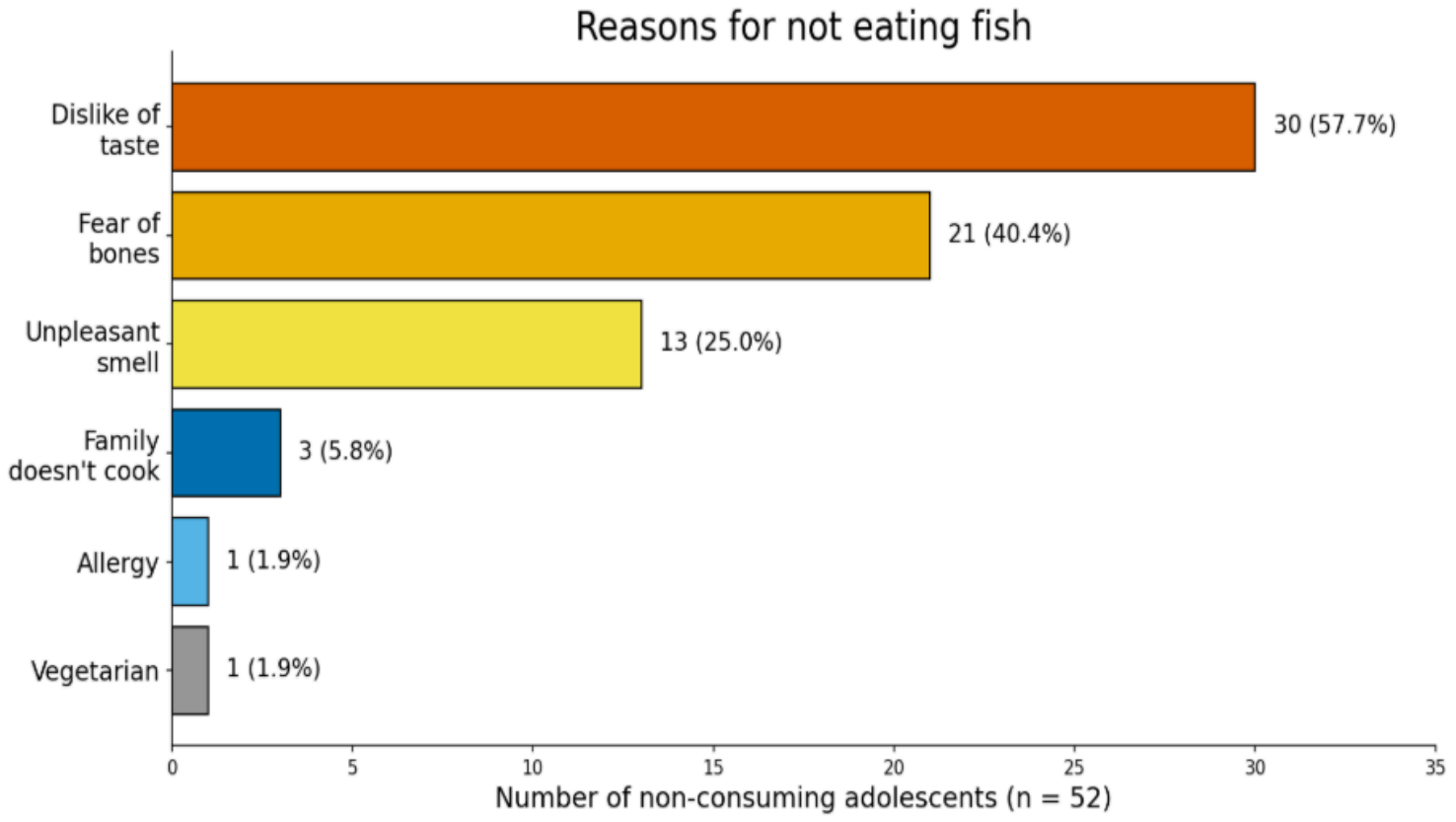


Figure 3

Reasons reported for not consuming fish among 52 non-consuming adolescents. Responses were multi-select, so counts sum to more than 52.

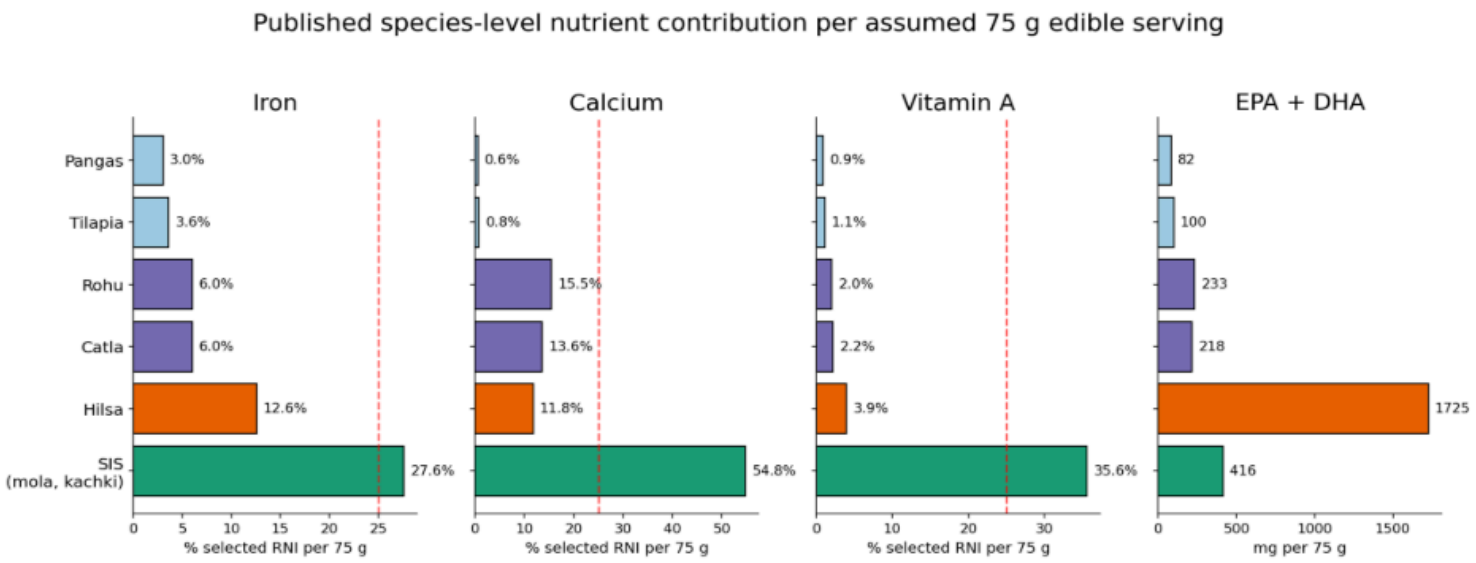


Figure 4

Published species-level nutrient contribution per assumed 75 g edible serving. Iron, calcium and vitamin A are expressed as percentages of the selected adolescent micronutrient reference value; EPA+DHA is expressed in mg per serving. The 25% line applies only to the micronutrient panels. SIS = small indigenous species.

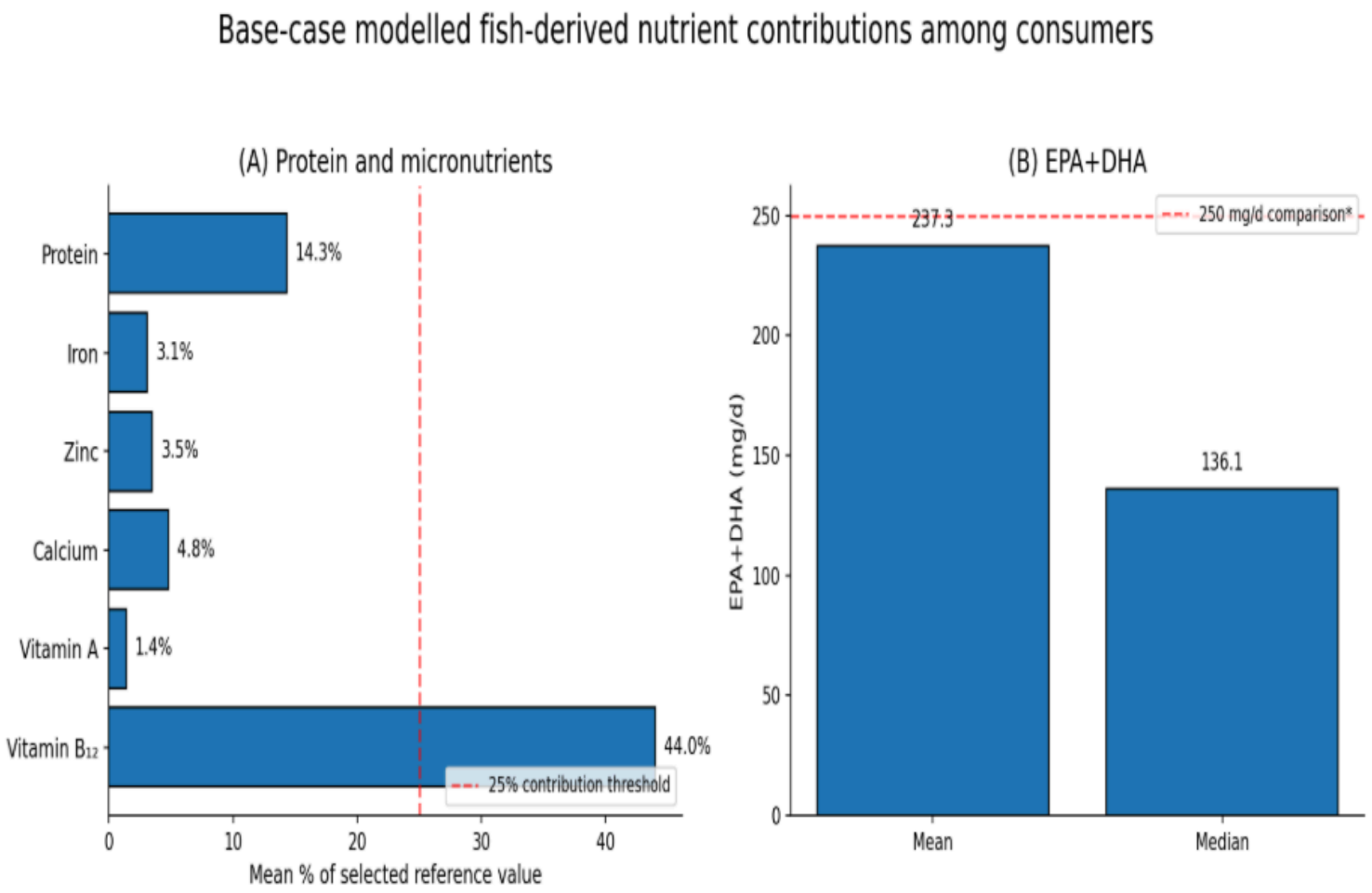


Figure 5

Base-case modelled fish-derived nutrient contributions among consumers. (A) Mean percentage of selected reference values for protein and micronutrients. (B) Mean and median EPA+DHA contribution in mg/d; 250 mg/d is shown only as a descriptive comparison value, not an adolescent RNI.

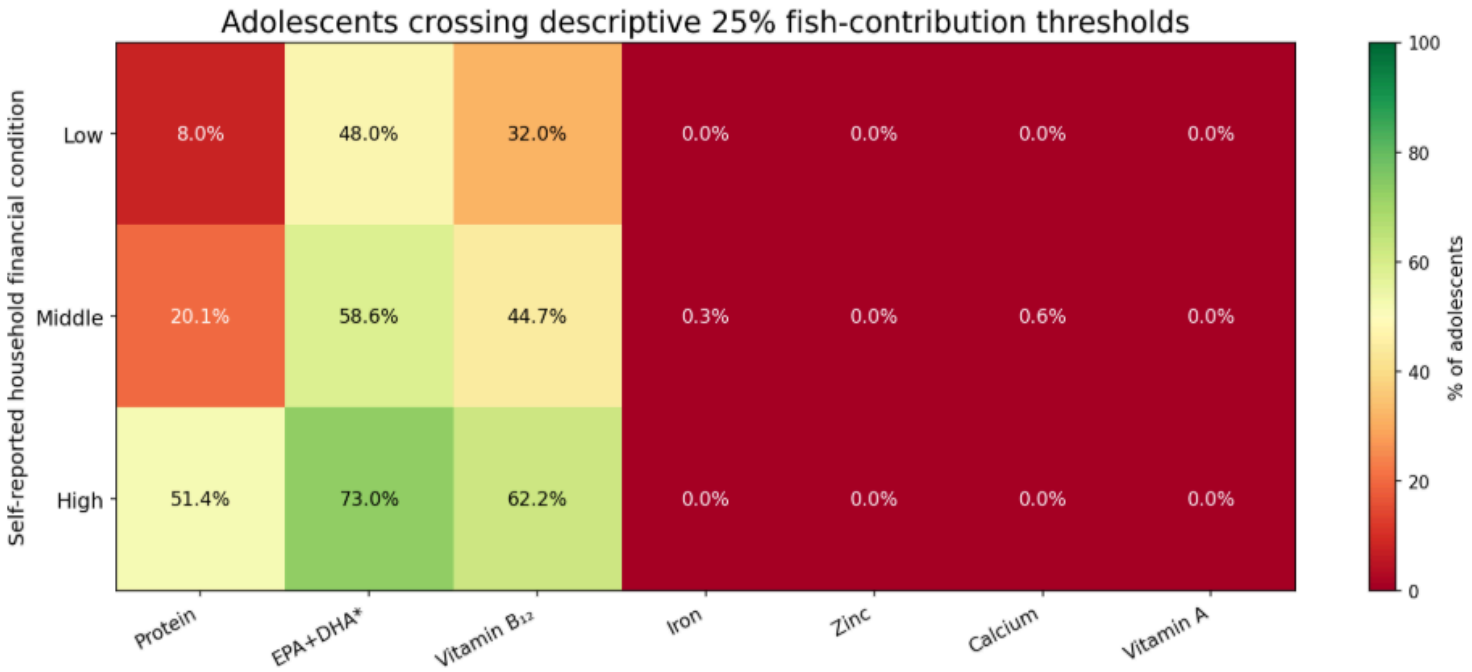


Figure 6

Percentage of adolescents (n = 396) crossing descriptive 25% fish-contribution thresholds, stratified by self-reported household financial condition. *EPA+DHA uses 25% of a 250 mg/d descriptive comparison value, not an adolescent RNI.

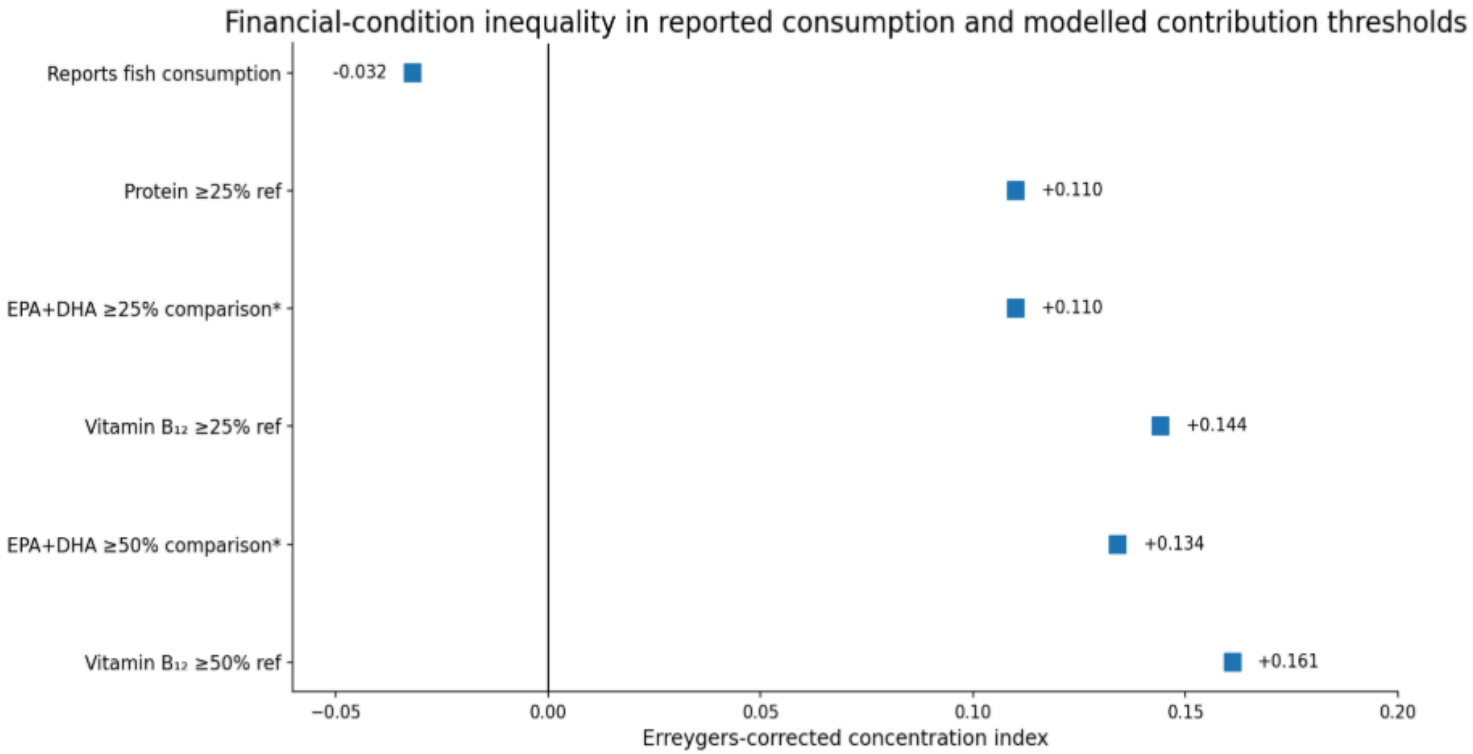


Figure 7

Erreygers-corrected concentration-index point estimates for reported fish consumption and modelled contribution thresholds. Positive values indicate concentration among adolescents reporting higher household financial condition. *EPA+DHA uses a descriptive 250 mg/d comparison value.

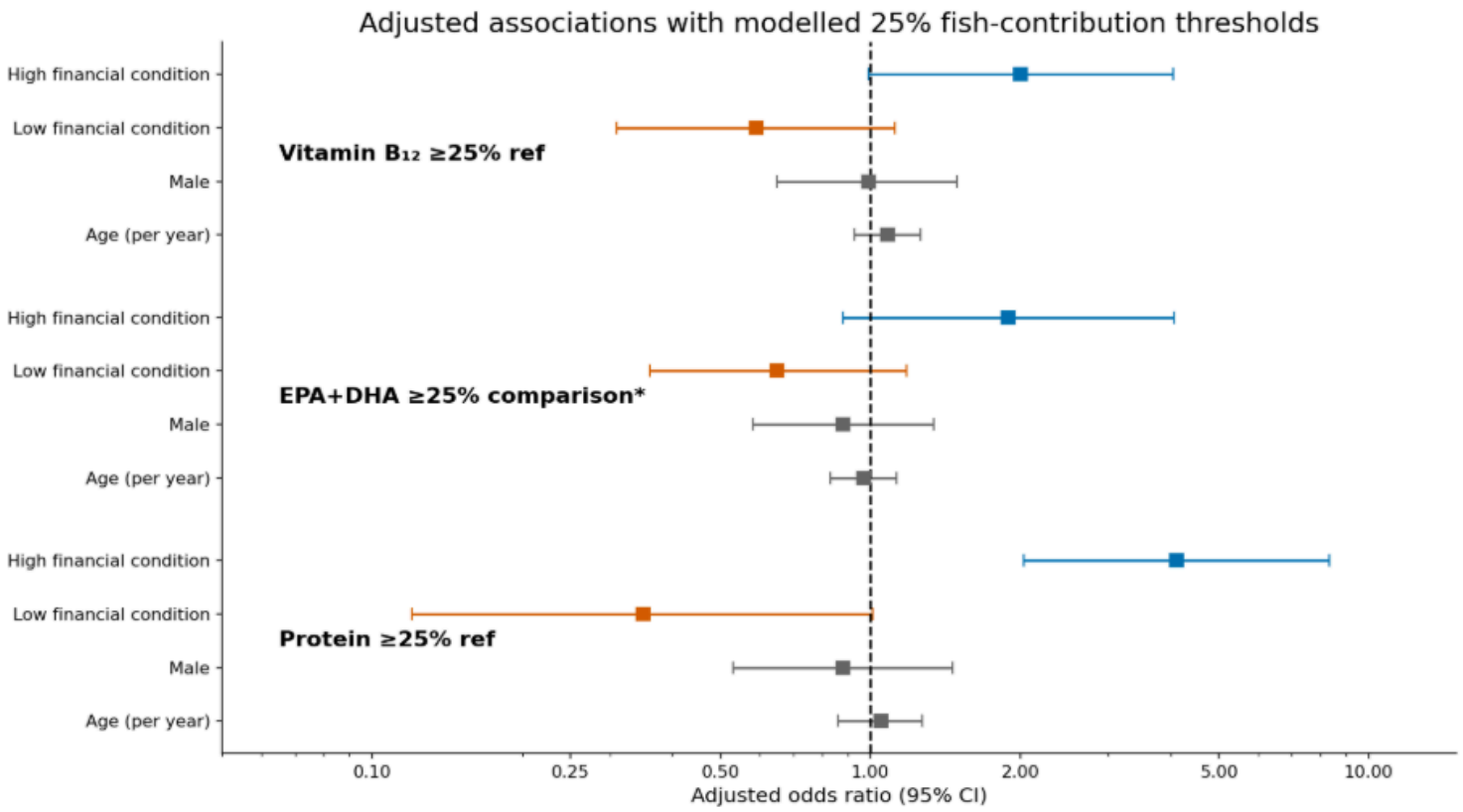


Figure 8

Adjusted odds ratios (95% CI) for modelled 25% fish-contribution thresholds by self-reported household financial condition, sex and age (n = 396). Reference categories: middle financial condition and female. *EPA+DHA uses a descriptive 250 mg/d comparison value.