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Fishing for nutrition - improving the connection between fisheries, the food system
and public health

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Abstract

Fishing for nutrition – improving the connection between fisheries, the food system and public health

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Fish and shellfish are rich in micronutrients. As aquaculture production grows and the pathways to sustainably manage our capture fisheries become clear seafood is positioned to play a major role in the fight against malnutrition, which is back on the rise. This PhD research endeavored to improve our understanding of how seafood production can contribute to the food system.

Chapter 2 assessed the policy landscape related to the integration national-level fishery and health policies to determine where these policies are most aligned and under what conditions.

The analysis evaluated 165 health and 158 fishery national-level policies around the world.

Overall, however, results indicated low levels of integration in fishery and health policies,

indicating that there is considerable potential for improvement. These results establish a

foundational understanding of the status of national policies connecting fisheries to the healthy

food system. Chapter 3 and Chapter 4 were part of the same project that evaluated at the regional scale of the US West Coast the current and potential contribution of rebuilding capture fisheries after a history of overfishing to the healthy food,. Chapter 3 used interview methods to learn from positive deviant case studies already achieving success. Chapter 4 utilized a mixed methodology that brought together quantitative and qualitative approaches. Quantitative data was synthesized to identify where affordable, underutilized fish species overlap with high food need communities who have the fishing capacity to access them. Interviews were used to determine challenges and enabling conditions of actors throughout the supply chain. Chapter 5 evaluating of the environmental impacts of nutrient-rich food production that compares diverse capture and aquaculture seafood production to other animal sourced and vegetable food groups by linking and evaluating environmental impact information from life-cycle assessments and nutrition information. Results indicate that some fish and shellfish have environmental impacts at least as low as vegetables when considering their potential to contribute nutrients towards a healthy, sustainable diet.

There are 6 supplemental spreadsheets including the raw data used to compute the impact ratios in Chapter 5 submitted alongside this ETD. There is one spreadsheet for each of the 6 impacts: Greenhouse gas emissions (GHG_table.csv), Acidification (Acid_table.csv), Eutrophication (Eutro_table.csv), Fuel use (Fuel_table.csv), Water use (Water_table.csv) and Land use (land_table_csv). Each of these spreadsheets includes the environmental impacts associated with each product and food group along with the daily requirements and nutrient richness index calculated from the daily requirements.

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Chapter 1. INTRODUCTION TO THE DISSERTATION

1.1 WHY WE SHOULD ENCOURAGE FISH ON PLATES AND WHERE FISH FIT IN FOOD SECURITY AGENDAS

Healthy seas are often equated with marine life. While healthy people are a concern in the context of growing populations and distributional inequity, the case is often not made to connect healthy seas with healthy people. Compared to the breadth of research and policy focus on fisheries and their management link to ecological or economic impacts, there is a relative absence focusing on their direct impacts to nutrition and food security. While seafood is unlikely to displace meat and poultry as a primary source of protein and other micronutrients associated with animal-source foods for the global population, its high diversity of vitamins and minerals make it a nutritionally valuable addition to diets especially for coastal communities where fish and shellfish are being caught, bought, or bartered.

Targeted provisioning of seafood offers considerable potential to alleviate global and regional micronutrient deficiencies. A number of micronutrients are present in higher concentrations and in more bioavailable forms than they are in vegetables, fortified staples and food supplements (Bogard, Thilsted, et al., 2015; Thilsted et al., 2016). Micronutrients including vitamin A, iron, and zinc are particularly important because long-term supply solutions have yet to be found and their deficiencies are prevalent in many parts of the world (Nozomi Kawarazuka & Béné, 2011). These micronutrients are critical for childhood development and maternal health. Fish and fish-derived products tend to be high in Omega-3 polyunsaturated fatty acids (PUFAs), which have been shown to reduce the risk of all-cause mortality, cardiovascular disease and stroke (Wang et al., 2006). Furthermore 1.3 million deaths per year are associated with inadequate consumption of Omega-3 PUFAs (Lim et al., 2012). Fish are not only high in nutrient *density* of

single nutrients, but tend to have a *diversity* of nutrients. A longitudinal study from pregnancy through childhood found that lower intelligence quotient (IQ) scores and behavioral issues were associated with children who were fed low levels of seafood (Hibbeln et al., 2007). Malnutrition can occur if an individual either receives too few calories (i.e., undernourishment) or too many calories (i.e., overnourishment – including obesity). Malnourishment also includes the ‘hidden hunger’ of micronutrient deficiency where the body is deficient in vitamins and minerals that it cannot produce itself. Relative to many animal-sourced proteins, the high nutrient density and diversity should make seafood a prime delivery vehicle to alleviate malnourishment.

In the United States and in much of the developed world, the hidden hunger of micronutrient deficiency and overconsumption of nutrient-poor energy-dense proteins is a serious public health concern. In the United States, between 80-90% of Americans who eat fish are eating only one half to one fifth of the recommended weekly intake for their age and sex (Jahns et al., 2014; USDHHS & USDA, 2015). For lower income households this can mean a shift away from the seafood that was traditionally part of their diets towards cheaper, energy-dense and nutrient-poor alternatives, regardless of the presence of nutrition assistance programs (Jahns et al., 2014; Leung et al., 2012). Over time, American seafood consumption has consolidated into increasingly fewer, typically imported products: shrimp, canned tuna, salmon, catfish and tilapia (Shamshak, Anderson, Asche, Garlock, & Love, 2019). US seafood consumption is demographically and socioeconomically stratified: younger or lower-income populations eat comparatively less seafood relative to dietary guidelines (Jahns et al., 2014) and low income households tend to purchase less seafood relative to more affluent households when making purchases for consumption at home (Gregory et al., 2019). This disparity is not a recent trend; a 1995 survey found that low-income pregnant mothers consumed about half the recommended intakes needed for Omega-3 PUFAs that

are critical to maternal and early childhood (Lewis, Widga, Buck, & Frederick, 1995), calling into question the social and economic equity of supply in the fish and shellfish food system (Kittinger et al., 2017). Questions regarding the access and availability of fish and shellfish – which are oftentimes healthier than many other foods – highlights the importance of critically examining the enabling conditions and facilitating factors determining how seafood connects into the food system, and how this connection can be improved to support improved health outcomes especially marginalized consumers or those at higher risk of diet-based disease.

1.2 GOVERNANCE AND POLICY MEDIATING THE FLOW OF FISH

Diverse pathways link fisheries to nutrition. In theory, pathways are mediated by the predominant governance and associated societal values surrounding fishery production. These pathways influence four dimensions of food security with the potential for operationalization: 1) food availability, 2) economic and physical access to food, 3) food utilization, and 4) stability over time (Food & Agricultural Organization, 2017). In practice, national policies reflect larger values of society and beliefs regarding the governance of natural resources. It is the goal of policy and management to make the “hard choices” on which aspects to pursue with the development of fisheries and their management (C. Bailey & Jentoft, 1990). The four dimensions of food security present four objectives often taken by policymakers and fisheries managers regarding the role that fisheries should play within their governance context.

Health and nutrition were surprisingly not a part of the definition of food security until recently. To understand how fisheries can contribute to food security and nutrition, it is first necessary to unpack the term “food security” often evoked but infrequently critically analyzed in fishery papers and is thus not helpful in providing scientific guidance to policy in support of food security goals. Food security terminology and meaning has evolved over decades, but has remained

centrally focused on addressing food absence by increasing availability and access. Food security emerged from international development discourses in the 1970s, at the time of the 1972 Sahelian famines and the 1974 world food price crisis, originally “aimed at governments and at international food supply with the eye to international price stabilization” (Jarosz, 2014). Food security was originally couched in terms of providing availability to food oftentimes via access to international markets, but after a series of global famines caused by global price volatility it became apparent that self-sufficiency –and the influence of the food sovereignty movement – should also be incorporated in the principle. The most recent definition, described in FAO’s 2017 *The State of Food Security and Nutrition in the World*, defines food security as a “situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” While not originally included, health and diet are now integral aspects of food security and nutrition. Critically, more recent evocations of food security also explicitly describe the need for the connection between fisheries, diet, and human health (Golden et al., 2016). The potential for capture fisheries alone to contribute a nutrient-dense food is considerable. For a number of countries with prevalence of micronutrient deficiencies, the nutrients available in only a fraction of current landings could exceed the dietary requirements for *all* people living within 100 km of the coast (Hicks et al., 2019). Even if these fish are available, the question remains on whether they are accessible to the populations that need healthy foods the most. Ethicists have considered that limiting access and availability to nutritious food should be considered a social injustice because “food is different from other commodities in the market as it is explicitly and intrinsically linked to our human existence” (Azétsop & Joy, 2013). Given that seafood provides critical nutrients necessary to human health, it is a safe assumption that fish and shellfish resources should

play a strong role in ameliorating food insecurity around the world, particularly regarding aspects of hidden hunger via high micronutrient density of fish and shellfish.

These decisions impact the contribution of fisheries to the food system and in turn to public health. Much of the discourse in fisheries development literature has focused squarely on tradeoffs in resource rent and labor, and more indirectly on food security as a related extension of these tradeoffs. For example under a governance context favoring “wealth-based” management, a preference for economic efficiency would guide fishery managers to exclude less efficient harvesters (Cunningham, Neiland, Arbuckle, & Bostock, 2009) and processors to focus sales towards high-demand or export markets. In this wealth-based management case, food security is addressed directly by increasing economic access to food for those who remain in ‘rationalized’ fisheries with improved wages and profits. Food security and nutrition is an indirect outcome in the wealth-based approach, which assumes that increases in revenue can support stable, long-term livelihoods that increase household wealth and enable the purchase of - hopefully healthy - food. Other “welfare-based” governance structures emphasize the importance of fisheries as a social safety net to absorb excess labor, focusing more on maximizing employment potential – and by extension the immediate availability to food resources - and less on overall rent of the system (Béné, Hersoug, & Allison, 2010). There is no clear answer across all governance contexts, and both wealth and welfare approaches should be considered (Ratner & Allison, 2012). What is clear from the fishery development literature is that food security implications are currently tied to the discourse on labor and income and that there is scant empirical evidence in the literature of the direct role that food security and nutrition might play in fishery development and policy literature.

Fishery policy and legislation that guides fisheries management is predominantly focused on biological and economic sustainability of target fish “stocks” and the contributions of fisheries

to communities are considered in terms of income and employment: not vitamins and minerals. Fisheries are often managed for multiple objectives, oftentimes reflecting the needs and values of the public or of particular facets of society. Each fishery resource contains a multitude of value propositions that differ by constituency - sometimes in agreement and sometimes sitting opposed. These values are debated in political arenas or by the society *writ large*, and may be institutionalized via legal mechanisms (e.g. Amendment 12 of the US Magnuson Stevens Act to ban the take of krill) or by a non-institutionalized shift in behavior (e.g., the local foods movement). Common social values that guide fishery decision making often reflect conservation, job creation, or economic efficiency across the fishery system (HLPE, 2014); food security and nutritional concerns are largely absent from discussion. One explanation is that food security is often tied to agricultural production whereas fisheries tend to be conceptualized as natural resources (Olson, Clay, & Pinto da Silva, 2014). As fisheries management becomes more inclusive and seeks more holistic improvements, they should also include dimensions outside of traditional socioeconomic “human dimensions” and towards better integration with other sectors of society, including the food system and public health. In the fisheries literature, recent attention has focused on the importance of fish and shellfish production to public health of vulnerable populations (Golden et al., 2016, 2017) and a growing number of policy-related research strives to link fisheries to public health, from national to local levels (Allison, Koehn, Franz, & Wiegens, 2016; Thilsted et al., 2016).

Understanding how policies do and do not include connections between seafood production and health can help to explain whether governance structures are effectively addressing these issues. Health policies recognize fish and shellfish as nutrient-dense alternatives to comparatively nutrient-poor and energy-dense foods. The most recent *Dietary Guidelines for Americans*

specifically calls for low-mercury seafood to replace other meats and poultry at least 2 meals per week, referencing strong evidence from studies that seafood reduces cardiovascular disease (USDHHS & USDA, 2015). However, recent review found that health policies do not “consider sustainability or source of fish, their connections with US fisheries systems, and global distribution of seafood” (D. Love, Pinto da Silva, Fry, & Clay, 2017). To date, there has been little focus on alignment between objectives in fishery and health policies that could facilitate the uptake of fish and shellfish into the food system to improve health outcomes.

1.3 FISHERIES AND THE FOOD PRODUCTION SYSTEM

The lack of policy coherence betrays the underlying lack of integrated research on how fisheries intersect with the food system where many diet-based health intervention strategies are implemented. The production of seafood does not exist in a vacuum; it should be considered within the context of the rest of the food system for potential nutrient contributions to be realized. Interestingly, food system science has been slow to consider seafood as a component of healthy diets. A pertinent recent review found that seafood is “regularly excluded from debate on food security and food systems research” and, when included, seafood consumption is viewed as a tradeoff between positive health outcomes and overfishing concerns, and that only a limited assessment of seafood was possible because relevant data sources were not incorporated into models (Farmery, Gardner, Jennings, Green, & Watson, 2017). Given the promise seafood has to provision nutrient rich and diverse animal proteins, its absence in food systems and sustainable diet research is remarkable. Even in communities not adjacent to marine coastlines, inland fisheries production has increased by 1.7 million tons between 2012 and 2014 (Food and Agriculture Organization, 2016). Regardless of access to marine coastlines, the food system should better reconcile fisheries production if seafood is to contribute to positive diet-based health outcomes.

We are not without any progress connecting fisheries production to the larger food system. Fisher et al. find that among 12 highly food insecure countries in Africa and Southeast Asia and Central Asia, between 10-45% of the population relies on fish as part of their diet but how they utilize their capital to support alternative livelihood strategies, and to supplement their nutrition, differs. In instances where capital was available, coastal fishing households could rely on land-based agricultural production, providing a buffer against shocks to either system (Fisher et al., 2017). Livelihood strategies can also be combined in one production system for substantially improved nutrition outcomes. A recent polyculture program in Bangladesh combined rice production with fish farming of cyprinids and found there could be considerable increases to household income as well as nutrient intake of vitamin A and iron (Castine et al., 2017). The study found that including women in training was critical to improvements in household consumption, as “homestead ponds are uniquely accessible to women who prepare the household food” (Castine et al., 2017). In this case, and doubtless many others, gender plays an important role in provisioning of seafood for household consumption. From these two very recent studies we can see that programs including agriculture along with fisheries – that integrate fisheries within the food system – can provide more resilient solutions.

From a volume-based food security perspective it appears that trade is fair, but what in terms of meeting nutritional goals? A recent study of household surveys in Bangladesh indicates that seafood consumption has increased overall, primarily from farmed species. However, the intake of iron and calcium actually decreased, suggesting that aquaculture-raised fish may have lower micronutrient quality and therefore relatively less potential to reduce malnutrition (Bogard et al., 2017). Another recent review found that micronutrient composition diets of farm-raised species fed fishmeal compositions higher in vegetable oil than fish oil were much higher in fats

detrimental to health including Omega-6 PUFAs and monounsaturated fatty acids (Fry et al., 2016). Thus trade does provide a mechanism that supplies more affordable fish to developing countries who export their own fish, but research is beginning to show that these imported products differ in nutritional quality and may in fact be detrimental to public health in the areas where nutrient deficiencies are most acute.

Food production does not occur without negative impacts; each acre farmed or fish caught has some associated environmental cost. As global populations continue to grow, increased strain will be placed on the farmlands and fishing grounds, both in terms of rising demand and competition with other uses. Continued growth and development also places additional strain on our climate, and the resulting climatic changes will in turn influence regional food productivity (Godfray et al., 2010). Higher concentrations of carbon dioxide in the atmosphere are expected to decrease iron, protein and zinc content of rice, wheat and other food crops (Medek, Schwartz, & Myers, 2017; Myers et al., 2014). This is especially troubling for the 1.4 billion children and women of child-bearing age who live in high risk countries where anemia is already highly prevalent (Smith, Golden, & Myers, 2017). Given the growing understanding of the negative impacts of climate change on nutrition, it is important to consider the environmental footprint of food production systems.

Life cycle assessments (LCAs) have emerged as a prominent method to estimate environmental impacts of agricultural production including seafood. The majority of recent LCA reviews were primarily focused on advancing our understanding of environmental impacts of food production systems, not on their potential to contribute specific nutrients to support a healthy diet, and typically focused on aggregated food group categories. Two large, recent efforts focused on predicting GHG emissions across a wide variety of food groups but included fish as a broad

category (Clune, Crossin, & Verghese, 2017; Poore & Nemecek, 2018), despite the immense diversity of production modes (e.g., hook and line or purse seine capture and industrial scale fish pond production) and species (wild-caught tuna and farmed tilapia). There are a few exceptions where LCAs have explicitly considered different species and production modes of seafood, including a review assessing how aquaculture systems compare to land-based animal-sourced foods (S. J. Hall, Delaporte, Phillips, Beveridge, & O’Keefe, 2011), and an LCA meta-analysis of animal proteins finds that across all production systems and environmental impacts (Hilborn, Banobi, Hall, Pucylowski, & Walsworth, 2018). Especially given the perceived negative impacts of climate change on nutrient outputs, there is still a considerable and practical need to understand how different production systems minimize environmental impacts and maximize nutritional output. A recent study compared seafood products commonly consumed in Sweden to determine their nutritional density (Hallström et al., 2019) relative to their greenhouse gas emission. When considering sustainable diets that are also healthful, the feasibility of these diets depends upon food culture, seasonality, and production possibilities of regional food production sectors (Tuomisto, 2019). There is currently a gap in the literature in evaluating how the environmental impacts of different fishery and aquaculture production sectors compare to other food production systems with respect to meeting recommended intakes across a suite of macro and micronutrients.

1.4 OVERVIEW OF THE DISSERTATION AND OBJECTIVES OF EACH CHAPTER

Improving the connection between fisheries and the food system requires an improved understanding of the policy landscape between the fishery and health sectors. Chapter 2 seeks to improve our systemic understanding on the overlap between fishery and FSN via global review of the level of integration between fishery and health policies to address FSN objectives. The aim is to develop a global picture of where fishery and health policies are most and least integrated and

what topics tend to be included or excluded from these policies. Chapter 2 also seeks to identify governance, socioeconomic and fishery conditions under which more integrated policies tend to arise. To do so we conducted a global review of the current national-level policy landscape related to this integration, and used a multinomial logit on wealth, health, governance and fish consumption indicators to determine conditions that lead to varying levels of integration between policies. The results suggest that there is a promising move towards improved integration of objectives between fishery and health policies, but that more targeted, and systematic policy approaches are needed to realize how contribution nutrient-rich fish and shellfish can better contribute to a healthier food system.

Along the US West Coast there are coastal communities with diet-based public health concerns. Interventions into the food system in these communities to reduce diet-related health risks have largely focused on the land-based part of the food system, yet, many of these communities are historically dependent on fish. The research presented in Chapters 3 & 4 aimed to examine the scope and mechanisms for improved utilization of available fish sources to improve diets and reduce incidence of non-communicable disease burdens in poor and marginalized coastal communities. It had the following specific objectives: 1) classify nutritionally-vulnerable US West coast communities who may benefit from improved fish access and quantify the extent of underutilized species in US West Coast fisheries, and 2) identify mechanisms that may block the utilization of such fish by low-income groups, such as fishery management regulations, market structures, and fish handling, processing and storage practices and learn from examples where obstacles to access have been overcome and evaluate if such cases can be scaled.

To answer the first objective, we synthesized secondary data across multiple sectors to create a situational baseline that found current catch is far below the total allowable catch set by

managers, foregoing millions of servings of fish that could be sustainably harvested and contribute to food need in adjacent communities. To answer the second objective, we interviewed “positive deviants” that are successfully incorporating local seafood into the food system to learn their enabling conditions and how they overcame challenges to intervene in the system. Then we used the situational baseline to interview representatives throughout the food system – from fisheries industry representatives to public health officials to school nutritionists – to learn more about the current state of connection between seafood and the food system and how they envision programs such as the positive deviants could improve this connection in their communities.

This research revealed the importance of taking a mixed methodological approach that uses both existing quantitative data to analyze the situation broadly as well as qualitative information to learn from existing practitioners and evaluate the feasibility of similar practices being implemented in other regions identified by the baseline as having the potential for improved connection between local fisheries production and the food system. It is important to note that for the structure of this chapter and the submission of peer reviewed articles, the majority of the content related to the positive deviance assessment will be reported in Chapter 3 and the content related to the situational baseline and associated interviews – as well as an overview of the positive deviance research - are reported in Chapter 4.

Within the context of anthropogenic, global environmental change, considering the potential contribution of healthy fish and shellfish to the food system requires an evaluation of the environmental impacts of those products relative to other food products. The research presented in Chapter 5 determines the environmental impact of fish, shellfish, livestock and vegetable food groups in terms of their nutrition contributions. The objective of the research presented in Chapter 5 was to evaluate how different species and modes of seafood production compare to other animal-

sourced foods and to vegetables with respect to their environmental impact and nutrient richness by linking information from a life-cycle assessment review to nutrient values for the same food products. We found that the lowest environmental impact and most nutrient rich foods were vegetable food groups like grain, tubers, root, seeds, as well as small pelagic fish in wild capture production and bivalves in aquaculture production. The highest impacts tended to be in beef, pork as well as catfish, tilapia and prawns in aquaculture production and crustaceans and prawn in wild capture fishery production. These results indicate that, among animal sourced foods, some fish and shellfish have environmental impacts at least as low as vegetables and should be seriously considered in subsequent research and in food systems policymaking for their potential to support a healthy, sustainable diet. Finally, Chapter 6 synthesizes the lessons learned across each of the individual chapters.

This dissertation project focused on improving our understanding of policy and practice pertaining to the contribution of fish and shellfish to food security and nutrition (FSN) objectives to improve the healthfulness of food systems. Together, the chapters establish an understanding of the policy landscape and address practical avenues that can be taken to encourage improvements to better align fishery and FSN objectives to improve the contribution of seafood towards a healthier food system.

Chapter 2. FISHING FOR HEALTH: DO THE WORLD'S NATIONAL POLICIES FOR FISHERIES AND AQUACULTURE ALIGN WITH THOSE FOR NUTRITION AND HEALTH?

2.1 ABSTRACT

Seafood is rich in micronutrients. There is a growing recognition, in the academic literature, of the potential benefit of fisheries and aquaculture to public health, especially to address global micronutrient deficiencies. This chapter assesses whether this growing recognition is reflected in an alignment between the stated objectives in national policies in the fishery and health sectors. Do fishery and aquaculture policies have explicit public health nutrition objectives? Do public health and nutrition policies recognize and support the contribution of seafood to human nutrition? We conducted a content-analysis of all the current national-level policy documents (fisheries policies and acts, nutrition-related health policies) we could obtain, to determine levels of such policy integration or coherence. We further determined conditions associated with and potentially leading to varying levels of integration between policies. We found that 77 of 158 fishery policies identified nutrition as a key objective in the sector, while 68 of 165 health policies identified the importance of fish and shellfish consumption as key objectives. More recent policies were associated with improved levels of integration between sectors. The presence of international organizations in policy development was also associated with national-level policies that had high levels of integration. Countries with high levels of childhood obesity tended to have no integration in fishery and in health policies - and a lack of association between integration and a country's prevalence of childhood stunting - suggests that much work could be done to improve the utilization of fish to contribute to the challenge of malnutrition where it is most prevalent. This review suggests that there is a promising move towards improved

integration of objectives between fishery and health policies, but that more targeted, and systematic policy approaches are needed to realize the potential contribution of nutrient-rich fish and shellfish to a healthier food system.

2.2 INTRODUCTION

Seafood production can, and should, increase its contribution to a healthier food system. In recent decades, advances in fisheries management allow us to envision win-win futures where capture fisheries production may *increase* over time by an estimated 16 million metric tons landed yet allow for the biomass in the oceans to grow by 600 million metric tons (Costello et al., 2016). Aquaculture is growing rapidly; sector production could increase 100 fold for finfish, an estimated 15 billion metric tons (Gentry et al., 2017). What is done with the potential production increases will be determined by the formal and informal institutions governing the flow of these resources. Stakeholders representing conservation and economic interests have ensured their values are well accounted for in policy. When considering the value of fish in fishery sector policymaking, the focus is thus on either conservation, resource rents, or employment (Béné et al., 2016): not micronutrients and human health. Fish and shellfish should contribute towards the food system. The environmental impacts of our food system, many fisheries and aquaculture production species rank among the lowest animal-sourced foods with respect to GHG emissions, ocean acidification and eutrophication impacts (Hilborn et al., 2018). Critically, the micronutrient richness of fisheries would greatly alleviate micronutrient deficiencies for millions in coastal regions where malnourishment is highest: it was estimated that by utilizing just 20% of coastal finfish catch in 22 countries would alleviate nutrient deficiencies for all children under 5 years old in those countries (Hicks et al., 2019), if the

mechanisms and policies were put in place to improved alignment between fishery and health sectors.

Policymakers tasked with governing fisheries and aquaculture often manage for multiple objectives, oftentimes reflecting the needs and values of the public or of particular facets of society. Fisheries policy is often organized around principles related to biological conservation and social benefit is focused either on rent-maximizing wealth-based policies (Cunningham et al., 2009) or welfare-based strategies that provision labor and income to marginalized stakeholders (Béné et al., 2010). While often viewed in opposition, wealth and welfare approaches are both viable and have their own benefits depending on broader governance context (Allison, 2011; Ratner & Allison, 2012), and management related to each has particular social, economic and environmental tradeoffs (Anderson et al., 2018). These tradeoffs often implicitly assume that food security will be accounted for implicitly within system governance, often relying on market mechanisms to deliver food where it is needed most.

There is a recent and growing number of research efforts striving to link fisheries to public health, from national to local levels to take advantage of culturally appropriate and available sources of micronutrients (Allison et al., 2016; Gurung, 2016; Thilsted et al., 2016). Depending on the species, fish and shellfish tend to have high levels of vitamin A, calcium, iron, zinc, and polyunsaturated fatty acids (*i.e.*, Omega 3s) critical for childhood development (Nozomi Kawarazuka & Béné, 2011). Decades of studies on the cardiovascular effects of fish have found benefits of modest fish consumption and – while exact mechanisms are still debated – have been encouraged for inclusion in food and nutrition policy to reduce the relative risk of diet-based disease (Mozaffarian 2016; Zhao et al. 2016). Programmatic interventions exist and show promise. One case study in Bangladesh found that the use of indigenous and culturally

appropriate small fish are critical in the first 1000 days of life for mothers and children, by providing significant contribution of Vitamin A, zinc, and iron (Bogard, Hother, et al., 2015). Another model-based approach estimated the efficacy of implementing a nation-wide program to improve small-scale production in Bangladesh would increase vitamin A intakes and save thousands of lives – at a cost less than a national wheat flour fortification program with similar aims (Fiedler, Lividini, Drummond, & Thilsted, 2016a). While specific regions see promising programmatic interventions, there are few examples of nutrition-sensitive strategies at national scales informative to improving integration with national policy (Koehn, Allison, Franz, & Wiegens, 2017; Thilsted et al., 2016).

There are also increasingly strong calls aimed directly towards improved fishery and health policy integration. In 2016, Golden *et al.* called for more recognition of the links between fishery production and human health in policies, warned that regions that are the most fish-reliant also tend to overlap with areas where marine ecosystems are likely to be more impacted by climate change and have poor fisheries governance, low knowledge of fish stock status and increasing demographic pressures on the environment (Golden et al., 2016). Hicks *et al.* filled an important policy gap by linking nutrition information with fish stock yields and country-level micronutrient deficiency information to determine where nutrient rich fish might best contribute to a reduction in malnutrition, suggesting the potential contribution fish-based food strategies (Hicks et al., 2019). How fishery and health policies reflect, or are responding to, this growing body of evidence and call to action remains unclear.

In 2012 the Special Rapporteur submitted a report to the UN General Assembly from the promotion and protection of access and availability of fisheries to support nutritional needs and livelihoods for fish dependent people *as a human right* (De Schutter, 2012). McClanahan et al.

argued that food insecurity is exacerbated by declining access to marine resources and competition with global markets, and encouraging fisheries development plans to secure basic human rights to food (McClanahan, Allison, & Cinner, 2015). Under a different framing on responsible conduct through the value chain, food security featured prominently along with two other pillars of socially responsible seafood – protecting human rights and dignity as well as ensuring equality and equitable opportunities to benefit – called for improvements throughout value chains (Kittinger et al., 2017). However a subsequent article found that violations to food security, along with other social and cultural rights of fisheries, was more challenging to enforce legally because there is a lack of clear legal mechanisms unlike political or civil violations (Teh et al., 2019). Food security and nutrition sits at the center of a moral question related to distributive justice on how society decides who has the opportunity to access fish and shellfish to benefit (Lam & Pitcher, 2012). These ethical dimensions of fisheries have long been ignored in fisheries decision-making (Lam & Pauly, 2010). However, whether or not a policy *should* contain food security and nutrition objectives such that nutrition-vulnerable people may benefit from improved access and availability *is* the charge of the policymaking process.

Policies are the guidelines that provide direction for decision-making, and as such represent the principle priorities for decisionmakers in the body politic. Whether their aims are to support wealth- or welfare-based policies; food security and nutritional concerns are largely absent from discussion. One rationale is that food security is often tied to agricultural production whereas fisheries tend to be conceptualized as natural resource commodities (Olson et al., 2014). Understanding the extent to which policies do and do not include connections between seafood production and health therefore can help to explain whether governance structures are effectively addressing these issues. A review of fishery and health policy integration of countries in eastern

and southern Africa indicated that the role of fish in economic and food security policies was underrepresented and that there was potential for increased fish consumption (Kurien & Ríos, 2013). A recent review of US health policies concluded that they do not “consider sustainability or source of fish, their connections with US fisheries systems, and global distribution of seafood” (D. Love et al., 2017). In public health literature, calls have been made to better align food systems policies to support improved health outcomes across jurisdictional scales (Muller, Tagtow, Roberts, & MacDougall, 2009) but such calls seldom include seafood explicitly in the food system. More recently, the general lack of integration between the agricultural food system and fishery and aquaculture production systems “has led to a disjointed understanding of our food system [and] contributed to inequalities in food access” (Seto & Fiorella, 2017).

While some work has been conducted in case studies and specific regions, there is a gap in analyses related to the contribution of fisheries to food security at the global level (Allison et al., 2016; Béné et al., 2016). Moreover, there has yet to be a systematic global review of policy integration – or lack thereof - between fisheries and aquaculture sectors and food, nutrition and health policies and advisories. The growing number of calls for such integration are therefore operating without an assessment of whether the perceived dis-articulation is an obstacle to progress towards a more nutrition-focused or ‘nutrition-sensitive’ fisheries and aquaculture sector (Thilsted et al., 2016). This paper therefore sets out to review evidence for the integration of food, nutrition and health concerns into fisheries sector policy, and, conversely, evidence for the integration of fish and seafood into food, nutrition and health policies. We focus our analysis on the content of national fisheries policies or legislative Acts, in all countries for which such policies are available, and on national-level food security, nutrition and health policies in the same countries. We also analyze whether more recent policies, developed since nutrition became

more of a focus in fisheries literature, are more integrated than older policies, and we attempt to identify some of the factors that may be associated with the degree of integration, such as the relative importance of fish in national diets and the active presence of key actors promoting the nutrition value of seafood, such as FAO and WorldFish, in the fisheries policy arenas of certain countries. This enables us to provide a first global overview on the degree to which these policies are aligned, and to identify conditions leading the highest and lowest degrees of integration across sectors.

2.3 METHODS

The policy documents reviewed were found in three main databases. Fishery policies¹ were either sourced through the UN Food & Agricultural Organization (FAO) Fishery and Aquaculture Country Profiles database (UN Food & Agricultural Organisation, 2019) and, if not found through that database, then via internet searches for “fishery policy” “aquaculture policy”, “fishery plan”, or “aquaculture plan” and each country name. Health policies were primarily sourced from the UN World Health Organization’s Global database on the Implementation of Nutrition Action (World Health Organization, 2019). If they could not be found via WHO, databases then internet searches were conducted using keywords for “food and nutrition policy,” or any policies specific to diet-based diseases (i.e., obesity or Type II diabetes) for each country.

When there were multiple relevant policy documents for a country, we followed a prioritization protocol. For fisheries, priority went to the most recent national policy. We also prioritized policy statements over Fisheries laws and Acts; policies tended to have a greater level

¹ Unless explicitly stated, ‘fishery policies’ refers to both capture fishery and aquaculture sub-sectors, as well as any hybrid production system (ocean ranching, culture-based fisheries, aquaculture based on gathering, wild seed, etc.)

of detail and their content was often based on legislation, or drawn up to guide legislation. Fishery and aquaculture policies were both collected, and were often contained in the same document. When one policy governed both sub-sectors, that policy was prioritized over the sector-specific policies. For health policies, priority was given to the most recent policy. Highest priority went to policies specifically addressing the food system or nutrition (e.g., nutrition policy, national policies on food and nutrition, plans on malnutrition) over more general public health policies. The next priority included policies on encouraging healthier diets by either reducing diet-based disease or by setting dietary guidelines. In a few cases where the above policies were not available, general policies that included a food system component were used, particularly poverty reduction policies.

A variety of methodological approaches can reveal important aspects of policy, including the content, policy process, organizations involved, effects of the policy as well as the context for its development (Runhaar, Dieperink, & Driessen, 2006). Given that the research objective is to evaluate the level of integration across national-level health and fishery policy documents, the method chosen here primarily focused on evaluating the content in these policies. However, it is important to be aware that choosing this approach also means ignoring the opinions of different stakeholders, as the content being analyzed is only the policy document itself (Runhaar et al., 2006) and not any critiques of it. Document analysis, or “a systematic procedure for reviewing or evaluating documents,” is a tool that is often used to analyze the content of policies; the approach is advantageous in that it is a cost-effective, efficient, unobtrusive, but is also disadvantageous in that it reflects policies as written, rather than policies that are actually put into practice. In the large number of fishery and health policy documents around the world, it was necessary to develop a straightforward metric that could be applied to each document.

Simple, metric-based approaches have been developed to assess content across a number of policy documents, including fisheries sector. One such approach focused the alignment of the fisheries sector with poverty reduction strategies by assessing Poverty Reduction Strategy Papers published by 50 countries (Thorpe, Reid, Anrooy, Brugere, & Becker, 2006). The metric developed and applied to each document evaluates how well (a) national fishery policies include food security and nutrition objectives and (b) health policies identify the role of fish in intervention strategies.

Fishery policy integration scores range from no mention of FSN keywords and objectives to inclusion of FSN objectives and clear discussion of how fisheries link to nutrition and public health to meet those objectives (Appendix Table 1). Health policy integration scores range from no mention of fish and potential contribution to health to seafood being recognized as a key element of nutrition and/or food security policies and dietary health interventions (Appendix Table 2). Along with the scoring, a number of other descriptions of the policy were recorded, including: the year the policy was published or enacted; the type of document (*e.g.*, national policy, law or act, national action plan); whether there were partners in the development of the policy, external to the government, who provided technical or financial support (*e.g.* WHO, WorldBank, a bilateral aid agency such as USAID, a large NGO such as Save the Children or the Worldwide Fund for Nature or a foundation or program such as The Gates Foundation or Feed the Future); which fisheries sector the policy addressed (*i.e.*, aquaculture sector only, capture fishery sector only, or both sectors combined). Justification for each score was also elaborated for each policy document reviewed. Initial data collection occurred as part of a master's level course at the University of Washington in Spring 2017. Students were asked to pick a region and search for relevant policies at the national level. If such policies were found, students were asked

to evaluate the national fishery and health policies using the scoring metrics (Appendix Table 1 & Appendix Table 2). If policies were not found, or were found to be published in a language not spoken by any of the students in the class, students were asked to enter either “NA” for not available or “NT” for not translated. Students with specific language aptitude were asked to review policies in their original languages. Using a keyword approach allowed us to evaluate most policies in their original language. The initial student-based scores were then reviewed for quality and to ensure the validity and reproducibility of scoring values. Scoring modified from the original response was noted along with justification. If the incorrect policy was analyzed, or if no policy was found when one was available, a new policy was identified and scored. Ultimately, each fishery and health policy was scored between 0 and 3, and this number is interpreted to represent the level of integration of food security and nutrition in fishery and aquaculture policies or the level of integration of seafood in health policies. A high score in both sets of policies indicates policy integration.

Table 2-1 Number of descriptive variables in each policy score category

	Presence of int'l partner in plan development			Type of policy		Sector - Fishery policies only		
	No	Yes	Law	National policy	Dietary guidelines	Aquaculture only	Both sectors	Capture fisheries only
Health policies (n = 165)								
No integration	49	4	0	6	47	NA	NA	NA
Low integration	35	9	3	5	36	NA	NA	NA
Moderate integration	31	4	6	3	26	NA	NA	NA
High integration	20	13	5	0	28	NA	NA	NA

	Presence of int'l partner in plan development			Type of policy		Sector - Fishery policies only		
	No	Yes	Law	National policy	Dietary guidelines	Aquaculture only	Both sectors	Capture fisheries only
Total	135	30	14	14	137	NA	NA	NA
Fishery policies (n= 158)								
No integration	57	1	51	7	NA	3	17	38
Low integration	19	4	13	10	NA	2	15	6
Moderate integration	43	1	36	8	NA	1	36	7
High integration	23	10	5	28	NA	5	21	7
Total	142	16	105	53	NA	11	89	58

The review found health policies for 165 countries and fishery policies for 158 countries (Table 2-1). For fishery policies, most countries had one document reviewed except for eight countries – including Australia, Colombia, Fiji, Namibia, Peru, South Africa, Timor-Leste, and Vanuatu – where specific policy documents for individual fishery sectors was found (*e.g.*, Fiji had two plans, one specific to capture fisheries and another specific to aquaculture). Most fishery policies covered both sectors (56%), and among sector-specific policies, most national policies reviewed were focused on capture fisheries (37%). Fishery and health policies were most often developed without the presence of an international organization providing technical or financial support - at least these partners were not included as authors or in acknowledgements. For health policies, the most reviewed type was dietary guidelines, with national policies or laws being equally reviewed but an order of magnitude fewer times. For fishery policies, laws or acts were

more frequently reviewed than national policies. Policies covering both fishery and aquaculture sectors were most often reviewed, followed by capture fisheries and then aquaculture with just 11 national policies. There were a few reasons why some subregions had fewer policies. First, some regions did not have as many policies in a language that we could not translate (e.g., Arabic, Greek, Slavic language group). For fishery and for health policies, this was true for Eastern Asia, Southern Europe and Western Asia. Another reason for a lack of policies from a given subregion was due to the policies not being available online. For health policies, this was especially true in Eastern and Southern Europe. For fishery policies, this was especially true in Southern Asia, Eastern Asia, and especially Western Asia.

To improve our understanding of conditions associated with policy integration, a series of national level indicators on wealth, health, governance, connectedness and fish consumption were collected. To evaluate these national-level indicators, representative metrics were found in databases from the UN Sustainable Development Goals, the World Bank, and the FAO Statistical Collection (Table 2-2), along with information collected during the policy review summarized in Table 2-1. The first indicator, wealth, was represented by GDP growth per capita. We hypothesize that increasing GDP per capita would lead to decreases in integration because policymakers in wealthier countries might have less need to rely on individual sources of protein to improve public health, and might also rely on other mechanisms outside of diets, such as health care. The second indicator, health, was also represented by two metrics: the percent of children who are overweight and of children with moderate or severe stunting. We expect to see an negative association between policy integration and the percent of children who are overweight but a positive association between policy integration and the percent of children who are experiencing moderate or severe stunting. We assume that regions where stunting is most

problematic are also most likely to recognize the benefits of nutrient-rich seafoods, whereas in regions where high proportions of children are overweight seafood consumption may be replaced by intake of higher calorie, nutrient poor alternatives. The third indicator focuses on governance, utilizing the composite indicator developed by the World Bank. We expect that countries with strong governance will have the ability to focus across multiple sectors and, therefore, may have capacity to focus on food security and nutrition alongside other objectives. As a result, we expect there to be a negative association between governance effectiveness and policy integration, where higher integration is associated with higher levels of governance. With the fish consumption indicator, the metric used is the ratio of domestic fish production to total animal protein. We expect that in countries that produce a high volume of fish relative to other animal proteins will have more integration in policies because fish play a more important role in overall protein supply in the country.

Table 2-2 National-level indicators used in fishery and health policy models

Indicator	Metric	Effect type in model	Source
Indicators collected from external country-level datasets			
Wealth	GDP growth per capita	Fixed	UN SDG Database (United Nations Development Programme, 2017)
Health	% children overweight, % children with moderate or severe stunting	Fixed	UN SDG Database (United Nations Development Programme, 2017)
Governance	Governance effectiveness index	Fixed	World Bank (The World Bank, 2019)
Fish Reliance	Domestic supply ratio of fish per total animal protein	Fixed	FAO Statistical Collection (FAO, 2019)
Indicators collected during policy review			
Recency of policy	Year of publication for the policy document	Fixed	Policy review
Development partner	Evidence that an international organization, or one external to the national	Fixed	Policy review

	government, aided in policy development process.		
Subregion	Subregions categorized using the UN Geoscheme (United Nations Statistical Division, 2017)	Random	Policy review
Policy type	Noted the type of policy document. Health policies included dietary guidelines, laws, and national policies. Fishery policy documents included laws and national policies.	Random	Policy review
Sector of fishery policy	Categorized whether fishery policy document was specific to aquaculture or to capture fisheries, or covered both sectors	Random	Policy reviews

The policy review also revealed a number of indicators included in the review, including publication year of the document, subregion – using the UN Geoscheme statistical system – of the originating document, the presence of an international partner in development, the type of the policy, and for fishery policy documents, the sector of focus. For publication year, the null hypothesis is that there is little integration in objectives between fishery and health policy objectives and therefore integration scores would not indicate increasing trends over time. For development partners, the null hypothesis is that there is no increase in probability of higher levels of integration in the presence of development partners during the policy development process. The model included the remaining policy review indicators as random effects, as there was more interest in the variability attributable to the predictors for subregion, policy type and fishery sector than in their specific effects on policy scores.

To test these hypotheses, an ordinal logit model was implemented using Bayesian modeling software STAN, which implements a No-U-Turn Markov Chain Monte Carlo sampler, interfaced through the R programming language package *brms* (Bürkner, 2019). Each prior in the logit was set to a weakly informative Cauchy distribution thereby assuming the priors are contributing less

to the model than the data itself (Gelman, Jakulin, Pittau, & Su, 2008). Cauchy distributions were then fit using the R package *fitdistrplus* (Delignette-Muller, Dutang, & Siberchicot, 2019) to the posterior distributions for each of the numeric variables to estimate the location and scale parameters of these posterior distributions, and a second set of models was run using these updated priors. These models were run with three chains each with 6500 post-warmup samples. While indicator variables in Table 2-2 were selected to maximize the sample size, national-level indicators were not available for all of the 165 health and 158 fishery policies. As a result, the fishery model was run on 72 policy documents and the health model was run on 75 policy documents for which we had complete data across all variables. To determine model fit and convergence, we examined posterior traces and Gelman-Rubin statistics. Both models had stable posterior traces across all three chains (Appendix Figure 1 & Appendix Figure 2), and Gelman-Rubin statistics very close to one (Appendix Table 3 & Appendix Table 4). This supports that the models converged and that posterior predictive distributions consistent with the observed data and support predictions with fishery and health models.

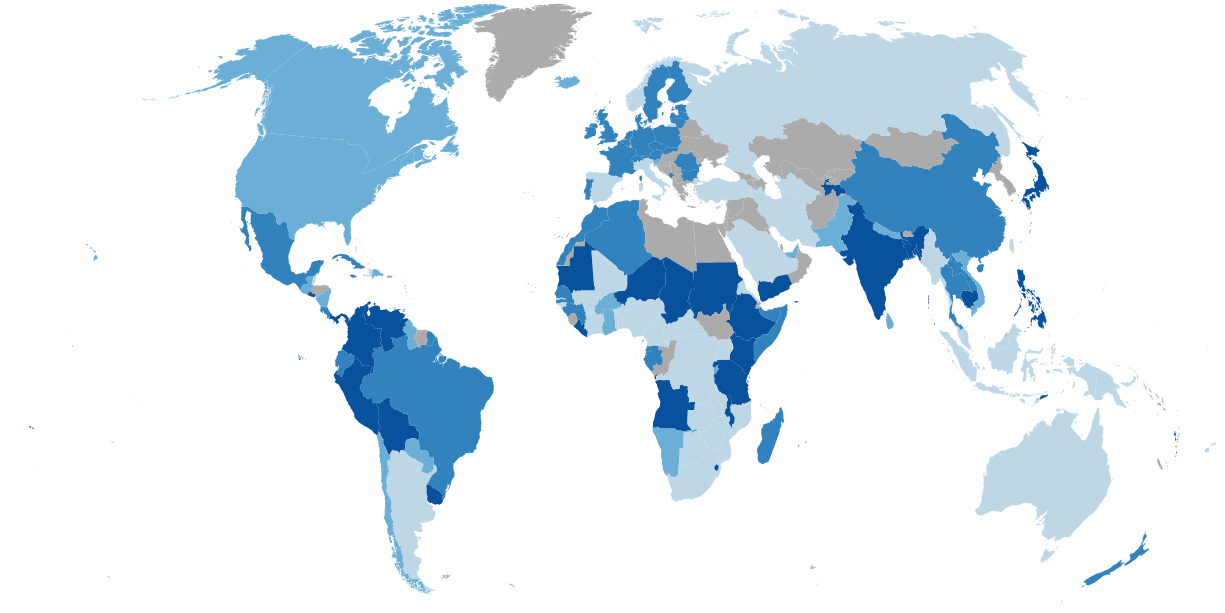
Using the posterior distribution of these parameters, we can determine the relative influence of each of these parameters. Bayesian analysts have decision rules for accepting or reject null that there is no effect of the parameter, based on how much of the parameter's posterior distribution - known as the high density interval (HDI), or the range of parameter posterior values that most credibly reflect the data (McElreath, 2018). To determine whether this HDI rejects the null based on how much of a range of parameter values with close proximity to the null, known as the region of practical equivalence (ROPE). Following Kruschke et al, the ROPE limits are $\beta x = \pm 0.055$ for parameters in a logistic regression (Kruschke, 2018). Parameter posteriors were accepted if the majority of their distribution fell inside of ROPE, rejected if the majority of their

distribution fell outside of ROPE, or where undecided if it fell partly within the ROPE (Kruschke, 2018). Marginal effects were calculated an 80% credibility interval, again using the *brms* (Bürkner, 2019).

2.4 RESULTS

Across all health and fishery policies, the mean policy integration score indicated that, on average around the world, fishery policies at best briefly mention food security and nutrition and health policies at best briefly mention seafood, with the former having a policy integration of 1.33 and the later with a mean integration of 1.29. This suggests that, globally, there is low integration around the world for fishery and health policies: health policies tend to briefly mention fish and shellfish but typically do not include them in their objectives, and fishery policies similarly mention FSN concerns briefly. There was no spatially explicit pattern visible (Figure 2-1 & Figure 2-2), however when considering the mean scores for each variable tracked in the review there do appear to be some regions with slightly higher mean integration by UN Geoscheme subregion (Appendix Table 5).

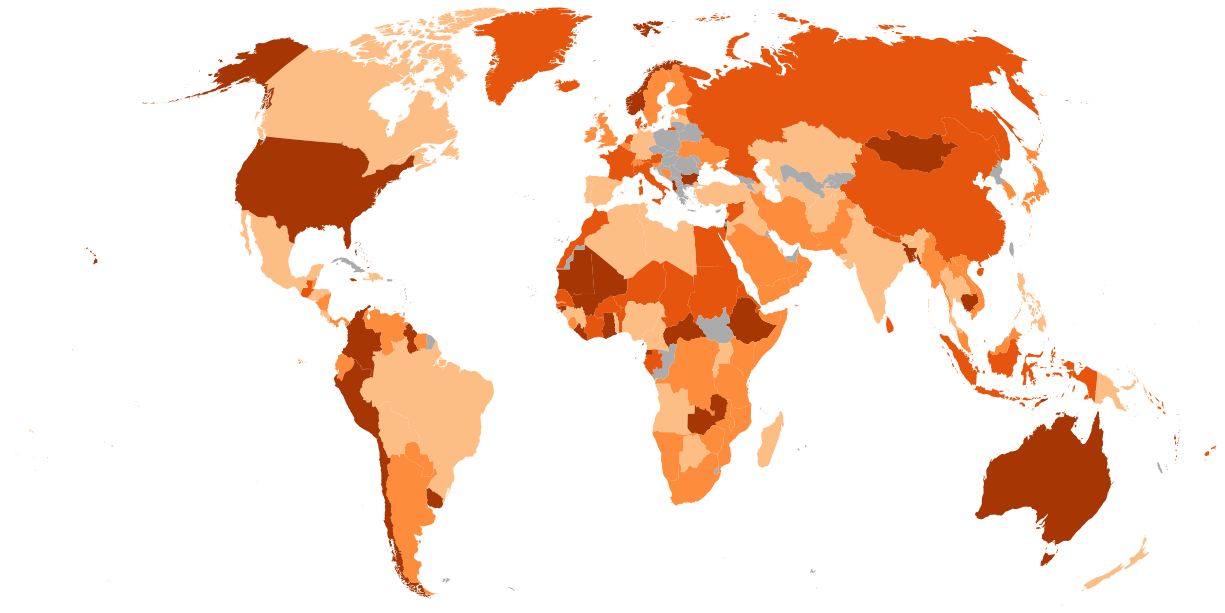
Fishery policy integration around the world



Level of integration with food security & nutrition ■ No ■ Low ■ Moderate ■ High ■ NA

Figure 2-1 – Global distribution of national fishery policies and integration scores.

Health policy integration around the world



Level of integration with seafood ■ No ■ Low ■ Moderate ■ High ■ NA

Figure 2-2 – Global distribution of national health policies and integration scores.

Summarized in Appendix Table 5 are the mean and standard deviation for all variables collected during the review. Mean health policy integration scores by UN Geoscheme Subregion ranged between low and moderate, and subregional fishery policy integration means are even lower. Caribbean health scores tended to be higher, and one explanation for this is the presence of a regional policy that may be influencing individual country scores. The presence of an international partner seemed to lead to higher average mean scores, with the effect being more noticeable in fishery policies than health.

2.4.1 *Differences from the null*

Many of the national-level parameters were influential in determining the level of policy integration in fishery and in health policies. Using the posterior distribution of these parameters, we can determine the relative influence of each of these parameters. Bayesian analysts have decision rules for accepting or reject null that there is no effect of the parameter, based on how much of the parameter's posterior distribution - known as the high density interval (HDI), or the range of parameter posterior values that most credibly reflect the data (McElreath, 2018). To determine whether this HDI rejects the null based on how much of a range of parameter values with close proximity to the null, known as the region of practical equivalence (ROPE). Following Kruschke et al, the ROPE limits are $\beta x = \pm 0.055$ for parameters in a logistic regression (Kruschke, 2018). Parameter posteriors were accepted if the majority of their distribution fell inside of ROPE, rejected if the majority of their distribution fell outside of ROPE, or where undecided if it fell partly within the ROPE.²

² It is important to clarify at the top of the reporting of model results that the effect sizes in the results section reported below do not imply causation. There are many processes and activities during policymaking that are likely to influence regional or subregional activities (e.g., strong

All parameters in the fishery model either rejected the null entirely, or that their effect did not reject the null (i.e., posterior distribution falling completely outside ROPE) (Table 2-3). Parameters with posterior distributions completely outside of ROPE indicated the strongest effects on fishery policy integration with health objectives, and included publication year, domestic supply of fish to total animal protein, and the prevalence of children who are overweight. Of those parameters that overlapped with ROPE, there were two categories: those that fell mostly outside of ROPE and thus had more effect on policy integration and those that were inside and thus had less effect. Parameters with the strongest effect – but not as strong as those falling completely outside of ROPE, included governance effectiveness and presence of a development partner. Parameters with the lowest effect included GDP per capita, and the prevalence of children experiencing stunting.

Table 2-3 - Region of practical equivalence for fixed effects in the fishery and health models

<i>Parameter</i>	<i>% in ROPE for fish model</i>	<i>% in ROPE for health model</i>
<i>Domestic supply of fish/total animal protein</i>	0%	1.3%
<i>Governance effectiveness</i>	6.1%	0%
<i>GDP per person</i>	34.1%	42.6%
<i>Development partner present</i>	2.8%	1.2%

stakeholder groups). Rather, effect sizes reported here imply association between parameter values and level of policy integration. A stronger effect indicates a stronger association, whereas a weaker association indicates a weaker association. For example, Table 3 indicates a strong, positive “effect” of publication year on integration score in the fishery model. The effect does indicate that more recently published policies were associated with high integration with food security objectives (as reported below). However, the strong, positive effect *does not* indicate that publications published more recently *cause* higher levels of integration.

<i>% children overweight</i>	0%	0%
<i>% children stunted</i>	84.8%	99.2%
<i>Year published</i>	0%	20.9%

In the health model, parameters that completely rejected the null (i.e., 0% overlap with ROPE) were governance effectiveness and the prevalence of children who are overweight. Parameters, with the next strongest effect on health policy integration with fishery objectives included domestic supply of fish to total animal protein and prevalence of a development partner. Parameters with the weakest effect included the percent of children experiencing stunting and the percent of the total population undernourished, publication year, and GDP per capita.

The region of practical equivalence test was also used to for the random effect variables policy type, fish sector and subregion (Table 2-4). For the fishery policy model, group-level effects for specific sectors were not strong. Policy type indicated a stronger effect in the fishery model than it did in the health model. Group-level effects for subregion indicated a stronger effect in the fish model than in the health model. Only the group-level effect for South America indicated an effect strong enough to completely reject the null that subregion had no effect on policy integration.

Table 2-4 - Region of practical equivalence for random effects in the fishery and health models

<i>Parameter</i>	<i>% in ROPE for fish model</i>	<i>% in ROPE for health model</i>
<i>Sector - aquaculture</i>	10.9%	-
<i>Sector - both</i>	9.9%	-
<i>Sector - capture</i>	10.8%	-
<i>Type - law</i>	1.7%	11.9%

<i>Type - policy</i>	1.5%	12.5%
<i>Type - diet guidelines</i>	-	12.3%
<i>Caribbean</i>	5.1%	16.8%
<i>Central Africa</i>	4.8%	15.2%
<i>Central America</i>	3.9%	14.7%
<i>Central Asia.</i>	4%	14.4%
<i>Eastern Africa</i>	4.5%	16.7%
<i>Eastern Asia</i>	3.7%	16.1%
<i>Melanesia</i>	4%	14.9%
<i>Northern Africa</i>	4.2%	16.2%
<i>Northern America</i>	3.7%	15.3%
<i>South America</i>	0%	12.5%
<i>Southeastern Asia</i>	5%	15.3%
<i>Southern Africa</i>	1.5%	15.9%
<i>Southern Asia</i>	1%	17.3%
<i>Southern Europe</i>	1.5%	14.9%
<i>Western Africa</i>	1.7%	17.5%
<i>Western Asia</i>	4%	12.5%

Between fishery and health policies, there were some noticeable similarities and differences in the fixed effect variables. Major differences included year of publication where there was a strong effect in the fishery model but not in the health model, governance effectiveness where there was a strong effect in the health model but not in the fishery model, domestic supply of fish to total animal protein where there was a strong effect in the fishery model but not in the health model. There was a very weak effect of the prevalence of children experiencing stunting in the

fishery model, but the null hypothesis of no effect of stunting on policy integration with seafood objectives was accepted in the health model. Both fishery and health policy integration shared strong effects for the prevalence of children who are overweight on policy integration scores. Both models had weaker effects on the presence of a development partner and GDP per person. With this understanding of the overall effect of the parameters on policy integration, we can look at the marginal effect of the parameters on the probability of a policy having no, low moderate or high integration given each of the parameters. The focus here will be on parameters with strong effects on health and fishery policy integration.

2.4.1 *Policy publication year*

Publication year had a strong effect on policy integration for fishery policy integration with nutrition objects, but a weaker effect on health policy integration with objectives utilizing seafood. In both cases, more recently published policies were associated with a decreasing probability that a policy would have no integration (Figure 2-3).

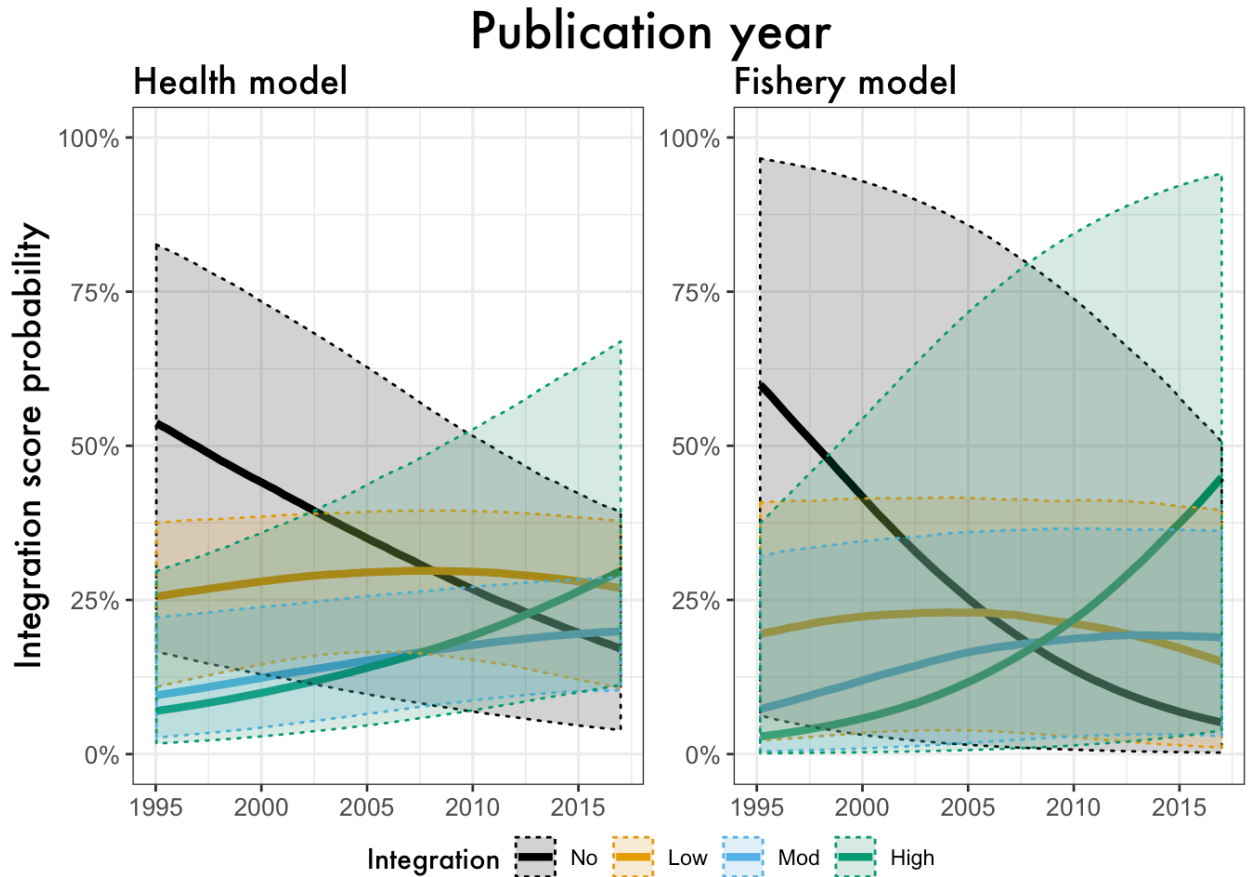


Figure 2-3 - Marginal effect (Median \pm 80% CI) of publication year on policy integration for health and fishery models, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with a change in publication year leads to specific increase - or decrease - in the probability of that level of integration.

For fishery policies, this indicates that more recently published policies are associated with higher levels of integration with food security and nutrition objectives. Between 1995 and 2017, the probability that a fishery policy had no integration went from 60% to 5% for health policies and from 53% to 17% for health policies. For fishery policies published during that the same span of time, the probability of high integration - including seafood not only in objectives but in specific action items - increased from 3% to 44%. With health policies, a less noticeable but similar trend occurred. As the probability of no policy integration declined, the probability that food security and nutrition had low integration - where FSN was at least mentioned in the policy - gradually increased to a peak of 30% between 2004 and 2005 before decreasing. More

recent publication years were associated with a higher probability that health and nutrition was moderately aligned in the goals of fishery policy objectives and, to a lesser effect on the probability of a policy having high integration that health and nutrition objectives were the focus of specific policy actions.

2.4.2 *Childhood malnutrition parameters – overweight and stunting*

The prevalence of children being overweight had a strong association with policy integration in both fishery and health models (Figure 2-4), but prevalence of childhood stunting had no clear association with policy integration (Figure 2-5). As the proportion of children who are overweight increases, the probability of high integration decreases in both fishery and health policies. The probability that health policies have high integration with seafood increases as prevalence of overweight children increases, from 45% to 4%. The probability that fishery policies have high integration with FSN objectives increases as prevalence of overweight children increases in country, from 49% to 1%. In both health and fishery models, as prevalence of children who are overweight increased, the probability of policies with no integration increases from 9% to 75% in health policies and 5% to close to 100% in fishery policies.

Marginal effect of the prevalence of overweight children on health policy integration

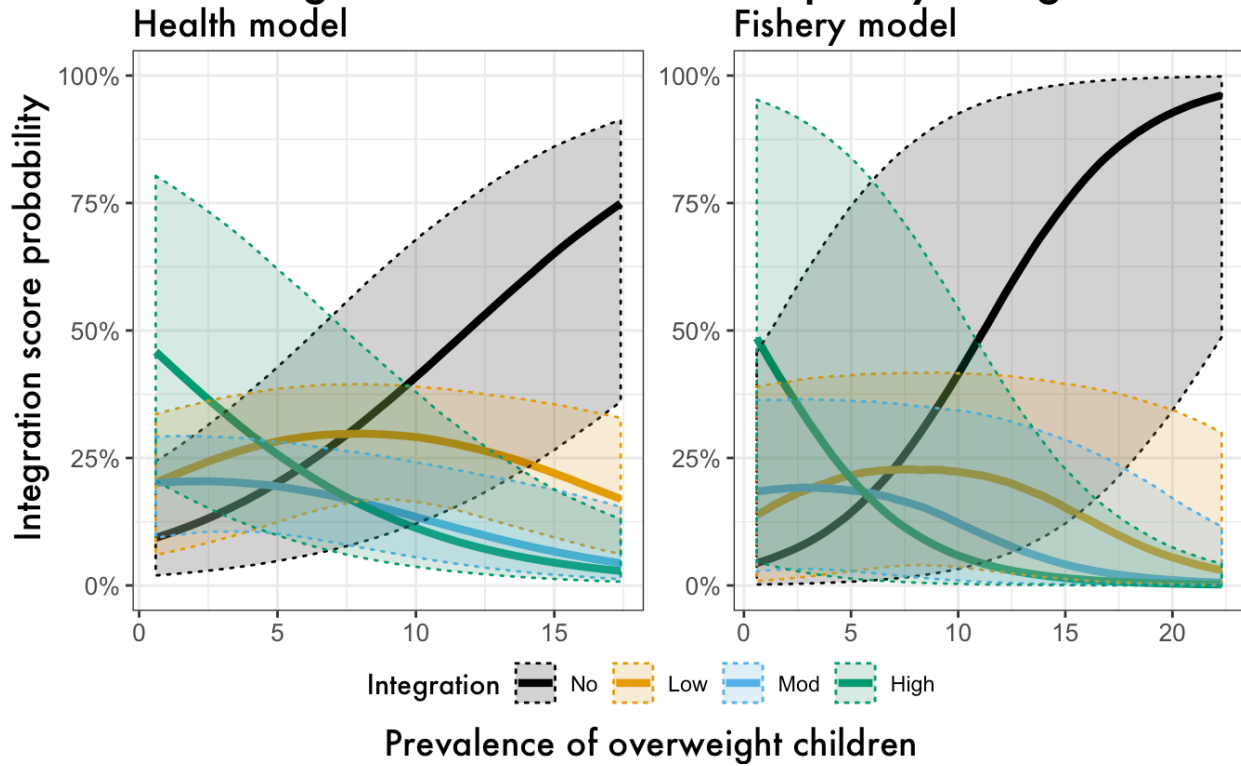


Figure 2-4 - Marginal effect (Median \pm 80% CI) of the proportion of children who are overweight on health policy integration scores, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with a change in prevalence leads to specific increase - or decrease - in the probability of that level of integration.

The ROPE equivalence tests above indicated no clear association between childhood stunting and fishery or health policy integration (Figure 2-5). Marginal effects plots do indicate that countries with higher prevalence of childhood stunting tend to see slightly higher probability of high integration and a slightly lower probability of no integration but given the broad credibility intervals for this parameter in both models, a definitive pattern was not likely.

Marginal effect of the prevalence of stunting among children on policy integration

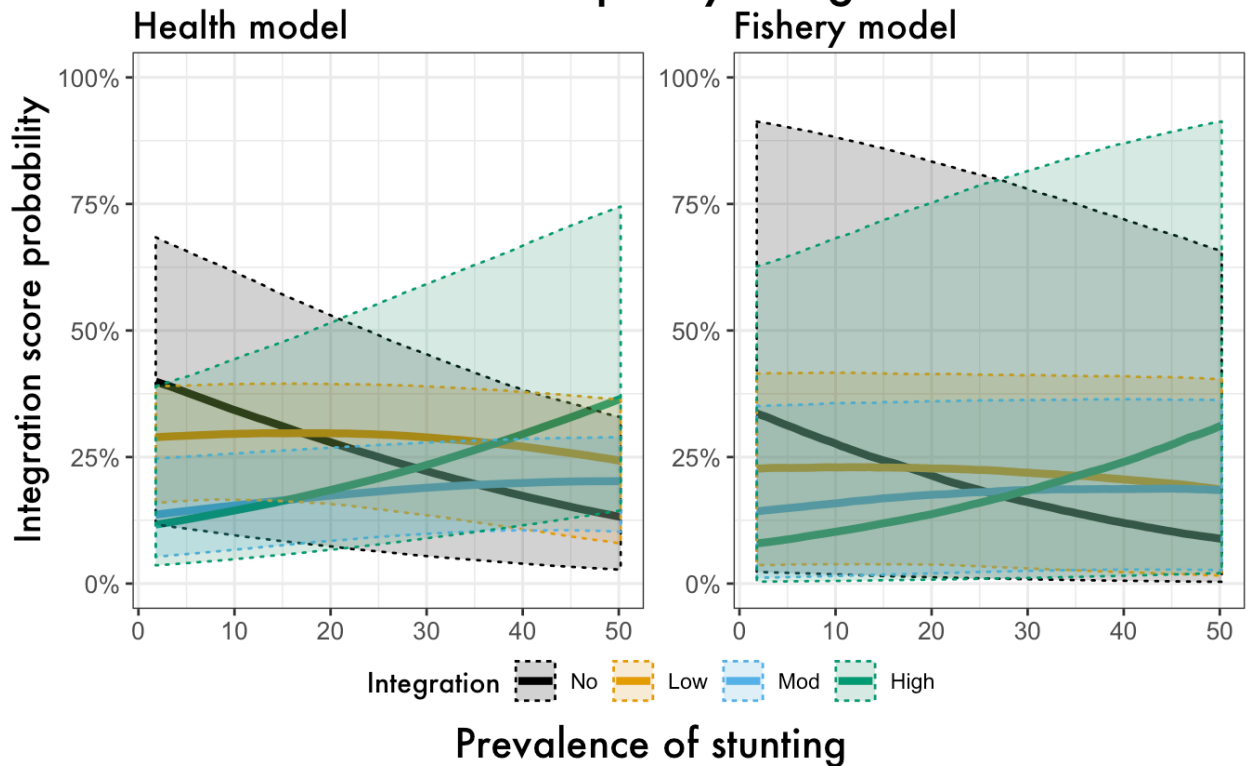


Figure 2-5 - Marginal effect (Median \pm 80% CI) of the proportion of children who are experiencing stunting on fishery and health policy integration scores, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with a change in prevalence leads to specific increase - or decrease - in the probability of that level of integration.

2.4.3 Development partners

Development partners parameter posterior distributions did not fall entirely outside of ROPE (Table 2-3), but most of the distribution did so we can assume there is some association with policy integration and partner presence, but that this association was not as strong as some other parameters given the data. In both models, recognizing the contribution of a development partner in the policy document most noticeably affected the probability of a high integration score, but notice that the 80% credibility intervals indicated considerable uncertainty - especially in the fishery model (Figure 2-6). For the health model, the presence of a development partner

increased the probability of high integration from 21% to 40%. For fishery models, the presence of a development partner in the policy document increased the probability that it had high integration from 16% to 36%.

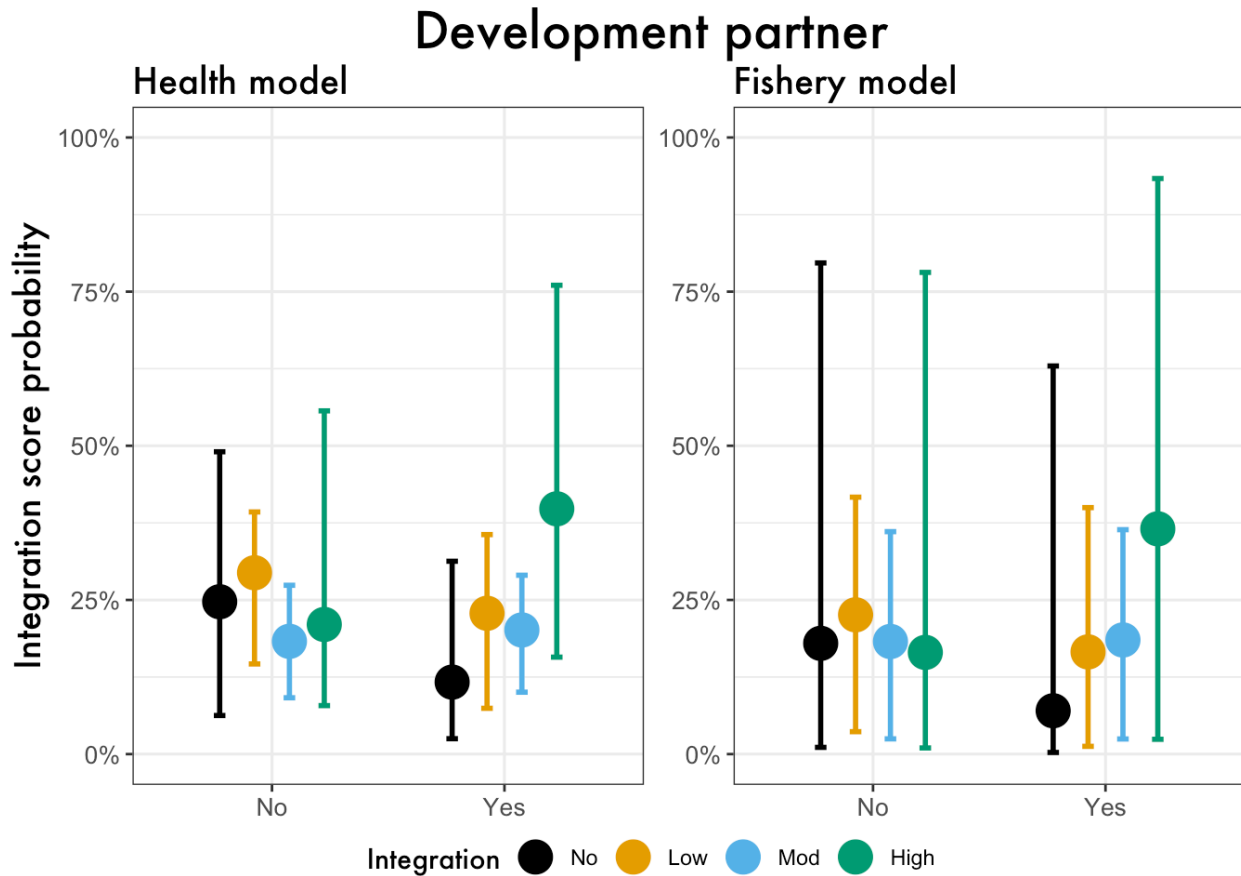


Figure 2-6 - Marginal effect (Median \pm 80% CI) of the presence of a development partner on fishery and health policy integration scores, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with the presence or absence of development partners leads to specific increase - or decrease - in the probability of that level of integration.

2.4.4 Governance effectiveness

Governance effectiveness rejected the null in the health model, and had an “undecided” effect in the fishery model (Figure 2-7), suggesting there was a strong association between the parameter and health policy integration and a much less noticeable association between the parameter and fishery policy integration. For the health model, as the governance effectiveness index of the

country creating the policy increased, so too did the probability that the policy document would have high integration with seafood, from 8% to 62%. The probability that a health policy would have no integration also decreased in countries where the governance effectiveness index was higher. For fishery policies, countries with higher governance effectiveness tended to have documents with more integration with FSN objectives, but the uncertainty of this parameter in the fishery model made any definitive statements tenuous.

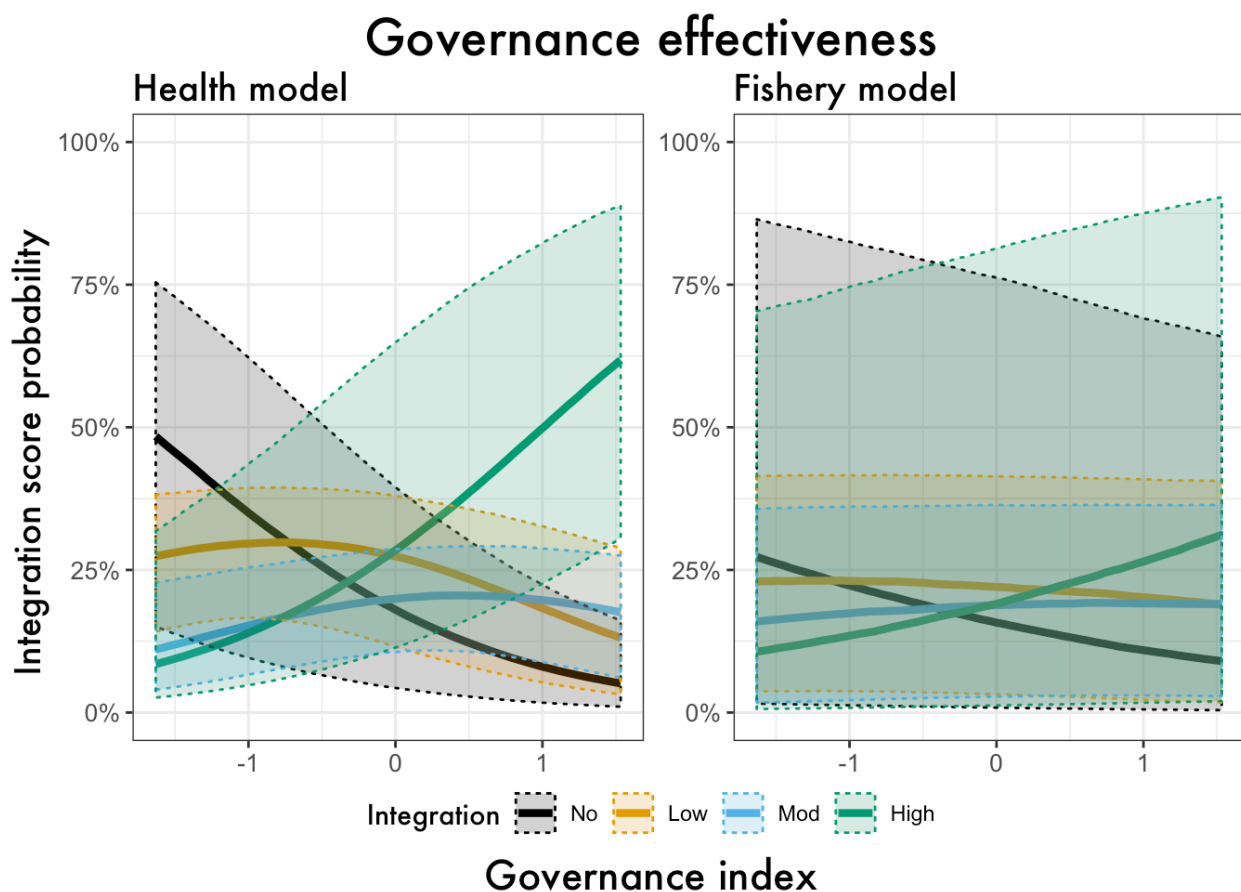


Figure 2-7 - Marginal effect (Median \pm 80% CI) of governance on health policy integration scores, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with a change in governance effectiveness index score leads to specific increase - or decrease - in the probability of that level of integration.

2.4.5 Per capita GDP

GDP per capita had no clear association with integration in fishery and health models; any slight trends were masked by the level of uncertainty.

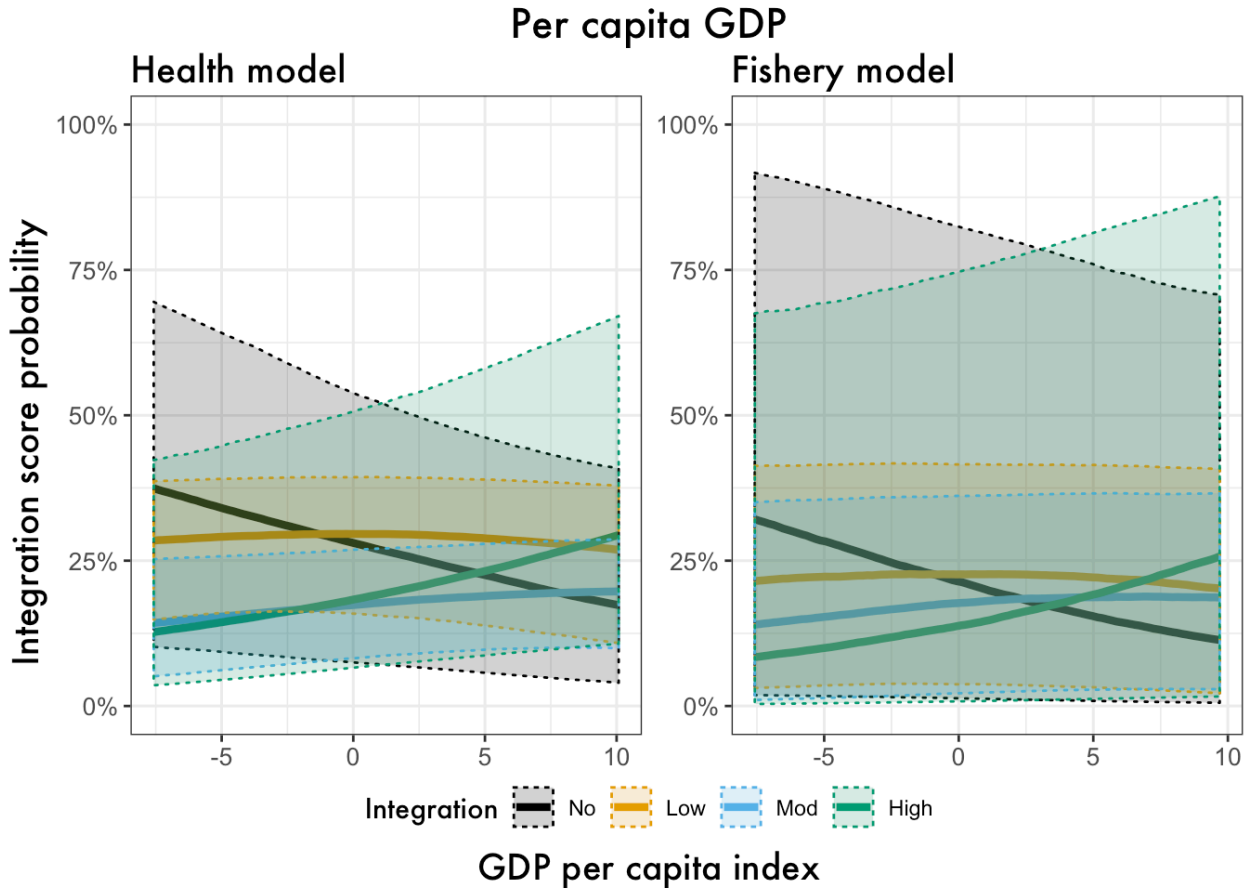


Figure 9 - Marginal effect (Median \pm 80% CI) of per capita GDP on fishery policy integration scores, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with a change in GDP per capita leads to specific increase - or decrease - in the probability of that level of integration.

2.4.6 Fish reliance: Domestic supply of fish to overall protein production

The fish reliance parameter rejected the null for the fishery model, and was mostly outside of ROPE for the health model (Table 2-3), suggesting there is a strong association between fish reliance and fishery policy and a weaker but still apparent association between fish reliance.

When considering the marginal effects of changes the parameter on policy integration levels, health model did not indicate any clear association in the level of integration with fish and

shellfish keywords as domestic production of fish changed. For the fishery model, in countries where domestic production of fish relative to overall protein production was higher, fishery policies tended have a higher probability of no integration and in countries where with low fish reliance, fishery policies tended to have high integration with FSN objectives.

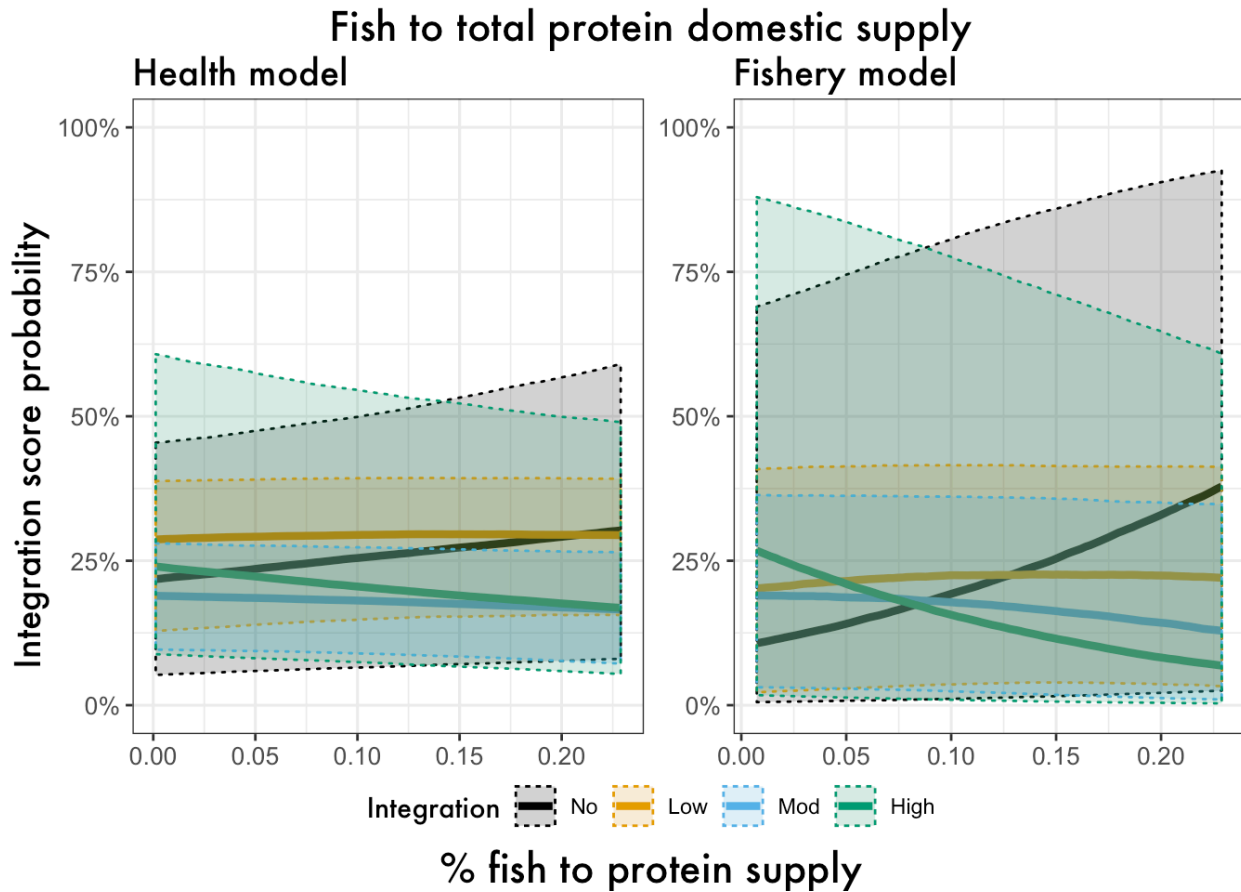


Figure 2-8 - Marginal effect (Median \pm 80% CI) of the proportion of fish to total domestic protein on fishery and health policy integration scores, where the median marginal effect of a change in the probability of a no, low, moderate or high integration associated with a change in fish reliance leads to specific increase - or decrease - in the probability of that level of integration.

2.4.7 Group-level effects of subregion, policy type and fishery sector

Subregion, policy type and fishery sector (for fishery policy model only) variables were collected during the policy review and were included as random effects in the models. The group-level effect sizes visualized in Figure 2-9 show the effect size of each subregion: subregions with more

positive effect estimate indicate that policies originating from that subregion have higher levels of integration, whereas a more negative effect indicates that policies originating from that subregion have lower levels of integration. For subregional group-level effects, we see a more noticeable negative effect on health model integration for Western Asia, Central Asia, and Central America and more noticeable positive effects for South America, Melanesia and Central Africa. As indicated above, only fishery policies originating in the South America subregion had an HDI totally outside of ROPE (Table 2-4), which indicates that South American fishery policies tended to have much higher levels of integration. When considering the mean health policy scores in each subregion (Appendix Table 5), Central and Western Africa, South America, Eastern Asia, the Caribbean, and Eastern Europe had higher levels of integration, but no means extended beyond moderate integration with seafood production. For the fishery model, subregion had the strongest negative effects on integration scores for Southern Asia and Southern Africa, and had the strongest positive effects for Southern Europe and South America. When considering mean fishery policy scores across regions (Appendix Table 5), Northern Africa, South America, and Western Europe had mean values with at least moderate integration with FSN objectives.

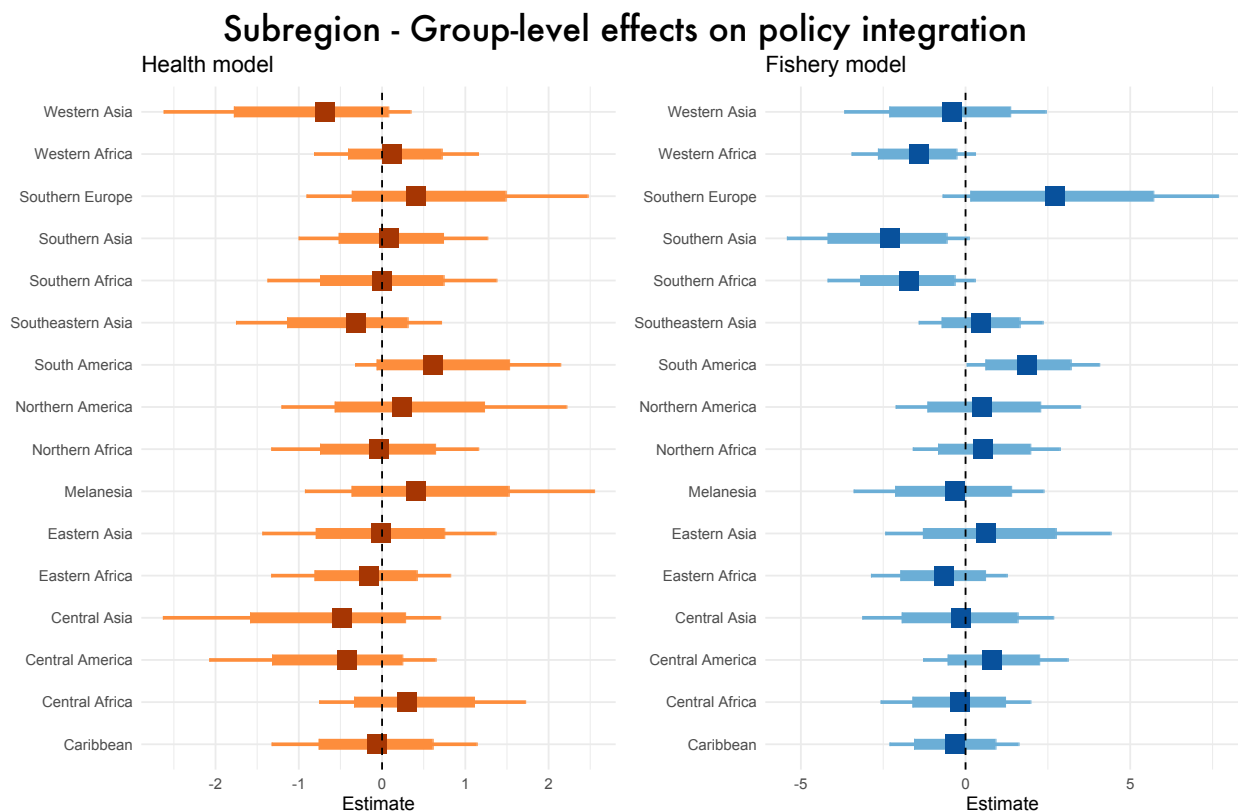


Figure 2-9 - Group-level effects of subregion on health and fishery policy integration, thick bar indicates CI \pm 80% and thin bar indicates CI \pm 95%. A positive effect estimate indicates that variable has higher levels of integration in policies, whereas a negative effect indicates that variable has lower levels of integration in policies.

Group-level effects of policy type on the health model indicated a slight negative association with integration with seafood production for national policies and national laws, and a slight positive effect of dietary guidelines on health policy integration (Figure 2-10). When considering policy type in aggregate, dietary guidelines had higher mean health policy integration than policies and laws (Appendix Table 5). For fishery policies, national policies had a positive effect and national laws had a negative effect on integration with FSN objectives, with the mean integration of national policies being greater than national laws (Appendix Table 5). Group-level effects were also estimated for the seafood sector being addressed in fishery policies (Figure 2-10). Policies that were specific to either aquaculture or capture fishery sector tended to have a slight, negative effect on policy score. If the policy covered both aquaculture and capture

fishery sectors, there was a very slight, positive effect on policy integration. The weak effect sizes of fishery sector variable in the model show that, relative to other group-level effects, sector was not especially indicative of higher or lower levels of fishery policy integration across sectors within the model. However, when considering the means across all policies for each sector group, aquaculture and policies addressing both sectors had higher mean levels of integration with FSN objectives than capture fisheries (Appendix Table 5).

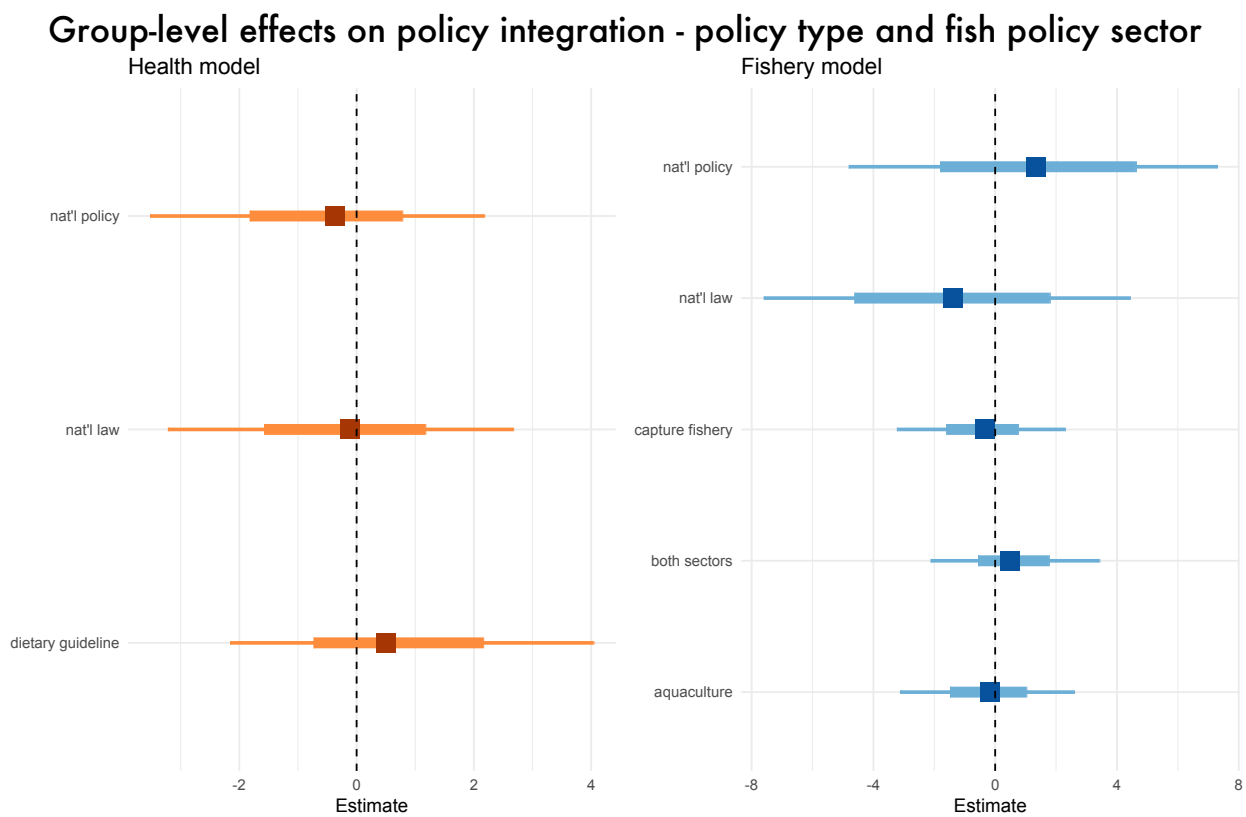


Figure 2-10 - Group level effects of policy type and fish sector on health and fishery policy integration, thick bar indicates CI ± 80% and thin bar indicates CI ± 95%. A positive effect estimate indicates that variable has higher levels of integration in policies, whereas a negative effect indicates that variable has lower levels of integration in policies.

2.5 DISCUSSION

Our analysis covering 165 health and 158 fishery policies at the national level revealed five key discussion points, finding that globally, there were low levels of integration in fishery and health policies to support food security and nutrition contributions from fishery sector. However, higher levels of integration were associated with particular policy characteristics. There is evidence that more recent fishery policies have higher integration with food security and nutrition objectives. To a lesser effect, the same is true of health policies. Second, there is a nuanced, but strong association between childhood malnutrition to fishery and health policy integration where higher rates of overweight children correspond with lower integration in fishery and health policies. This suggests that countries do not consider the nutritional value of fish to improve the healthfulness of diets away from calorie rich but nutrient poor diets, further supported by the result that there is no evidence of a relationship between integration in fishery and health policies and childhood stunting prevalence. Third, when development partners are present, that country has a higher probability of high integration in its fishery and health policies. This suggests that the work of development and health and fishery sector actors appear to be having demonstrable outcomes to improve the level of integration between fishery and health policies. Fourth, countries that rely on a greater proportion of fish to total domestic protein supply surprisingly tend not to have integration with food security and nutrition goals and fish consumption has no clear relationship with health policies. Finally, countries with high governance effectiveness tended to see much higher integration of nutrition concerns in fishery policies but there was a less noticeable effect on the integration of seafood into health policies, suggesting countries with stronger governance recognize the nutritional value of fish and seek to align the fisheries to meet food security and nutrition goals.

2.5.1 *More recent policies have higher integration between fisheries and food security & nutrition goals*

Progress is being made: in the fishery and, to a lesser extent, the health model found there was a much higher probability of high integration between the two policies in countries with more recently published policies. Fishery policies indicated a stronger effect where more recent publications included more food security & nutrition objectives and at higher levels of detail. At the same time, more recent policies were less likely to just contain allusions to FSN and more likely to have clear objectives related to it (*i.e.*, low integration score towards moderate or high integration). As policies trend away from general use of FSN keywords they are moving towards more specific terminology and objectives, suggesting decisionmakers are beginning to think more proactively about managing fisheries for food security and nutrition. It is important to note that without systematic ground truthing and finer-scale data (e.g., (Fisher et al., 2017; Kurien & Ríos, 2013)), it is difficult to know if these policies are as effectively implemented with the same regard as are other objectives (e.g. are the actions required to meet nutrition-sensitive policy objectives monitored or enforced as adequately as effort is to meet objectives related to biological sustainability of the stock). The results provided here nevertheless suggest that fishery policies are moving in a promising direction that echoes calls for greater inclusion of nutrition-sensitive policies in capture fisheries and aquaculture (Golden et al., 2016; Thilsted et al., 2016).

Health policies also showed that more recently published documents tended to have improved integration with seafood. This suggests that the rapid increase in academic literature and policy briefings on the potential contribution of fish to human health is leading to recognition in key national policy documents in both sectors and that policies are becoming more aligned. This is an encouraging step in creating the enabling context for action to use fish to

tackle micronutrient malnutrition (Hicks et al., 2019). Our results indicate that there is still considerable room to guide future policy development towards more specifically highlighting how to guide decision-makers and enable effective action to better realize the nutritional benefits of seafood in health policies.

2.5.2 *Childhood malnutrition – understanding the conditions for improving alignment*

A motivating reason for the design of this research was to determine whether fishery and health policies had complementary objectives that enabled seafood to be distributed in pathways that alleviate malnutrition. We learned that of the two health indicators related to the dual burden of malnutrition, only the prevalence of overweight children was associated with policy integration, and that countries with high overweight prevalence were associated with *low* levels of integration of FSN objectives in fishery policies and of fish and shellfish in health policies. There was a strong association between the proportion of overweight children and the level of integration in fishery and health policies, however, in this case it was a negative association, suggesting that as proportion of overweight children increases, so does the probability that fishery and health policy scores will not be integrated.

While the proportion of children overweight is only a proxy by no means a perfect analogue for obesity and diet-related disease, the negative association suggests fish are not currently considered for their role in nutrition for countries where such diseases are prevalent. In some cases, fishery policies make no mention of seafood despite having a large fishery production sector and high prevalence of overweight children such as Indonesia where much of its fishery resources are exported. In other cases, overweight prevalence is high but capture fishery production is low – for example in Kazakhstan’s inland lakes where there was Soviet and post-Soviet era overfishing – where the opportunity is in aquaculture production, which is being

to improve supply to local markets (Graham, Pueppke, & Uderbayev, 2017). In such regions where overfishing depleted wild fishery resources, aquaculture may present an alternative to improve seafood consumption. The contexts underlying the negative association between overweight prevalence and policy integration are diverse, as are their potential solutions. There are many opportunities for context-specific policy changes to address disconnects and improve alignment across the sectors to alleviate diet-based disease.

Neither fishery nor health policy model indicated that childhood stunting was a national-level indicator associated with higher, or lower, integration; but this does not necessarily indicate that the lack of association between stunting and policy integration signals a lack of effort on-the-ground. Food system pathways can be developed outside of formal processes, such as in Bangladesh where programs are already underway to increase consumption of fish using aquaculture development to target Vitamin A deficiencies (Fiedler, Lividini, Drummond, & Thilsted, 2016b). Some of the highest rates of fish consumption in the world occur in Cambodia, - where fishery policies are highly aligned with nutrition – yet malnutrition remains because of other health risks impacting nutrition: low consumption of vegetables and a lack of nutritional education (Vilain, Baran, Gallego, & Samadee, 2016). In other cases, food pathways do not exist even if there *is* a policy that supports integration between fish and shellfish and nutrition objectives. There are areas where childhood stunting is prevalent and domestic supply of fish is low, there are still isolated examples where fishery policies do have high integration with food security. For example, Yemen has some of the highest stunting rates in the world, approximately half its population cannot secure access healthy food, due in large part to ongoing civil disputes disrupting food supply (El Bcheraoui, Jumaan, Collison, Daoud, & Mokdad, 2018). The 2012 Yemeni policy sought to improve the management of its fishery resources so that it can improve

current methods “directly reflected in loss of market value and loss of nutritional opportunity” and contribute towards a domestic food supply of high nutritional quality (Ministry of Fish Wealth, 2012). The Yemeni policy exemplifies an important point: even policies with strong support can be ineffective if the objectives cannot be implemented due to influences external to policymaking process, such as civil war. The potential for fish to alleviate malnutrition in coastal communities is great (see Hicks et al.), yet our results indicated that there is currently a complete lack of association between stunting and policy integration. There is considerable room for fishery and health policies to improve their alignment across sectors combat malnutrition.

2.5.3 *Development partner presence influences fishery and health policy integration across sectors*

Development partner presence was associated with higher levels of with seafood production in health policy objectives and of food security and nutrition concerns in fishery policy objectives. These development partners were almost entirely from large international organizations affiliated with the United Nations and had unified mission statements, yet the content within each policy was tailored towards individual health risks and disease burdens within the country context. These organizations provided much of the technical and financial support in plan development among low and middle income countries, and alongside this there is a recognized need to also provide capacity for coordination between in-country agencies in order to meet policy objectives and, logistically, how to work with potential new food products. Given the explicit focus of many development groups on food security, it was surprising that there wasn't a more evident association between the presence of development partners and higher levels of integration with food security and nutrition concerns in fishery policies.

Numerous international organizations are working to improve the supply of sustainably produced seafood for food and nutrition purposes. Relative to health policies, there were fewer fishery policies that included development partners despite an explicit focus of food security by mission-driven groups like FAO or Worldfish collaborating on national and sub-national policy development. One explanation is there were fewer fishery policies with development partners than there were in health policies, relative to those who don't have any such partners. It is possible that, compared to other model parameters, there were simply too few examples to have a statistically-significant population-level effect. Another explanation for the absence of development partners might be a shift in partner preference over whether they wanted to be visible in the national policy document. Ownership of national and sub-national policies and programs has been a key aim of donor-funded policy reform initiatives in the natural resources sector (e.g., Hayman, 2007) and the technical agencies and consultants assisting governments with these reforms may remain invisible as part of that process of encouraging national ownership.

2.5.4 *Countries where people eat more fish tend to also have fishery policies that do not consider nutrition*

Countries that rely on a greater proportion of fish to total domestic protein supply did not integrate with food security and nutrition goals, and had no clear relationship with health policies. The expected relationship would be that countries where fish represent a large proportion of total protein in diets might have developed fishery policies that are more integrated with food and nutrition goals because there is already a demonstrable contribution that fish are making to diets in these countries. The opposite was shown to be true for fishery policies and there was no clear relationship between domestic fish supply and integration in health policies.

For fishery policies, as the contribution of fish to total protein increased so did the probability that policies would have no integration with food and nutrition goals. This suggests that, at least in some cases, countries recognize that fish are already making a contribution to diets and that there is no further need to integrate fish with the food system. It also suggests that, for countries where fish are not an important protein contributor, there is an interest in improving their supply with the explicit desire to better contribute to human health. Most of the country plans reviewed that had no integration but high domestic fish consumption tended to be laws rather than policies. Laws were overwhelmingly lacking in detail regarding food and nutrition goals, and this might explain some of the results. The only document that was a fishery policy with no integration with food security and nutrition concerns but had a high fish consumption was Indonesia, where there is also a strong emphasis on exports in the fisheries policy.

Many of the countries where fish consumption was low but where fishery policies had high integration with food and nutrition goals were in South America (e.g., Bolivia, Venezuela, Uruguay) or in Southern Africa (e.g., Eswatini, South Africa) and tended to have lower levels of fisheries production and their export. In these cases, fish may be conceptualized and valued as more of a food to aid in nourishment than as a commodity to generate wealth. For example in the landlocked Southern African country of Eswatini, the fishery policy aligns recommendations from its National Food Security Policy and recognizes importance of inland fisheries primarily as a vehicle to improve human health and to improve the lives of people living with HIV/AIDS (The European Union & The Government of the Kingdom of Swaziland, 2011). The recognition of fish primarily for their nutritional value rather than their economic value was unusual in this review. Taking such a view represents a novel political vision on how fisheries policy may contribute to a healthier food system. When the primacy is towards economic or ecological value

the food supply adjust accordingly as the goals are to take few, higher value fish. These management priorities often lead to positive conservation and economic outcomes (Anderson et al., 2018). Overfishing leads to negative health outcomes in the food system dependent on fishing as the supply becomes unstable or at worst absent, and sustainable harvest guidelines should be set and followed even if the primary objective is food. However without explicitly valuing fish for their nutritive value, wealth-based approaches reallocate fish towards larger markets willing to pay for them and from regions least able to afford them (Asche, Bellemare, Roheim, Smith, & Tveteras, 2015), and what replaces them may be of lower nutrient quality. In the worst of cases the resulting nutrient transition represents a shift from nutrient rich foods to calorie rich, nutrient poor ones that worsen diet-based disease (Popkin, Adair, & Ng, 2012). Explicitly recognizing the nutritional value of better aligns fish with the existing agricultural system (Seto & Fiorella, 2017), and helps to facilitate intersectoral connections necessary for fish to contribute towards a healthier food system.

2.5.5 *Low integration across most subregions, but promise in developing country areas*

Subregions were included as random effects for both models, and the variable had stronger effects in the fish policy model than in the health policy model. Only South America had a posterior distribution completely outside of ROPE. When looking at mean subregional scores in Appendix Table 5, align with the global mean in both fishery and health policies: most subregions currently have low integration. For health policies, this means that most countries do not currently consider seafood as a major contributor to meeting health objectives. Indeed, seafood is oftentimes excluded from food systems research that feed into aspects of health policy related to food and nutrition. A recent review of the inclusion of seafood in sustainable diets literature found these researchers presented seafood as having a conflict between positive health

outcomes and concerns about overfishing and the limits of increasing production, and the already broad footprint of seafood (Farmery et al., 2017). If these truly are the views of non-fisheries focused food systems researchers, this helps to inform the low levels of integration found among policies in this review. The exceptions were policies from Africa or the Caribbean, suggesting these regions consider fish and shellfish resources as components of the food system. Countries in Western Africa saw higher high levels of integration. The 2008 *National Food Security and Nutrition Strategy* in Liberia, for example, described fish as a high-protein nutrient-dense food that was underexploited and an important communal resource. While specific regions did indicate some integration of health policies with seafood, the low integration scores likely in most regions indicate that seafood is not well represented in health policies around the world and considerable progress can be made.

Fishery policies showed lower integration with FSN for the regions of Asia, the Caribbean and Oceania. The mean integration scores of fisheries policies originating from these regions is a surprising result considering many of these countries have high seafood consumption (FAO, 2018). In contrast, policies originating in Europe and the Americas both had higher integration with food security and nutrition objectives and specific details to meet those objectives. In Europe, a major driver for integration was the Common Fisheries Policy, which 19 of the 30 plans in Europe, set long-term food security as an overall aim to the policy and contribute to the supply of nutritional food to EU markets. The majority of the countries in the Americas, where policies had higher with FSN, were from Central America (*e.g.*, El Salvador, Panama) or South America (*e.g.*, Peru, Columbia, Venezuela). These plans emphasized strong connections between fisheries and the food system and directed agencies to meet food security and nutrition goals. Peru's 2004 plan to develop artisanal fisheries recognized improving seafood

consumption as a way to mitigate malnutrition via improving transportation, improving the culture around consumption. Peru has a number of related programs to create subsidies to supply school children and a series of “Anchoveta Weeks” to improve cultural awareness of the health benefits and cooking methods (Majluf, De la Puente, & Christensen, 2017). It is also important to caution that even if a plan receives a high integration score, there are still obstacles to overcome if the policy is to have efficacy. In Peru, there have been challenges in achieving the goals of the policy; weak rule of law in the artisanal sector may enable anchoveta intended for direct human consumption being diverted to fishmeal reduction plants and the aquaculture industry (Fréon et al., 2014). In policy development, careful thought must be paid to scenario development that explores potentially perverse incentives that limit the capacity and efficacy of plans to meet FSN objectives especially in regions that overlap with malnutrition or cultures with fish consumption.

Interactions between countries also influence how well a given geography is able to meet its food security and nutrition goals with seafood – whether it is produced domestically or imported from other countries. Trade is influential in seafood production systems, but how this trade benefits, or does not benefit, nutritionally vulnerable populations is under much debate. In response to early criticism that trade is inequitable because it exports nutrient-rich fish to wealthy countries and imports nutrient-poor processed products to poorer countries, an economic assessment of more and less developed countries suggested trade was “fair enough” because developing countries exported a lower volume of high value fish and imported a higher volume of low value fish (Asche et al., 2015). However, deciding to rely on seafood trade opens up local consumers to international market shocks common in fisheries and especially aquaculture (Gephart, Deutsch, Pace, Troell, & Seekell, 2017). These macroeconomic approaches cannot

account for dynamics occurring at local scales, which sees far more diversity in production to meet local demand among across the income spectrum (Belton, Bush, & Little, 2017). When consumption of seafood is disrupted by trade or by overfishing, consumers shift to alternative, oftentimes less healthy diet patters emphasizing consistent, nutrient-poor and affordable products. Across developed and developing countries, this “nutrition transition” has seen increasing prevalence of diet-related diseases like diabetes, hypertension and obesity (Popkin et al., 2012). It is likely that imported seafood is relied upon in meeting FSN objectives for regions or countries with low integration in fishery policies and high integration in health policies. The literature is far from clear on trade’s influence on seafood, trade and nutrition. In light of this uncertainty, our results suggest that improved integration between policies can help to ensure that seafood remains an accessible and available source of nutrition across for the wealthy and the poor.

2.5.6 *Sector-specific fishery scores*

Fishery models were also included as random effects, and there were no strong effects of sector-specific (i.e., aquaculture or capture fisheries) policies or policies addressing both sectors on the level of integration in fishery policies, but the mean score of aquaculture-specific scores was higher than capture fishery-specific integration. This difference might be explained by an underlying focus on other objectives, namely conservation and resource production. For capture fisheries, this result supports the existing literature indicating a lack of integration to the food system (Thilsted et al., 2016). This also reflects the longstanding focus of conservation strategies to reduce overfishing risks. There is an emerging discourse on alternative strategies to prevailing narratives on Malthusian overfishing and the fisheries crisis, that maintain food security for fishers by instead addressing power imbalances and inequity (Finkbeiner et al., 2017). This

review does not address the political economy of policies, but does suggest that most capture fishery policies do not address food security. Aquaculture did not have an effect on higher integration scores. The rapid growth of aquaculture is well documented, and research suggests that the potential efficiency of aquaculture could create a market environment where fish and shellfish production can meet demand and help to ensure food security (Davies et al., 2019a; Gentry et al., 2017). At regional or local scales there is evidence indicating the opposite and there is much for policy professionals to gain from these finer scale studies. Aquaculture has been found to contribute low market-value fish available accessible to low income consumers (Belton et al., 2017). For households who are fish reliant, they depend on agriculture just as much to meet food demands (Fisher et al., 2017), suggesting the importance of combining farming with aquaculture for small-scale policy interventions.

Surprisingly, the mean integration score covering both sectors had higher integration than capture-specific policies but slightly below aquaculture. This suggests a broadened understanding of the role of fisheries and aquaculture with respect to contributing to the food system. This result reflects much of the literature around nutrition-sensitive programs that encourage coordination across sectors to address malnutrition (Ruel & Alderman, 2013). Policies addressing both fisheries and aquaculture can also help to meet the needs of all consumers across income levels; species produced by aquaculture and by fisheries can differ in terms of price, preference and nutrient composition (Beveridge et al., 2013). Given a broader diversity of fish products supplied across both sectors, food security and nutrition objectives of these sector-unspecific policies can be met.

2.5.7 *Limitations and next steps*

Results discussed here contain caveats. In order to cover the extent of fisheries policies around the world, this method required a broad treatment. First, it is possible that a particular set of documents was not available online. There were also a number of documents only available in specific languages which we could not translate (*e.g.*, Czechoslovakian, Arabic) that were omitted from the analysis. We intend to continue to update this database as new policies are found. The results here represent the set of documents available at the time of data collection. The statistical model found the best performance without interaction effects, it is likely that policies are likely influenced by different combinations of predictors (*e.g.*, development partners and sub-regional scales, regional and publication years, etc.). These interaction effects can be explored in subsequent endeavors. Policies written alongside development partners were not likely to have, especially given the food security-specific mission of many of the partners (*e.g.* UN Food & Agricultural Organization). It might be the case that the use of a dummy variable to indicate the presence or absence of development partners was insufficient. In future work, including the individual partners as factors in the model might be beneficial. Across many of the predictors, there were few marginal effects on the probability of a high integration scores. This suggests that relative to no scores, much less of the variability could be explained by the predictors. One way to further explore the conditions leading to high levels of integration might be to include social, economic, fishery, food system and governance information in the modeling framework.

2.6 CONCLUSION

Pathways forward to sustainably manage our fisheries are becoming clear, and estimates and models indicate that with good stewardship futures can be envisioned where there are both more

fish in the ocean and more seafood being landed. Aquaculture's growth indicates another pathway by which seafood can meet demand for nutrient-dense, healthy food. At the same time malnutrition continues to rise, both from malnutrition and from diet-related diseases associated with overnutrition. Fish and shellfish, as rich and diverse sources of micronutrients, could contribute to improving global public health, and efforts to improve the contribution of fish to the diets of malnourished people are encouraged by the number of calls for greater integration between seafood producing sectors and the healthy food system.

Fisheries and aquaculture can better contribute to the food system if we create an enabling environment – with coherent policies across sectors that establish clear pathways linking fish production and distribution with nutrition needs and health policies. Without such policy direction, fish will continue to be produced and managed for revenues, jobs and conservation: all of which are important but don't necessarily ensure that fish reaches households most vulnerable to malnutrition. Around the globe our results indicate there was low integration in fisheries and health policies, but that there is evidence of improvements in more recent policies. The study also identifies geographic scales where we see more – and less – integration in policies, opening up the opportunity to discuss interventions to improve connections between seafood and the healthy food system. Despite seafood's nutrient richness, results were unclear in their successful integration of fishery and health policies to connect seafood with the healthy food system to combat malnutrition and there is considerable potential for improvement. Taken together, these results establish a foundational understanding of the status of national policies connecting fisheries to the healthy food system.

2.7 SUPPLEMENTAL TABLES AND FIGURES

2.7.1 *Fishery policy scoring metric and search terms*

Appendix Table 1 - Fishery policy scoring metric and search terms

Fishery policy scoring metric and search terms			
Search terms: food security, nutrition, health, healthy diet			
Score	Description		
0	No mention of search terms in fisheries and aquaculture policy documents.		
1	Search terms appear in general preambles or as passing mentions in various parts of the documents but NOT in the overall aims or specific objectives of the policies.		
2	Search terms appear in the stated overall aim of the policy, but no detail is presented in subsequent specific policy objectives.		
3	Search terms appear in clearly stated policy objectives and are discussed in the policy narrative and/or plans to fulfill objectives. there are clear discussions in the document on how fisheries contribute to food security, nutrition and health. There are likely to be specific technical words and phrases used (see list below).		
Technical lexicon			
Nutrition		Food security keywords	
Anemia	Nutritious	(Food) access	Food insecurity
Animal protein	Obesity	(Food) availability	Food prices
Calories/kilocalories	Overnutrition	(Food) utilization	Food production
Double burden	Protein	Affordable (food)	Food quality
Fatty acids	Severe acute	Agriculture	Food safety
Global acute malnutrition (GAM)	malnutrition (SAM)	Animal products	Food security
Height-for-age	Stunting	Diet	Food supply
Height-for-weight	Undernutrition	Dietary diversity	Hunger
Iron	Underweight	Dietary needs	Nutritious (food)
Iron deficiency	Vitamin A	Food	Processed foods
Kwashiorkor	Vitamin A deficiency	Food consumption	
Malnutrition	Vitamin B12		
Marasmus	Vitamins		
Micronutrients	Wasting		
Minerals	Weight-for-height		
Nutrition	Zinc		
	Zinc deficiency		

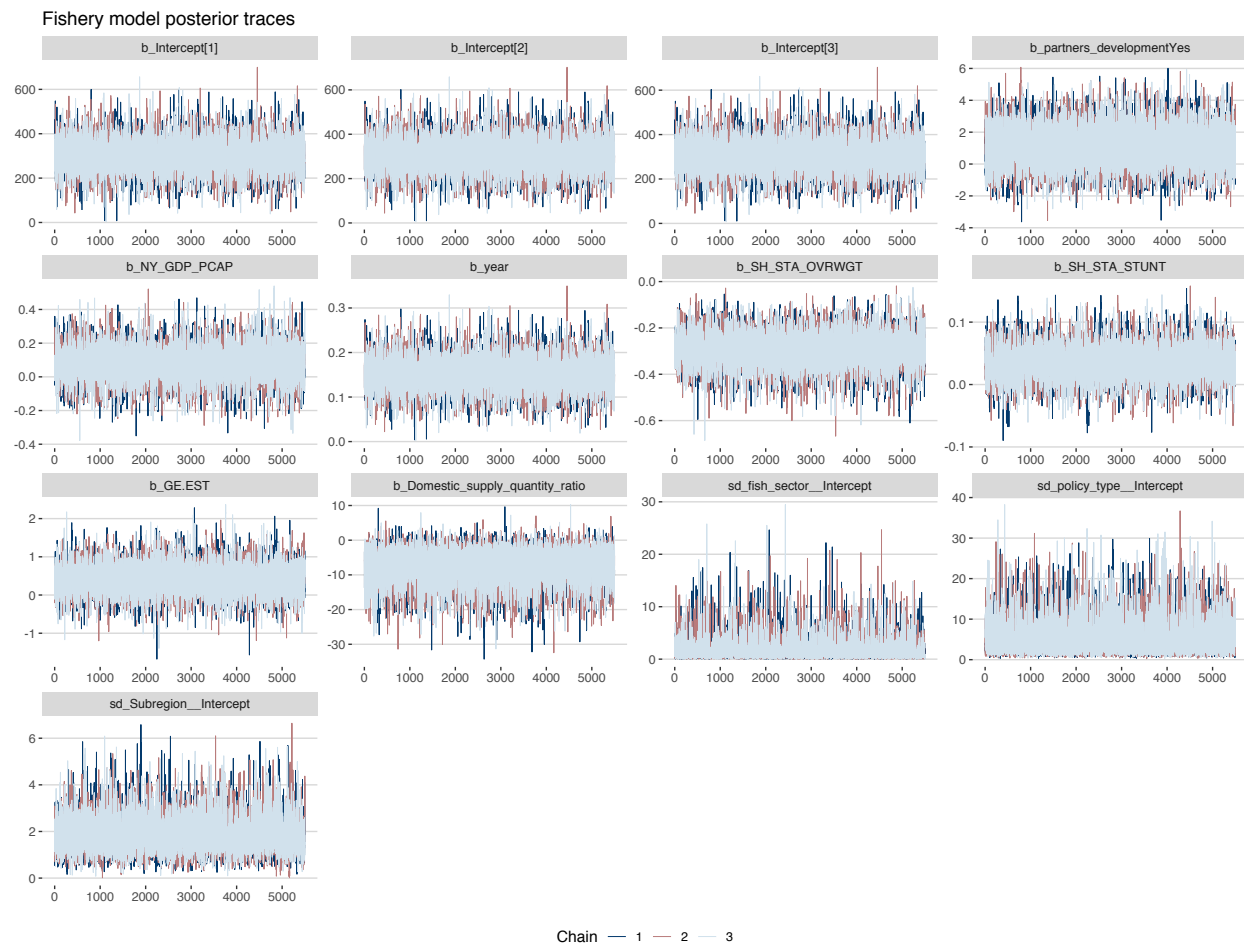
2.7.2 *Health policy scoring metric and search terms*

Appendix Table 2 - Health policy scoring metric and search terms

Health policy scoring metric and search terms	
Search terms: fish, seafood, shellfish, algae, fisheries, fishing, "fish farming", aquaculture, mariculture	
Score	Description
0	None of search terms appear in health, nutrition or food policy documents. There is no mention of fisheries or aquaculture, or fish/seafood in the health document or policy being considered.
1	One or more of the search terms appear in preambles, annexes, or as passing mentions with no specifics, suggesting that fisheries are not a focal issue or concern.

2	One of more of the search terms appear in either overall aims or in one or more policy objectives suggesting a recognition of the role of fish/seafood in healthy diets, or fisheries/aquaculture in food security, but there are no programmatic specifics.
3	At least one objective of nutrition and health policy contains a clear analysis of the role of fisheries/nutrition in addressing that concern (e.g. a micronutrient deficiency, or access to food for the landless rural poor), as evidenced by clear identification of seafood/fish in health policy aims and objectives and discussion of play concepts and keywords listed here, in clear connection to the role that fish/shellfish can play in these health concerns.

2.7.3 Fishery model trace plots for diagnostics



Appendix Figure 1 - Traceplots for fishery model

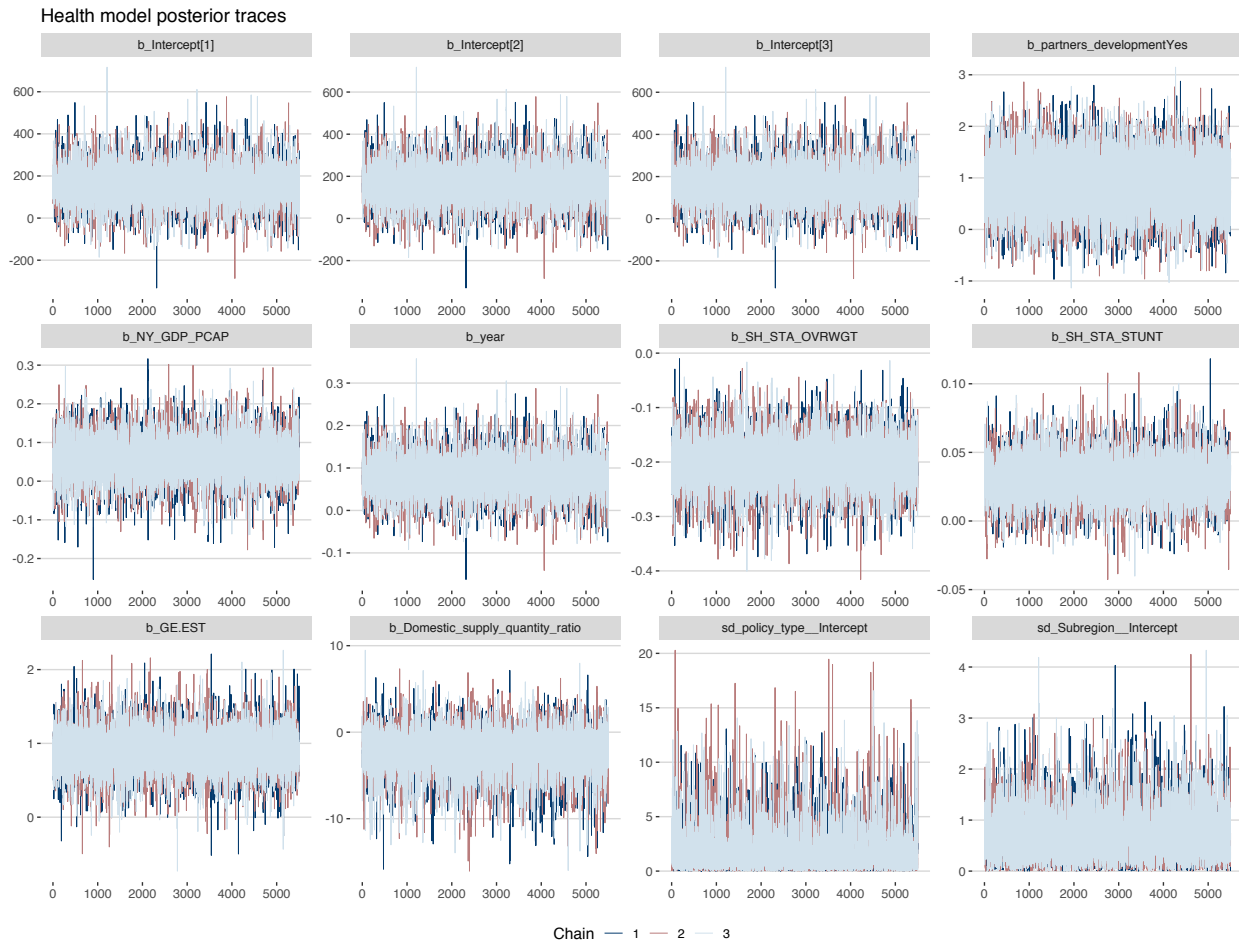
2.7.4 Fishery model summary and diagnostics

Appendix Table 3 - Summary and model diagnostic table for fishery model

Parameter	Estimate	Std.Error	HDI(89%)	pd	ESS	Rhat	MCSE
Fixed effects							
Intercept.1.	302.4946	59.2035	[186.59, 404.03]	1.0000	16139	0.9999	0.5395
Intercept.2.	304.2142	59.3505	[190.70, 408.21]	1.0000	16125	0.9999	0.5400
Intercept.3.	305.6466	59.3140	[190.04, 407.56]	1.0000	16111	0.9999	0.5404
partners_developmentYes	1.0404	1.1940	[-0.81, 2.97]	0.8162	10538	1.0000	0.0117
NY_GDP_PCAP	0.0785	0.0806	[-0.06, 0.23]	0.8289	16046	0.9999	0.0007
year	0.1520	0.0295	[0.10, 0.21]	1.0000	16168	0.9999	0.0003
SH_STA_OVRWGT	-0.2922	0.0592	[-0.40, -0.19]	1.0000	10048	1.0001	0.0007
SH_STA_STUNT	0.0355	0.0220	[-0.00, 0.07]	0.9288	9941	1.0000	0.0003
GE.EST	0.3978	0.3158	[-0.17, 0.98]	0.8875	15153	0.9999	0.0030
Random effects							
Domestic_supply_quantity_ratio	-6.4234	4.0471	[-14.94, -0.54]	0.9759	9631	1.0002	0.0487
fish_sector.a	-0.0658	0.6865	[-1.92, 1.74]	0.5595	10296	1.0000	0.0130
fish_sector.b	0.3535	0.6604	[-1.10, 2.36]	0.7355	9494	1.0001	0.0133
fish_sector.f	-0.2223	0.6504	[-2.07, 1.44]	0.6653	10033	1.0001	0.0129
policy_type.l	-1.2794	2.1372	[-5.93, 3.16]	0.7346	7247	1.0003	0.0341
policy_type.p	1.3343	2.1595	[-2.93, 6.18]	0.7416	7199	1.0003	0.0343

Parameter	Estimate	Std.Error	HDI(89%)	pd	ESS	Rhat	MCSE
Subregion.Caribbean	-0.3088	0.9278	[-1.90, 1.22]	0.6312	14864	1.0000	0.0081
Subregion.Melanesia	-0.2001	1.2998	[-2.64, 1.92]	0.5649	11785	1.0003	0.0133
Subregion.Central.Africa	-0.1482	1.0345	[-2.04, 1.53]	0.5569	13631	1.0000	0.0097
Subregion.Central.America	0.7704	1.0577	[-0.88, 2.64]	0.7769	13701	1.0002	0.0095
Subregion.Central.Asia	-0.1129	1.2962	[-2.58, 1.99]	0.5358	20820	1.0001	0.0100
Subregion.Eastern.Africa	-0.5941	0.9843	[-2.37, 0.92]	0.7385	9352	1.0005	0.0107
Subregion.Eastern.Asia	0.4826	1.4828	[-2.03, 3.29]	0.6350	16502	1.0001	0.0135
Subregion.Northern.Africa	0.4866	1.0431	[-1.20, 2.29]	0.6863	15316	1.0000	0.0090
Subregion.Northern.America	0.4304	1.2810	[-1.59, 2.77]	0.6393	16638	0.9999	0.0108
Subregion.South.America	1.7716	1.0055	[0.15, 3.39]	0.9748	10412	1.0001	0.0101
Subregion.Southeastern.Asia	0.4474	0.8886	[-1.06, 1.98]	0.6944	12347	1.0000	0.0086
Subregion.Southern.Africa	-1.6570	1.1259	[-3.51, 0.12]	0.9492	10035	1.0005	0.0116
Subregion.Southern.Asia	-2.1654	1.3866	[-4.27, 0.11]	0.9661	6157	1.0005	0.0180
Subregion.Southern.Europe	2.4732	2.1683	[-0.44, 6.16]	0.9244	6088	1.0006	0.0278
Subregion.Western.Africa	-1.3583	0.9432	[-2.89, 0.11]	0.9447	8492	1.0002	0.0104
Subregion.Western.Asia	-0.3494	1.3330	[-2.80, 1.91]	0.6061	17921	0.9998	0.0112
fish_sector_Intercept	0.9933	0.9062	[0.00, 3.52]	1.0000	7176	1.0003	0.0239

2.7.5 Health model trace plots for diagnostics



Appendix Figure 2 - Traceplots for health model

2.7.6 Health model summary and diagnostics

Appendix Table 4 - Summary and model diagnostic table for health model

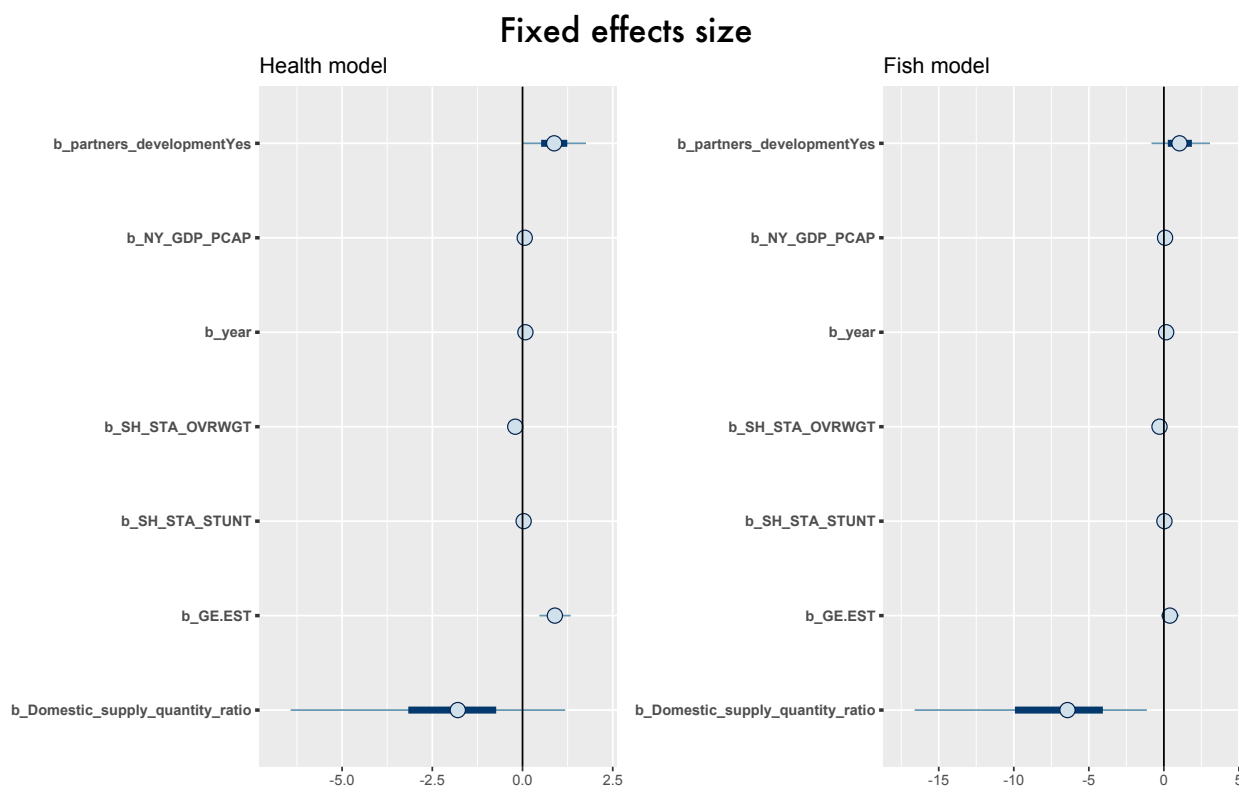
Parameter	Estimate	Std.Error	HDI(89%)	pd	ESS	Rhat	MCSE
Fixed effects							
Intercept.1.	158.0109	69.5870	[26.48, 288.31]	0.9679	17002	0.9999	0.6391

Parameter	Estimate	Std.Error	HDI(89%)	pd	ESS	Rhat	MCSE
Intercept.2.	159.4406	69.6535	[27.17, 289.03]	0.9684	16996	0.9999	0.6393
Intercept.3.	160.4331	69.6376	[28.64, 290.55]	0.9693	16993	0.9999	0.6394
partners_developmentYes	0.8765	0.5377	[-0.03, 1.70]	0.9457	16857	1.0000	0.0042
NY_GDP_PCAP	0.0609	0.0436	[-0.02, 0.14]	0.8959	16716	0.9999	0.0004
year	0.0796	0.0345	[0.01, 0.14]	0.9688	16984	0.9999	0.0003
SH_STA_OVRWGT	-0.2018	0.0359	[-0.26, -0.14]	1.0000	17414	0.9999	0.0003
SH_STA_STUNT	0.0309	0.0128	[0.01, 0.05]	0.9801	14968	1.0001	0.0001
GE.EST	0.8967	0.2286	[0.49, 1.33]	0.9973	14463	1.0000	0.0022
Random effects							
Domestic_supply_quantity_ratio	-1.7940	1.7741	[-5.72, 1.48]	0.8668	11978	0.9999	0.0213
policy_type.g	0.2282	0.7590	[-1.37, 2.73]	0.6592	6832	1.0004	0.0173
policy_type.l	-0.0065	0.6843	[-2.11, 1.79]	0.5076	5785	1.0010	0.0172
policy_type.p	-0.1739	0.6697	[-2.26, 1.37]	0.6411	5255	1.0013	0.0171

Parameter	Estimate	Std.Error	HDI(89%)	pd	ESS	Rhat	MCSE
Subregion.Caribbean	-0.0212	0.4040	[-0.95, 0.83]	0.5368	16993	1.0000	0.0043
Subregion.Melanesia	0.1806	0.5200	[-0.72, 1.74]	0.6678	9029	1.0004	0.0091
Subregion.Central.Africa	0.1712	0.4521	[-0.60, 1.25]	0.6779	12433	1.0002	0.0054
Subregion.Central.America	-0.2419	0.4791	[-1.45, 0.50]	0.7241	10091	0.9999	0.0065
Subregion.Central.Asia	-0.2472	0.5269	[-1.77, 0.59]	0.7148	8079	1.0001	0.0094
Subregion.Eastern.Africa	-0.0848	0.3927	[-0.99, 0.63]	0.6124	14494	1.0001	0.0042
Subregion.Eastern.Asia	-0.0007	0.4446	[-1.06, 1.00]	0.5022	14708	1.0007	0.0054
Subregion.Northern.Africa	-0.0138	0.4221	[-0.97, 0.91]	0.5261	19761	1.0000	0.0041
Subregion.Northern.America	0.0964	0.4931	[-0.99, 1.42]	0.6121	12858	1.0002	0.0071
Subregion.South.America	0.4546	0.6145	[-0.25, 1.64]	0.8379	8432	1.0003	0.0071
Subregion.Southeastern.Asia	-0.1733	0.4329	[-1.31, 0.53]	0.6893	12261	0.9999	0.0054
Subregion.Southern.Africa	0.0006	0.4321	[-0.88, 1.04]	0.5018	18652	1.0000	0.0045

Parameter	Estimate	Std.Error	HDI(89%)	pd	ESS	Rhat	MCSE
Subregion.Southern.Asia	0.0389	0.3816	[-0.72, 0.95]	0.5634	17211	1.0001	0.0040
Subregion.Southern.Europe	0.1838	0.5171	[-0.75, 1.68]	0.6728	9750	0.9999	0.0083
Subregion.Western.Africa	0.0760	0.3628	[-0.59, 0.89]	0.6122	15522	0.9999	0.0037
Subregion.Western.Asia	-0.4624	0.6668	[-1.82, 0.36]	0.8238	8236	1.0002	0.0086

2.7.7 Fixed effect size for health and fishery models



Appendix Figure 3 - Fixed effects intervals for health and fishery models

2.7.8 *Mean and standard deviation of policy integration for all indicators used in the fishery and health models*

Appendix Table 5 - Mean and standard deviation for all indicators

	Health policies			Fishery policies		
	Mean	SD	n	Mean	SD	n
By UN Geoscheme Subregion						
Central Africa	1.8	1.3	8	1.2	1.4	8
Eastern Africa	1.1	1.0	14	1.5	1.4	13
Northern Africa	1.0	1.1	6	2.3	0.6	3
Southern Africa	0.5	0.6	4	0.8	1.2	6
Western Africa	1.8	1.1	16	0.9	1.2	16
Central America	0.6	0.7	8	1.7	1.1	7
Northern America	0.5	1.2	6	1.2	0.8	5
South America	1.7	1.2	12	2.1	1.0	14
Central Asia	0.0	0.0	3	1.0	1.7	3
Eastern Asia	1.8	1.0	4	1.7	1.5	3
Southeastern Asia	1.2	1.2	8	1.7	1.3	10
Southern Asia	1.4	1.2	10	1.3	1.3	7
Western Asia	0.7	0.9	13	1.0	1.4	4
Caribbean	1.8	1.3	11	0.5	0.8	13
Eastern Europe	2.0	1.0	3	1.7	0.8	6

	Health policies			Fishery policies		
	Mean	SD	n	Mean	SD	n
Northern Europe	1.5	0.8	11	1.5	0.8	11
Southern Europe	1.3	1.1	7	0.9	0.9	7
Western Europe	1.3	0.8	6	2.0	0.0	6
Australia and New Zealand	1.5	2.1	2	0.7	1.2	3
Melanesia	1.8	1.3	4	1.2	1.3	6
Micronesia	1.0	1.4	4	1.0	1.7	3
Polynesia	1.0	1.2	5	0.8	1.5	4
Presence of int'l partner in plan development						
No	1.2	1.1	135	1.2	1.1	142
Yes	1.9	1.1	30	2.2	1.1	16
Type of policy						
Dietary guideline	2.1	0.8	14	NA	NA	NA
Law	0.8	0.8	14	1.0	1.0	105
National policy	1.3	1.1	137	2.1	1.1	53
Sector - Fishery policies only						
Aquaculture only	NA	NA	NA	1.7	1.3	11
Both sectors	NA	NA	NA	1.7	1.0	89
Capture fisheries only	NA	NA	NA	0.7	1.1	58

Chapter 3. MAKING SEAFOOD ACCESSIBLE TO LOW-INCOME AND NUTRITIONALLY-VULNERABLE POPULATIONS ON THE US WEST COAST

3.1 ABSTRACT

Along the US West Coast, sustainable management has rebuilt fish stocks, providing an opportunity to supply nutrient-rich food to adjacent coastal communities where food insecurity and diet-based diseases are common. However, the market has not successfully supplied locally-sourced seafood to nutritionally vulnerable people. Rather, a few organizations make this connection on a limited scale. We study these “positive deviants” to learn how their efforts developed, how they overcame challenges, and what conditions enabled their interventions. We found that organizations in these positive deviant cases provided fish from a wide variety of species and sources, and distributed them through different channels to a diversity of end consumers. A key factor facilitating success was the ability to negotiate a price point that was both profitable and reasonable for institutions supplying nutritionally vulnerable or low-income consumers. Furthermore, securing access to grants overcame initial costs of establishing new supply channels. All cases also noted the importance of individual champions who encouraged development, and cultural connections between the initiative and the nearby community. Organizations overcame key challenges by establishing regulations governing these new channels, and using partnerships or by vertical integration to reduce costs associated with processing and transport. Oftentimes educational programs were also critical to instruct workers on how to process fish and to increase consumer awareness of local fish and how to prepare

them. These lessons illuminate pathways to improve the contribution of local seafood to the healthy food system.

3.2 INTRODUCTION

In much of the world, overfishing and the consequent need to restrict fishing levels in order to sustain stocks, is a key issue affecting people's access to fish as a nutritious food. This is not the problem in the West Coast of the United States. Here, science-based and conservation-focused management has successfully restored key fish stocks. As of the mid 2010s, almost all U.S. West Coast commercially harvested fish populations are now abundant enough to be classified as rebuilt by fisheries managers (National Marine Fisheries Service, 2018). However, harvests for many species have remained far below what biologists advise can be harvested sustainably; in part due to low demand for some of the abundant fish populations landed in nearby harbors.

These abundant and low-cost fishery resources exist alongside human populations that could benefit from affordable, culturally-appropriate, and healthy food options. These include coastal tribes, diaspora populations traditionally reliant on seafood, and economically struggling towns engaged or formerly engaged in primary industries such as logging and industrial fishing. The food environment along the US West Coast reflects a familiar problem where an available source of healthy food – in this case underutilized local fish resources – is inaccessible to low income and food insecure people in rural communities experiencing higher rates of diet-based disease.

3.2.1 *Seafood Consumption in the U.S.*

Across the United States, seafood consumption is lower than recommended levels: between 80-90% of Americans who eat fish consume only one fifth to one half of the recommended weekly

intake (Jahns et al., 2014; USDHHS & USDA, 2015). Further, the amount of seafood an individual eats differs by age and social class: younger or lower-income populations eat comparatively less seafood relative to dietary guidelines (Jahns et al., 2014). This situation holds even along the West Coast, where fish stocks are abundant and well-managed and communities are located near fishing harbors, have cultural or demographic ties to fishing, and often fish as part of their food acquisition efforts. One study found daily fish consumption was slightly higher for the West Coast region – but not significantly so - when compared to nationwide consumption rates (U.S. Environmental Protection Agency, 2014). The same study also found that consumption was one and one-half to two times greater for respondents with incomes of \$75,000 or greater (U.S. Environmental Protection Agency, 2014) when compared to those with incomes less than \$45,000. This disparity is not a recent trend; a 1995 survey found low-income pregnant mothers ate about half the recommended intake of fish needed for Omega-3 polyunsaturated fatty acids (PUFAs) critical to maternal and early childhood development (Lewis et al., 1995).

For US West Coast households not actively engaged in subsistence food harvest, seafood is store-bought. There is limited publicly-available data on fish consumer taste preferences and price-related choices; what data there is points to consumers' lack of understanding about how to prepare and handle seafood (Jahns et al., 2014). A recent article reviewing reports from private consumer datasets on US seafood found that price remains an obstacle especially when the prices of other proteins fall, but there are few exceptions like high-volume species like Alaska pollock that are meeting these price points and sales have increased (Parr, 2018). Alaska pollock is harvested and processed at sea, far from West Coast communities and is oftentimes only available to these communities in a breaded, and less healthy, product.

Increasing the consumption of nutrient-rich fish can aid in addressing the micronutrient deficiencies still prevalent in the US. The Dietary Guidelines for Americans calls out potassium, dietary fiber, choline, magnesium, calcium, and Vitamins A, D, E, and C as under-consumed; of these, calcium, potassium, dietary fiber, and Vitamin D are considered “nutrients of public health concern” because low intakes are associated with poorer health outcomes. (USDHHS & USDA, 2015). Several micronutrients are present in high concentrations (e.g., Vitamin A and calcium, Vitamin B12, iron, zinc) and in more bioavailable forms in fish and shellfish than they are in many vegetables, fortified staples, and food supplements (Bogard, Thilsted, et al., 2015; Thilsted et al., 2016). Nutrition surveys have found that the US population generally has low concentrations of two PUFAs that are derived from marine-sourced foods – Docosahexaenoic and Eicosapentaenoic acid (DHA and EPA, respectively) – and rates of intake differ by race and ethnicity (CDC & National Center for Environmental Health, 2014). Thus, increasing consumption of local, sustainable fish in poorer communities on the West Coast - displacing less nutritionally rich foods - is one a pathway toward improving community level health outcomes. What potential do West Coast fish stocks offer as a sustainable sources of such food?

3.2.2 *Capture Fisheries on the U.S. West Coast*

The U.S. West Coast Groundfish fishery, for example, is a complex fishery that harvests over 100 species in a variety of habitats using multiple fishing gears. This fishery is guided by a science-based management plan overseen by the federal government and is increasingly considered a sustainability success story. However, it has not always been that way.

Landings of groundfish species on the U.S. West Coast increased through the 1970s, particularly by foreign vessels. At about the same time the UN Convention on the Law of the Sea established exclusive economic zones along the coastline and, by 1976, the U.S. had passed the

Fishery and Conservation Act which excluded foreign vessels from U.S. waters. Over the next decade, the domestic fleet saw high production, and new vessels were drawn to the fishery. As the scientific understanding of sustainable fisheries management developed. By the late 1990s, many of the species were in rapid decline, and overcapitalization and resulting labor losses prompted the U.S. Secretary of Commerce to declare the West Coast groundfish fishery an official national disaster in 2000. A series of relief funds then became available to assess damages and restore the fishery. Over the next decade science-based and conservation-focused management restricted fishing harvests while stocks were carefully observed and fish populations rebuilt. As of the mid 2010s, almost all commercially important fish populations in the groundfish fishery were once again abundant enough to be classified as rebuilt by fisheries managers.

Each year, the Pacific Fishery Management Council approves maximum total allowable catch (TAC) levels that ensure harvests are sustainable. However, harvest rates have remained far below these levels for most species; it is only high value species with greater demand in regional or international markets (e.g., Sablefish for export and Petrale sole for domestic urban markets) whose TACs are reached. For the majority of groundfish species that lack markets, a negative feedback loop constrains improvements in utilization. Continued low catch means inconsistent supply for processors. In the years following the collapse, processors and wholesalers were forced to switch to “less discriminating protein markets” to stay in business – presumably switching from the overfished species to more consistently affordable and available imported and farmed fish like tilapia and Alaskan pollock (Pacific States Marine Fisheries Commission & National Marine Fisheries Service, 2017). Thus, when low value west coast fish

is landed, processors must work to find buyers on a day-to-day basis, whereas more consistently supplied fish can be allocated into standing buyer orders.

The typical supply chain is as follows. Target species with strong markets are purchased by “first buyers” who are sometimes also processors turning it into useable product, such as fillets. Along with the target species, other underutilized species with weaker markets or species caught as unintended bycatch may also be bought from fishers, typically at much lower prices. Some fish are exported depending on the species, but those remaining in domestic markets are bought by wholesalers who are either themselves large- or small-scale distributors or sell to these distributors. The distributors then sell product to consumer facing institutions (e.g., hospitals) or retail (e.g., supermarkets). At each node in the supply chain, there is waste, which may include fish discarded by fishers because they do not have market value (this is often regulated), processing byproducts from the creation of fillets, or spoilage. There are a diversity of vertically integrated approaches that combine aspects of the supply chain. Much of the global volume of seafood passes through large businesses that own fishing vessels, processing plants, and transportation, and sell to larger-scale distributors. Not all vertically integrated firms are such high volume. Community supported fisheries models internalize the processing, transportation, and marketing costs by purchasing directly from fishers and selling to end-consumers. Even these community-supported fisheries may vary in whether they process or distribute the fish in-house based on their cost structures.

3.2.3 *Study Purpose and Approach*

With evidence of low consumption of fish along the US West Coast and increasingly abundant capture fisheries offshore, there are emerging opportunities to connect vulnerable communities with affordable seafood. The goal of this study was to understand these opportunities more

deeply through examination of current successful efforts. To do so, we employed a “positive deviance” approach to explore how several existing West Coast organizations make harvests of underutilized fish in the region available to populations of low-income or nutritionally vulnerable people. Positive deviance seeks to learn from the individuals or institutions who achieve success where the majority do not (Pascale & Sternin, 2005). In this case, the ‘failure’ is the inability of the seafood marketing system to supply cheap fish to the nutrition-poor communities of potential fish-eaters who live next to those abundant resources. The ‘positive deviants’ are those individuals, organizations or market schemes that do find a way to supply local low-cost seafood to lower-income or nutritionally-vulnerable consumers. This juxtaposition of rich fishery resources with undernourished people is a global problem (Hicks et al., 2019) so understanding how it might be overcome is of interest beyond the US West Coast.

Positive deviance analysis is similar to best practice case studies in that both seek to learn from success. However, positive deviance tends to focus on learning from communities that have found their own solutions rather than on transferring lessons from an external authority. The best practice case study approach often leads to the feeling that the circumstances that elicited a feeling that the successes of the best practice case studies were exceptional and quite different from their own whereas applying and transmitting knowledge learned using a positive deviance approach can help communities realize that they may already have the answers, they only need to see examples of strategies to achieve that solution (Pascale & Sternin, 2005). Identifying the practices used by successful actors in neighboring communities can help to change attitudes and facilitate such success within the local context (Pascale & Sternin, 2005). The approach has been used to assess food and nutrition security strategies, for example to determine that – despite data indicating a positive correlation between diet cost and nutritional quality - some low income

households were able to sustain healthier diets without accruing more cost when prioritizing items for their nutrient quality (Marty et al., 2015). On the other end of the spectrum from positive deviant analysis is gap analysis, which is useful in revealing shortcomings but the emphasis on failure can be seen as disempowering for practitioners and counterproductive to engaging with policymakers; in contrast, research focusing on success encourages optimism and more effective collaboration and creative solutions for “navigating the interface of science, policy and practice” to complex environmental challenges (Cvitanovic & Hobday, 2018). Positive deviance not only empowers communities to recognize the potential for change in their own community, it transforms the dialogue towards optimism, catalyzing collaboration and action. It also emphasizes the agency within communities, rather than the just the need for change in higher-level policies.

To achieve this study’s goals, we interviewed actors responsible for organizations, programs, and initiatives along the U.S. West Coast that are successfully connecting low income and nutritionally vulnerable populations with fish. We use this data to describe individual positive deviant case examples (i.e., “positive deviant cases”) as well as common themes running across them relating to how they operate within the dominant supply chain(s), how they create new supply chains, the enabling conditions for their success, and how they were able to overcome challenges associated with the distribution of landed fish. Interviews with program participants were used to assess enabling conditions for success and strategies to overcome challenges. We hypothesized that positive deviants might take two key pathways for achieving success and inquired about these in interviews: (1) by shortening the number of connections in the value chain for low value fish, so that fewer costly searches for trading partners need to be priced to final consumers to make distribution worthwhile; and, (2) by aggregating diffuse

supplies of fish and connecting the bundles with large-scale consumer markets with flexible demands.

3.3 METHODS

We used semi-structured interviews to collect qualitative data from ongoing initiatives that connect underutilized fish to nutritionally vulnerable populations on the U.S. West Coast.

3.3.1 *Sample and recruitment*

Based on initiatives known to the team, web searches, and snowball sampling from initial interviewees, we compiled a list of organizations engaged in West Coast activities to direct underutilized fish to food insecure and nutritionally vulnerable populations. This process resulted in the identification of one nationwide and three local or regional cases. We acquired and used the organizations' own websites, personal contacts, or information from other interviewees to identify contact information for one or more representatives to schedule interviews. For three the interviews, two interviewees were present and for two of the cases we interviewed more than one person per organization (Appendix Table 6). In total, we conducted six interviews with a total of nine interviewees across the four cases studied (Table 3-1).

3.3.2 *Semi-structured interviews*

Semi-structured interviews were conducted in-person or via phone. Interview questions related to how the organization's effort first began and which partners were involved, the fish supply (fishers and method, amount and type of species caught, marketability and cost); how fish is acquired, processed, and distributed; and descriptions of consumers and how/where they access the fish (e.g.,

demographics, preferences, food environment). The interview guide also included questions about challenges experienced, factors or conditions that enabled success, and perceived potential for expansion. The interviews were designed to investigate whether and how the cases succeeded or overcame relevant challenges and to illuminate potential opportunities for adapting, replicating, or scaling up any successes. They were also designed to assess our conceptual framework of supply chain pathways for West Coast groundfish (see Figure 1). Interviews lasted up to sixty minutes and were audio recorded with participant permission. The University of Washington Human Subjects Division determined the study to be exempt (IRB ID: STUDY00004939).

3.3.3 *Data analysis*

Interviews were transcribed and analyzed using Dedoose (version 8.1.8). One team member developed a preliminary code list based on the interview guide. Two team members then individually assigned codes to one transcript, compared their coding, and refined the coding guidance as necessary to ensure consistent coding applications across the full dataset. The two team members then both coded a second transcript using the updated code list and assessed coding agreement. As only minor adjustments to the code list and definitions were required at this stage, one team member coded the remaining four transcripts using the refined code list. Team members then reviewed and summarized the transcripts and coded excerpts to identify key elements of each effort (e.g., associated costs, facilitating factors), and to look for emerging themes across the cases. Finally, we applied the conceptual framework (see Figure 3-1 below) to each case to determine how they overlaid on the map and to visualize similarities and differences in how each of the positive deviants utilized the supply chain.

3.4 RESULTS

First, we present the key characteristics of each of the four cases studied. Then, we discuss how these four cases fit into our conceptual framework for a seafood value chain or how we adapted this model based on them. Finally, we present and describe emerging themes from the interviews.

3.4.1 *Key characteristics of case studies*

We describe key characteristics of West Coast cases in Table 3-1.

Table 3-1 - Key Characteristics of U.S. West Coast cases connecting underutilized fish to food insecure and nutritionally-vulnerable populations.

INITIATIVE OR LEAD AGENCY NAME	LOCATION	DESCRIPTION	FOOD ENVIRONMENT FOR END CONSUMERS
SEASHARE	Bainbridge, WA	Nationwide nonprofit organization with a 25 year history of directing donated fish from Alaska-based fish companies to food banks across the country via Feeding America, the nation's largest network of food banks.	Emergency food programs and distribution sites (e.g., food banks and on to food pantries)
CLATSOP COMMUNITY ACTION REGIONAL FOOD BANK	Warrenton, OR	Regional food bank in a single county that sources and processes fish on a donation basis for its partner food pantries in a variety of ways.	Local food pantries
BAY2TRAY	Moss Landing, CA	Program across multiple counties within a for-profit firm dedicated to sourcing and selling local fish to school districts for their meal programs.	School districts
SAN DIEGO FOOD SYSTEMS ALLIANCE & SEAFOOD WORKING GROUP	San Diego, CA	Collaborative that works to support the sustainability and economic strength of the local fishing industry in San Diego county	Restaurants, hospitals, schools

The positive deviant cases were nonprofit organizations except for Bay2Tray, which is program run by a for-profit fish distributor in California. The scale of sourcing and distribution for these initiatives range from one or a few adjacent counties to nationwide sourcing and distribution in the case of SeaShare's partnership with Feeding America. In these four cases, fish were sourced from a wide variety of sources, but have in common that the product tends to have lower or no value in standard supply channels. Commercially sourced low-value fish were used across all case studies, but food banks had slightly more regulatory latitude to distribute high value fish from sources that were prohibited to sell it (*i.e.*, fish sourced from illegal poaching). For food banks, commercially sourced fish were donated from various points in the supply chain. This might include individual boats, surplus inventory from large-scale processors, or from vertically integrated large fishing companies. In some cases, these species were profitable fish donated for philanthropic reasons. These donated fish were most often targeted high volume species like Alaska pollock or species with higher dock prices like salmon or halibut. In other cases, commercially sourced fish were species without strong markets and low dock prices that were processed and sold to institutional buyers at affordable prices - including underutilized species like Chilipepper rockfish and bycatch species like Opah or California grenadier. Bycaught species tend to be on-hand and caught alongside more desirable species, and oftentimes, like Opah, can have a low market value.

In delivering fish for schools or larger institutions some fish are caught on contract. As an example, Bay2Tray works with California fishermen to negotiate price and volume ahead of time to source fish for its school program. These more affordable species were most often sourced as a healthy protein in budget-limited institutions, such as hospitals and schools. Fishing companies

were notably willing to also distribute fish throughout their regional network to wherever there is opportunity to donate fish they cannot sell.

Fish hatcheries were another important supplier in Oregon. The goal of “enhancement aquaculture” facilities like hatcheries is to supplement natural stocks via controlled breeding operations. Hatchery-raised steelhead and salmon are released to the wild and years later then return to their natal stream—in front of the hatchery—where their eggs and milt are manually harvested; the remaining meat cannot be legally sold but can be donated to food banks. These species would have high value if they came from commercial sources, and are typically well-received by customers. Hatchery returns are variable, but, in some years, millions of fish return and food banks receive hundreds of thousands of kilos of fish (Miller, 2015).

Illegally harvested fish provided another source for the food bank case. Interviewees described “seized” species apprehended by law enforcement or wildlife officials having been caught in excess of legal limits or for fish for which catch of the species is illegal. Seized fish included a remarkable variety of species, from commercially harvested salmon to sturgeon. Enforcement officials contacted food banks as potential outlets for the unsellable, seized fish. Other sources of fish for food banks included importers with issues on orders, donations from tribal commercial fisheries in Washington, and sport fishing tournaments.

3.4.2 *Conceptual framework*

Using the existing value chain as a foundation, we visualized how and where interviewees’ efforts might fit within the supply chain. Responses of the case study interviews were used to ground truth and adjust our conceptual map of the various pathways via which fish is harvested and reaches consumers (Figure 3-1).

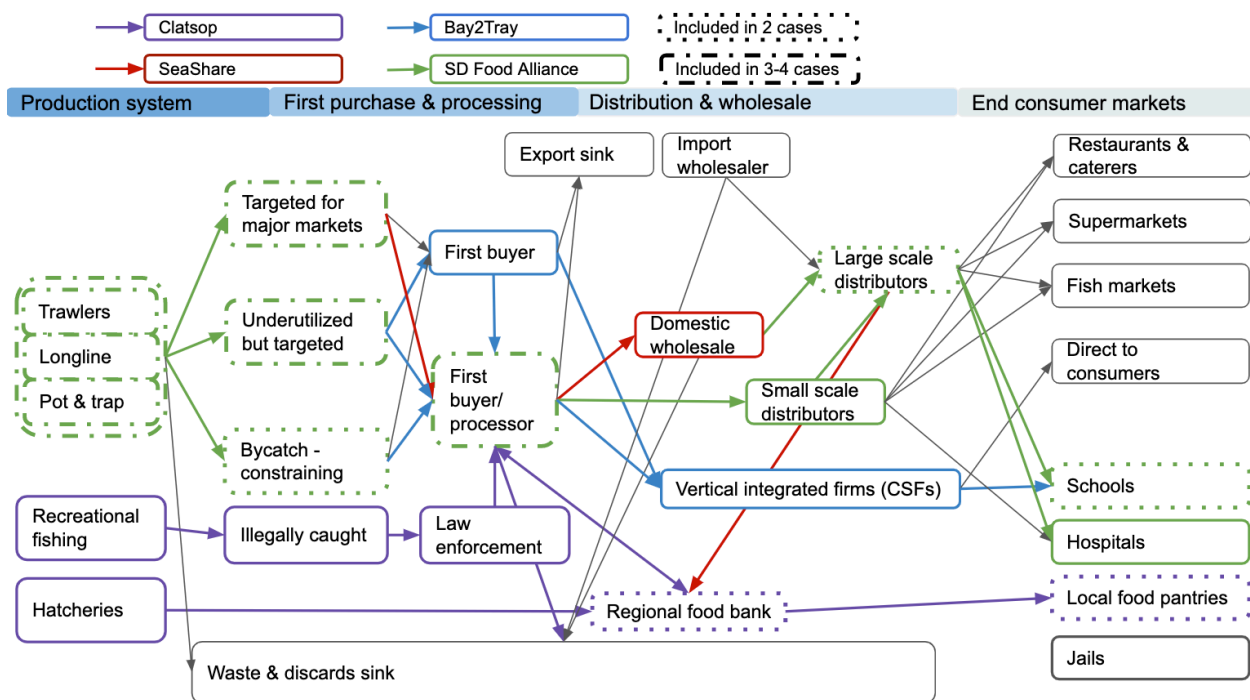


Figure 3-1 – Conceptual map of entry points of seafood to vulnerable populations used by the positive deviant cases.

The four positive deviant cases innovated within the typical supply chain in different ways. In all of these cases, positive deviants shortened the supply chain by bundling different aspects of the supply chain or strengthening the relationships with local seafood producers.

- SeaShare runs the logistics to connect some of the largest seafood companies – mostly operating in the Northeast Pacific Ocean but also on the East Coast – to Feeding America, a nationwide network of food banks. They work directly with the large companies who own the vessels catching the fish, and who also process, transport and store the fish for pickup. SeaShare’s role is to organize the supply chain to facilitate these donations.
- Clatsop Regional Action Food Bank aggregates fish from a variety of sources, arranges for custom processing, and distributes it to food bank locations. While the food bank originally processed its fish on location, the volume of fish outstripped their capacity to process it and they outsourced custom processing to a nearby plant of Pacific Seafoods – a large seafood

company with a facility in a neighboring harbor who donates its labor. Once processed, the food bank picks up the fish and integrates it into its existing delivery to local food pantries.

- Bay2Tray’s program operates within the community-supported fishery. Bay2Tray uses the firm’s vertically-integrated approach to source fish from fishers throughout Northern California for direct-delivery to schools who purchase the entire commercial order. Once the fish is purchased, it is processed, portioned into school servings, packed for delivery, and transported to schools where the schools take over and kitchens prepare the fish for service in the cafeteria.
- San Diego Food Alliance did not create novel market channel, but rather connected hospitals and schools to the local fishing industry, ensuring the commercial food distributors normally bridging the two of a market for the entire commercial catch. The distributors now source the fish from local harbors instead of imported or nonlocal commodity species for which there are more developed markets. The Alliance also worked with fishers to advocate for regulations allowed for permitting of a dockside fish market

Emerging themes particularly important to developing low-cost distribution links for local seafood coalesced into two categories: enabling conditions and facilitating factors, as well as strategies to overcome challenges.

3.4.3 *Enabling conditions and facilitating factors*

Low access populations needing low price points are low access because they cannot afford the market-making services of the standard fish value chain. Thus, making connections that established markets for large volumes of fish was critical to creating an alternative fish supply chain where participants could reach these populations. These connections often depended on, or were deepened by, shared values, mutual benefit, or simply being willing to ask. For example, in

connecting local fish to schools, mutually workable products, price points, and timing were essential for developing the relationships between fishers, Bay2Tray, and schools; in the standard supply, there is no forum for a conversation about necessary price points between harvesters and schools, as distributors simply tell schools they cannot meet their price point, and harvesters they cannot buy the fish.

“[The partnership between Bay2Tray and schools] was a sourcing partnership but also like a value partnership, which was really important to us, too, just to kind of ... because it’s hard work changing the deeply entrenched school food system, so finding a partner who was ... who shared values was really important because it let us ... that allows you to be able to like when things get hard or when there’s challenges, you both are kind of in it to figure out solutions. So that was a really important part of it was having that like similar dedication to making this happen.”

This partnership depended on finding the right balance of affordability for schools and profits for fish businesses. In San Diego, the SD Food Systems Alliance saw value in creating local supply chain connections and thus facilitated relationships between regional and local hospitals and schools to more easily purchase local fish. In doing so, they helped fishers gain access to a larger, urban markets.

“[A fisheries representative and a chef at hospitals] really connected through [the Alliance] and maintaining connections, doing things together, promoting local fishing. For him it’s about the fishermen, for me it’s about health, but that was the genesis of my work and it’s impacted a lot of other institutions here as well”

In this case, large institutional buyers (i.e., hospitals, schools) were able to rely on contractual arrangements with broadline distributors who, once notified of the interest in local seafood, were able to source from nearby fishers and smaller distributors with whom they held existing relationships. These relationships also allowed fishers to work with processors to develop and sell incidentally caught Opah in a form which is processed locally into products that are affordable and useful for school meals (e.g., ground Opah chili). Intentional connection-

making was equally necessary for regional food bank initiatives. For Clatsop Oregon's regional food bank, relationships and communication between the hatchery, law enforcement, the local processing plant, and the regional food bank allowed them to establish a process for when fish became available, and ensured timely delivery of fresh product. Finally, for SeaShare's national effort, they provide a central point of entry to food banks for companies with fish donations, and food banks with the capacity to handle the product; intentional relationship-making between willing fishing businesses and regional food banks is core to their mission.

Of the four cases, two aimed to develop a program or arrangement that would eventually prove profitable for the fishing stakeholders and the two others relied on distributing and securing donated fish. Regardless of the intent, search costs were still incurred in finding partners to make the alternative market; these are the costs the standard markets were unable to cover. A reliance on grants, at least initially, to establish new supply channels was a common trait. Some used federal grants to broadly support program actions or to hire program coordinators. For public-private partnerships between public entities and private enterprise (fishing business) it was stressed that scaling is necessary for the program to become profitable, and up until that critical point it is also necessary to find funding from foundations or government. For food bank examples, fishing industry donations or significant discounts were critical to continued operations. Fishing companies and processors had the opportunity to seek tax deductions to offset the costs their donations to food banks. While some large scale fishing companies were taking advantage of these incentives in donations to SeaShare, processors in Oregon found that their contributions to the regional food bank were low enough that they did not see the need to seek donation-based tax deduction. During the three to four month period that one large processor prepares fish for food banks, the daily volume of fish processed for donations never

exceeded 2,000 to 3,000 pounds, whereas their total daily volume can be 300,000 to 400,000 pounds.

“The reason we did it was just that whatever we can do to help a community and put [our company] in a positive light in our community is what we always strive to do. But other than that, it was just very little hassle for us. It’s just a small thing we could do to help our community. And that was the whole purpose of it. It’s like, is it an inconvenience for us? No, it isn’t at all.”

When asked, this interviewee speculated that they could increase donation-based processing by two to three fold before they would consider seeking tax reductions just based on the additional amount of labor.

In each of the four cases there were specific people, or champions, who personally incurred the cost of identifying and recruiting direct partners and circumventing the established supply channel. For example, these champions recruited people within the fishing industry who were willing to donate processing, storage, and freight (e.g., SeaShare board members, Pacific Seafoods processing company). For schools and hospitals, champions included those in leadership roles (e.g., nutrition directors, superintendents) who decided to innovate with programs like Bay2Tray or kitchen workers, who were willing to learn to cook with fish and from scratch. It was not only adults; in leadership councils high school students were advocates for Bay2Tray, and championed an improved connection between the environment and the food served in their cafeterias. Local media outlets also helped publicize and garner support for programs. Especially with Bay2Tray, news articles helped to familiarize the local public with local seafood and with the efforts of the program. Along with the programs’ internal media campaigns, this outreach expanded the message to other school districts and opened them up to new supply chains.

Cultural connections to seafood facilitated establishing connections. For geographies with fishing heritage, people tend to be more comfortable with fish processing and preparation. In the community where Bay2Tray operated, for example, many of the school kitchen workers either had relatives or friends who had worked or were currently working in the fisheries sector. Community fishing culture may facilitate the process of finding fishers or processors who are willing to innovate (e.g. keeping bycatch for use in schools). For communities in close proximity to harbors, processors are more available, transportation is less expensive, and the general population likely has more exposure to seafood and how it is processed. Ethnicity was also an important driver in regions with populations that connect seafood to their cultural heritage (e.g., Filipinos, Japanese, Chinese). Cultural connections to local seafood was a strong enabling theme in the positive deviant cases; sourcing local fish was not only seen as cost-effective, sustainable and healthier, it was also a way to revitalize the local food economy and support community members engaged in the fishing industry.

3.4.4 *Challenges and how to overcome them*

A significant challenge described by interviewees related to managing costs and volumes to ensure pricing made the relationship worthwhile to participating parties regardless of whether entities were for-profit or nonprofit. The price needs to be low enough for institutions serving end-consumers, but cover costs or be profitable for those processing and catching the fish. Processing was a major contributor to cost, which is mitigated for fish that are easier to process, more valuable even in these alternative channels, or that yield more salable product per whole fish.

Even when food banks receive fish for free, they may still have to pay for procurement, collection, distribution, [internal] fish processing, and labor. Several programs relied on

volunteer or donated labor to save the costs of paying another firm to process or distribute the fish. Early in its development, Clatsop food bank relied on in-house labor from workers who had grown up around fishing, but as they grew they sought to partner with a nearby processing facility.

“The key is food banks not being processors; it’s them being delivery people. Delivery and distribution people. That’s what we can do well. And that’s the key to this.

In realizing their niche and the limits to how much of the seafood supply chain it could internalize, Clatsop identified how to scale by partnering with key participants in the conventional supply chain. Each node of the supply chain has its costs, and future initiatives need to consider whether they must internalize these costs or work with suitable partners to forward their mission. Similarly, as the fish moves throughout the supply chain, it accrues additional transportation costs. While the shortened supply chain minimizes this, some costs are unavoidable, and need to be absorbed by participants or recovered from end users. In some cases, transportation costs to the processor and food service/retail settings are covered by partners (e.g., SeaShare relies on regional food banks’ transportation network or on partner fishing companies); in other cases, the institution pays for transport associated costs, such as the truck and the driver’s time. Transport becomes a major challenge in rural regions or areas further from the coast.

“[Schools] needed distribution, they needed it dropped at each school site, which to like a small guy would kill you. But if you’re SYSCO, it was like their mainstream distributor, it’s no big deal. But so that made them ... that was another hurdle that kept them from wanting to really go full-on with the program.”

“[The positive deviant case doesn’t] distribute through SYSCO. The question is, how many school districts out there want to do our fish if they could access it through their mainstream distributor?”

In this case, mainstream distributors may be called upon to increase the potential reach of local seafood, especially to areas where there are few alternatives. Our interviews indicated that some of these distributors are receptive. In San Diego, purchasing institutions successfully applied pressure on their mainstream distributors to source local seafood options instead of imported product. Seafood is also highly perishable, forcing additional costs due to the requirement of refrigeration throughout transportation as well as during storage.

Another challenge is the affordability of fish from the perspectives of institutions purchasing or acquiring it for end consumers. Food service providers and food banks talked about seafood as a protein source/component and occasionally referenced a single “protein budget,” a price per serving of protein which was acceptable within their contexts. Chicken is typically the benchmark that the price of other proteins are considered against; any seafood purchased oftentimes needs to be priced competitively. Prices for local seafood also have to compete with imported fish, a challenge when imported products are processed abroad but local products must pay local labor rates. Some underutilized species can be more affordable than imported fish or chicken. For example, one bycaught species landed in San Diego is “comparable to what they would do if they were putting the usual chicken nuggets and pizza and the other USDA-kind of supplied process foods.” Particularly for institutions with budgets per protein serving, like hospitals or schools, a creative shift of ingredients can enable a lower priced product: a pound of protein need not all be fish; it can be fish and beans.

For end consumers unfamiliar with handling uncommon species, or fish in general, education surrounding “what to do” with fish can create a challenge throughout the value chain from processing to transportation to preparation. Learning how to prepare fish may require

training, particularly in schools where scratch-based cooking is not often used. End consumers also need more education on the benefits of eating fish and how to prepare it.

“We’re trying to give them what they would find on a grocery shelf or in a restaurant. Hoping that they’ll get used to eating more seafood and they’ll improve their diet and their nutrition by buying more seafood when they get back on their feet.”

Education was also required to encourage supply of local alternatives in order to become more comfortable with alternatives to the “big three” most consumed species: shrimp, salmon and tuna. For each of these four cases, interviewees at least mentioned education as a complementary activity to their primary focus on making fish available. In San Diego, schoolchildren worked with a local celebrity chef to develop recipes using local seafood. Some of these recipes are now on school programs. The Alliance also included a story project called FishTales that explains things about the fish and fishermen to generate interest in what’s being served. Bay2Tray mentioned the value in schools offering students taste tests of new fish menu items.

Permitting and regulations can also present challenges, which were overcome in a variety of ways. In addition to finding direct partners, in some cases modifying the supply chain required policy change. In order for bycatch to be used by regional food banks, SeaShare worked with legislators and stakeholders in the pollock fishery to allow them to collect prohibited species catch—which can be caught at low levels, but not sold—of salmon and halibut. Clatsop’s regional food bank gained access to hatchery products or illegally harvested fish after the Oregon state legislature unanimously passed House Bill 4068 in 2012. They testified in front of Oregon legislature to advocate for its passage. This bill also enabled seized fish, as well as fish returning to hatcheries, for donation to regional food banks. In addition to developing an institutional market, the SD Food System Alliance worked with fishers to advocate for regulations allowed for

permitting of a dockside fish market. Many fishers are used to engaging in fishery policy processes, but food policy is a different domain, often with different politicians and less developed relationships with these politicians. But in this case the alliance influenced policy on their behalf. These food system advocacy groups can be useful for enabling policy change.

3.5 DISCUSSION

This study utilized a positive deviance approach to learn from programs successfully linking nutritious fish with low-income or nutritionally sensitive populations. First, we established where these programs innovate in the supply chain and how they source their fish. Then, we explored what facilitating factors and enabling conditions were important to their initiatives. These included strong relationships throughout the [shortened] supply chain, champions who supported the initiative, connections to fishing industry heritage or seafood-consumption, and financial support of partners or grantmaking institutions. These programs were also faced with, and overcame, a number challenges related to the costs accrued through the value chain, a lack of public awareness of local seafood options and methods of preparation, and policy conditions restricting potential availability. The next three sections build upon the results of this study and suggest future actions needed to increase the contribution of local seafood to nutrition-vulnerable populations.

3.5.1 *Selecting fish that make sense for consumers and suppliers*

Critical to understanding the fish sourcing and distribution process is that each transaction is costly to establish: it requires the upstream supplier to engage in a search to find a downstream buyer for a product they hold. For products with reliable downstream demand, these links can be stable—thorough standing orders - and maintained at a low cost. One species with reliable downstream demand is Alaskan pollock, which is supplied in high volume to SeaShare to be distributed out to

food banks. But, for products with occasional or highly variable supply, a costly search is needed with each landing, or when more than previously contracted is landed; this is a major obstacle for programs attempting to source underutilized species that tend to have variable supply and little demand. To do so, programs must short-wire a negative feedback loop common to fisheries anywhere where fisheries have rebuilt but catches remain low: it is difficult to source these underutilized species because fishers do not find them profitable to weak markets which in turn signals fishers to continue to avoid catching them. Without consistent fishing effort directed towards underutilized species, their low and variable availability is difficult to market, especially towards large-volume purchasing institutions who need a consistent supply of fish that is familiar enough to be useful to their staff.

For-profit programs that seek to connect fish with low-income or low-access populations will need to focus on fish that has low value in the standard supply chain. It is unlikely that species with existing stable, high-value markets (e.g., salmon or halibut) are viable selections for budget-based institutional buying programs. However, on the U.S. West Coast, these programs do have a considerable opportunity to source from a wide variety of underutilized or bycaught species that are affordable and could be available in nearby harbors. Large volume purchasing institutions like hospitals and schools can make large orders that make handling these species, which may flood standard daily retail markets, worthwhile for harvesters and processors. But, they too require subsidization and encouragement. The positive deviants interviewed in this study employed a number of strategies to circumvent this feedback and encourage supply that fits end-consumer preferences.

Improving the understanding of consumer preferences within low seafood access communities will aid in the identification of preferred, but still underutilized species and in their

integration into the healthy food system as an affordable food. This work could be facilitated by partnering with private-sector organizations such as seafood marketing associations currently trying to improve consumption of regional species. At present, consumer surveys on current and potential seafood preferences are either sparse or rarely conducted. More information is needed about the preferences of nutritionally vulnerable or low-income communities and high-volume institutions value chain demands. Nonprofit programs working with regional food banks and local food pantries indicated remarkable flexibility to utilize a broad diversity of species that were either donated by fishing companies and hatcheries or seized by law enforcement. This indicates that local pantries were willing participants to try species outside of the “big three” tuna, salmon and shrimp, suggesting that further sourcing of less typical donated or seized fish would be possible. Since consumers are unfamiliar with these species, effort is needed to generate interest in and empower end users to use them.

Education was an important component of the strategies used by both Bay2Tray and San Diego Food Systems Alliance, in order to improve understanding of how to cook the fish in institutional settings or at home. Both of these cases also described innovative recipes make unknown fish more approachable, like chili made from Opah. Respondents showed that kitchen preparation and familiarity were important enabling conditions for institutions, and we expect that previously unsourced species that are similar in preparation, taste, and appearance to already-consumed products are likely to be more readily adopted in these environments. Media outreach can also play a role to develop potential new customer bases. Messaging is important, and may require alternative strategies to the conservation or economic justifications most commonly used when advocating for seafood. A recent study of North American consumers by the Marine Stewardship Council found that consumers make seafood selections based primarily on food

safety, freshness, and health benefits rather than the sustainability of the resource or origin frequently found in marketing approaches of local seafood firms and nonprofit advocates (Marine Stewardship Council & Globescan, 2018).

Sustainability concerns could arise as the volume of fish increase to meet demand from large institutions serving low income or nutritionally vulnerable communities. Fortunately, for species caught within the US West Coast Groundfish Fishery Management Plan, there is a management safeguard for effort expansion. Many species have established Total Allowable Catches (TACs) that will be enforced when they become binding, just as with the current major market species now. For species which are not currently exploited at a level to warrant assessment, once it becomes consistently exploited there is potential for decline and the species comes under additional monitoring to determine the sustainability of the stock using the same set of rules that were able to successfully rebuild most of previously overexploited stocks (Pacific States Marine Fisheries Commission, 2016).

Growth in the aquaculture industry presents another considerable opportunity and potential win-win between meeting conservation and recreational objectives as well as contributing to the healthy food system for low-income or nutritionally-sensitive populations. The Clatsop Food Bank involved hatchery-raised salmon and steelhead trout returning from the ocean to hatcheries, seafood products rich in Omega-3 that consumers prefer. Unlike hatchery goals focused on stocking wild populations, aquaculture presents an opportunity as it has the explicit goal of providing for the food environment. The growth of the broader aquaculture sector is both well documented and staggering, and its potential to continue growing is massive: 15 billion tons of additional fish could be produced, “over 100 times the current global seafood consumption” (Gentry et al., 2017). Aquaculture is oftentimes overlooked as a viable alternative to land-based

agriculture. The policy environment in the US, for example, has yet to embrace aquaculture; federal spending from 1990 to 2015 was just over \$1 billion USD while agriculture spending was \$41 billion USD (D. C. Love, Gorski, & Fry, 2017). While food policy originates within the USDA, fisheries and aquaculture policies are primarily the purview of NOAA and as such their goals regarding nutrition are oftentimes misaligned (D. Love et al., 2017); this disconnect creates an obstacle to how readily domestically produced seafood can contribute to the food system. With U.S. agricultural policy programs like Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and National School Lunch programs, an argument should be made to place fish production on equal footing with other healthy foods.

3.5.2 *Finding financial resources critical for program development*

Establishing alternative supply chains still requires resources to identify who can play critical roles in processing and distribution. Reliance on grantmaking was mentioned as critical to all case studies: grants were essential to overcoming initial costs to establish an alternative supply chain, and sometimes in covering continuing costs necessary to operate. Especially for private or public-private partnerships, succeeding in finding a long-term, financially viable model is of critical importance. In these cases, scale was consistently mentioned as critical. Oftentimes scaling requires additional infrastructure which can be costly. While additional grantmaking could be undertaken, there are growing opportunities for for-profit firms to seek private investment. Once there was limited investment potential for firms focused on nonmonetary or philanthropic objectives, but that has changed with the increases in social impact investment strategies that explicitly seek out firms that at scale can provide positive environmental or social outcomes (Pons, Long, & Pomares, 2011). In the US, there are a variety of additional public funding mechanisms that help support connecting healthy foods to food insecure populations, often with parallel goals

of supporting farmers or economic development. These include farm-to-school programs and the U.S. Department of Agriculture Gus Schumacher Nutrition Incentive program that matches Supplemental Nutrition Assistance Program (SNAP) spending on fruit and vegetable purchases by low-income consumers, both operated by the USDA Food and Nutrition Service (United States Department of Agriculture, 2019b, 2019a). This also includes public-private ventures designed to bring grocery stores to communities such as the Healthy Food Financing Initiative, which funds food retail projects to expand access to healthy foods in underserved areas and create quality employment. Such mechanisms for using public funds, infrastructure, and procurement mechanisms can be leveraged to connect low income populations to with healthy foods such as seafood.

Philanthropic actions of the fishing industry buoyed the ability for regional food banks to source fish caught along the Pacific. These responses suggest that there need not be tradeoffs for fishing companies between philanthropy and profitability. Some fishing companies reported passing on tax deductions for their contributions, motivated by the community impacts of their donated seafood seen in their community. In US legal contexts, when an institution's volume, and associated labor cost, is high, tax deductions can create incentives for continued growth. SeaShare, which works with some of the largest American seafood companies, includes information on its website for how these companies can seek deductions under the "Good Samaritan Act," which currently allows tax write-offs up to twice the cost of the donated product. Growing awareness of the incentives for philanthropy may encourage other large agents in the fishing industry to consider donating. Results of the interviews indicate that even a relatively small volume of fisheries production could represent a large increase in the supply of fish to food assistance programs in similar legal contexts and donation-based food pathways.

3.5.3 *Supporting champions throughout the system*

Champions were present in every positive deviant case, and could arise at any level of influence in the supply chain. Some champions held positions of power in school districts or within the fishing industry; their decisions to modify their institutions actions to increase availability of fish had considerable top-down effect. However, champions were not always actors with the highest amount of influence in the food system but were nevertheless were critical to success; for example, the willingness of a group of kitchen workers to learn new cooking methods meant they had to spend additional time learning new preparation techniques or of student leadership groups to encourage consumption among their peers. There is also a growing recognition in gender research of the particular role that female fishers play to improve nutrition, especially for the household (Harper, Zeller, Hauzer, Pauly, & Sumaila, 2012). In our results, positive deviant interviewees noted that among champions in school kitchens, women were vocal in their support of increasing fish consumption in schools and willing to take the extra time in kitchen preparation. Future interventions should consider that successful interventions in the food system require buy-in from actors throughout the supply chain, regardless of their level of influence.

3.5.4 *Limitations and looking to other geographies*

There are a few limitations to this study. First, our study aimed to conduct a relatively deep, qualitative analysis of a small number of successful cases rather than a comprehensive survey of all programs and organizations involved in the kind of efforts described. Additional programs and organizations doing this work likely exist and would have augmented our findings in important ways. Additionally, we only interviewed 1-2 individuals involved with each case; perspectives of other stakeholders involved in these cases are not reflected. In particular, these results reflect little fisher, processor, and distributor perspectives. Bay2Tray and Pacific Seafoods – who processes

fish for Clatsop Community Action Regional Food Bank - were the only interviewees directly engaged in the fishing industry. These interviews were important in discussing fisher decision-making and thoughts on the viability of their contribution to the programs. Importantly, it must be stated that the information learned from these positive deviant cases may not be directly replicable across other social, environmental or governance contexts.

The focus of this study was on positive deviant cases specifically on the US West Coast, but there are numerous other innovative programs. A Philadelphia-based *Fishadelphia* is a community-supported fishery that connects lower income households with coastal harvesters enabled a grant from the USDA Farmers' Market and Local Food Promotion Program. They provide discounts for households eligible for SNAP or Medicaid and work with local high schools to provide training in entrepreneurship and business management (J. Hall, 2018). There are also multiple fish-to school programs partner with commercial fishermen to provide locally caught fish to multiple Alaskan schools, even including a “good-natured” contest between fishermen to see who is able to donate the most fish, with poundage announced over VHF radio. Some of these school districts also include curricula to educate students on the role of their locally produced seafood has the surrounding ecosystem (Justa, 2018). In these US cases from other regions, and likely many more cases around the world, there are many more opportunities to learn about how these programs leverage enabling conditions and strategies to overcome challenges and improve the connection between sustainably produced local seafood and the healthy food system.

3.6 CONCLUSION

Taken together, our positive deviant cases provide insight into how underutilized seafood can be directed to low income and nutritionally vulnerable populations. First, since these populations are generally not going to compete within the current supply chain, a supply of fish not valued by that

system must be identified. We saw a considerable range, from species with low market value which are not caught because they are not valued in commercial distribution channels, to high-value species that cannot be sold because they are prohibited bycatch, seized fish, or hatchery products. Second, an alternative, low-cost supply chain must be constructed. Our case studies cut out the network of fish distributors and traders who disaggregate bundles to the sizes demanded by particular downstream buyers: the new value chain is shorter, and deals with large quantity so less effort is required to distribute it. In these deals, initial fish buyers connect with food banks or institutional food preparers, often mediated by their contracted provisioning companies. Costly processing can sometimes be donated by willing processors, especially at small scale, or done within an organization with volunteer labor. Constructing this supply channel is itself expensive and time consuming. Here, the energy of a champion from some place in the industry is key to identifying and developing relationships with others and ensuring work gets done, and grants cover direct costs.

Future interventions that improve the connection between local seafood and the healthy food system can look to enabling conditions, facilitating factors and strategies used to overcome challenges reported here by the positive deviant cases. To inform these interventions, future research is necessary. Further research directed towards the fishers, hatchery managers and broadline distributors that weren't possible to include in this research would reveal much about their logistics, enabling conditions and challenges. Interviewing *potential* end consumers not currently engaged in positive deviance cases would also be critical to the development of pilot programs. With an improved understanding of the challenges and conditions enabling successful distribution of fish from local markets *throughout* the value chain, work can begin to implement pilot programs along varied coastlines to evaluate the feasibility of similar programs in regions

where such positive deviants do not exist. Promising areas can then scale their impact to improve the flow of local seafood to nutritionally vulnerable people in schools, food banks, hospitals, jails, and even directly to along the coast.

3.7 SUPPLEMENTAL TABLES AND FIGURES

3.7.1 *Description of the positive deviance interviewees*

Appendix Table 6 - Descriptive results of positive deviance interviewees

	Case Study (n)
Total interviews	6
Total respondents	9
Respondent demographics	
Sex	
Male	5
Female	4
Institution (e.g., employer)	
Non-profit food rescue/emergency food	5
Schools	1
Hospital	1
Public agency (e.g., health, planning)	0
Fish-related business/entrepreneur	2
Community food coalition	1

Chapter 4. CONNECTING FISHERY AND HEALTH POLICIES FOR DIET-SPECIFIC SOLUTIONS FOR VULNERABLE POPULATIONS

4.1 ABSTRACT

After decades of careful conservation-based management, many US West Coast fish stocks have rebuilt from overfishing. To date little work has been completed on how local fisheries production – where many affordable species are now being caught at levels far below maximum sustainable yield – may contribute to healthful diets in the region. The research discussed here identifies the scope and strategy for scaling the isolated success stories we have located as well as challenges to that scaling. Due the low current demand for fish, we synthesized secondary data across multiple sectors to create a situational baseline that found current catch is far below the total allowable catch set by managers, foregoing millions of servings of fish that could be sustainably harvested and contribute to food need in adjacent communities. Despite broad lack of connection between local seafood and the healthy food system, we interviewed positive deviants finding to learn their enabling conditions and how they overcame challenges to intervene in the system. Then we used the situational baseline to interview representatives throughout the food system – from fisheries industry representatives to public health officials to school nutritionists – to learn more about the current state of connection between seafood and the food system and how they envision programs such as the positive deviants could improve this connection in their communities. This research revealed the importance of taking a mixed methodological approach that uses both existing quantitative data to analyze the situation broadly as well as qualitative information to learn from existing practitioners and evaluate the feasibility of similar practices being implemented in other regions identified by the baseline as having the potential for improved connection between local fisheries production and the food system.

4.2 INTRODUCTION

Global recognition of the nutritional importance of fish and shellfish production to vulnerable populations (Golden et al., 2016; HLPE, 2014). A rising number of policy-related research strive to link fisheries to public health, from national to local levels (Koehn et al., 2017; Thilsted et al., 2016). Health policies recognize fish and shellfish as nutrient-dense alternatives to comparatively nutrient-poor energy-dense foods, but do not proffer a mechanism to supply fish to vulnerable populations. While seafood is unlikely to displace meat and poultry as a primary source of protein and other micronutrients associated with animal-source foods, its high diversity of vitamins and minerals, including bioavailable iron, Vitamin B12, and Vitamin D, make it a nutritionally valuable addition to diets. Between 80-90% of Americans who eat fish are eating only half to one fifth of the recommended weekly intake for their age and sex (Jahns et al., 2014; USDHHS & USDA, 2015). Seafood consumption is demographically and socioeconomically stratified: younger or lower-income populations eat comparatively less seafood relative to dietary guidelines (Jahns et al., 2014). Furthermore, A recent report by the United States Department of Agriculture found that food insecure households in the US acquire less seafood and plant proteins compared to food secure households (Gregory et al., 2019). This disparity is not a recent trend; a 1995 survey found that low-income pregnant mothers consumed about half the recommended intakes needed for Omega-3 polyunsaturated fatty acids that are critical to maternal and early childhood (Lewis et al., 1995).

Considerable differences in access, availability and affordability have called to question the social and economic equity of the seafood value chain (Kittinger et al., 2017). One major determinant is that seafood is often more expensive than other protein sources, due in part to an

export-focused supply chain for high quality seafood. For lower income households, this can mean a shift away from the seafood that was traditionally part of their diets towards cheaper, energy-dense and nutrient-poor alternatives, regardless of the presence of nutrition assistance programs (Jahns et al., 2014; Leung et al., 2012). In addition to the higher price of seafood, low consumption of seafood is due in part to a lack of integration between health and fishery policies.

A recent review found that health policies do not “consider sustainability or source of fish, their connections with US fisheries systems, and global distribution of seafood” (D. Love et al., 2017). Disconnect also occurs in fishery system, where predominant policy and legislation that guides fisheries management is primarily focused on biological and economic sustainability of target fish “stocks” and the contributions of fisheries to communities are considered in terms of income and employment: not vitamins and minerals. Reflecting the lack of policy coherence, there have been few US-based studies on the contribution of fish to the food system, and they are focused on artisanal, or small-scale, fisheries systems. In Hawaii, fish caught by artisanal fishers were tracked through multiple channels –through gift-giving as well as via sale – to determine the contribution of fish to households across one island in the archipelago (Kittinger et al., 2015). In the North Pacific region, the majority of studies on the role of seafood to meeting food security and nutrition goals have taken place in Alaska where communities are both rural and proximate to abundant fishery resources. In Alaskan communities with active subsistence food practices, seafood improves food security of households across income levels either by direct harvest of fish resources or by sharing, but that there is still uneven access across communities (Loring, Gerlach, & Harrison, 2013). Understanding how larger commercial fisheries contribute to food systems in communities adjacent to fishing harbors in the United States, especially from inshore processing to end consumers, is largely unknown.

While 33% of the world's fisheries remain overfished (FAO, 2018); advances in science-based management show that rebuilding stocks is not only possible, but could increase global catch by 16 million metric tons while also increasing marine ecosystem biomass by 619 million metric tons (Costello et al., 2016). The US West Coast is an example of a once overfished region whose fisheries have seen rebuilding success. In 1976, the United States passed the Fishery and Conservation Act, excluding foreign vessels and leading to rapid growth of domestic fishing industry. As the scientific understanding of sustainable fisheries management developed, it was clear many of the species were being overfished. By the late 1990s, many of the species were in rapid decline, and overcapitalization and resulting labor losses prompted the West Coast groundfish fishery to be declared an official national disaster by the US Secretary of Commerce in 2000. Over the next decade science-based and conservation-focused management restricted fishing harvests while stocks were carefully observed and fish populations began to rebuild. As of the mid 2010s, almost all commercially important fish populations are now abundant enough to be classified as rebuilt by fisheries managers. Now many of its rebuilt stocks are fished at levels far below their maximum sustainable yield and, while biological objectives are being met, over 50% of the quota for some species are left in the water foregoing social and economic benefits (Pacific States Marine Fisheries Commission & National Marine Fisheries Service, 2017). In the five year review of the West Coast Groundfish Fishery Management Plan, a negative cycle is described that explains the continued low harvests despite rebuilding successes: Inconsistent supply to processors due to low utilization, that makes it hard to develop new markets and low prices which in turn don't incentivize fishers to harvest more fish which feeds back into continued inconsistent supply (Pacific States Marine Fisheries Commission & National Marine Fisheries Service, 2017).

There is lost potential for these fish to contribute to improved nutritional status for low income low access communities adjacent to productive fishing grounds. This is a stark contrast to the fishery's most recent management plan, which calls for improved utilization to "promote year-round availability of quality seafood to the consumer" (Pacific States Marine Fisheries Commission, 2016). One sensible justification for this omission is lack of system-wide research that connects fisheries to the food system, including in developed economies such as the US (D. Love et al., 2017).

This research intends to inform ongoing government processes to improve the connection between fisheries and the food system forward by synthesizing existing quantitative data with qualitative surveys to examine the scope and mechanisms for improved utilization of available fish sources to improve diets and reduce incidence of non-communicable disease burdens in poor and marginalized coastal and nearby urban communities. It had the following specific objectives:

- 1) Identify nutritionally-vulnerable US West coast communities who may benefit from improved fish access;
- 2) Quantify the extent of underutilized species in US West Coast fisheries;
- 3) Identify mechanisms that may block the utilization of such fish by low-income groups, such as fishery management regulations, market structures, and fish handling, processing and storage practices;
- 4) Identify examples where obstacles to access have been overcome and evaluate if such cases can be scaled.

To meet these objectives existing secondary data on nutritionally-vulnerable US West coast communities who may benefit from improved fish access was synthesized and the extent of underutilized species in US West Coast fisheries was quantified in terms of serving size. It also uses in-person surveys to identify mechanisms that may block the utilization of such fish by low-

income groups and learns from case study positive deviants how obstacles to access by low income low access communities have been overcome and evaluates if such cases can be scaled.

4.3 METHODOLOGIES

Two main methodological approaches were used to address the objectives of this research. First, secondary data was synthesized across diverse sources to broadly a) identify nutritionally vulnerable coastal communities and b) determine potentially available sources of fish and what regions might have the infrastructure necessary to access them. Second, interviews were used to create in-depth understandings by a) learning from both learn from positive deviant cases currently intervening in the space and, using the results of the quantitative synthesis to identify a few potential regions, b) query actors in these regions to determine the current challenges they face in bringing locally caught seafood to nutritionally-vulnerable communities. The overall framework is first introduced, followed by a description of the methods used to calculate each of the three indices.

4.3.1 *Synthesis of evidence to establish a baseline for intervention – introducing the framework*

Spatially-explicit quantitative secondary data on fish catches, vessel permits, food environment, harbor infrastructure and socioeconomic conditions was collected and visualized. The full extent of these data by spatial and temporal scale and by source is included in Appendix Table 7. We organized the data into an analytical framework that identified nutritionally vulnerable communities and linked them to offshore underutilized fish (Table 4-1). The focus was on the

federally managed US West Coast Groundfish fishery for a number of reasons³, foremost among them: there is extensive information available on this fishery regarding offshore fish abundance, catch levels and distribution, dock prices for the species and the range of the fishery extends almost the entire length of the US West Coast – from the Canadian border to just north of Point Conception, California.

Using our framework, we categorized our information into three main components, as shown in Table 4-1: availability, capacity, and food need. This framework quantified the potential availability of fish to port groups⁴ and adjacent communities; the capacity for a community to both fish that resource and process the fish into edible and healthful product; and determined the level of food need in these communities.

Availability is determined by where fish are caught and brought in to port group – known as “landed” – to determine the potential number of servings that could be sustainably provided by each species for each port group. By using this method we determine the volume of catch brought into the port groups *and* the amount of catch that is left in the water as

³ The US West Coast Groundfish fishery is a mixed-species fishery including both high-price species and lesser known, more affordable species. Managers set a total allowable catch (TAC) based on scientific advice for targeted species, allowing us to determine utilization for any species with a TAC. Furthermore, management of this stock helps ensure each species in the fishery is not overexploited by constrains catch to levels that ensure enough fish remain to allow the stock to rebuild. Importantly, many of these stocks are currently harvested at levels below their TAC (Pacific States Marine Fisheries Commission & National Marine Fisheries Service, 2017), creating the potential opportunity to source healthy proteins to low income low access communities living adjacent to port groups. Finally, there is a strong narrative of renewal in the history of groundfish fishing by port groups along the West Coast, from one of foreign exclusion to domestic overexploitation to a Congressional declaration of economic disaster to development of progressive evidence-based management that the rebuilding of many of its targeted species (Pacific States Marine Fisheries Commission & National Marine Fisheries Service, 2017).

⁴ The term “port group” is used by the Pacific States Marine Fisheries Commission to aggregate nearby harbors into groups to respect confidentiality required by law where there are less than three operators.

underutilized catch – this is labeled “underutilized catch.” For each port group and each year we can use these volumes as a baseline to calculate the number of servings of fish landed and underutilized.

Capacity is a measure of the ability of each community to access the fishery resources available to nearby port groups. Capacity is high when there are: licensed vessels to fish for groundfish; onshore infrastructure required to process the fish into saleable product; and buyers, wholesalers, and markets indicative of a value chain that could be leveraged to supply fish to vulnerable markets. It is important to note that regions with lower capacity to access these resources do not have an inability to access them. Rather, they have less fishery-related infrastructure *per county capita* relative to other US West Coast regions. Conversely, the existence of capacity does not indicate that this capacity is currently utilized.

Food need is defined by USDA Food Security and Environment data, as well as US Census data that are relevant to identifying social and economic determinants of health. Food need is defined as the combination of having communities USDA characterizes as low income and low food access, have a high percentage of the population on SNAP benefits, and have a high percentage of students in schools who are eligible for free or reduced fee meals.

Table 4-1 - Analytical framework to synthesize fishery, socioeconomic, and food access information at policy-relevant scales.

Indicators	Question answered	Description	Data sources ⁵
Availability	Where are affordable and underutilized fish species and in what quantities?	Annual fish species availability offshore as a function of catch utilization	NMFS, PSMFC
Capacity	Do communities adjacent to port groups have ways to access these fishery resources?	Per capita values on access to vessels and presence of processors, buyers, wholesalers	NMFS, CBP

⁵ NMFS (National Marine Fisheries Service), PSMFC (Pacific States Marine Fisheries Commission), CBP (US Census County Business Patterns), USDA (United States Department of Agriculture), US Census ACS (US Census - American Community Survey)

Food Need	Are there food insecure people living nearby the port group?	Low Income Low Food Access, % on SNAP, % population on food assistance	USDA Food Access, US Census ACS
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This framework allowed us to identify areas on the coast where there are underutilized, affordable fish species and calculate how many servings could be available to nearby communities. We used the capacity and food need indicators to determine where efforts should be most concentrated to have the greatest impact. Our initial findings indicate that harvest of many managed stocks with strong scientific harvest guidelines co-occur in areas with indicators that are high in both food need and capacity to access these fishery resources.

4.3.2 *Availability in terms of serving portions*

The first step in calculating availability is to determine how much of the total allowable catch set by fisheries managers is actually being utilized (Eq 1). To do so we calculate the proportion of the catch of each species for each year in each port group relative to the catch across the entire West Coast management block. This ratio represents the proportion of annual catch of a species landed by each port group, and is then multiplied by the species TAC to determine the relative proportion of TAC utilized for each port group for each species in each year.

$$TAC\ Utility_{Port,Yr,Spec} = \frac{Catch_{Port,Yr,Spec}}{\sum Catch_{Port,Yr,Spec}} * TAC_{Spec,Yr} \quad (1)$$

After apprehending TAC utilized in Eq 1 the next step is to determine the amount of equivalent servings that could be provided to communities by each volume of fish (Eq 2).

$$Servings\ Provided_{Port,Yr,Spec} = TAC\ Utility_{Port,Yr,Spec} * Edible_{Spec} * \frac{1e6\ g}{1\ MT} * \frac{1\ serv}{226\ g} \quad (2)$$

First, the TAC Utility for each port group, year and species is multiplied by an edible coefficient for that species. The edible coefficient represents the proportion of the whole fish that can be

consumed.⁶ Then the edible volume was transformed first to grams from metric tons and then to a serving size. We assumed 1 serving of fish was 226 grams. The final product indicates the annual number of servings provided to each port group for each species.

The final calculation determines the number of servings underutilized, which is the edible volume of fish left in the ocean by not catching fish up to the total allowable catch. This value was again expressed in terms of servings (Eq 3).

$$Servings\ Unutilized_{Port,Yr,Spec} = (TAC_{Spec,Yr} - TAC\ Utility_{Port,Yr,Spec}) * Edible_{Spec} * \frac{1e6\ g}{1\ MT} * \frac{1\ serv}{226\ g} \quad (3)$$

In this case, we take the catch by port group and subtract it from the total allowable catch for each species. This gives us the catch could have been caught and still be within sustainable harvest guidelines of the TAC, yet were not. This “underutilized catch” is then multiplied by the edible coefficient and converted to servings. The resulting value indicates the annual number of servings that are “left in the water”, or available, for each port group and species. For a detailed breakdown of utilization rates and affordability across the coastline, see Appendix Figure 5.

4.3.3 Calculating index scores for Capacity and Food Need

Single index scores for capacity and food need were calculated using the multidimensional scaling approach of principal component analysis using the R package *psych* (Revelle, 2019).

There were numerous and diverse socioeconomic variables that could be used in these indices, sourced from a number of US government datasets including the National Marine Fisheries Service, the Census Bureau and the US Department of Agriculture. Ultimately, the variables

⁶ Processing yield is the amount of edible weight from fish species. We used fillets as our yield coefficient based on the results of the interviews. Respondents mentioned that their end-consumers were more likely to eat fish if they were as ready-to-eat as possible. The yield database can be found at:

<https://www.commerce.alaska.gov/web/ded/DEV/FisheriesDevelopment/SeafoodProcessingRecoveryRatesYields.aspx>

selected represented discrete aspects of the communities as they relate either to the capability of people to access fish resources or related to the level of food need in these communities, resulting in 4 variables to represent Capacity and 3 variables to represent Food Need (see Table 1 above).

A separate principal component analysis (PCA), with varimax rotation, was run for each of the two indices to determine whether the variables could be reduced to a single “component” variable that accounts for a sufficient amount of the variation in the data to be considered representative of those variables. Eigenvalues were used to determine whether or not a single component could be used to represent sufficient variance. In both with both the four variable Capacity index and the three variable Food Need index, only the single component solutions had eigenvalues greater than one, suggesting that these single components were able to explain more of the variance than individual variables could – thus composite index was able to be at least as informative as at least one variable . With this determination, it became possible to reduce the variables in each of the indices down to single components.

After running separate single-component PCAs on the Capacity and Food Need indices it was found that the resulting component explained 63% and 67% of the variation in the raw data, respectively. The scores represented in the baseline represent where each county sits along the spectrum of the single index corresponding with a low or high values in the individual indicators making up the composite index. For example, a low food need score indicates that a given harbor had lower individual indicator scores for food need. To aid in interpretation, these numeric scores were divided into 3 categories - low, medium, high using quantiles.

While availability and capacity are recorded annually, the Food Need indicator relies on information in the US Census American Community Survey (ACS), which is only reported in 5

year aggregates for 2010 and 2015. Maps were created with annual fishery information from 2000-2016 to determine where future interventions might best be focused through time, even though the capacity and food need indicators were only available in select years. As a result, the Food Need index, which relies on ACS data, could only be calculated for 2010 and 2015. The 2015 version will be reported below.

4.3.4 *Using interviews to identify potential approaches and obstacles to intervention*

The first two objectives of the research were met by synthesizing existing data, but to best inform the development and implementation of potential interventions, an in-depth understanding of on-the-ground dynamics was necessary. In reviewing our data, it was apparent there was a paucity of information that systematically identified fishery-based interventions in the food system to address the factors preventing access to underutilized fish by low-income consumers (research Objectives 3 and 4). In order to meet our objectives, we conducted a two-stage process using qualitative research methods. This involved:

- a) identifying and exploring “positive deviant” case studies of existing efforts that successfully directed underutilized fish to consumers and nutritionally vulnerable populations along the West Coast, and
- b) assessing the need for and feasibility of implementing additional systems and partnerships in regions where quantitative data indicate that fish availability and food need exist.

For the first stage, we identified existing efforts to link underutilized fish to communities with food need based on web searches and pre-existing knowledge among team members. We utilized a “positive deviance” framework (Pascale & Sternin, 2005) to interview the case studies to explore key elements, facilitating factors, and lessons learned based on the efforts’ existing success -

Methods and in-depth reporting of the results for the positive deviant cases can be found in Chapter 3 of this PhD dissertation.

For the second stage, a place-based sampling approach utilized key informant interviews to develop a qualitative, exploratory feasibility assessment in sampled communities for which quantitative data indicate large potential sources of underutilized fish and high proportions of low income, food insecure populations. We assessed the feasibility of interventions in geographies where significant landings of low-cost fish overlap with populations of low-income, food insecure consumers that we had identified using the quantitative indicator approach developed above. Using the conceptual model developed with results from the positive deviant cases, we identified actors throughout the seafood supply chain to explore potential need for, interest in, and conditions that might facilitate or pose barriers to interventions designed to direct underutilized fish to consumers. We designed the feasibility study to explore potential need for, interest in, and conditions that might facilitate or pose barriers to interventions designed to direct underutilized fish to consumers in the food system.

We conducted telephone and in-person interviews with 11 key informants. Participants reflected all three states along the West Coast and worked in fields including fishing; seafood processing, distribution, and marketing; emergency food; school nutrition; institutional food service; and public health and food systems planning. For each organization on the list, we identified one or two potential contacts and emailed or called them with an interview invitation. The invitation or telephone recruitment script briefly described the purpose of the study and requested an interview with them or others on their team to take place in-person or over the phone at their convenience (up to but not exceeding one hour); we did not offer incentives for participating in the interviews. The team sent no more than three email or phone recruitment

messages to each individual. In each interview, we asked for additional relevant interviewee from their community or sector, adding a snowball sampling approach to our process and connecting us with 2 additional interviewees. In total, 9 of 21 invited to participate in feasibility assessment interviews consented to participate (see Appendix Table 8 for more information on interviewees).

The interview guide for the feasibility assessment included questions about the local community's fish availability, consumption, and fish preferences; how community and food services source and offer or serve fish; and which populations could most benefit from additional fish in their diet. Because each institution plays a different role in the value chain, some questions might not be relevant so we created different versions of each interview guide with questions most relevant to their role (see Section 4.5, page 150 for interview guides). Additionally, we shared preliminary case study findings and asked for interviewees' reactions to and interest in similar efforts in their own community, any related or prior similar efforts in their community, potential community partners (e.g., fishers, processors, food service/retail), and perceived benefits and challenges that might arise with such efforts.

4.4 RESULTS

This project involved a mixed methodology approach. Results will first be reported for the data synthesis of secondary data. Then the results of the interview methods on positive deviant case study as well as the feasibility assessment will be reported.

4.4.1 *Using secondary data to bridge available fish to counties with high food need and the capacity to access them*

Harvest of many managed stocks with strong scientific harvest guidelines co-occur in areas with high food and capacity to access these fishery resources. Between 2007 and 2016 the baseline

assessment found a total of 167,752 tons – or 739 *million* servings – of fish were foregone across the entire coastline. That is an annual median value of foregone fish estimated to be 15,355 tons or 67.7 million servings that could be harvested and still remain under the sustainable harvest guidelines set by the National Marine Fisheries Service. There are six regions from northern California to the Canadian border categorized as high food need and where there is high capacity to access fishery resources (Figure 4-1).

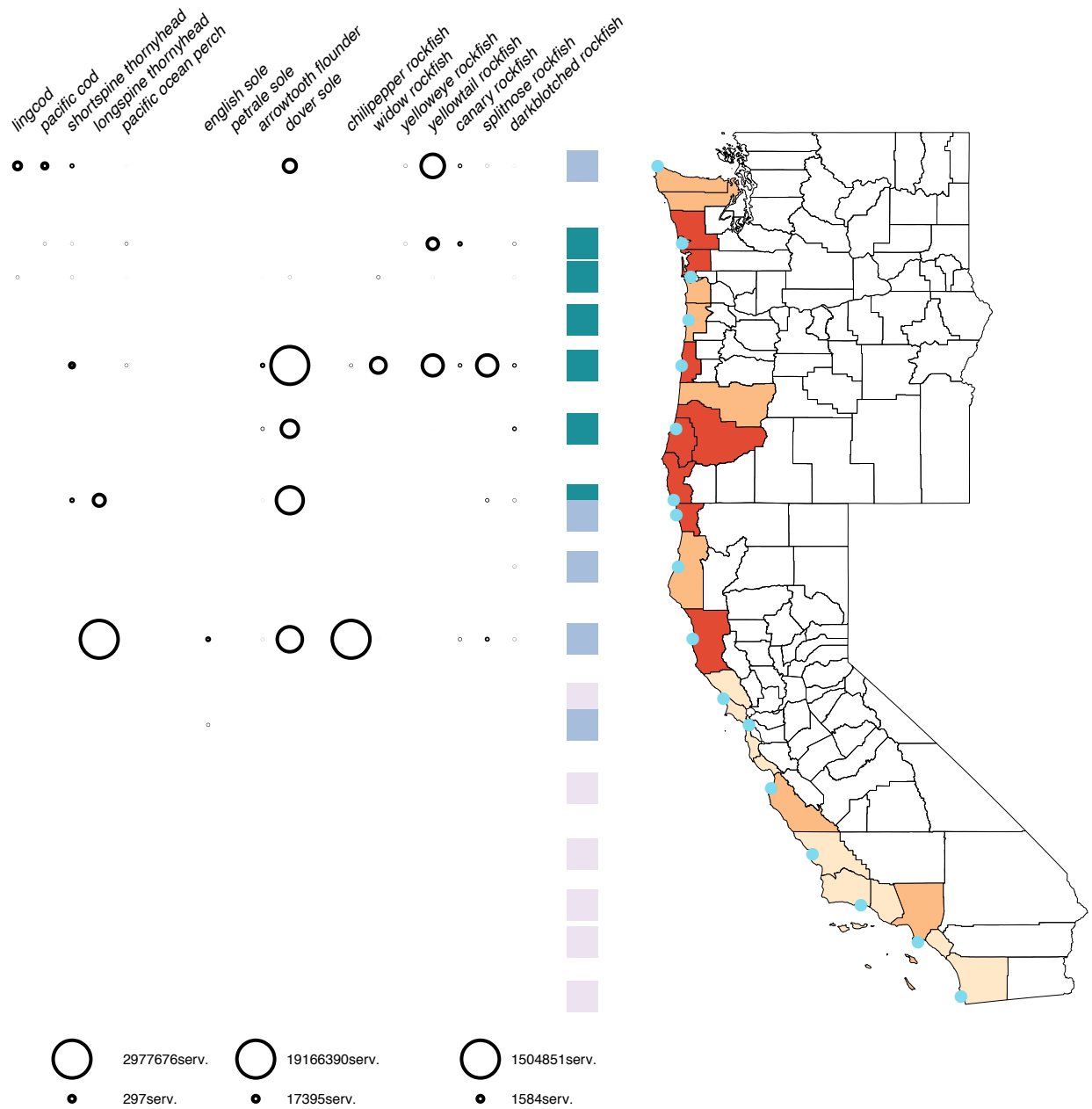


Figure 4-1 - Most affordable fish under \$1.00 per pound, overlaid with Capacity, and Food Need in Pacific Ocean coastal-adjacent counties near major harbors in 2015.

Counties from the Canadian border in Washington to Northern California score highest for both Capacity and for Food Need. Availability in a given county depended on the species. Counties with high Food Need included Grays Harbor and Pacific counties in Washington;

Lincoln Douglas, Coos and Curry counties in Oregon; Del Norte and Mendocino counties in California. Counties with that had harbors with high Capacity to access available fish included Grays Harbor in Washington; Clatsop, Tillamook, Lincoln, Coos and Curry counties in Oregon; there were no counties in California with high Capacity. There is a noticeable decrease in Capacity as well as Food Need for the southernmost counties relative to those further north. There were numerous counties across the three states that had combinations of moderate and high Capacity or Food Need.

In many of these counties, there are species of fish that are being harvested at levels far below stock assessment guidelines and have dock prices of less than \$1.00 USD per pound. However, the distribution of available fish to meet these needs depends on the species and programmatic interventions will need to consider the potential volume of harvestable species. In some cases, there are a variety of underutilized fish species that could feasibly be used, such as in Lincoln County Oregon where we see a portfolio of species that could be harvested including Yellowtail rockfish, Splitnose rockfish, Darkblotched rockfish and Dover sole. In central Oregon, the coastal county of Lincoln demonstrates high food needs, high fishing capacity in the fishing harbor of Newport, and a portfolio of underutilized and affordable fish stocks just offshore. In northern California, Fort Bragg represents a place where there is high food need in the county, millions of potential servings offshore but with a moderate fishing capacity. At the border of Oregon and California there are considerable differences despite being separated by a few kilometers. Both Del Norte Cty. California and Curry Cty. Oregon have high food needs but Oregon's Brookings harbor has higher fishing capacity than Crescent City. While Brookings indicates over 2 million servings of groundfish available Crescent City does not have any available groundfish under \$1.00 per pound. Synthesizing data across datasets from diverse

sectors clarifies the potential connection between communities with high food need, available fish stocks offshore, and the capacity of nearby harbors to access those resources.

For Dover sole in 2015, fishers are only utilizing 5% of their total allowable catch, which meant that over 20 *million* servings of underutilized product offshore from Oregon's southern coast, which was characterized by high food need and high capacity in 2015 (Figure 1 above). The reason for underutilized fish may be due to undeveloped markets or, as is the case in Dover sole, is limited by choke species. Splitnose rockfish tells a different story of a rebuilding stock that remains underutilized. As recently as 2010 fishery managers set the Total Allowable Catch to only 461 tons landed in harbors in Central Oregon and Northern California fishers were only catching about 11% of what that allowance. As a result over 100,000 servings of Splitnose rockfish remained in the water that could be landed in harbors with moderate to high fishing capacity and high food need (Figure 2). The average off-the-boat price for Splitnose rockfish was only \$0.38 per pound. Across all groundfish species - except high-value species including sablefish and Petrale sole with strong existing demand from major or international markets - we found that a large magnitude of servings of fish are left underutilized in high food-need adjacent waters. By 2015, the stock had rebuilt considerably, and response by fishery managers was to raise the Total Allowable Catch fourfold to over 1700 tons. Fishers did increase their effort but catch remained only 6% of the allowance and became much more focused in the Newport port group in Central Oregon than it was in 2010. While the volume of underutilized servings increased considerably to 800,000 servings, the opportunity to benefit became much more constrained to communities in Central Oregon. That said, even in Northern California, which in 2010 had a higher proportion of overall catch, still had over 6000 servings of underutilized Splitnose rockfish that could be used to meet food needs in adjacent communities. The narrative

of Splitnose rockfish demonstrates that as fisheries rebuild, the potential number of servings increases substantially. However, catch of these rebuilt fish has not kept pace and underutilization has increased. As reported below in the interview results section, increasing the amount of fish caught in many port groups is hindered by a lack of harbor infrastructure and processing.

4.4.2 *Learning from success: results of the positive deviant cases*

Positive deviant cases were identified as having existing initiatives that improve the connection between regional fisheries and low income or the healthy food system. The results of that work are shown in full in Chapter 3, and are only summarized in this this chapter. These case studies included a fishery-to-school program, two regional food banks consistently sourcing regional seafood, and a nonprofit that helps to connect schools and hospitals to local harbors and seafood distributors. Enabling conditions and facilitating factors facilitated success in these programs. Identifying partners with shared values and creates strong relationships throughout the value chain helped to ensure that buyers and suppliers could negotiate on a fair price. For donation-based cases, relationships are critical to ensure efficient processing of fisheries resources into products that can be distributed to local food pantries. Cultural connections to seafood enabled program development, especially in communities with a fishing heritage or with large communities of with ethnic connections to seafood consumption. Champions throughout the value chain facilitated success by advocating for change within their institution. These champions ranged from school superintendents and nutrition directors to individual kitchen chefs and fishers willing to alter their activities to better support the intervention. Finally, in some cases policy changes enabled programs to modify supply chains; this was especially the case for food banks sourcing bycatch or illegally caught fish apprehended by law enforcement.

Positive deviant programs faced a number of challenges. Foremost among them was managing costs such that the final product was both affordable to low-budget institutions and viable for suppliers. The costs of fish processing was mentioned as a major challenge. Selecting “high yield” fish that yielded more useable product in proportion to their raw form helped minimize these costs. In large institutions, chicken is used as the benchmark price for healthy proteins, in 2015 the farm gate price was \$0.90 USD per pound for broiler chicken compared with \$1.48 USD per pound for beef (Congressional Research Service, 2018). In cases where local seafood is more expensive, positive deviant programs lowered costs by combining seafood with low-priced, healthy protein ingredients like pulses in tacos or stews. A continuing challenge is the decay of infrastructure in many harbors that requires considerable front-end costs and potentially investment. If rebuilt, respondents suggest they can cut the middlemen to lower costs and have more control over the destination of their seafood. A lack of knowledge on the benefits of eating fish, and the methods of preparation, was a challenge that was overcome with education programs.

4.4.3 *Identifying obstacles and potential with feasibility assessment interviews*

Key findings from the feasibility assessment address the need for and feasibility of implementing additional systems and partnerships in regions where quantitative data indicate that fish availability and food need exist. Interview results summarized here focus both on the current state of seafood supply within their local context: the demand for fish, current sourcing, offering and messaging related to fish, availability. These results also describe responses to questions on envisioning whether local seafood could better contribute to their initiatives: the interest in developing partners and systems to increase access to fish, as well as potential partners, and challenges.

Fish is sometimes, but not always a popular item in schools, food banks, and communities, and is under-consumed in the general population. Schools and emergency food interviewees described limited current demand for fish in their service settings and reasons for this; most indicated that demand could potentially increase if fish was promoted, prepared well, or more consistently available. Several interviewees described limited knowledge about storing and preparing fish which may be a factor especially among populations using food banks; these skills have been a focus in the public health and nutrition world for fruit and vegetables, but not fish. School-based interviewees mentioned that fish is not always a popular choice for students, but that they have had success in developing some new fish entrées (e.g., fish tacos with "local" fish) and promoting them through taste tests. Public-facing interviewees said fish is often seen as unaffordable for families, especially in their lower income communities. There is a sense, however, that demand can shift and be influenced. Interviewees described using taste tests and new recipes to expose people to fish and increase demand. Some also mentioned that just having it offered more frequently might help consumers to become more comfortable with it, and in turn might increase demand.

Fish is offered in limited ways through programming for food insecure and low income populations including USDA procurement mechanisms for school meals; WIC eligibility for canned tuna, salmon, and sardines; and canned tuna in food banks. One school described sourcing fish a few times a month in the form of fish sticks or tuna through a major school food distributor at an affordable rate, and one opportunity to taste test local crab based on a donation from a community connection. Another school described identifying a local fish market from whom she could buy fish on occasion for some but not all schools, with cost being the limiting factor. Respondents working in emergency food settings described sourcing fish in the form of canned

tuna from their food bank distributor, canned tuna donations from events such as a large “Tuna Classic”, and salmon from hatcheries (procured locally or through a regional food bank distributor). In general, interviewees indicated that fish need to be canned or processed in some way although one food bank had distributed whole fish for a time and also experimented with processing on site. Food banks discussed other sources of protein being more popular (e.g., canned beans, peanut butter, shredded meats) and/or more affordable. They also discussed food distribution and procurement decisions as being made based on criteria other than nutrition, this includes both availability and demand among consumers. Public health-related interviewees described little to no focus on fish other than the inclusion of WIC eligibility for canned tuna, salmon, and sardines. No interviewees described a focus on promoting or discussing fish as part of a healthy diet, other than public health messaging related to mercury during pregnancy. Several interviewees indicated that fish likely should be discussed more often.

Although the sampled communities are located near harbors and have a long history of fishing, several interviewees indicated that fresh, local fish is not readily available to the general population, especially those with lower incomes. Fishery sector respondents note that although the supply of west coast groundfish is increasing in the water - due to improved management and resulting increases in TAC for many species - these fish aren’t necessarily made “available” due to low demand and low prices. Furthermore the industry is getting more skilled at avoiding bycatch, so there is less and less bycaught fish and more fish destined for international or domestic metropolitan markets. Furthermore, respondents indicate that harbor infrastructure (i.e., processing, services for fishing vessels) still has yet to rebuild from the 2000 collapse of West Coast groundfish stocks. Interviewees in Crescent City described a situation in which commercial fishing licenses are unavailable and all caught fish is currently sold to one buyer, making it

essentially unavailable to the local community. Emergency food settings did describe a “Tuna Classic” event that resulted in sizeable donations of canned tuna once a year, as well as salmon hatchery donation programs. One school interviewee described a relationship with a local fish market that supplied fish for school meals a couple of times a year, but said that the cost of purchasing the fish at markets makes it prohibitively expensive to draw on this source more often.

In Washington, Oregon and California all needs assessment interviewees indicated an interest in developing partners and pathways to increase access to local fish. When presented with details from the positive deviant cases they indicated interest in similar approaches for their communities, even among those who had described limited demand for seafood in their communities. They saw that the benefits of such arrangements might include increased availability of healthy food for populations in need - specifically, a healthy source of protein, value in community and fishery connections that would be involved, and the ability to highlight and tie into an important aspect of their community’s history and cultural identity. Several, but not all interviewees suggested potential partners for efforts to direct underutilized fish to populations in need or those they serve. Potential partners mentioned ranged across the value chain. They specifically included food distributors, trucking companies, Farm-to-School programs at the state level, school personnel with ties to community partners (*e.g.*, Youth Transitions teacher), other institutions offering food service (*e.g.*, schools, hospitals, prisons), other nearby fishing communities, and wholesalers and food retailers.

Interviewees described a number of potential considerations or challenges that would need to be addressed for the kinds of arrangements highlighted in case studies to work for their communities and service settings. Schools and emergency food interviewees discussed a need for fish to come to them in a particular form (cut, canned or packaged), for it to be affordable or free

in the case of food banks, and the need for clients and kitchen staff to know how to prepare the fish. Additionally, schools mentioned the constraints they face in procurement rules (but said involvement of Farm-to-School partners could help address this by facilitating purchases from approved fish sources). Some interviewees also mentioned the demand and availability issues described above as potential challenges. Furthermore, the lack of harbor infrastructure requires improved equipment as well as a renewed labor force is needed, requiring considerable costs. Respondents mention that without external funding, in order to improve infrastructure processors and fishers would have to negotiate transactions that are profitable to fishers yet allow generate enough revenue for shoreside infrastructure companies that they can progress the rebuilding process.

4.5 DISCUSSION

The research presented here utilized a mixed methodology approach by bringing together quantitative and qualitative approaches to determine how we can improve the connection between local seafood production and the healthy food system. Secondary data was brought together information across a number of databases to identify the a) availability of affordable underutilized stocks currently managed, b) the capacity for nearby harbors to access these resources, and c) whether there is a food need from populations living in the area. Interview methods were also used to understand enabling conditions and challenges facing programs attempting to improve this connection by interviewing a) positive deviant cases actively operating along the West Coast to learn how they achieved their success and b) actors throughout the value chain where interventions might occur via feasibility assessments.

4.5.1 *Seafood can better contribute to the healthy food system*

Along the US West Coast the food system still faces challenges in meeting dietary needs of households; we have shown that local fisheries have considerable potential to contribute to a healthier food system, and that there is the desire and a blueprint to improve supply. We found that counties with high food needs have nearby harbors with the capacity to access fishery resources offshore. These resources could contribute millions of additional, nutritious servings of fish to these regions of high food need. Millions of servings of locally produced seafood are not only available, but are more affordable than many animal proteins: from 2000 to 2016, an annual median estimate of 51 *million* servings of groundfish with dock prices at or under \$1.00 USD per pound may be harvested, all while remaining within sustainable harvest guidelines. While the dock prices of these fish are comparable to animal proteins at the same point their supply chain, respondents mentioned that there are considerable internal costs – or value additions - in processing and storage that raise the price of the seafood product by the time it reaches consumers. It is at this point that the price of fish tends to increase beyond many animal proteins, and potentially out of reach for many low income consumers or institutions serving nutritionally-sensitive.

In lieu of product and processing labor donations experienced by some of the food banks, a paramount future action should be to explore financing mechanisms for harbor infrastructure to ensure that fishers have everything they need to land, process and store these fish. This critical infrastructure is costly but respondents felt that if such equipment could be secured they would be able to reduce price increases due to the need for middlemen. Having a clear understanding of the value chain and where most of the costs are centered aids in pinpointing where additional capacity is most needed.

Policy alignment is a critical component to ensure local seafood's contribution to improved diet-based public health outcomes for low-income or nutritionally vulnerable households. The results of this analysis describe the potential for improved contributions of seafood to the healthy food system, but fishery, food system and health policies need improved alignment to truly realize change. The complexity of the food system, and the resulting lack of clarity on where to intervene in the supply chain, is recognized as a challenge to identifying how policies in the food system can contribute to health (Muller et al., 2009). In the US, there is an additional misalignment between fishery policy and health policies; fishery policies manage fish resources as a for economic and social - not nutritional - objectives whereas health policies oftentimes recommend fish consumption but offer little guidance on sourcing and supporting the domestic seafood system (D. Love et al., 2017). This work describes numerous pathways by which seafood can contribute to the food system, defined with respect to both successful implementation of programs and challenges to doing so in regions without such programs. The results identify the regions where interventions are possible and the species that might be most available in those regions. In doing so, we provide direction to policymakers seeking clarity on potential market channels to leverage to develop food system and health policies that integrate seafood.

This research represents a growing, but understudied aspect of fisheries: how fisheries can contribute to the food system. The vast majority of fisheries research is focused on production, entry to the fishery (*e.g.*, catch share allocation) and to a limited extent, purchasing. Especially in developed country contexts, there is far less research focused on inshore dynamics of fish and, importantly, how these dynamics eventually lead to meals for end consumers. There are a few recent exceptions. Van Putten et al. investigated why fishers were discarding fish in

Australia despite a large portion being edible species and found that it was the demand side creating barriers with respect to low consumer awareness, inconsistent supply, and few market channels among others (van Putten et al., 2019). Many of these barriers are the same challenges that limit the utilization of West Coast groundfish. Another example describes how recreationally harvested To improve the contribution of fish to the healthy food system we need to have a clearer understanding of the varied market channels that currently exist and how interventions might be shaped. This research presents a potential avenue that researchers in other regions could take to provide in-depth assessments of seafood pathways.

4.5.2 *Securing healthy food supplies in uncertain futures*

Fisheries are a wild resource, and require management to guide the actions of fishers ensure sustainable harvest year after year in changing environmental conditions. There is a growing consensus among fisheries scientists on methods by which fished stocks can be allowed to successfully recover from overexploitation, and we are learning that there is potentially a much higher volume of fish that can be harvested sustainably *above* current levels (Hilborn & Costello, 2018). As we seek to meet societal objectives by sourcing currently underutilized – such as improving the health of low income or nutritionally-sensitive communities – how can we safeguard that this new demand does not repeat our legacy of overexploitation? In the United States, fisheries in federal waters are guided by science-based management and harvest levels are seasonally using stock assessments that estimate the population's year-to-year viability. In a complex fishery involving many species such as West Coast Federal Groundfish Trawl fishery, there are three categories of assessment based on the quantity and quality of life history and catch information and level of fishing engagement. The harvest levels are iteratively set based on the levels of certainty; with increased uncertainty, a more precautionary approach is taken

(Pacific States Marine Fisheries Commission, 2016). If uptake is successful and interventions into the food system are implemented, public-facing institutions like hospitals, schools or jails will raise the demand for fish in adjacent harbors. Increasing fishing effort will be needed to meet growing demand. While current utilization is currently far below maximum sustainable yield for a majority of groundfish, when fishing effort does begin to reach this maximum it will be mediated by a fishery management plan that has had success at rebuilding stocks and maintaining sustainable harvest into the future. Each fishery has a unique management structure that must be considered when sourcing fish.

As the climate continues to change, the food system will have to adapt in order to continue – and to improve – an equitable supply of nutritious foods. Especially in coastal regions or where inland fish production is possible, the production of nutrient-rich seafood is fit to play a pivotal role if market channels are structured to ensure seafood may reach low-income or nutritionally-sensitive communities. As waters continue to warm, species will be effected differentially with mobile fished species who are able will move toward more favorable habitats, and sometimes across regulatory boundaries and into conflict over resource access (Pinsky et al., 2018). This shifting geographic mosaic also rearranges access to seafood for communities adjacent to harbors, as the supply chain provisioning this seafood may have more infrastructural inertia than the fish offshore (Dubik et al., 2019): these changes will in turn influence availability and access to nutritious fish resources for communities with high need. Our results indicated that infrastructure - including processing facilities, dockside hoists and cold storage - were critical to the contribution of fish to these communities. As fish respond to large changes in ocean temperature and move, they may move into areas with less capacity to utilize the fish available. In these instances, not only is there a loss in availability for communities near grounds where

fish are leaving, but without adequate infrastructure to access this newfound availability, the potential access to communities also might not be realized. As some species leave, others might become available, but the capacity to access that fish (i.e., appropriate fishing gear) must align so that these new resources can be utilized. Shifting populations can also impact food preparation in institutional kitchens regarding food preparation, recipe development and end consumer preferences. In some cases, newly available fish might be easier to prepare and more desirable to consumers. But if they are species that communities are unaccustomed to, then outreach to both kitchen workers and to end consumers about the new species, as well as recipe development, might be necessary to facilitate uptake of these species into the food system.

4.5.3 *Unraveling complex food systems by combining quantitative and qualitative data*

Quantitative information generated by the situational baseline data gives a broad, coastwide understanding on where fish might best contribute to food needs by describing where affordable and underutilized fish are being harvested and whether there is capacity to access the resource. With the project's goal of informing programs to improve supply of affordable fish to nutritionally vulnerable populations, these data broadly indicate where programs might best be implemented. However, it does not provide the in-depth understanding of challenges and enabling conditions that would be necessary for successful implementation of a similar program. The two interview methodologies provide this deepened context. The positive deviant cases highlight factors that facilitated programmatic interventions to improve supply. Coupled with the baseline quantitative data, this provides valuable insight for specific characteristics of fish that might best be utilized.

The two interview methodologies provide this deepened context. The positive deviant cases highlight factors that facilitated programmatic interventions to improve supply. Coupled

with the baseline quantitative data, this provides valuable insight for specific characteristics of fish that might best be utilized. For example, in bringing fish to schools, Bay2Tray originally sourced Pacific grenadier – incidentally caught low-value fish in the more lucrative sablefish fishery. Over time, sourcing switched to Chilipepper rockfish, which is another affordable species caught in nearby waters that is more consistently available to meet rising demand from an increasing number of school districts. The baseline explains this when looking at annual pricing and location of catch. Chilipepper rockfish is consistently caught in northern California at price points between \$0.50 and \$1.00 per pound off the docks, and even when processing costs are considered, within the range of being affordable to institutions serving nutritionally vulnerable people. From 2009 to 2016, the baseline indicated that more than 1.5 million servings of Chilipepper rockfish remained underutilized *per year*. Bay2Tray saw a potential new source and negotiated with fishers to negotiate a price point to purchase it and provide thousands of meals to school children. When considering that they are utilizing only a fractional volume of the potential catch of Chilipepper available along the coastline, there is clearly more utilization possible in this initiatives and those seeking similar interventions. It is important to note that this is one of many species that could be used. There are many opportunities to learn from positive deviants to develop programs to open new market channels to source local seafood and ameliorate the challenge of low demand mentioned in feasibility assessments. The baseline and case study narratives can help guide similar strategic interventions once challenges have been identified by the feasibility assessment.

Feasibility assessment interviews in areas without current supply of local fish to nutritionally vulnerable people provide critical insight into challenges that might face development of such interventions. These interviews spoke to decreased availability of local fish

at harbors, sometimes due to the presence of only one buyer. Data included in the baseline assessment can help identify where there are few buyers. Another challenge brought up by needs assessment interviews regarded limited knowledge on storing and preparing of fish. While this concern can somewhat be ameliorated by education, it could also be addressed by selecting species that are easier to process and prepare for serving in large-scale institutions like schools or hospitals. These species might include rockfish as opposed to flatfish like sole, the location of these species can be identified by the baseline. Importantly, when briefed on positive deviant cases ongoing in other regions, the needs assessment interviews indicated interest in pursuing something similar, and identified potential partners in their community. This approach highlights the value of mixed methodologies: using the baseline as a foundation of knowledge and the case studies as a guide, in-depth needs assessments interviews explore opportunities for intervention.

4.6 FUTURE DIRECTIONS AND CONCLUSIONS

Future research might include an in-depth assessment of the current and future potential a coastal region from fish produced in local harbors all the way through to consumption most likely in a rural region where these links can be readily identified. This would require investment in collecting primary data on diets, as the US has a shocking deficit of publicly available food consumption data. This would build off the results from the West Coast-wide assessment. Partners here would likely originate from relationships being built through the existing PHI survey initiative. Another important avenue of research for which we did not cover in this research was the connection between coastal seafood production and large, urban populations. This future work could focus on large coastal metropolitan areas (*i.e.*, Seattle, San Francisco Bay Area, Los Angeles) specifically on immigrant and diaspora populations who are culturally fish-reliant. The research will apply the methods developed here to identify the pathways through

which they are or are not able to access fish resources via subsistence/recreational harvest or in fish markets. If the answer is that these groups are not consuming as much fish as they are accustomed to, either because of regulatory constraints or the cost of purchasing fish, this presents an opportunity for an intervention. Future work can also take a programmatic approach. One option would be to work with partners to develop a program similar to “Fresh Bucks” for local seafood. Fresh Bucks provide a \$1:\$1 match to shoppers who make purchases with EBT benefits (SNAP/Basic Food/Food Stamps) when they purchase fruits and vegetables. At this time seafood is not included in the Fresh Bucks program, but the inclusion of affordable fish could provide a micronutrient-diverse protein source to the nutritionally vulnerable populations who are eligible for EBT benefits.

Along the US West Coast there are abundant fishery resources due to improvements in fisheries management, standing to improve the connection with the healthy food system. The research discussed here identifies the scope and strategy for scaling the isolated success stories we have located as well as challenges to that scaling. Due the low current demand for fish, we synthesized secondary data across multiple sectors to create a situational baseline that found current catch is far below the total allowable catch set by managers, foregoing millions of servings of fish that could be sustainably harvested and contribute to food need in adjacent communities. Despite broad lack of connection between local seafood and the healthy food system, we interviewed positive deviants finding to learn their enabling conditions and how they overcame challenges to intervene in the system. We found that positive deviants stated the importance strong relationships with partners in the value chain and of champions of the initiative’s mission, and educational programs to improve consumer awareness, as well as a noted emphasis that grants and the willing philanthropy of industry partners – for food banks -

were critical to continued operations. Then we used the situational baseline to interview representatives throughout the food system – from fisheries industry representatives to public health officials to school nutritionists – to learn more about the current state of connection between seafood and the food system and how they envision programs such as the positive deviants could improve this connection in their communities.

We learned that there is considerable interest across the coastline for improved market channels to access local seafood, but that a lack of local demand and a lack of infrastructure remain major obstacles. This research revealed the importance of taking a mixed methodological approach that uses both existing quantitative data to analyze the situation broadly as well as qualitative information to learn from existing practitioners and evaluate the feasibility of similar practices being implemented in other regions identified by the baseline as having the potential for improved connection between local fisheries production and the food system.

4.7 SUPPLEMENTAL TABLES, FIGURES AND INTERVIEW GUIDES

4.7.1 *Datasets used in the synthesis baseline*

Appendix Table 7 - Data used in synthesis baseline

Database	Variable	Years
USDA/ERS Food Access	low access	2010,2015
	vehicle access	2010,2015
	SNAP benefits	2010,2015
State of WA OSPI (Washington); kidsdata.org (California); datacenter.kidscount.org (Oregon)	Eligible for Free & Reduced meal	2008,2012
USDA/ERS Food Environment	SNAP Authorized	2010
	WICParticipants%TotalPop	2009,2014
	WIC redemptions/WIC-authorized stores	2008,2012
	Child & Adult Care Food Assistance	2009,2014

	Farmers Markets Count	2009,2013
	FarmersMarketsWithSNAP	2013
	FarmersMarketsWithWIC	2013
	FarmersMarketsSellingAnimalProducts	2013
	Food Hubs	2012
USDA PolicyMap	SNAPstores	2013
CDC BRFSS - Policy Map Small Area Estimates	corHeartDisDiag	2013
	diabetesDiag	2013
	highCholesterolDiag	2013
	strokeDiag	2013
	PhysicallyInactive	2013
	lowFruitVegCons	2013
	ObesityRiskFactor	2013
PacFIN	landedWeight	2000-2015
	landedWeightPricePerPound	2000-2015
	landedWeightRevenue	2000-2015
NFMS	CPUE abundance estimates	2000-2015
	Vessel permits by gear - groundfish	2015
	First receiver permits - groundfish	2015
Census - County Business Patterns	superMarkets/Grocer	2000-2015
	meatMarkets	2000-2015
	meatMarkets	2000-2015
	seafoodMarkets	2000-2015
	fruitVegMarkets	2000-2015
	seafoodWholesaler	2000-2015
	fruitVegWholesaler	2000-2015
	meatWholesaler	2000-2015
Demographic - Dicennial and ACS	Race Asian	2000,2010,2015
	Race PacificIsland	2000,2010,2015
	Race TwoPlus	2000,2010,2015
	Race White	2000,2010,2015
	Race AfricanAm	2000,2010,2015
	Race AmericanIndian	2000,2010,2015
	HispanicAndRace	2000,2010,2015
	HouseholdsWithChild18Under	2000,2010,2015
	HouseholdsWithNonrelatives	2000,2010,2015
	HouseholdsInGroupQuarters	2000,2010,2015

	HouseholdsInstitutionalized	2000,2010,2015
	FamilySizePerHousehold	2000,2010,2015
	HousingVacancyRate	2000,2010,2015
	HousingOwnerOccupied	2000,2010,2015
	HousingRentalOccupied	2000,2010,2015
Housing - Dicennial and ACS	IncomeFamilyMedian	2000,2010,2015
	HousingWithMortgage35PerIncome	2000,2010,2015
	Rent35PerIncome	2000,2010,2015
	HouseholderAlone	2000,2010,2015
	HouseholdAveSize	2000,2010,2015
Economic - Dicennial and ACS	IncomeWithSNAPBenefitsPercPop	2000,2010,2015
	IncomeWithPubAssistPercPop	2000,2010,2015
	NoHealthInsuranceEmployedPercPop	2000,2010,2015
	NoHealthInsuranceUnEmployedPerPop	2000,2010,2015
	NoHealthInsuranceNotInLaborForcePerPop	2000,2010,2015
	HouseholdsWithSocialSecurity	2000,2010,2015
	FamiliesBelowPovertyWithYoungChildrenPercPop	2000,2010,2015
	BelowPovertyPercPop	2000,2010,2015
	FamiliesNoHusbandBelowPovertyPercPop	2000,2010,2015
Social - Dicennial and ACS	EducNoHighSchIDegr	2000,2010,2015
	EducHighSchIDegrNoCollege	2000,2010,2015
	EducSomeCollegeNoDeg	2000,2010,2015
	GparantsCaregiverPercPop	2000,2010,2015
	Age65OverMalesPercPop	2000,2010,2015
	Age65OverFemalesPercPop	2000,2010,2015
	HouseholderAlone65OverPercPop	2000,2010,2015

4.7.2 Interviewee overview table for positive deviant case study and feasibility assessment

Appendix Table 8 - Interviewee overview table for positive deviance case study and feasibility assessment

	POSITIVE DEVIANCE CASE STUDY (N)	FEASIBILITY ASSESSMENT (N)
TOTAL INTERVIEWS	6	9
TOTAL RESPONDENTS	9	9
RESPONDENT DEMOGRAPHICS		
SEX		
MALE	5	1+
FEMALE	4	5+

INSTITUTION (E.G., EMPLOYER) – ADDS UP TO >100%		
NON-PROFIT FOOD RESCUE/EMERGENCY FOOD	5 (SSx2, SFFBx2, Clatsop)	2 (Wax2)
SCHOOLS	1 (Jenn)	2 (CA, OR)
HOSPITAL	1 (Cynthia)	
PUBLIC AGENCY (E.G., HEALTH, PLANNING)	0	3 (CA, WA, Sea)
FISH-RELATED BUSINESS/ENTREPRENEUR	2 (PacSfd, Bay2Tray)	2? (Regx2)
COMMUNITY FOOD COALITION	1 (Cynthia)	
COMMUNITY		
CURRY COUNTY, OR (BROOKINGS)	2	1
DEL NORTE, CA (CRESCENT CITY)	5	2
GRAYS HARBOR, WA (WESTPORT)	2	3
SEATTLE, WA		1
REGIONAL		2

4.7.3 *Interview guides for positive deviant cases & feasibility assessment*

We collected data for both portions of this study through semi-structured key informant interviews conducted in-person or over the phone. Both of these interview guides were submitted to University of Washington Human Subjects Division and were determined to be exempt (IRB ID: STUDY00004939).

4.7.3.1 Positive deviant case study interview guide

To develop the interview guide for the case study portion of the study, we first identified a guiding framework outlining the US West Coast groundfish supply chain. Using the framework as a guide, we included open-ended questions about the fish supply involved (fishers and method, amount and type of species caught, marketability and cost); how fish is acquired, processed, and distributed; and descriptions of consumers and how/where they access the fish (e.g., demographics, preferences, food environment. The interview guide also included questions about the challenges, facilitating factors, and perceived opportunities for replicating or scaling up efforts.

POSITIVE DEVIANT INTERVIEW QUESTION GUIDE

Mention: If there is anything in this that you DON'T WANT TO BE SHARED let us know and we will flag it in the recording.

- 1) To begin, please describe [this partnership/system] in your own words.

Probe for:

- Which organization (or individual[s]) came up with the idea or initiated the effort? Why? What was/were their key interest(s)?
- Who are the key partners in this arrangement? (Probe for: purchasing/procuring organizations, suppliers, distributors)
- When did this happen? (Ask if not evident from other sources.) About how long did it take to get the process off the ground?

- 2) What types of fish species or product types are supplied through [this program/arrangement]?

- a. Do these species or products change or fluctuate, or generally stay the same throughout the year?

Probe for:

- ocean productivity change?
- fishing effort change?
- seafood market change?
- Certain times of the year when more of a species outside of market requirements become more available at the docks?

- b. What is the broader market generally like for these fish species and products? (Probe for waste, export/domestic/regional markets)

We are interested in understanding at least 6 different aspects of this effort/arrangement/program, specifically: your supply and distribution approach, interests of the buyers and consumers, things that posed challenges or enabled success, how you define success, and opportunities for replicating or scaling up this approach. In this interview, I'll ask about each of these topics.

- 3) First, who are the suppliers and distributors in [this program/arrangement]? (Probe for organization name, type, size, specialty if interviewee doesn't offer this information.)

- a. Have these changed at all over time, or do they always stay the same?
- b. Did you use existing distribution or create new?
- c. What is the incentive for these suppliers and distributors to participate in this particular program/supply/distribution arrangement?

- 4) Please tell me more about the pricing for the fish and products supplied through [this program/arrangement].

- a. Were you looking for a particular price point or range of pricing? (record points in supply chain)
 - b. Is there a price point at which the fish off the docks become too expensive to supply?
Probe for:
 - Whether changing markets changes this price point at different times of the year
 - c. To what extent do the suppliers see this arrangement as financially worthwhile?
 - d. To what extent do the purchasers see this arrangement as affordable?
- 5) What other notable issues have there been to contend with regarding supply of the fish or fish products, if any? *For example:*
- a. Is there a minimum or maximum supply volume required?
 - b. Any constraints from conservation measures (ie bycatch limits of conservation-concern species)
 - c. Are there any seasonality issues you had to contend with?
Probe for:
 - Day-to-day changes in availability of low-value
 - day-to-day variability in other species that meant there wasn't slack labor for low-value species
- 6) Next, please describe the types of institutions purchasing or procuring the fish in this arrangement. (*Probe for* size of fish, yield potential, maybe how else they procure food and if they procured fish before this program/arrangement)
- a. Why are these institutions interested in purchasing these particular fish types or products through [this program/arrangement]? (*Probe for* whether there is a specific interest in nutritional aspects of fish?)
 - b. How did you identify that these institutions might be willing to buy fish?
- 7) Who are the ultimate consumers of the fish in this arrangement? (Probe for significant demographics; values held; generally dietary preferences, restrictions or needs; socioeconomic status)
- a. Are there any particular fish species or product types that these consumers do or don't prefer?
 - b. Are consumers offered a choice in species? What constrains this choice?

8) What other notable issues have there been to contend with from the perspective of the buyer or consumer?

Probe for:

- Was it necessary to “market” the fish or provide any education to buyers or consumers?
- Did the people preparing the fish require any training or preparation to be able to use the fish?
- To what extent, if at all, is waste of fish a concern for the fish purchasers or consumers? Why is this?

9) What factors or conditions were critical to helping this arrangement be successful?

Probe for:

- Were there any champions on supply or demand side that were critical to success?
- Was the underlying motivation for this arrangement charitable or ethical in nature (e.g. desire to reduce the inequity of access of healthy foods for vulnerable people)? If so, how?
- Was this arrangement motivated by desires in the broader community?
- Did maritime heritage or identity as a current/former fishing community influence success?
- Was the local food movement influential?
- Perceptions that fish are a healthy animal protein?
- Did potential tax incentives factor in to development of the model?
- Was social media outreach or media coverage important?
- Did you receive grants or investment that was essential to development?
- Any essential partnerships that were either necessary to meet goals of the program?

10) What challenges have come up over the life of [this program/arrangement], and what did you do to address these?

Probe for:

- Any groups/stakeholders who were particularly resistant to the change?
- Were there any issues of consistency or seasonality (from producers or buyers)?

11) How have you defined success for [this arrangement/program]?

- a. Do any of the suppliers, buyers, or other partners collect or report data to monitor the success of this arrangement? If so, what measures and data do they use?

12) Finally, to what extent do you think there is potential for this model to expand and reach more people? If so, how? (*Probe for:* future plans of the business? change of plan? straight expansion?)

- a. What are the limits to the potential of this model?

Probe for: awareness of similar initiatives they either participated in or heard about that did not succeed.

- b. What would it take for other communities or regions to implement something similar?
 - c. What data points would you recommend that other communities track to assess success?
- 13) Thank you for your time. Is there anyone else you recommend that we speak with to understand this program?
- a. If so, would you be willing to introduce us?

4.7.3.2 Feasibility assessment interview guide

The interview guide for the feasibility assessment included questions about the local community's fish availability, consumption, and fish preferences; how community and food services source and offer/serve fish; and which populations could most benefit from additional fish in their diet. Additionally, we shared preliminary case study findings and asked for interviewees' reactions to and interest in similar efforts in their own community, any related or prior similar efforts in their community, potential community partners (e.g., fishers, processors, food service/retail), and perceived benefits and challenges that might arise with such efforts.

FEASIBILITY ASSESSMENT INTERVIEW QUESTION GUIDE

Mention: If there is anything in this that you DON'T WANT TO BE SHARED let us know and we will flag it in the recording.

Questions for "Fish facing" first buyers/harbor representatives/processors (n= 2-8 stakeholders/community) – The first set of interviews will focus on actors and firms closest to the docks

- 1) To begin, please describe what is landed in this port and where it goes.

Probe for:

- Local caught fish going to big buyers? Small buyers?
 - Are there specific species that remain local versus being sent to major markets?
 - Estimate of the proportions each species remaining local versus being sent to major markets?
 - Are there any species that used to be caught locally but are no longer? Any idea why?
- 2) How do you decide whether to sell locally?

Probe for:

- To what extent do perceptions of demand influence decisions to sell or not sell, or is this decision based on other factors?
 - a) To what extent does the local fishing industry currently catch/bring in underutilized/low market fish? If so, what kinds of bycatch go underutilized/unsold?
 - b) In what quantities?
 - c) How regularly?
 - d) Particular fisheries?
- 4) To what extent would the local fishing industry be interested in selling more underutilized fish? Bycatch?

- a) What are some challenges to selling more underutilized fish? Bycatch?

Probe for:

- Particular groups that might be resistant?

We have done some research and identified several interesting examples of harbors selling low market fish to schools, hospitals, and food banks. (describe key aspects of the case studies results from the first part of this interview protocol)

- 1) To what extent, if at all, do you think an arrangement along these lines might be beneficial for this port?
 - a) If so, in what ways?
 - b) If not, what are your concerns?
- 2) What, if anything, are you interested in learning more about these examples?

Questions for “Public-facing” public health planning agency officials/healthy diet program officials (X stakeholders/community, 2-4 communities) - actors and agencies that can speak to the dietary health and other food systems concerns of the local community in relation to potential integration (local/state public health, food insecurity/hunger, agriculture); status of healthy diet/food access programs and availability in communities:

- 1) Is fish consumption tracked?
 - a) What does this look like in the general population in your community? Is the demand/consumption higher or lower for specific groups?
- 2) Is fish demand tracked?

- a) What does this look like in the general population in your community? Is the demand/consumption higher or lower for specific groups?
- 3) Is fish supply tracked?
 - a) What does this look like in the general population in your community? Is the demand/consumption higher or lower for specific groups?
- 4) In your community, to what extent is fish/seafood addressed in messaging about healthy diets?
 - a) Why or why not?
 - b) To what extent, if at all, do you think there should be more discussion about this?
- 5) In your community, to what extent is fish/seafood focused on in terms of healthy food availability and affordability? Why or why not?
 - a) Why or why not?
 - b) To what extent, if at all, do you think there should be more discussion or focus on these topics?

We have done some research and identified several interesting examples of harbors selling low market fish to schools, hospitals, and food banks. (describe key aspects of the case studies results from the first part of this interview protocol)

- 6) Now we will ask about your thoughts on improved integration
 - a) Potential benefits?
 - b) Potential challenges?
 - c) General level of enthusiasm
- 7) In your community, which specific partnerships would be essential to creating an arrangement like this?

Probe for:

- 1) Particular actors in the potential supply chain (harvesters, wholesale distributors, public-facing buyers)

Now we will ask a bit about the capacity of healthy diet programs occurring in your community to use locally caught seafood.

- 8) Are there particular institutions in your community that might purchase fish to improve diets via healthy diet programs?
 - a) If so, what price, purchasing, or procurement considerations might each institution have?

Probe for:

- Schools? Hospitals? Food banks?

- 9) Is there a particular price break point of affordability to local consumers/institutions?

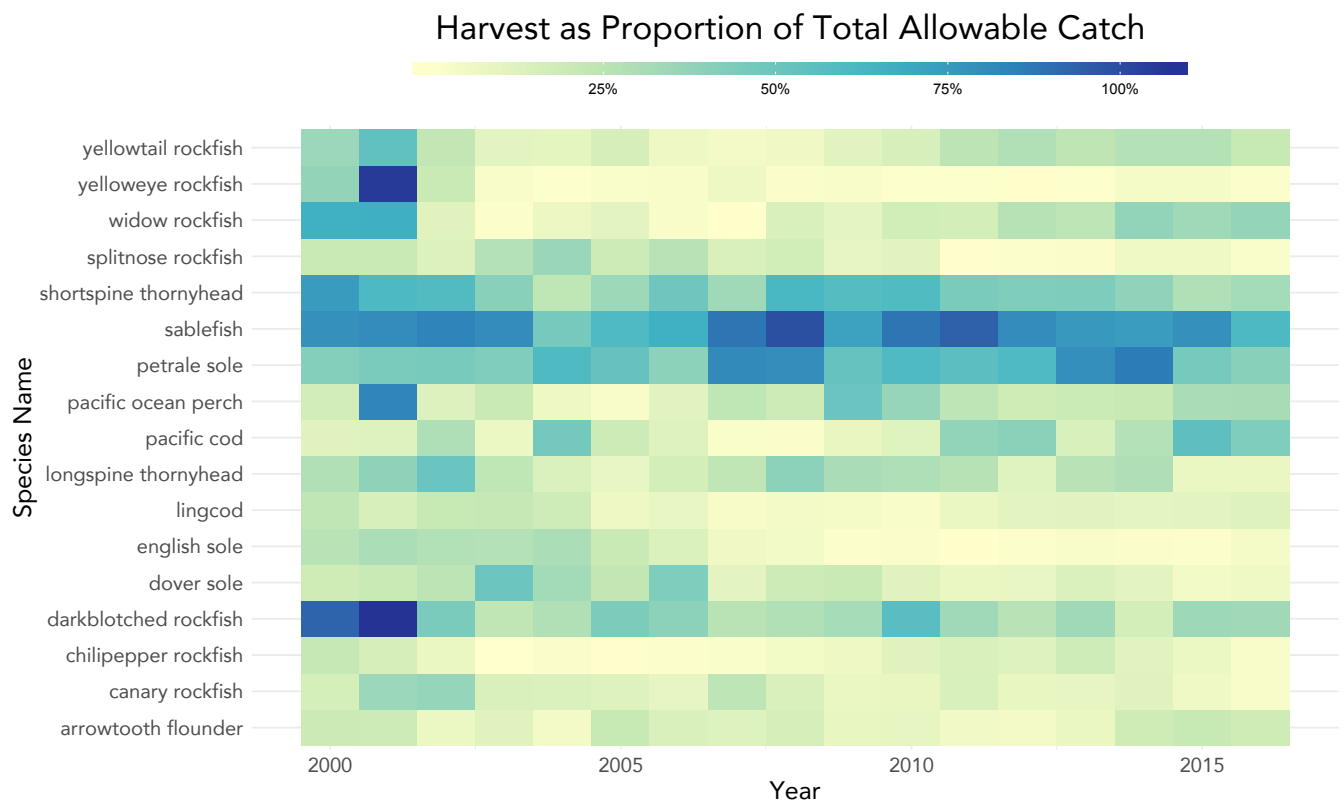
Questions for institutional buyers (*X stakeholders/community, e.g., emergency food distributor reps, schools, hospitals*) – *status of non-seafood sectors and market channels, and their integration potential with seafood:*

- 1) Is fish currently being purchased at/for your institution(s)?
If yes, Probe for:
 - a) Kinds of fish being purchased? Provenance of fish?
 - b) Quantity or frequency of fish purchased
 - c) Destination of fish (*Probe for: local markets, regional/export*)
 - d) Are there particular challenges?
 - e) Were there particular actors important to this?
- 2) Is your institution interested in purchasing more or different kinds of fish? Please explain.
- 3) To what extent is there demand for fish in your institution?
Probe for:
 - Is the demand for fish is tracked/understood?
 - Granularity of demand (general, subpopulations)
- 4) To what extent does your perceptions of demand influence your decisions to purchase fish/seafood, or is this decision based on other factors? *If other factors, Probe for: what are these?*
- 5) Is there a particular price break point of affordability to local consumers/institutions?
- 6) Are there notable benefits of offering/selling to your market?
We have done some research and identified several interesting examples of harbors selling low market fish to schools, hospitals, and food banks. (describe key aspects of the case studies results from the first part of this interview protocol)
- 7) Are there particular institutions that might purchase fish to improve diets?
- 8) To what extent, if at all, do you think an arrangement along these lines might be beneficial for this port?
 - a) If so, in what ways?
 - b) If not, what are your concerns?

4.7.4 *Diving into the details – utilization rates and affordability*

There was a noticeable difference in utilization rates – or harvest as a proportion of TAC – for species over time (Appendix Figure 4). In the years just after 2000, utilization was at its highest for many species but declined over time. For Yelloweye rockfish and Darkblotched rockfish,

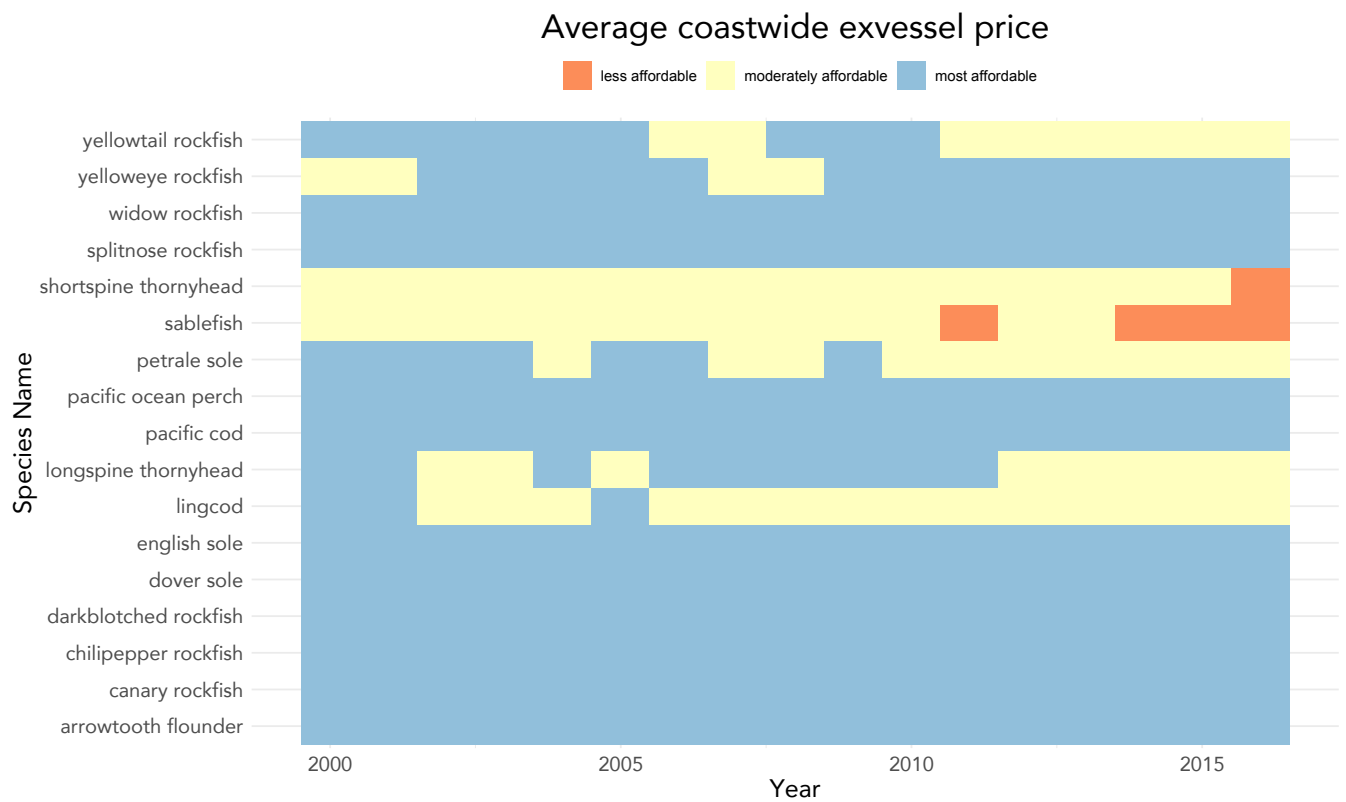
utilization were greater than 100%, which indicates overfishing. Now utilization for those species is far under TAC. The only species that have continued to have harvest rates close to their TACs are Sablefish and Petrale sole. A few of these species, including Yellowtail rockfish and Dover sole now have fairly high TACs but, as indicated in Figure 2, utilization is low, suggesting both of the species may be in position to provide high volumes of potential servings as shown in Figure 4-1.



Appendix Figure 4 - Proportion of catch to total allowable catch over time for quota species in the non-whiting US West Coast Trawl Fishery. When the proportion is close to 100%, that means the annual harvest is close to the TAC guideline set by managers for that year.

Affordability of the fish was based on benchmarks set by positive deviant cases discussed in Chapter 3. The values used were based on the exvessel price. We learned that the maximum wholesale price – which typically included processing and transportation for our case studies and increased the exvessel price two fold – that large purchasing institutions were typically willing to

pay was approximately \$5.00 per pound. Thus, the least affordable category was fish that were being landed at greater than \$2.50 per pound *average* exvessel price along the entire coastline. The moderate price point was between \$1.00 per pound and \$2.50 per pound and the most affordable price was less than \$1.00 per pound (Appendix Figure 5). Note that the only two species that are less affordable (exvessel prices greater than \$2.50 per pound are also the species that have recently had harvests closest to their TAC, suggesting the potential for increased profit, due to existing markets for these few species, is a major driver for utilization.



Appendix Figure 5 - Average coastwide exvessel price for quota species in the non-whiting US West Coast Trawl Fishery.

Chapter 5. ENVIRONMENTAL IMPACTS OF NUTRIENT PRODUCTION IN THE FOOD SYSTEM

5.1 ABSTRACT

Choosing what to eat impacts both health and the environment. Unhealthy eating is detrimental to personal health, and tends to have higher environmental impacts. As pressures continue to mount on environments around the world, there is increasing emphasis in research and in policymaking to press for an agenda for food production that meets two objectives: to decrease human impacts on their environment and to improve human health. Recent discussions of healthy, and sustainable diets have encouraged an increased consumption of vegetables and a decreased consumption of animal-sourced foods, especially red meats like beef. As a broad food group, fish and shellfish are often considered a better alternative to other animal-sourced foods. However, life-cycle assessments have shown that fish and shellfish production varies widely in terms of its environmental impact and with respect to the nutrient richness of different species. Our research evaluated how different species and modes of seafood production compare to other animal-sourced foods and to plant-based foods with respect to their environmental impact and nutrient richness by linking information from a life-cycle assessment review to nutrient values for the same food products. We found that the lowest environmental impact and most nutrient rich foods were vegetable food groups like grain, tubers, root, seeds, as well as small pelagic fish in wild capture production and bivalves in aquaculture production. The highest impacts tended to be in beef, pork as well as farmed catfish, tilapia and prawns and crustaceans and prawn in wild capture fishery production. These results indicate that, among animal sourced foods, some fish and shellfish have environmental impacts at least as low as vegetables and should be seriously

considered in subsequent research and in food systems policymaking for their potential to support a healthy, sustainable diet.

5.2 INTRODUCTION

Food production does not occur without negative impacts; each acre farmed or fish caught has some associated environmental cost. As global populations continue to grow, increased strain will be placed on the farmlands and fishing grounds, both in terms of rising demand and competition with other uses. Continued growth and development also places additional strain on our climate, and the resulting climatic changes will in turn influence regional food productivity (Godfray et al., 2010). Our food systems include not only land-based production, but also wild capture fisheries and, increasingly, aquaculture (Seto & Fiorella, 2017). Interestingly, food system science has been slow to consider seafood as a component of the food system and healthy diets. A pertinent review by Farmery et al. found that seafood is “regularly excluded from debate on food security and food systems research,” and when included seafood consumption is viewed as a tradeoff between positive health outcomes and overfishing concerns, and that a limited assessment of seafood was possible because relevant data sources were not incorporated into models (Farmery et al., 2017). When included in global assessments all fish, both wild capture and aquaculture is often included as a single commodity despite the widely varying environmental impacts of different fish production systems. This is, in part, due to the fact that the research and policy agenda for fishery systems and food security run “on independent tracks, with only loose and superficial links between them” (S. J. Hall, Hilborn, Andrew, & Allison, 2013).

Seafood production does not exist in a vacuum; the nutrient content and environmental costs of alternative seafoods should be compared to alternative food production systems. While

most discourse on the nutritional benefits of fish and shellfish have centered on protein and Omega-3s, many fish and shellfish may play a critical role in addressing micronutrient deficiencies (e.g., Vitamin A, calcium, Vitamin B12, iron, zinc) (N. Kawarazuka, 2010), and these nutrients are oftentimes in more bioavailable forms in fish and shellfish than they are in many vegetables, fortified staples, and food supplements (Bogard, Thilsted, et al., 2015; Thilsted et al., 2016). For many countries facing nutrient deficiencies, finfish catches alone could exceed dietary requirements for all people living within 100 km of the coast and even a fraction of this catch could be important for childhood nutrition (Hicks et al., 2019), if these fish resources were accessible to fishers and made available to consumers. Potential nutritional benefits are not limited to coastal communities inland capture fisheries production has increased each year, with most recent data indicating a 11.6 million metric tons in 2016, and inland aquaculture is much larger, producing 51.4 million metric tons in the same year (FAO, 2018). Given the potential of seafood to provision nutrient-rich and diverse animal proteins, its absence in food systems and sustainable diet research is remarkable. In countries with current or potential fishery production and consumption, food system researchers should at least consider fisheries and aquaculture production in any analysis related to food security and diet-based health outcomes, especially as researchers begin to considering the environmental impact of food production at planetary scales.

A number of analyses have assessed the environmental impacts of our diets and, relatedly, of the food production system. Life cycle assessments (LCAs) have emerged as a prominent method to estimate environmental impacts of agricultural production including seafood. A review of seafood LCAs revealed metrics ranging from greenhouse gas emissions and per capita energy use to eutrophication to human and ecological toxicity (Pelletier et al., 2007). A 2017 paper by Clune et al. synthesized 369 published studies across vegetable and animal

sourced foods (ASFs) to help streamline subsequent work on the global warming potential of diet options, and found that fruit and vegetables had the lowest impact whereas ruminant meat had the highest (Clune et al., 2017). This research also included a variety of species of fish and shellfish, and determined that the broad category of fish were among the lowest global warming potential across all ASFs, comparable to chicken, but that some small fish (e.g., pilchard and herring) had a global warming potential similar to some vegetables (Clune et al., 2017). In 2018, Poore and Nemecek used a model-based approach to estimate multiple environmental impacts throughout the supply chain, relying on thousands of datapoints from farms, processors, packaging and retailers (Poore & Nemecek, 2018). It estimated that throughout the supply chain, production up to the farm gate hold the greatest proportion of GHG emissions, acidification and eutrophication relative to subsequent links in the supply chain (Poore & Nemecek, 2018). However Poore and Nemecek considered “fish” and “crustaceans” as broad categories, and not further breaking down into finer-scale food groups. Both Clune et al and Poore & Nemecek were primarily focused on advancing our understanding of environmental impacts of food production systems, not on their potential to contribute specific nutrients to support a healthy diet.

Life cycle assessments have also been used to analyze the environmental impacts of entire diets. Recent findings indicate that the global transition towards less healthy “Western” diets high in calories and low in nutrients also have higher greenhouse gas emissions (GHGs) relative to Mediterranean, pescatarian or vegetarian diets (Tilman & Clark, 2014). More recently, The Lancet commissioned a consortium of researchers in health, agriculture, political and environmental science with the goal of consumption targets that achieve a healthy reference diet and also minimize environmental impacts, consisting “primarily of vegetables, fruits, whole grains, legumes, nuts, and unsaturated oils, includes a low to moderate amount of seafood and

poultry, and includes no or a low quantity of red meat, processed meat, added sugar, refined grains, and starchy vegetables” (Willett et al., 2019). Fish, like many other foods, were considered in aggregate for many of these studies. As a category, “seafood” represents a multitude of species and modes of production, it is important to consider not only the species but also both broad production system (i.e. capture fisheries or aquaculture) but also the specific form of production (e.g., trawl, troll, trap gear types for capture fisheries) that produce specific species with particular nutrient compositions and environmental impacts.

There were few reviews of LCAs focused specifically on fisheries and aquaculture production sectors. As aquaculture production continued to grow, so too did interest in its environmental impact. In 2011, a review by two environmental nonprofit organizations assessed different aquaculture systems and found that they compared favorably to land-based animal-sourced foods (i.e., beef and pork, but that there was considerable variability in aquaculture systems by species type and production intensity, driven primarily by energy use and feed inputs (S. J. Hall et al., 2011). An LCA meta-analysis of animal proteins finds that across all production systems and environmental impacts, wild-capture small pelagic fisheries performed best while industrial beef and catfish aquaculture performed worse (Hilborn et al., 2018). Especially given the perceived negative impacts of climate change on nutrient outputs, there is still a considerable and practical need to understand how different production systems minimize environmental impacts and maximize nutritional output. A recent study compared seafood products commonly consumed in Sweden to determine their nutritional density (Hallström et al., 2019). While most LCAs look at GHG and nutrient release, capture fisheries also have no use of antibiotics, pesticides or herbicides, little if any freshwater, and rarely transform ecosystems to the extent that crop production does.

To date, research into the environmental impacts of food production have not, in one study, evaluated the variability across fishery and aquaculture production relative to other food systems as well as considered how these impacts compare in terms of meeting recommended intakes across a suite of macro and micronutrients. This research extends the work of Hilborn et al. (2018) and Hallstrom et al. (2019) to include products range from land and marine animal-sourced foods as well as a selection of plants that have yet to be reconciled with the ASF literature. This work establishes a connection between nutrient outputs and environmental footprints to determine which sectors of animal-sourced protein production are the most efficient providers relative to their impact on the environment. This work evaluates environmental tradeoffs in the production of macro- and micro-nutrients to improve decision-making toward more nutrient-dense food outputs that minimize environmental impact.

5.3 METHODOLOGY

5.3.1 *Summary of datasets*

The environmental impacts database includes 1826 observations for 160 plant- and animal-based food products, originating from 84 databases Appendix Table 10. LCAs included in these datasets measured a variety of impacts (Table 5-1). To generalize the specific chemicals, the LCAs had converted all chemicals to equivalents commonly used to quantify broader impacts (e.g., CO₂ equivalent for GHG emissions or SO₂ equivalent for acidification), using calculations provided by Hilborn et al. (Hilborn et al. 2018). For animal-based foods also converted all impacts to grams of edible product using conversion tables from Hilborn et al. System boundaries - which bound the aspects of the value chain for which impacts are to be estimated in a life cycle assessment - were standardized to the farm/dock gate. When system boundaries in the LCA extended beyond the farm or dock gate for plant based products, we subtracted the post

farm gate contribution estimated by Clune et. al (Clune et al., 2017). Because Clune et al. only included GHG estimates, we were able to transform system boundaries GHG impacts (Eq. 1). Any remaining impacts that were not transformed to the farm/dock gate were excluded from the analysis.

$$I_{p,g} = I_{p,t}S_{p,g-t} \quad (1)$$

Where I is the impact such as GHG, p is the product, g designates to the farm gate, t is the total impact to retail, S is the fraction of the impacts that occur from one stage to another and g-t indicates the fraction from farm gate to total.

Table 5-1 - Frequency of observations in each environmental impact and food production system boundary group included in the studies.

	Processing	Farm gate or dock	Distribution	Retail	Consumption	Incomplete	Unknown	Total
Acidification	4	153	8	3	8	16	1	193 (11%)
Eutrophication	4	151	8	3	8	10	1	185 (10%)
Fuel use	4	153	19	0	12	10	1	199 (11%)
GHG emissions	0	927	0	4	11	17	1	960 (52%)
Land use	0	125	4	3	6	18	0	156 (9%)
Water use	1	21	4	0	3	5	99	133 (7%)

	Processing	Farm gate or dock	Distribution	Retail	Consumption	Incomplete	Unknown	Total
Total	13	1530	43	13	48	76	103	1826

5.3.2 *Methods used relate environmental impacts to nutrient production*

Impacts from this dataset included greenhouse gas emissions, eutrophication, ocean acidification, and water, land and fuel use. The largest number of impact studies were for greenhouse gas emissions, followed by fuel use, acidification and eutrophication (Table 1). Impacts in these datasets varied both in terms of the units of impact as well as the units of the food product. GHG emission, eutrophication and acidification impacts were standardized to gram of impact per 100 gram equivalents; land use was standardized to meters squared per 100 grams of product, water use was standardized to meters cubed per 100 grams of product, and fuel use impacts were standardized to MJ per 100 grams of product. Nutrition information from the USDA Food Composition database includes information on 43 nutrients across 213 food products in 34 different food groups. All products within the food groups are listed in Appendix Table 9. Units were standardized to the same gram per 100 gram equivalents.

To create the nutrition richness index, we followed the method of Drewnowski et. al (Drewnowski, 2009) that calculated the ratio of nutrient concentrations in nutrient per 100 grams to daily needs for each nutrient from to calculate the proportion of daily requirements for each nutrient contained in 100 g of the product. Then, the mean across each nutrient ratio was calculated, both for “beneficial” nutrients and “limiting” nutrients that should be limited from the diet (i.e., saturated fats, sugars, sodium). We modified the original method of the nutrient richness index in two ways. The first was to add a combined value of DHA and EPA Omega-3

fatty acids - marine-based and often discussed as important contributors to maternal and childhood health (N. Kawarazuka, 2010) - to the “NR15” nutrient group used by Drewnowski 2009 and to make these calculations just on the “beneficial” set of nutrients scaled by the energy density for each food product. The second was to only focus on richness of “beneficial” nutrients in each product and to maximize the number of nutrients for which we had more products represented. In total, 12 beneficial micronutrients were used (Appendix Table 11). To calculate the nutrient richness index, we determined the individual richness of each nutrient in terms of 100 gram servings. (Eq. 2).

$$N_{p,n} = \frac{C_{p,n}}{D_n} \quad (2)$$

Where nutrient richness N is the proportion of the daily requirement of a given nutrient n per 100g of edible product met by that product’s concentration of a given nutrient per 100 grams, n is the nutrient, p is the product. C is the concentration of a given nutrient per 100 grams of edible product, and D is the daily requirement required by adults.

Once nutrient richness scores were calculated for each individual nutrient the scores were averaged across all 12 micronutrients to create the nutrient richness composite index (Eq. 3).

$$R_p = \frac{\sum_{i=1}^{12} N_{p,n}}{12} \quad (3)$$

Calculating the environmental impacts of nutrient production required a ratio of impacts to nutrient concentrations. Impact ratios were calculated for as both impacts per individual nutrients (Eq. 4) and per nutrient richness composite index (Eq. 5).

$$S_{p,n} = \frac{I_p}{N_{p,n}} \quad (4)$$

S is the impact ratio for each product and each individual nutrient richness value, calculated as the ratio of impact per 100g of edible product to nutrient richness value.

$$G_p = \frac{I_p}{R_p} \quad (5)$$

G is the impact ratio for each product and each nutrient richness composite index, calculated as the ratio of impact per 100g of edible product to nutrient richness composite value.

Each impact ratio was calculated for each combination of environmental impact and nutrient concentration for each product (e.g. 3 observations of GHG impacts per nutrient meant 3 impact ratios). Impact ratios were also calculated for specific micronutrients where there are remaining concerns from the public health community regarding their deficiencies in diets around the world, namely zinc, iron, folate and vitamin A (R. L. Bailey, West, & Black, 2015). Vitamin B12 and Omega 3's from DHA and EPA fatty acids - which are only available in marine-sourced products – were also included. These impact ratios for specific micronutrients were calculated using Eq. 4.

5.4 RESULTS

5.4.1 *Nutrient richness across foods*

The nutrient richness index reveals a considerable difference across food production groups. The index represents the ratio of nutrient concentrations in each food to the daily recommended intake for that nutrient is averaged across 12 beneficial micronutrients for each food. Among most nutrient rich food product groups, salmon and small pelagic fish (e.g., anchovy, herring, pilchards) rated highest, along with bivalves (e.g., mussels), crustaceans and, surprisingly shark – though that had a single sample in the food group. Some plant products - particularly nuts, grains and seeds - were nutrient-rich (Figure 5-1). Beef, lamb and veal were the most nutrient-rich of land-based ASFs. As a product group whitefish exhibited considerable variability, including products among the highest nutrient richness to some of the lowest. The lowest nutrient richness among ASF

products were prawns, tilapia, catfish, pork and dairy products and among plants were bulbs, stems and fruits. In this nutrient index, small pelagic fish and salmon products both had median food scores *higher* than vegetables.

Nutrient Richness Index

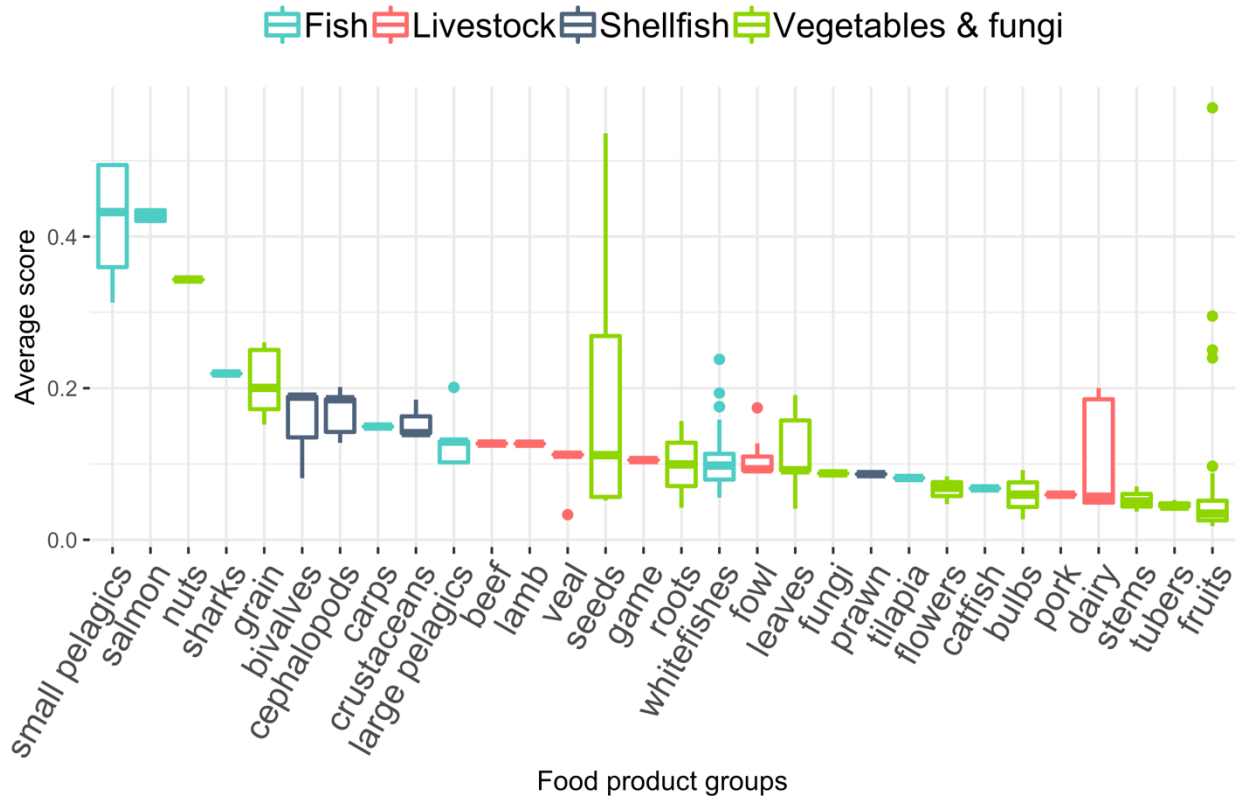


Figure 5-1 - Nutrient richness index scores averaged across 15 nutrients. For this and subsequent bar plots the horizontal bar is the median for each food group. The boxes represent 50% of the products in each food group, whereas the vertical lines represent 95% of the products in each food group. Dots represent outliers.

5.4.2 GHG emissions

Greenhouse gas emissions were by far the most studied in LCAs of environmental impacts. With respect to nutrient richness index reported above, plant-based foods had generally lower GHG emissions per unit of the richness index compared to most ASFs (Figure 5-2). But there were significant exceptions. Small pelagic fish (the most abundant in global capture fisheries) which

were shown to be the most nutrient rich across all food groups, when considering GHG emissions associated with their production, the median level of emissions for root vegetables is lower.

GHGs relative to nutrient richness

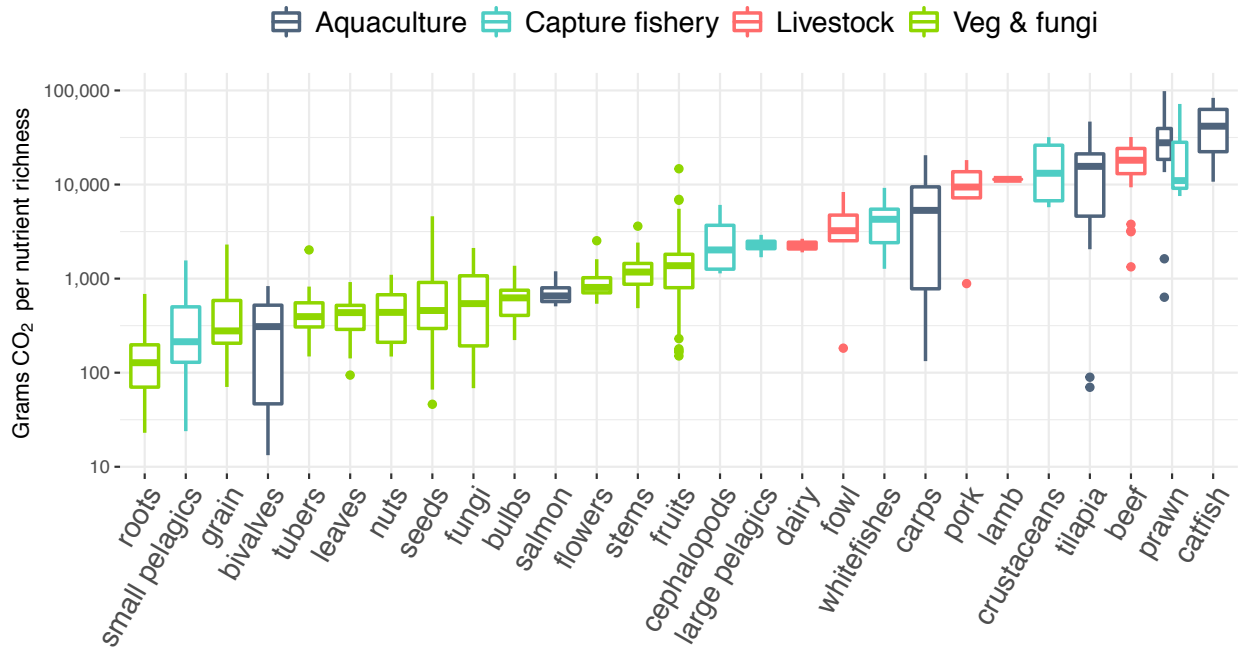


Figure 5-2 - Greenhouse gas emissions relative to nutrient richness across major food groups. Note the y-axis is on a logarithmic scale.

Small pelagic fish, bivalves and salmon all had GHG impacts per nutrient richness much lower than other land-based ASFs, where dairy and fowl (e.g., chicken) had the lowest GHG impacts per nutrient richness and pork, lamb and beef had the highest. Land-based ASFs had much higher median GHG emissions than most marine and aquatic ASFs, with the exceptions of crustaceans, tilapia, prawns, catfish where the LCAs show GHG impacts per nutrient values higher than livestock.. The GHG emissions per nutrient richness of small pelagic fish was a 77 fold less than beef and a 204 fold less than farmed catfish. While prawn production generally had very high GHG emissions per nutrient richness, it varied depending on production sector: prawn capture fisheries had lower GHG emissions per nutrient richness compared to prawn aquaculture.

For individual micronutrients where there are known micronutrient deficiencies - all of which were included in the nutrient richness average calculation in Figure 5-2 above - again there is a consistent pattern of bivalves and small pelagic fish having the lowest GHG emissions in order to meet daily requirements among all ASFs because of high concentrations of many micronutrients, but vegetables are oftentimes even lower.

For Zinc, grains, fungi and bivalves have the lowest GHGs to meet the dietary requirement while prawn, tilapia and catfish are the highest (Figure 5-3). Compared to the lowest emitting ASF bivalves, grain had 2.7 times lower emissions in order to meet the daily requirement for Zinc. To meet iron requirements, tubers and grains had the lowest impact, with bivalves being the lowest among ASFs by a considerable amount (Figure 5-3). Tubers were 1.7 times lower than bivalves, which were 1.4 times lower than small pelagic fish - the next lowest GHG emissions in order to meet this commonly deficient micronutrient requirement.

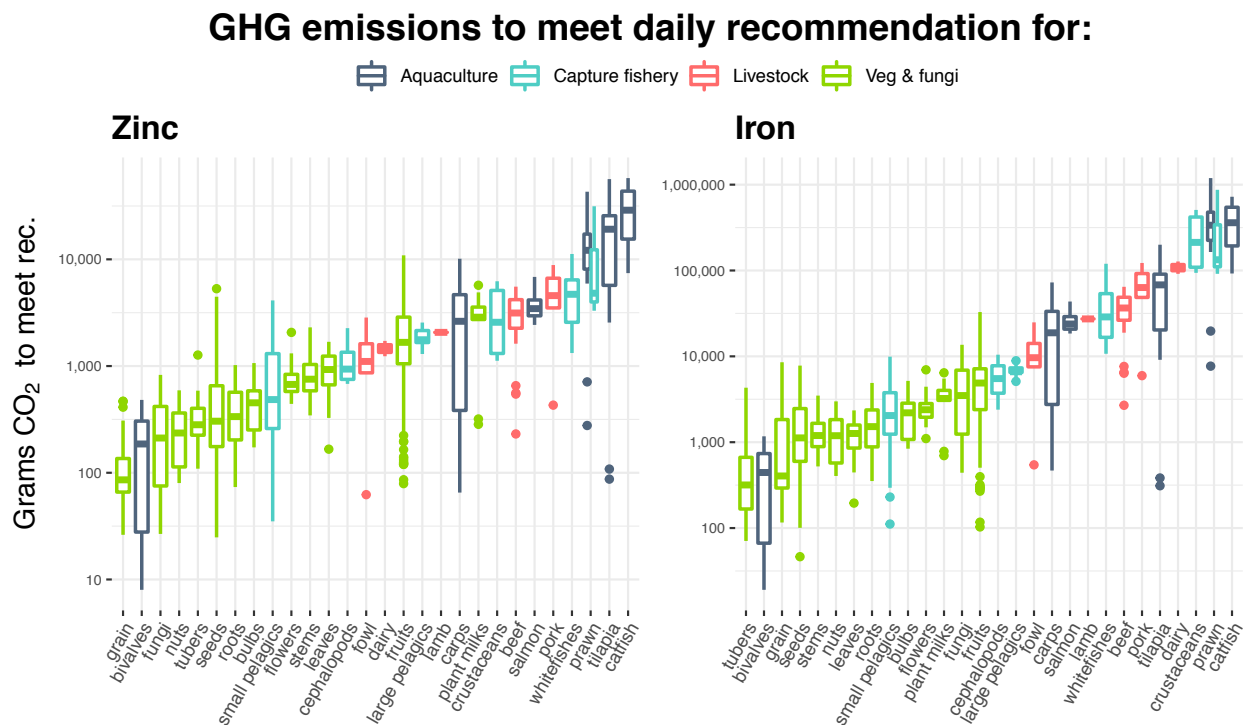


Figure 5-3 - Greenhouse gas emissions associated with meeting daily recommended intake of Zinc and Iron. Note the y-axis is on a logarithmic scale.

The GHG emissions to meet Vitamin A requirements were markedly lower for root vegetables and leaves, followed by bivalves with emissions 62 times higher than roots (Figure 5-4). Dairy products are the next lowest ASF, followed by small pelagic fish. Across all food groups, crustaceans had the highest GHG emissions required to meet the daily requirement for Vitamin A. Folate tends to be most concentrated in vegetables, and most of the lowest emission food groups are consequently seeds, flowers, roots, leaves bulbs and tubers (Figure 5-4). Bivalves require the lowest GHG emissions to meet folate recommendations at 84.3, but this is still 2 times higher than seeds. Beef had the highest impacts in order to meet folate recommendations.

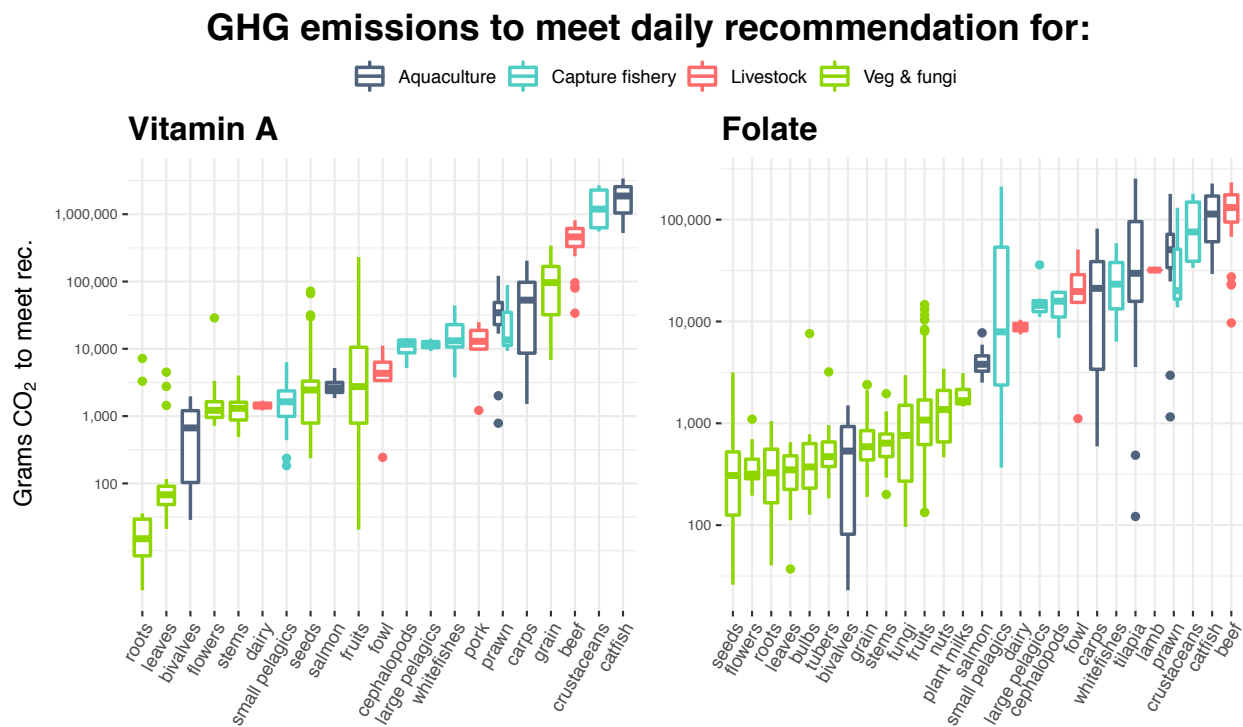


Figure 5-4 - Greenhouse gas emissions associated with meeting daily recommended intake of Vitamin A (RAE) and Folate. Note the y-axis is on a logarithmic scale.

DHA and EPA Omega 3 fatty acids and Vitamin B12 are two final micronutrients that are specific to marine products and to animals, respectively (Figure 5-5). The GHG emissions needed to meet Omega 3 requirements are lowest for small pelagic fish, salmon and bivalves and highest

for beef, catfish and pork. While DHA & EPA Omega 3's originate in marine environments, fishmeal is sometimes fed to livestock, which explains how food groups like fowl, pork and beef have some, but low, Omega 3 concentrations. Small pelagic fish have GHG emissions 3 times lower than salmon and bivalves, and 368 times lower than tilapia and catfish. For Vitamin B12, the lowest GHG emissions are found in bivalves and small pelagic fish, followed by salmon and cephalopods. Livestock considered rich in Vitamin B12 like pork, beef and fowl emit CO₂ in quantities 109 times higher than bivalves and small pelagic fish in order to meet daily recommendations.

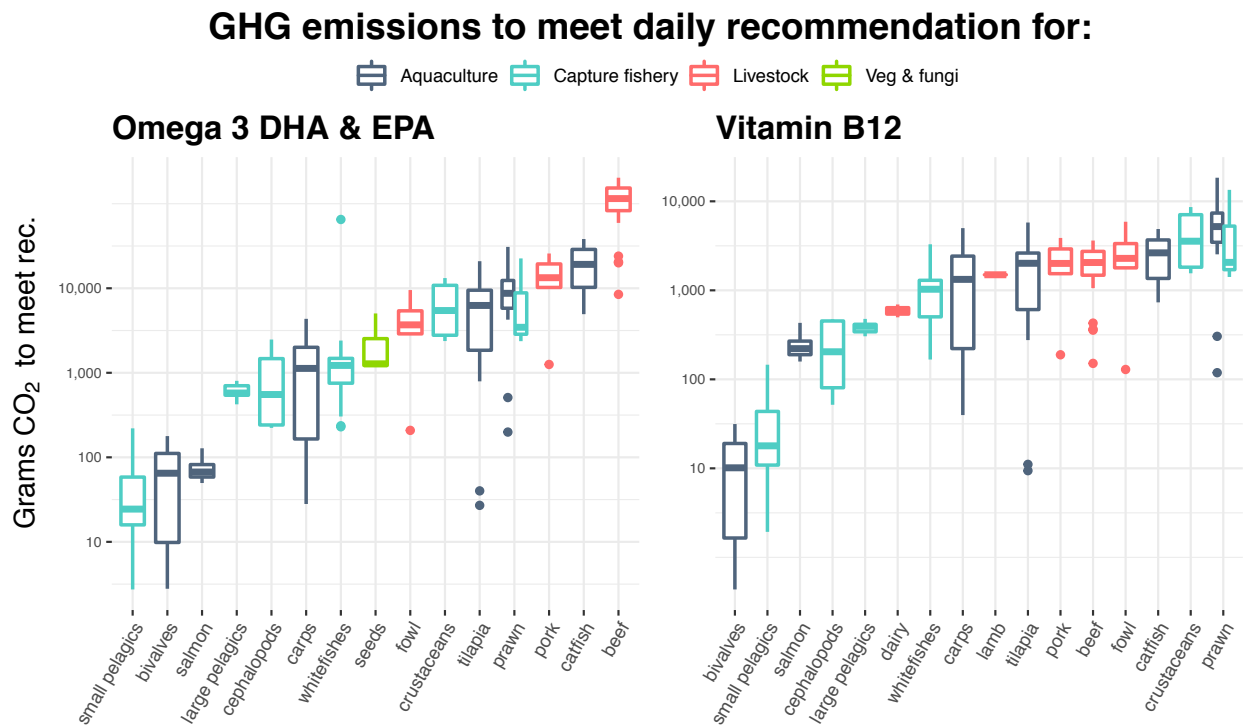


Figure 5-5 - Greenhouse gas emissions associated with meeting daily recommended intake of Omega 3 (DHA & EPA) and Vitamin B12. Note the y-axis is on a logarithmic scale.

5.4.3 Eutrophication

The median score for bivalves was negative, because bivalve species like mussels, oysters and clams filter out chemicals associated with eutrophication (Figure 5-6). Of studies that found there

was a positive contributed towards eutrophication, bivalves remained the lowest eutrophication impacts relative to their nutrient richness with an 4 fold decrease from the impact of the next lowest - and only vegetable food product with measured eutrophication impact - of tubers and an 2 fold decrease of the median value for small and large pelagic fish together. Farmed fish had much higher eutrophication impacts; tilapia, carp and catfish had 369 times the eutrophication impact for their nutrient richness as bivalves. Among specific nutrients with higher prevalence of deficiencies, bivalves have the lowest eutrophication impacts. Compared to bivalves, small pelagic fish and dairy have an impact 10 times higher for Vitamin A, and the impacts are 9865 times greater for beef.

Eutrophication relative to nutrient richness

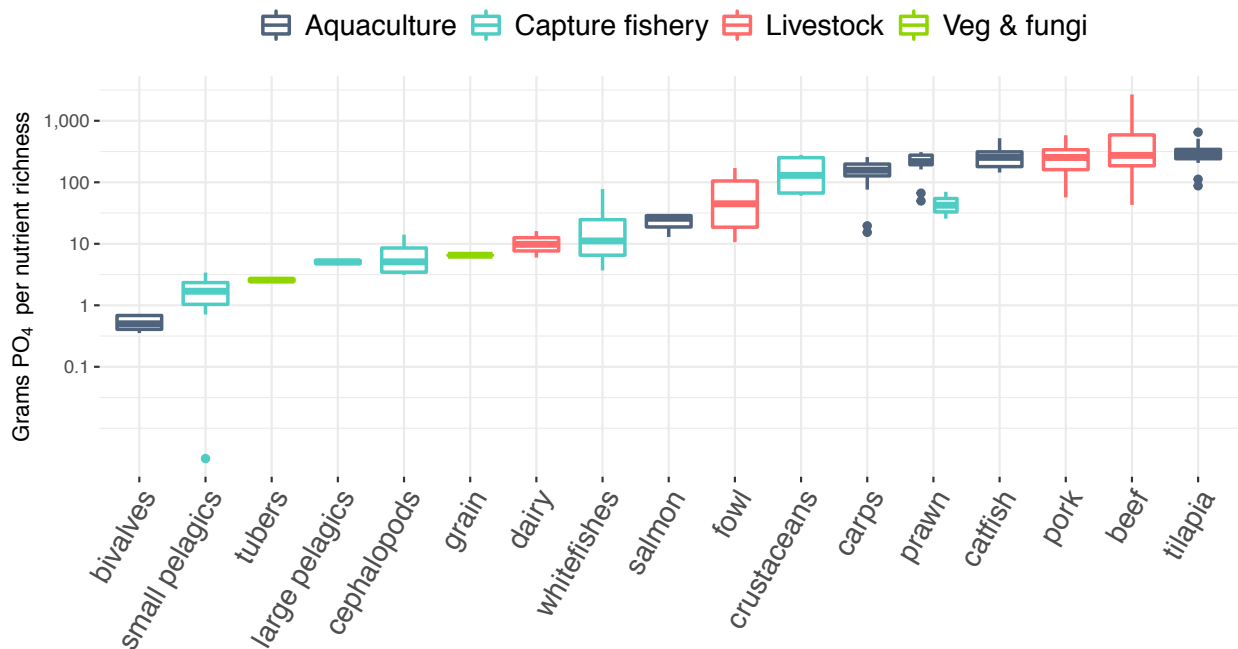


Figure 5-6 - Eutrophication impacts relative to nutrient richness across major food groups

Eutrophication impacts relative to nutrient richness were lowest for bivalves and small pelagic fish. There was limited data on vegetables, but foods in the tubers and grains groups had low eutrophication relative to their nutrient richness. The poorest performing food groups were

tilapia, catfish, beef and pork. Tilapia and catfish had the highest eutrophication impacts relative to its nutrient richness, 532 times higher than bivalves and small pelagic fish.

In meeting the daily recommendation for zinc and for iron, bivalves have the lowest eutrophication levels (Figure 5-7). For zinc, grain and tubers provide the next lowest eutrophication, whereas catfish and tilapia provide the highest. Salmon also has high eutrophication impacts in meeting the daily needs for zinc. For iron, tubers, small pelagic fish, large pelagic fish and cephalopods have low eutrophication impacts, whereas crustaceans, prawn and catfish have the highest impacts. Other than bivalves, capture fisheries had lower eutrophication impacts than most aquaculture production food groups.

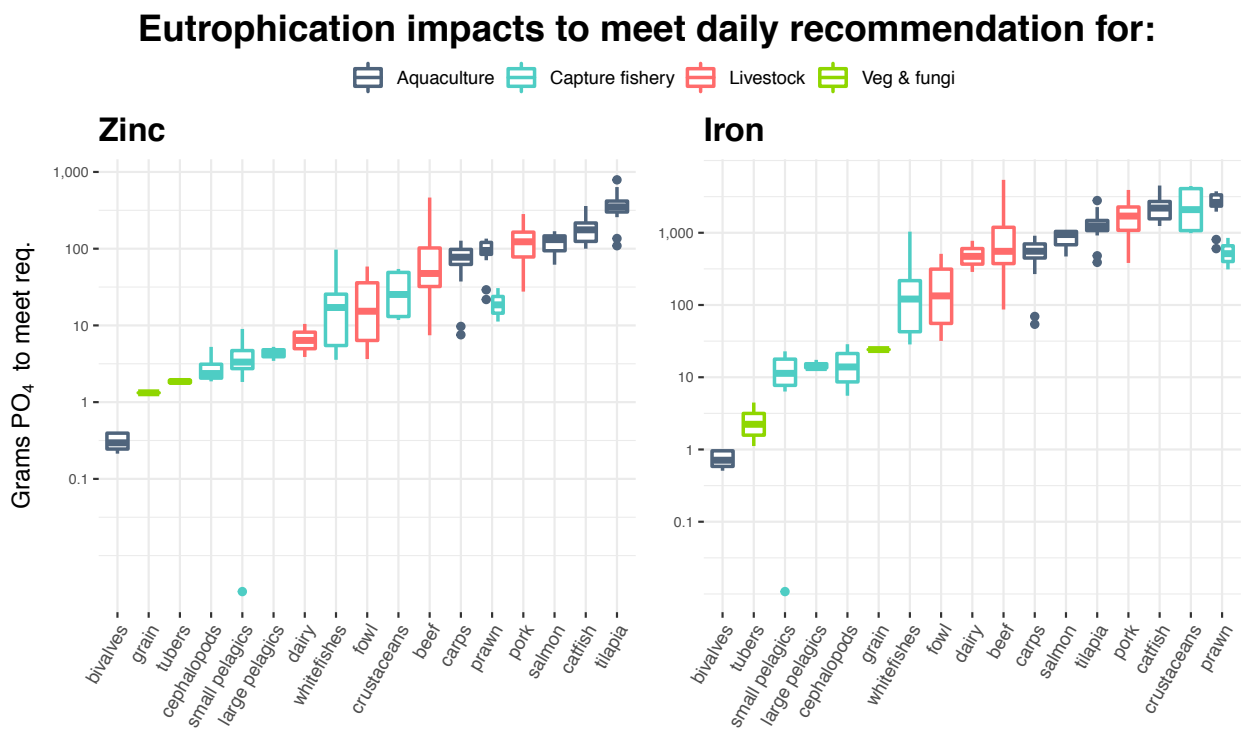


Figure 5-7 - Eutrophication impacts associated with meeting daily recommended intake of zinc and iron. Note the y-axis is on a logarithmic scale.

Eutrophication impacts for folate and for Vitamin A reflect the same trend: bivalves have the lowest eutrophication impacts in order to meet Folate and Vitamin A daily requirements and, unlike many other metrics, dairy also had a fairly low impact in meeting both micronutrients

(Figure 5-8). For Folate, the next lowest eutrophication impacts were tubers, grains and large pelagic fish, whereas the highest were beef, crustaceans and carp. For Vitamin A, small pelagic fish, large pelagic fish and cephalopods had low eutrophication whereas crustaceans, beef and carp had the highest. Similar to zinc and iron above, it tended to be the case that capture fisheries had lower eutrophication impacts than most aquaculture production food groups.

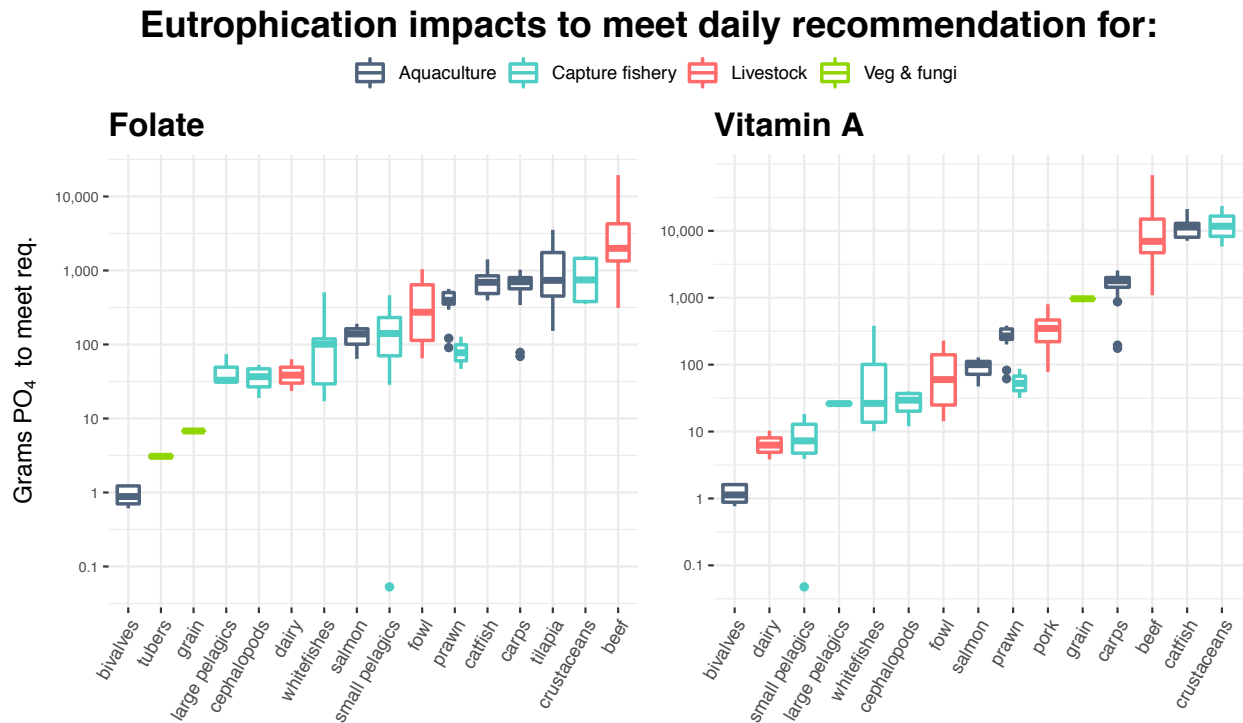


Figure 5-8 - Eutrophication impacts associated with meeting daily recommended intake of Folate and Vitamin A (RAE). Note the y-axis is on a logarithmic scale.

Bivalves and small pelagic fish had the lowest eutrophication impacts associated with meeting Omega 3 (DHA & EPA) and Vitamin B12 (Figure 5-9). With Omega 3s, the next lowest eutrophication impacts were large pelagic fish and salmon, whereas the highest were beef and pork. For Vitamin B12, cephalopods and large pelagic fish had the lowest eutrophication impacts whereas pork, crustaceans and carp had the highest. For Vitamin B12, seafood caught in capture fisheries tended to have lower eutrophication than aquaculture-produced foods though Omega 3s did not show as noticeable of a pattern.

Eutrophication impacts to meet daily recommendation for:

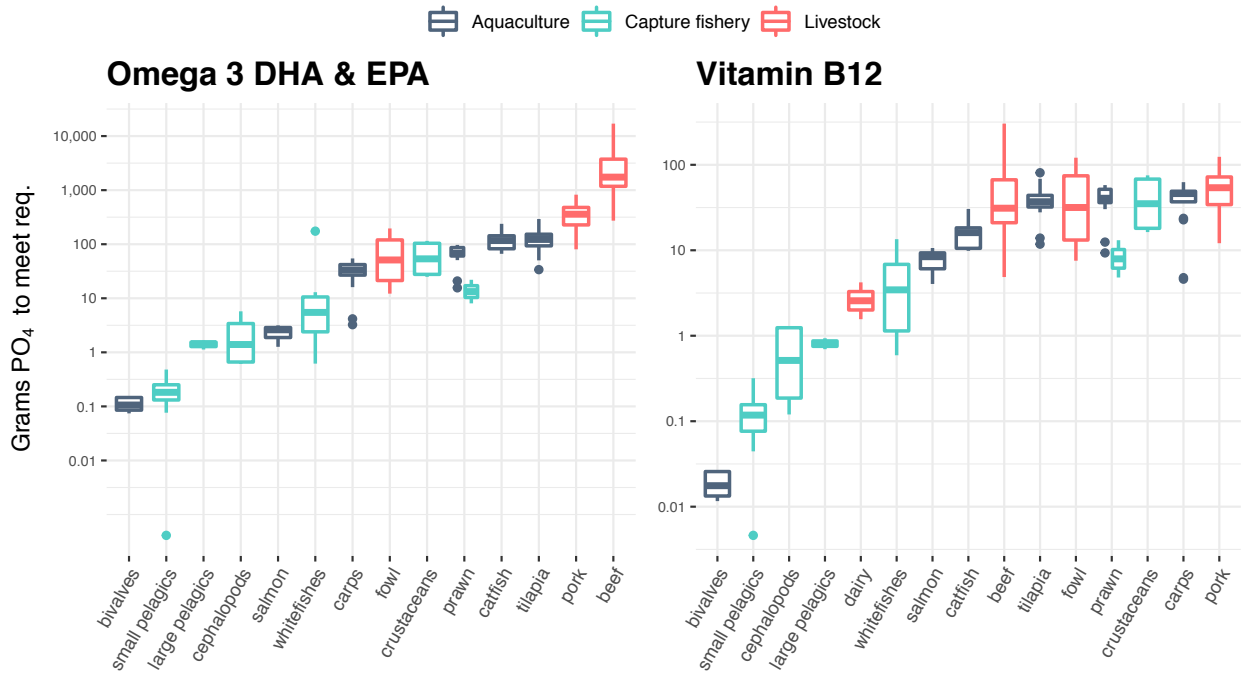


Figure 5-9 - Eutrophication impacts associated with meeting daily recommended intake of Omega 3 (DHA & EPA) and Vitamin B12. Note the y-axis is on a logarithmic scale.

5.4.4 Acidification

When considering nutrient richness, acidification impacts were lowest for bivalves, tubers and small pelagic fish (Figure 5-10). Among land-based ASFs, dairy had the lowest acidification levels, but was still 14 times higher than bivalves or the lowest impact vegetable, tubers.

Acidification relative to nutrient richness

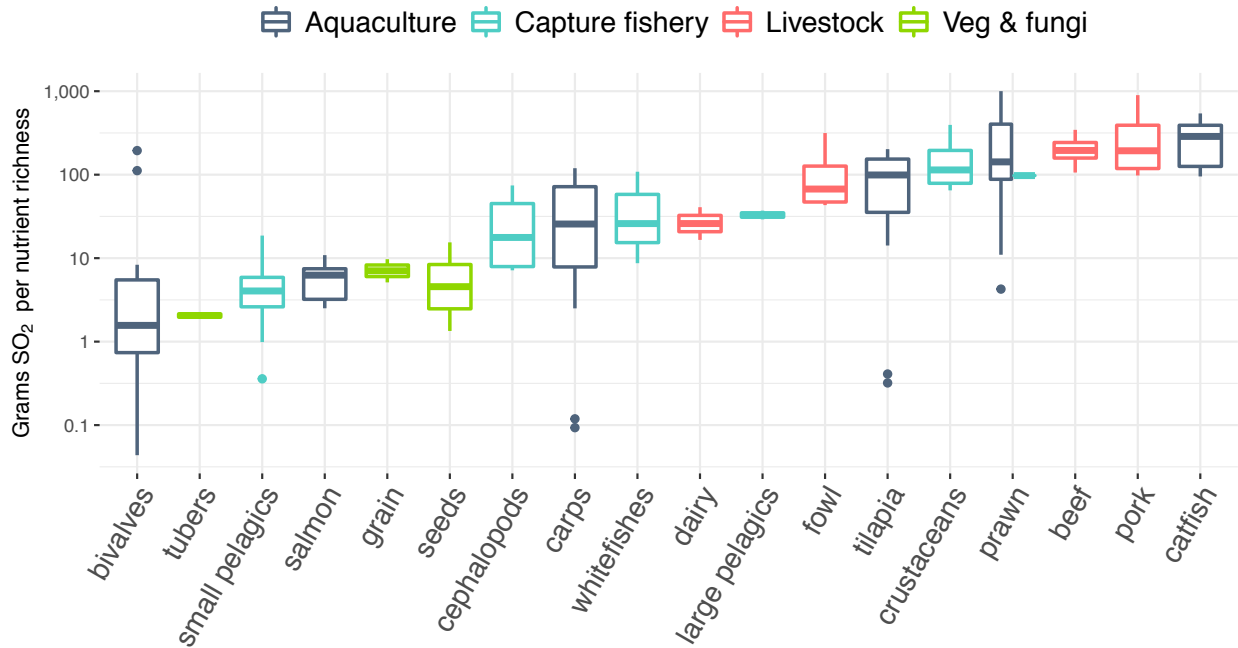


Figure 5-10 - Acidification impacts relative to nutrient richness across major food groups. Note the y-axis is on a logarithmic scale.

To meet acid the daily recommended intake for zinc, bivalves, tubers, grain and seeds had the lowest acidification impacts (Figure 5-11). Catfish, tilapia and pork had the highest acidification impacts in order to meet zinc recommendations. To meet iron recommendations, tubers and bivalves had the lowest acidification impacts, followed by grains, seeds and small pelagic fish. Catfish, crustaceans, prawns and pork had the highest acidification impacts in order to meet iron recommendations. Small pelagic fish, which was consistently among the lowest impact across most micronutrients had comparably higher acidification impacts in order to meet zinc recommendations, approximately 9 and 11 times higher than bivalves for zinc and iron, respectively.

Acidification impacts to meet daily recommendation for:

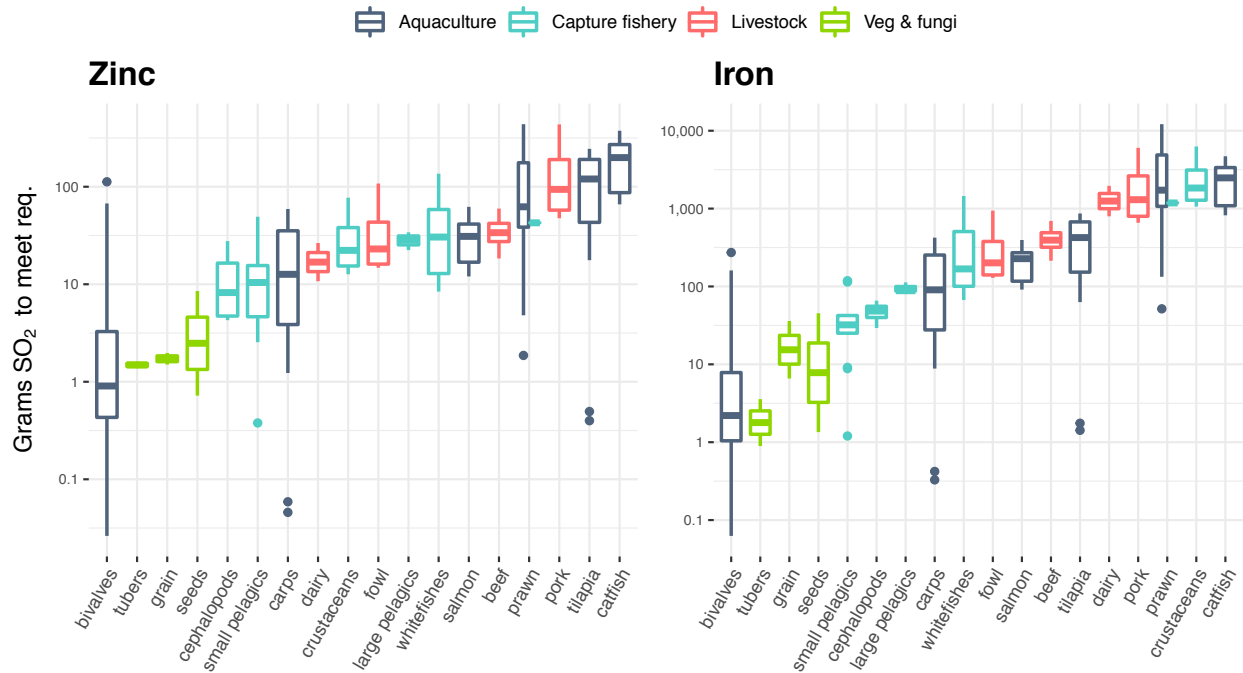


Figure 5-11 - Acidification impacts associated with meeting daily recommended intake of Zinc and Iron. Note the y-axis is on a logarithmic scale.

To meet requirements for folate, acidification impacts were lowest for tubers, bivalves, seeds and grain (Figure 5-12). Salmon, dairy and carp were the next lowest ASFs. Small pelagic fish were noticeably higher - more comparable to catfish or beef than bivalves - in acidification impacts in order to meet folate requirements due to the food group having low concentrations of this micronutrient. Beef had the highest impact required to meet folate requirements, 385 times higher than bivalves. Small pelagic fish were 157 times higher than bivalves. For Vitamin A, bivalves had the lowest acidification impacts in order to meet daily requirements (Figure 5-12). Dairy had the next lowest impact, followed by small pelagic fish. The only vegetable food groups that had Vitamin A values were seeds and grain, both of which had fairly high impacts in order to meet daily requirements. Grain higher acidification impacts than bivalves and crustaceans had the highest acidification impacts, 2221 times higher than bivalves.

Acidification impacts to meet daily recommendation for:

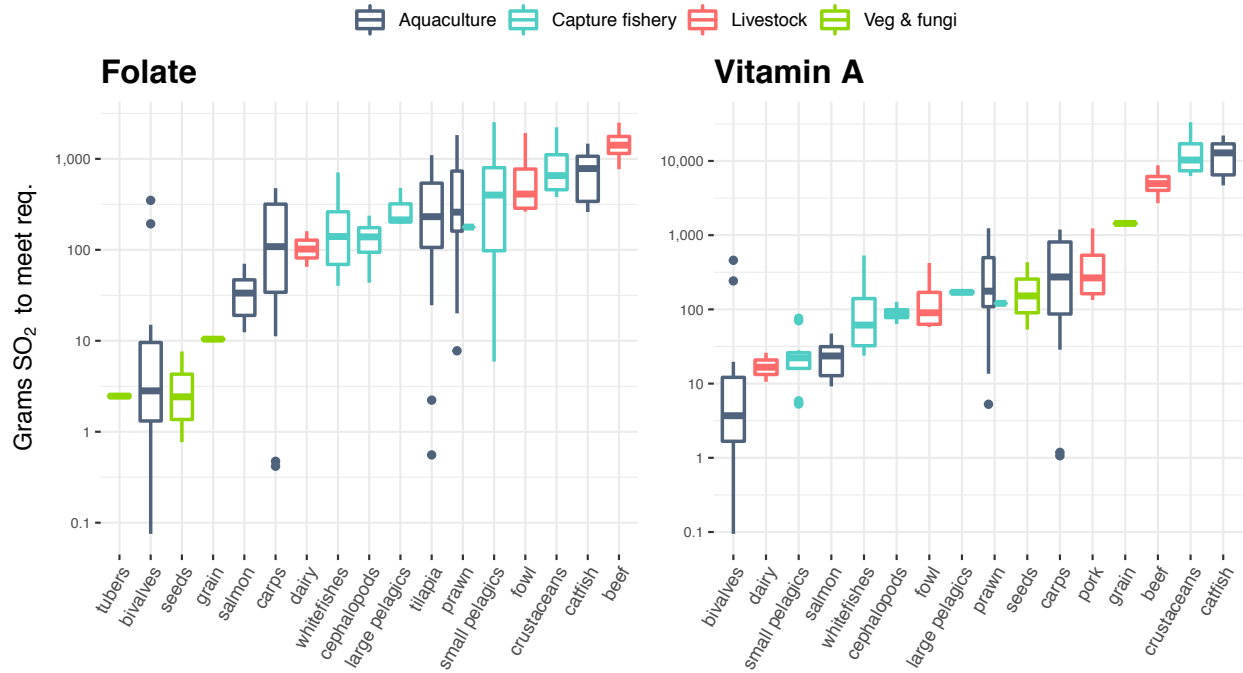


Figure 5-12 - Acidification impacts associated with meeting daily recommended intake of Folate and Vitamin A (RAE). Note the y-axis is on a logarithmic scale.

When meeting Omega 3 (DHA & EPA) daily recommendations, small pelagic fish have the lowest acidification impacts, followed by bivalves and salmon (Figure 5-13). Beef, pork and catfish have the highest acidification impacts. Again, because DHA and EPA are marine-sourced fatty acids the origin of the low concentrations of Omega 3 in beef, pork and chicken their fish-based meals. The highest impact fish is the farm-raised catfish, which has acidification impacts 378 times higher than small pelagic fish. With Vitamin B12, acidification was lowest for bivalves, followed by small pelagic fish, salmon and cephalopods. Fowl, pork crustaceans and prawn production have the highest acidification impacts in order to meet Vitamin B12 recommendations. Bivalves had impacts 651 times lower than fowl and 444 times lower than the highest impact seafood product crustaceans.

Acidification impacts to meet daily recommendation for:

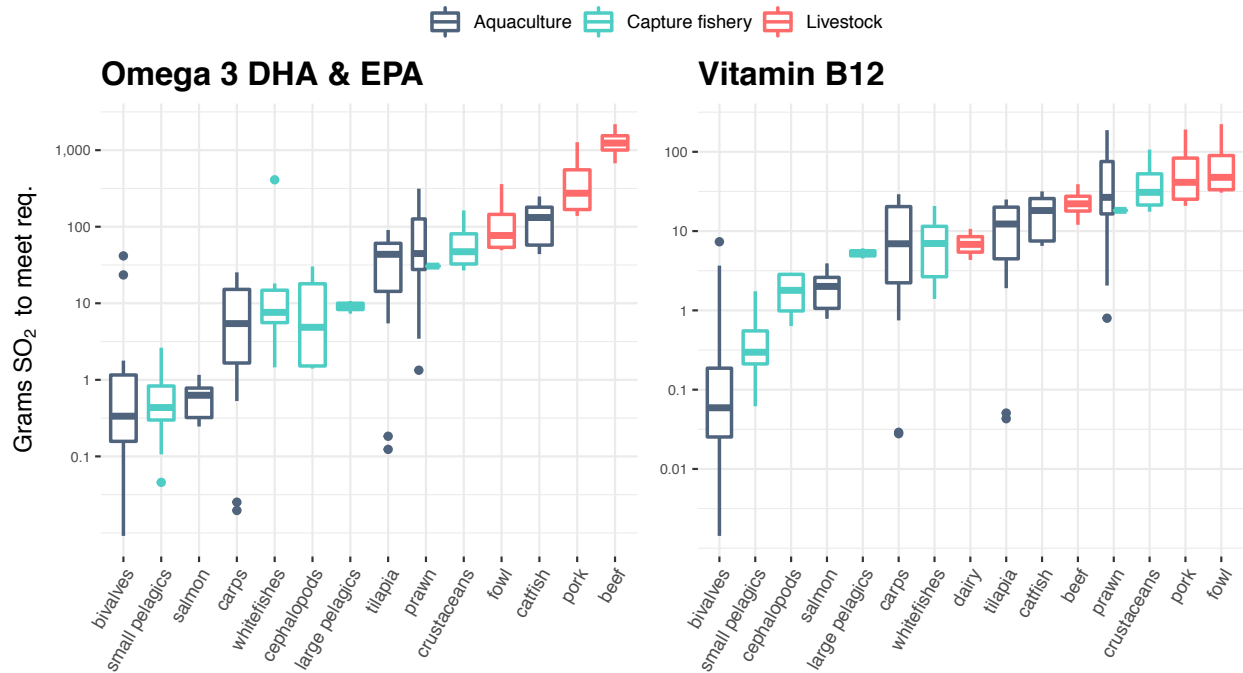


Figure 5-13 - Acidification impacts associated with meeting daily recommended intake of Omega 3 fatty acids (DHA and EPA) and Vitamin B12. Note the y-axis is on a logarithmic scale.

5.4.5 Fuel use

Fuel use impacts were lowest for grain, small pelagic fish and seeds with respect to their nutrient richness (Figure 5-14). Following a similar pattern to other impacts, catfish, tilapia and prawns had the highest fuel use impacts. The food group with the highest fuel use was catfish, 206 times higher than small pelagic fish which had the lowest fuel use impact across all ASFs. For the vegetable food groups where there was fuel use data available, grains, seeds and tubers all had lower fuel use given their nutrient richness compared with most ASFs, other than small pelagic fish. Dairy had the lowest fuel use per nutrient richness of all land based ASFs. Carp, crustaceans prawn tilapia and catfish all had higher fuel use per nutrient richness than any of the land based ASFs.

Fuel use relative to nutrient richness

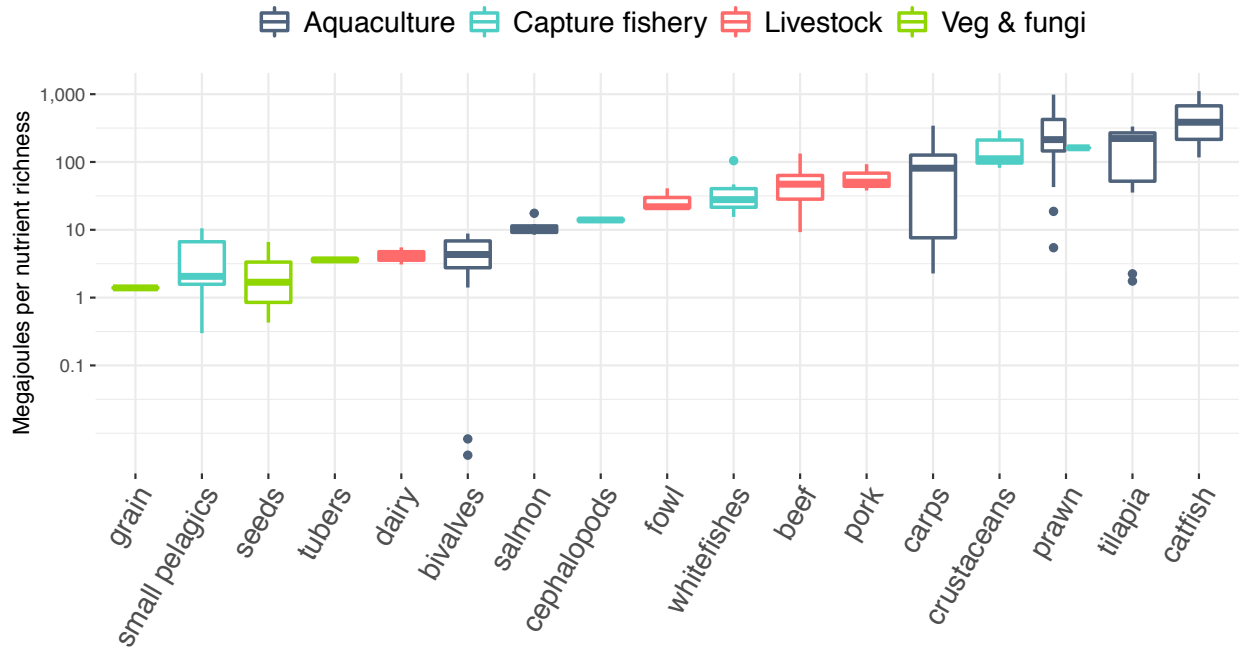


Figure 5-14 - Fuel use impacts (in megajoules) per nutrient richness. Note the y-axis is on a logarithmic scale.

Fuel use impacts in order to meet zinc daily recommendations are lowest for the three vegetable food groups: grain, seeds and tubers (Figure 5-15). Of ASFs, dairy had the lowest fuel use to meet the daily recommendation for zinc, followed by small pelagic fish and bivalves. Prawn, catfish and tilapia have the highest fuel use to meet zinc recommendations. The fuel use in order to meet grain is 956 times lower than it is for tilapia. In order to meet iron recommendations, vegetable food groups, along with bivalves have the lowest fuel use. The highest fuel use to meet iron recommendations were catfish, prawn production and crustaceans. Catfish had fuel use 330 times higher than grain.

Fuel used to meet daily recommendation for:

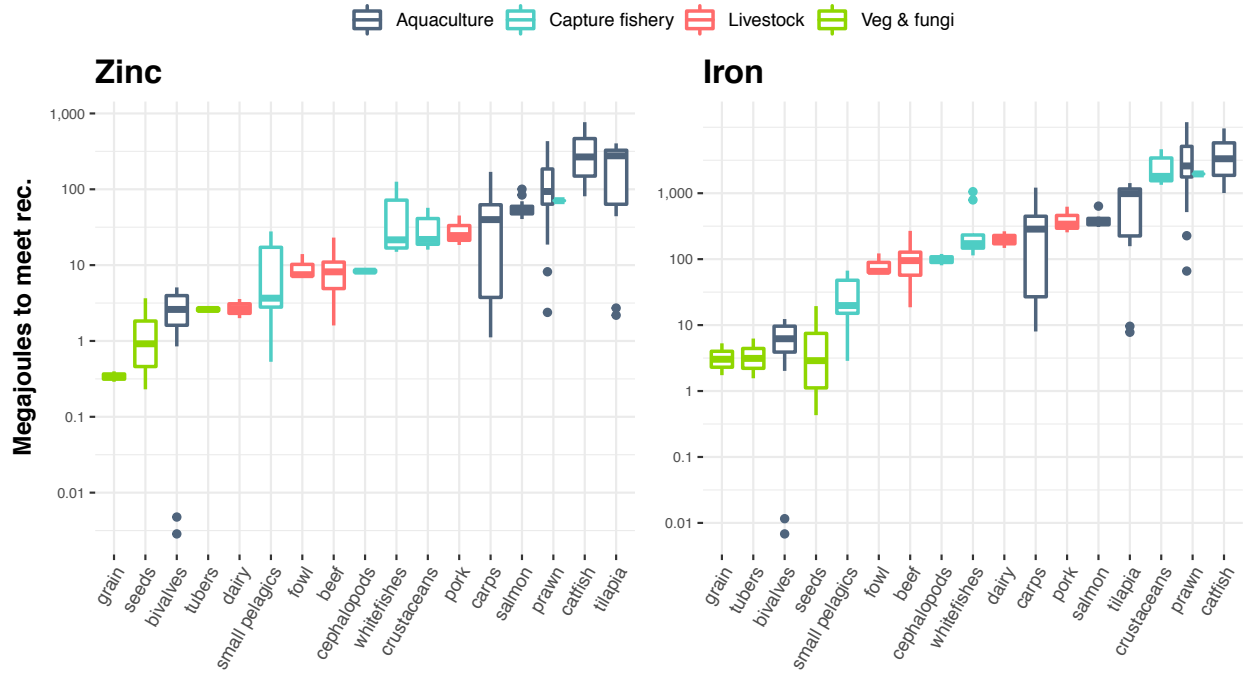


Figure 5-15 - Fuel use impacts in megajoules in order to meet daily recommended intake of zinc and iron. Note the y-axis is on a logarithmic scale.

To meet folate recommendations, vegetable food groups again had the lowest fuel use (Figure 5-16). Seeds, grains and tubers had the lowest fuel use whereas catfish, crustaceans and carp had the highest fuel use to meet folate recommendations. Seeds used 655 times less fuel than catfish to meet folate recommendations, 93 times less for the lowest ASF food group, bivalves. To meet Vitamin A recommendations vegetable groups of seeds, grain and tubers again had the lowest fuel use (Figure 5-16). Among ASFs, food groups with the lowest fuel use were bivalves and dairy, followed by small pelagic fish. The highest fuel use in order to meet Vitamin A recommendations were catfish, crustaceans and carp.

Fuel used to meet daily recommendation for:

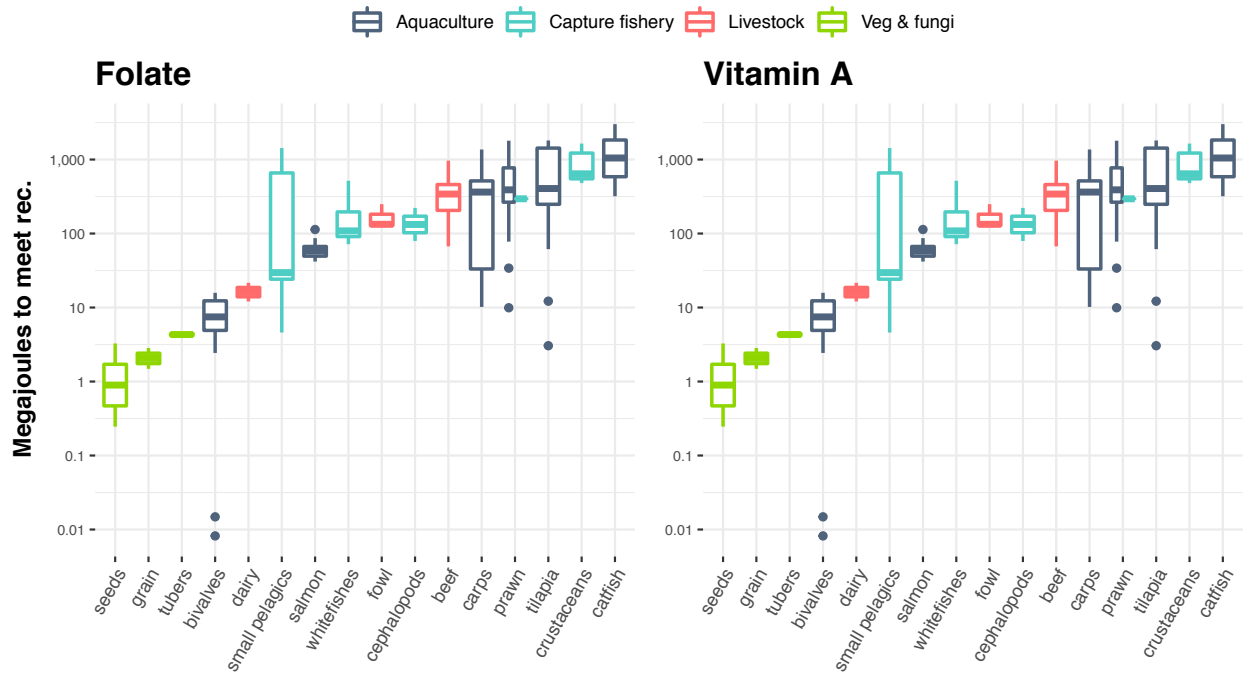


Figure 5-16 - Fuel use impacts associated with meeting daily recommended intake of Folate and Vitamin A (RAE). Note the y-axis is on a logarithmic scale.

To meet Omega 3 DHA and EPA daily recommendations, small pelagic fish have the lowest fuel use followed by salmon and bivalves (Figure 5-17). Beef, catfish and tilapia have the highest fuel use in order to meet Omega 3 recommendations. Among land based ASFs, fowl had much lower fuel use in order to meet omega 3 recommendations, but these were still 106 times higher than small pelagic fish. Small pelagic fish use 1270 times less fuel than beef and 824 times less fuel than catfish to meet Omega 3 recommendations. In order to meet Vitamin B12 requirements, small pelagic fish and bivalves have the lowest fuel use, followed by dairy whereas prawn production, tilapia and catfish had the highest fuel use. Prawn had fuel use 298 times higher than small pelagic fish.

Fuel used to meet daily recommendation for:

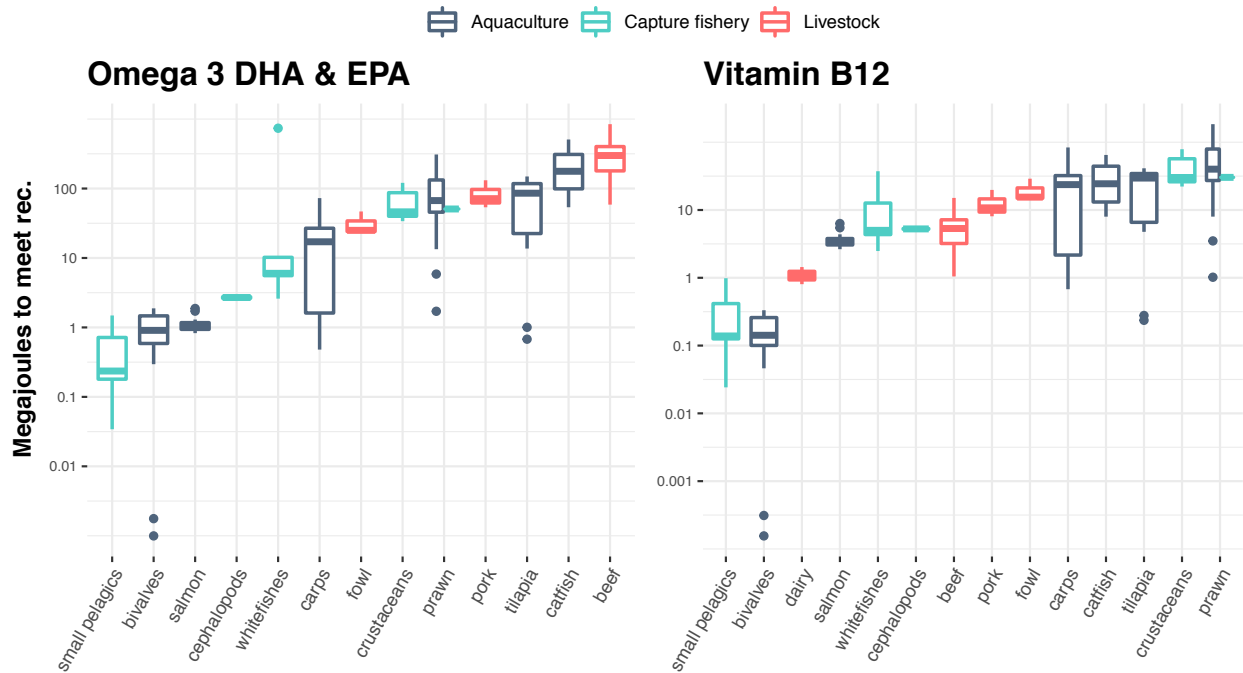


Figure 5-17 - Fuel use impacts associated with meeting daily recommended intake of Omega 3 DHA & EPA and Vitamin B12. Note the y-axis is on a logarithmic scale.

5.5 DISCUSSION

Environmental impacts associated with our food production system vary across plants, livestock and seafood food groups, and these differences are important the potential of these food groups to contribute towards healthy diets is considered. We found that the most nutrient rich foods were small pelagic fish, salmon, nuts, shark, grain and bivalves. When considering GHG emissions relative to nutrient richness index, roots, small pelagic fish, grain and bivalves have the lowest impact whereas catfish, prawn, tilapia and beef have the highest. Bivalves, small pelagic fish, tubers and large pelagic fish have the lowest eutrophication impacts relative to nutrient richness and tilapia, catfish, beef and pork have the highest. Acidification impacts are lowest for bivalves, tubers, small pelagic fish and salmon relative to their nutrient richness, whereas impacts are highest for catfish, pork, beef and prawn production. Fuel use impacts relative to nutrient richness were

lowest for grain, small pelagic fish and seeds and where highest for catfish, tilapia and prawns. Across all environmental impacts relative to nutrient richness, we found that plant food groups like grain, tubers, root, seeds, as well as small pelagic fish in wild capture production (*i.e.*, anchovy, herring, pilchards) and bivalves in aquaculture production (*i.e.*, mussels and clams) tend to have impacts at least as low relative to their nutrient richness. Foods with the highest impacts tended to include beef, pork as well as catfish, tilapia and prawns in aquaculture production and crustaceans and prawn in wild capture fishery production. When considering the impacts of specific nutrients for which we know deficiencies are more common, a similar pattern holds where specific vegetables as well as small pelagic fish and bivalves tended to have the lowest impacts relative to their high concentrations of these micronutrients. These results indicate that, among animal sourced foods, some fish and shellfish have environmental impacts at least as low as vegetables when considering their potential to contribute nutrients towards a healthy, sustainable diet.

5.5.1 *Impacts and nutrient richness - thinking at broader scales*

Planning for our planetary future requires an acknowledgement that food systems must address malnutrition for growing populations across the development spectrum. Decisions made on how food is produced, processed and distributed creates environmental impacts with consequences that range from exacerbating global climate change and its affects to finer-scale impacts on the surrounding environment like eutrophication or acidification. The results of this research are intended to provoke discussions surrounding decision-making on selection of food production systems that minimize environmental impacts and maximize contributions to food security and nutrition outcomes.

Across the development spectrum, nutrient-rich foods are to play an important role in diet-based diseases and health risks caused by a transition to calorie-rich nutrient poor foods, a concern

most recently voiced in FAO's most recent *State of Food Security and Nutrition in the World* report (FAO, IFAD, UNICEF, WFP, & WHO, 2019). We found that vegetables, as well as a number of marine-based animal-sourced foods tended to have much higher nutrient richness than land-based ASF production systems. While leafy vegetables, fungi, stem and root vegetables all were more nutrient-rich, marine-based ASFs including small pelagic fish, salmon and bivalves were more similar to vegetables than to beef, fowl or pork. As suggested by Hallström et. al, the all-too-common focus on environmental impact with respect to “coarse indicators” like energy density could point the food system towards food groups that are low in impact but also may be nutrient poor (Hallström et al., 2019). Results here extend that line of argument by comparing wild-caught and farm raised seafood to a variety of vegetables and terrestrial animal-sourced foods. Low environmental impacts of the most nutrient-rich ASFs bivalves and small pelagic fish, have at least as low of environmental impact as vegetable production systems.

A recent study on environmentally sustainable diets found that vegetable availability is insufficient to meet recommended consumption levels and this gap is only expected to widen (Mason-D'Croz et al., 2019). If regional supply solutions are not found, sustainable food systems in these areas will have to find alternative sources of comparably low environmental impact. Our results indicate that some fish and shellfish have comparably low environmental impacts given their nutrient richness and may provide. However, underlying the increased supply of such healthful and environmentally friendly seafood requires careful consideration for the governance and value chains of seafood provisioning. For wild-capture fish, sourcing must come from sustainably managed stocks, sourcing from *any* small pelagic fisheries with low GHG emissions without considering how well that stock is governed may incentivize continued overexploitation and negative ecosystem impacts.

As food production systems continue to reconcile their contributions to global environmental change, they also need to recognize the impact that these changes have throughout supply chains from decreasing nutritional quality of crops to increasing the need for additional cold storage infrastructure (Fanzo, Davis, McLaren, & Choufani, 2018). For many marine and aquatic fisheries and aquaculture, the impacts of increasing water temperatures can influence ideal locations for wild fisheries habitat or aquaculture production, which could also mean changes to regulatory access and physical availability of fishery resources to communities (Gentry et al., 2017), and change the level of access to nutrient-rich seafoods by increasing, or reducing, fuel use to fishing grounds or to maintain optimum temperature for aquaculture production.

Continued production of marine and aquatic production systems with high environmental impacts will exacerbate high, negative impacts on the entire food system, including their own production in the future. When considering planetary boundaries of our food system, it is necessary to also consider the often-overlooked inefficiency with which specific food systems produce nutrient-rich food. The results suggest that, without innovation, systems with high impacts relative to their nutrient richness - including farmed catfish, prawns, pork and beef have a disproportionately higher impact not only on their own continued production but on other more nutrient-rich foods with lower environmental impacts. Without production innovations, future decision-making should shift towards more healthful, lower impact vegetable and ASF production. Given the recent understanding that climate change will interfere not only with the supply chain but the nutrition concentrations of these products, there should be a growing preoccupation with identifying, and weaving into the food system, alternative and nutrient-rich sources that not only combat malnutrition but also reduce environmental impacts on the entire food system.

Managing food systems for planetary health includes consideration of the impacts of food production for each country around the world together, not separately. While trade provides a mechanism to access healthful, sustainable foods, it also enables telecoupling of consumed foods in one country while environmental impacts are produced, or felt, in other systems potentially with weaker governance needed to mitigate these impacts (Pace & Gephart, 2016). Telecoupling also exists in the global seafood supply system, and there is growing evidence that trade enables negative ecological and environmental impacts to be externalized away from countries consuming healthy fish and towards countries where policies to mitigate these impacts are not in place (Crona, Holt, Petersson, Daw, & Buchary, 2015; Helvey, Pomeroy, Pradhan, Squires, & Stohs, 2017). There are growing discussions on the equity of the flows of trade to provide healthful seafood to those in need, but it remains unclear how trade influences the equity of healthful *and* sustainable foods together. A recent study of household surveys in Bangladesh indicates that seafood consumption has increased overall, primarily from farmed species. However, the intake of iron and calcium actually decreased, suggesting that aquaculture-raised fish may have lower micronutrient quality and therefore relatively less potential to reduce malnutrition (Bogard et al., 2017).

Trade does provide a mechanism that supplies more affordable fish to developing countries who export their own fish, but research is beginning to show that these imported products differ in nutritional quality and may in fact be detrimental to public health in the areas where nutrient deficiencies are most acute. Equitable supply of nutrients is of paramount importance. We are learning that higher concentrations of carbon dioxide in the atmosphere are expected to decrease iron, protein and zinc content of rice, wheat and other food crops (Medek, Schwartz, and Myers

2017; Myers et al. 2014). This is especially troubling for the 1.4 billion children and women of child-bearing age who live in high risk countries where anemia is already highly prevalent (Smith, Golden, and Myers 2017). Given the growing understanding of the negative impacts of climate change on nutrition, it is important to consider the environmental footprint of food production systems.

5.5.2 *Constraints on the oceans and the role of farmed seafood*

While there are substantial gains to be made by improved management (Hilborn & Costello, 2018), wild fishery stocks are unlikely to meet growing, global demand. Well-designed aquaculture is positioned to relieve pressure on wild stocks still experiencing overfishing while also creating a low-emissions contribution to conservation of nearby natural resources (Froehlich, Gentry, & Halpern, 2017), as well as aid in meeting seafood consumption levels that are currently below health recommendations in much of the world. As aquaculture continues to grow, investigations into how it compares with the sustainability and healthfulness of wild and terrestrial animal-sourced foods will increasingly come into focus. This research did not endeavor to directly compare nutrition concentrations, but it does shed early light on the question of how farmed substitutes compare to wild capture seafood in terms of their nutritional quality. Alongside the ascendancy of aquaculture, there is additional incentive to improve management of capture fisheries. As fishery populations begin to rebuild alongside management reform, there is a corresponding increase in catch given the effort needed to find fish (i.e., catch per unit effort), and alongside this, there is reason to believe that fuel use and, resultingly GHG emissions, could decrease as a byproduct of improved management. Under the right environmental conditions, policies, technological advancements and institutions, fisheries and aquaculture can improve their contribution to food security and nutrition six fold, to over 364 million metric tons of animal

protein (Costello et al., 2019). As the results have shown, the impact that this increase might have on the environment, and how nutrient rich these new ocean-based proteins are, varies considerably.

For shellfish, farmed bivalve species like mussels had low environmental impacts, due to both their low environmental impacts and high nutrient richness. Wild-caught shellfish like many crustacean species had much higher impacts even when considering fairly high nutrient richness; many of these species are caught using traps and pots, which tend to require a return trip to retrieve their catch. While farm-raised bivalves have high potential to contribute nutrient rich food at low environmental impact but their production depends on regional growth potential and strong governance that guides financial and regulatory backing to support development (Davies et al., 2019b). Furthermore, their contribution to diets is mediated by broader climate processes, including production in the broader food sector. For example, the production of farmed catfish and tilapia, as well as beef and pork, creates much higher rates of SO₂ equivalents that cause acidification. This in turn impacts bivalves, whose calcium carbonate shells are particularly vulnerable to ocean acidification which alone could cost \$100 billion USD to the shellfish industry (Narita, Rehdanz, & Tol, 2012). To buffer such effects, smart sector development must consider these changes to ensure nutrient contributions are best realized.

With respect to their nutrient richness, wild-capture fish tended to have much lower environmental impacts than farmed fish. This was due to both the high environmental impacts and low nutrient richness of many farmed fish species, especially catfish, tilapia and carp. Some farmed fish, like Atlantic salmon and trout, had lower environmental impacts with respect to their nutrient richness. In some cases, this higher efficiency was due to different farm practices and in others due to the higher nutrient richness in salmonids compared to other farmed fish, but still much lower than small pelagic fish caught with purse seine fishing techniques like anchovy, herring and

sardine. There are already interventions that seek to realize the nutritional value of small pelagic fish. For example in Peru, intersectoral partnerships sought improve consumption of Peruvian anchoveta and has seen some progress, but face challenges in present markets where consumers are unfamiliar with cooking preparation for small fish (Majluf et al., 2017). Efforts to provision small pelagic fish will likely face tradeoffs due to their value as both keystone species in marine ecosystems as well as a critical component in fishmeal fed to carnivorous farmed fish. Additionally, Across all food production systems, when considering diet-based interventions, policymakers and managers must decide between ecological and economic value in addition to the potential contribution to human health.

5.5.3 *Caveats of this study and future directions*

Studies included in this meta-analysis can be primarily classified as large-scale production systems embedded within the Western diet. This excluded “transformative” food production systems that are either developing or may be commonly consumed elsewhere, many of which may be nutrient rich nutrition and have lower environmental impact (Hadjikakou, Ritchie, Watermeyer, & Bryan, 2019). Insect-based proteins provide one such example. Nutritionally, insect species vary broadly. A recent review compared the nutrient concentration of insect species to land-based animal-sourced foods found that there is “no evidence that any commercially available insect evaluated in the current study is significantly preferable to meat for the purpose of combating diet- related disease caused by over-nutrition” (Payne, Scarborough, Rayner, & Nonaka, 2016). In a review of environmental impacts of insect production, it was found that there are few LCA studies on insects and that they are heterogenous; this it difficult to draw generalizations about their environmental impacts (Halloran, Roos, Eilenberg, Cerutti, & Bruun, 2016). “Boutique” production systems that are currently small-scale were also not included in this analysis. This includes seaweed which is

of growing interest as a food with low environmental impact, and potentially a net positive impact as it may mitigate, and locally reverse, some effects of climate change thereby contributing to “blue economic growth” (Duarte, Wu, Xiao, Bruhn, & Krause-Jensen, 2017). Seaweed is also rich in nutrients, including DHA and EPA Omega-3 fatty acids. Seaweeds also provide for habitat, which adds a conservation benefit to economic and food provisioning goals (Froehlich et al., 2017). Foods like insects and seaweed both have considerable potential to be of low environmental impact and high nutrient richness but are currently limited by a lack of study (Parodi et al., 2018), and would potentially compare favorably to many of the foods included in this analysis. More research is required to extend the evaluation to these foods of the future to determine the environmental impact of their production and whether scaling their production would provide a sustainable contribution to a more healthful food system.

Results of this research indicate food groups and food products that have low environmental impact given their nutrient richness. These products rank the most environmentally efficient and nutrient rich foods in our database, but this list is not exhaustive. These products do not represent all traditionally consumed foods or those that are culturally appropriate. They also do not include all consumed foods; of special note they do not include highly processed foods of any kind. Importantly, the most efficient of these foods should not, when taken together, be considered a standalone “sustainable diet.” Instead of interpreting the results of this research as a sustainable diet, consider them as represent foods that are worth consideration in diets that drive a sustainable, healthy food system. There is recognition that predominant diets have starkly different impacts on our environment and, in turn, our ability to continue to provision food (Ritchie, Reay, & Higgins, 2018). A such, defining the sustainable diets has received increased attention from the research and policy communities. While each uniquely defines its diet and its definitions of

sustainability, they share recommendations to decrease consumption of ruminant meat and to encourage plant-based consumption (Searchinger et al., 2019). The EAT-Lancet Commission shows using a set of scenarios that a shift towards higher quality, nutritious plant-based food systems that can maintain a safe operating space across a suite of environmental impacts (Willett et al., 2019). Our results support this conclusion as a majority of plant-based foods tend to have some of the lowest environmental impacts given their nutrient richness. Results also indicated the efficiency of capture fish and farmed shellfish have environmental impacts at least as low as many plants, and lower than most animal-sourced proteins. Interestingly, seafood is not often included in the sustainable diet literature (Farmery et al., 2017) and wider recognition of the contribution of fish to the food system can help drive fishery reform where overexploitation remains a concern (Bogard, Farmery, Little, Fulton, & Cook, 2019). Our results reemphasize the need for additional consideration of fish and shellfish in sustainable diet research. Instead of interpreting the results of this research as a sustainable diet, consider them as represent foods that are worth consideration in diets that drive a sustainable, healthy food system.

5.6 CONCLUSION

Food production varies in terms of its environmental impact and its capacity to meet nutritional needs; this research compares these two outputs by comparing products across plants and animal sourced foods from terrestrial, capture fishery and aquaculture production systems. Foods sourced from plants as well as bivalve aquaculture and small pelagic fisheries tended to have the lowest environmental impact given their "nutrient richness to meet dietary requirements across a diversity of micronutrients. In contrast, species more commonly produced in aquaculture including catfish and tilapia, prawns, pork and beef had the highest environmental impacts given their nutrient richness. The contribution of plant-based foods discussed here supports the existing literature, but

the potential role that certain species of fish can play in meeting dietary guidelines provides a novel insight to identify nutrient-rich sources that not only combat malnutrition but also reduce environmental impacts on the entire food system.

5.7 SUPPLEMENTAL TABLES

5.7.1 *Food products in each food group*

Appendix Table 9 - Food products in each food group

Food groups	Food products in each group (by USDA NDB Number product name)
Small pelagic fish	Mackerel (Fish Stick), Anchovy, Herring, Mackerel, Mackerel Atlantic, Mackerel Horse, Pilchard
Whitefishes	Pollock (Fish Stick), Pomfret Atlantic, Hake (Fish Stick), Hake European, Cod (Fish Stick), Hake Senegal, Pomfret, Bass, Cod, Fork Beard, Sole, Plaice, Megrin, Flatfish, Rhombus, Haddock, Ling Common, Ling, Milkfish, Monkfish, Anglerfish, Saithe, Pollock, Rockfish, Roughy, Sea bass, Splendid Alfonsino, Snapper, Alfonsino, Trout, Turbot, Whiting, Whiting Blue, Gourami, Hake Fillet, Hake
Salmon	Salmon, Chinook salmon, Atlantic salmon
Sharks	Porbeagle, Shark, Shark Mako
Fruits	Citrus fruits, Misc., Citrus Small, Nuts Misc., Palm Nuts-Kernels (Nut Equiv.)/Oil, Apples, Apricots, Avocados, Bananas, Cranberries, Blueberries, Cherries, Figs, Currants and Gooseberries, Grapefruits and Pomelo, Grapes, Guavas, Kiwi fruits, Lemons and Limes, Guavas, Mangoes Etc., Rockmelon / Cantelope, Melons, Peaches and Nectarines, Olives, Oranges, Mandarin, Tangerines, Mandarins Etc., Papayas, Peach, Pears and Apples, Pears, Pineapples, Plantains, Plums and Sloes, Pears and Quinces, Quinces and Pears, Quinces and Pears, Raspberries and Other Berries, Strawberries, Watermelon, Watermelons, Dates, Cucumbers, Eggplants, Pumpkins, Pumpkins, Squash and Gourds, Zucchini/Button Squash, Tomatoes, Chillies, Cucumbers and Gherkins, Gherkins, Capsicums/Peppers, Peppers/Capsicums, Chillies and Peppers, Dry, Coconuts (Incl. Copra), Hazlenuts, Pistachios, Walnuts, Peanuts
Seeds	Beans, Ground Nuts, Peas - Yellow Dried, Rape Seed, Cereals Misc., Rapeseed and Mustard Seed, Beans - Green Beans, Beans - Green, Beans - French and Runner, Beans - Plake, Corn, Maize Sweet Corn, Maize, Cowpeas, Peas - Green - Shelled, Chick Peas, Peas - Green, Peas - Dry, Peas, Soybean, Beans - Pinto Usa Dried, Sesame Seed, Sunflower Seed, Cashew Nuts, Chestnuts, Lentils, Beans - Gigante/Butter, Soy, Quinoa
Grain	Oat Berry, Oatmeal, Barley, Millet, Oat, Oats, Rye, Sorghum, Wheat, Rice
Game	Kangaroo, Buffalo, Goat, Rabbit
Roots	Starchy Root, Beetroot, Carrots, Swedes (Rutabage)
Dairy	Camembert Cheese, Mozarella, Cream, Buffalo Milk, Yogurt, Goats Cheese, Cow Milk, Cheddar Cheese, Onion
Fowl	Eggs, Chicken, Duck, Turkey, Emu
Pork	Pork
Flowers	Artichokes, Broccoli, Cauliflowers

Stems	Asparagus, Celery, Fennel
Leaves	Cabbage, Lettuce and chicory, Lettuce, Spinach
Bulbs	Garlic, Onion
Tubers	Ginger, Potatoes
Fungi	Mushrooms
Nuts	Almonds
Beef	Beef
Carps	Carp, Silver Barb
Eel	Eel
Large pelagic fish	Swordfish, Tuna, Skipjack Tuna, Bigeye Tuna, Yellowfin Tuna
Crustaceans	Crab, Lobster
Prawn	Prawns/Shrimp, Shrimp, Prawns
Bivalves	Clam, Mussels
Cephalopods	Cuttlefish, Octopus, Squid
Catfish	Catfish, Striped Catfish
Tilapia	Tilapia
Veal	Veal
Lamb	Lamb

5.7.2 *List of studies included*

This list was extracted directly from the dataset used and it needs to be cleaned up for the publication (and final dissertation). Question for you all: would this list be cross-referenced with the actual “References” section or is it a stand-alone reference list?

Appendix Table 10 - List of studies included in the environmental impacts dataset

Study #	Study
1	Hall 2011
2	Alig et. al. 2012 Comparing env impacts of beef production systems: a review of LCA Vries 2015
3	Ayer 2009 LCA FarmedSalmon Canada
4	Baruthio FishPrawn Filipino
5	Basset Mens and Van der Werf 2005
6	Basset Mens LCA NZ milk production
7	BassetMens LCA Pigs France
8	Beauchemin et al 2011 Comparing env impacts of beef production systems: a review of LCA Vries 2015
9	Biswas 2008 global warming wheat western Australia
10	Blonk et al. 1997

11	Capper 2012 Comparing env impacts of beef production systems: a review of LCA Vries 2015
12	Carlsson 2003 Food LifeCycle Energy
13	Casey and Holden 2005
14	Casey and Holden 2006
15	Cederberg and Darelus 2002
16	Cederberg and Flysj� 2004
17	Cederberg and Mattsson 2000
18	Clune et al 2017
19	Dick 2014 LCA BeefCattleBrazil
20	Driscoll 2010 GHG AtlanticHerring
21	Driscoll 2015 LCA Maine and southwest Nova Scotia lobster industries
22	Ellingsen FarmedSalmon Norway 2008
23	FAOCircular1044 Shrimp Senegal
24	Farmery 2015 Life cycle assessment of wild capture prawns: expanding sustainability considerations in the Australian Northern Prawn fishery
25	Freon 2014 LCA PeruvianAnchovyFleet
26	Gonzalez Garcia 2014 LCA broilerchicken
27	Gonzalez Garcia 2015 LCA of pigmeat production: Portuguese case study and proposal of improvement options
28	Haas 2001 LCA Milk Germany
29	Hall 2014 CF localchickenlettuce
30	Hilborn and Tellier 2012 ECFPNZ
31	Hospido et al. 2003 c
32	Hospido 2005 LCA SpanishTuna
33	Hospido 2006 LCA CannedTuna
34	Huerta 2016 Environmental impact of beef production in Mexico through life cycle assessment
35	Iribarren 2010 Mussels culture
36	Iribarren Update Coolant 2011
37	Katajajuuri 2008
38	LCA Food Database website http://www.lcafood.dk/
39	Lebel Shrimp Thailand 2010
40	Ling Shrimp China Intensive
41	Lupo et al 2013 Comparing env impacts of beef production systems: a review of LCA Vries 2015
42	McGrath 2015 LCA Farmed Salmon
43	Mogensen et al 2015 Comparing env impacts of beef production systems: a review of LCA Vries 2015
44	Mollenhorst et al. 2006
45	Nguyen 2010 Beef LCA Europe

46	Ogino 2016 Environmental impacts of extensive and intensive beef production systems in Thailand evaluated by life cycle assessment
47	Ogino 2007 LCA Beef Japan
48	Opio et. al 2013 Comparing env impacts of beef production systems: a review of LCA Vries 2015
49	OtherImpactsTable
50	Pelletier 2008 Crops LCA
51	Pelletier 2008 LCA Poultry
52	Pelletier 2009 LCA GlobalFarmedSalmon
53	Pelletier 2010 LCA Beef Midwest
54	Pelletier 2010 LCA IndonesianTilapia
55	Peters et al. 2010 Comparing env impacts of beef production systems: a review of LCA Vries 2015
56	Phong Mekong Integrated Fish 2011
57	Reckmann et al 2013
58	Roop 2013 Cradle to gate life cycle assessment of locally produced beef in the palouse region of the northwestern US
59	Roop 2014 LCA regionalbeefproduction
60	roos 2010 Uncertainties in the carbon footprint of food products: a case study on table potatoes
61	Rotz 2015 cradle to farm gate environmental footprints of beef cattle production in Kansas, Oklahoma, and Texas
62	Ruviaro 2015 CF beef
63	Stackhouse Lawson et. al 2012 Comparing env impacts of beef production systems: a review of LCA Vries 2015
64	Sun Shrimp Indoor
65	Svanes et al 2011 Int J LCA Autoline Cod
66	Svanes 2011 Allocation Cod
67	Svanes 2011 IntJLifeCycleAsses b
68	Thomassen et al. 2008b
69	Thomassen et al. 2009
70	Thrane 2006 LCA DanishFish
71	vandenBurg whitefish 2012
72	Vasquez Rowe HorseMackerel 2010
73	Vasquez Rowe Hake 2011
74	Vasquez Rowe Octopus 2012
75	Vazquez Rowe 2014 life cycle assessment of European pilchard <i>Sardina pilchardus</i> consumption. A case study for Galicia NW Spain
76	Wang 2010 Rice china
77	Wiedemann 2015 Env impacts and resource use of Australian beef and lamb exported to the USA determined using life cycle assessment
78	Williams et al. 2006
79	Williams 2010 potatoes England
80	Winkler 2016 LCA Austrianpork

81	Winther CarbonFootprint Norwegian Fish&Aqua 2009
82	Zhu XueQin and Van Ierland 2004c
83	Ziegler 2008 NorwayLobster
84	Ziegler LCA Cod 2003

5.7.3 *List of nutrients included in the index, along with daily recommended values as well as the source of the information.*

Appendix Table 11 – Nutrients included in the nutrient richness index along with daily recommended values

#	Nutrient	Daily Value	Source	Notes
1	Protein	50 g	Drewnowski et al. 2009*	
2	Fibre	25 g	Drewnowski et al. 2009*	
3	Vitamin A (RAE)	45 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
4	Calcium	1000 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
5	Iron	29.4 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
6	Potassium	3510 mg	WHO Guidelines***	Value recommended to reduce blood pressure and risk of cardiovascular disease, stroke and coronary heart disease in adults
7	Zinc	4.9 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
8	Riboflavin	1.1 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
9	Thiamin	1.5 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
10	Folate	400 mcg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
11	Magnesium	220 mg	FAO/WHO Joint panel of experts**	Value based on requirements for a female aged 19-50
12	Omega 3 fatty acids (DHA plus EPA)	0.5 g	International Society for the Study of Fatty Acids and Lipids****	Expected to significantly reduce risk for death from CHD in healthy adults.

* Citation using daily intake information that was used to develop the original nutrient richness (Drewnowski, 2009)

** Citation from FAO and WHO joint expert panel (FAO & World Health Organization, 1998)

*** Citation from WHO Potassium intake guideline (WHO, 2012)

**** Citation from International Society for the Study of Fatty Acids and Lipids study on recommended intake of PUFAs (Cunnane, Drewnowski, Harris, Sinclair, & Spector, 2004)

Chapter 6. SUMMARY OF THE DISSERTATION

As the pathways to sustainably manage our fisheries become clear, we are beginning to envision aquatic and marine environments where there are both more fish in the water and more seafood being landed. Aquaculture's growth indicates another pathway by which seafood can meet markets. At the same time, malnutrition continues to rise, both from undernutrition (too few calories or macro-nutrients like protein), malnutrition (micronutrient deficiencies and imbalances) and from diet-related diseases associated with overnutrition. The diversity of micronutrients in fish and shellfish positions these products in combatting malnutrition, encouraged by the number of calls for greater integration between seafood producing sectors and the healthy food system. This PhD research endeavored to improve our understanding of how seafood production can contribute to the food system by 1) assessing the policy landscape related to the integration national-level fishery and health policies to determine where these policies are most aligned and under what conditions 2) using a mixed method approach to evaluate at the regional scale of the US West Coast the current and potential contribution of rebuilding capture fisheries to the healthy food system, and 3) an evaluation of the environmental impacts of nutrient-rich food production that compares diverse capture and aquaculture seafood production to other animal sourced and vegetable food groups.

The policy analysis in Chapter 2 developed a clearer picture on the overlap between fisheries and the health system policies. While some work has been conducted in case studies and specific regions, a systematic global review of policy integration does not exist. Chapter 2 sought to fill that gap and improve our systemic understanding on the overlap between fishery and FSN via global review of the level of integration between fishery and health policies to address FSN objectives. The research evaluated the level of alignment between national-level fishery and health

policies around the world to develop a global distribution of where fishery and health policies are most and least integrated and what topics tend to be included or excluded from these policies. The policy integration scores were then regressed governance, socioeconomic and fishery information to determine the conditions under which more or less integrated policies tend to arise.

The analysis in Chapter 2 covered 165 health and 158 fishery national-level policies around the world. It found evidence that more recent fishery policies have higher integration with food security and nutrition objectives. It also found a problematic relationship between childhood malnutrition to fishery and health policy integration: higher rates of overweight children correspond with lower integration in fishery and health policies, suggesting there remains a lack of recognition of the nutritional value of fish to improve the healthfulness of diets away from calorie rich but nutrient poor diets. When development partners were present, that country policy had a higher probability of high integration in its fishery and health policies, demonstrating that these organizations improve the level of integration between fishery and health documentation. The study also identified geographic scales where we see more – and less – integration in policies, opening up the opportunity to discuss interventions to improve connections between seafood and the healthy food system. Despite seafood’s nutrient richness, results were unclear in their successful integration of fishery and health policies to connect seafood with the healthy food system to combat malnutrition. It indicates that there is considerable potential for improvement. Taken together, these results establish a foundational understanding of the status of national policies connecting fisheries to the healthy food system.

Along the US West Coast, fish stocks have rebuilt from overfishing after decades of conservation-based management; now seasonal catch of many species is much lower than the harvest guidelines set by fishery managers. Chapters 3 and 4 sought to fill gaps in knowledge that

are surprising considering policy mandates to improve food system outcomes. For example, Management Goal III of the most recent West Coast Groundfish Fishery Management Plan (2016) calls for improved utilization to “promote year-round *availability of quality seafood* to the consumer.” This management goal is explicitly oriented toward food security, yet it is lost in the management objectives that immediately follow. One reason for this absence is the lack of system-wide research that connects fisheries to the food system, including in developed economies such as the US. This research uses a mixed methodology approach to better understand how US West Coast fisheries production may better contribute to healthful diets in the region.

Results of the research in Chapter 3 identified the scope and strategy for scaling by learning from isolated success stories in Washington, Oregon and California, where schemes to get low-cost seafood to low-income, nutritionally-vulnerable communities are working. We established where these programs innovated in the supply chain and how they source their fish and learned that strong relationships throughout the [shortened] supply chain, champions who supported the initiative, connections to fishing industry heritage or seafood-consumption, and financial support of partners or grantmaking institutions facilitated their success. These programs also overcame a number of challenges related to the costs accrued through the value chain, a lack of public awareness of local seafood options and methods of preparation, and policy conditions restricting potential availability.

In Chapter 4, secondary fishery, socioeconomic and food systems data was used to create a situational baseline that quantified the annual catch relative far below the total allowable catch for a number of species, foregoing millions of servings of fish that could be sustainably harvested and contribute to food need in adjacent communities. We used this baseline to identify regions where the potential availability of fish was high, there was higher capacity in nearby harbors, and

where food insecurity was high. In two of these regions, we interviewed representatives throughout the food system – from fisheries industry representatives to public health officials to school nutritionists – to learn more about the current state of connection between seafood and the food system and how they envision programs such as the positive deviants could improve this connection in their communities. The regional focus on the West Coast seafood system in Chapters 3 and 4 provided finer scale baseline for the status of fisheries contribution to the food system and envisaged how locally harvested fish could play a greater role in improving the healthfulness of diets.

In contributing towards a healthier food system, it is imperative to consider the environmental impacts associated with that production. Increasing media attention is being garnered by our food system and its footprint on the environment. Fish are often considered as a “good alternative” to other major protein groups, but as a category “seafood” represents a multitude of species and modes of production. It is important to consider not only the species but also both broad production system (i.e. capture fisheries or aquaculture) and also the specific form of production (e.g., trawl, troll, trap gear types for capture fisheries) that produce specific species with particular nutrient compositions and environmental impacts, especially relative to other animal-sourced foods and vegetables. To date, research into the environmental impacts of food production evaluated the variability of different forms of fishery and aquaculture production relative to other food systems, and compared these with respect to meeting recommended intakes across a suite of macro and micronutrients. Chapter 5 of this dissertation sought to fill that gap by connecting existing LCA datasets with a nutrient richness index calculated from food composition data evaluate environmental tradeoffs in the production of macro- and micro-nutrients to improve decision-making toward more nutrient-rich food outputs that minimize environmental impact.

Environmental impacts associated with nutrient-rich food products across vegetable, livestock and seafood food groups. With respect to nutrient richness, we found that vegetable food groups like grain, tubers, root, seeds, as well as small pelagic fish in wild capture production (*i.e.*, anchovy, herring, pilchards) and bivalves in aquaculture production (*i.e.*, mussels and clams) tend to have impacts at least as low relative to their nutrient richness. Foods with the highest impacts tended to include beef, pork as well as catfish, tilapia and prawns in aquaculture production and crustaceans and prawn in wild capture fishery production. When considering the impacts of specific nutrients for which we know deficiencies are more common, a similar pattern holds where specific vegetables as well as small pelagic fish and bivalves tended to have the lowest impacts relative to their high concentrations of these micronutrients. These results indicate that, among animal sourced foods, some fish and shellfish have environmental impacts at least as low as vegetables when considering their potential to contribute nutrients towards a healthy, sustainable diet.

While food security is often considered a goal of fisheries management and of fisheries science, comprehensive understanding of how fisheries can contribute to food security and nutrition is in its earliest stages of development. It was the goal of this PhD dissertation to improve our knowledge base on the contribution of seafood production to the food system by focusing on an assessment of the alignment between fishery and health policies in Chapter 2, an assessment of current and potential contribution of capture fisheries in Chapter 3 and 4, and in Chapter 5 an evaluation of the environmental impacts associated with nutrient rich foods. Results of Chapter 1 provide a systemic review that is useful to public and private entities interested in food security and in regions with diet-based health concerns. It is the hope that these results will help guide the development of strategies to better integrate policies to realize nutrition benefits of seafood.

Results may be informative to international and regional organizations seeking to identify areas where integration is lacking and financial or technical capital can be provided to affect change. Building our understanding on the conditions that seem to influence the alignment of fishery and health policies will serve as the foundation for further research and policymaking to increase the interchange between the two sectors.

The research in Chapters 3 and 4 revealed the importance of taking a mixed methodological approach that uses both existing quantitative data to analyze the situation broadly as well as qualitative information to evaluate at a deeper context how we might improve the connection between local fisheries production and the food system. Such research lays the foundation for policy guidance and future research to enable federal and state management bodies to meet commitments to the provisioning of local seafood. While there is current lack of integration in policy between health and fisheries in the USA, these results are intended to facilitate the emerging dialogue on how seafood can better contribute to positive nutrition transition that redefines the Western diet towards more nutrient rich products like locally available seafood.

Chapter 5 builds upon existing scientific approaches by looking at per capita environmental impacts of different food production systems in terms of nutrient estimates and density. Malnutrition remains prevalent and hidden hunger is on the rise. As a result, policymakers and industry groups around the food system are increasingly interested in reducing environmental impacts and improve health outcomes, either to meet policy objectives or stakeholder demands and these results are useful to food system policy making to improve our understanding of the environmental impacts of provisioning food that is not only environmentally friendly, but healthful.

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VITA

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