Supplementary Information for

Aquatic foods for nourishing nations

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The Supplementary Information includes:

- Supplementary Methods and Figures M1 to M2
- Supplementary References
- Supplemental Data Figures S1 to S18
- Supplemental Data Tables S1 to S6

Supplementary Methods

Overall Food System and Nutrient Modeling Methods

The workflow for this research (Fig. M1) included the integration of the FAO FISH model into the AgLink Cosimo model to allow for simultaneous food system modeling of terrestrial and aquatic food systems. The FAO FISH model, although operating independently, was included as a subsumed modular component of the AgLink Cosimo model which then produced an output for 22 food groups, one of which was aquatic foods. The 21 terrestrial food groups were assigned nutrient composition values through the Global Nutrient Database (GND), while aquatic foods were treated separately. To understand the role of diversity in aquatic food consumption, we disaggregated the mix of species available for consumption beyond the typical 12 ISSCAAP categories that the GND uses (see below for more detailed methods). We then assigned each species identities (or sometimes broad taxa) to a matched nutrient composition profile with the Aquatic Food Composition Database. By combining the aquatic food nutrient supply with the terrestrial food nutrient supply, we were able to model the total nutrient supply from all food sectors. To understand how these national level aggregated nutrient supplies were distributed subnationally, we used SPADE- a software that allows for the modeling of subnational habitual intake distributions based on quantitative dietary intake data from repeat 24-hour recalls. This allowed us to estimate nutrient intake per capita, specified within particular age-sex groups. We then calculated summary exposure values (SEV) to identify the proportion of the population that would be nutrient deficient in each nation (see below for detailed methods).

This modeling approach was used for a moderate production and high production scenario. The moderate production scenario was driven by the OECD-FAO Agricultural Outlook 2020-2029, while the high production scenario is detailed in depth below.

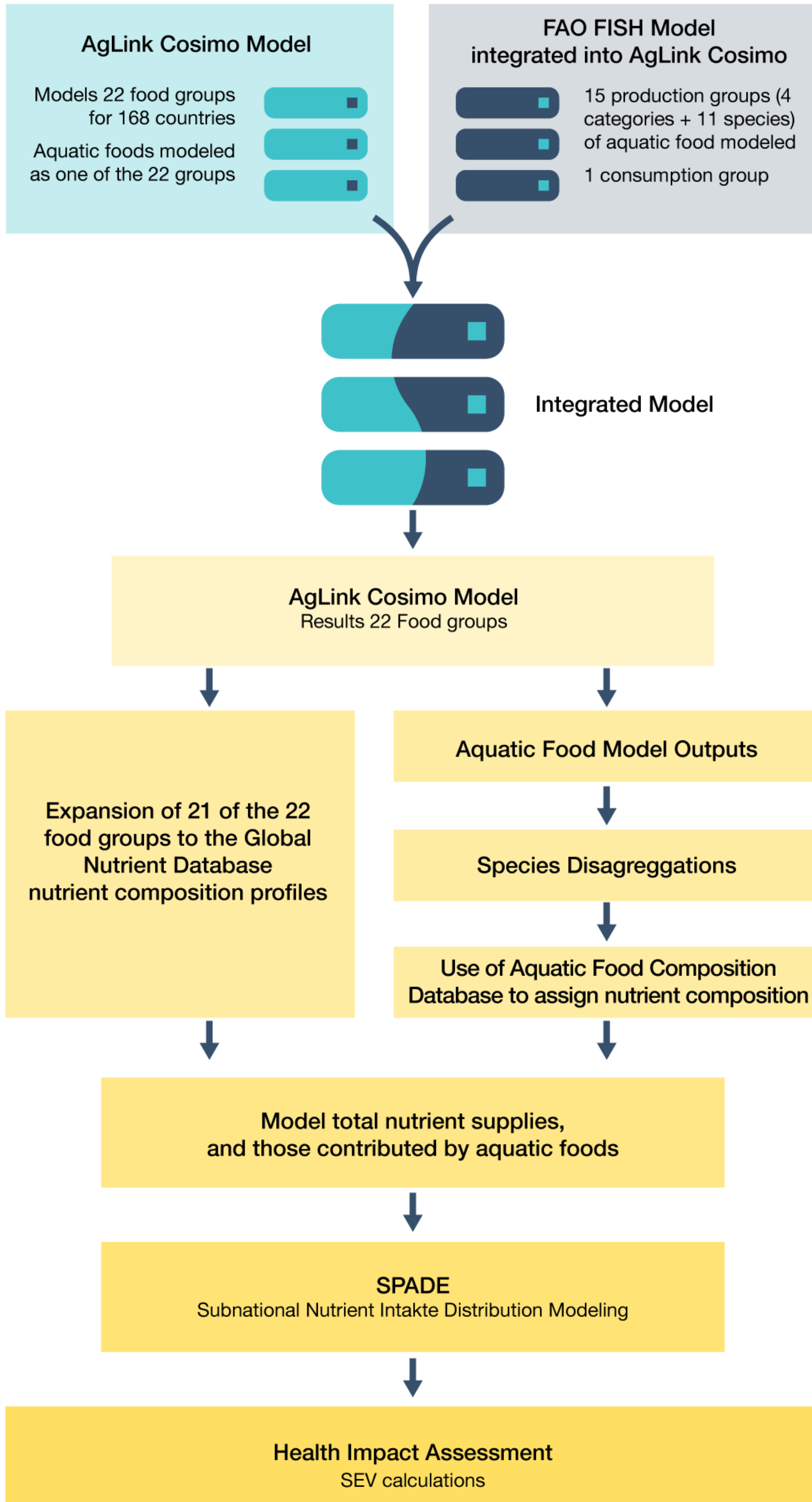

Figure M1: Description of modelling workflow. This figure describes how the various modelling components and data sources were integrated into this analysis.

High Production Scenario

We project future aquaculture growth under a "strategic investment" scenario that seeks to simulate ambitious yet plausible aquaculture growth resulting from strategic investments in aquaculture production capacity. The scenario is ambitious in that it stimulates growth in countries without aquaculture production, with declining aquaculture production, and with slow-growing aquaculture production. The scenario is plausible in that it gently accelerates growth in these countries and reduces growth in the countries exhibiting the fastest growth.

We parameterized the scenario by calculating recent (2008-2017) country-level changes (annual percent) in production in five different aquaculture sectors (environment-taxonomic group combinations) and by classifying these changes into five growth categories: a category for declining production and a category for each quartile of historical growth (Fig. S1).

We then assume that strategic investments result in the following:

1. **Sectors without production** are developed and exhibit production equivalent to that of the lowest producing country in the 1st quartile of sector-specific historical growth; production grows at the median rate of countries in that quartile.
2. **Sectors with declining production** reverse trends and grow at the median rate of countries in the 1st quartile of sector-specific historical growth.
3. **Sectors with slow production growth** (growth in the 1st quartile of sector-specific historical growth) grow at the median rate of the countries in the 2nd quartile of sector-specific historical growth.
4. **Sectors with moderate production growth** (growth in the 2nd quartile of sector-specific historical growth) maintain their historical growth rates.
5. **Sectors with fast production growth** (growth in the 3rd and 4th quartiles of sector-specific historical growth) grow at the median rate of the countries in the 2nd quartile of sector-specific historical growth.

These assumptions lead to sector-specific growth rates ranging from 1-9% per year and lead to the production of 161.1 mmt by 2030 (Fig. S2). This is 82 mmt higher than 79 mmt in 2017.

Post-Model Species Disaggregations

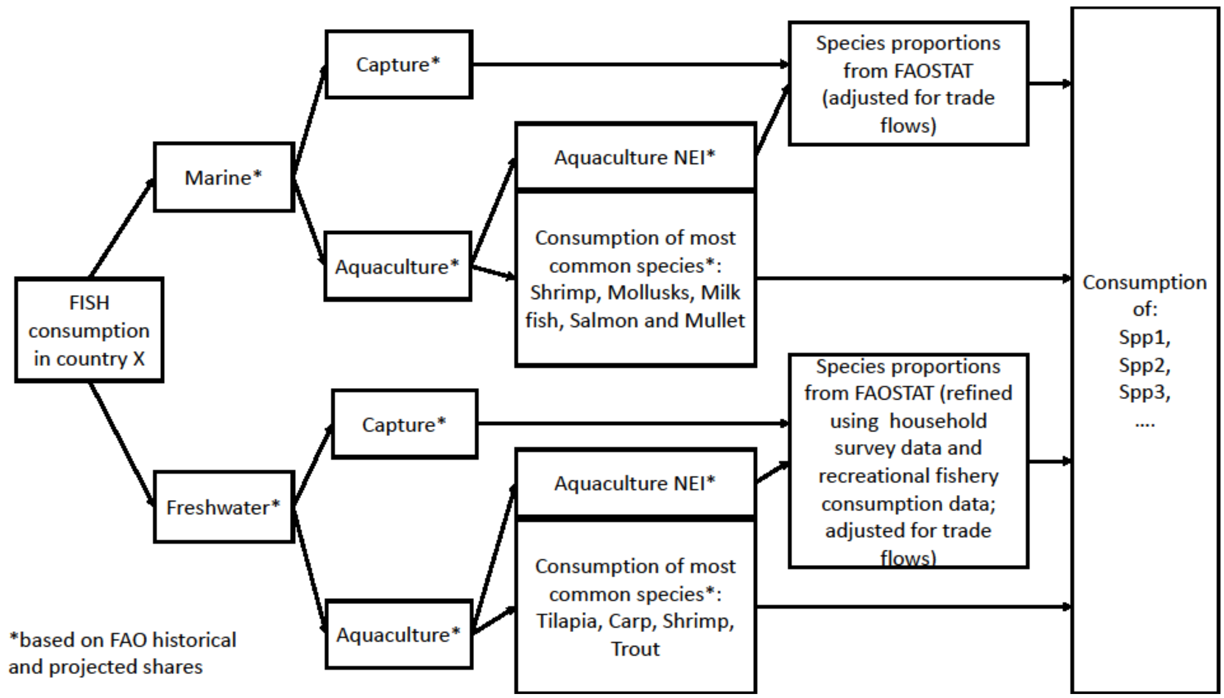

Figure M2: Description of disaggregation workflow. This figure describes the post-model marine and freshwater species disaggregation to derive more resolved consumption estimates.

Taxonomic Disaggregation of Freshwater Fish Consumption

We estimated country-level freshwater fish consumption at the finest taxonomic level possible by combining three data sources:

1. FAO freshwater capture and aquaculture production data (with matching of FAO FishStat trade labels to account for imports and exports)
2. Household Consumption and Expenditure Surveys (HCES; used to disaggregate species-specific consumption for Bangladesh, Cambodia, Democratic Republic of Congo, Myanmar, Zambia)
3. Consumption from recreationally harvested fishes used to disaggregate species-specific consumption (for Australia, Belarus, Canada, Iceland, Lithuania, Netherlands, New Zealand, Norway, Sweden, Ukraine, and USA)

The adjusted volumes were converted to a percentage of national consumption before use in the nutritional analysis.

Species-level mass balance from FAO statistics

Species-level aquaculture and capture production statistics were matched with FAO FishStat commodity trade groups to account for fish species produced but not consumed within a country, and *vice versa* (i.e., imports and exports). Trade data are not reported at the species-level, but are instead recorded in broader commodity groups (e.g., 'Carps, Eels, and Snakeheads'), and also labeled based on processing (e.g., fresh, frozen, fillets, etc.). To account for quantities exported, we used a fuzzy matching approach with the Harmonized System (HS) coding structure to add HS codes to the species-specific production table. Species were matched to 6-digit HS codes according to the taxa named in code descriptions, or in a "not elsewhere indicated" (nei) code, where applicable. Exported commodity weights were converted to live weights using live-weight conversion factors for freshwater fish from Fluet-Chouinard et al. (2018). Where the number of individual aquatic animals (as opposed to tonnes) was reported by FAO, (e.g.,crocodiles, alligators, turtles, seals, etc.) these values were converted to tonnes using average wild-caught adult body size from the literature. To reflect that most of these animals' mass is not edible, we applied the highest whole-weight factors from our database (i.e., for fillets).

We subtracted exported weights from production in four sequential steps. First, we assumed that exports and imports of the same species in the same country signified re-exported commodities. Second, we subtracted the exports from the matched aquaculture production to reflect the greater supply chain integration of aquaculture with trade. Exported commodities under generic HS codes (e.g. 'freshwater fish nei') were matched with every production item falling under that same HS code. Inversely, non-generic (e.g.,'tilapia') export HS codes were matched with generic production items. Third, this process was repeated to subtract unaccounted exports from capture production. Fourth, any remaining exports were assigned exports to all generic production (e.g., all 'nei' categories) for that country.

Once the exports were subtracted from production, the remaining weight was assumed to represent apparent domestic consumption per commodity group. Processed weights were converted to consumed weights using a conversion factor of 0.8 to generate estimates of freshwater fish species consumption. Our species-level mass balance accounting produced 69 instances of negative consumption in 14 countries. We assigned these as zeros assuming that the negative cases arise from erroneous assumptions regarding exports. Total negative consumption was 6061.5 tonnes, accounting for a negligible 0.014% of total consumption.

Supplementing with HCES and recreational data

The above process produced species-specific, trade-adjusted FAO capture and aquaculture production estimates, which closely reflect the Food Balance Sheet calculations of FAO. However, it is widely recognized that freshwater fishery production tends to be underreported in most countries. This underreporting exists in both low income countries where freshwater subsistence and informal artisanal fisheries are geographically dispersed, and in developed countries where catch from large-scale and intensive recreational fisheries are challenging to monitor and report to FAO. To account for these potential sources of error we (A) scaled up production with under-estimation factors from HCES for 31 countries known to have underreported subsistence production, (B) used HCES data to improve taxonomic resolution of FAO data for five countries in Africa and Asia that had already been scaled up in A, and (C) appended estimated consumption from recreational fisheries for 11 countries with high recreational harvest not reported to FAO (Figure S17).

To increase taxonomic resolution of FAO data for five countries (B) we first removed all marine species categories from the HCES dataset, and then estimated the freshwater fraction inside categories with mixed marine and freshwater species following proportions in Fluet-Chouinard et al. (2018). Common names of species reported by HCES were converted to scientific names based on FAO reports and FishBase searches for matching with FAO data. To integrate HCES data with FAO, we first checked if the HCES species were already represented within FAO. For species present in both FAO and HCES, we took the higher consumption estimate. For species only present in HCES, we took the sum of all HCES consumption estimates and compared this to the generic 'freshwater fish nei' FAO category. If the summed HCES consumption estimates were less than consumption of 'freshwater fish nei', we allotted that generic catch to each of the HCES species and left the remainder as 'freshwater fish nei'. If HCES consumption was greater than 'freshwater fish nei', we proportionally allocated the entirety of the FAO capture 'freshwater fish nei' among the HCES species. Inclusion of upward conversion factors for 31 countries and HCES species disaggregations resulted in a 10.4% increase in overall consumption estimates from FAO data (4,184,717 tonnes).

Data processing of recreational species was led by the U.S. Geological Survey National Climate Adaptation Science Center. Countries were included based on recreational participation rates (i.e., Arlinghaus et al. 2015) and species breakdown availability. Although not fully comprehensive of recreational consumption globally, the additions do include substantial recreational fisheries not otherwise reported in official FAO channels (see supplementary data). Eleven countries were supplemented using these data: Australia, Belarus, Canada, Iceland, Lithuania, Netherlands, New Zealand, Norway, Sweden, Ukraine and USA. We additionally compiled data for Finland, but since Finland reports recreational fisheries to FAO, our recreational data did not add further detail to the FAO dataset. Recreational fish consumption estimates were added to the dataset using the same protocol as outlined above for HCES data. Inclusion of recreational fish consumption for 11 countries resulted in a 0.17% increase in overall consumption estimates from FAO data (67840 tonnes).

Finally, to ensure that our supplemented consumption data do not deviate greatly from the official FAO statistics, we compare both sets of per capita consumption of freshwater fish (Figure S18). Notably, some countries had increases in their share of capture fisheries due to the upward adjustment with household surveys (e.g. Zambia, Myanmar & Cambodia).

Aquatic Foods Composition Database

A systematic literature review was conducted to compile international and national food composition data to supplement the international food composition databases (Fig. M1). The search strategy was conducted on Web of Science, binned from 1990 to 2020, and used 20 aquatic and 15 nutritional search terms. Search terms included: *(TI=("aquatic insect*" OR "aquatic plant*" OR "algae" OR "algal" OR "aquatic food*" OR "bivalve*" OR "crustacean*" OR "finfish*" OR "fish" OR "fishes" OR "marine invertebrate*" OR "marine mammal*" OR "mollusc*" OR "mollusk*" OR "sea food*" OR "seafood*" OR "sea weed*" OR "seaweed*" OR "shell fish*" OR "shellfish")) AND (TI=("beta carotene" OR "fat" OR "fats" OR "fatty acid*" OR "iron" OR "lipid*" OR "macro nutrient*" OR "macronutrient*" OR "micro nutrient*" OR "micronutrient*" OR "mineral*" OR (("nutrient*" OR "nutritional" OR "nutritive" OR "proximate") NEAR/3 ("density" OR "composition" OR "value*" OR "profile*")) OR "protein*" OR "vitamin*")) OR (AB=("beta carotene" OR "fat" OR "fats" OR "fatty acid*" OR "iron" OR "lipid*" OR "macro nutrient*" OR "macronutrient*" OR "micro nutrient*" OR "micronutrient*" OR "mineral*" OR ("nutrient*" OR "nutritional" OR "nutritive" OR "proximate") NEAR/3 ("density" OR "composition" OR "value*" OR "profile*") OR "protein*" OR "vitamin*"))*.

The following elimination hedges were also applied: *(TI=(antibacterial OR antimicrobial OR microplastic OR genome OR microbiota OR microbacteria OR sediment OR soil OR milk OR chicken OR vegetable OR pathogen)) OR (AB=(antibacterial OR antimicrobial OR microplastic OR genome OR microbiota OR microbacteria OR sediment OR soil OR milk OR chicken OR vegetable OR pathogen)).* Studies were excluded if they did not mention the scientific name of the organism or only assessed aquatic foods destined for fish oil or as an ingredient in processed seafood products (e.g., fish burgers).

Quality checks were conducted on the peer review data to ensure that data were correctly extracted from the literature. Aquaculture feeding trials (i.e., fish nutrition) were excluded. Protein concentration values were used to identify and exclude outliers; especially high or low protein values flagged issues of unit misalignment or of sample preparation, or identifying a broad publication of low quality. Outliers were identified with protein values above 40 g/100g, many of these were reported on a dry weight basis. For observations where Moisture content was also available, we converted to wet weight equivalence. In most cases, these Studies were deemed low quality if they did not contain sufficient information about the unit of analysis, whether values were given on a weight or dry weight basis or if there were obvious errors reporting data (e.g. fat + protein + ash + moisture = 150 g/100g). While this method was cost-effective given the large number of studies, it does not necessarily specify the accuracy of e.g. instrumentation, sample size and protocols for other nutrients. All units were standardized to those set forth by FAO INFOODS guidelines (FAO/INFOODS 2012).

The AFCD includes 29,603 lines of data and 3,666 unique taxa. Within the analysis, species nutrient composition information was aggregated across analyses in order to complete the nutrient information available for the nutrients of interest for each species (e.g, for species X one study analyzed vitamin A, another study analyzed zinc and iron). When multiple studies analyzed the same species, we took the average for that species. In addition, data entries for internal parts of fish (e.g. liver, roe) were removed for nutrient assignment and nutritional value was averaged across all preparation types (e.g. raw, cooked, baked).

[Paragraph expanding on how data were used to fill across species when nutrients unknown, Figure S16?]

Visualizing nutrient richness across food groups in Figure 1

All aquatic food composition data was sourced from AFCD. Food composition data for terrestrial animals were downloaded from the USDA Food Composition database (United States Department of Agriculture and Agricultural Research Service 2019) except for Iodine, which was sourced from the Norwegian Food Composition Database (2020). Details on the specific products are available in Table S6.

Data were first standardized to 100 grams of raw product. Then any dry-weight observations were converted to a wet weight basis. The ratio of nutrient richness across food categories was calculated following the general method of Drewnowski (2009). First, the richness ratio of individual nutrients was calculated by dividing nutrient density in a given food by the daily recommended intake for that nutrient (See Table S5 for a description of the RNI values and their sources). A richness ratio of 1.0 for an individual nutrient indicates that 100% of the daily requirement of that nutrient is met by eating 100 grams of the food product. Once each of the individual nutrient richness ratios were calculated, the mean richness across the food was calculated. Richness ratios of individual nutrients as well as the mean richness were calculated for individual foods at the taxonomic level of order *before* being aggregated to create the broader categories in Figure 1. The one exception was for aquatic mammals, where none of the observations included complete data. For aquatic mammals, the median value across each of the richness ratios for each nutrient was first aggregated across all aquatic mammals, and then the mean richness was calculated.

The panels visualized in Figure 1 represent these richness ratios calculated for each of the seven nutrients (i.e., Vitamin A (RAE), Vitamin B12, Calcium, Iodine, Iron, Zinc, and Omega-3 fatty acids DHA and EPA). The food categories are ordered by their mean nutrient richness value. High mean nutrient richness was in some cases due to relatively high richness ratios for specific nutrients For example, small pelagics had very high Omega-3 and Vitamin B12 values, 218% and 416% respectively, of the RNI but more moderate richness ratios for Iodine and Iron. while others were driven by a more moderate richness ratio across a broader range of nutrients (e.g., aquatic mammals).

Acknowledging Limitations of our Nutrient Projections

Much of our analysis focuses on shifts in production, and how that will influence consumption, without adequate attention to the role of human culture. Cultural norms around consumption of aquatic foods, and indeed what is considered 'edible,' are highly variable. Such norms are also subject to change, and linked both to species-size variation and consumer socio-economic status. Often consumption of whole fish can provide more substantial nutritional benefits over, for example, fillets due to the bioavailability of minerals and nutrients in the bones and other parts of the fish commonly discarded with processing (Roos et al. 2007). However, some forms of processing such as drying or fermentation, particularly of small fish, that retain most of the carcass and micronutrients, are sometimes preferred and have nutritional value in traditional diets and food cultures (e.g., fermented fish, Zang et al. 2019; dried kapenta, Haug et al. 2010).

Food cultures, including the processing and cooking of aquatic foods, also impact nutrient availability and uptake. Fish consumption is often limited to fillets, and nutrients are often lost to processing and plate waste. Critically, cooking methods can alter the bioavailability of nutrients, in some cases reducing it (e.g., deep frying fish fillets leading to reduced potassium and magnesium content; Gall et al. 1983), and in other cases increasing it (e.g., grilling and baking salmon to preserve the n-3 polyunsaturated fatty acid content; Şengör et al. 2013). Further, nutrient analysis often focuses on muscle tissue of raw fish, as is the case for our analyses. Yet, analysis of muscle may miss edible portions of aquatic foods that are widely consumed, especially for small species often eaten whole, while analysis of whole fish may fail to account for plate waste (e.g., discarded bones, head and skin).

Supplemental References

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FAO/INFOODS. *FAO/INFOODS Guidelines for checking food composition data prior to the publication of a user table/database-version 1.0*. FAO, Rome (2012).

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Zang, J., Xu, Y., Xia, W., & Regenstein, J. M. Quality, functionality, and microbiology of fermented fish: a review. *Critical Reviews in Food Science and Nutrition* **60**, 1228–1242 (2020).

Supplemental Figures

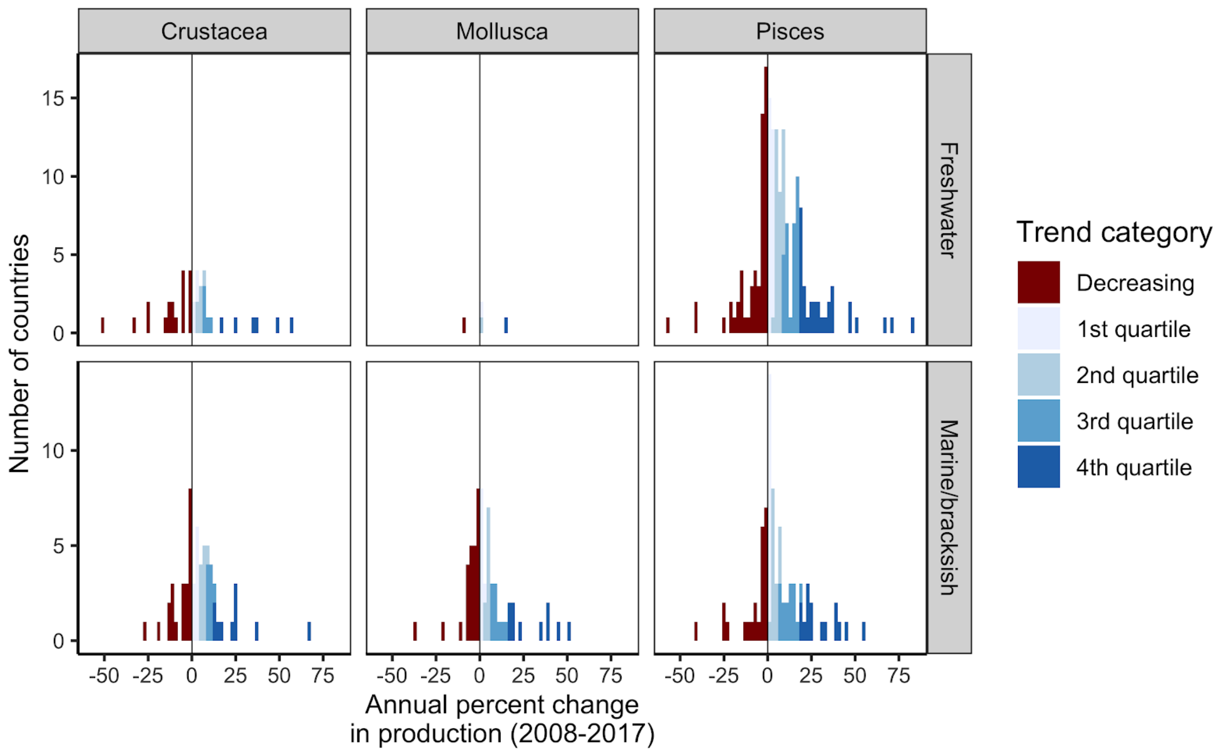


Figure S1. Trends in aquaculture production over the last 10 years. Distribution of recent (2008-2017) country-level trends in aquaculture production by environment (inland, marine/brackish) and major group (fish, bivalves, crustaceans).

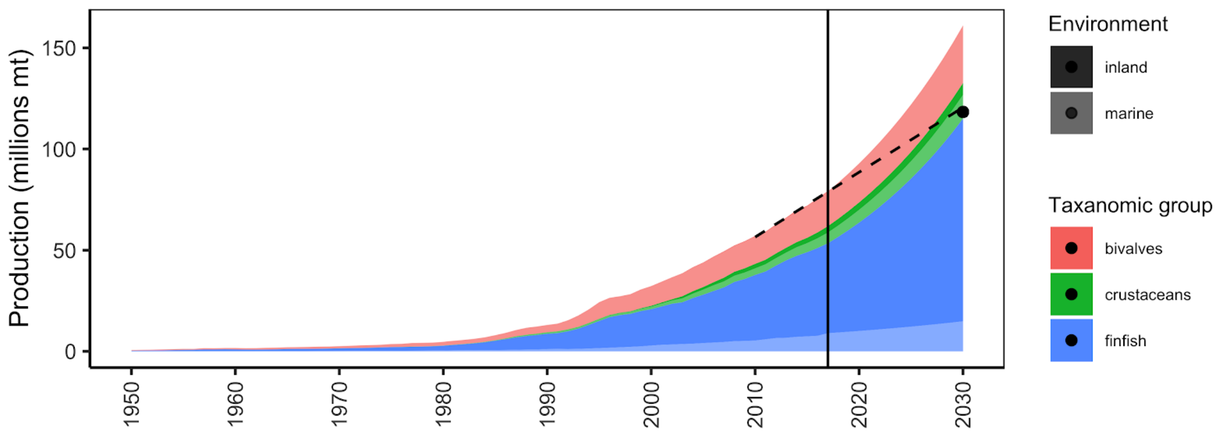


Figure S2. Growth in aquaculture under the high production scenario. The black dashed line shows a linear growth projection for 2018-2030 based on growth since 2010 and the black point shows the FAO high road estimate.

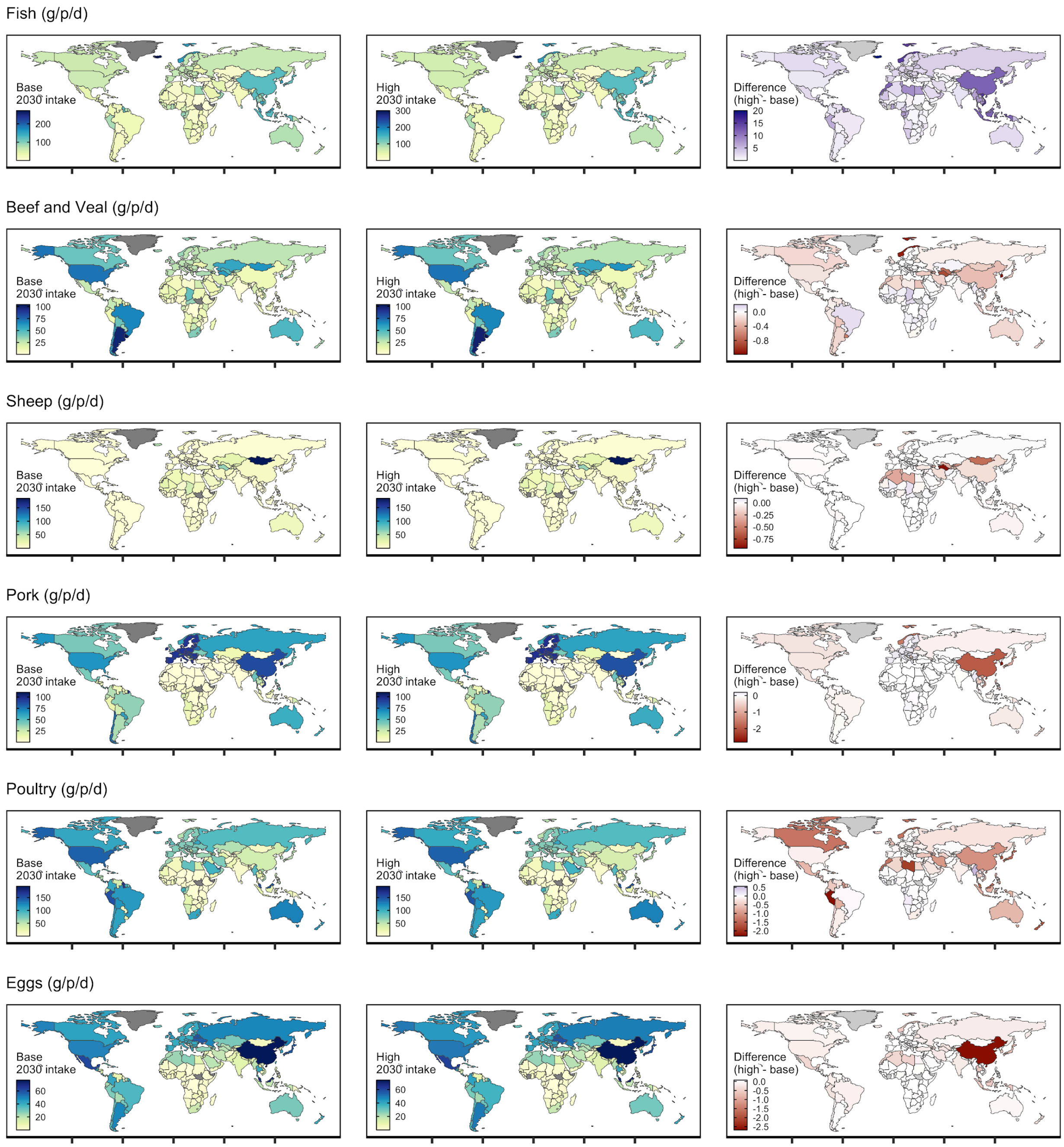


Figure S3. Difference in 2030 food consumption under the base and high production scenarios. Mean daily per capita food consumption in 2030 under the (A) base and (B) high production scenarios and (C) the difference in consumption between the high production and base scenarios.

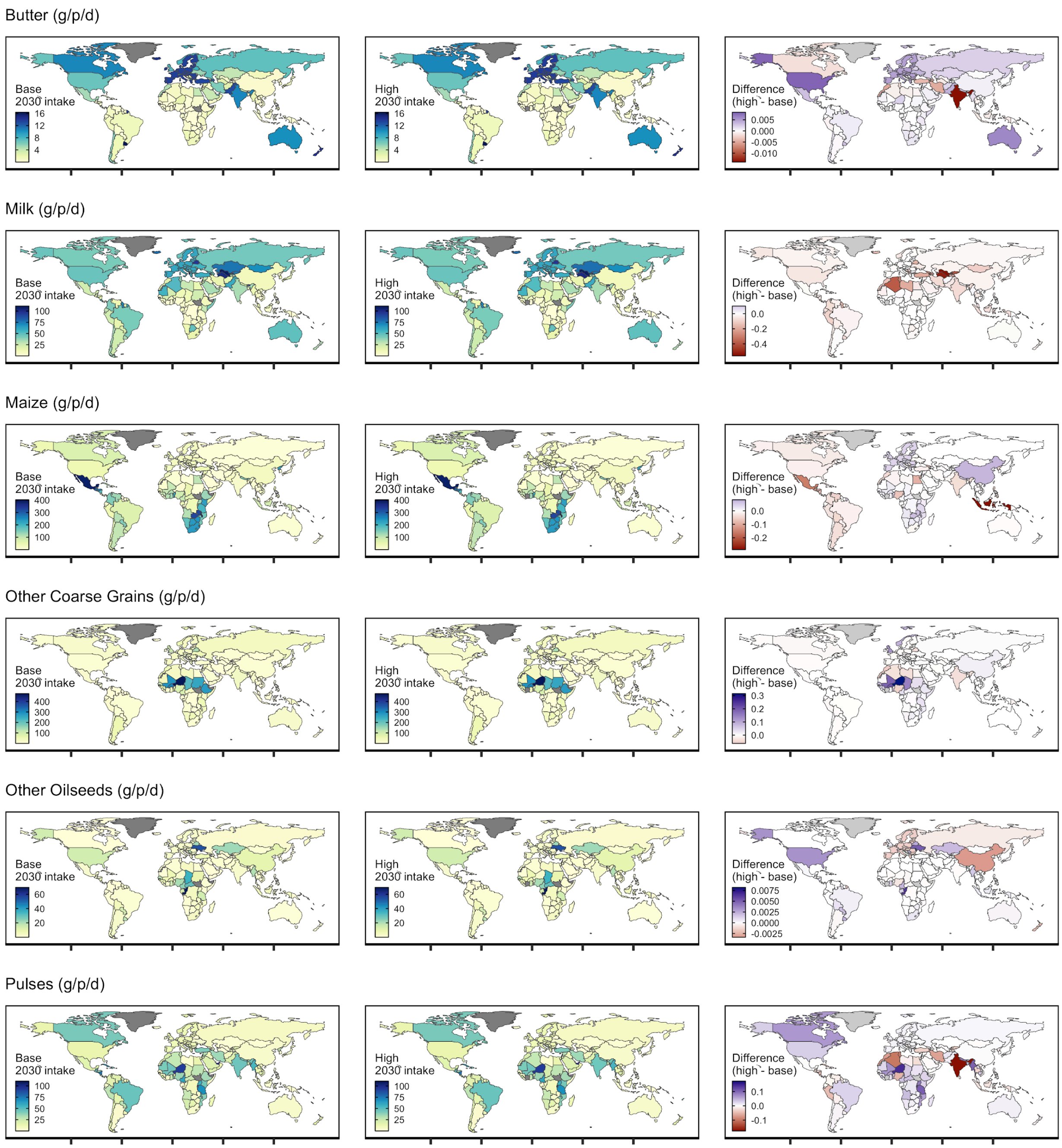


Figure S3 (continued). Difference in 2030 food consumption under the base and high production scenarios. Mean daily per capita food consumption in 2030 under the (A) base and (B) high production scenarios and (C) the difference in consumption between the high production and base scenarios.

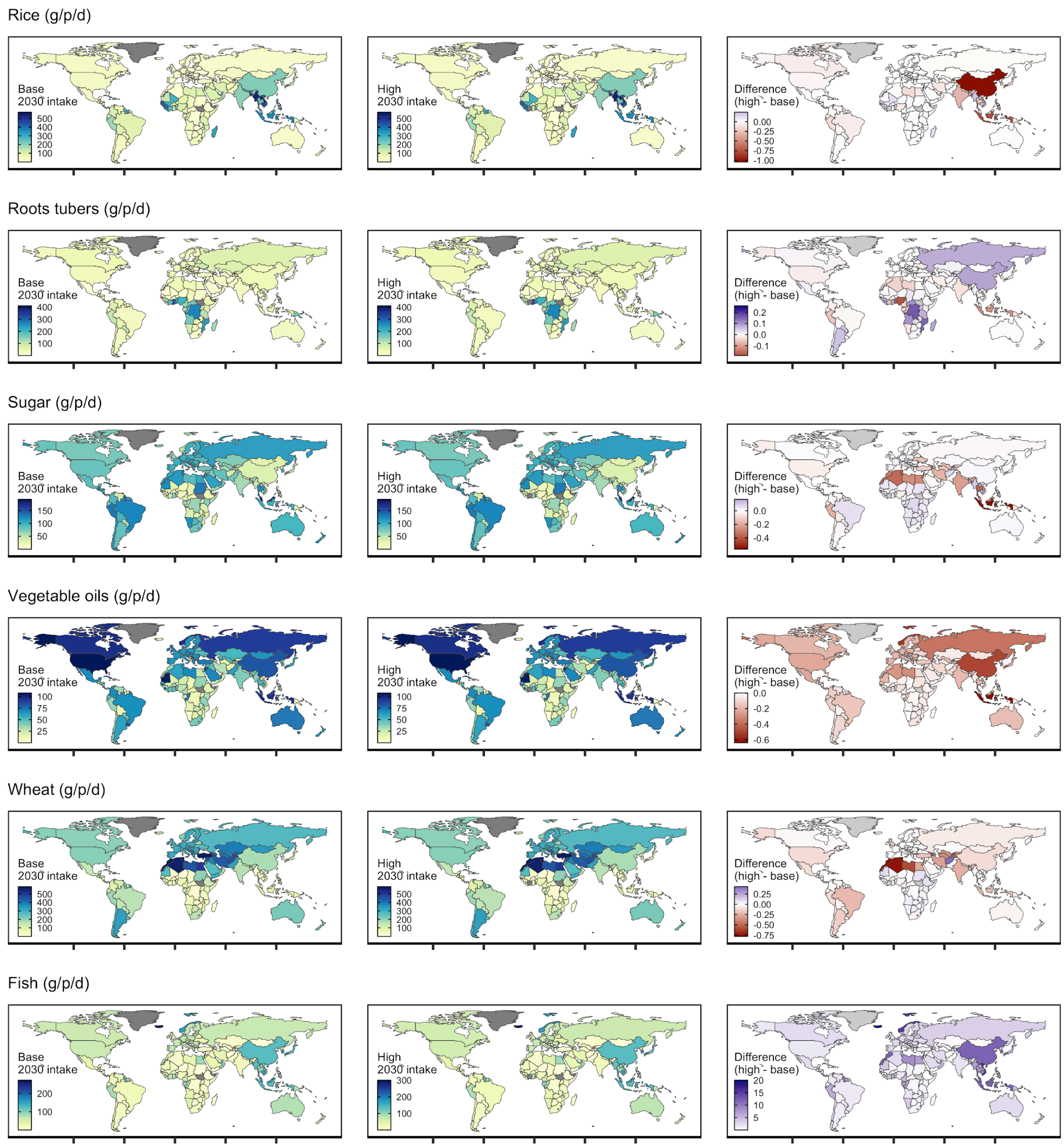


Figure S3 (continued). Difference in 2030 food consumption under the base and high production scenarios. Mean daily per capita food consumption in 2030 under the (A) base and (B) high production scenarios and (C) the difference in consumption between the high production and base scenarios.

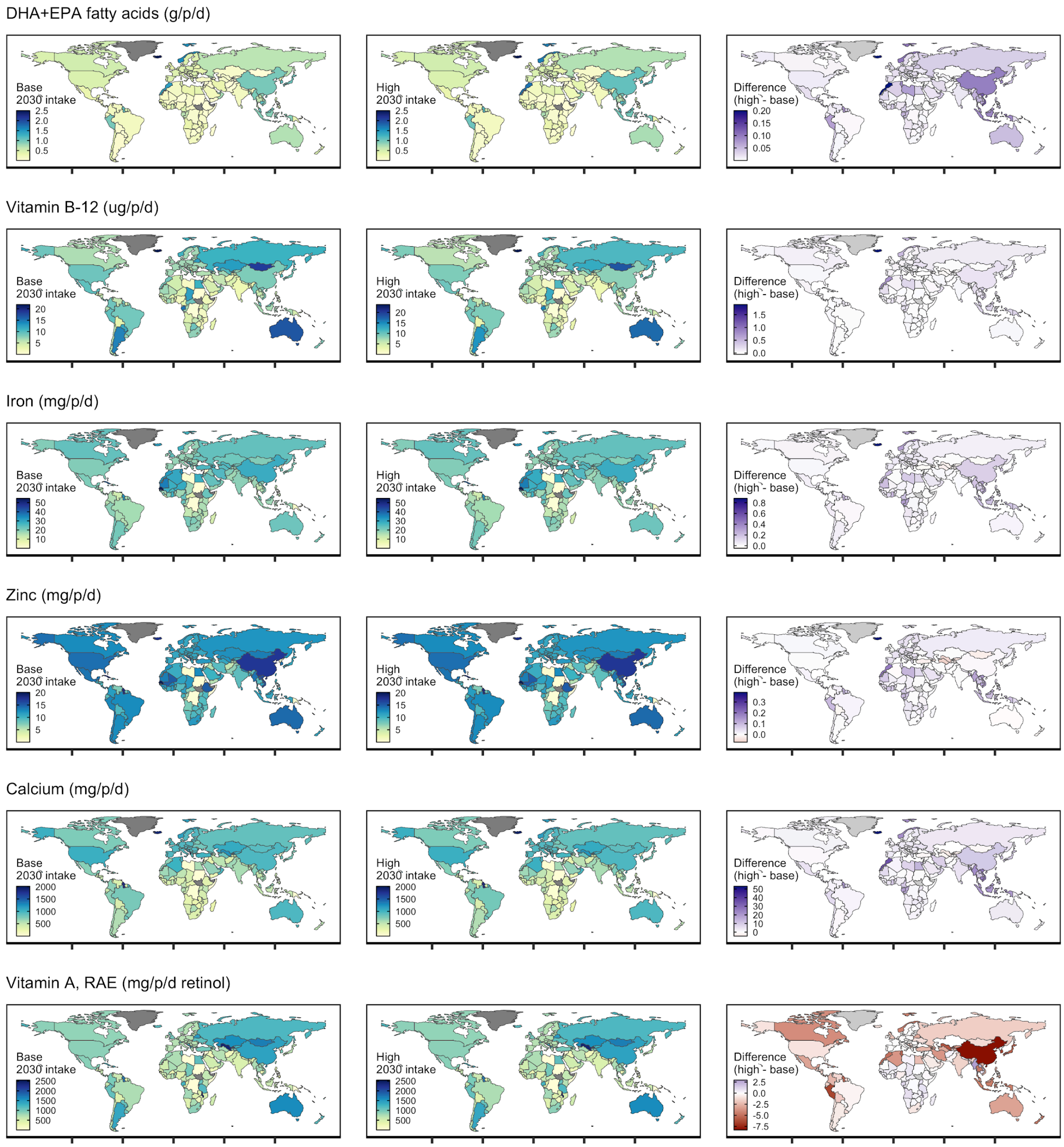


Figure S4. Difference in 2030 nutrient intakes under the base and high production scenarios accounting for the full diversity of nutrient compositions in seafood. The mean daily per capita nutrient intake in 2030 when accounting for the full diversity of nutrient compositions in seafood under the (A) base and (B) high production scenarios and (C) the difference in intakes between the high production and base scenarios.

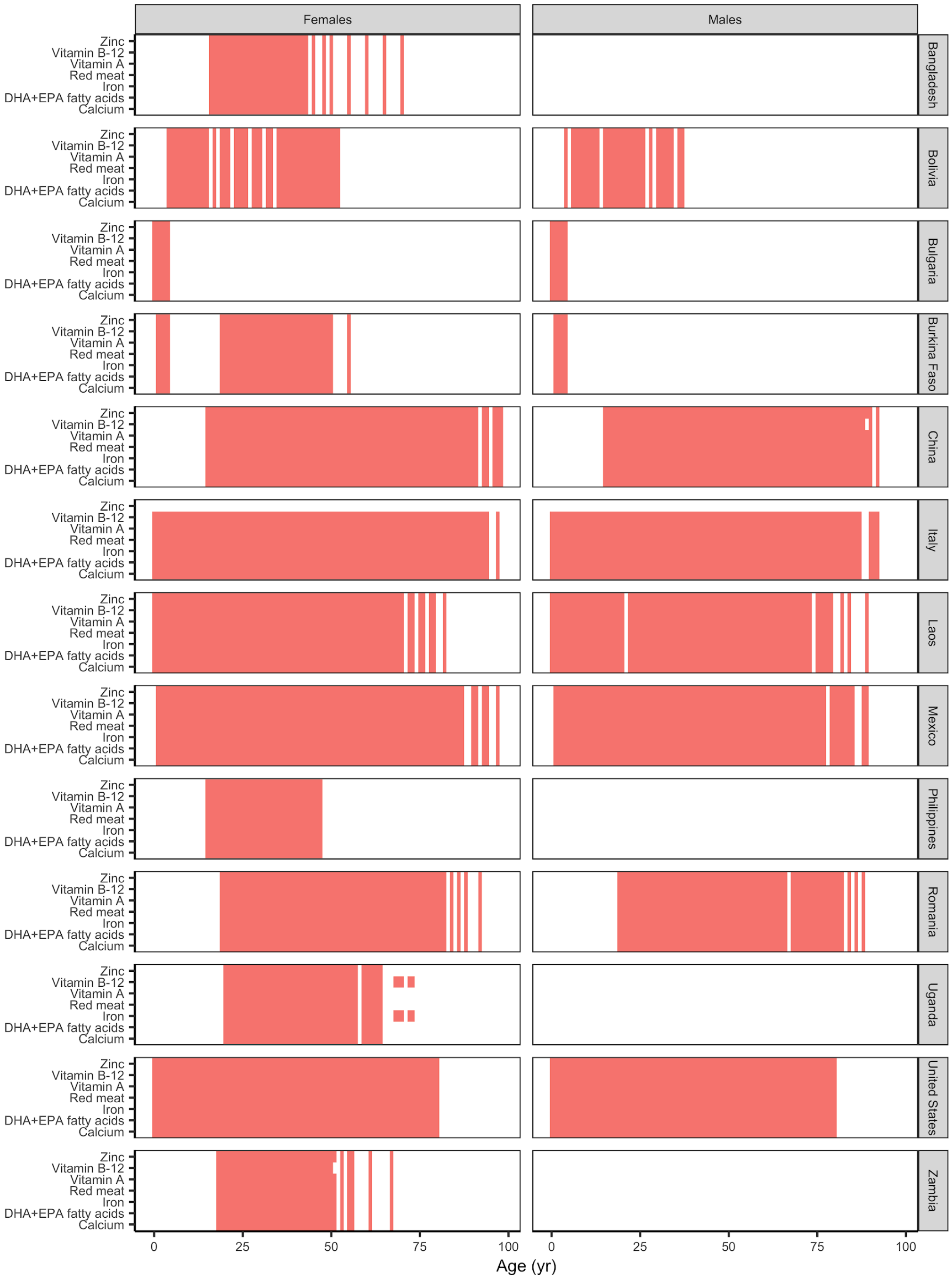
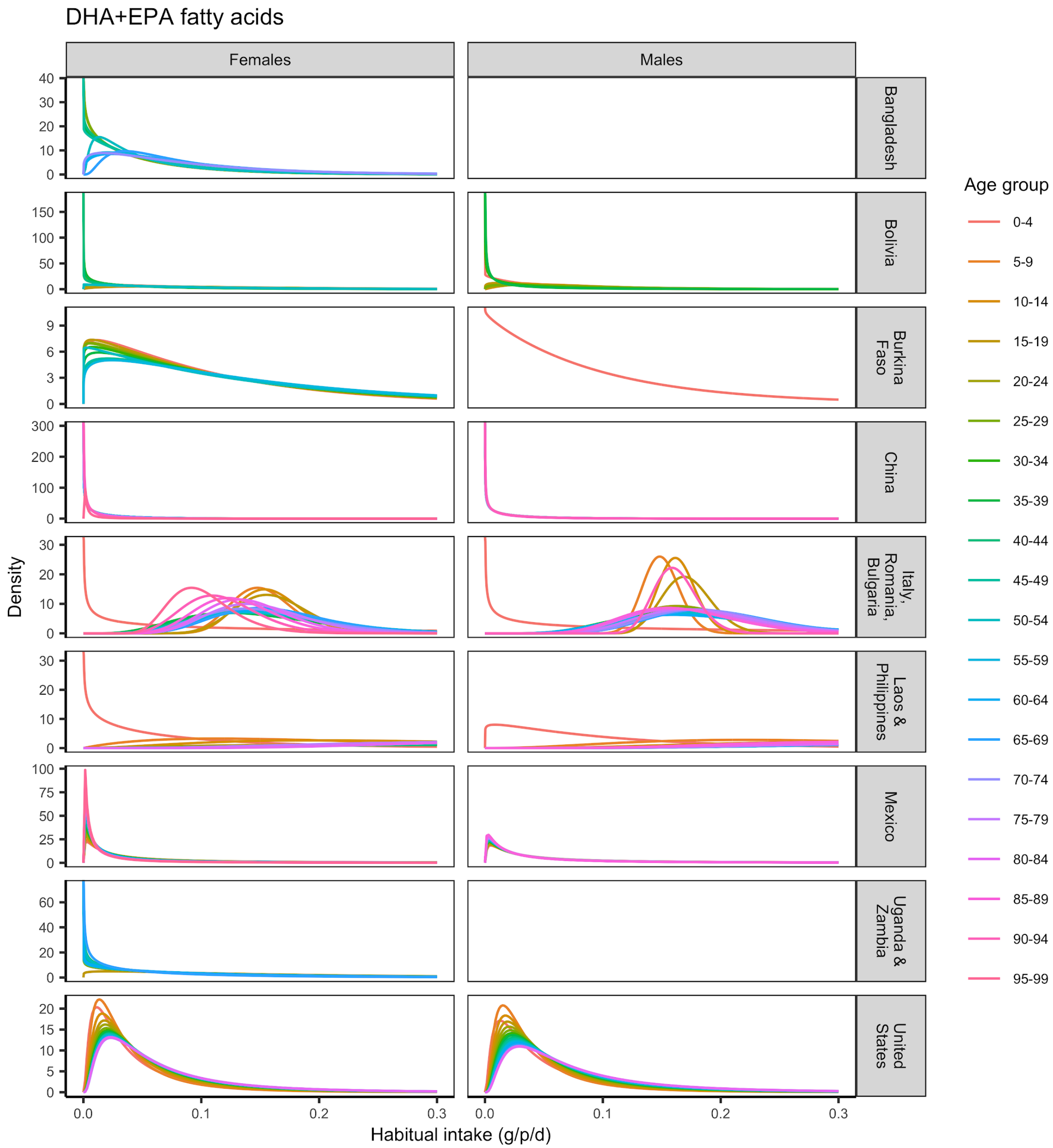
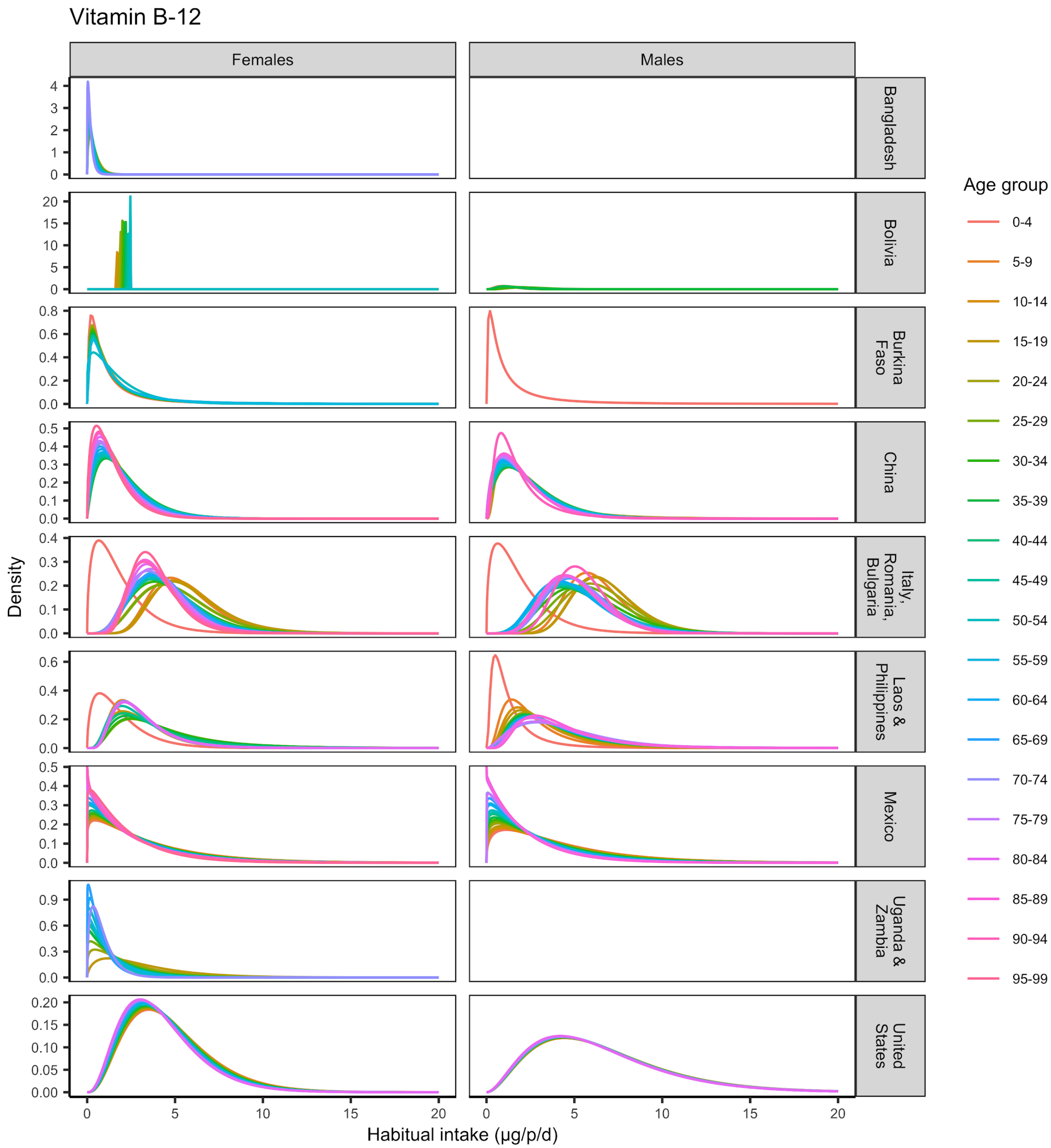


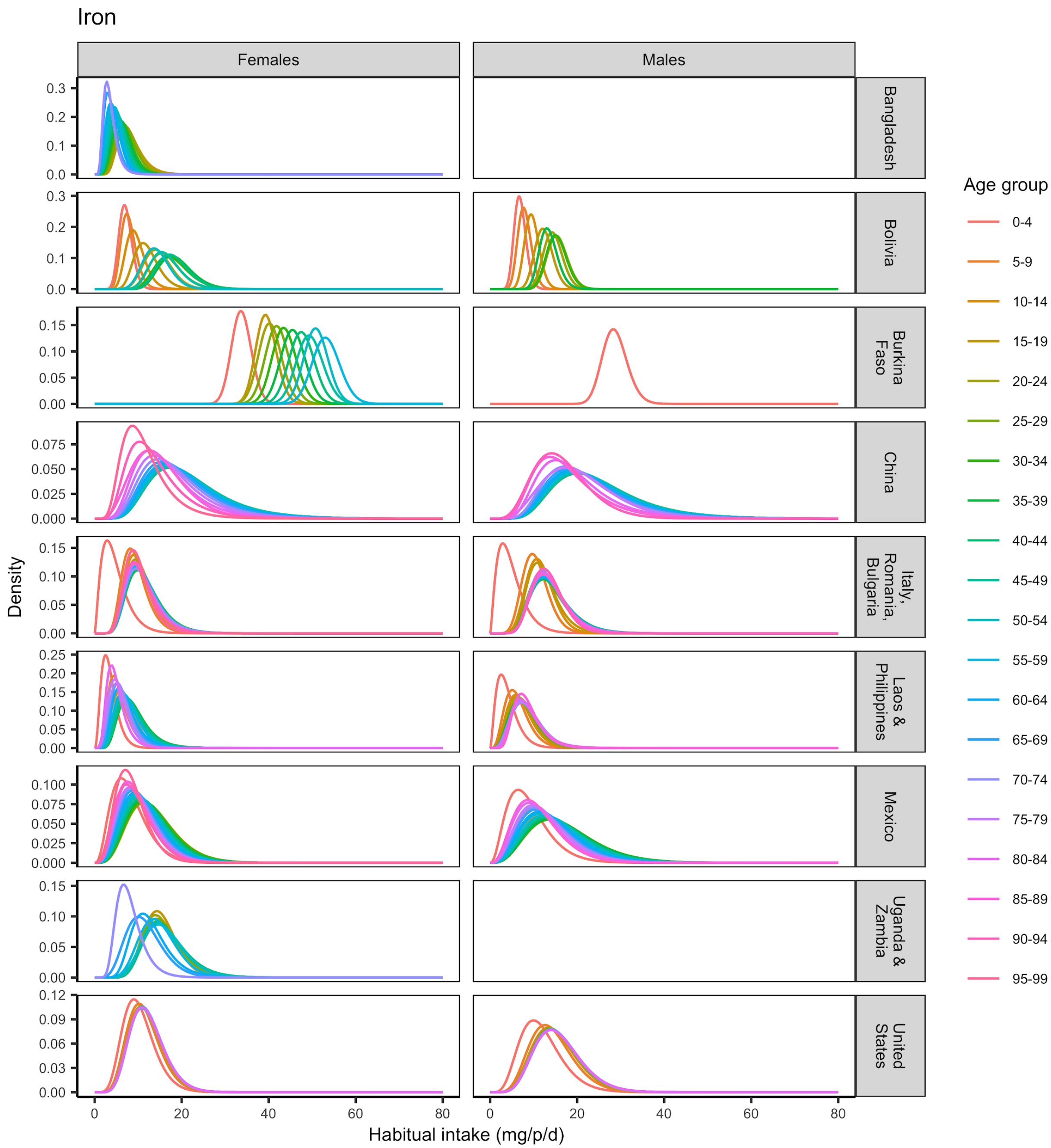
Figure S5. Coverage of habitual intake distribution data. Coverage of habitual intake distributions derived using the SPADE algorithm and data from household-level recall surveys by country, sex, and age. Red shading indicates groups with available repeat 24-hour recall data.



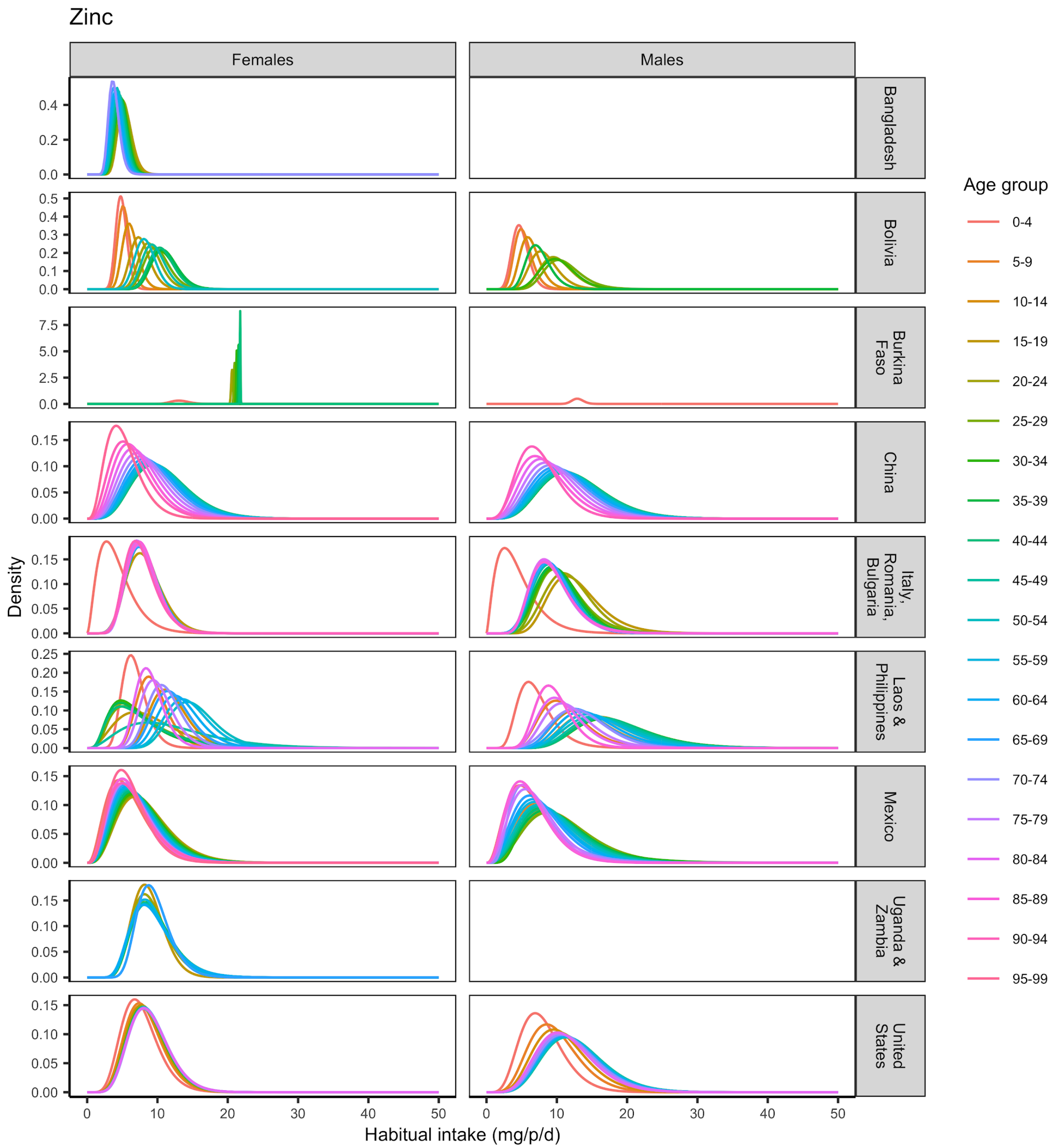
Figures S6. DHA+EPA fatty acid habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.



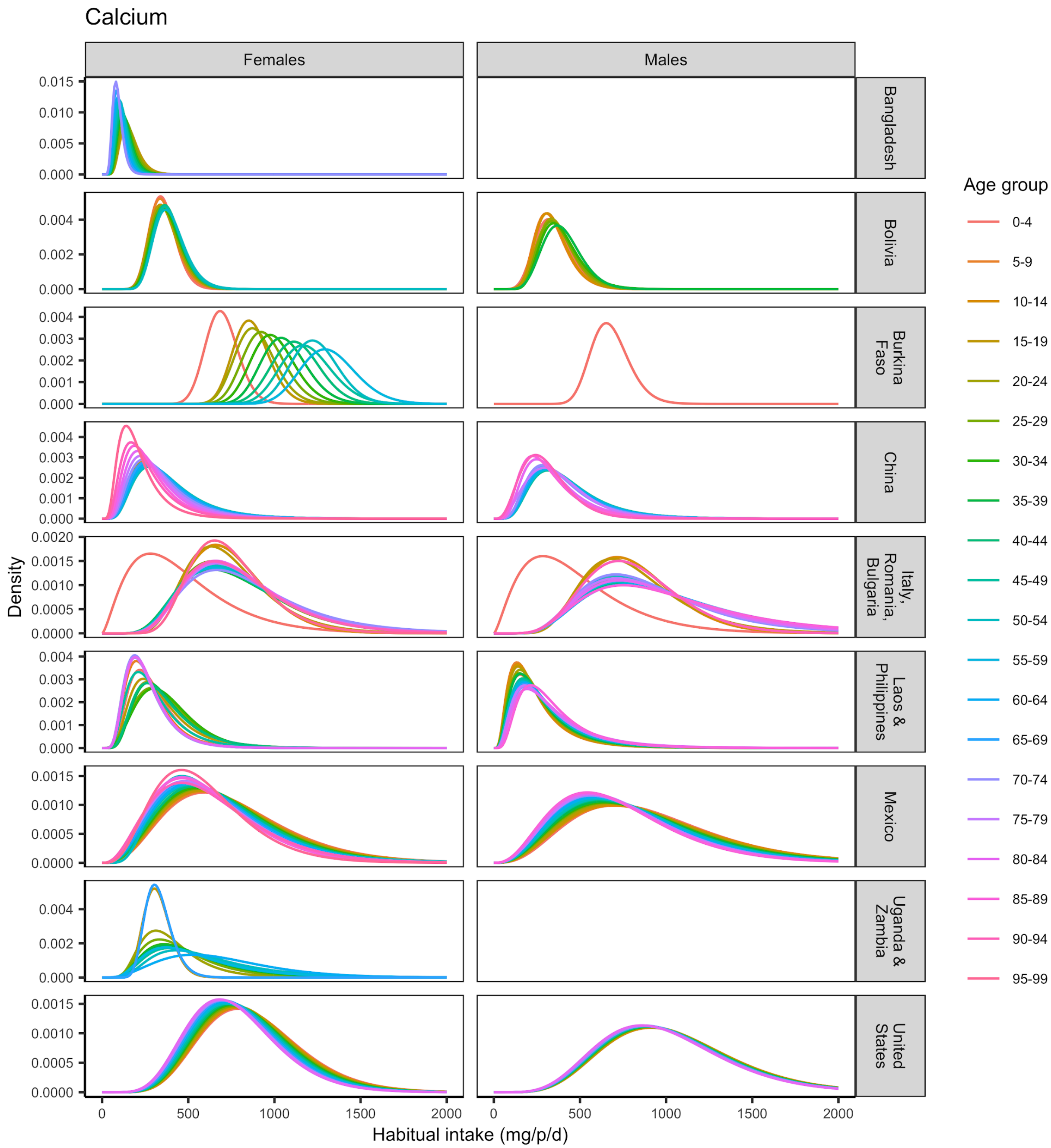
Figures S7. Vitamin B-12 habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.



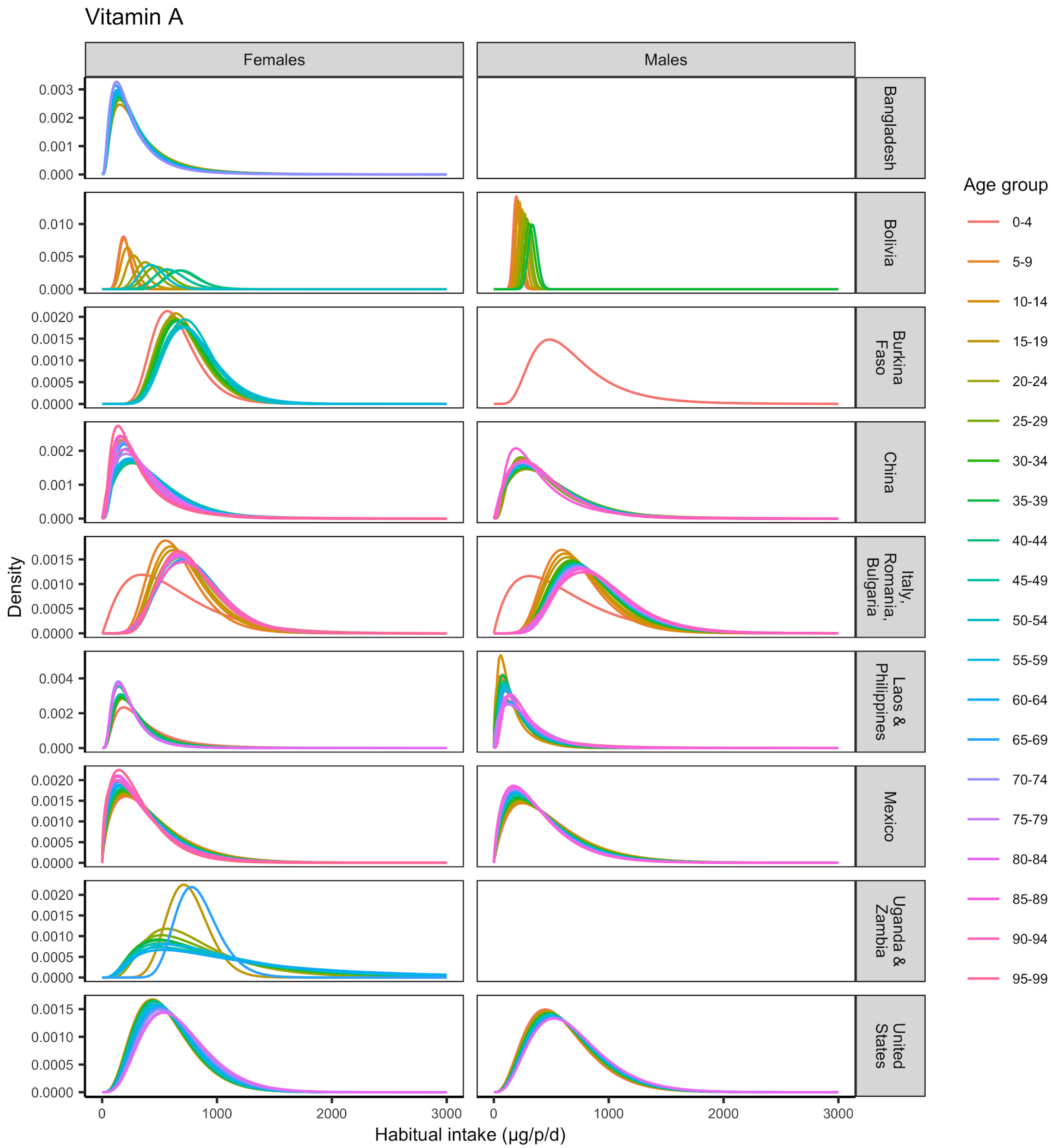
Figures S8. Iron habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.



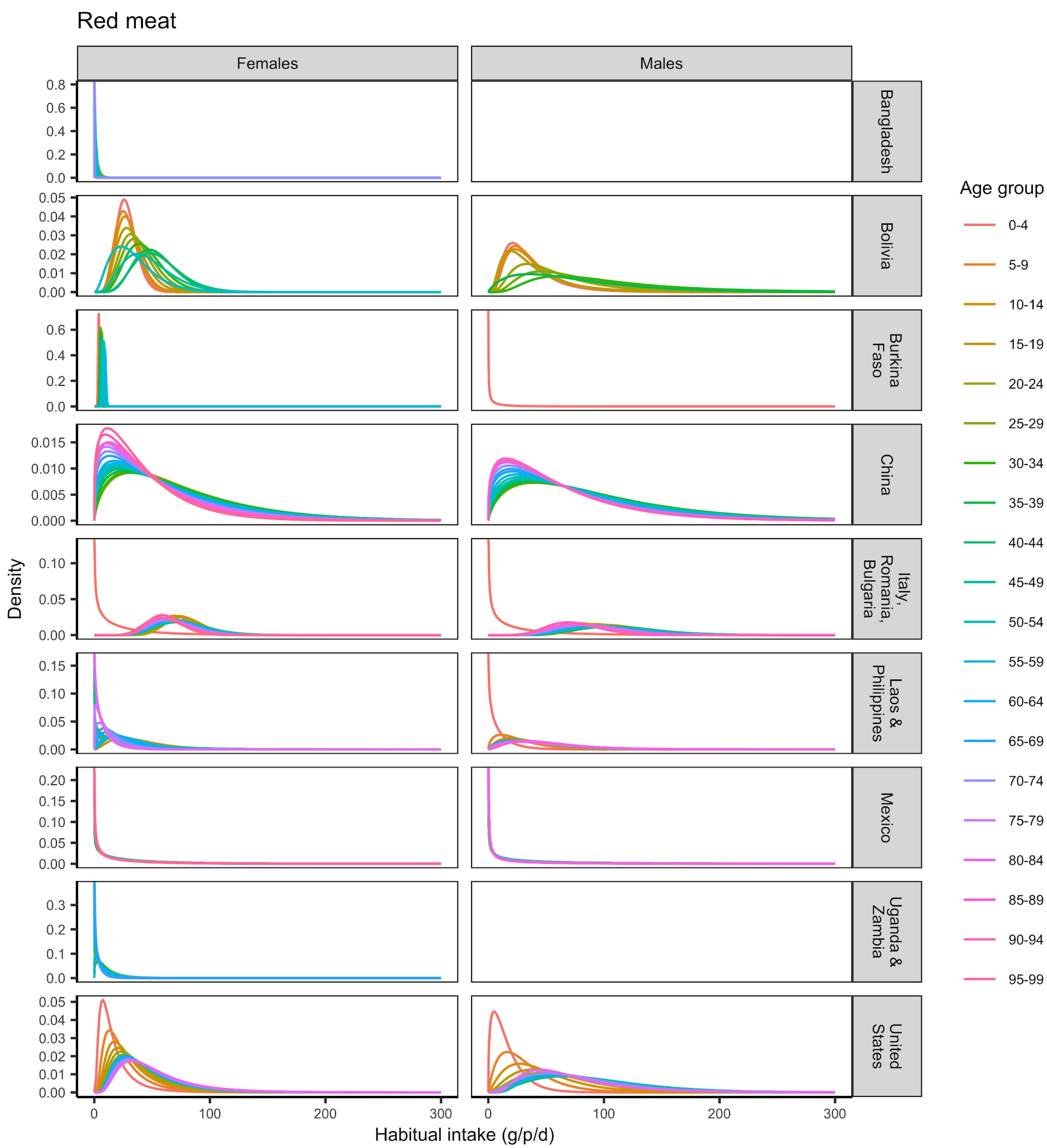
Figures S9. Zinc habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.



Figures S10. Calcium habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.



Figures S11. Vitamin A habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.



Figures S12. Red meat (i.e., beef/veal, pork, sheep) habitual intake distributions by country, sex, and age group. The best statistical distribution (either a log-normal or a gamma distribution) for each country group, sex, and age group is shown. The family of distribution may differ among age groups within a country and sex.

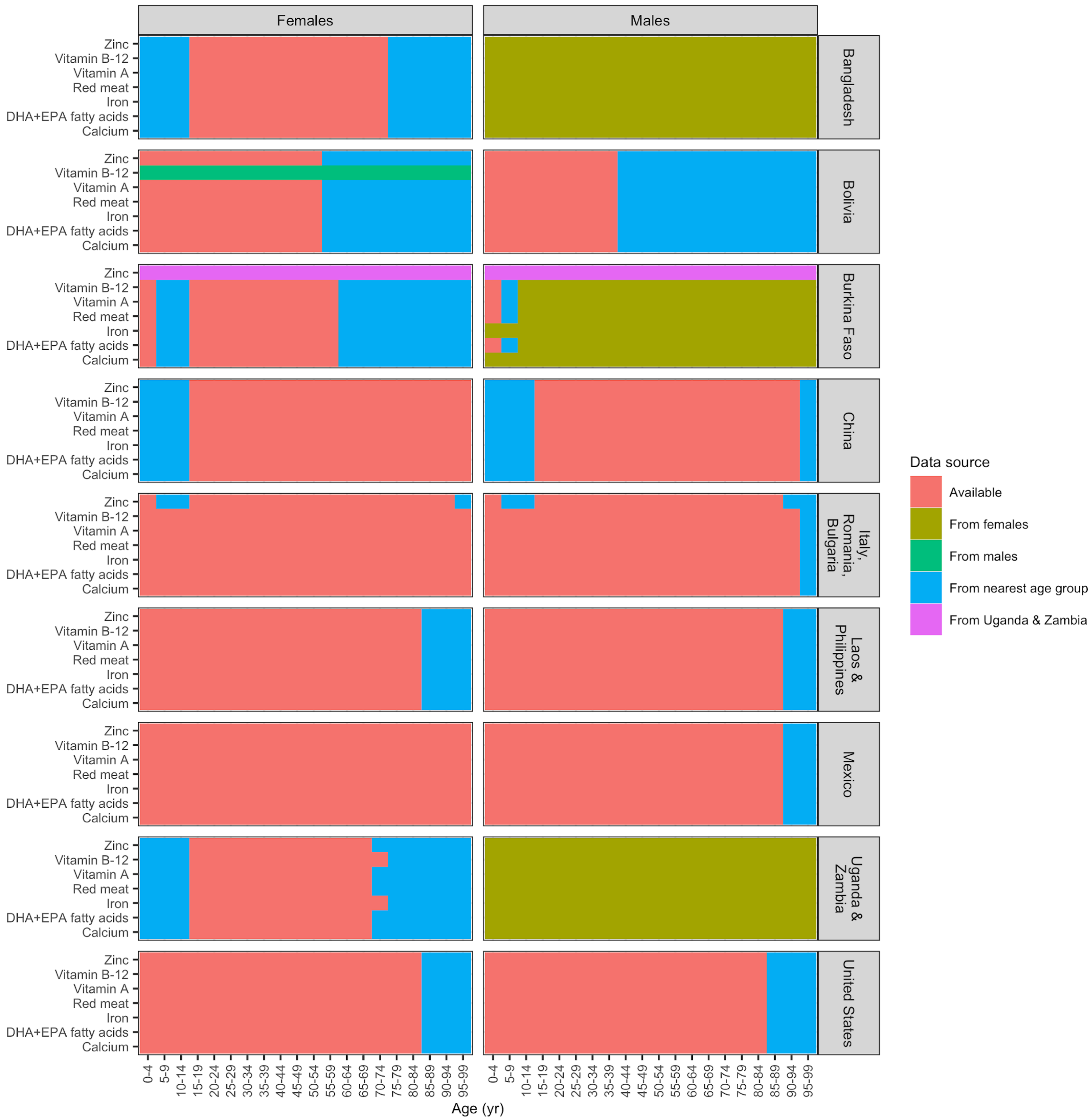


Figure S13. Approach to imputing habitual intake data for age and sex groups without habitual intake data. The red shading indicates age/sex groups with data. Missing data were imputed by borrowing from the nearest neighbor (32% of age-sex groups). We filled within country gaps by borrowing intake distributions, in order of preference, from the: (i) nearest age group within a sex and country; (ii) the opposite sex from within a country; and (iii) the nearest country geographically and/or socioeconomically.

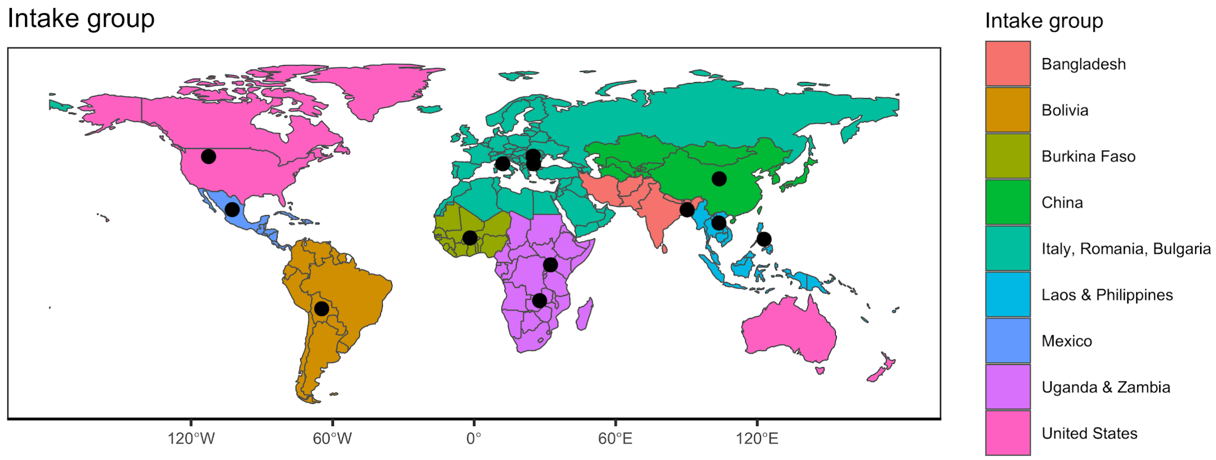


Figure S14. Map of the nutrient intake groups used to scale the subnational habitual intake distributions across countries. These groups are based on U.N. subregions with a few expert-identified modifications.

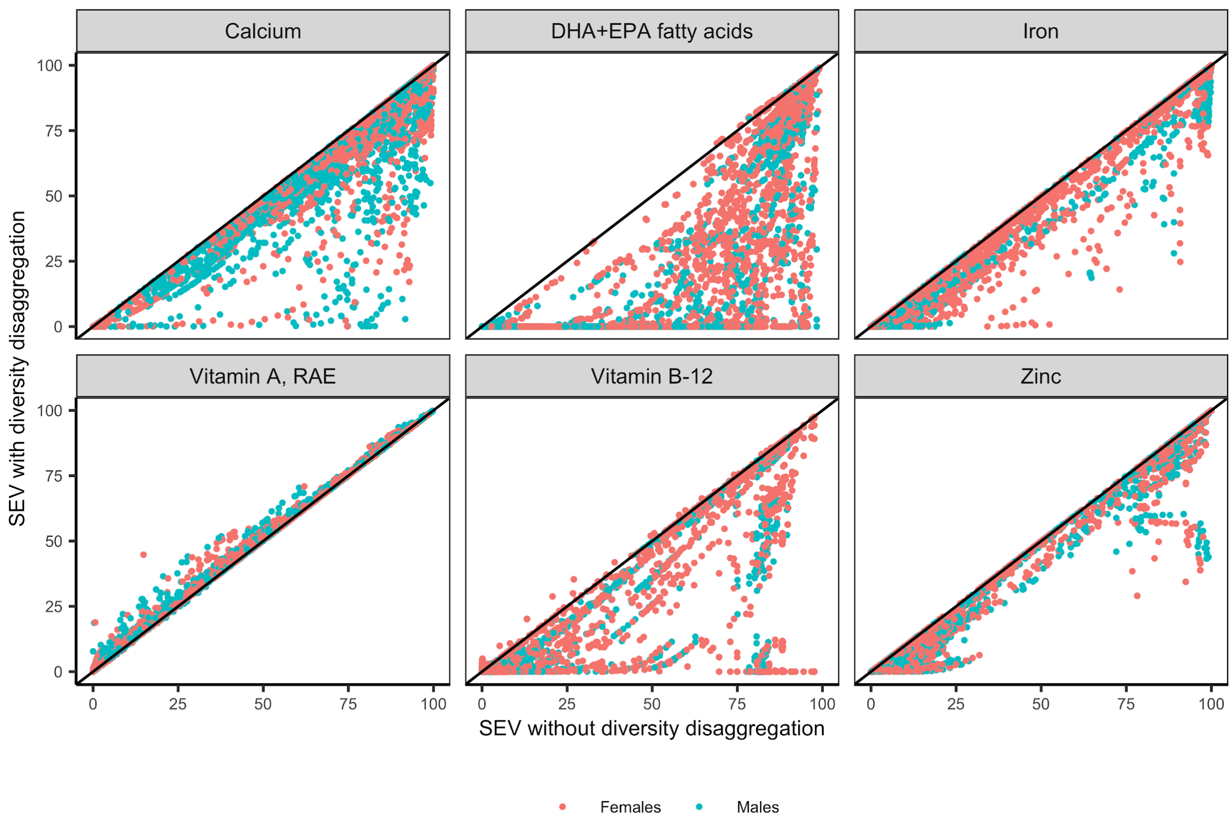


Figure S15. Summary exposure values (SEVs) in the high production scenario with and without the diversity disaggregation. Summary exposure values (SEVs) for each country-age-sex group in the high production scenario with and without the diversity disaggregation. The diagonal line indicates the 1:1 line. Points below this line indicate country-age-sex groups with lower SEVs with the diversity disaggregation. Points above this line indicate country-age-sex groups with higher SEVs with the diversity disaggregation.

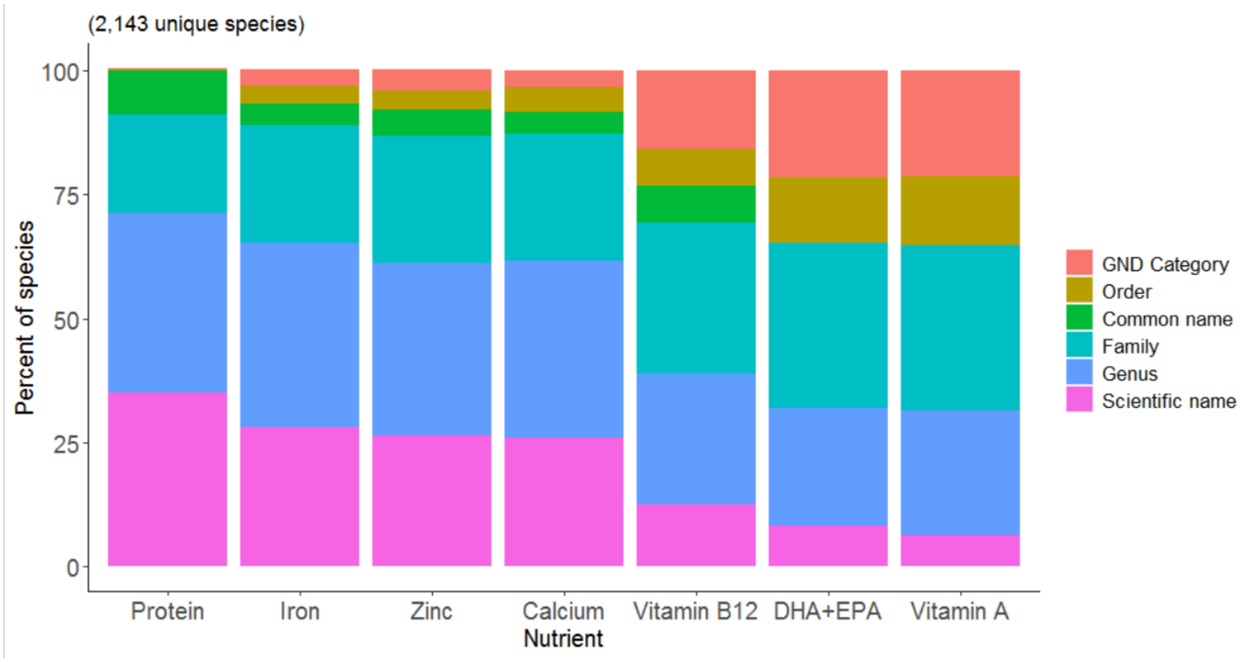


Figure S16. Total number of species per nutrient and criteria used to fill nutritional values from the Aquatic Foods Composition Database (AFCD). For all nutrients, there are a total of 2,143 unique species derived from disaggregation efforts.

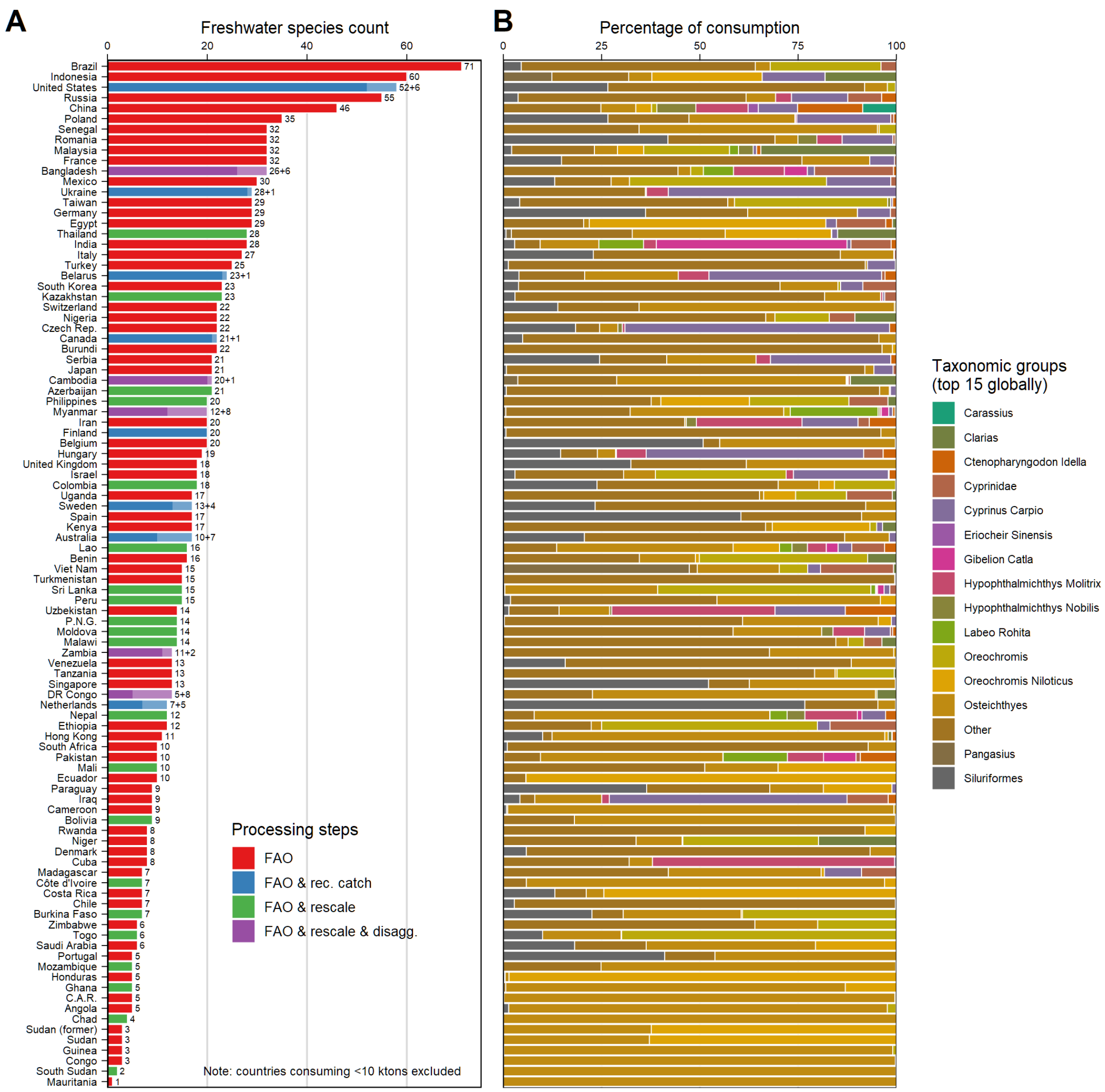


Figure S17. (A) Number of freshwater fish species consumed in each country sorted from highest to lowest. Bar color indicates the processing and data inputs used to generate the final taxonomic list. The darkened section of each bar represents the number of species from FAO data, while the lighter color represents species added from ancillary data. Red - only FAO data; Blue - FAO data further disaggregated with recreational fisheries catch; Green - FAO data whose wild catch was upward-scaled based on HCES underestimation factors; Purple - FAO data that were upward-scaled based on HCES underestimation factors and then disaggregated with HCES data. The exact number of species is labeled next to each bar as: FAO + supplementary (if any). **(B)** Percentage of national consumption across the largest taxonomic group according to global consumption. All other taxonomic groups are lumped into 'Other'. Note that taxonomic groups are not the finest level of consumption data, as a single taxa can be processed into different commodities (dried, filleted, frozen, etc.).

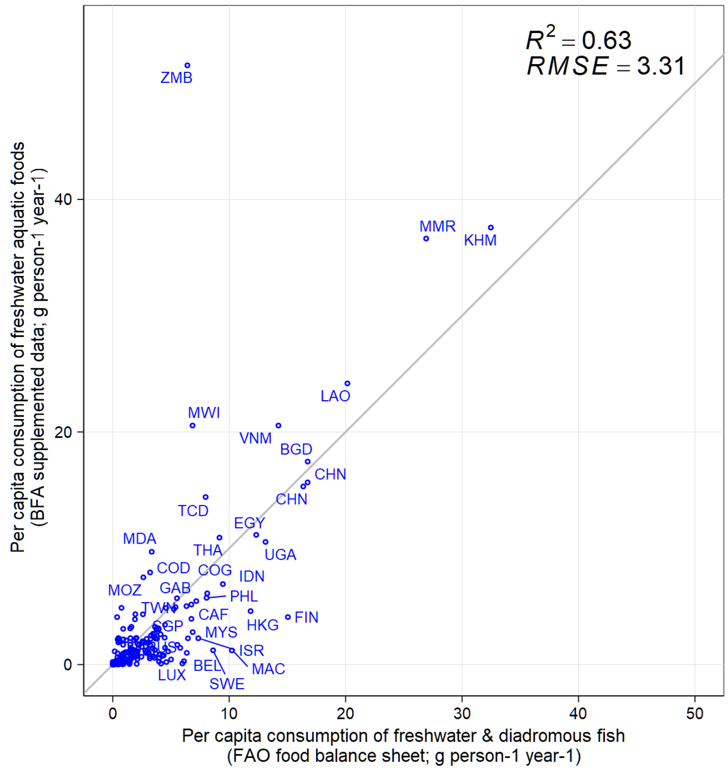


Figure S18. Scatterplot showing the broad alignment (R2=0.63) of the per capita consumption from our species disaggregation against the food supply estimated by the FAO food balance sheets. The diagonal segment represents the 1:1 line.

Supplemental Tables

Table S1. Aglink-Cosimo nutrient intakes and units.
Classifications and units used for the Aglink-Cosimo model.

Type	Nutrient	Units
Fatty acid	Monounsaturated fatty acids	g/p/d
Fatty acid	Omega-3 fatty acids	g/p/d
Fatty acid	Polyunsaturated fatty acids	g/p/d
Fatty acid	Saturated fatty acids	g/p/d
Macronutrient	Energy	Kcal/p/d
Macronutrient	Protein	g/p/d
Macronutrient	Total lipids	g/p/d
Mineral	Calcium	mg/p/d
Mineral	Iron	mg/p/d
Mineral	Zinc	mg/p/d
Vitamin	Vitamin A	IU/p/d
Vitamin	Vitamin A, RAE	mg/p/d retinol
Vitamin	Vitamin B-12	ug/p/d

Table S2. EU27 countries.
Countries included in the EU27 in the Aglink-Cosimo model.

ISO3	Country
AUT	Austria
BEL	Belgium
BGR	Bulgaria
HRV	Croatia
CYP	Cyprus
CZE	Czechia
DNK	Denmark
EST	Estonia
FIN	Finland
FRA	France
DEU	Germany
GRC	Greece
HUN	Hungary
IRL	Ireland
ITA	Italy
LVA	Latvia
LTU	Lithuania
LUX	Luxembourg
MLT	Malta
NLD	Netherlands
POL	Poland
PRT	Portugal
ROU	Romania
SVK	Slovakia
SVN	Slovenia
ESP	Spain
SWE	Sweden

Table S3. Crosswalking GENuS database and Aglink-Cosimo output.
The following countries with output from the Aglink-Cosimo model do not have information on subnational mean intakes in the GENUS database. To fill this gap, we used subnation mean intakes from the nearest neighbor with information in the GENUS database.

COSIMO country		GENUS country	
ISO3	**Country**	**ISO3**	**Country**
AFG	Afghanistan	PAK	Pakistan
ANT	Netherlands Antilles	VEN	Venezuela
BDI	Burundi	RWA	Rwanda
BHR	Bahrain	SAU	Saudi Arabia
BLX	Belgium-Luxembourg	BEL	Belgium
BMU	Bermuda	USA	United States
BTN	Bhutan	NPL	Nepal
COD	Congo - Kinshasa	COG	Congo
COM	Comoros	MDG	Madagascar
CZ2	Czechoslovakia	CZE	Czech Republic
DMA	Dominica	LCA	Saint Lucia
ERI	Eritrea	DJI	Djibouti
ESH	Western Sahara	MAR	Morocco
ET2	Ethiopia PDR	ETH	Ethiopia
FSM	Micronesia (Federated States of)	FJI	Fiji
GAB	Gabon	COG	Congo
GNQ	Equatorial Guinea	CMR	Cameroon
HKG	Hong Kong SAR China	CHN	China
KHM	Cambodia	THA	Thailand

KIR	Kiribati	PYF	French Polynesia
KNA	St. Kitts & Nevis	ATG	Antigua and Barbuda
LBR	Liberia	CIV	Côte d'Ivoire
LSO	Lesotho	ZAF	South Africa
MAC	Macau SAR China	CHN	China
MHL	Marshall Islands	FJI	Fiji
MMR	Myanmar (Burma)	LAO	Laos
OMN	Oman	YEM	Yemen
PLW	Palau	PHL	Philippines
PNG	Papua New Guinea	IDN	Indonesia
PRI	Puerto Rico	CUB	Cuba
PRK	North Korea	KOR	South Korea
QAT	Qatar	ARE	United Arab Emirates
SGP	Singapore	MYS	Malaysia
SLB	Solomon Islands	NCL	New Caledonia
SLE	Sierra Leone	GIN	Guinea
SMR	San Marino	ITA	Italy
SOM	Somalia	ETH	Ethiopia
SRM	Serbia and Montenegro	SRB	Serbia
STP	São Tomé and Príncipe	CMR	Cameroon
SYC	Seychelles	MDG	Madagascar
TCD	Chad	SDN	Sudan
TGO	Togo	BEN	Benin

TKM	Turkmenistan	UZB	Uzbekistan
TLS	Timor-Leste	IDN	Indonesia
TON	Tonga	FJI	Fiji
TUV	Tuvalu	FJI	Fiji
TWN	Taiwan	CHN	China
UGA	Uganda	KEN	Kenya
USR	USSR	RUS	Russia
VNM	Vietnam	LAO	Laos
VUT	Vanuatu	FJI	Fiji
WSM	Samoa	FJI	Fiji
YUG	Yugoslav SFR	SRB	Serbia
ZMB	Zambia	ZWE	Zimbabwe

Table S4. Data sources used for estimation of habitual intake.
Description of datasets with repeat 24-hour recalls that were used to determine habitual intakes in SPADE.

Dataset	Data source	Age/sex groups	Number of recall days	Sample size	Year	Nutrients available	Representa-tiveness
Bangladesh	FAO/WHO GIFT	Female, ages 16-70	2	475	2007-2008	omega-3, red meat, calcium, vitamin A, iron, vitamin b12	Two rural upazillas
Bolivia	FAO/WHO GIFT	Female/male, ages 4-52	3	153	2009-2012	omega-3, red meat, calcium, vitamin A, iron, vitamin b12	One rural tropical area
Bulgaria	FAO/WHO GIFT	Girls/boys, ages 0-4	2	1723	2007	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
Burkina Faso	HarvestPlus	Female, ages 19-55; girls/boys 1-4	2	960	2010	omega-3, red meat, calcium, vitamin A, iron, vitamin b12	Two rural provinces
China	China Health and Nutrition Survey/ Carolina Population Center	Female/male, ages 15-	3	10197	2009	omega-3, zinc, red meat, calcium, vitamin A, iron	National
Italy	FAO/WHO GIFT	Female/male, ages 0-89	3	3323	2005-2006	omega-3, red meat, calcium, vitamin A, iron, vitamin b12	National
Lao	FAO/WHO GIFT	Female/male, ages 0-89	2	2045	2016-2017	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
Mexico	ENSANUT	Female/male, ages 0-97	2	4343	2016	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
Philippines	FAO/WHO GIFT	Female, lactating, ages 15-47	2	1205	2002	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
Romania	FAO/WHO GIFT	Female/male. ages 19-92	7	1382	2011-2012	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
Uganda	HarvestPlus	Female, ages 20-73	2	554	2006-2007	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
USA	NHANES	Female/male, ages 0-80	2	7640	2017-2018	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	National
Zambia	HarvestPlus	Female, ages 18-67	2	374	2009	omega-3, zinc, red meat, calcium, vitamin A, iron, vitamin b12	Two rural regions

Table S5. List of nutrients included in Figure 1, with daily recommended nutrient intakes and their source. Describes the recommended nutrient intake (RNI) visualized in Figure 1, and used to calculate the ratio of nutrient concentration per 100 gram of each food group for each of the 7 nutrients.

Nutrient	Daily Value	Source	Notes
Vitamin A (RAE)	45 mg	FAO and World Health Organization 1998 *Vitamin and mineral requirements in human nutrition Second edition* (Bangkok) Online: www.who.org	Value based on requirements for a female aged 19-50
Vitamin B12	2.4 mcg	FAO and World Health Organization 1998 *Vitamin and mineral requirements in human nutrition Second edition* (Bangkok) Online: www.who.org	Value based on requirements for an adult 19-65+
Calcium	1000 mg	FAO and World Health Organization 1998 *Vitamin and mineral requirements in human nutrition Second edition* (Bangkok) Online: www.who.org	Value based on requirements for a female aged 19-50
Iodine	150 mcg	FAO and World Health Organization 1998 *Vitamin and mineral requirements in human nutrition Second edition* (Bangkok) Online: www.who.org	Value based on requirements for adolescents and adults from 13-65+
Iron	29.4 mg	FAO and World Health Organization 1998 *Vitamin and mineral requirements in human nutrition Second edition* (Bangkok) Online: www.who.org	Value based on requirements for a female aged 19-50
Zinc	4.9 mg	FAO and World Health Organization 1998 *Vitamin and mineral requirements in human nutrition Second edition* (Bangkok) Online:	Value based on requirements for a female aged 19-50

		www.who.org	
Omega 3 fatty acids (DHA plus EPA)	0.5 g	Cunnane S, Drevon C A, Harris B, Sinclair A and Spector A 2004 Recommendations for intakes of polyunsaturated fatty acids in healthy adults. *ISSFAL Newsletter*, *11*, 12-25.	Expected to significantly reduce risk for death from CHD in healthy adults.

Table S6. Database description of terrestrial animal food categories. Describes the source and product form for the terrestrial animal food categories visualized in Figure 1. Nutrient data sourced from USDA included Vitamin A (RAE), Vitamin B12, Calcium, Iron, Zinc, and Omega-3 fatty acids DHA and EPA. Iodine data was sourced from the Norwegian Food Composition Table.

Food category	**USDA [code] description**	**Norway description (Iodine)**
Eggs	[01123] Egg, whole, raw, fresh	Eggs, raw
Chicken	[05006] Chicken, broilers or fryers, meat and skin, raw	Chicken with skin, raw
Pork	[10006] Pork, fresh, separable fat, raw	Pork, inside round, raw
Beef	[13002] Beef, carcass, separable lean and fat, select, raw	Beef, inside round, topside, raw
Goat	[17168] Game meat, goat, raw	No Iodine available in Norway's database or elsewhere, assumed to be 0.
Lamb	[17224] Lamb, ground, raw	Lamb, inside round, raw
Cow Milk	[01211] Milk, whole, 3.25% milkfat, without added vitamin A and vitamin D	Milk , cultured, plain, organic
Butter	[81101000] Butter	Butter
Veal	[17104] Veal, loin, separable lean and fat, raw	Veal, chops, raw