Dear Chris

I hope this finds you well. My apologies for the delay in giving you a decision on this. Your manuscript entitled "Aquatic Foods for Nourishing Nations" has now been seen by six referees, whose comments are attached below. While they find your work of potential interest, as do we, they have raised important concerns that in our view need to be addressed before we can consider publication in Nature.

Should further work allow you to address these criticisms, we would be happy to consider a revised manuscript (unless something similar has been accepted at Nature or appeared elsewhere in the meantime).

In revising the manuscript we will need you to address all of the referee concerns. There are a few general points coming out of the reports that we will need you to pay particular attention to. Specifically, it seems that much more transparency in the methods is needed, along with greater clarity and discussion about the limitations of the scenario analysis, including underlying assumptions. It also seems that the dietary intake analysis needs strengthening and the limitations need to be bought more to the fore. More generally it seems important to discuss the barriers to aquaculture expansion, and to ensure that the benefits of aquatic food are not being oversold in relation to available evidence.

We are committed to providing a fair and constructive peer-review process. Please do not hesitate to contact us if there are specific requests from the reviewers that you believe are technically impossible or unlikely to yield a meaningful outcome.

In the meantime, we hope that you will find our referees' comments helpful. Please do not hesitate to contact me if there is anything you would like to discuss.

Best wishes,

Anna

Anna Armstrong

Senior Editor

Nature

**Dear Anna, we thank you for the opportunity to submit revisions for this manuscript. Throughout the reviewer comments, we have provided our responses in bold. We have accepted nearly every comment and are grateful for the helpful reviews we received. Many thanks, Chris (on behalf of the entire authorship)**

### Referee #1

This is an interesting manuscript that reports some very important findings including the importance of proper accounting of the diversity of seafood in terms of its nutrient value, which may help some groups to better recognize the value of aquatic foods for human health and hopefully lead to policy change. The figures are very appealing and interesting and the paper presents a lot of new analyses that I’ve not seen before, while in other places building on work that has already been done.

The manuscript does take a bit of an advocacy slant in places, and I would encourage the authors to revisit certain aspects of it with a fresh eye including being up front about the limitations related to the use of modeled data, and softening some of the claims around the health benefits of aquatic foods to better align with the evidence base.

Specific comments

Line 79. This claim is a bit odd because the pathways from food to health do not necessarily all go through nutrient deficiencies. Given high morbidity could also be a reason for nutritional deficiencies in many settings, do we really know that dietary inadequacies are the leading reason for multiple nutrient deficiencies? Or are you specifically talking about dietary nutrient gaps and not physiological micronutrient deficiencies? It would help to clarify exactly what is being referred to here.

**We thank the reviewer for this comment and the opportunity for clarification. In the text, we state that the “leading” cause, not exclusive cause, of micronutrient deficiencies are dietary inadequacies. To soften the language, we have changed the text to “may be” rather than “are.” Though this claim is substantiated by our citation, we agree with the reviewer that this is still not well known.**

Lines 122-124. These are three pathways that the paper examines but these are not the only pathways. I would clarify this. Substitution could also be for other foods. Also, Aquatic foods are not unique sources of DHA, in fact the enhancement of eggs with DHA is an increasingly important contribution to intake of this nutrient in some settings (mostly developed countries to date but some middle income countries). It would be important to specify that it is long chain polyunsaturated fatty acids you have in mind here, not all omega 3’s, which would include ALA, provided by seed and nut oils.

**We agree with the reviewer that these are three potential pathways, though not an exhaustive list, and have clarified that in the text. We have also clarified the types of fatty acids being discussed (DHA+EPA PUFA) rather than omega-3s broadly.**

**The reviewer also notes that DHA is increasingly being provided by enhancement of eggs. It is true that chickens fed flaxseed which contains ALA (18:3) do convert inefficiently to DHA so this can be a source for “marine” fatty acids especially in depleted populations. Or, some chickens may be fed fish oil directly. Of course, in most depleted populations it is unlikely that (and hard to know if) chickens are fed this more pricey feed. We would argue that this is a very minor source of DHA, particularly as it relates to nutritionally vulnerable populations.**

Line 142. Is it realistic to frame this as aquatic foods preventing the nutrition transition or “averting” the nutrition transition (line 294). To me, this seems like a pretty big claim. I’d suggest reframing this around attenuating chronic disease morbidity/mortality. The commonly used concept of nutrition transition also involves shifts in activity levels, dietary changes, shifts in the burden of disease that I don’t think can be prevented by more consumption of aquatic foods.

**We thank the reviewer for this comment and have clarified this distinction throughout the manuscript (L284 & L302, etc.) to state that the function is to “attenuate chronic disease morbidity and mortality characteristic of the nutrition transition.”**

Line 152. Moderate growth trends of what? Fish production and consumption or other things too?

**This is referring to moderate growth in production based on the OECD-FAO annual projections for production growth based on a Business as Usual scenario. This has now been clarified in the main text, and exhaustively described in the Supplementary Methods.**

Lines 163-171 how was loss and edible portion accounted for and what was the source of information used by the global nutrient database for aquatic foods? How adequate is this database as a source of nutrients from aquatic foods given the diversity of nutrient composition recognized by this paper? [for people not familiar with this database I think 1-2 sentences here describing what was used to create it would be important as it is not primary data].

**A set of refuse factors is applied to all foods; these refuse factors are highly specific to individual foods and their respective forms of preparation. Within the food group of fish and seafood, these refuse factors vary from 55% for fresh crustaceans to 10% for fresh cephalopods. AFCD contains information on edible portions for 1,445 unique species/preparation types, which was used to match edible portions of all consumed species.**

Line 164 I was a bit confused here about how these two databases are being used; perhaps you could stress that they are being compared here--is that the case?

**For 21 of the 22 food commodity categories (all terrestrially produced foods), the GND was used as the source of nutrient composition data. For the one commodity category containing aquatic foods, the AFCD nutrient composition values were used.**

Line 199 could you expand on what drives these models and their limitations? Is this strictly based on cross-price elasticity of demand or are there other assumptions (such as cultural importance/preferences) that are/are not incorporated?

**Per capita consumer demand of any specific type of food is mainly influenced by the price of that item, the price of other types of food, and income. The availability of different types of food in any specific geographic region is reflected in the price charged to consumers. Starting from an equilibrium point if production of one type of food like aquatic products is increased, its price will fall and if income and other prices do not change, consumption of aquatic products will increase. However, the price of aquatic food products also affects the demand and consumption of other types of food. Aquatic food products are often a substitute to meat from terrestrial animals. The lower price of aquatic food products will generate lower consumption of these terrestrial meats. So, the net effect on the overall consumption of the different nutritive elements depends on the level of substitution of aquatic food products with terrestrial foods. That relationship can be very different depending on different countries. The Aglink-Cosimo model used for this analysis includes these different relationships for 48 countries/regions. This is all included in the Supplementary Methods.**

Lines 192-195 and Line 205-207 The evidence base linking aquatic food consumption to some of these items is stronger than others. Even for some of the better studied linkages (omega-3 fatty acids and cardiovascular disease) studies are inconsistent throughout the literature. For others such as cancers, my understanding is that any associations would primarily be driven by substitution of processed meats rather than unique characteristics of aquatic food and for depression I don’t believe there is enough evidence to claim a benefit. I’m also thinking here about the U.S. dietary guidelines which represented a recent effort to collate the evidence… I would suggest that any claims beyond the dietary guidelines should be strongly supported by literature and that expanding on the mechanisms through which aquatic foods could lead to such health benefits would also be useful and will lead to a more defensible argument.

**Thank you for this comment and important point about the strength of evidence for aquatic foods and risk of chronic disease. Although conducting long term randomized clinical trials on aquatic foods is not feasible, they are an important component of the “Mediterranean diet” which has the strongest body of evidence to support a link with lower risk of many chronic diseases and is recognized by the US Dietary Guidelines as a healthy diet pattern. As noted in the US Dietary guidelines, 90% of Americans do not achieve recommended seafood levels, but “selecting from the seafood subgroup or the beans, peas, and lentils subgroup more often could help meet recommendations while still ensuring adequate protein consumption. Replacing processed or high-fat meats (e.g., hot dogs, sausages, bacon) with seafood could help lower intake of saturated fat and sodium, nutrients that are often consumed in excess of recommended limits”.   It is very hard to state directly that increasing aquatic species is directly causally related to depression or cancer, but diets high in processed foods, sodium and saturated fat have been linked to cancer and mental health outcomes. The evidence for aquatic foods and reduced risk of mental health and for treatment of depression is not as strong as the evidence for cancer so we will remove that from this statement to reduce confusion.**

Line 218. Again, It may help to clarify what is meant here by “nutrient deficiencies” do you just mean dietary nutrient deficiencies or biological deficiencies? If the latter, there are other causes… perhaps those fit under what is listed as “other individualized factors” but things like malabsorption or higher needs due to illness are quite important causes of nutrient deficiencies.

**We have clarified in the text that we had intended to say inadequate intake of nutrients rather than biological nutrient deficiencies.**

Line 228… Would be helpful to discuss what changes these represent from today’s levels as this seems to be a major part of the discussion.

**We have clarified in the text that each nutrient increases by 0-10% above 2020 values.**

Line 234 “total amount of nutrition required” seems like an unusual use of this term. Similarly “nutritional outcomes” on line 237 could be more specific

**We have clarified in the text that we are referring to age- and sex-specific nutrient demands in what is now L244; and, we have clarified that we meant “risk of nutritional deficiencies” rather than “nutritional outcomes” in now L247.**

Line 242 what level of EPA/DHA deficiency is being used and what is that based on? Is it for all age/demographic subpopulations?

**We used the updated IHME Global Burden of Disease’s relative risk curves for omega n-3 EPA+DHA that are only associated with ischemic heart disease and have different values for adolescent and adult subpopulations (with no risk for children). These relative risk curves capture mild risk associated with consumption of under 0.4 g/d. We have now updated the methods section to say this more explicitly. For low aquatic food consumption, we use the relative risk of ischemic heart disease associated with consumption of omega n-3 EPA and DHA derived from the Global Burden of Disease24.**

Lines 254-259 This is a nice idea, consistent with the “Fill the nutrient gap” efforts by WFP and others, but the examples seem overly simplistic to me. How much of the variation in dietary deficiencies is there across countries vs within countries; with large within country disparities in nutritional deficiencies (which I believe are often typical) does it make sense to promote for countries as a whole or to promote for specific populations within a country? And is the solution to focus on promoting consumption or supply? And of course it neglects the fact that there are non-aquatic foods related solutions to nutrition problems as well, the solution does not always have to come from aquatic foods. It would be nice to see a more balanced/pragmatic discussion of the solution to nutritional problems here. The solution does not always need to come from aquatic foods although they may have considerable potential.

**We agree with the reviewer’s comment. We have softened the language to describe this as potential solutions among others. Additionally, we added a concluding sentence: “These types of food system solutions will require subnational targeting of vulnerable populations and will rely on efforts to increase both production and consumption.”**

Lines 271-289 Are the benefits here calculated based on nutrient gaps or based on health outcomes (the first sentences suggests health outcomes but the rest of the paragraph seems to suggest this thinking is about correcting nutrient gaps.

**The calculations we perform in this paper are based on comparing nutritional intakes with relative risk curves to quantify nutritional deficiencies and risks (gaps) and not health outcomes (e.g. DALYs). Beginning on line 239 we say “Our food system-wide nutrient calculations assess the level of excess risk each country experiences because of deficiencies in their overall food systems. We calculated summary exposure values (SEVs) of the population to measure this excess risk, comparing the total amount of nutrition derived from apparent consumption against the total amount of nutrition required (see Methods).”**

Lines 300-302 Again, these are for the most part not well-established benefits of consumption of aquatic foods with the exception of cognition. Is that the reason you didn’t quantify them? I would suggest either rephrasing or removing.

**We have removed this sentence.**

Line 330. How about poultry? Seems like that should also be mentioned.

**The comparison to poultry is certainly relevant and of interest. We modified this sentence to now read “Despite the variability in environmental impacts across animal-source food production sectors, aquaculture (as wild capture fisheries) nearly always produces fewer greenhouse gas emissions and uses less land than red meats and many aquatic foods outperform poultry (Gephart et al. *in revision*).” The comparison to poultry requires more caveating than the comparison to red meats based on work in another paper that is part of the Blue Foods Assessment and under consideration at *Nature*. This study develops a model to consistently compare environmental stressors across farmed and wild aquatic food production (as well as chicken for a terrestrial benchmark). The study finds that poultry compares similarly to tilapia across a range of environmental stressors, which places it roughly in the middle of farmed species groups and on the lower third of capture species groups in terms of greenhouse gases (but higher than all capture production in land, water, and N/P emissions). Since we do not have sufficient space to detail this here, we now reference Gephart et al (*in revision*) to support the point.**

Paragraph starting line 337. It would be helpful to add more discussion about the problems that these products are intending to solve. Why is processing necessary?

**The problems that these products are intending to solve reflect inequity in access to aquatic foods mediated by wealth, age, gender, ethnicity etc. Some of these inequities reflect cultural norms that occur, for example, within households that restrict access to adequate amounts of aquatic foods required by the nutritionally most vulnerable such as adolescent women. Processing may improve access to, and consumption of, aquatic foods of such groups in several ways. To some extent, processing may even out access to, and affordability of, aquatic foods linked to geographical variation or seasonal availability of fresh aquatic foods. This is borne out by the centrality to diets of processed fish in areas of the world that lack affordable fresh fish-that range from populations distant from perennial water sources and where distribution and storage of fresh fish is problematic or impossible.**

Synthesis. I find some of the wording here confusing, are “nutritional assessments” really what are needed as a policy opportunity? This doesn’t seem to make sense given the rest of the sentence. How does one harness “diversity of aquatic foods nutrient portfolios”, what does that mean in practice? Would be worth re-reading these and the rest of the recommendations to make sure that they are concrete and actionable.

**Thank you for the suggestions to further clarify the synthesis section of the paper. We have modified the language considerably to ensure that the recommendations are action-oriented and have removed obtuse language. The synthesis section now reads as follows:**

**Our findings suggest strategic research and policy opportunities:**

**1) in countries where there are high burdens of micronutrient deficiencies, supply chains and availability of aquatic foods may be strengthened by improving fisheries management; enhancing sustainable aquaculture; and building more equitable national and regional trade networks;**

**2) promoting a diversity of nutrient-rich aquatic foods in sustainable aquaculture systems, in designing national food-based dietary guidelines, and for public health interventions targeting particular nutritional deficiencies among vulnerable populations living in particular geographies;**

**3) incentivizing access and affordability of aquatic foods in countries experiencing a rapid nutrition transition;**

**4) prioritizing aquatic foods in social protection programs including food assistance, school meal programs, and safety nets for the most nutritionally vulnerable, including pregnant and lactating women, young children in the first 1000 days, and the elderly.**

**In line with the Committee on World Food Security’s Voluntary Guidelines on Food Systems and Nutrition39, calling for greater attention to diverse nutritious foods for transformation of food systems, national food and nutrition policy may include and prioritize aquatic foods where culturally and socially appropriate. Also, policy may ensure that the governance of and investment in aquatic food systems aim to preserve, support and innovate with: a diversity of aquatic species; improved production and harvest methods and practices; and increasing efficient and safe distribution channels. These measures should enable aquatic foods to play an important role in nourishing nations and improving global nutrition and health.**

Line 451. How was the inedible portion of each food item “adjusted for”? What does this mean in practice? Given some fish are consumed whole others are consumed as fillets, how did you approach the issue of edible portion, and what assumptions were made about how food preparation and cooking influenced nutrient content?

**As mentioned above, a set of refuse factors is applied to all foods; these refuse factors are highly specific to individual foods and their respective forms of preparation. Within the food group of fish and seafood, these refuse factors vary from 55% for fresh crustaceans to 10% for fresh cephalopods. AFCD contains information on edible portions for 1,445 unique species/preparation types, which was used to match edible portions of all consumed species. Averages across preparation methods were taken, and this is stated as an assumption in the methods.**

How did you estimate the nutrient values for fish that you did not have composition data for? Did you use the same approach as Hicks et al or the values they estimated for those species? Or was there a different approach taken?

**Our approach to estimating nutrient values is described in detail in the Supplementary Methods. To link disaggregated species to the AFCD, we used a hierarchical approach to fill the nutritional value for all 7 nutrients to all species consumed globally (Supplemental Fig. S16). When multiple entries were present for a single species, we took the mean of all entries. We built this hierarchy according to the following order: 1) scientific name, 2) average of species genus, 3) average of species family, 3) common name, 4) average of species order, and 5) average of GND category. In the disaggregation effort, we found 2,143 different aquatic species being consumed globally. The nutrients to be matched were: iron, zinc, protein, vitamin A, vitamin B12, omega-3 long-chain polyunsaturated fatty acids and calcium. After this matching process, we updated the estimates of nutrient intake at national levels.**

Line 520 . Were the nutrition surveys you incorporated comprehensive in capturing age-sex groups or did you make assumptions about intake of groups not represented in those surveys? If the latter, how did you do it?

**We substantially rewrote the section describing our supplemental methods for deriving subnational habitual intake distributions to increase clarity and to address this and other comments.**

**The section now begins with an overview of our methods for deriving subnational habitual intake distributions and includes a new conceptual figure (Figure M4) to visualize this workflow. It then presents the methods in a new and more logical order. We first describe how we derived mean subnational intakes from mean national intakes using the GENuS database and then describe how we derived the shape of subnational intake distributions around these means through analysis of dietary survey data. In rewriting this section, we more clearly highlight where imputation occurs and the assumptions and methods leveraged to perform these imputations. We also more clearly highlight the considerable advancements that our modeling methods make in carefully and transparently modeling subnational intake distributions.**

**We believe this restructuring better highlights the coverage of the survey data (visualized in Figure S8) and the methods used to impute missing data (visualized in Figures S16 and S17). Specifically, we point the reviewer to the following text:**

**“Because the habitual intake data and associated statistical probability distributions were incomplete across all country-nutrient-sex-age combinations (Figure S8), we filled gaps by imputing data from the nearest neighbor (37% of sex-age 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 S16). We then mapped these to the rest of the world, based on UN sub-regions, with a few expert-identified modifications (Figure S17).”**

Line 551. Is it the case that the dietary survey data is 10 years old? If so this should be listed as one of the limitations (noted below). Diets have changed a lot in the past 10 years in many countries.

**We substantially rewrote the section describing our methods for deriving subnational habitual intake distributions to increase clarity and to address this and other comments.**

**We believe this restructuring has made it more clear that the AgLink-Cosimo model projects changes in diets and subsequent changes in nutrition to 2030. We then use the GENuS data to guide the disaggregation of the projected national means into subnational means and the dietary survey data (which is variable in age) to inform the shape of intakes around the projected means.**

**We also added text to the supplemental methods in a new section entitled “Acknowledging Limitations of our Nutrient Projections” to better highlight and discuss our limitations.**

Methods: As with any efforts to model data there are decisions made that lead to limitations and open questions about how well the modeling efforts reflect reality. What are the limitations of the approaches used? Could you add a paragraph about that somewhere? Were there attempts to validate the models against actual consumption?

**We added text to the supplemental methods in a new section entitled “Acknowledging Limitations of our Nutrient Projections” to better highlight and discuss our limitations.**

### Referee #2

This paper study the future impact of aquatic foods on human nutrition by forecasting aquatic food consumption to 2030 in different scenarios. The paper is on the one hand interesting and innovative in combining consumption of aquatic food with micronutrients and nutrition, but is on the other hand difficult to follow, doesn’t provide details on the modelled applied (the OECD-FAO model) and can scope the discussion more in relation to existing literature on aquaculture growth.

Comments:

1. Title: What is a nourishing nation?

**We have altered the title to read “Aquatic Foods to Nourish Nations”**

2. Abstract: A price reduction is mentioned for one of the scenarios, but it is not described in the paper. Where does this price forecast comes from? How have it been obtained? What are the assumptions behind it? How does the model that provides this estimate works?

**We thank the reviewer for pointing out that we had not adequately described this part of our methods/results. The price forecast is generated by the Aglink-Cosimo model and all of the details of this model, and how the price forecast was developed, are discussed in depth in the Supplementary Methods in the “Aglink-Cosimo” section.**

3. The authors look at the effect of more farmed fish supply without discussing how to achieve growth. A discussion of barriers to aquaculture growth is suggested included in the discussion section, including environmental impacts such as nutrient discharges, escapements, lack of space, etc.

**We added these environmental impacts to the existing discussion paragraph describing the environmental , economic, and social barriers to expanded aquatic food production. Additionally, we added the following sentence to the conclusion of this paragraph to emphasize the importance of mitigating these impacts and overcoming these barriers:**

**“Sustainably and equitably achieving the human health benefits of expanded aquaculture production will require policies and technologies that mitigate impacts on adjacent ecosystems, industries, and communities (Costello et al. (2020).”**

4. It could be mentioned that aquaculture for long have been the fastest animal food producing sector worldwide, although the growth rates have been reduced in recent years. Also, the about half-half share of farmed/wild seafood globally deserves mention as does the fact that wild catches provide in the range of 1000 species commercial used worldwide, while for aquaculture species, the species produced are concentrated on much fewer species. And that fish supply is more diverse than for meat, where 4-5 species cover more than 80 % of global consumption.

We added the following sentence to the “Aquatic food diversity” section to describe the diversity of harvested and cultured organisms: “Currently, wild fisheries harvest more than 2,300 species and aquaculture growers farm approximately 630 species or species-types (FAO 2020).” This sentence follows an existing sentence that describes the comparably less diverse make-up of terrestrial animal-source food. We added a new figure to the supplement (**Figure S1**) to illustrate historical (2010-2018) trends and relative contribution of fisheries and aquaculture to aquatic foods production along with the projected production in our future production scenarios.

5. The overall conclusion of the paper could appear much clearer. It is suggested explained what the main point is.

**We completely revised our Synthesis section. It now reads as follows:**

**Our findings suggest strategic research and policy opportunities:**

**1) in countries where there are high burdens of micronutrient deficiencies, supply chains and availability of aquatic foods may be strengthened by improving fisheries management; enhancing sustainable aquaculture; and building more equitable national and regional trade networks;**

**2) promoting a diversity of nutrient-rich aquatic foods in sustainable aquaculture systems, in designing national food-based dietary guidelines, and for public health interventions targeting particular nutritional deficiencies among vulnerable populations living in particular geographies;**

**3) incentivizing access and affordability of aquatic foods in countries experiencing a rapid nutrition transition;**

**4) prioritizing aquatic foods in social protection programs including food assistance, school meal programs, and safety nets for the most nutritionally vulnerable, including pregnant and lactating women, young children in the first 1000 days, and the elderly.**

**In line with the Committee on World Food Security’s Voluntary Guidelines on Food Systems and Nutrition39, calling for greater attention to diverse nutritious foods for transformation of food systems, national food and nutrition policy may include and prioritize aquatic foods where culturally and socially appropriate. Also, policy may ensure that the governance of and investment in aquatic food systems aim to preserve, support and innovate with: a diversity of aquatic species; improved production and harvest methods and practices; and increasing efficient and safe distribution channels. These measures should enable aquatic foods to play an important role in nourishing nations and improving global nutrition and health.**

6. It is difficult to achieve an overview of the results presented in the maps. An alternative presentation form is preferred, such as in tables.

**We uploaded data appendices that provide the data underlying the map figures as tables:**

* **Appendix A - National per capita food consumption in 2030 under both scenarios**
* **Appendix B - National per capita nutrient intake in 2030 under both scenarios**
* **Appendix C - National per capita nutrient deficiencies in 2030 under both scenarios**

**Additionally, all raw and processed data used in the health impacts analysis are on GitHub here: https://github.com/alonshepon/Health-Benefit-Calculation-BFA**

7. While the authors explain the handling of data in details, they assume that the applied models are well-known, doesn’t present the models, doesn’t discuss the assumptions behind the models, doesn’t explain how the models works and doesn’t discuss their limitations. The models, and in particular the OECD-FAO model, needs more detailed presentation including the main equations, in order for the reader to follow how the results are achieved and for the reader to assess the reliability and validity of the results.

**We thank the reviewer for pointing out that we had not adequately described this part of our methods/results. We have added a detailed “Aglink-Cosimo” section in the Supplementary Methods where we now exhaustively describe the model and its assumptions.**

8. Page 4 paragraph 3: The assumptions behind the forecast of growth in aquaculture must be related to current growth rates and presented much clearer in the main text.

**We appreciate this comment and took several actions to address it. We (1) added a section to the supplement to describe the Aglink-Cosimo model; (2) we significantly expanded the supplemental text describing the parameterization of the aquatic food production scenarios; and (3) this expansion included referencing the FAO report where the scenarios were designed (Ahern et al. 2021), adding a new table (Table S1) to explicitly show current production and 2030 production under the base and high production scenarios, and a new figure (Figure S1) to illustrate the growth in inland/marine aquaculture/fisheries production under both scenarios.**

9. While the abstract forecast a price reduction on 26%, assumptions behind this result in relation to price elasticities must be qualified, included and discussed.

**We thank the reviewer for pointing out that we had not adequately described this part of our methods/results. The price forecast is generated by the Aglink-Cosimo model and all of the details of this model, and how the price forecast was developed, are discussed in depth in the Supplementary Methods in the “Aglink-Cosimo” section.**

### Referee #3

Report on Aquatic Foods for Nourishing Nations

This is a very impressive publication based on a very rich and interesting study, [https://www.bluefood.earth/.](https://urldefense.proofpoint.com/v2/url?u=https-3A__www.bluefood.earth_.&d=DwMGAg&c=WO-RGvefibhHBZq3fL85hQ&r=JXqYpKlfrgRDkFLKLOodJG2H62fOYHKvM-oGegaHVsY&m=ISlFoZj0IWNbkkBtX4y13-I7uU4FA0Oxp2EkRObMiDo&s=V6SaQvB2Zwc6zCMYHckIN_xbNx1Q3xSG9wwzCOBug4o&e=) The paper showed that the extreme diversity of fish and seafood and the nutritional richness, and the potential to address multiple medical challenges, and improve nutritional wellbeing. It also contrasts the richness of seafoods, compared to terrestrial foods and present a model showing how much food security will improve with transition towards seafood and fish. I have no problem with the databases, the models, and the text. They are very interesting and useful.

However, the paper doesn’t belong to Nature. It provides a very detailed explanation of essentially known information. My medical doctor tells me that fish are good for us. They include micronutrients and are superior to meat. I’m also aware that there is a diverse fish population and they can be harvested in the ocean and grown by aquaculture. People who are interested can be referred to Blue Food and I suggest that the author can write a popular book. There is a place for a nice piece for this content in Nature Information. But I don’t really see the policy relevance of this paper. We have multiple problems of declining fisheries, polluting agricultural facilities, conflict in perspective on fishery management (see a recent article in Nature Sustainability by Belton et-al. 2020), major international trade conflicts about fisheries and the challenges of management of the fishery commons in the deep ocean. We know that the potential is there and they provide us much detail, but how should we reach there?

**We thank the reviewer for this critique and have tried to emphasize its clear policy implications that the reviewer felt were missing.**

### Referee #4

An excellent paper which I am sure will raise awareness of the global importance of nutritional value and important role played by aquatic food products in human nutrition. Notwithstanding the above, I felt the authors could have stressed the importance of price and income in dictating food selection, and why regions such as Asia (and to a lesser extent Africa in the case of small pelagics) that aquatic food products are actively consumed (often representing one the cheapest forms of animal protein available in the market place; unlike most countries in the Americas and Europe). Aquatic foods are already a major supplier of animal protein and essential amino acids for many Asian and African countries (not mentioned - line 294; see FAO Food Balance Sheets), and also a major supplier of iodine (including seaweeds: essential for thyroid function and brain development, especially in pregnant women and young children).

Albert G.J. Tacon

**Yes, it is true that aquatic foods contribute significantly to the human diets in terms of high-quality, easily-digestible high-quality proteins and essential amino acids PUFAs and micronutrients. The contribution of fish to nutritional intake varies considerably between and within countries depending on the availability and cost of fish and alternative foods, as well as the accessibility of fishery resources in adjacent waters, disposable income and socioeconomic and cultural factors such as food traditions, eating habits, tastes, demand, etc. Other determinants include climate, market penetration, regional demographic characteristics, urbanization, as well as the density and quality of transportation and distribution infrastructure.**

**Fish proteins can represent a crucial component in the diets of some densely populated countries where total protein intake levels may be low. In some countries/ populations, fish often represents an affordable source of animal protein that may not only be cheaper than other animal protein sources, but preferred and part of local and traditional recipes. In 2017, Asia consumed 71 percent of all fish food supply, while Africa only 8 percent. Yet, despite the relatively low per capita consumption in Africa, fish play an important role in terms of share of fish proteins in total animal proteins across many countries.**

**To be mentioned that in the Least Developed Countries, most of which are located on Africa, there has been an increase in annual per capita fish consumption from 6.1 kg in 1961to 12.6 kg in 2017, at an average annual rate of 1.3 percent. This growth rate has increased significantly in the last 20 years, reaching an average of 2.9 percent per year, explained primarily by the expansion of fish production and imports, in particular of small pelagic species, by a number of African States.**

**At world level, in 2017, fish accounted for about 17 percent of total animal protein, and 7 percent of all proteins, consumed globally. Moreover, fish provided about 3.3 billion people with almost 20 percent of their average per capita intake of animal protein. In Bangladesh, Cambodia, the Gambia, Ghana, Indonesia, Sierra Leone, Sri Lanka and some Small Island Developing States, fish contributed 50 percent or more of total animal protein intake.**

**Significant expansion of aquaculture since the mid-1980s has resulted in a sharp increase in the proportion of farmed fish consumed relative to wild-caught alternatives, even if differences exist among countries and regions in terms of preference. Species such as shrimps, salmon, bivalves, tilapia, carp and catfish (including Pangasius) have been instrumental in driving global demand and consumption, thanks to the shift from being primarily wild-caught to aquaculture-produced, with a decrease in their prices and a strong increase in their commercialization.**

**Seaweeds and other aquatic plants, the majority being farmed, are not currently included in FAO Food Balance Sheets and in the FAO Fish mode, despite their growing production and representing important components of national cuisines in many parts of Asia, in particular East Asia. Seaweeds contain micronutrient minerals (e.g. iron, calcium, iodine, potassium and selenium) and vitamins (particularly A, C and B-12) and are the only non-fish sources of natural omega-3 long-chain fatty acids.**

**(*SOFIA 2020 as major source of these last four paragraphs*)**

### Referee #5

Remarks to the Authors

In this interesting and ambitious paper, the authors examine the potential effects of an increase in the consumption of aquatic foods on a number of dietary deficiencies in countries around the world. They base their analysis on two hypothetical scenarios; a trajectory of current trends and one with specific focus/strategy to increase catch and investments and innovation in aquaculture production and biotechnologies.

The concept of analyzing how a scenario with a policy to increase in the supply of foods from aquatic environments would affect human diet and nutrition related health issues around the world is admirable. The basic principle in the analysis is to model 1) the potential effect of a change in policy on aquatic food production, 2) the resulting change in diet based on a price and availability principle, and 3) the consequence on health, mainly dietary deficiencies based on estimated average dietary requirements. Pursuing an answer to the overall public health question requires very many assumptions e.g. in terms of imputing data, extrapolating to 2030, and estimating the composition of innovative aquatic food production, and some reductions in complexity is inevitable. The authors do an amazing amount of work to examine the effects of diversity disaggregation on the estimated consumption, and the results from this analysis are very important. Thus, as hypothesized by the authors, choices, with respect to not only diversity but also other methodological approaches, are of importance for the results from a complex modelling analysis.

The results show that if such policies are set in motion they can have a large effect on production and availability of aquatic animal foods, which would affect human health. The results illustrate the need to look at the diet as such and not only the increase in the intake of aquatic animal foods and essential nutrients from these foods, but also potential adverse effects on intake of essential nutrients from the terrestrial animal foods that they replace. Not surprisingly, the authors find that an increase in consumption of nutrients from aquatic animal foods is associated with decreases in deficiencies of these nutrients, which depend on the frequency of deficiency of the nutrients in the population. However, due to the potential adverse effects on the consumption of other nutrients, the overall effect on health depends on the specific substitution in the individual countries. The authors therefore conclude that the implementation of policies to increase aquatic animal food production should be strategic and target for the specific population. The paper provide a good proof of the concept that such analyses would serve as a good source of information in the planning of public health policies and there is no doubt large health benefits to gain from strategic efforts to increase the supply of aquatic animal foods in many countries.

The paper is difficult to read, due to the complexity of the question, the complicated pipeline of analysis and the many results. I therefore have a number of methodological questions and comments regarding various nutritional aspects.

**We thank the reviewer for this thorough summary and have attempted to increase the clarity (reducing complexity) throughout the manuscript.**

What is aquatic food and what is the focus in the analysis?

It is not clear to me which aquatic foods the authors include in their study. The authors define aquatic foods to include animals, plants and microorganisms, wild, reared and various biotech products. I find this pooling of foods from the three kingdoms problematic and confusing. The authors set up three pathways by which aquatic foods could improve human health – supplying micronutrients and long-chain n-3 fatty acids (n-3 LCPUFA) and substituting for red and processed meat (l. 122). While aquatic animals may substitute for meat and provide n-3 LCPUFA this is not the case for aquatic plants. The mixing foods across kingdoms also gives rise to confusion, e.g. when the authors write (l. 86-92) that the EAT Lancet Commissions strategy is problematic because a solely plant-base diet cannot fulfill the dietary requirements in many populations. However, this would not be the case if the increase in intake of healthy foods included fish, poultry or other none-four legged animals. The content in Fig. 1, and the other figures plus the text, indicate that the authors do in fact focus on animal foods. Unless the authors mean to make any points about conversion to a plant-based diet, I would advise a more strict focus on aquatic animal foods in the text.

**We thank the reviewer for pointing out this lack of clarity. Although we keep the original definition of aquatic foods, we add a sentence to say that our research in the manuscript focuses on aquatic animal-source foods.**

Selection of focus points with respect to nutrients and health aspects.

The authors state (l. 294) that they focus on critical micronutrients and adverting nutrition transition. It is not clear why a selection based these two issues would lead to the choice of n-3 LCPUFA, B12, iron, zinc, calcium and vitamin A.

- Are these the nutrients with the highest frequency of deficiency worldwide?

**We thank the reviewer for this comment. We selected these nutrients for three reasons: 1) there are large populations with deficiencies of these nutrients globally; 2) they are commonly found in aquatic foods; and 3) they are often measured in nutrient composition analyses for aquatic foods to allow for our quantitative comparisons.**

- I am not sure what the author mean by adverting nutrition transition given the countries that they mention (l. 209-211). Furthermore, how did they influence on the choice of nutrients?

**We have changed the phrasing of this to say “attenuate chronic disease morbidity and mortality associated with the nutrition transition.” We focused on the role of LCPUFA when thinking of the function of aquatic foods in attenuating this morbidity and mortality.**

- I suspect that the selection also reflects the nutrient content of aquatic animals (and the terrestrial animals that they replace, as reflected in Fig. 1) and if that is the case, then why not include vitamin D? Aquatic animals are the only dietary source of vitamin D and vitamin D deficiency is a big health problem in most northern and southern hemispheres and a problem in cultures where religious traditions prescribe skin coverage.

**We completely agree with the reviewer that Vitamin D is likely an important benefit of aquatic food consumption and that large populations suffer from its deficiency. First, it is still not clear whether low vitamin D is an outcome reflecting severity of a disease or is in fact an independent risk factor that can be amended through supplementation (Amerin et al, EJCN, 2020). Moreover, it is not easy to model as the recommended requirements are highly variable across countries, and range from 400 to 2000 IU daily (Institute of Medicine. Dietary reference intakes for calcium and vitamin D. Washington, DC: The National Academies Press; 2011). Vitamin D can be endogenously synthesized through exposure to sunlight and thus highly modifiable depending on which country you are in. As a global analysis, we are unable to look at this successfully.**

- Aquatic animals are also the only source of n-3 LCPUFA, but it is difficult to define the adequate intake and thus, the frequency of deficiency as there are no well-defined cut-off values in status and dietary recommendations differ and many countries do not specify a need for n-3 LCPUFA. There are many theories about health effects of n-3 fatty acids. Only some of these relate to related to actual deficiencies (e.g. brain development and sperm production) and they are at least to some extent fulfilled by an adequate intake of α-linolenic acid. The most well proven health effect of additional intake of n-3 LCPUFA is the effects that are of relevance for cardio-metabolic diseases, but many of these effects require more than 0.5 g/d. The authors mention a number of effects – e.g. l. 193-195, some of these are not very well proven and it is not clear to me which of the effects the authors consider in their estimation of the health consequences of low intake.

**We acknowledge that the health outcomes of omega n-3 (EPA+DHA) are still debated. Although we mention a few health outcomes in the text, we focus only on ischemic heart disease in our quantitative analysis for PUFA EPA+DHA. We use the recent Global Burden of Disease relative risk factors (2019), which to our knowledge coalesces the most up-to date data on the impacts of omega n-3 PUFA on health. The Global Burden of Disease relative risk curves for omega EPA+DHA capture very mild risks for ischemic heart disease for consumption under 0.4 g/d and only for adolescents and adults. This excess risk is then presented as omega n-3 SEV (summary exposure values). We now say this more explicitly in the Methods:” For low aquatic food consumption, we use the relative risk of ischemic heart disease associated with consumption of omega n-3 EPA and DHA derived from the Global Burden of Disease24.”**

Nutrient content in aquatic food and databases.

The disaggregation analysis clearly show that decisions regarding the food database can have an impact on the results. I am concerned that some of the results, specifically regarding the adverse effect of vitamin A could be erroneous due to assumptions about the food intake and the nutrient database.

**We thank the reviewer for this comment and we agree. The projections are reliant on the underlying nutrient contribution and this may, perhaps, be most striking for vitamin A, where contents in liver, eyes, roe, etc. are much higher than muscle tissue. We also know that vitamin A can be grossly underestimated because dihydroxyretinol (A2) - the major form of vitamin A in aquatic foods - is rarely measured. We have emphasized this in the Supplementary Methods.**

**Additionally, Figures S18 and S19 highlight the differences in health outcomes based on choice of nutrient dataset and production scenario which serves as a sensitivity analysis to the values of the nutrient content. We acknowledge that focusing on muscle tissue and ignoring other parts can underestimate the nutritional supply of aquatic foods, particularly for vitamin A. Other parts of aquatic species such as liver, eyes or roe can have particularly high concentrations of vitamin A. However, consumption of such parts can be specific to certain cultures, which makes it challenging to quantify consumption on a global scale. In addition, data on the nutritional composition of such parts is still sparse. To standardize these values across the breadth of aquatic food species and countries, focusing on muscle tissue was the most pragmatic approach. We have retained this important metadata in the AFCD to further explore the nutritional value of these other parts in the future.**

Fig. 1 provides a nice overview of aquatic and terrestrial animal foods and their nutritional value. I suppose the information about their nutrient content is based on the nutrient content of the different types of animals in the database, but I am curious about how they were combined. Are the information based on a mean or were the contributions from the different species weighted based on level of consumption worldwide?

**The food group level information shown in Figure 1 takes the median of all the species-level observations in that food group (e.g., the Iodine value for small pelagics is the median value across all individual Iodine observations for herring, sardines, etc.). We chose to use the median to account for the middle observation, rather than the mean that might be more sensitive to long tails present in the data. Once the medians were calculated for each food group, the nutrient medians for each food group were averaged to calculate the nutrient richness values that order the food groups along the y axis. The method of calculating the values has now been clarified in the caption of the figure.**

The nutrient contributions are not in agreement with common diet recommendations and some of the authors’ points in the discussion (l. 256-259). Furthermore, the authors specify that the nutrient content in their analysis (and Fig. 1) is based on muscle tissue and do not consider parts that are actually eaten in different cultures. However, given that the BFA project address sustainable food production and environmental issues it would make sense to assume optimal use of the aquatic foods and include everything that is eaten in reality.

**We completely agree with the reviewer. In many ways, our estimates can be seen as a conservative estimate of the contribution of aquatic foods as we are using the “muscle tissue” as our standard value. This is certainly not perfect, but it is the best we are able to do with the current status of these databases. Our new AFCD is laying the groundwork to look at exactly these types of important questions in the future. We have now more clearly articulated this limitation in the Supplementary Methods: “Focusing on muscle tissue and ignoring other parts of the fish is certainly not a reflection of how cultures consumed these aquatic foods. However, to standardize these values across the breadth of aquatic food species, this was the most pragmatic approach. We have retained this important metadata in the AFCD to further explore the nutritional value of these other parts in the future.”**

- Fish with soft bones and dairy are the best animal food sources of calcium according to among other an EFSA scientific opinion (doi:10.2903/j.efsa.2015.4101). Eating small pelagic fish with bones is common in many cultures, e.g. in Scandinavia, we eat herrings with bone and people in Southern Europe eat whole sardines and anchovies. Contrary, I have never heard that crustaceans should be high in calcium and suspect that this could be due to inclusion of the exoskeleton. If so, which species is eaten with the exoskeleton?

**All nutrition information analyzed and visualized in Figure 1 was based on samples of muscle tissue, so no whole products, bones or exoskeletons were used. We agree with the reviewer that it was surprising, but the high calcium content in crustaceans was driven by a few high calcium species of prawn and crab, specifically (in mg/100g) "Eriphia verrucosa" (456.76 mg not commonly consumed), "Fenneropenaeus indicus" (two observations, 429.7mg & 304mg, mass production), "Metapenaeus monoceros" (421mg - caught and consumed in tropics but not a major fishery), "Penaeus monodon" (419.3g, mass production), "Calappa granulata" (375.9218mg not commonly eaten), "Fenneropenaeus chinensis" (236mg, mass production) and "Cancer pagurus" (128.61mg, major production and consumption in N Atlantic). The daily recommended intake is 1000 mg of calcium; the median calcium value across all crustaceans is about 22% of the recommended value, whereas the median value for small pelagic fish is just over 100%, large pelagics are 65% of the daily value and bivalves are about 96% of the daily value. So while crustaceans do appear high, many other aquatic foods are much higher.**

- Oily fish is said to be one of the best source of vitamin A along with liver, egg and dairy ([https://www.nhs.uk/conditions/vitamins-and-minerals/vitamin-a/](https://urldefense.proofpoint.com/v2/url?u=https-3A__www.nhs.uk_conditions_vitamins-2Dand-2Dminerals_vitamin-2Da_&d=DwMGAg&c=WO-RGvefibhHBZq3fL85hQ&r=JXqYpKlfrgRDkFLKLOodJG2H62fOYHKvM-oGegaHVsY&m=ISlFoZj0IWNbkkBtX4y13-I7uU4FA0Oxp2EkRObMiDo&s=yE6fpyleMiEQ6Y_xj78MKx2HBruDheyI8grwbTZRu4E&e=)). The only indicated source in is butter, which I think must be a mistake, because I cannot think of any reason not to mark egg and dairy. I am concerned if the information in the figure reflects the nutrient contents in the database for the analysis. This would explain (at least to some extent) the adverse effects on vitamin A.

**The data for butter originates from the USDA, and the Vitamin A RAE value is simply much higher than the other foods so it washes out the color scale. The standardized portion (100 grams) of butter is higher than the others (as a ratio of the daily recommended value, where 1 is it meets that value)**

**Butter = 1.14**

**Eggs = 0.267**

**Marine mammals (a median of all foods in group) = 0.212**

**Small pelagics (a median of all foods in group) = 0.0258.**

**After consideration of the reviewers concerns, we removed all non-meat tissue food products (i.e., butter, cow’s milk, and eggs are all made from animals, not the animal’s muscle tissue itself) from the visualisation, which led to marine mammals becoming more noticeably high (by color shading) in Vit A RAE.**

- It is obvious that fatty aquatic animal foods supply most n-3 LCPUFA and although there is much variation between species, many crustaceans are quite lean, so why the high score? The score for aquatic mammals are low, because it only consider the muscles. Nonetheless, marine mammals supply most of the n-3 LCPUFA in the Inuit diet today, because they often eat blubber and mattak from whale, which are true delicacies among Inuit.

**We agree with the reviewer and thank her for this comment. As mentioned above when we describe our rationale for using muscle tissue, we are unable to add this level of detail and nuance to our global analysis, but these nutrient values are captured within AFCD and we hope that we, and other researchers, can focus on these important questions in the future.**

- Given that aquaculture is central to the concept, it would be important to consider differences in nutrient composition between farmed and wild fish in the modeling. Fish oil, which is an important commodity and used in innovative foods, is likely included in the analysis, but to what extent was it disaggregated? Cod liver (oil) supplies high amounts of n-3 LCPUFA as well as vitamin A and D, but most other fish oils do not contain these vitamins. What about the cod liver and other internal organs, are they considered edible?

**In the Aglink-Cosimo model, fish meal and fish oil is treated separately to all other aquatic foods. The organs and oils are of course considered edible, but we do not focus on these for our nutrient projections as the focus is on increased production of fish (and their muscle tissue as this is where we have standardized data for consumption and composition). Our model therefore predominantly considers them as feed products, not as food products. Please see the details in the Supplementary Methods for the Aglink-Cosimo model where we now describe this in detail.**

Estimating food supply, intake of nutrients and health effects.

Diet data are never accurate and in a large scale analysis it is likely just as exact to use supply data as making surveys to get information about the diet (foods and the nutrients in them) in a population, but I think it should be referred to as consumption and not as intake. In the last analysis step, the supply data from 191 countries are mixed with actual dietary recall data from nine countries/regions to estimate changes i frequency of deficiency based on intake of the nutrients compared to recommended intakes in age\*sex subgroups (called sub-national?). The idea of using the same dietary data e.g. for populations in North Africa, Northern and Southern EU, and all the way across Russia to Alaska concerns me. The age\*sex distribution curves differ quite a lot both within and between countries. How can you use data from Bolivia with zero fish intake to estimate age and sex-specific DHA+EPA intake in Peru and Chile with relatively high fish intakes? Did you or could you make analysis similar to the one in Fig. S15 based on different intake group allocations? A few expert-identified modifications were made in this process (l. 574-575); could you elaborate a bit on the nature of these?

**We thank the author for this important comment, and we have substantially rewritten the section describing our methods for deriving subnational habitual intake distributions to increase clarity and to address this and other comments.**

**The section now begins with an overview of our methods for deriving subnational habitual intake distributions and includes a new conceptual figure (Figure M4) to visualize this workflow. It then presents the methods in a new and more logical order. We first describe how we derived mean subnational intakes using country-nutrient-sex-age specific data from the GENuS database and then describe how we derived the shape of subnational intake distributions around these means through analysis of dietary survey data. In rewriting this section, we more clearly highlighted where imputation occurs and the assumptions and methods leveraged to perform these imputations. Specifically, we highlighted that mean national nutrient intakes are country-specific (require no imputation), mean subnational nutrient intakes are mostly country-specific (require limited imputation by borrowing information from nearest neighbors), and shape parameters for subnational nutrient intake distributions are rarely country-specific (require significant imputation) but are only used to describe the shape (i.e., not the magnitude) of within-group intake distributions. We also more clearly highlight the considerable advancements that our modeling methods make in carefully and transparently modeling subnational intake distributions.**

**We hope that this substantial restructuring clarifies that the greatest amount of imputation occurs in the final and least sensitive step of the subnational intake modeling methods. For example, country-specific mean national DHA+EPA intake in Guatemala and Belize is set by the AgLink-Cosimo model without imputation; the disaggregation of these mean intakes into subnational mean intakes is informed by country-specific data from the GENuS database without imputation; finally, the shape of the distribution around the country-nutrient-sex-age-specific mean is informed based on dietary data from Mexico.**

**We added dark lines to Figure S17 to delineate U.N. subregions so the reader can see how our designations of “intake distribution” groups differed from these groups.**

The modelling of the high and basic production scenarios is clearly explained when it comes to aquaculture, but it gets very complicated when it comes to estimating the effect catch and changes in consumption. It would be nice if the assumptions for this step were listed clearly as well as the principles for the overall diet modeling.

**We agree and thank the reviewer for flagging this important omission. We revised the methods section to more explicitly describe the modeling of catch from capture fisheries under the baseline and production scenarios. We also added a supplemental table (Table S1) and figure (Figure S1) to more easily allow comparison of values across scenarios.**

**We also added a new section to the methods section to describe the integrated AgLink-Cosimo and FAO FISH model and significantly restructured the section describing the disaggregation of mean national intakes into subnational intake distributions (see the comment above for details).**

- Substituting aquatic for terrestrial foods (l. 147-149), but there is no mentioning of any modeling of increases in none-animal aquatic foods, so I suppose the differences between high and base are in aquatic animal foods. The assumption was that when the supply of aquatic animal foods went up this would be compensated by a decrease in supply and demand for mainly terrestrial animal-source foods. I suppose that the exact substitution differed between countries and likely also the degree of substitution with non-animal foods. How did you model the changes in different types of terrestrial animal foods? It would make sense to substitute for carbohydrate rich staple foods in counties where low intake of animal protein is a problem. Did you set any rules in that respect? Did you make any modelling choices that can explain the observed increases in supply of terrestrial animal products in EU and central Africa in the high aquatic production scenario?

**We thank the reviewer for these comments. They are critically important. We have added an entire section in our Supplementary Methods on the Aglink-Cosimo model to describe all of these issues in detail.**

- Secondly, export is considered (Supplementary Material p. 6) in the estimation of consumption in the individual countries, but how was this done. Was it based on an extrapolation of current export and an assumption that the increased production was used locally or did you have some principles regarding changes in export in the two scenarios?

**We thank the reviewer for these comments. They are critically important. We have added an entire section in our Supplementary Methods on the Aglink-Cosimo model to describe all of these issues in detail.**

- I am concerned about Norway, they have a large production of fish, much of it for export and their diet does not differ so much from the diet in the rest of Scandinavia. Some of the difference could however, be because the rest of Scandinavia is in EU. EU is a common market so I suppose this was one unit in the production and consumption modelling, but that they were disaggregated for the SEV estimation (l. 541-542). Why did you do that when you were using the same Bulgaria/Italy/Romania data? How can you add data from recreational fishery to Sweden, Finland and NL separately? Yet, despite large variations in diet all EU countries come out the same on all the figures, so it may have been more correct to skip the borders.

**It is correct that the difference between Norway and the rest of Scandinavia is because EU countries (including Sweden and Finland) are modeled as a single unit within the Aglink-Cosimo model and Norway is not a member of the EU. We clarify this in the new methods section that describes the Aglink-Cosimo model and added the following text to the Figure 2 and 3 captions to remind the reader of this visual anomaly:**

**“All European Union (EU) member countries have the same value because they are modelled as a single economic unit in the AgLink-Cosimo model”.**

**It is also correct that EU countries were disaggregated for the SEV analysis (Figure 4); although results appear visually similar in this figure, they are empirically different. This is evident in the new appendix added to the supplement. The difference between EU countries in the GENuS data does not appear to be large enough to drive a difference in SEVs, likely because the identical nature of the national means subsumes these differences and because of the generally high nutritional intakes in EU countries.**

**We refer the reviewer to our response regarding the substantial restructuring of the methods section that clarifies the defensibility of using shape parameters derived from Bulgaria/Italy/Romania to define the shape (but not the magnitude) of subnational nutrient intake distributions in other European countries (EU and non-EU).**

**We supplemented FAO consumption with additional data on freshwater recreational fisheries to improve the taxonomic resolution of freshwater fish species consumed in countries where: 1) national reporting excluded recreational fishery or lumped them with ‘freshwater fishes nei’, and 2) where data was available. This inclusion was done for 11 countries worldwide, with three of them in Europe (Sweden, Norway, and the Netherlands). This step increased the overall fish consumption by a minor amount (0.17% increase) but had only negligible impacts on total consumption in Sweden, Norway and the Netherlands. We did not adjust consumption for Finland because they already report recreational fish catch to FAO (see Supplementary Materials).**

The paper is as mentioned hard to read especially when the outline differs from a standard scientific journal (narrative results, methods last and parts of both methods and discussion in supplementary material). Some suggestions that could maybe help guide the reader:

- The overall aim and the sub-questions are given along the way - spread out in the flow of the text. If given together in the beginning it would be easier to follow. Not just as “We create”, “We project”, but also why.

**Thank you for this comment. We have endeavoured to increase clarity throughout the paper.**

- Similarly, in the method section start with the purpose to provide a link to the results – e.g. L. 441-443 “We estimated country-level aquatic food consumption (and consumption of other foods?) …..outputs.” then l. 425-441 “the Aglink-Cosimo ….. and 2030” ending with l. 443-445. You could also make reference to the figure that present the data.

**We have endeavoured to clarify our methods throughout the Methods section of the main text, and throughout the Supplementary Methods. We thank the reviewer for bringing this up, so that we have the opportunity to showcase our work.**

- In the same way, you should add some results clues in the discussion to combining it all. E.g. L. 305 “The estimated consumption of essential nutrients increased, specifically n-3 LCPUFA, when the 12 GND aquatic food categories were disaggregated into 2143 taxa.” Although the discussion and synthesis is good, short results summaries and references to the data could give the arguments more weight – less theoretical.

**We have also endeavoured to offer more results summaries as you have suggested throughout the manuscript.**

- The Supplementary discussion about choices in the nutrient projections is also good, but the authors need to include some discussion about limitation in the SEV estimation based on data from only nine countries, the precision in the supply equals consumption assumption in high vs. low-income countries, and potential modelling limitations. I am not sure about the formal constraints but some of this ought to be in the discussion in the main paper as this is important for the future target modellings you suggest.

**We** **thank the reviewer for this comment. We have reordered our methods section so that the steps taken in the assignment of these distributions is clearer. We have also added text to the supplemental methods in a new section entitled “Acknowledging Limitations of our Nutrient Projections” to better highlight and discuss the limitations of this approach. Although our approach uses data from only nine regions/thirteen countries, we also incorporate both age and sex to add additional nuance to the assignment of distributions. Previous research has used only one, two, or three countries to determine global nutrient intake distribution shapes and has not considered age and sex in such detail as we have here. Therefore, we see our approach as a major advance in the literature compared to previous studies by adding more geographic diversity and subpopulation characteristics.**

- Fig. M1 is a great help, but I got confused a couple of time when linking the results data to the steps in the analysis. Maybe you could add result output arrows (Fig 1, 2, 3 and 4)

**We have now added indications of where results were produced for each figure in our overall project flow of this figure (Supplementary Figure M1).**

Minor comments:

L. 192-195. Relating to the aquatic food definition: n-3 LCPUFA are practically only delivered directly by aquatic animals and there are many theories about effects on human health that are only exerted by the marine n-3 fatty acids, but many of them are not yet conclusive. The effects of n-3 LCPUFA on lifestyle diseases – specifically the cardio-metabolic diseases, MS, CVD, T2D, are the most well-proven, whereas visual effects are only clear in early development (l. 194-195) and effects on anxiety, depression, ADHD, cognitive function, growth etc. (+l. 300-302) not yet conclusive in meta-analysis and some not at a stage where meta-analysis are relevant. I would suggest some use of “potential”.

**We thank the reviewer for this comment. We have added the word “potentially” and have removed mention of anxiety, depression, etc.**

L. 209-211: Fig. 3F only shows Increase/No change/Decrease, which makes it more immediately interpretable, but it is not possible to see that the effect is largest in the countries mentioned. Would it be possible to make some grading in the blue and the red to indicate the extent of the increase/decrease? If not please give some data to exemplify.

**We changed this panel to illustrate a continuous gradient of increasing (more red), decreasing (more blue), and stable (white) animal-sourced food consumption.**

L. 368: “The results presented … can be used….” I suppose you mean the concept? If I was to make policies to increase in aquatic foods in a situation like the ones you mention I would make a small model that considers local factors and not a worldwide model based on generalized assumptions and compromises.

**We have rewritten the entire “Synthesis” section.**

The figures are quite busy. I tried to read across the figures, which was hard and changes are hard to interpret when you do not have the baseline – e.g. knowing if a lack of change in deficiency status is due to a lack of change in the nutrient consumption or lack for deficiency to improve. Given that all data are shown in supplementary material, consider if it might make sense to focus and select to make Figure 4 easier to read.

**This is an interesting suggestion and we added a new figure (Figure S19) to the supplement to visualize the relationship between the difference in deficiency status and the baseline conditions. The figure illustrates the impact of baseline intakes and deficiency status on determining the impact a change in intake has on improved status.**

Consumption is shown as g/p/d (Fig. 2 & 3 and Fig. S6-S12), which is not a SI-unit and to be mathematically correct should be g × p-1 × d-1. For consumption, it would be enough to use g/d as the legend say per capita and since it is obviously not meaningful to give it combined for all individuals in populations of different size.

**We changed the Figure 2 panel titles to “g/d”. We changed the x-axis titles in Figures S6-S2 to “xg/d”. We do not see “g/p/d” in Figure 3 or its caption.**

L. 456: What is mean by post-model? Fig. M1 describes a modelling workflow – so more like alternative modelling of nutrient consumption, right?

**We had intended to refer to the steps and analysis that occur after the AgLink-Cosimo agricultural model. We have revised the text**

L. 237-238 Supplementary Material: Seems like you missed something ;-)

**Thank you for catching this! We have now added this paragraph as intended.**

Fig. S3: The fish panel is shown twice.

**Thank you for catching this error. We deleted the duplicate row of “fish” maps from the third-page of this 3-page figure.**

Fig. S17: Could you give the names of the taxonomic groups somewhat like in Fig. 1, so it is understandable for a greater number of readers? It would be optimal with more precise information “percentage of consumption” – weight%? The axis in A says “Freshwater species counts” – why not just “number of consumed freshwater species”?

**We updated the names of taxonomic group in Fig. S17 to common names as in Fig.1, as well as changed the axis labels of Fig. S17 in both panels according to the reviewer’s suggestions. Moreover, we modified the terminology of ‘species’ to ‘taxonomic groups’ because many groups are not in fact at the species level.**

I would have been happy if the country abbreviations in Tab. S2 & S3 were in alphabetical order when I consulted them in order to read Fig. S18.

**We changed the alphabetization of countries in Table S2 and S3 so that they are ordered by ISO3 code rather than by country name.**

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### Referee #6

The authors have created a model to calculate the impact of aquatic foods on nutrition of the global population. The used 2 projection scenarios (one baseline and one high production scenario) for estimation of the situation in 2030. The results highlight the potential of aquatic foods for future food security and reduction of nutrient deficiency.

The idea is novel and the approach of great significance for evaluation of global future food security as, due to my knowledge aquatic foods have not been evaluated in that large and broad scale.

I am not an expert statistician, but the approach is logic, the used data of relevance and high quality (existing databases and significant research papers). The approach and methodology is explained well and in a clear way, even highlighting the limitations (supplemental methods).

The data presentation is clear and the conclusions are adequate.

However, I am not so sure about the projection of data for the national and subnational distribution of intake. For example Italy, Bulgaria and Romania are used to calculate for Europe (Figure S14) and I do not believe that the intake patterns of those countries are similar to for example Nordic countries. I cannot speak so much for the other countries but Australia and US might also have different food patterns. Maybe the rational behind this projection should be explained a bit more or at least the limits should be mentioned.

Also the approach to imputing habitual intake data for age and sex groups without habitual intake data seems a bit critical and the limits of this should be highlighted.

I can see that this was maybe the best way to do some estimation but again I am not so sure it is the best way to do it. Maybe it should be accepted that not all data can be estimated for all categories.

**We substantially rewrote the section describing our methods for deriving subnational habitual intake distributions to increase clarity and to address this and other comments.**

**The section now begins with an overview of our methods for deriving subnational habitual intake distributions and includes a new conceptual figure (Figure M4) to visualize this workflow. It then presents the methods in a new and more logical order. We first describe how we derived mean subnational intakes using country-nutrient-sex-age specific data from the GENuS database and then describe how we derived the shape of subnational intake distributions around these means through analysis of dietary survey data. In rewriting this section, we more clearly highlighted where imputation occurs and the assumptions and methods leveraged to perform these imputations. Specifically, we highlighted that mean national nutrient intakes are country-specific (require no imputation), mean subnational nutrient intakes are mostly country-specific (require limited imputation by borrowing information from nearest neighbors), and shape parameters for subnational nutrient intake distributions are rarely country-specific (require significant imputation) but are only used to describe the shape (i.e., not the magnitude) of within-group intake distributions. We also more clearly highlight the considerable advancements that our modeling methods make in carefully and transparently modeling subnational intake distributions.**

**We hope that this substantial restructuring clarifies that the greatest amount of imputation occurs in the final and least sensitive step of the subnational intake modeling methods. For example, country-specific mean national DHA+EPA intake in Nordic countries are set by the Aglink-Cosimo model without imputation; the disaggregation of these mean intakes into subnational mean intakes is informed by country-specific data from the GENuS database without imputation; finally, the shape of the distribution around the country-nutrient-sex-age-specific mean is informed based on dietary data borrowed from their Italy/Bulgaria/Romania neighbors.**

References: sometimes there are written references in the text without being numbered and not in the reference list (for example line 580, 597) that should be changed.

**Thank you for catching this. These references have been updated.**

Figures s6-s12 are difficult to read, as many coloured lines are overlapping in those cases were all data is available. Maybe the age groups should be reduced (by increasing the intervals to for example 10 years or choosing intervals used in medicine /food intake recommendations (toddlers 1-3, children 4-18, adults 19-30, 30-50, 50-75 and 75+ maybe or something similar).

**We modified these figures to address clarity by: (1) cropping the x-axis by the 99th percentile of the habitual intake probability distributions to enlarge the data wherever possible and (2) by changing the color palette to a continuous color scale to ease interpretation of the colors. We did not bin the data into larger groups because it is important to represent the data as it is used in our analysis (in 5-yr age groups).**