International protein reliance by seafood consumption sourcing

Connor Quiroz and Jessica A. Gephart

School of Aquatic and Fishery Sciences, Box 355020
University of Washington, Seattle, WA, 98195-5020

Introduction

Knowing how we eat is critical for gauging our health. Nutrition has been an important focus for millennia as the macro- and micronutrients we consume can prevent disease, improve our energy, and our well-being (Kimokoti and Millen 2016, Malik et al. 2023). Nutritional information and security is important for both households and governments to gauge one's own food welfare which can bolster livelihoods, culture, and well-being. It can also be used to develop and monitor food-based dietary guidelines (Elmadfa and Meyer 2010, Cafiero et al. 2018), as food security is a substantial issue. Since the COVID-19 pandemic, global food insecurity has been on the rise, primarily due to reduced income, disproportionately affecting Africa and Asia and an estimated 691–783 million globally (Kuchechuk 2022, Iannotti et al. 2024). Food-based dietary guidelines can improve nutritional consumption, but these policies may not be representative of the latest national level consumption patterns (Herforth et al. 2019, Iannotti et al. 2024).

Food consumption databases can help build out food-based dietary guidelines. These databases, including the Food and Agriculture Organization Food Balance Sheets (FAO-FBS) and the Data Food Networking Databank, provide national level dietary estimates for what we eat (e.g., protein, caloric, fat intake), and have had global effort for being built out the past decades (Szűcs et al. 2013). FAO-FBS, however, does not contain information on the food sourcing (e.g., method of capture, production origin), which is important for constructing representative food-based dietary guidelines (Elmadfa and Meyer 2010, Gephart et al. 2021). Seafood, more specifically aquatic animals (AA), which contributes to 15% of globally consumed animal protein (FAO 2024), has broad measurements in the FAO-FBS onits apparent consumption, has also not been disaggregated by source. As shifting climates can reduce macro and micronutrients found in seafood and access to seafood may be increasingly constrained by supply disruptions, it is critical to identify AA's nutritional contributions toward international food security by source (Farmery et al. 2022, Shalders et al. 2022).

What is the AA contribution towards total daily consumed animal protein and consumed animal calories nationally? We will address this research question by leveraging the FAO-FBS as well as the new Aquatic Resource Trade in Species (ARTIS). ARTIS has disaggregated global trade data by country of harvest, production method, and species, resulting in estimated consumption for over 2400 species, 193 countries, and 35 million bilateral trade records going back to 1996 (Gephart et al. 2024). By combining holistic FAO-FBS estimates to ARTIS' sourcing data, we can estimate how much AAs contribute to nationally consumed animal protein and calories. This data will allow for trade analysis on how seafood consumption sourcing change with respect to governments' changing social-environmental-governmental conditions as well as risk assessments on countries' reliance on seafood.

Methods

To derive seafood supply and protein importance by sourcing, we leveraged the new ARTIS database (Gephart et al. 2024) the Food and Agriculture Organization Food Balance Sheets (FAO-FBS; FAO 2013; FAO 2022). The ARTIS database has seafood consumption quantities by habitat (i.e., inland; marine), by method (i.e., capture; aquaculture), and by the producer source (i.e., foreign; domestic) while the FAO has food supply and protein amounts across all food sources (e.g., seafood, agriculture, grains, plants) by country and by year. We can use these FBS variables to derive the proportion that seafood contributes to: (1) total protein consumption and (2) total food supply quantity (grams) by dividing the seafood protein/food supply quantity by the total amount found across all food groups for a particular year and country. This, however, only captures countrywide seafood contributions, and not the importance by sourcing.

One caveat with the FBS is that they revised their methods for calculating protein and food supply quantities in 2013, leading to slightly different calculations between the two datasets (FAO 2013; FAO 2022). There are overlapping years from 2010-2013 since they began using the new method in 2010 and did not stop using the historical method until 2013. To ensure these calculations may not have a substantial impact on seafood importance by source, we compared protein and food supply quantities across countries for these given years between these two datasets. We found no significant differences between the method calculations and proceeded with joining the data to ARTIS.

Similar to the proportioning calculations done with the FBS, we used ARTIS to calculate the proportion that seafood consumption for a given year and country contributes to domestic/foreign consumption, inland/marine sourcing, and capture/aquaculture methods. There were 8 total categories which consumption can be disaggregated into (i.e., 2 x 2 x 2 combinations), so adding across all these categories in a country and year will sum the seafood consumption contribution to 100%. We joined ARTIS to the FAO-FBS by consuming country and by year and multiplied the ARTIS sourcing percent contribution to seafood consumption by the FBS seafood percent contribution to protein supply and the percent contribution to protein supply to get the overall sourcing contribution. These calculations provide the proportion that seafood domestic/foreign sourcing, habitat, and method of capture contributes to: (1) daily total protein consumption (grams per capita per day); and (2) daily total food consumption (calories per capita per day).

Results

Our data captures the trends in international protein and food supply importance by consuming sources from 1996-2019. Globally, ~15% of seafood contributes to consumed animal proteins while AAs contribute ~9% to global daily caloric intake (Figure 1). Globally, aquatic animal contribution has declined, but overall contribution to the calories which we consume has increased. Presently, Oceania has had the highest reliance on seafood, followed by Africa, Asia, North America, Europe, and South America. Marine capture has been the highest contributor to protein supply and food supply (Figure 1) followed by domestic inland capture. Aquaculture has not contributed to as much daily protein and food consumption as capture fisheries has, but has been steadily increasing, particularly in inland farms. The importance of foreign dependency has steadily increased while the importance of domestic production has steadily declined for marine capture seafood.

Aquatic animal reliance has been an important contributor to overall food consumption. Across 184 consuming countries, 106 have had an increase in aquatic animal protein reliance. Europe had the highest increase in aquatic animal protein reliance followed by the United States, with Africa having the highest decrease (Figure 2). At the same time, foreign dependency has also increased, with the highest increases also in Europe. We thought Europe's increase in foreign dependency could have resulted in their reliance from other adjacent countries in Europe, but it foreign sources came from outside Europe. (Figure 3).

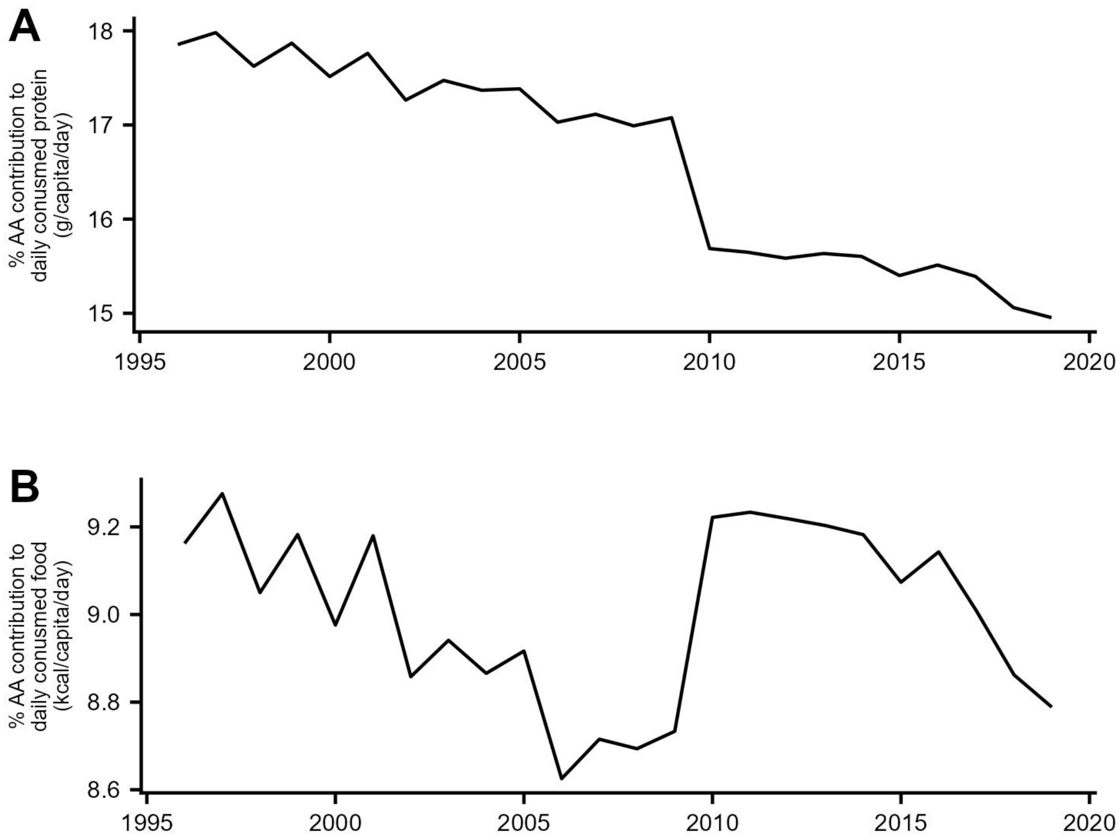

Figure 1: Global aquatic animal contribution to daily animal protein intake (A) and daily animal caloric intake (B). Ex: 15 percent would indicate that AAs contribute 15 percent toward the total consumed animal protein per day for a given year.

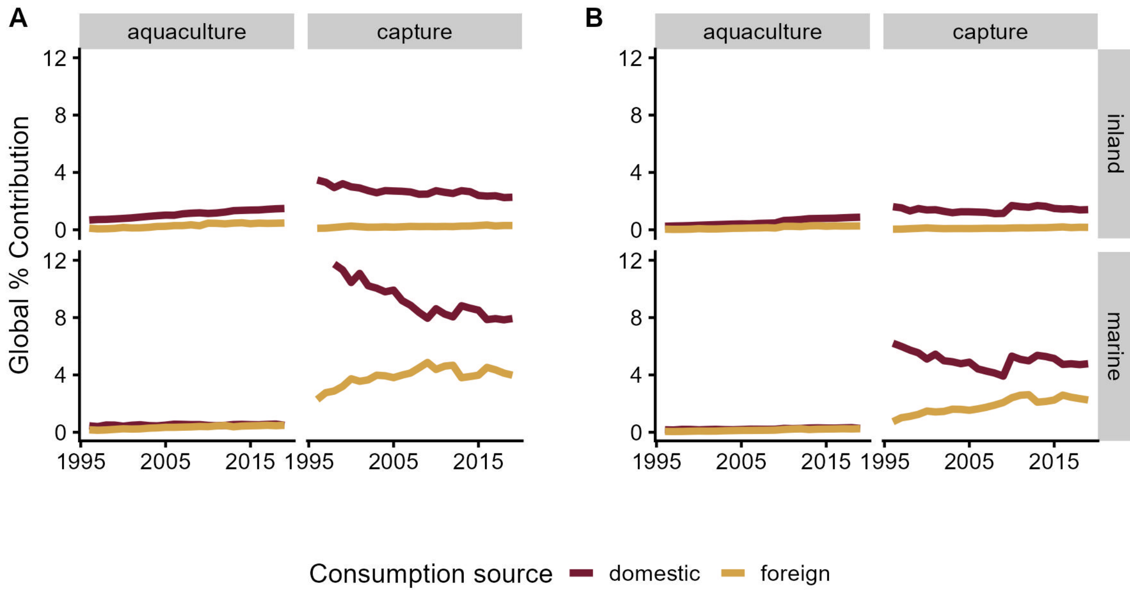

Figure 2: Annual global percent contribution to daily protein intake in grams (1A) and daily food intake in calories per capita (1B). This data derives these estimates from joining ARTIS data to the FAO-FBS.

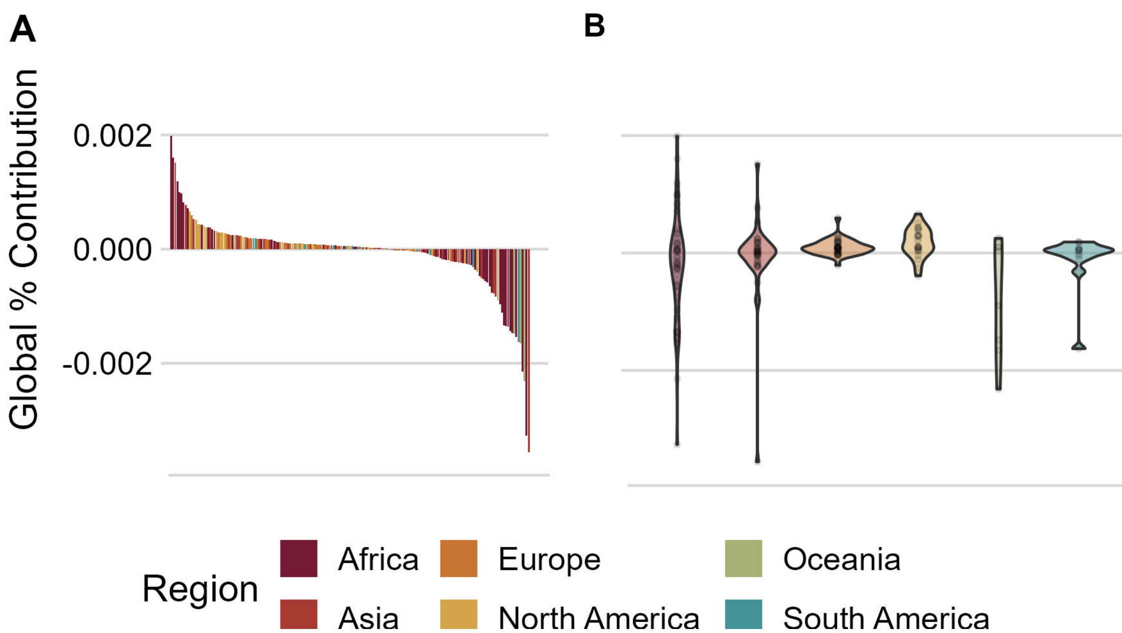

Figure 3: Change in aquatic animal reliance from 1996-2019. These slopes were calculated by obtaining the change in aquatic animal reliance for a country from 1996-2019. Positive slopes indicate that a country has increased its seafood consumption sourcing from foreign countries, and negative slopes indicating a shift toward an increased domestic consumption. Plot 2A shows the highest to lowest aquatic animal reliance slopes, centered around 0 (i.e., no change). Plot 2B highlights continential distributions of changes in foreign aquatic animal reliance.

Discussion

Aquatic animal reliance has been an important contributor to overall food consumption. This new dataset provides high resolution estimates into international AA contribution by sourcing, which is important for informing food-based dietary guidelines. Our data shows that global AA contribution to protein and caloric consumption has increased over the past couple decades. While there has been a global decrease in the mean percent reliance towards protein consumption (Figure 1), this reliance when measured within individual countries, has collectively increased with the highest increases in Europe and North America (Figure 3). We believe this suggests that seafood is becoming increasingly important, particularly sourced from marine capture fisheries. Aquaculture production is on the rise as well as foreignly sourced AAs. While foreign imports can increase food availability and diversity (Subramaniam et al. 2024), we believe that a heavy reliance on foreign sourcing may leave countries vulnerable to climatically induced food shortages.

The accuracy of this dataset also needs to be considered. While the ARTIS database leverages different Harmonized system versions to layer and provide the most accurate seafood consumption data (Gephart et al. 2024), the FAO-FBS was split into different datasets with old methodologies ending in 2013 and new one starting in 2010. There are currently no harmonization methods for merging historical and new FAO-FBS. Differences in historical vs new values can be explained as transnational shifts, but these differences can be nuanced when looking across countries and may need careful curation if focusing on a specific country (Vonderschmidt et al. 2024). Averaging over multiple years with FAO-FBS fata can produce more reliable trends - this could be a technique used to interpret our FAO-FBS-ARTIS joined data (Thar et al. 2020).

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