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Contribution of Fisheries to Food and Nutrition Security

Current Knowledge, Policy, and Research

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Current Knowledge, Policy, and Research

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Summary

In the context of the recently agreed-on United Nations 2030 Agenda for Sustainable Development, which includes the goal to end hunger, achieve food security, and improve nutrition, this report synthesizes current understanding of capture fisheries' contributions to food and nutrition security and explores drivers of those contributions.

Capture fisheries produce more than 90 million metric tons of fish per year, providing the world's growing population with a crucial source of food. Due to the particular nutritional characteristics of fish, fisheries represent far more than a source of protein. They provide essential micronutrients—vitamins and minerals—and omega-3 fatty acids, which are necessary to end malnutrition and reduce the burden of communicable and non-communicable disease around the world. Yet the contributions of fisheries may be undermined by threats such as overfishing, climate change, pollution, and competing uses for freshwater.

To support the food and nutrition security contributions of capture fisheries, policies must be developed both to ensure the sustainability of resources and to recognize tradeoffs and synergies between conservation and food security objectives. A growing body of data and research focused specifically at the intersection of fisheries, nutrition, and food security can inform such efforts by improving understanding of fisheries' production and distributional dimensions, consumption patterns, and nutritional aspects of fish in the context of healthy diets and sustainable food systems. This expanding body of knowledge can provide a basis for more directly considering fisheries in the food and nutrition security policy dialogue.

This report serves as a contribution to the World Bank's regional flagship report on ending malnutrition in South Asia, scheduled for release in October 2018.

Nicholas Institute for Environmental Policy Solutions

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nicholas Institute responds to the demand for high-quality and timely data and acts as an "honest broker" in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute's leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

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World Food Policy Center

Operating within Duke University's Sanford School of Public Policy and under the direction of food expert Kelly Brownell, the World Food Policy Center (WFPC) plays a critical role in catalyzing innovative thinking and coordinated action that is needed to change policy; support strategic, effective solutions, and increase investments needed to end hunger, achieve food security, promote sustainable agriculture, and impact diet-related disease..

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Environmental Defense Fund, a leading international nonprofit organization, creates transformational solutions to the most serious environmental problems. EDF links science, economics, law, and innovative private-sector partnerships. By focusing on strong science, uncommon partnerships and market-based approaches, EDF tackles urgent threats with practical solutions. EDF is one of the world's largest environmental organizations, with more than two million members and a staff of approximately 700 scientists, economists, policy experts, and other professionals working in 22 geographies around the world on unique projects running across four programs. The organization's oceans program aims to create thriving, resilient oceans in our lifetimes that provide more fish in the water, more food on the plate and more prosperous fishing communities, even with climate change.

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Duke University Marine Lab

The Duke University Marine Lab is a campus of Duke University and an academic unit within the Nicholas School of the Environment. The Duke Marine Lab has a distinguished record of research and education in marine science, conservation, and governance and a strong international reputation with research interests spanning diverse taxa and including both human and natural systems. The mission of the laboratory is to be at the forefront of understanding marine environmental systems and their conservation and governance through leadership in research, training, communication, inclusion, and diversity.

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OBJECTIVES AND APPROACH

Objectives

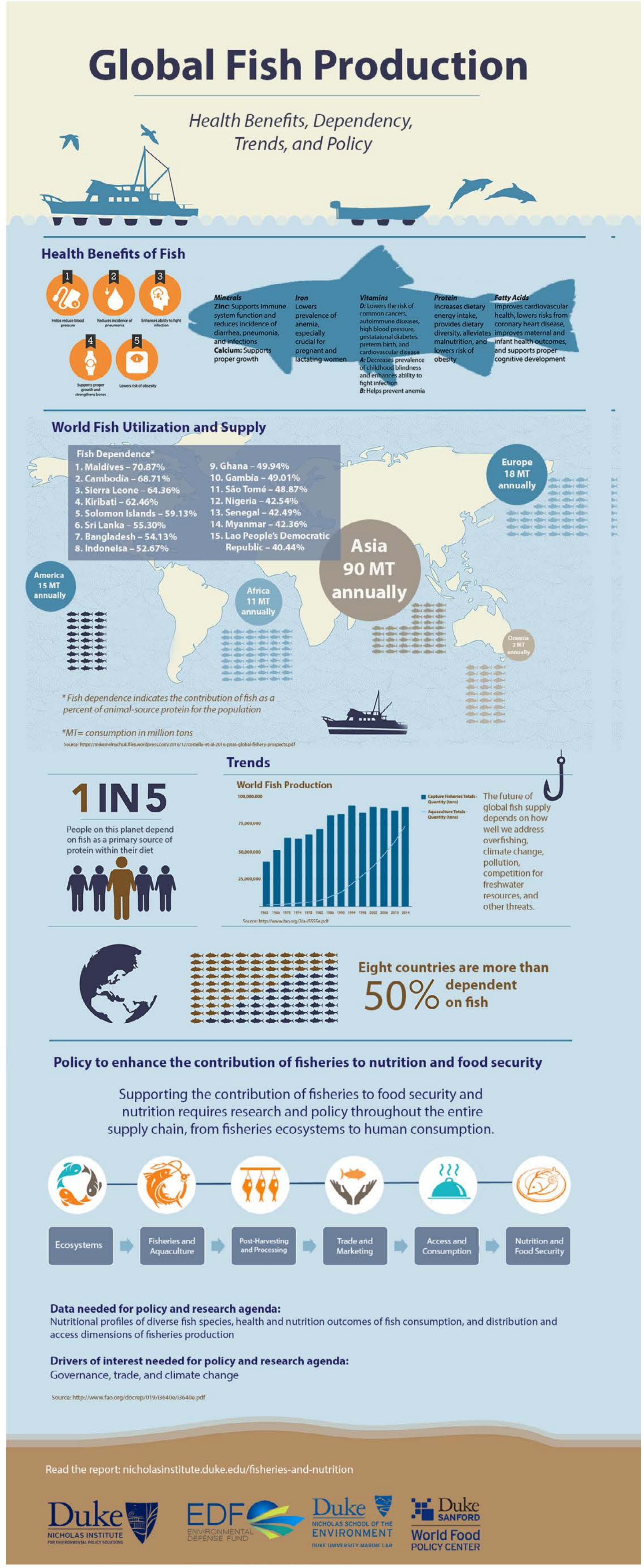
This report synthesizes current understanding of the contributions of capture fisheries to food and nutrition security and explores drivers of those contributions. It addresses three overarching questions: (1) What contributions do capture fisheries make to food and nutrition security? (2) What is the current policy dialogue regarding the links between capture fisheries and food and nutrition security? (3) What data are available to inform research and policy development to support the contributions of capture fisheries to food and nutrition security?

The report addresses these questions with the aim of situating dialogue squarely within the science-policy interface. The overall goal is to provide a foundation of knowledge to inform the trajectory of research, policy, and practice that supports the role of capture fisheries in achieving sustainable development goals (SDGs) to end poverty (SDG1) and hunger (SDG2).

Scope

Both capture fisheries and aquaculture are important food production systems that can make complementary contributions to food and nutrition security. The primary focus of this report is on fisheries, which provide diverse forms of nutrition to a wide range of people and which face significant threats. This focus addresses SDG14 of the United Nations 2030 Agenda for Sustainable Development: to "conserve and sustainably use the oceans, seas and marine resources for sustainable development" as the "increasingly adverse impacts of climate change (including ocean acidification), overfishing and marine pollution are jeopardizing recent gains in protecting portions of the world's oceans" (UN 2015b; 2017, 15). Just as importantly, the emphasis on capture fisheries acknowledges the unique threats to inland fisheries, including invasive species, pollution from agricultural runoff, and competition with other freshwater uses such as hydropower, irrigation, and aquaculture (Youn et al. 2014).

However, fully removing aquaculture from discussions of capture fisheries is impossible. First, aquaculture influences the dynamics of capture fisheries in multiple ways. Second, some key data and research do not differentiate between farmed and captured fish. Finally, despite the guidance provided by the definitions included in the glossary of this report, the distinction between aquaculture



Graphic credit: Micaela Unda

and capture fisheries is not always clear. For example, culture-based fisheries release hatchery-reared animals into the wild and aquaculture-based capture grows wild caught fish in captivity until they reach marketable size (Ottolenghi, Silvestri, Giordano, Lovatelli, and New 2004). Capture fisheries and aquaculture will inevitably play interconnected and, ideally, complementary roles in alleviating hunger and malnutrition.

The actual contribution that fisheries can make to nutrition and food security depends on the supply, distribution, and utilization of fish. These dynamics inevitably rely on the sustainable and equitable governance of the world's marine and inland fisheries, compelling us to look deeper into the knowledge, research, and policy that link fisheries governance with nutrition and food security. In this sense, the present report also aligns with the contemporary discourse on food and nutrition security that increasingly pays attention to the environmental sustainability and biodiversity of the food systems on which we depend (Berry, Dernini, Burlingame, Meybeck, and Conforti 2015; Powell et al. 2015).

The literature review of this report summarizes research findings and data at the global level as well as in particular countries and regions, including both developed and developing countries. The broad geographical scope aims to capture the range of food and nutritional contributions that fish can make in combatting different manifestations of malnutrition and associated communicable and non-communicable health conditions. The prominence of research on the Pacific island countries and territories (PICTs) and on Southeast Asia reflects the geographical emphasis of the body of reviewed literature.

Methods

This report reflects a literature review of peer-reviewed articles, gray literature, and key reports from international organizations. Most of the peer-reviewed literature was obtained through the Web of Science and ProQuest databases. In each database, key word searches using the search strings "fisheries AND nutrition" and "fisheries AND food security" returned a large number of results. Within the 500 most-relevant results, only those containing the term "fisheries" as well as a food security or nutrition term in the abstract or keywords list were retained. Within the set of retained sources, only those that directly address the intersection of fisheries and nutrition, food security, or both were included in the review. This set excluded, for example, articles that mentioned the food security contributions of fisheries but did not discuss or present findings related to such contributions. Articles that focused entirely or primarily on aquaculture were also excluded. After the peer-reviewed literature search, gray literature was obtained from the websites of key organizations, such as the United Nations Food and Agriculture Organization (FAO), the WorldFish Centre, and the International Food Policy Research Institute (IFPRI). Finally, additional resources specifically related to nutrition and food security were incorporated as needed. These resources included highly cited peer-reviewed literature on the health benefits of fish and reports available from the World Health Organization (WHO). During the literature review, sources were coded according to topical themes that encompassed the main categories of nutrition and food security contributions and the factors and processes driving those contributions. The coding themes emerged inductively through a preliminary review of key literature sources.

EXECUTIVE SUMMARY

This report aims to synthesize information on the contribution of capture fisheries to food and nutrition security and on the potential for these food production systems to do more to help end hunger and malnutrition. The information here comes from peer-reviewed articles, gray literature, and key reports from international organizations, including findings and data at global, national, and subnational levels. Although knowledge about fisheries' contributions to nutrition and food security continues to increase, particularly in the wake of agreement on the United Nations Sustainable Development Goals, it has yet to sufficiently influence the policy realm, where explicit links between fisheries governance and food and nutrition security need to be amplified. For that reason, this report's assessment of emerging data and research pays attention to the distinct challenges and opportunities facing capture fisheries and, to a lesser extent, aquaculture.

The Social Problem: Hunger and Malnutrition

The social problem targeted by this report is the continued prevalence of hunger and malnutrition worldwide and the global commitment to end this problem by 2030 (Sustainable Development Goal 2). Between 2015 and 2016, the prevalence of hunger is estimated to have increased from 10.6 percent of the global population (777 million people) to 11 percent (815 million people). Essentially 1 in 10 people on the planet suffers from hunger. More than one in five children are stunted—have low height relative to weight—often indicating undernutrition or micronutrient deficiency. The problem has many dimensions, often intersecting with geography (i.e., the "birth lottery"). For example, the highest rates of undernourishment and child stunting are in Africa, where one in five people is undernourished (one in three in Eastern Africa); the highest absolute number of undernourished people are in Asia (519.6 million). Child wasting—low weight relative to height—occurs in 9 percent of children under the age of five in Asia and in 16 percent of such children in Southern Asia. At the same time, the prevalence of children under age five who are overweight is increasing in all regions of the world.

The Role of Capture Fisheries Food Production Systems in Helping to Solve the Problem

The world's capture fisheries are major food production systems that could play a larger role in meeting SDG2. Since 1945, the FAO has promoted the role of capture fisheries in ending hunger, but in the last seven years, the number of research publications on the topic has grown substantially. This trend reflects the fact that, unlike some staple foods such as rice and other grains, fish is unique in that it has the potential to address multiple dimensions of food and nutrition security simultaneously.

Capture (or wild-caught) fisheries and aquaculture (farmed fish production) together produced 167.2 million metric tons of fish in 2014. That amount is equivalent to 20 kilograms per capita annually and to 17 percent of animal protein consumed by the global population. In 2014, the split in production between capture fisheries and aquaculture was roughly half and half, though a greater proportion of aquaculture production was destined for human consumption (e.g., some of the products from capture fisheries provide feed for aquaculture and livestock). Within capture fisheries, nearly half of production is from smallholders, or "small-scale fisheries," which also employ an estimated 90 percent of the world's fishers, almost all of whom live in developing countries.

This global supply of fish from both capture fisheries and aquaculture provides nearly one-fifth of the average per capita animal protein intake for more than 3.1 billion people. Given that subsistence fishing (fishing for own consumption) and informal trade is often underreported in official statistics, this number may underestimate the contribution of fisheries. This contribution is much higher in a number of regions, countries, and communities. For example, the populations of some countries (Maldives, Cambodia, Sierra Leone, Kiribati, Solomon Islands, Sri Lanka, Bangladesh, Indonesia, and Ghana) obtain more than half of their animal protein from fish. In countries such as Iceland, Japan, Norway, the Republic of Korea, and some small island developing states (SIDS) where fish is the most available animal protein source, fish provide almost four times the global average of animal protein in terms of dietary energy. In aggregate, developing countries consume an annual per capita average of 18.8 kilograms of fish, and low-income, food-deficit countries consume 7.6 kilograms of fish, falling below the global average. Yet these countries tend to rely on fish for a greater portion of their animal protein than the global average, even when total consumption levels are lower. Fish is typically more affordable than other animal-source foods (ASFs), and it plays an especially important dietary role in countries in which access to animal protein is low and staple foods such as rice, wheat, corn, roots, and tubers predominate.

The most important contribution of fish are multiple micronutrients essential to addressing a variety of health issues worldwide. Fish contain vitamin A, D, and B and calcium, phosphorus, zinc, iron, and iodine. Precise nutrient profiles vary across fish species, processing and preparation techniques, and habitat. Micronutrients in fish can lead to a variety of health benefits, including lowered risk of cardiovascular disease; positive maternal health and pregnancy outcomes and increased early childhood physical and cognitive development; improved immune system function; and alleviated health issues associated with micronutrient deficiencies such as anemia, rickets, childhood blindness, and stunting. Vitamin D deficiency alone is a prevalent health issue worldwide. It can lead to rickets in children, affect bone health in adults, and is associated with increased risk of common cancers, autoimmune diseases, high blood pressure and cardiovascular disease as well as communicable diseases. For pregnant women, insufficient levels of vitamin D are associated with increased risk of preeclampsia, gestational diabetes, preterm birth, and low birth weight. Vitamin A deficiency is the leading cause of preventable childhood blindness and can also contribute to weakened immune system and anemia, given that it supports the body's use of iron. Vitamin B is also important in combination with iron and folate to prevent anemia and a number of neurologic and cognitive problems. Similarly, the minerals available in fish can help address a number of health issues, for example, iron deficiency, which leads to anemia (estimated to affect about 800 million women and children worldwide), and zinc deficiency, which correlates with the prevalence of child stunting.

The global fish supply also provides crucial fatty acids, including omega-3 polyunsaturated fatty acids essential for cardiovascular and brain health. The consumption of fish or fish oil has been shown to be associated with a number of benefits to coronary health, for example, lowered risk of death and sudden death from coronary heart disease, ischemic stroke, atrial fibrillation, and congestive heart failure. Worldwide, 1.4 million deaths are attributable to diets low in seafood-source omega-3 fatty acids. Fish consumption correlates with a 36 percent reduction in heart disease and heart attacks and a 12 percent reduction in mortality from all causes.

Fish consumption is particularly important to women, infants, and children who have higher demand for micronutrients and protein. In low-income countries, malnutrition accounts for 45 percent of mortality in children under age five and half of years lived with a disability for children age four and younger. In Bangladesh, the risk of child mortality is significantly lower for children born during peak fishing seasons to mothers who have a preference for fish. One study found that a number of inland fish are capable of providing at least 25 percent of recommended nutrient intake across multiple micronutrients for infants and pregnant or lactating women in Bangladesh. In Cambodia, nutrient-rich fish, especially wild-caught fish, are an essential part of the diets of infants and children, even those under 12 months of age. A study in Tanzania found that the breastmilk of women who consumed high levels of freshwater fish had levels of DHA (an important omega-3 fatty acid) even higher than those recommended for baby formulas. When consumed by mothers, the omega-3 fatty acids DHA and EPA from fish have been linked with improved infant and child cognitive development, reduced preterm delivery, and decreased risk of asthma, food allergy, and eczema in children. However, in many countries, the low amount and frequency of fish consumption among young children and late introduction of fish in complementary feeding of infants likely limits health benefits.

Consumption of fish does carry some risk of exposure to toxic substances, such as polychlorinated biphenyls, dioxins, methylmercury, and, increasingly, microplastics. This risk varies dramatically by type of fish consumed as well as by environment. Primary concerns are with levels of methylmercury, which can cause neurodevelopmental problems in children and which may contribute to cardiovascular disease in adults, and polychlorinated biphenyls (PCBs) and dioxins that may lead to cancer risks. These risks are an important consideration for certain groups such as high consumers of fish, the elderly, pregnant women, nursing mothers, and children. The general agreement of experts, however, is that the benefits of consuming fish outweigh the risks, even at high consumption levels for the general population and moderate consumption levels of most species for pregnant and lactating women.

Public Policies Needed for Fisheries to Meet SDG2

Although capture fisheries and aquaculture are both important food production systems to help end hunger and malnutrition, capture fisheries are distinct in that a number of processes, if not addressed, stand to undermine their food and nutrition contributions. In particular, population growth, overfishing, climate change, and trade are likely to alter the volume and distribution of the supply from capture fisheries, potentially to the detriment of sufficient and equitable global food provisioning. The supply of fish from capture fisheries grew exponentially during the twentieth century until peaking in the 1990s, and it has essentially stagnated since that time as concerns of overfishing have grown (currently FAO characterizes 31 percent of assessed fish stocks as overexploited). A recent analysis predicts that 10 percent of the world will experience deficiencies in essential micronutrients and fatty acids as a result of declining capture fisheries and that these implications will be concentrated in low-latitude developing countries.

Even though some capture fisheries are overexploited and others at threat to join them, with the appropriate governance reforms, most could recover and contribute more to ending hunger and malnutrition. Estimates suggest that the world's marine capture fisheries could sustainably contribute an additional 16 million metric tons annually with governance reforms to address overfishing. Policies to enact these reforms will need to grapple with the more general challenges associated with governing common pool resources. Monitoring and enforcing rules limiting who can harvest these resources and how much they can harvest are costly and difficult. Governance reforms can be particularly challenging when fish resources are highly mobile and in contexts in which the number of fishing vessels is high and in which fishing activities are highly dispersed. Inland fisheries face unique governance challenges related to competition over alternative freshwater uses. Any reforms will need to address the tradeoffs and synergies related to reducing fishing effort (or allocating freshwater resources) while maintaining a nutritious food supply and ensuring traditional access for small-scale fishers. Accordingly, policy interventions and responses will need to take into account distributional consequences as well as geographically differentiated needs and vulnerabilities to short-term fluctuations in the supply of fish.

The potential health and nutrition payoff for recovering and sustaining these food production systems has often been missing in the global food policy dialogue. For example, SDG2 targets spell out concrete actions that are relevant almost exclusively to terrestrial agricultural food systems. Similarly, much of the current thinking about nutrition-sensitive food systems—that is, about the design of interventions specifically to support diverse diets and improve nutrition—generally overlooks the role of sustainable fisheries.

A Research Agenda for Increasing the Contributions of Capture Fisheries to Ending Hunger and Malnutrition: The Food-Environment Nexus in the Water

Although overfishing has long been studied as one of the world's major environmental problems, quantification of its effects on food and nutrition security is lacking. Building a comprehensive understanding of the role that capture fisheries play in nutrition and food security entails integrating different data sources to address a number of key questions. Data on the production and distribution of fish provides a baseline for understanding the extent to which fisheries can contribute to food and nutritional needs in different places. Data on fish consumption patterns, typically collected at the household level, lend further insight into how fish supply translates into food provision. Consumption data can also serve to triangulate and add granularity to production and trade data. Knowledge about the nutrient profiles of different fish and the ways that processing, preservation, and preparation techniques affect nutritional characteristics can augment understanding of potential nutritional contributions associated with different fish consumption patterns. Dietary guidelines and recommended nutritional intakes for different populations then provide a basis for understanding the significance of nutrition from fish consumption with respect to individual nutritional requirements. Finally, these data can be situated within the broader context of global food and nutrition security, informing a more comprehensive understanding of where fish currently support good nutrition or could contribute more to alleviating particular forms of malnutrition. Although some of these data are established or emerging, they face substantial challenges related to reliability and comparability. Furthermore, these sources of information have only begun to be integrated to improve understanding of the current and future contributions of fisheries to food and nutrition security.

Fisheries policy that attends explicitly to food and nutrition security dimensions will depend on research that enhances understanding of both the magnitude of fisheries' contributions as well as the factors that affect the distribution, access, and use of fisheries resources. A critical need, given evidence that many capture fisheries are overexploited, is understanding of the implications of reducing fishing effort on food and nutrition security. Accurately predicting and evaluating the effects of any policy on that security is challenging from a methodological standpoint. However, the more that research explicitly attends to these effects, the better it stands to inform integrated, coherent, and equitable policy.

Key research topics include the role of gender dynamics, interactions between fisheries and aquaculture, the distributional consequences of trade, and the climate footprint of fisheries vis-à-vis other food production systems. Understanding the contributions that capture fisheries make to food and nutrition security requires more rigorous and systematic research on multiple drivers of fish supply distribution (for example, trade and climate change), particularly because the challenge of ending hunger and malnutrition may be focused as much on distribution as on sustainably increasing food supply. Furthermore, the geographic scope of research would need to be expanded, because most of the research to date has taken place in a relatively small number of countries or regions, notably the United States, Pacific Island countries and territories, Bangladesh, and Cambodia. Although the body of research explicitly aimed at understanding linkages between capture fisheries and nutrition and food security is growing, it is nonetheless incipient. More robust evidence is needed to evaluate the multiple pathways (for example, direct consumption, income, empowerment of women, macroeconomic growth) through which fisheries contribute to nutrition and food security.

BACKGROUND

Fostering sustainable ways to provide adequate food and nutrition to the world's growing population is an urgent challenge, prioritized as the second of 17 SDGs (UN 2015b). Recent projections indicate that the world's current population of 7.6 billion people is likely to grow by another billion by the year 2030 and to reach 9.8 billion by 2050 (UN DESA 2017). Although substantial progress in reducing hunger worldwide has been made this century, millions of people still lack access to an adequate supply of nutritious food (UN 2015a). Recent data suggest that malnutrition, in the form of nutritional deficiencies as well as overconsumption of unhealthy foods, is on the rise (figures 3 and 4). In 2016, there were an estimated 815 million chronically undernourished people in the world compared with 777 million in 2015 (FAO 2017c).

International policy agendas increasingly acknowledge the need for a multifaceted approach to food security and nutrition. In 2000, UN Millennium Development Goal 1c (MDG1c) established the aim of halving the proportion of the world's population suffering from hunger by 2015 (UN 2015a). Hunger, or chronic undernourishment, occurs when an individual is habitually unable to access enough food for dietary energy intake (FAO, IFAD, and WFP 2015). The more recent second goal of the 2030 Agenda for Sustainable Development (SDG2) aims not only to end hunger, but also to achieve food security and improved nutrition (UN 2015b). Food security takes into account the quality as well as quantity of food that people are able to access. Improving nutrition entails addressing overnutrition, indicated, for example, by rates of overweight children and adult obesity, and undernutrition, evidenced by the prevalence of conditions such as stunting, wasting, and micronutrient deficiencies (FAO 2017c). International organizations such as the UN and WHO are increasingly paying attention to micronutrient deficiencies, often referred to as "hidden hunger" due to their effects on immune system and cognitive function, physical disabilities, maternal and infant well-being, and overall prospects for prosperous livelihoods, rather than more visible manifestations of hunger such as wasting, stunting, and mortality (IFPRI 2014). Attending to the multiple facets of food security and nutrition is important because they influence risks for a suite of communicable and non-communicable diseases in different ways.

Current Context of Food and Nutrition Security

Food insecurity and malnutrition remain urgent challenges:

- Alleviating hunger and malnutrition is critical because the global population is likely to grow by about two billion over the next two decades.
- Research and policy seeking to alleviate hunger and malnutrition increasingly recognize multiple facets of food security, which include sufficient energy intake, food access and quality, and dietary and micronutrient diversity.
- The most recent estimates suggest that between 2015 and 2016, the prevalence of hunger increased from 10.6 percent of the global population (777 million people) to 11 percent (815 million people).

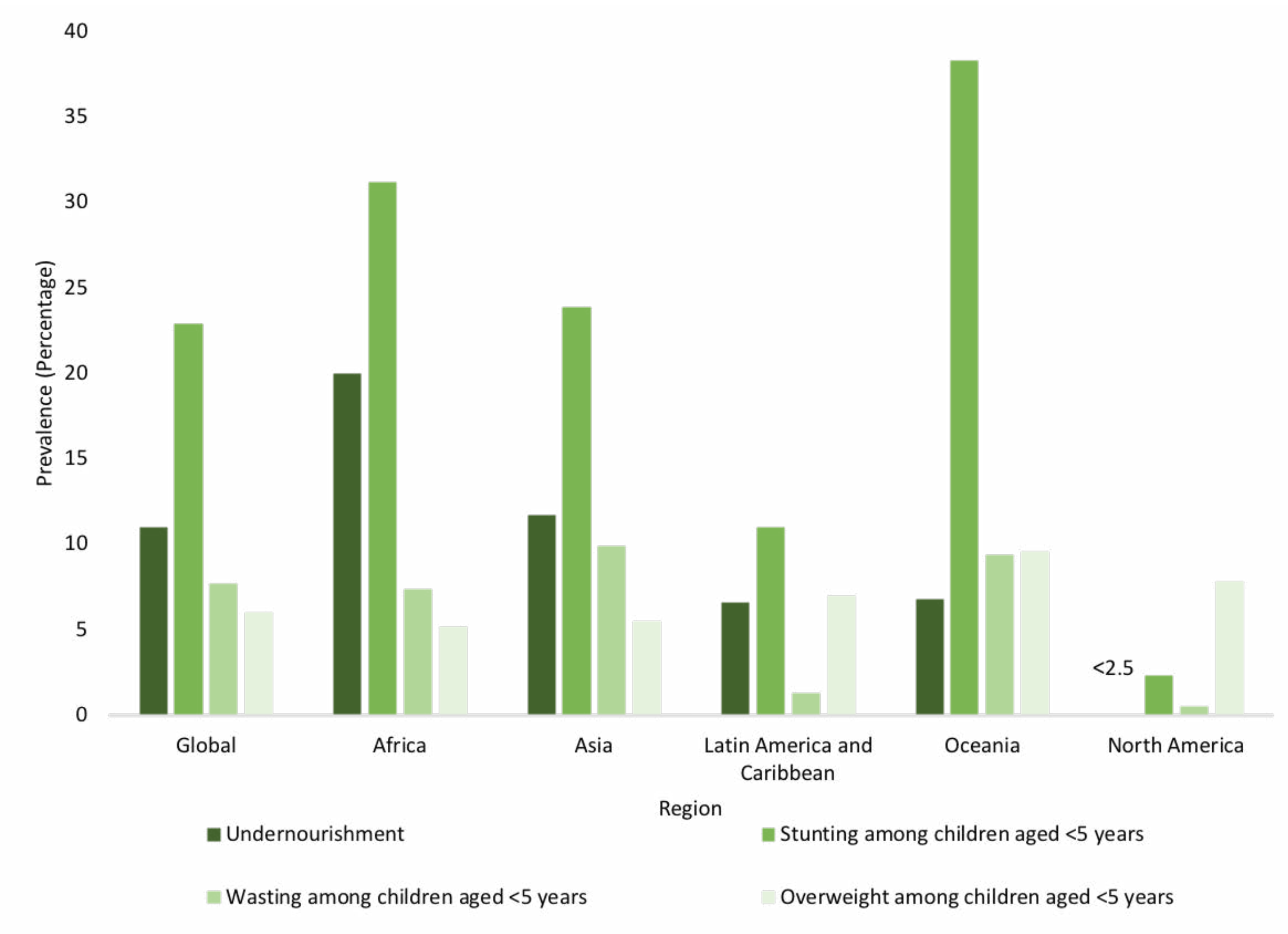
Dietary diversity, defined as the number of different foods or food groups consumed over a given reference period (Ruel 2003), is a basic tenet of a nutritious diet. It is a commonly used indicator of food and nutrition security (FAO 2016a). Measures of dietary diversity can serve as proxies for the nutritional quality of diets, access facets of food security, and micronutrient intake. Dietary diversity is measured as a count of the number of food groups consumed within a given timeframe. Food groups can be delineated in different ways, reflecting the needs of particular segments of the population, for example, women (FAO and FHI 360 2016) and infants and children (WHO 2008), and precise operational measurement often varies by country (Ruel 2003). For example, the Minimum Dietary Diversity for Women of reproductive age (MDD-W) indicator measures the proportion of women in a population or group that have consumed at least 5 of 10 defined food groups during the previous day or night and is intended to assess sufficiency across 11 micronutrients (FAO and FHI 360 2016). The recent emphasis on dietary diversity underscores the focal shift in policy and research from alleviating hunger and malnutrition to attaining nutritional quality in overall dietary patterns in addition to energy sufficiency.

Figure 1. Food Insecurity Experience Scale

Source: Adapted from FAO (2017c, 10).

Estimates presented in the recent FAO report *The State of Food Security and Nutrition in the World* show that the prevalence of different facets of hunger and malnutrition vary by region (Figure 2). For example, the highest rates of undernourishment are in Africa, where one in five people is undernourished, and especially Eastern Africa, where the prevalence of undernourishment is 33.9 percent. Asia has the highest absolute number of undernourished people at 519.6 million of the 815 million globally. Figure 3 shows the prevalence of undernourishment for countries in which greater than 20 percent of the population is undernourished. Child stunting, defined as low height relative to weight and indicative of micronutrient deficiencies, has declined over the last decade; nonetheless, 155 million, or 22.9 percent of the world's children under age five, are stunted. Like chronic undernourishment, rates of stunting are highest in Africa and in particular sub-Saharan and Eastern Africa. The prevalence of child wasting, in which weight is too low relative to height, is highest in Asia, where 9 percent of children age five or younger are wasted, and especially in Southern Asia, where 15.9 percent of children younger than age five are wasted. Oceania, a sub-region for which fisheries are particularly important, has especially high levels of child stunting and wasting and adult obesity (FAO 2017c).

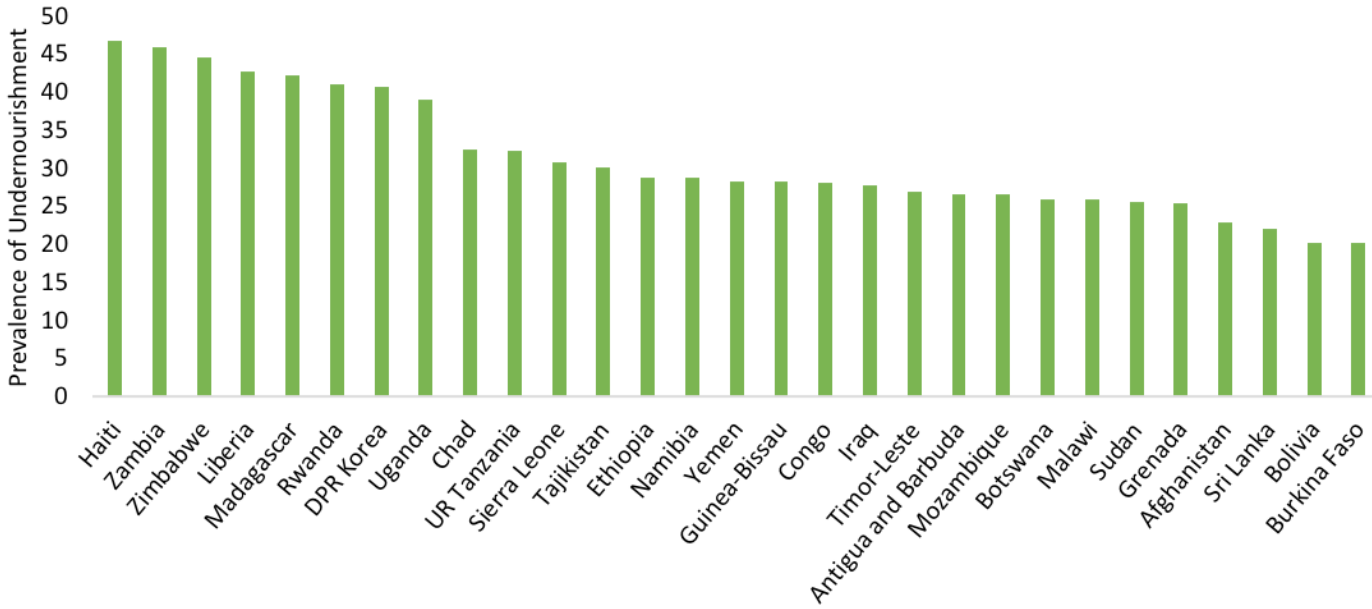
Figure 2. Dimensions of hunger and malnutrition: 2016 estimates



Source: Data presented in FAO (2017c). Undernourishment data are from FAO. Stunting, wasting, and overweight among children aged <5 years data are from UNICEF/WHO/World Bank Joint Child Malnutrition Estimates.
Notes: Asia excludes Japan. Oceania excludes New Zealand and Australia. For estimates of stunting, wasting, and overweight among children aged <5 years, certain sub-regions, namely Central Asia, Southern Asia, South America, and Caribbean, have consecutive low population coverage. FAO (2017c) provides confidence intervals for the above estimates, except for stunting among children aged <2.5 years in North America, because estimates are based on U.S. data.

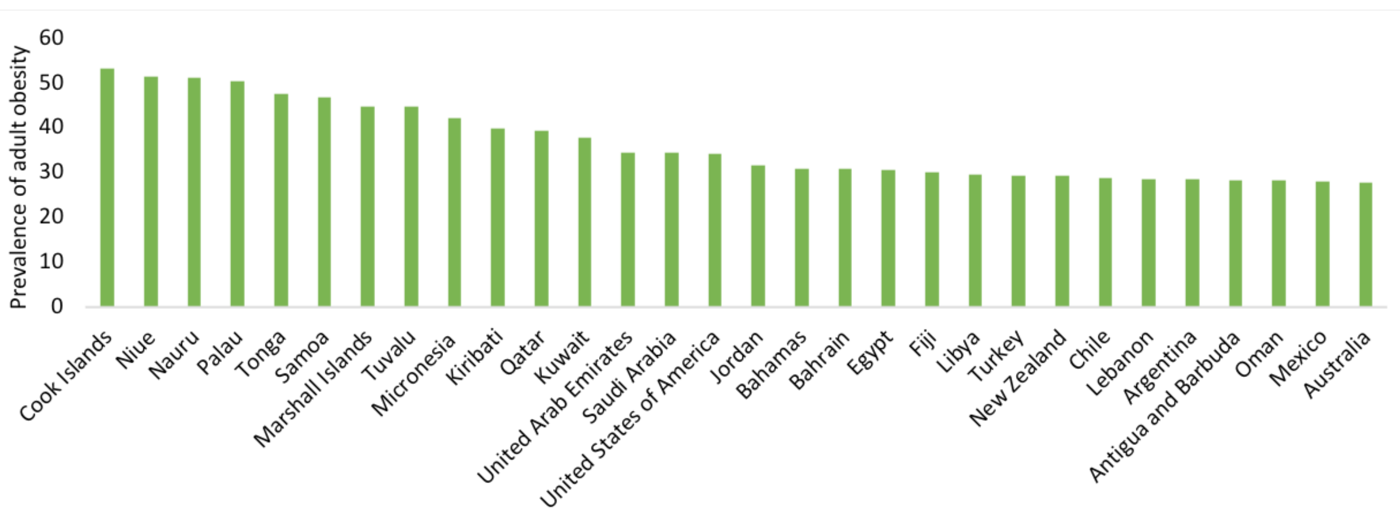
Overnutrition is another form of malnutrition with important implications for risks of non-communicable diseases such as heart disease and diabetes. The prevalence of children under age five who are overweight is increasing in all regions. Oceania, North America, and Latin America and the Caribbean have the highest prevalence of overweight children at 9.6 percent, 7.8 percent, and 7.0 percent, respectively, while the northern and southern sub-regions of Africa both have rates above 10 percent. Adult obesity is similarly on the rise in all regions; in 2014, obesity affected 13 percent of the global adult population, or some 600 million adults (Figure 4). Places where high rates of under- and overnutrition coincide (for example, Iraq, Egypt, and Vanuatu, where the prevalence of childhood stunting and that of adult obesity are both more than 20 percent) are likely to face an especially high burden of both communicable and non-communicable disease, often referred to as the double burden.

Figure 3. Countries where more than 20 percent of total population were undernourished in 2015 (3-year average 2014–2016)



Source: FAOSTAT, http://www.fao.org/faostat/en/#data/FS (accessed September 24, 2017).
Note: See Appendix 1 for a table of undernourishment by country for all FAO reporting countries.

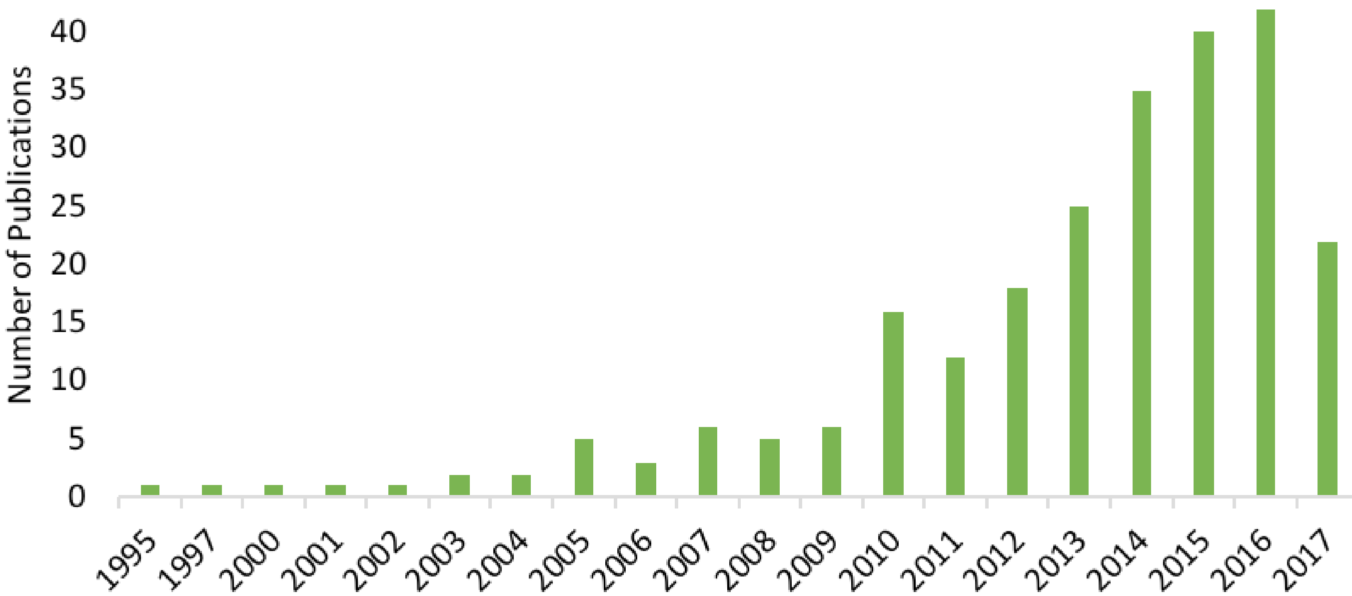
Figure 4. Countries with the highest prevalence of adult obesity



Source: WHO Global Health Observatory, Annex B: Tables of health Statistics by Country, WHO Region, and Globally. http://www.fao.org/faostat/en/#data/FS (accessed September 24 2017).*Note:* Reported prevalence corresponds to the mean of adult female prevalence and adult male prevalence. Confidence intervals are available in the original dataset.

Unlike some staple foods such as rice and other grains, fish is unique in that it has the potential to address multiple dimensions of food security and nutrition simultaneously. Fish is an excellent source of lean protein, fatty acids, and essential micronutrients that can combat undernourishment and nutritional deficiencies as well as contribute to an overall dietary pattern that supports healthy weight and body composition. Although the role that fisheries can play in enhancing food and nutrition security worldwide has often been sorely understated in policy arenas (HLPE 2014), there exists a burgeoning interest in it. For example, a recent global study on the contributions of marine fisheries uses novel datasets to underscore the magnitude of potential health consequences related to reduced fisheries production (Golden et al. 2016). The body of research on the contribution of capture fisheries to food and nutrition security is growing (Figure 5).

Figure 5. Growth in the number of research publications on the contribution of capture fisheries to nutrition or food security



This report's literature review provides an overview of the state of the field of knowledge, policy, and research on the contributions of fisheries to nutrition and food security. The section Current Knowledge synthesizes the findings of the peer-reviewed papers and gray literature that examine the role of capture fisheries in global food security and nutrition. In doing so, it presents a picture of the current understanding of the magnitude of capture fisheries' contributions to nutrition and food security both globally and in specific regions, countries, and communities as well as of the broader processes that influence those contributions. The following section, Implications for Public Policy, describes the contemporary and evolving policy discourse on capture fisheries' nutrition and food security contributions and highlights a few of the most salient policy issues in the field. Finally, the section Data and Research describes the body of research in the field, highlighting in particular the geographical distribution of research and identifying key datasets that underpin current and potential research on fisheries' contributions to food and nutrition security.

CURRENT KNOWLEDGE

Total Global Fish Production

According to the FAO's most recent *State of the World Fisheries and Aquaculture* report, global total fish production has kept pace with population growth as of 2014. However, aquaculture accounts for the bulk of increased production, suggesting that capture fisheries may be approaching their food provision limits, at least in terms of volume (c.f. Costello et al. 2016; World Bank 2013).Of the 167.2 million metric tons of total

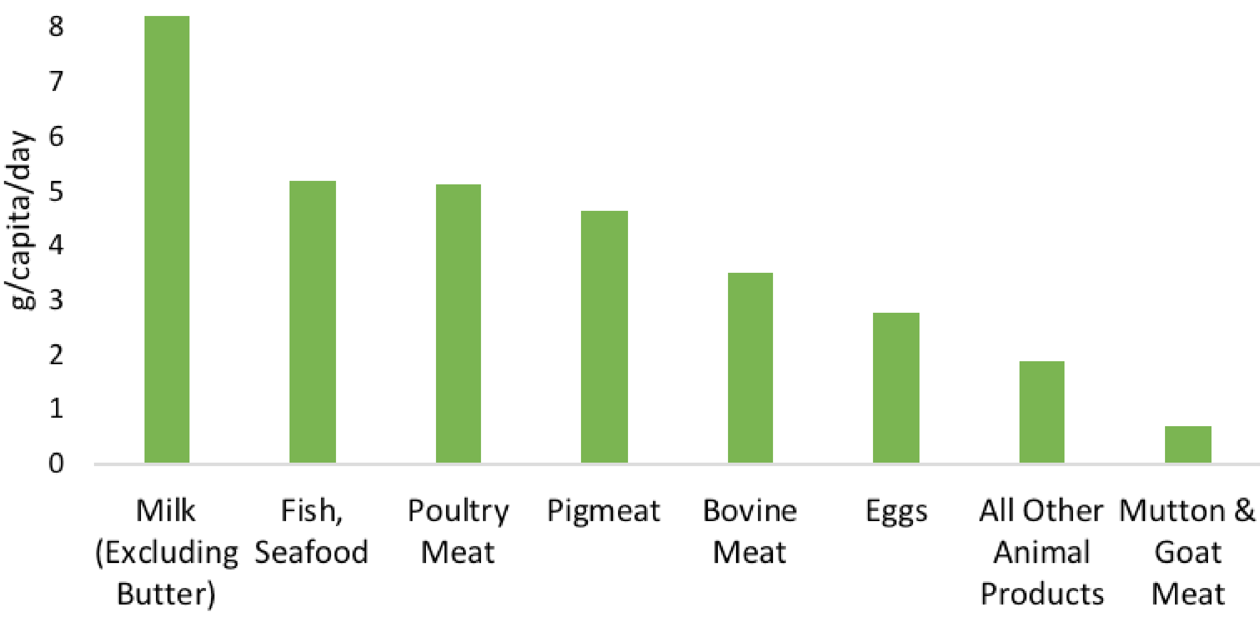
Current Supply of Fish

Understanding fisheries' role in food and nutrition security requires information on how much fish is available and where it comes from.

- In 2014, fisheries and aquaculture produced 167.2 million metric tons, amounting to 20 kilograms per capita for the year, or 17 percent of animal protein consumed by the global population.
- Capture fisheries contributed more than half of the total global fish production. However, a greater proportion of aquaculture production was destined for human consumption.
- Many projections indicate that capture fisheries production is likely to stagnate or decline due to overfishing and other threats such as climate change. However, other analyses suggest that under appropriate management the supply of fish from capture fisheries could expand in the relatively short term.
- Small-scale fisheries contribute nearly 50 percent of global capture fisheries production, and inland fisheries, many of which are small scale, reported producing 13 percent of capture production in 2014.

fish produced in 2014, capture fisheries accounted for 93.4 million metric tons (just under 56 percent), and aquaculture contributed 73.8 million metric tons (some 44 percent). Eighty-seven percent of total world fish production was destined for direct human consumption, and the rest was used for fishmeal and fish oil, ornamental and culture purposes, bait, pharmaceutical uses, and aquaculture and livestock feed. Of that 87 percent destined for human consumption, aquaculture produced slightly more than half, owing to the larger portion of wild-caught fish destined for other uses, including aquaculture feed (FAO 2016b). Overall 2014 saw an all-time high of 20 kg per capita supply of fish, amounting to 17 percent of the animal protein consumed by the global population (FAO 2016b). The world protein contribution of fish is similar to that of poultry and greater than the individual contributions of pig meat, bovine meat, mutton and goat, and eggs (Figure 6). These global statistics suggest the overall contribution of capture fisheries to the world's food supply, yet obscure important geographical and nutritional nuance.

Figure 6. World protein contribution of primary animal sources 2013



Source: FAO Food Balance Sheets, http://www.fao.org/faostat/en/#data/FBS (accessed September 21, 2017).

Small-Scale Fisheries Production

Small-scale fisheries are an important sub-production system of the broader capture fisheries production system for food and nutrition security. According to current data, the small-scale sector accounts for about half of global catch and 90 percent of the world's fishers (World Bank 2012). Despite general agreement about the significance of small-scale fisheries for food security and livelihoods, lack of reliable data precludes a more rigorous quantification of that significance. Often, small-scale vessels are not registered or their catches are not reported in government statistics. Moreover, it is difficult to discretely classify small-scale production as subsistence, that is, for direct consumption by the family or community, or commercial, because many of the fisheries are multi-species and harvest concurrently for household consumption and trade (Allen 2013). As a result, official statistics (that is, those reported to FAO) likely underreport small-scale fisheries catches. Catch reconstruction data estimate much higher landings for marine small-scale fisheries (Belhabib, Sumaila, and Pauly 2015; Chuenpagdee et al. 2006; Jacquet, Fox, Motta, Ngusaru, and Zeller 2010; Dirk Zeller, Booth, Davis, and Pauly 2007; D Zeller, Harper, Zylich, and Pauly 2015). This finding suggests that nutrition and food security contributions of small-scale fisheries are also higher than currently known, especially because nearly all of small-scale fisheries catch is destined for human consumption in contrast to the industrial sector, which contributes a substantial portion to non-consumptive uses (Chuenpagdee et al. 2006).[1]

[1] Here, Chuenpagdee et al. (2006) use national criteria for distinguishing between small-scale and industrial sector/large-scale fisheries. Definitions vary by country, referencing a range of possible criteria such as boat size and type, gross registered tonnage (GRT), engine size, gear type, distance from shore, water depth, level of commercialization, number of crew, or travel time.

Inland Fish Production

Inland fisheries, which comprise capture fisheries harvesting from inland waterbodies, rivers, floodplains, lakes, reservoirs, and even aquatic agriculture systems such as rice fields, are also important for nutrition and food security. Inland fisheries contributed nearly 12 million metric tons of the total 93.4 million metric tons from capture fisheries in (FAO 2016b). Although this production represents only 12.7 percent of all capture fisheries, inland fish supplies are crucial for countries in Asia such as Cambodia, Myanmar, Bangladesh, and Lao PDR and are particularly crucial for landlocked countries in Africa, for example, Uganda, Chad, Congo, and Malawi. Some inland fisheries are large-scale operations harvesting fish for high-value markets, for example the Nile perch fishery and the trawl fisheries of Lake Malawi and the Amazon River estuary (Cooke et al. 2016). However, most inland fisheries are oriented to household consumption and local trade, with direct benefits to local food security (Welcomme et al. 2010). As a result, inland fisheries face challenges similar to those confronting small-scale fisheries with regard to being data-limited and underrepresented in policy arenas.

Contribution of Fish to Global Food Security

The importance of global fish production for nutrition and food security varies geographically across regional, national, and subnational scales with many regions, countries, and communities dependent on fish at rates far above the global average. Figure 7 shows geographical variation in fish dependency, calculated as the percent of animal-source protein provided by fish. Maldives, Cambodia, Sierra Leone, Kiribati, Solomon Islands, Sri Lanka, Bangladesh, Indonesia, and Ghana all obtain more than half of their animal-source protein from fish.[2] In Iceland, Japan, Norway, and the Republic of Korea and in some small island states, where fish is the preferred and most available protein source, animal-source protein from fish provides more than 130 calories per capita per day (compared to the 34-calorie global average) (FAO 2016b). For 3.1 billion people, fish makes up almost one-fifth of total protein consumption.[3] Southeast Asia is an especially fish-dependent region. For example, within the ASEAN region, fish consumption is almost twice the global average (even though overall animal protein consumption is much lower), offering 38 percent of animal protein to the population and 33.4 kg per capita per year (Chan et al. 2017).[4] In Lao PDR, where the prevalence of undernourishment is 17 percent (see Appendix 1), wild fish are the most frequently eaten animal protein (Arthur and Friend 2011). In Bangladesh, fish contribute more than 60 percent of animal-source food (Belton et al. 2011; Roos, Wahab, Hossain, and Thilsted 2007). Multiple studies point to fish as the main source of food and protein for people in various parts of the Pacific (Charlton et al. 2016). Fish is crucial for coastal indigenous groups, who on average consume fish at a rate that is 15 times higher than the global average (Cisneros-Montemayor, Pauly, Weatherdon, and Ota 2016).

Even national statistics belie the most crucial food security contributions of fish. Some of the most fish-dependent populations are located in countries in which the contribution of fish is relatively low at the national level. At subnational scales, individual communities can be almost entirely dependent on seafood for protein. For example, in Velondriake, Madagascar, fish are the protein source for 99 percent of meals with concentrated protein (Barnes-Mauthe, Oleson, and Zafindrasilivonona 2013). In some isolated communities in the Brazilian Amazon, fish is consumed on average six days per week, amounting to an average of 169 kg per capita per year, one of highest rates in the world (Isaac et al. 2015). Fish is often one of the only animal protein sources available for increasing dietary diversity in populations where the

Food Security Contributions of Fish

Fish makes crucial contributions to food security at global, national, and local levels.

- Globally, more than 3.1 billion people rely on fish for nearly one-fifth of their average per capita protein from animal sources.
- Some countries (Maldives, Cambodia, Sierra Leone, Kiribati, Solomon Islands, Sri Lanka, Bangladesh, Indonesia, and Ghana) obtain more than half of their animal-source protein from fish.
- Certain individual communities are nearly entirely dependent on fish for protein. For example, in Velondriake, Madagascar, fish constitute 99 percent of meals with concentrated protein, and some communities in the Brazilian Amazon consume 169 kilograms of fish per capita per year, much higher than the global average of 20 kilograms per capita per year.

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[2] See Appendix Table 2.

[3] FAO (2016b).

[4] The ASEAN, or Association of Southeast Asian Nations, includes Brunei, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand ,and Vietnam (Chan et al. 2017).

starch-based staples predominate, especially because fish is often less costly and more accessible than other animal-source foods (Belton and Thilsted 2014).

Figure 7. Fish dependency around the world

Source: FAOSTAT Food Balance Sheets, http://www.fao.org/faostat/en/#data/FBS (accessed September 21, 2017).
Note: Fish dependence is defined here as percent of animal source protein from fish.

Even national statistics belie the most crucial food security contributions of fish. Some of the most fish-dependent populations are located in countries in which the contribution of fish is relatively low at the national level. At subnational scales, individual communities can be almost entirely dependent on seafood for protein. For example, in Velondriake, Madagascar, fish are the protein source for 99 percent of meals with concentrated protein (Barnes-Mauthe, Oleson, and Zafindrasilivonona 2013). In some isolated communities in the Brazilian Amazon, fish is consumed on average six days per week, amounting to an average of 169 kg per capita per year, one of the highest rates in the world (Isaac et al. 2015). Fish is often one of the only animal protein sources available for increasing dietary diversity in populations where starch-based staples predominate, especially because fish is often less costly and more accessible than other animal-source foods (Belton and Thilsted 2014).

In addition to direct consumption, fisheries contribute to food and nutrition security through income generation, increasing the household's ability to purchase food and providing a source of employment for women who participate in fishing and postharvest activities (Kawarazuka and Béné 2010). Although it is difficult to quantify the extent of their total contribution to income and impact on food security, fisheries are a crucial source of income for many people. Recent estimates suggest that fisheries and aquaculture support the livelihoods of 10 percent to 12 percent of the world's population, providing income of more than half a billion people worldwide (FAO 2014b; WorldFish 2011). Capture fisheries, alone, provide full- and part-time employment to approximately 120 million people, 97 percent of whom live in developing countries and 47 percent of whom are women (World Bank 2012). The small-scale sector, making up 90 percent of the world's fishers, is especially important in terms of enhancing food and nutrition security through income generation

(Barnes-Mauthe et al. 2013; Béné, Steel, Luadia, and Gordon 2009; Kawarazuka and Béné 2010; World Bank 2012). In theory, capture fisheries could also enhance national food security through macro-economic contributions to countries' GDP, for example, through exports or licensing fees paid by foreign fishing vessels. In practice, the extent to which such contributions translate into improved nutrition and food security depends on a range of governance and political factors that vary by country and that are difficult to measure (Béné, Lawton, and Allison 2010). More empirical research is needed to evaluate the connections between capture fisheries and food security through multiple pathways beyond direct consumption of fish (Kawarazuka and Béné 2010).

Health Benefits and Risks of Fish Consumption

The nutritional contributions of fish are multiple and go beyond simply providing a source of calories and protein. Fish are a valuable source of fatty acids, including the omega-3 polyunsaturated fatty acids (PUFAs), docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA) (HLPE 2014). One of the most important contributions of fish is in the form of essential micronutrients (Golden et al. 2016; Hughes et al. 2012), including vitamins D, A, and B (of which B12 is particularly associated with seafood), and calcium, phosphorus, iodine, zinc, iron, and selenium (Béné et al. 2016). The actual nutritional content of fish varies substantially by species and species group (Bogard et al. 2015) (tables 1 and 2). Variation also occurs according to a number of factors such as seasonality, habitat, trophic level, and diet (Sushchik, Rudchenko, and Gladyshev 2017). For example, the fatty acid composition of different gastropods was found to vary, likely due to their different locations within tidal zones and associated microalgal diets (Bano, Ayub, and Siddiqui 2014). In addition to providing micronutrients directly, consumption of fish and other animal-source foods increases nutrient absorption from plant-based sources (Neumann, Harris, and Rogers 2002).

The vitamins that fish provide have important health implications. Vitamin D deficiency is a prevalent health issue worldwide and is especially severe in countries in the Middle East (Palacios and Gonzalez 2014). Vitamin D deficiency can lead to rickets in children, can affect bone health in adults, and is associated with increased risk of common cancers, autoimmune diseases, high blood pressure, and cardiovascular disease as well as communicable diseases (Holick 2007; Holick and Chen 2008; T. J. Wang et al. 2008). For pregnant women, insufficient levels of vitamin D are associated with increased risk of preeclampsia, gestational diabetes, preterm birth, and low birth weight (Wei, Qi, Luo, and Fraser 2013). Natural low-cost dietary sources of vitamin D are highly scarce (Bhutta et al. 2013), so the contribution of fish is particularly important. Vitamin A deficiency is the leading cause of preventable childhood blindness, and because vitamin A supports the body's use of iron, its lack can also contribute to weakened immune system and anemia (WHO 2009). In part due to its contributions to the ability to fight infection, vitamin A supplementation has been associated with reduced child and maternal mortality (Bhutta et al. 2008; Fawzi, Chalmers, Herrera, and Mosteller 1993; West Jr. et al. 1999). Vitamin B is important in combination with iron and folate to prevent anemia and a number of neurologic and cognitive problems (Moll and Davis 2017; Tiemeier et al. 2002; H.-X. Wang et al. 2001; Wilson et al. 1999). By providing these vitamins, fish has the potential to help alleviate a number of serious health conditions.

Minerals available in fish are equally crucial to human health. For example, iron deficiency leads to anemia, a serious worldwide problem that causes fatigue, low

Multifacted Health Benefits from Fish

Fish provide essential micronutrients—vitamins and minerals—and omega-3 fatty acids, which are necessary to end malnutrition and reduce the burden of communicable and non-communicable disease around the world.

- In addition to healthy lean protein, fish provide crucial fatty acids, including omega-3 polyunsaturated fatty acids, and essential micronutrients, including vitamins A, D, and B and calcium, zinc, iron, and iodine.
- The density of different nutrients in fish varies by species, habitat, and environmental factors as well as by how the fish are processed, prepared, and consumed.
- The multiple nutrients found in fish have a variety of health benefits, including lowered risk of cardiovascular disease; improved maternal health, pregnancy outcomes, and infant and early childhood physical development; improved immune system function; and alleviation of health issues associated with micronutrient deficiencies such as anemia, rickets, childhood blindness, and stunting.
- Consumption of fish also carries some risk of exposure to toxic substances such as polychlorinated biphenyls, dioxins, methylmercury, and microplastics.

productivity, and maternal and perinatal mortality. Globally, anemia is estimated to affect about 800 million women and children, a number that could be reduced by approximately half through increases in iron intake (WHO 2009). Zinc is important for growth and development and supports immune system function. Zinc supplementation has been associated with reductions in the incidence and prevalence of diarrhea, pneumonia, and infections such as malaria as well as with improved brain development (Hambidge 2000). Zinc deficiency, which correlates with the prevalence of child stunting at the country level, is especially prevalent in sub-Saharan Africa and South Asia (Wessells and Brown 2012). In places where an increasing reliance on staple foods may reduce the bioavailability of zinc, fish can play an especially important role (Kawarazuka and Béné 2010).

A large body of work places particular emphasis on high levels of polyunsaturated fatty acids (PUFAs) in fish, especially the long-chain omega-3 fatty acids DHA and EPA, which are essential for cardiovascular and brain health. The consumption of fish or fish oil has been shown to be associated with benefits to coronary health, for example, lower risk of death and sudden death from coronary heart disease, ischemic stroke, atrial fibrillation, and congestive heart failure (Mozaffarian and Rimm 2006). Worldwide, 1.4 million deaths are attributable to diets low in seafood-source omega-3 fatty acids (Lim et al. 2012). Fish consumption correlates with a 36 percent reduction in heart disease and heart attacks and a 12 percent reduction in mortality from all causes (Mozaffarian and Rimm 2006; Zhao et al. 2016). Although marine fish, especially tuna and small pelagic forage fish, typically have higher levels of polyunsaturated fatty acids than freshwater fish, many freshwater fish also can contain high levels of DHA and EPA, for example, rainbow trout, lake trout, common carp, wild tilapia, high waterman catfish, and speckled pavon (Youn et al. 2014).

Fish consumption is particularly important to pregnant and lactating women, infants, and young children who have particular nutrient requirements and are especially vulnerable to malnutrition (Allison 2011; FAO 2016b; Kawarazuka and Béné 2010). In poor countries, malnutrition accounts for 45 percent of mortality in children under age five and for half of the total number of years that children age four years and younger lived with a disability. In Bangladesh, the risk of child mortality is significantly lower for children born during peak fishing seasons to mothers who have a preference for fish (Dasgupta, Mustafa, Paul, and Wheeler 2017). One study found that a number of inland fish are capable of providing at least 25 percent of recommended nutrition intake for infants and pregnant or lactating women in Bangladesh (Bogard et al. 2015). In Cambodia, fish are a crucial source of iron for women and children (Roos, Chamnan, Loeung, Jakobsen, and Thilsted 2007) and nutrient-dense fish, especially wild-caught fish, are an essential part of the diets of infants and children, even prior to 12 months of age (Brooks and Sieu 2016). A study in Tanzania found that the breastmilk of women who consumed high levels of freshwater fish had DHA levels above even those recommended for baby formulas (Kawarazuka 2010). When consumed by mothers, DHA and EPA from fish have been linked with better infant and child cognitive development, less preterm delivery, and a decreased risk of asthma, food allergy, and eczema for the child (Swanson, Block, and Mousa 2012). Omega-3 fatty acids have also been successfully used to treat behavioral problems in children (Raine, Portnoy, Liu, Mahoomed, and Hibbeln 2015). Freshwater fish eaten whole contribute substantially to overall calcium intake in Bangladesh and sub-Saharan Africa, thus helping prevent cases of childhood rickets (Youn et al. 2014).

In addition to health benefits, fish are associated with some health risks (e.g., Chou, Paon, Moffatt, and Zwicker 2000). Primary concerns are with levels of methylmercury, which can cause neurodevelopmental problems in children and which may contribute to cardiovascular disease in adults, and with polychlorinated biphenyls (PCBs) and dioxins that may lead to cancer risks (Mozaffarian and Rimm 2006; Oken et al. 2012). These risks are an important consideration for certain groups such as high consumers of fish, the elderly, pregnant women, nursing mothers, and children.[5] As with nutritional advantages of fish, health risks can vary dramatically by type of fish consumed as well as by the environment. For example, the U.S. Food and Drug Administration (FDA) and U.S. Environmental Protection Agency (EPA) distinguish between "best choices" (e.g., anchovy, lobster, and trout), "good choices" (e.g., halibut, grouper, and albacore tuna), and "choices to avoid" (e.g., king mackerel, bigeye tuna, and marlin) (FDA and EPA 2017). The FDA and EPA advise pregnant women and breastfeeding women to consume two to three servings of "best choices" fish per week or one "good choice" serving of fish per week. The USDA 2015–2020 Dietary Guidelines also recommend consumption of species known to be low in methylmercury, such as sardines, salmon, anchovies, or trout (HHS and USDA 2015). Typically, the bioaccumulation of toxins is lower among fish species from lower trophic levels (Burger et al. 2001; Denton and Burdon-Jones 1986; Lacerda, Bidone, Guimaraes, and Pfeiffer 1994), which happen to be those most accessible to the poor in developing countries.

[5] See https://www.epa.gov/choose-fish-and-shellfish-wisely/fish-and-shellfish-advisories-and-safe-eating-guidelines.

Nonetheless, in some places, there are still acute health risks. In the Pacific, ciguatera, a foodborne illness caused by consuming fish with accumulated levels of certain marine algal toxins from the food chain (Van Dolah 2000), can lead to serious neurologic, gastrointestinal, and cardiac symptoms (Béné et al. 2016). Increasing evidence demonstrates that microplastics, tiny plastic particles smaller than five millimeters, from marine litter and runoff are ubiquitous in the marine environment and are consumed by a range of fish and invertebrate species (Auta, Emenike, and Fauziah 2017). Recent evidence raises concerns about potentially widespread health risks of exposure to microplastics (Deng, Zhang, Lemos, and Ren 2017). The general agreement of experts, however, is that the benefits of consuming fish outweigh the risks, even at high consumption levels for the general population and at moderate consumption of most species for pregnant and lactating women (HLPE 2014; Mozaffarian and Rimm 2006).

Multifaceted Contributions of Fish

In relation to nutrition, food security, and health outcomes, the research frames the role for fish differently in developed and developing countries. In developing countries, fisheries' food and nutrition contributions are evaluated with respect to their role as a low-cost animal-source food and essential micronutrients (Béné et al. 2016). Developing countries and low-income food-deficit countries consume an annual per capita average of 18.8 kg and 7.6 kg, respectively, falling below the global average for per capita fish consumption of 20 kg. Yet these countries also tend to have higher fish dependency, meaning that they rely on fish for a greater portion of animal protein than developed countries (FAO 2016b). In developing countries, small indigenous fish species (SIS) that are consumed whole provide especially high levels of vitamins and minerals, in particular vitamin A, calcium, and iron (Roos, Islam, and Thilsted 2003; Roos, Wahab, Chamnan, and Thilsted 2007). Women in Cambodia obtain a large portion of their calcium, zinc, and iron from fish (51 percent, 39 percent, and 33 percent, respectively), and in Bangladesh, 40 percent of vitamin A and 31 percent of calcium requirements come from fish (WorldFish 2011). Additionally, fish could potentially support the health of two billion people deficient in vitamin A, many of whom are concentrated in Africa (Kawarazuka and Béné 2010). Fish, which is typically more affordable than other animal-source foods (Kawarazuka and Béné 2010), plays an especially important dietary role in countries where staple foods like rice, wheat, corn, roots, and tubers make up a large portion of diets and access to protein is low, thereby improving the energy/protein ratio (FAO 2016b). Nonetheless, the role of fresh fish is likely declining in some developing countries as dietary patterns shift toward imported and processed foods high in fat and carbohydrates and as the costs of fresh and canned fish become increasingly prohibitive (Andersen, Thilsted, and Schwarz 2013).

In developed countries, the importance of fish and fish oils is framed more often in terms of providing polyunsaturated fats to lower the risk for chronic disease and coronary heart disease, managing elevated triglyceride levels, lowering blood pressure, reducing obesity, and boosting infant and child cognitive development (Jenkins et al. 2009; WorldFish 2011). In general, industrialized and developed countries have an annual per capita consumption of fish higher than the global average, consuming 26.8 kg and 23.0 kg respectively (FAO 2016b). Nonetheless, some countries consume fish below recommended rates. The U.S. Department of Agriculture (USDA) recommends that Americans eat at least eight ounces of seafood per week, which provides 250 milligrams (mg) of DHA and EPA. This level of seafood consumption correlates with decreased rates of cardiac arrest, reduced risk of cardiovascular disease, and vitamin D deficiency as well as with improved infant health outcomes when consumed by pregnant and breastfeeding mothers (HHS and USDA 2015). However, the U.S. population on average consumes well below the recommended amount of seafood and, as a result, the USDA recommends replacing other sources of animal protein with seafood twice a week (HHS and USDA 2015). In some industrialized countries of Europe and Asia, diets high in fish are traditionally popular, although there are signs that dietary patterns may be shifting. In Spain, for example, adherence to the Mediterranean diet has waned, suggesting a lower reliance on fish (Bach-Faig et al. 2011).

Threats to Capture Fisheries Production

Although capture fisheries and aquaculture are both important food production systems for alleviating hunger and malnutrition, capture fisheries are distinct in that a number of processes, if not addressed, stand to undermine their food and nutrition security contributions. In particular, overfishing, population growth, and climate change are likely to alter the volume and distribution of wild-caught fish supply, potentially to the detriment of sufficient and equitable global food provisioning. A recent analysis predicts that 10 percent of the world will experience deficiencies in essential micronutrients and fatty acids as a result of declining capture fisheries and that these implications will be concentrated in low-latitude developing countries (Golden et al. 2016). Production levels for marine capture fisheries are projected to stagnate or decline unless there is dramatic change to existing management regimes (Costello et al. 2016; World Bank 2013). These fisheries' continued capacity to provide nutrition will depend on multiple factors, including governance arrangements, climate change effects, and technological change (Garcia and Rosenberg 2010).[6]

Research is beginning to document examples of management deficiencies. In the Caribbean, for example, overfishing coupled with increasing trade of commercially valuable fish species has contributed to a dietary pattern shift in which households are substituting fresh fish with imported and highly processed foods (Paddock 2017). In Kuwait, overfishing and high population growth are projected to lead to a severe shortage of domestic fish supply, which is estimated to decrease to 0.5 kg per capita per year by 2025 (Al-Zaidan, Al-Mohanna, and George 2013). Some studies suggest that fish-dependent communities have so far been able to compensate by fishing in new areas and even at new times of day (Albert, Aswani, Fisher, and Albert 2015). Population growth further compounds the challenges of maintaining a sufficient supply of fish to meet food security needs. For example, on the basis of surveys of fish consumption and population projections, Bell et al. (2015) predicted that coastal fisheries in more than two-thirds of Pacific Island country territories (PICTs) will fall short of producing enough fish to support the region's growing population by the year 2030.

The effects of climate change on fisheries' contribution to food security is likely to be geographically variegated and dependent on policy measures (Campbell et al. 2016). For example, eastern PICTs may see an increased catch of tuna, whereas western PICTs may see decreases (Bell et al. 2013). One model predicted that climate change might negatively affect the Mexican shrimp industry but benefit the sardine industry; the food security implications of the latter phenomenon would depend on nuanced issues of use and distribution of sardine protein (Ibarra, Vargas, and López 2013). A projection of the response of West African fisheries to climate change suggested 21 percent lower landings value, 50 percent fewer jobs, and losses to the West African economy exceeding 300 million U.S. dollars by 2050 (Lam, Cheung, Swartz, and Sumaila 2012).

Some research suggests that there is room to expand inland capture fisheries production (Amarasinghe, Kumara, and De Silva 2016), but inland fisheries face unique threats in addition to those affecting capture fisheries more broadly. Many of these threats emerge from external environmental pressures and other sectors, for example, polices promoting the conversion of wetlands for aquaculture infrastructure and diversion of freshwater for other uses such as hydropower dams, flood control, irrigation projects, crop and livestock production, forestry plantations, and industrial uses. Furthermore, inland water bodies are often more easily altered through climate change, pollution, and invasive species (Arthur and Friend 2011; Baird 2011; CGIAR 2012; Kafumbata, Jamu, and Chiotha 2014; Ottaviani, De Young, and Tsuji 2016; Youn et al. 2014). Loss of inland fisheries is especially alarming from a food security perspective because replacing lost protein with less sustainable land-based sources most likely implies increasing footprints of water, energy, and greenhouse gas emissions (Cooke et al. 2016).

IMPLICATIONS FOR PUBLIC POLICY

The threats to capture fisheries described above point to the need to forge integrated public policies to sustainably govern capture fisheries. Fisheries policies must grapple with the more general challenges associated with governing common-pool resources (CPRs). In capture fisheries, as in other CPRs, monitoring and enforcing rules limiting who can harvest resources, how they can harvest them, and how much they can harvest is costly and difficult. Governance burdens can be especially high when the number of vessels is high and fishing activities are highly dispersed (as in many small-scale fisheries) or when resources are highly mobile (as in tuna and other pelagic fisheries). Under such conditions, high market value for resources as well as population growth, technological change, and detrimental political economic relations at multiple scales can drive overexploitation, not to mention conflict over distribution of benefits and the management objectives themselves.

The FAO, WorldFish, and many other organizations have been working to increase knowledge and awareness of fisheries' contributions to food and nutrition security for a long time. However, within the policy realm there remains a need to amplify explicit links between issues of food security and fisheries governance, which are often isolated from one another. For example, the 1995 Code of Conduct For Responsible Fisheries, an international agreement that provides guidance

[6] See Costello et al. (2016) for a range of projections under different conditions.

to states regarding the development of fisheries policies and regulations, pays only nominal attention to issues of food security (HLPE 2014). SDG14, "to conserve and sustainably use the oceans, seas, and marine resources for sustainable development" highlights the need to expand marine conservation and enhance economic benefits, but it does not mention food or nutrition (UN 2015b).

At the same time, fisheries are often sorely absent in global food security and nutrition policy discourse (Béné et al. 2015; FAO 2017a) and in scientific dialogue on sustainable food systems (Farmery, Gardner, Jennings, Green, and Watson 2017; Thilsted et al. 2016). For example, SDG2 to "end hunger, achieve food security and improved nutrition, and promote sustainable agriculture," spells out concrete actions that are relevant almost exclusively to terrestrial agricultural food systems (UN 2015b). As a result, the role of inland fisheries in food security and nutrition is nearly entirely excluded from the sustainable development agenda, considering that SDG 14 (oceans) pertains only to marine environments. The current thinking on nutrition-sensitive food systems, that is, the design of interventions specifically to support diverse diets and improve nutrition, generally overlooks the role for sustainable fisheries (Thilsted et al. 2016). Even though the sustainability of many fisheries is under threat, Costello et al. (2016) argue that under appropriate management reforms, overexploited fisheries can recover in the relatively short term, increasing global annual marine capture production by 16 million metric tons. This outlook suggests there may be ample space to advance integrated fisheries policies that account explicitly for nutrition and food security outcomes. Ultimately, establishing more explicit links between fisheries governance and food policy can facilitate informed dialogue about tradeoffs and synergies among conservation, economic growth, and food security and livelihoods (Béné et al. 2016; CGIAR 2012).

Keys to Policy Development

Developing policy that supports fisheries' food and nutrition contributions requires a shift from the status quo.

- Fisheries policy and food policy arenas have been largely isolated from each other.
- Fisheries policies often aim to optimize economic benefits or conserve charismatic species, and most food policies tend to focus almost exclusively on terrestrial systems.
- Supporting the food and nutrition security contributions of fisheries will thus require development of coherent policies integrated across domains (economic, social, environmental, legal, and political), issues (health and nutrition, climate change adaptation, trade), and sectors (capture fisheries and aquaculture, agriculture).
- Developing policies that support the nutrition and food security contributions of capture fisheries also entails balancing multiple and potentially conflicting objectives, including optimizing economic benefits, enhancing nutrition and food security, and conserving biodiversity.

There are signs that the policy salience of capture fisheries as food production systems is increasing. For example, the FAO recently formed a new intradepartmental technical group on fish, food security, and nutrition to enhance analysis and communication of the topic (FAO 2017a), and the FAO recently published *The Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication* (FAO 2015). The Second International Conference on Nutrition (ICN2) explicitly called for the development of coordinated public policies regarding fisheries and aquaculture (FAO and WHO 2014). The High-Level Panel of Experts (HLPE) on Food Security and Nutrition of the Committee on World Food Security convened by the FAO published *Sustainable Fisheries and Aquaculture for Food Security and Nutrition*, which articulates specific policy strategies for advancing such policies. Recommendations of the report include linking climate change adaptation strategies with fisheries' roles in food security, explicitly considering food security in policies related to trade, protecting labor rights and promoting gender equity in the fisheries sector, and developing fisheries governance aimed at food security and nutrition outcomes (HLPE 2014).

Effective integrative policy relies on policy coherence, which entails accounting for interactions across different domains (e.g., economic, social, environmental, legal, and political), institutional mechanisms that monitor and address those interactions, rigorous empirical-analytical bases for decision making, and multi-stakeholder dialogue (OECD 2017). Policy coherence that supports fisheries' nutrition and food security contributions means designing fisheries policy with greater involvement of development specialists and increasing cross-sectoral initiatives that integrate fisheries and aquaculture, agriculture, health and nutrition, climate change adaptation, energy, water, and trade policy (WorldFish 2011). Although the original language of SDG14 (oceans) does not explicitly recognize nutrition or food security goals, a recent OECD publication highlights the interlinkages with a number of SDGs:

> The ocean (SDG14) provides resources and services to address the economic, social, and environmental challenges and commitments embodied in the SDGs. The ocean contributes to a wide range of goals and targets, from poverty eradication (SDG1), food security (SDG2) and climate change (SDG13) to the provision of energy (SDG7), employment creation (SDG8) and improved health (SDG3). Fisheries and aquaculture have a particularly important role to play in achieving the poverty eradication targets in SDG1, as the sector is estimated to support the livelihoods of about 10–12 percent of the world's population (OECD 2017, 14–15).

The extent to which this policy discourse will translate into action is as yet unclear, although examples of fish-based interventions are emerging. Over the last 15 years or so, a number of interventions aimed at enhancing nutrition by increasing direct consumption of fish, income from fish, and empowerment of women have resulted in improved nutritional outcomes; many of these interventions focused on aquaculture and did not necessarily draw connections with broader policies related to sustainable capture fisheries (Kawarazuka 2010). Although inland development policies have tended to downplay capture fisheries in favor of other freshwater uses such as energy and irrigation, in Laos, food-centered development is emerging as a counter-narrative emphasizing the importance of capture fisheries (Arthur and Friend 2011).

Integrating nutrition and food security objectives into traditional fisheries policies entails confronting challenging tradeoffs among different management goals (e.g., sustainability, food security, economic efficiency, and macro-economic development), which involve ethical choices in addition to technical advancements (Hall, Hilborn, Andrew, and Allison 2013; Jennings, Smith, Fulton, and Smith 2014). For example, managing capture fisheries production to maximize economic benefits does not optimize food availability because it typically entails reducing fishing effort below the maximum sustainable harvest levels to increase economic efficiency. Conversely, harvesting the highest sustainable amount of food tends to reduce economic benefits. Likewise, Szuwalski, Burgess, Costello, and Gaines (2016) assert that there is an inherent tradeoff between maintenance of overall biodiversity and conservation (e.g., the depletion of top predators) and total fish production. They illustrate this idea in the East China Sea, an area that has been heavily exploited, but lightly managed, and claim that implementing polices to conserve individual species would result in decreases in catch at the ecosystem level there and possibly globally. Certainly, this idea is controversial; some would argue that enhancing biodiversity promotes overall system resilience, an important benefit as ecosystems are subjected to various stressors including climate change. In this vein, some models suggests that under ecosystem-based management, increasing production to meet food security objectives would not necessarily threaten resource sustainability as long as consumers substitute different fish species according to production levels (Cissé, Doyen, Blanchard, Béné, and Péreau 2015). However, determining production levels to achieve the optimum balance of food production, sustainability, and economic benefits is a complicated task, because these parameters are also affected by environmental, economic, and technological factors that influence biological abundance and economic profitability (Dueri et al. 2016). Furthermore, even when there is evidence of stock declines, reductions in fishing effort are unlikely if there are few or no alternative options for accessing protein (Batista, Fabre, Malhado, and Ladle 2014). Nonetheless, developing policy explicitly directed at maintaining or enhancing fisheries' nutrition and food security contributions requires determining whether management goals aim to maximize economic benefits, maximize food security, or achieve a balance between the two goals.

The most appropriate policy approaches to promoting the contribution of fisheries to nutrition and food security will inevitably be context dependent. In industrialized and developed countries, where higher incomes and fisheries imports provide ample access to fish, interventions that focus on individual behavior and preferences may be a useful strategy for increasing consumption. However, tension arises with regard to the implications of increased consumption for fisheries sustainability and for equitable distribution of fish supply between developed countries and developing countries and with regard to perceptions about potential health risks, for example, from PCBs and methylmercury (Brunner, Jones, Friel, and Bartley 2008; Clonan, Holdsworth, Swift, Leibovici, and Wilson 2012). Some even suggest that reducing fish as total percentage of protein supply will move the world toward improving the sustainability of marine ecosystems (Almeida, Karadzic, and Vaz 2015; Villasante, Rodríguez, Antelo, Quaas, and Österblom 2012).

One policy approach to increasing fish consumption in the developed world without threatening sustainability or supply elsewhere involves shifting consumption to domestic and sustainable species. For example, the Environmental Defense

Fund encourages consumers in the United States to seek out domestic fish species whose stocks have been rebuilt and managed at sustainable levels.[7] Efforts to modify tastes and preferences may allow fisheries to redistribute harvests across a greater spread of species in the ecosystem that have not been as intensely exploited (Zhou, Smith, and Knudsen 2015). Another potential approach is to promote the consumption of sustainable seafood through ecolabels, although the effectiveness of this strategy in the context of food security is still unclear, especially given that seafood sustainability does not drive seafood consumption choices in many places (Clonan et al. 2012; Cooke, Murchie, and Danylchuk 2011; Fabinyi and Liu 2014). Policies focusing on individual choice and behavior may not always be as appropriate contexts where dietary shifts are more about decreased access and affordability (Darling 2014; Paddock 2017).

The effects of trade on how and where fisheries contribute to food security and nutrition is the subject of ongoing debate, as are the policy implications. Seafood is one of the most-traded food commodities in the world. The value of seafood trade is higher than that of sugar, maize, coffee, rice, and cocoa combined (Asche, Bellemare, Roheim, Smith, and Tveteras 2015). An estimated 78 percent of fish and fishery products are exposed to international trade competition (FAO 2016b), so accounting for trade is an important aspect of overall policy regarding fisheries, nutrition, and food security, especially policy for capture fisheries, given the increasing pressures that trade can place on fish stocks and broader ecosystems (Bennett and Basurto 2018; Smith et al. 2010).

At a conceptual level, there are debates about whether free trade or protectionist policies favoring domestic production over imports better support food security. Some organizations such as the WTO maintain that free trade, not protectionism, enhances food security. At the same time, some countries—such as Japan and developing countries seeking to enhance their fishing sectors—argue that self-sufficiency in food production is a key component of food security. This perspective can serve to justify policies such as capacity-enhancing fishing subsidies, including fuel subsidies, boat and infrastructure investment, and price, marketing, and post-harvest sector support (Barclay and Epstein 2013). Opposing viewpoints contend that such subsidies seriously undermine food security because they can stimulate fisheries production to exceed the limits of biological sustainability (Sumaila, Dyck, and Cheung 2013; Sumaila et al. 2010).

There is evidence on both sides of the debate regarding whether trade positively or negatively affects food security (Béné et al. 2010). On the one hand, trade may divert fish from local consumption. On the other hand, contributions to income and GDP may support food security through indirect pathways. Additionally, trade can distribute seafood to places that would otherwise have limited access. As global demand for seafood continues to rise, in part driven by economic growth in many regions of the world (Naylor 2016), net trade in seafood flows from developing countries and into developed countries. Although concerns for food security exist because developing countries export more seafood than they import, this trade deficit is less apparent when measured in quantity rather than value, indicating that developing countries export high-value seafood and import more low-value seafood (Asche et al. 2015; Smith et al. 2010). Further, it suggests that developing countries are well-compensated for the seafood that they export and (at least in theory) could substitute seafood with the purchase of other food (Asche et al. 2015).

Some research suggests that the discourse on fisheries' contribution to food security has tended to neglect the complementary roles that trade and subsistence play; low-value fish species can be used for household consumption, whereas high-value species can be traded for purchases of staples such as rice (Fabinyi, Dressler, and Pido 2017). Longitudinal household surveys provide evidence that the Nile perch trade boom increased average income and reduced the share of household income spent on food in two Lake Victoria communities, suggesting that trade can enhance food security through the "income" pathway (Eggert, Greaker, and Kidane 2015). However, the dual goals of increasing fishers' income by increasing the price they receive for fish and making the price of fish accessible to low-income consumers can be at odds. Furthermore, prices that reflect export market value may not be accessible to local consumers (Andrée, Langille, Clement, Williams, and Norgang 2016). In addition to international trade, local trade may be particularly important to food security. A study in Brazil showed that fisher and non-fisher households consumed similar amounts of fish protein, suggesting that local fish availability, rather than subsistence fishing *per se*, influences food security (da Costa, De Melo, and Lopes 2014). Environmental, socio-economic, and multi-sectoral dynamics affect fish marketing channels and the availability of fish for local consumption (Abbott, Hay, Næsje, Tweddle, and van der Waal 2015). Ultimately, understanding how trade shapes the contributions that fisheries make to nutrition and food security is a complex issue requiring more rigorous and systematic research into the multiple mechanisms at work at local, regional, and international scales.

[7] https://www.edf.org/card/12-fish-youve-probably-never-heard-should-eat.

DATA AND RESEARCH

Data Needs and Availability

Building a comprehensive understanding of the role that capture fisheries play in nutrition and food security entails integrating different data sources to address a number of key questions (Table 1). Data on the production and distribution of fish provide a baseline for understanding the extent to which fisheries can contribute to food and nutritional needs in different places around the world. Data on fish consumption patterns—typically collected at the household level—lend further insight into how fish supply translates into food provision. Consumption data can also serve to triangulate and add granularity to production and trade data. Knowledge on the nutrient profiles of different fish and the ways that processing, preservation, and preparation techniques affect nutritional characteristics augment knowledge about potential nutritional contributions associated with different fish consumption patterns. Dietary guidelines and recommended nutritional intakes for different populations then provide a basis for understanding the significance of nutrition from fish consumption with respect to individual nutritional requirements. Finally, these data can be situated within the broader context of food and nutrition security, creating a more comprehensive understanding of where fish currently support good nutrition or could contribute more to alleviating particular forms of malnutrition.

Emerging Data and Research

Data availability and research related to fisheries' food and nutrition security contributions are rapidly expanding, but more is needed.

- An expanding body of data and research is adding breadth and specificity to knowledge about fisheries' nutrition and food security contributions.
- Informing both research and policy are datasets such as the FAO's collections of data on fish production, trade, food balance, and food security indicators as well as food composition tables.
- However, important data gaps exist, in particular regarding the nutrient content of different fish species and fish supply and consumption at subnational levels.
- Research on data gaps has focused primarily on certain countries and regions—especially the United States, Pacific Island countries and territories, Bangladesh, and Cambodia—indicating a need to expand the geographical focus of research.
- Key emerging research themes include improving understanding of (1) the role of gender dynamics in linking capture fisheries to household nutrition and food security, (2) interactions between capture fisheries and aquaculture and the nutrition and food security implications of those interactions, and (3) the nutrition and food security implications of particular fisheries policies.

Production

The FAO's production and trade databases are the most widely used datasets for assessing the quantity of fish produced at different spatial scales.[8] The FAO's Global Capture Production database includes annual fisheries production statistics for some 240 countries and 26 major fishing areas for the years 1950 to 2015, disaggregated over approximately 1,800 marine and freshwater animal and plant species and products (FAO 2017b). In addition, the FAO houses a number of regional capture statistics databases.[9]

Table 1. Understanding fisheries' contribution to nutrition and food security

Key data	Key questions
Fisheries production Fisheries distribution and trade Fish supply	How much fish is available for consumption? Where are fish available for consumption?
Fish consumption Social, cultural, and political economic dimensions of fish consumption	Who is consuming fish? What fish are being consumed and how? How do social, economic, and political factors affect fish consumption?
Nutrient profiles of different fish species Nutritional implications of processing and preparation techniques	What are the potential nutritional contributions of the fish being consumed? How do processing and preparation techniques affect nutritional contributions?
Dietary guidelines Recommended nutrient intakes for specific sub-populations	What is the potential nutritional contribution of fisheries to an overall healthy diet? What is the potential nutritional contribution of fisheries to sub-populations with specific needs?
State of food and nutrition security in the world Geographic distribution of specific forms of malnutrition	Where can fisheries make the most significant contributions to food and nutrition security?

[8] Access to FAO's global statistical databases on fisheries is available at http://www.fao.org/fishery/statistics/en.

[9] FAO regional production statistics databases include the CECAF (Eastern Central Atlantic) Capture Production database (1970 onward), the GFCM (Mediterranean and Black Sea) Capture Production database (1970 onward), and the RECOFI Capture Production database).

The FAO datasets are the official statistical collections on global fisheries production and are the most comprehensive such collections; however, they are subject to some challenges related to accuracy. Because reporting countries provide the catch statistics that populate FAO's databases, the data quality can vary from country to country or over time for the same country. In the aggregate, errors could potentially lead to misunderstandings about the current and future predicted availability of fisheries resources. For example, possible over-reporting by major fish-producing nations such as China may tip the scales on global catch rates from declining to stable, potentially producing inaccurate assessments of the sustainability of fish supply from capture fisheries (Pauly and Zeller 2017). Conversely, China's increased reported catch may also reflect, in part, increased available biomass of lower trophic species after the removal of top predators from the ecosystem (Szuwalski et al. 2017).

A database developed by the Sea Around Us Project (SAUP database) has sought to use catch reconstructions to generate estimates that correct for reporting errors, in particular, to better account for fish discards and unreported catches in sectors frequently underrepresented in official government reporting systems such as subsistence fisheries.[10] The catch reconstruction data cover the time period from 1950 onward and can be broken down at different spatial scales (e.g., EEZ or FAO region) and sectors (industrial, artisanal, subsistence) (D Zeller et al. 2016). Notably, the SAUP database does not include data on inland fisheries, and there are inherent limitations to the accuracy of catch reconstructions resulting from uncertainty about the assumptions underlying them (Ye et al. 2017).

A particular need remains to better account for production from small-scale and inland capture fisheries (FAO and WorldFish 2008). The report *Hidden Harvest: The Global Contribution of Capture Fisheries* generated estimates of the contributions of small-scale fisheries to fish production and employment, and it represents the current authoritative statistics on the sector (World Bank 2012). An updated Hidden Harvest study evaluating small-scale fisheries contributions across a broader set of indicators is in development. The Too Big to Ignore (TBTI) project is a global research network that addresses concerns affecting the viability and sustainability of small-scale fisheries.[11] TBTI has launched the State of the Art project, a comprehensive literature review of research on small-scale fisheries around the world that draws on the Information System on Small-Scale Fisheries (ISSF).[12] On the basis of this information system, TBTI has recently assembled regional fact sheets that characterize the existing body of literature pertaining to each region along dimensions of research emphasis, technical aspects, trade dynamics, governance and management, and the country and species coverage of the literature as well as research gaps.[13] Although the TBTI data do not represent a comprehensive database, they can highlight key issues and address knowledge gaps with detailed information about localized cases. For inland fisheries, the FAO's *Review of the State of the World Fisheries Resources: Inland Fisheries* provides detailed information on the world's inland fishery resources, including contribution to food supply. An updated revision of this report will be published in 2018.

The measurement of illegal, unreported, and unregulated (IUU) catches has also evaded accurate quantification for obvious reasons, in small-scale as well as industrial fisheries. However, Agnew et al. (2009) generated a global estimate of illegal and unreported catches and the SAUP catch reconstruction database also contains estimates of discarding. Given the crucial roles that both small-scale and inland fisheries play in providing fish for direct human consumption, improving the availability and completeness of data is essential for research and policy related to fisheries' role in food security and nutrition. Similarly, because unreported and unregulated catches potentially constitute substantial subsistence harvests, continuing to improve estimates of those catches is equally important.

Distribution

Quantifying how much fish is produced is not sufficient to understand food security implications because fish trade redistributes this production around the world; 36 percent of global fish production is traded internationally among more than 200 countries (FAO 2016b). The FAO's Fisheries Commodities and Trade dataset provides national import and export data (by both value and volume) for the years 1976 to 2013, broken down into more than 100 commodities and commodity

[10] Access to the SAUP data is available at http://www.seaaroundus.org/data/#/eez.
[11] See www.toobigtoignore.net.
[12] The Information System on Small-scale Fisheries (ISSF) is accessible at https://issfcloud.toobigtoignore.net.
[13] One example can be found at http://toobigtoignore.net/wp-content/uploads/2014/11/Africa_poster_final.pdf, which is accessible from the page linked in footnote 12 above.

groups (FAO 2014a).[14] When taken together, statistics on fish production and on fish trade can provide a coarse-grained picture of the distribution of fish supply. Key reports by the World Bank, WorldFish, and IFPRI have utilized the FAO databases to project future fisheries supply and demand around the world (Chan et al. 2017; World Bank 2013).

The FAO fisheries commodities and trade data have some important limitations. First, these data do not differentiate between fish commodities originating from aquaculture and capture fisheries. Second, the commodity categories do not necessarily correspond with the species categories reported in the fisheries production database. Furthermore, import data and export data are reported independently and therefore do not indicate trade flows of fish. Watson, Nichols, Lam, and Sumaila (2017) have attempted to link fish-exporting and -importing countries with most likely trading partners to create a database of trade flows.

Supply

Together, data on domestic fish production, fish trade, and quantities of fish directed to non-food uses allow the FAO to generate data on the supply of fish available for consumption in a given country. Based on this approach, the FAO Food Balance Sheets include data on national supplies of different food sources, including different fish groups (freshwater, demersal, pelagic, marine, crustacean, cephalopod, and so on) and their contribution to per capita dietary energy (kcal), protein, and fats.[15] These data allow the calculation of measures such as fish dependency, defined as the percent of animal-source protein provided by fish. Food balance data provide a measure of apparent, rather than direct, fish consumption. However, these data often do not fully account for informal cross-border trade or food waste within households. And, notably, national-level statistics often belie high rates of fish consumption in particular sub-national locales, for example, communities of the Brazilian Amazon whose fish consumption far exceeds the relatively moderate national levels of fish consumption (Isaac et al. 2015).

Consumption

In many countries, data on the amount of fish and other foods consumed is collected through household surveys, often referred to as household income and expenditure surveys (HIES). Although these surveys represent a more direct measure of consumption than food balance, they are collected with survey instruments that vary with respect to fish and food categories, sampling methodologies, and year conducted, making multi-country comparisons or aggregation difficult. Furthermore, the data are typically not publicly available. The FAO/WHO Global Individual Food Consumption Data Tool (GIFT) is currently under development with the aim of harmonizing and disseminating these dispersed and disparate data.[16] Cisneros-Montemayor et al. (2016) have drawn together a comprehensive collection of studies to create a database of fish consumption levels among coastal indigenous peoples.

In addition to numbers and types of fish consumed, it is also important to understand the social, cultural, and political economic factors that influence choices about fish consumption. Religious and cultural traditions can shape whether fish are consumed and how they are prepared. Political economic factors at different scales affect access to fish. Power dynamics within the household, including gender relations, can influence who accesses the fish available for consumption. At a broader level, changing market dynamics can affect the availability of fish for local consumption (Abila 2003) or the relative accessibility of packaged or processed foods (Paddock 2017). Finally, changing social conceptions about what constitutes a desirable diet intersect with ideas of class and development, so understanding how different kinds of fish are positioned within these social narratives is also key. Acquiring these types of knowledge will likely depend on in-depth qualitative analyses in addition to quantitative datasets.

Nutrient Profiles

Not all fish are equal with respect to the nutrients they contain, so data on the nutrient profiles of different fish species are needed to begin to understand the implications of supply or consumption of fish for actual nutritional outcomes. In addition to peer-reviewed studies (e.g., Bogard, Marks, Mamun, and Thilsted 2017; Bogard, Marks, Wood, and Thilsted 2017; Bogard et al. 2015), a number of data sources compile information on the nutritional characteristics of seafood. Within the FAO/INFOODs databases, the Global Food Composition Database for Fish and Shellfish contains data on the energy, macronutrients, vitamins, minerals, amino acids, and fatty acids content of different species, separated by

[14] This dataset does not differentiate capture sources from aquaculture sources.

[15] Access to FAO Food Balance Sheets is available at: http://www.fao.org/faostat/en/#data/FBS.

[16] Updates on the development of FAO/WHO GIFT are available at http://www.fao.org/nutrition/assessment/food-consumption-database/en/.

geographical region.[17] The USDA also has a food composition database that includes fish.[18] The Global Expanded Nutrient Supply (GENuS) database has linked detailed food composition tables with FAO's Food Balance Sheets and Production and Trade datasets to provide data on the supply of individual micronutrients from different food categories at the country level (see Smith et al. 2016; Golden et al. 2016).

Dietary Guidelines and Recommended Nutrient Intake

Dietary and nutritional guidelines provide information on recommended seafood consumption for countries, regions, and population subgroups around the world. Countries and regions regularly publish government recommendations on nutritional guidelines. For example, the *Dietary Guidelines for Americans 2015–2020* (USDA 2105), *Guidelines for the Brazilian Population* (Ministry of Health Brazil 2014), *Dietary Guidelines for Bangladesh* (BIRDEM 2013), and the *Food-based Dietary Guideline for Nigeria* (NDFMH 2006) all highlight different nutritional issues and recommendations based on the particular context. The FAO makes a number of countries' dietary guidelines available on its website on food-based dietary guidelines.[19] WHO also publishes nutrition-related guidelines and recommendations based on systematic literature reviews—guidelines that pertain to specific nutritional topics and subpopulations, such pregnant women and infants.[20] These represent current (although ever-evolving) recommendations regarding the role of seafood in contributing specific nutrients and as part of overall healthy dietary patterns.

State of Food Security and Nutrition

Finally, data on the distribution of hunger and malnutrition can inform where fisheries' impact may be the greatest. Data sources include WHO's Global Health Observatory Data Repository as well as FAO's suite of food security indicators, which provide information on the distribution of hunger and malnutrition around the world.[21]

Research Trends

Since 2010, a number of papers and reports discuss fisheries and aquaculture in relation to nutrition and food security, each with a slightly different scope. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, *Sustainable Fisheries and Aquaculture for Food Security and Nutrition,* provides a thorough review of the importance of fisheries and aquaculture for food and nutrition security and strategies for maintaining the contributions of those systems (HLPE 2014). The WorldFish working paper, *Fisheries, Aquaculture, Poverty and Food Security,* which focuses on developing countries, examines how a transition to more sustainable and efficient fisheries and aquaculture management can be formulated with sensitivity to enhancing food security and poverty reduction (Allison 2011). Béné et al. (2016), focusing specifically on developing and emergent countries, offer an assessment of the literature on the contributions of fisheries and aquaculture to nutrition, food security, and economic growth. The authors assess the literature with respect to the scientific rigor and agreement among conclusions about salient themes, including the evidence linking fish to food security, nutrition, health, and poverty alleviation; interactions between fisheries and aquaculture; and drivers of change. Béné et al. (2015) position their review of the topic in terms of establishing an evidenced-based argument for a more conspicuous role for fish in the broad food security debate, highlighting the magnitude of fisheries;' contributions, efficiency, and environmental sustainability (Béné et al. 2015). Kawarazuka and Béné (2010) identify and evaluate the evidence for three causal pathways linking small-scale fisheries and aquaculture to nutritional security through direct consumption, income generation, and increased status and involvement of women in fisheries and aquaculture-related activities. Finally, Kawarazuka (2010) emphasizes similar fish-nutrition linkages in a review of the potental impacts and limitations of fish-based nutritional interventions. All of these review pieces point to the need to hone methodological and conceptual approaches to generate more robust evidence on the role of fish in nutrition, food security, and livelihoods more broadly.

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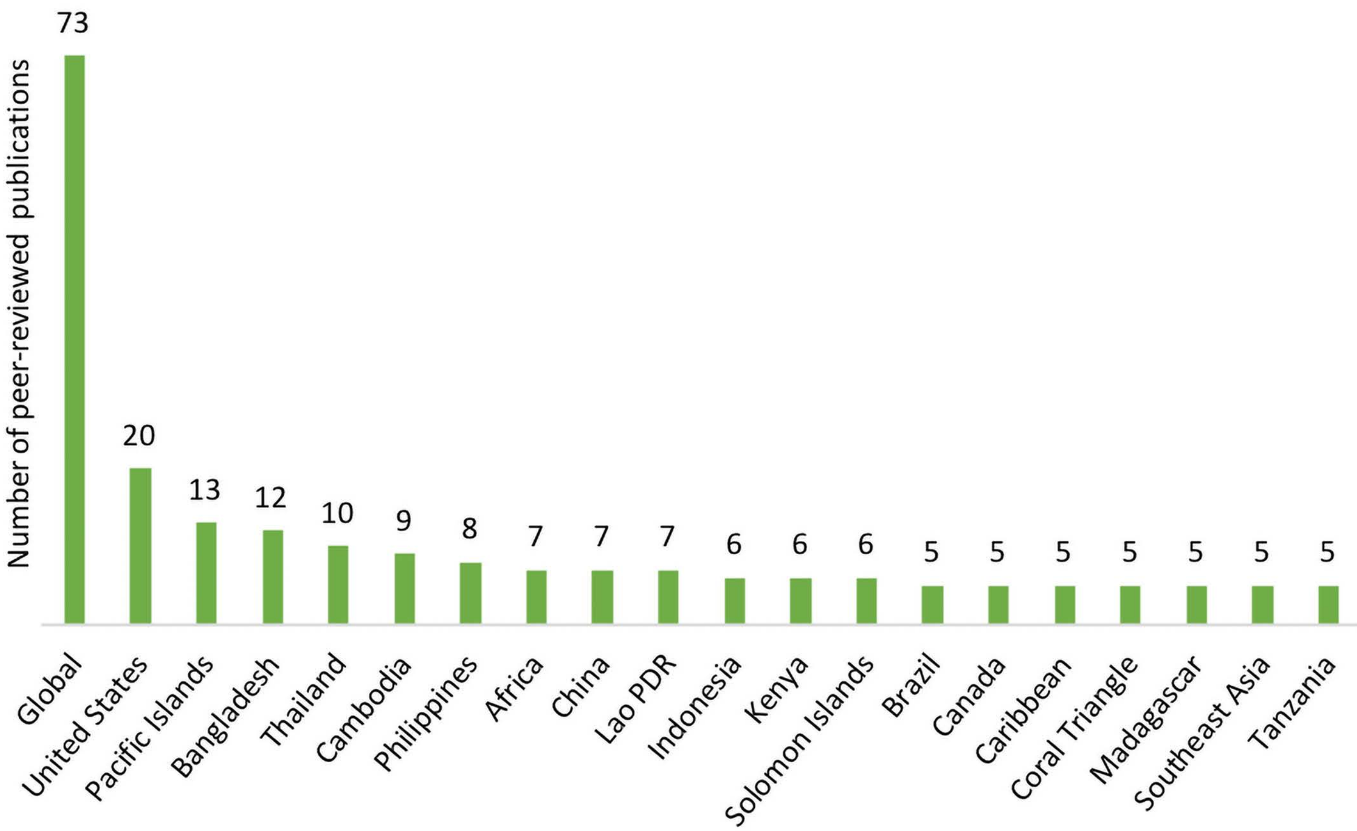
[17] The Global Food Composition Database for Fish and Shellfish is accessible at http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/.
[18] The USDA Food Composition Database is accessible at https://ndb.nal.usda.gov/ndb/.
[19] See http://www.fao.org/nutrition/education/food-dietary-guidelines/home/en/.
[20] See http://www.who.int/publications/guidelines/nutrition/en/.
[21] FAO's Food Security Indicator data are available at http://www.fao.org/faostat/en/#data/FS. The WHO's Global Health Observatory Data Repository is available at http://www.who.int/gho/database/en/.

Geographies

The peer-reviewed literature search conducted for this report returned articles covering a wide range of geographic delineations (Figure 8): 73 articles reflected a global perspective were the most common. The United States was the next most-represented geographic area, with 20 articles, and Pacific Islands, Bangladesh, and Thailand were each covered by more than 10 articles. One to four papers covered each of more than 100 other countries and regions (Table A.1).[22]

Figure 8. The 20 most-represented geographical delineations in the peer-reviewed literature on the contribution of fisheries to nutrition and food security



The impact of a policy shift toward integrating fisheries, nutrition, and food security will depend on research that enhances understanding of the magnitude of fisheries' contributions to food security and nutrition as well as the factors that affect the distribution, access, and use of fisheries resources and alternative resources. Existing datasets and literature provide a basis for guiding the focus of research to the places, species, and themes that can contribute the most valuable insights into evolving policy discourses. In particular, data on fish dependency (e.g., Table A.2) and prevalence of undernourishment (e.g., Table A. 3) can be used as guides to select particularly significant cases. These data can be coupled with studies that project where processes such as climate change, overfishing, and population growth are likely to have greatest impact on supply and demand for fish.

Conducting research in regions and countries that have already been the subject of extensive study in the field has value in that it can build on a foundation of analyses, research networks, and policy partnerships. The Pacific Islands are one important center of fisheries and food security research. Among the peer-reviewed papers assembled for this report, the Pacific Islands region garnered only less attention than the world at large and the United States. The emphasis on the Pacific is well justified given that fish constitutes a high percentage of animal-source protein for many PICTs. Projections suggest that given current conditions of population growth, fisheries governance, overfishing, and climate change, many PICTs will

[22] This breakdown does not offer a precise analysis of coverage by region or country because the geographic delineations of the articles were not always mutually exclusive (e.g., Solomon Islands are part of the Pacific Islands). However, it is informative to understand how the published literature geographically bounds the research.

not be able to meet their fish supply needs within the next few decades (Bell et al. 2009; WorldFish 2008). Although PICTs are not, in general, among the most undernourished countries, they tend to have high rates of adult obesity. Thus, despite the substantial body of research already taking place in PICTs, much more is needed, in particular to understand the current and potential nutritional outcomes of reduced access to fresh fish, especially in the context of rapid ongoing dietary transitions and the rising prevalence of the double burden of communicable and non-communicable disease (Charlton et al. 2016). The south and southeast Asian countries of Bangladesh, Thailand, Cambodia, and the Philippines immediately follow the Pacific Islands in research coverage. These countries are also among the most fish-dependent; Cambodia and Bangladesh count on fish for more than half of their animal protein, and Thailand and the Philippines rely on fish for approximately one-third of theirs. In addition, Cambodia, Bangladesh, and the Philippines each have among the 50 highest rates of undernourishment prevalence in the world.

Greater knowledge about the status and drivers of fisheries' nutrition and food security contributions in many countries and regions could be valuable. For example, Sierra Leone, Congo, Mozambique, and Uganda all rely on fish for more than 30 percent of animal protein and also suffer from a high prevalence of undernourishment yet are not well-represented in the literature. For other countries in Africa, research to bolster knowledge about inland fisheries is especially important. Alternatively, research on countries for which fish consumption is particularly low, such as India and some Latin American countries, may contribute to better understanding of the barriers associated with incorporating more fresh fish into diets.

It is worth noting that country-level statistics can obscure important variations valuable for guiding research. For example, Brazil is not particularly fish-dependent or food insecure, but it is home to isolated communities that are nearly entirely dependent on fish for protein. This geographical variation in fish dependency also underscores the need to seek improved data and knowledge regarding the nutritional contributions of fish at sub-national scales. Otherwise, policy makers focused on national averages may not sufficiently attend to the significance of fish for particular segments of the population – many of which may not have sufficient access to other animal-source foods.

Themes

Gender, Fisheries, and Nutrition and Food Security

Gender equity and women's empowerment play an important role in food and nutrition security, including in the context of fisheries. Multiple studies have put forth the hypothesis that women's engagement in the fisheries sector, either through harvesting or post-harvesting activities, can lead to increased access to food at the household level, especially for mothers, infants, and children (Kawarazuka and Béné 2010; Thilsted et al. 2016; World Bank 2011). For example, when women participate in harvesting fish, they may target small, nutritious species for the household rather than commercially valuable products intended for trade (Béné et al. 2009; Friedman et al. 2008; Pinca et al. 2008). A study of chronically poor communities in the Congo reported that women, who target smaller fish, direct 60 percent of their harvests to household consumption compared with 27 percent of men's harvests (Béné, Steel, Luadia, and Gordon 2009). Kawarazuka and Béné (2010) and Heck, Béné, and Reyes-Gaskin (2007) highlight multiple examples in which women's role in marketing leads to empowerment and provides a significant proportion of women's household income contributions (e.g. Gnimadi 2004; Rubinoff 1999). Data about the fisheries sector that are disaggregated by gender is limited. However, estimates suggest that women occupy some 56 million of the 120 million full-time and part-time jobs that depend directly on commercial capture fisheries (World Bank 2012). In the Pacific, women harvest 56 percent of catch from small-scale fisheries (Harper, Zeller, Hauzer, Pauly, and Sumaila 2013). In addition to harvesting, post-harvest jobs allow women to contribute directly to the nutritional well-being of their children (Heck, Béné, and Reyes-Gaskin 2007). Given the importance of fish to the health and nutrition of mothers, infants, and children and a growing recognition of an important role for fish in the first 1,000 days of life (Longley et al. 2014), a time when women often make decisions about infants' nutrition, more research is needed with regard to how enhancing gender equity can increase food security and nutritional outcomes from capture fisheries. The current evidence connecting the empowerment of women with fisheries' contributions to food security and nutrition remains limited to a few cases and needs further hypothesis testing (Kawarazuka and Béné 2010). This work can benefit from being situated within broader critical examinations of gender and other power dynamics shaping the fisheries-food security nexus.

Interactions between Capture Fisheries and Aquaculture

Although this report focuses primarily on wild-caught seafood, the role of capture fisheries must necessarily be understood in the context of the fact that aquaculture is the world's fastest-growing food production sector. The rise of aquaculture interacts in several potential ways with capture fisheries. Aquaculture may lower seafood prices by increasing supply, although this outcome depends on the size of aquaculture production relative to capture production for a given commodity as well as on the substitutability of farmed and wild-caught fish (Asche, Bjørndal, and Young 2001; Norman-Lopez 2009; Valderrama and Anderson 2010). Although this substitutability may enhance the affordability of seafood for consumers, it can also reduce income to producers.

Aquaculture may negatively affect the environment, potentially undermining wild-capture fisheries. Environmental effects include increased eutrophication of coastal zones, as has been a result of shrimp aquaculture in Bangladesh (Bala and Hossain 2010). Antibiotics, parasiticides, antifoulants, supplements, and escapement of farmed fish all generate potential for disease, contamination, and dilution of wild stocks (Cabello 2006; Guardiola, Cuesta, Meseguer, and Esteban 2012; Jensen, Dempster, Thorstad, Uglem, and Fredheim 2009). The use of performance indicators such as the Global Aquaculture Performance Index can provide important information on how specific farmed fish stocks fair in terms of their impact on the ecosystem and environment.[23]

Aquaculture does not necessarily alleviate pressure from wild fish stocks because many farmed species currently require wild fish feed supplied by capture fisheries. Forage fish, which are typically low-cost nutritious fish, play an important role in food security in developing countries. Yet competition for these fish for aquaculture and animal feed is likely to affect their prices (Alder, Campbell, Karpouzi, Kaschner, and Pauly 2008). Although market forces largely shape the distribution of forage fish among food and non-food uses, there are a few examples of legislation that favor direct human consumption (Majluf, De la Puente, and Christensen 2017; Tacon and Metian 2009). One solution may be to shift away from wild feed, but that approach would tend to reduce the omega-3 content of farmed fish and thus nutritional value of those fish.

In terms of nutrition and food security, capture fisheries play a role distinct from but complementary to that of aquaculture (Thilsted et al. 2016). Nations with the highest fish dependence, which are mostly developing countries, are those that reap a larger portion of their fish from capture fisheries than from aquaculture (Hall et al. 2013). In developing regions, capture fisheries provide a greater diversity of highly nutritious fish than that produced through aquaculture (Belton and Thilsted 2014). In Bangladesh, aquaculture, which has compensated for decreased fish supply from capture fisheries, may not provide the same micronutrient profiles and dietary diversity to the poorest segments of the population that capture fisheries once did (Belton, van Asseldonk, and Thilsted 2014). The decline in consumption of non-farmed species in Bangladesh was accompanied by significant decreases in the contributions of fish to iron and calcium intake, suggesting that the commonly farmed fish are not as nutritious as the species targeted by capture fisheries (Bogard et al. 2017). Another case study in Bangladesh found that capture fisheries provided significantly more iron, zinc, calcium, vitamin A, and vitamin B12 than farmed fish (Bogard, Marks, Mamun, and Thilsted 2017). However, some aquaculture interventions are focusing specifically on incorporating micronutrient-dense small fish (Bogard, Marks, Wood, and Thilsted 2017). Although most fish produced by aquaculture are consumed domestically in Bangladesh and other countries, including China and India, there are still concerns that aquaculture production fails to reach the most nutritionally vulnerable and food insecure people in places like sub-Saharan Africa and some PICTs (Belton, Bush, and Little 2016, 2017; Golden 2016; Golden et al. 2016). Given the rising prominence of aquaculture as the world's fastest-growing food production system, empirical analyses into how the sector affects the viability of capture fisheries, the cost and accessibility of fish for different groups, and the nutritional content of the world's fish supply will help to strike a balance and avoid unintended consequences.

Nutrition and Food Security Impacts of Fisheries Governance

Working toward policy coherence involves explicitly evaluating the extent to which particular fisheries governance arrangements undermine or enhance nutrition and food security. An emerging segment of research highlights potential synergies of sustainable fisheries governance and food security. Strategies that redistribute fishing effort across a greater spread of species in an ecosystem, for example, through a balanced harvesting approach in which all species and sizes are harvested in proportion to the ecosystem's productivity, may strike a balance between ecosystem integrity and overall food supply (Burgess, Diekert, Jacobsen, Andersen, and Gaines 2016; Zhou et al. 2015). Beyond redistributing effort across different species, other research explores the potential for diverting current fish production from international markets to domestic consumption. The case for this approach is being made in the context of PICTs' tuna fisheries (Bell et al. 2015; Bell et al. 2009; Campbell, Hanich, and Delisle 2016). Other research investigates the food security implications of reducing

[23] See www.gapi.com.

fishing effort. Teh et al. (2016) project that a high-seas fishing closure could lead to net gains in catches of straddling stocks that are consumed domestically for some countries and to net losses for others, highlighting the importance of evaluating the distributional consequences of new governance measures affecting food security (Teh et al. 2016). Multiple studies on marine protected areas (MPAs) attempt to assess the food security effects of closing fishing areas (Aswani and Furusawa 2007; Añabieza, Pajaro, Reyes, Tiburcio, and Watts 2010). Accurately predicting and evaluating the effects of any policy measure on nutrition and food security is challenging from a methodological standpoint, but the more that research explicitly attends to these effects, the better it stands to inform integrated, coherent, and equitable policies. Given evidence that many species and ecosystems are currently being fished beyond sustainable limits, understanding the nutrition and food security implications of reducing fishing effort is a primary challenge.

CONCLUSION

The literature review presented here highlights multiple facets of the role of fish in nutrition, food security, and livelihoods; the different pathways by which fish are linked with nutrition and food security; and the processes shaping the potential role for fish in that context. This report builds on that work with a specific focus on capture fisheries, recognizing the sector's distinct nutritional contributions, severe threats from factors such as overfishing and climate change, and the need for a unique policy outlook. The report highlights the nutrition and food security contributions of fish in developed and developing countries, contributing to a broader dialogue on nutrition that recognizes not only undernutrition, but also dietary patterns linked with a range of communicable and non-communicable disease risk factors in the developed world. The broad literature review informing this report highlights four key points:

- ***The nutrition and food security contributions of fish, in particular from capture fisheries, are of crucial importance to the world's growing population.*** Fish provide 17 percent of the global supply of animal protein. Yet this global average belies the intensity of fish dependency in many places. Some countries rely on fish for more than half of their animal-source protein, and individual communities can be entirely reliant on fish. Perhaps even more crucial than protein and energy provision are the nutritional contributions that fish make in the form of micronutrients (vitamins, minerals) and fatty acids that are essential to alleviating malnutrition and preventing communicable and non-communicable disease. Fish-based interventions can substantially lower the risk of cardiovascular disease, prevent childhood blindness and rickets, improve immune function, and support maternal health and the cognitive and physical development of infants and children. Capture fisheries, in particular, provide a diversity of highly nutritious fish not matched by aquaculture.
- ***To maintain these important nutrition and food security contributions, policy needs to address a number of drivers of and threats to capture fisheries.*** According to recent estimates, 10 percent of the world will experience deficiencies in essential micronutrients and fatty acids as a result of declining capture fisheries. Left unchecked, overfishing will ultimately undermine the capacity of capture fisheries to contribute to nutrition and food security. Fisheries and food policy will need to address the tradeoffs and synergies related to reducing pressure on marine and inland resources while maintaining a nutritious food supply. Trade and climate change both drive shifts in the distribution of the world's fish supply. Each of these processes requires policy interventions and responses that match an understanding of the distributional consequences with geographically differentiated needs and vulnerabilities.
- ***Policy is only just beginning to recognize, and explicitly account for, the importance of capture fisheries to nutrition and food security.*** Traditionally, fisheries and food and nutrition policy have been largely isolated from each other. However, increasing recognition of the importance of fish for meeting global nutritional needs has yielded calls for coherent policy across domains (e.g., economy, environment, and development) and specific issues (e.g., climate change, public health, trade, and fisheries governance). Although language in key policy documents on fisheries governance, sustainable development, and food security is beginning to reflect these needs, the extent to which that language will translate into effective action is not yet known.
- ***More research on the magnitude and drivers of fisheries' contributions to nutrition and food security is needed to strengthen the evidence base for informed, integrated, and coherent policies.*** Although the body of research explicitly aimed at understanding linkages between capture fisheries and nutrition and food security is growing, it remains incipient. More robust evidence is needed to evaluate the multiple pathways (e.g., direct consumption,

income, empowerment of women, macroeconomic growth) through which fisheries contribute to nutrition and food security. Success in this regard will depend on enhancing the availability and reliability of data. For example, the development of datasets with increased nutritional specificity underpin promising new research into the role of fish not only in food security but also in fighting malnutrition and micronutrient deficiencies worldwide. Moving forward, expanding the geographical scope of research will inform a more complete understanding of the full range of relationships between capture fisheries and nutrition and food security. A focus on emerging issues regarding gender, aquaculture interactions, and the food and nutrition impacts of fisheries policies will further support effective and appropriate policy interventions.

APPENDIX: EXTENDED DATA TABLES

Table A.1. Frequency of peer-reviewed articles covering different geographic delineations

Geographic area	Article #	Geographic area	Article #	Geographic area	Article #
Global	73	Sri Lanka	3	Eritrea	1
United States	20	Timor-Leste	3	Ethiopia	1
Pacific Islands	13	Vietnam	3	Finland	1
Bangladesh	12	Zambia	3	French Guiana	1
Thailand	10	Angola	2	Global South	1
Cambodia	9	Benin	2	Greenland	1
Philippines	8	Equatorial Guinea	2	Guatemala	1
Africa	7	Europe	2	Haiti	1
China	7	Gambia	2	Honduras	1
Lao PDR	7	Ghana	2	Korea Republic	1
Indonesia	6	Guinea	2	Kuwait	1
Kenya	6	Guinea-Bissau	2	Maldives	1
Solomon Islands	6	Iceland	2	Micronesia	1
Brazil	5	Indian Ocean	2	Mozambique	1
Canada	5	Latin America	2	Myanmar	1
Caribbean	5	Malawi	2	Netherlands	1
Coral Triangle	5	Mauritania	2	Niger	1
Madagascar	5	Mekong	2	North America	1
Southeast Asia	5	Mexico	2	North Wales	1
Tanzania	5	New Zealand	2	Oman	1
Asia	4	Nicaragua	2	Pacific Ocean	1
Congo DRC	4	Oceana	2	Pakistan	1
Peru	4	Pacific Region	2	Papua New Guinea	1
Sub Saharan Africa	4	Russia	2	Portugal	1
Uganda	4	Sierra Leone	2	Samoa	1
West Africa	4	South Korea	2	Sao Tome Principe	1
Australia	3	Taiwan	2	Seychelles	1
Cameroon	3	The Amazon	2	Small Island Developing States	1
Comoros	3	Togo	2	Somalia	1
Fiji	3	Western Pacific	2	South America	1
India	3	African Great Lakes	1	Sudan	1
Ivory Coast	3	Atlantic Ocean	1	Tropical Pacific	1
Japan	3	Cape Verde	1	Turkey	1
Kiribati	3	Central America	1	Turks and Caicos Islands	1
Liberia	3	Coastal Tropics	1	Tuvalu	1
Malaysia	3	Costa Rica	1	United Kingdom	1
Namibia	3	Developing Countries	1	Vanuatu	1
Nigeria	3	Djibouti	1	West Indies	1
Senegal	3	Dominican Republic	1	Western Sahara	1
South Africa	3	Eastern Caribbean	1	Yemen	1
South Asia	3	Egypt	1		

Table A.2. Top 100 fish-dependent nations, measured in percent of animal-source protein derived from fish

Country	Fish-derived animal protein	Country	Fish-derived animal protein
Maldives	70.87%	China, Taiwan Province of	21.06%
Cambodia	68.71%	French Polynesia	21.02%
Sierra Leone	64.36%	Peru	21.01%
Kiribati	62.46%	Saint Kitts and Nevis	20.40%
Solomon Islands	59.13%	Bermuda	20.22%
Sri Lanka	55.30%	Portugal	20.18%
Bangladesh	54.13%	Burkina Faso	19.78%
Indonesia	52.68%	United Republic of Tanzania	19.71%
Ghana	49.94%	Spain	19.52%
Gambia	49.01%	Zambia	19.39%
Sao Tome and Principe	48.87%	Chad	19.28%
Nigeria	42.54%	China, Hong Kong SAR	18.73%
Senegal	42.49%	Mauritius	18.66%
Myanmar	42.36%	Jamaica	18.00%
Lao People's Democratic Republic	40.44%	Trinidad and Tobago	16.17%
Malaysia	38.88%	Namibia	16.11%
Philippines	37.46%	Dominica	16.00%
Togo	37.39%	Suriname	15.72%
Congo	36.63%	Latvia	14.38%
Mozambique	36.54%	Madagascar	14.17%
Cameroon	36.32%	Finland	14.14%
Japan	36.13%	Haiti	14.09%
Thailand	34.21%	New Caledonia	14.03%
Republic of Korea	34.16%	Malta	13.95%
Ivory Coast	33.80%	Tunisia	13.89%
Vanuatu	33.46%	Liberia	13.76%
Fiji	32.99%	Russian Federation	13.55%
Uganda	30.10%	Cyprus	13.47%
Malawi	27.98%	Central African Republic	13.31%
Iceland	27.83%	Saint Lucia	13.18%
Viet Nam	27.38%	France	13.04%
Guinea	26.86%	Iran (Islamic Republic of)	12.96%
Democratic People's Republic of Korea	25.52%	United Arab Emirates	12.73%
Benin	25.26%	India	12.68%
China, Macao SAR	24.48%	Bahamas	12.65%
Egypt	23.99%	Oman	12.56%
Gabon	23.75%	Cabo Verde	12.42%
Barbados	23.73%	Denmark	12.33%
Samoa	23.05%	Belize	12.19%
Brunei Darussalam	22.81%	Croatia	12.19%

Continued

Antigua and Barbuda	22.79%	New Zealand	12.10%
Rwanda	22.54%	Panama	11.91%
Morocco	22.18%	Italy	11.90%
Norway	22.15%	Sweden	11.73%
Lithuania	21.90%	Luxembourg	11.66%
Angola	21.79%	Saint Vincent and the Grenadines	11.26%
Guyana	21.79%	Belgium	11.11%
China, mainland	21.38%	Georgia	11.03%
China	21.34%	Ukraine	10.71%
Grenada	21.21%	Republic of Moldova	10.39%

Source: Data accessed from FAOSTAT.

Table A.3. Countries with the highest rates of undernourishment prevalence (percent of total country population)

Country	Prevalence of undernourishment	Country	Prevalence of undernourishment
1. Central African Republic	58.6	26. Grenada	25.5
2. Haiti	46.8	27. Afghanistan	23.0
3. Zambia	45.9	28. Sri Lanka	22.1
4. Zimbabwe	44.7	29. Bolivia (Plurinational State of)	20.2
5. Liberia	42.8	30. Burkina Faso	20.2
6. Madagascar	42.3	31. Pakistan	19.9
7. Rwanda	41.1	32. Mongolia	19.6
8. Democratic People's Republic of Korea	40.8	33. Swaziland	19.6
9. Uganda	39.0	34. Kenya	19.1
10. Chad	32.5	35. Guinea	17.5
11. United Republic of Tanzania	32.3	36. Lao PDR	17.1
12. Sierra Leone	30.9	37. Nicaragua	17.0
13. Tajikistan	30.1	38. Saint Lucia	17.0
14. Ethiopia	28.8	39. Myanmar	16.9
15. Namibia	28.8	40. Guatemala	15.6
16. Yemen	28.8	41. Sierra Leone	15.4
17. Guinea-Bissau	28.3	42. Cambodia	15.3
18. Congo	28.2	43. Bangladesh	15.1
19. Iraq	27.8	44. Honduras	14.8
20. Timor-Leste	26.9	45. India	14.5
21. Antigua and Barbuda	26.7	46. Lesotho	14.5
22. Mozambique	26.6	47. Angola	14.0
23. Botswana	26.0	48. Solomon Islands	13.9
24. Malawi	25.9	49. Philippines	13.8
25. Sudan	25.6	50. Cabo Verde	13.7

GLOSSARY

Aquaculture. The farming of aquatic organisms including fish, mollusks, crustaceans and aquatic plants with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. This definition is based on the definition provided by the UN Food and Agriculture Organization, accessible online through the TERM PORTAL at www.fao.org/faoterm/.

Capture fisheries. Refers to all kinds of harvesting of naturally occurring living resources in both marine and freshwater environments.

Dietary diversity. The number of foods or food groups consumed over a given reference period. See Ruel (2003).

Fish. For the purposes of this report, the term "fish" includes finfish, crustaceans, mollusks, and miscellaneous aquatic animals (from marine and inland sources) but excludes aquatic plants and algae. This report follows the definition used in Béné et al. (2016).

Food security. 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. This report follows the definition provided in the UN Food and Agriculture Organization's 2017 report *The State of Food Security and Nutrition in the World* (FAO 2017c).

Hunger. In this report, hunger is synonymous with chronic undernourishment (see undernourishment).

Industrial fisheries. Large-scale, commercial fishery subsector most often conducted from motorized vessels greater than 20 meters in length operating inshore and/or on open waters. This definition is based on the World Bank Report *Hidden Harvest: The Global Contribution of Capture Fisheries* (World Bank 2012).

Inland Fisheries. Capture fisheries harvesting from inland water, rivers, lakes, reservoirs and wetlands.

Overfishing. A generic term used to refer to a fish stock that is subject to a level of fishing effort or fishing mortality above that which would produce an optimum yield. Optimum yield may refer to maximum sustainable volume harvested, maximum economic value, or the maximum yield that permits the maintenance of historical or pre-existing ecosystem structure.

Malnutrition. An abnormal physiological condition caused by inadequate, unbalanced, or excessive consumption of macronutrients and/or micronutrients. Malnutrition includes undernutrition and overnutrition.

Micronutrients. Vitamins, minerals, and certain other substances that are required by the body in small amounts.

Small-scale fisheries. There is no universal definition of small-scale fisheries appropriate to all contexts. However, countries generally base definitions on vessel size, operational distance from shore, level of mechanization, motorization, gear type, or level commercialization. This definition based on discussions by Chuenpagdee, Liguori, Palomares, and Pauly (2006), and World Bank, FAO, and WorldFish (2012).

Stunting. Low height for age, reflecting a past episode or episodes of sustained undernutrition. In children under five years of age, stunting is defined as height-for-age less than -2 standard deviations below the World Health Organization (WHO) Child Growth Standards median.

Sustainable diets. Diets that are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe, and healthy; while optimizing natural and human resources. This definition is provided in FAO (2010).

Overweight and obesity. Body weight that is above normal for height as a result of excessive accumulation of fat. In adults, overweight is defined as a Body Mass Index (BMI) of more than 25 but less than 30 and obesity as a BMI of 30 or more. In children aged under five years, overweight is defined as weight-for-height greater than 2 standard deviations above the WHO Child Growth Standards median, and obesity as weight-for-height greater than 3 standard deviations above the WHO Child Growth Standards median.

Undernourishment. A state, lasting for at least one year, of inability to acquire enough food to meet dietary energy requirements.

Undernutrition. Undernutrition signifies deficiencies in any or all of the following: energy, protein, or essential vitamins and minerals. This report follows the definition used by IFPRI (2014).

Wasting. Low weight for height, generally the result of weight loss associated with a recent period of starvation or disease. In children under five years of age, wasting is defined as weight-for-height less than -2 standard deviations below the WHO Child Growth Standards median.

REFERENCES

Abbott, J.G., C.J. Hay, T.F. Næsje, D. Tweddle, and B.C. van der Waal. 2015. "Rain and Copper: The Evolution of a Fish Marketing Channel in a Rapidly Changing Region of Southern Africa." *Journal of Southern African Studies* 41(1): 29–45.

Abila, R.O. 2003. "Fish Trade and Food Security: Are They Reconcilable in Lake Victoria. *Kenya Marine and Fisheries* 31.

Agnew, D.J., J. Pearce, G. Pramod, T. Peatman, R. Watson, J.R. Beddington, and T.J. Pitcher. 2009. "Estimating the Worldwide Extent of Illegal Fishing." *PloS One* 4(2): e4570.

Al-Zaidan, A.S., S.Y. Al-Mohanna, and P. George. 2013. "Status of Kuwait's Fishery Resources: Assessment and Perspective." *Marine Policy* 38: 1–7.

Albert, S., S. Aswani, P.L. Fisher, and J. Albert. 2015. "Keeping Food on the Table: Human Responses and Changing Coastal Fisheries in the Solomon Islands. *PloS One* 10(7): e0130800.

Alder, J., B. Campbell, V. Karpouzi, K. Kaschner, and D. Pauly. 2008. "Forage Fish: From Ecosystems to Markets." *Annual Review of Environment and Resources* 33.

Allen, S. 2013. "Carving a Niche or Cutting a Broad Swath: Subsistence Fishing in the Western Pacific 1." *Pacific Science* 67(3): 477–488.

Allison, E.H. 2011. Aquaculture, Fisheries, Poverty and Food Security. Working Paper 2011-65. Penang, Malaysia: The WorldFish Center.

Almeida, C., V. Karadzic, and S. Vaz. 2015. "The Seafood Market in Portugal: Driving Forces and Consequences." *Marine Policy* 61: 87–94.

Amarasinghe, U.S., P.D.A. Kumara, and S.S. De Silva. 2016. "A Rationale for Introducing a Subsidiary Fishery in Tropical Reservoirs and Lakes to Augment Inland Fish Production: Case Study from Sri Lanka. *Food Security* 8(4): 769–781.

Añabieza, M., M. Pajaro, G. Reyes, F. Tiburcio, and P. Watts. 2010. "Philippine Alliance of Fisherfolk: Ecohealth Practitioners for Livelihood and Food Security." *EcoHealth* 7(3): 394–399.

Andersen, A.B., S.H. Thilsted, and A.M. Schwarz. 2013. Food and Nutrition Security in the Solomon Islands. Working Paper AAS-2013-06. CGIAR Research Program on Aquatic Agricultural Systems.

Andrée, P., L. Langille, C. Clement, P. Williams, and E. Norgang. 2016. "Structural Constraints and Enablers to Community Food Security in Nova Scotia, Canada." *Journal of Hunger and Environmental Nutrition* 11(4): 456–490.

Arthur, R., and R. Friend. 2011. "Inland Capture Fisheries in the Mekong and Their Place and Potential within Food-led Regional Development." *Global Environmental Change* 21(1): 219–226.

Asche, F., M.F. Bellemare, C. Roheim, M.D. Smith, and S. Tveteras. 2015. "Fair Enough? Food Security and the International Trade of Seafood."*World Development* 67: 151–160.

Asche, F., T. Bjørndal, and J.A. Young. 2001. "Market Interactions for Aquaculture Products." *Aquaculture Economics and Management* 5(5–6): 303–318.

Aswani, S., and T. Furusawa. 2007. "Do Marine Protected Areas Affect Human Nutrition and Health? A Comparison between Villages in Roviana, Solomon Islands." *Coastal Management* 35(5): 545–565.

Auta, H., C. Emenike, and S. Fauziah. 2017. "Distribution and Importance of Microplastics in the Marine Environment: A Review of the Sources, Fate, Effects, and Potential Solutions." *Environment International*.

Bach-Faig, A., C. Fuentes-Bol, D. Ramos, J.L. Carrasco, B. Roman, I.F. Bertomeu, I. F., . . . L. Serra-Majem. 2011. "The Mediterranean Diet in Spain: Adherence Trends During the Past Two Decades Using the Mediterranean Adequacy Index." *Public Health Nutrition* 14(4): 622–628.

Baird, I.G. 2011. The Don Sahong Dam: Potential Impacts on Regional Fish Migrations, Livelihoods, and Human Health. *Critical Asian Studies* 43(2): 211–235.

Bala, B., and M. Hossain. 2010. "Food Security and Ecological Footprint of Coastal Zone of Bangladesh." *Environment, Development and Sustainability* 12(4): 531–545.

Bano, A., Z. Ayub, and G. Siddiqui. 2014. "Fatty Acid Composition of Three Species of Siphonaria (Gastropoda: Pulmonata) in Pakistan. *Pakistan J. Zool* 46(3): 813–818.
Barclay, K., and C. Epstein. 2013. "Securing Fish for the Nation: Food Security and Governmentality in Japan." *Asian Studies Review* 37(2): 215–233.
Barnes-Mauthe, M., K.L. Oleson, and B. Zafindrasilivonona. 2013. "The Total Economic Value of Small-scale Fisheries with a Characterization of Post–Landing Trends: An Application in Madagascar with Global Relevance." *Fisheries Research* 147: 175–185.
Batista, V.S., N.N. Fabre, A.C. Malhado, and R.J. Ladle. 2014. "Tropical Artisanal Coastal Fisheries: Challenges and Future Directions." *Reviews in Fisheries Science and Aquaculture* 22(1): 1–15.
Belhabib, D., U.R. Sumaila, and D. Pauly. (2015). Feeding the poor: contribution of West African fisheries to Employment and Food Security." *Ocean and Coastal Management* 111: 72–81.
Bell, J. D., V. Allain, E.H. Allison, S. Andréfouët, N.L. Andrew, M.J. Batty . . . Q. Hanich. 2015. "Diversifying the Use of Tuna to Improve Food Security and Public Health in Pacific Island Countries and Territories." *Marine Policy* 51: 584–591.
Bell, J. D., M. Kronen, A. Vunisea, W.J. Nash, G. Keeble, A. Demmke . . . S. Andréfouët. 2009. "Planning the Use of Fish for Food Security in the Pacific." *Marine Policy* 33(1): 64–76.
Bell, J. D., C. Reid, M.J. Catty, P. Lehodey, L. Rodwell, A.J. Hobday . . . A. Demmke. 2013. "Effects of Climate Change on Oceanic Fisheries in the Tropical Pacific: Implications for Economic Development and Food Security." *Climatic Change* 119(1): 199–212.
Belton, B., S.R. Bush, and D.C. Little. 2016. "Aquaculture: Are Farmed Fish Just for the Wealthy?" *Nature* 538(7624): 171.
———. 2017. "Not Just for the Wealthy: Rethinking Farmed Fish Consumption in the Global South." *Global Food Security*.
Belton, B., M. Karim, S.H. Thilsted, K. Murshed-E-Jahan, W. Collis, and M.J. Phillips. 2011. "Review of Aquaculture and Fish Consumption in Bangladesh." *Studies and Reviews* 2011–53. Penang, Malaysia: The WorldFish Centre.
Belton, B., and S.H. Thilsted. 2014. "Fisheries in Transition: Food and Nutrition Security Implications for the Global South." *Global Food Security* 3(1): 59–66.
Belton, B., I.J.M. van Asseldonk, and S.H. Thilsted. 2014. "Faltering Fisheries and Ascendant Aquaculture: Implications for Food and Nutrition Security in Bangladesh." *Food Policy* 44: 77–87.
Béné, C., R. Arthur, H. Norbury, E.H. Allison, M. Beveridge, S. Bush . . . D. Squires. 2016. "Contribution of Fisheries and Aquaculture to Food Security and Poverty Reduction: Assessing the Current Evidence." *World Development* 79: 177–196.
Béné, C., M. Barange, R. Subasinghe, P. Pinstrup-Andersen, G. Merino, G.-I. Hemre, and M. Williams. 2015. "Feeding 9 Billion by 2050–Putting Fish Back on the Menu." *Food Security* 7(2): 261–274.
Béné, C., R. Lawton, and E.H. Allison. 2010. "Trade Matters in the Fight against Poverty: Narratives, Perceptions, and (Lack of) Evidence in the Case of Fish Trade in Africa."*World Development* 38(7): 933–954.
Béné, C., E. Steel, B.K. Luadia, and A. Gordon. 2009. "Fish as the 'Bank in the Water'--Evidence from Chronic-Poor Communities in Congo." *Food Policy* 34(1): 108–118.
Bennett, A., and X. Basurto. 2018. "Local Institutional Responses to Global Market Pressures: The Sea Cucumber Trade in Yucatán, Mexico."*World Development* 102: 57–70.
Berry, E.M., S. Dernini, B. Burlingame, A. Meybeck, and P. Conforti. 2015. "Food Security and Sustainability: Can One Exist without the Other?" *Public Health Nutrition* 18(13): 2293–2302.
Bhutta, Z.A., T. Ahmed, R.E. Black, S. Cousens, K. Dewey, E. Giugliani . . . H. Sachdev. 2008. "What Works? Interventions for Maternal and Child Undernutrition and Survival."*The Lancet* 371(9610): 417–440.
Bhutta, Z.A., J.K. Das, A. Rizvi, M.F. Gaffey, N. Walker, S. Horton . . . T.L.N.I.R. Group. 2013. "Evidence-based Interventions for Improvement of Maternal and Child Nutrition: What Can Be Done and at What Cost?" *The Lancet* 382(9890): 452–477.

Bogard, J.R., S. Farook, G.C. Marks, J. Waid, B. Belton, M. Ali . . . S.H. Thilsted. 2017. “Higher Fish but Lower Micronutrient Intakes: Temporal Changes in Fish Consumption from Capture Fisheries and Aquaculture in Bangladesh.” *PloS One* 12(4): e0175098.

Bogard, J.R., G.C. Marks, A. Mamun, and S.H. Thilsted. 2017. “Non-farmed Fish Contribute to Greater Micronutrient Intakes Than Farmed Fish: Results from an Intra-household Survey in Rural Bangladesh.” *Public Health Nutrition* 20(4): 702–711.

Bogard, J.R., G.C. Marks, S. Wood, and S.H. Thilsted. 2017. “Measuring Nutritional Quality of Agricultural Production Systems: Application to Fish Production.” *Global Food Security*.

Bogard, J.R., S.H. Thilsted, G.C. Marks, M.A. Wahab, M.A. Hossain, J. akobsen, and J. Stangoulis. 2015. “Nutrient Composition of Important Fish Species in Bangladesh and Potential Contribution to Recommended Nutrient Intakes.” *Journal of Food Composition and Analysis* 42: 120–133.

Brooks, A., and C. Sieu. 2016. *The Potential of Community Fish Refuges (CFRS) in Rice Field Agro-ecosystems for Improving Food and Nutrition Security in the Tonle Sap Region.* Program Report 2016-10. Penang, Malaysia: The WorldFish Centre.

Brunner, E.J., P.J. Jones, S. Friel, and M. Bartley. 2008. “Fish, Human Health and Marine Ecosystem Health: Policies in Collision.” *International Journal of Epidemiology* 38(1): 93–100.

Burger, J., K.F. Gaines, C.S. Boring, W.L. Stephens, J. Snodgrass, and M. Gochfeld. 2001. “Mercury and Selenium in Fish from the Savannah River: Species, Trophic Level, and Locational Differences.” *Environmental Research* 87(2): 108–118.

Burgess, M.G., F.K. Diekert, N.S. Jacobsen, K.H. Andersen, and S.D. Gaines. 2016. “Remaining Questions in the Case for Balanced Harvesting.” *Fish and Fisheries* 17(4): 1216–1226.

Cabello, F.C. 2006. “Heavy Use of Prophylactic Antibiotics in Aquaculture: A Growing Problem for Human and Animal Health and for the Environment.” *Environmental Microbiology* 8(7): 1137–1144.

Campbell, B., Q. Hanich, and A. Delisle. 2016. “Not Just a Passing FAD: Insights from the Use of Artisanal Fish Aggregating Devices for Food Security in Kiribati.” *Ocean and Coastal Management* 119: 38–44.

Campbell, B.M., S.J. Vermeulen, P.K. Aggarwal, C. Corner-Dolloff, E. Girvetz, A.M. Loboguerrero . . . P.K. Thornton. 2016. “Reducing Risks to Food Security from Climate Change.” *Global Food Security* 11: 34–43.

CGIAR. 2012. *Resilient Livelihoods and Food Security in Coastal Aquatic Agricultural Systems: Investing in Transformational Change.* Project Report AAS-2012-28. Penang, Malaysia: CGIAR Research Program on Aquatic Agricultural Systems.

Chan, C.Y., N. Tran, C.D. Dao, T.B. Sulser, M.J. Phillips, M. Batka . . . N. Preston. 2017. Fish to 2050 in the ASEAN Region. Working Paper 2017-01. Penang, Malaysia and Washington, D.C., USA: WorldFish and International Food Policy Research Institute (IFPRI).

Charlton, K.E., J. Russell, E. Gorman, Q. Hanich, A. Delisle, B. Campbell, and J. Bell. 2016. “Fish, Food Security and Health in Pacific Island Countries and Territories: A Systematic Literature Review.” *BMC Public Health* 16(1): 285.

Chou, C., L. Paon, J. Moffatt, and B. Zwicker. 2000. “Copper Contamination and Cadmium, Silver, and Zinc Concentrations in the Digestive Glands of American Lobster (Homarus americanus) from the Inner Bay of Fundy, Atlantic Canada.” *Bulletin of Environmental Contamination and Toxicology* 65(4): 470–477.

Chuenpagdee, R., L. Liguori, M.L. Palomares, and D. Pauly. 2006. “Bottom-up, Global Estimates of Small-scale Marine Fisheries Catches.” *Fisheries Centre Research Reports* 14(8).

Cisneros-Montemayor, A.M., D. Pauly, L.V. Weatherdon, and Y. Ota. 2016. “A Global Estimate of Seafood Consumption by Coastal Indigenous Peoples.” *PloS One* 11(12): e0166681.

Cissé, A., L. Doyen, F. Blanchard, C. Béné, and J.-C. Péreau. 2015. “Ecoviability for Small-scale Fisheries in the Context of Food Security Constraints.” *Ecological Economics* 119: 39–52.

Clonan, A., M. Holdsworth, J.A. Swift, D. Leibovici, and P. Wilson. 2012. "The Dilemma of Healthy Eating and Environmental Sustainability: The Case of Fish." *Public Health Nutrition* 15(2): 277–284.

Cooke, S.J., E.H. Allison, T.D. Beard, R. Arlinghaus, A.H. Arthington, D.M. Bartley . . . K. Lorenzen. 2016. "On the Sustainability of Inland Fisheries: Finding a Future for the Forgotten." *Ambio* 45(7): 753–764.

Cooke, S.J., K.J. Murchie, and A.J. Danylchuk. 2011. "Sustainable 'Seafood' Ecolabeling and Awareness Initiatives in the Context of Inland Fisheries: Increasing Food Security and Protecting Ecosystems." *BioScience* 61(11): 911–918.

Costello, C., D. Ovando, T. Clavelle, C.K. Strauss, R. Hilborn, M.C. Melnychuk . . . R.B. Cabral. 2016. "Global Fishery Prospects Under Contrasting Management Regimes. *Proceedings of the National Academy of Sciences* 113(18): 5125–5129.

da Costa, M.K.B., C.D. De Melo, and P.F.M. Lopes. 2014. "Fisheries Productivity and Its Effects on the Consumption of Animal Protein and Food Sharing of Fishers' and Non-Fishers' Families." *Ecology of Food and Nutrition* 53(4): 453–470.

Darling, E.S. 2014. "Assessing the Effect of Marine Reserves on Household Food Security in Kenyan Coral Reef Fishing Communities." *PloS One* 9(11): e113614.

Dasgupta, S., M.G. Mustafa, T. Paul, and D. Wheeler. 2017. The Socioeconomics of Fish Consumption and Child Health in Bangladesh. Policy Research Working Paper 8217. Washington, D.C.: World Bank.

Deng, Y., Y. Zhang, B. Lemos, and H. Ren. 2017. "Tissue Accumulation of Microplastics in Mice and Biomarker Responses Suggest Widespread Health Risks of Exposure." *Scientific Reports* 7.

Denton, G., and C. Burdon-Jones. 1986. "Trace Metals in Fish from the Great Barrier Reef." *Marine Pollution Bulletin* 17(5): 201–209.

Dueri, S., P. Guillotreau, R. Jiménez-Toribio, R. Oliveros-Ramos, L. Bopp, and O. Maury. 2016. "Food Security or Economic Profitability? Projecting the Effects of Climate and Socioeconomic Changes on Global Skipjack Tuna Fisheries Under Three Management Strategies." *Global Environmental Change* 41: 1–12.

Eggert, H., M. Greaker, and A. Kidane. 2015. "Trade and Resources: Welfare Effects of the Lake Victoria Fisheries Boom." *Fisheries Research* 167: 156–163.

Fabinyi, M., W.H. Dressler, and M.D. Pido. 2017. "Fish, Trade and Food Security: Moving Beyond 'Availability' Discourse in Marine Conservation." *Human Ecology* 45(2): 177–188.

Fabinyi, M., and N. Liu. 2014. "Seafood Banquets in Beijing: Consumer Perspectives and Implications for Environmental Sustainability." *Conservation and Society* 12(2): 218.

FAO (Food and Agriculture Organization). 2010. Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action. Proceedings of the International Scientific Symposium Biodiveristy and Sustainable Diets United Agianst Hunger, November 3–5 2010. Rome: Food and Agriculture Organization of the United Nations.

———. 2014a. Fishery Statistical Collections: Fisheries Commodities and Trade from Food and Agriculture Organization of the United Nations. http://www.fao.org/fishery/statistics/global-capture-production/en

———. 2014b. *State of the World Fisheries and Aquaculture: Opportunities and Challenges*. Rome: Food and Agriculture Organization of the United Nations.

———. 2015. *Voluntary Guidelines for Security Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication.* Rome: The Food and Agriculture Organization of the United Nations.

———. 2016a. *Compendium of Indicators for Nutrition-Sensitive Agriculture.* Rome: Food and Agriculture Organization of the United Nations.

———. 2016b. *State of the World Fisheries and Aquaculture: Contributing to Food Security and Nutrition for All.* Rome: Food and Agriculture Organization of the United Nations.

———. 2017a. A Case for Fish to Lead to Greater Food Security and Nutrition Outcomes. *FAO Aquaculture Newsletter* 56.

———. 2017b. Fishery Statistical Collections: Global Capture Production from Food and Agriculture Organization of the United Nations. http://www.fao.org/fishery/statistics/global-capture-production/en.

———. 2017c. *The State of Food Security and Nutrition in the World: Building Resilience for Peace and Food Security.* Rome: Food and Agriculture Organization of the United Nations.

FAO and FHI 360. 2016. *Minimum Dietary Diversity for Women: A Guide for Measurement.* Rome: Food and Agriculture Orgnization of the United Nations.

FAO, IFAD (International Fund for Agricultural Development), and World Food Program (WFP). 2015. *The State of Food Insecurity in the World 2015*--Meeting the 2015 International Hunger Targets: Taking Stock of Uneven Progress. Rome: Food and Agriculture Organization of the United Nations.

FAO and WHO (World Health Organization). 2014. Rome Declaration on Nutrition: Conference Outcome Document. Second International Conference on Nutrition. Rome: Food and Agriculture Organization of the United Nations.

FAO and WorldFish. 2008. *Small-scale Capture Fisheries: A Global Overview with Emphasis on Developing Countries.* A preliminary report of the Big Numbers Project. Rome and Washington, D.C.: The Food and Agriculture Organization of the United Nations and The Worldfish Centre.

Farmery, A.K., C. Gardner, S. Jennings, B.S. Green, and R.A. Watson. 2017. "Assessing the Inclusion of Seafood in the Sustainable Diet Literature." *Fish and Fisheries* 18(3): 607–618. doi:10.1111/faf.12205.

Fawzi, W.W., T.C. Chalmers, M.G. Herrera, and F. Mosteller. 1993. "Vitamin A Supplementation and Child Mortality: A Meta-analysis." *Jama* 269(7): 898–903.

FDA (U.S. Food and Drug Administration) and EPA (U.S. Environmental Protection Agency). 2017. Eating Fish: What Pregnant Women and Parents Should Know. U.S. Food and Drug Administration.

Friedman, K., M. Krone, S. Pinca, F. Magron, P. Boblin, K. Pakoa . . . L. Chapman. 2008. *Papua New Guinea Country Report: Profiles and Results from Survey Work at Andra, Tsoilaung, Sideia and Panapompom.* Pacific Regional Oceanic and Coastal Fisheries Development Programme, New Caledonia.

Garcia, S.M., and A.A. Rosenberg. 2010. "Food Security and Marine Capture Fisheries: Characteristics, Trends, Drivers and Future Perspectives." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 365(1554): 2869–2880.

Golden, C. 2016. "Aquaculture: Are Farmed Fish Just for the Wealthy? Golden et al. Reply." *Nature* 538(7624): 171.

Golden, C., E.H. Allison, W.W. Cheung, M.M. Dey, B.S. Halpern, D.J. McCauley . . . S.S. Myers. 2016. "Fall in Fish Catch Threatens Human Health." *Nature* 534(7607): 317–320.

Guardiola, F.A., A. Cuesta, J. Meseguer, and M.A. Esteban. 2012. "Risks of Using Antifouling Biocides in Aquaculture." *International Journal of Molecular Sciences* 13(2): 1541–1560.

Hall, S.J., R. Hilborn, N.L. Andrew, and E.H. Allison. 2013. "Innovations in Capture Fisheries Are an Imperative for Nutrition Security in the Developing World." *Proceedings of the National Academy of Sciences* 110(21): 8393–8398.

Hambidge, M. 2000. "Human Zinc Deficiency." *The Journal of Nutrition* 130(5): 1344S–1349S.

Harper, S., D. Zeller, M. Hauzer, D. Pauly, and U.R. Sumaila. 2013. "Women and Fisheries: Contribution to Food Security and Local Economies." *Marine Policy* 39: 56–63.

Heck, S., C. Béné, and R. Reyes-Gaskin. 2007. "Investing in African Fisheries: Building Links to the Millennium Development Goals." *Fish and Fisheries* 8(3): 211–226.

HHS (U.S. Health and Human Services) and USDA (U.S. Department of Agriculture). 2015. *2015–2020 Dietary Guidelines for Americans.* 8th Edition. Washington, D.C.: U.S. Department of Health and Human Services and U.S. Department of Agriculture.

HLPE (High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security). 2014. *Sustainable Fisheries and Aquaculture for Food Security and Nutrition. A Report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security.* Rome.

Holick, M.F. 2007. Vitamin D Deficiency. *New England Journal of Medicine* 2007(357): 266–281.

Holick, M.F., and T. Chen. 2008. "Vitamin D Deficiency: A Worldwide Problem with Health Consequences." *The American Journal of Clinical Nutrition* 87(4): 1080S–1086S.

Hughes, S., A. Yau, L. Max, N. Petrovic, F. Davenport, M. Marshall . . . J.E. Cinner. 2012. "A Framework to Assess National Level Vulnerability from the Perspective of Food Security: The Case of Coral Reef Fisheries." *Environmental Science and Policy* 23: 95–108.

Ibarra, A.A., A.S. Vargas, and B.M. López. 2013. "Economic Impacts of Climate Change on Two Mexican Coastal Fisheries: Implications for Food Security." *Economics* 7(36): 0–1.

IFPRI (International Food Policy Research Institute). 2014. *2014 Global Hunger Index: The Challenge of Hidden Hunger*. Washington, D.C.: International Food Policy Research Institute.

Isaac, V.J., M.C. Almeida, T. Giarrizzo, C.P. Deus, R. Vale, G. Klein, and A. Begossi. 2015. "Food Consumption as an Indicator of the Conservation of Natural Resources in Riverine Communities of the Brazilian Amazon." *Anais da Academia Brasileira de Ciências* 87(4): 2229–2242.

Jacquet, J., H. Fox, H. Motta, A. Ngusaru, and D. Zeller. 2010. "Few Data but Many Fish: Marine Small-scale Fisheries Catches for Mozambique and Tanzania." *African Journal of Marine Science* 32(2): 197–206.

Jenkins, D.J., J.L. Sievenpiper, D. Pauly, U.R. Sumaila, C.W. Kendall, and F.M. Mowat. 2009. "Are Dietary Recommendations for the Use of Fish Oils Sustainable?" *Canadian Medical Association Journal* 180(6): 633–637.

Jennings, S., A.D. Smith, E.A. Fulton, and D.C. Smith. 2014. "The Ecosystem Approach to Fisheries: Management at the Dynamic Interface between Biodiversity Conservation and Sustainable Use." *Annals of the New York Academy of Sciences* 1322(1): 48–60.

Jensen, Ø., T. Dempster, E. Thorstad, I. Uglem, and A. Fredheim. 2009. "Escapes of Fishes from Norwegian Sea-cage Aquaculture: Causes, Consequences and Prevention." *Aquaculture Environment Interactions* 1(1): 71–83.

Kafumbata, D., D. Jamu, and S. Chiotha. 2014. "Riparian Ecosystem Resilience and Livelihood Strategies Under Test: Lessons from Lake Chilwa in Malawi and Other Lakes in Africa." *Philosophical Transactions of the Royal Society B: Biological Sciences* 369(1639): 20130052.

Kawarazuka, N. 2010. The Contribution of Fish Intake, Aquaculture, and Small-scale Fisheries to Improving Food and Nutrition Security: A Literature Review. Working Paper No. 2106. Penang, Malaysia: The WorldFish Centre.

Kawarazuka, N., and C. Béné. 2010. "Linking Small-scale Fisheries and Aquaculture to Household Nutritional Security: An Overview." *Food Security* 2(4): 343–357.

Lacerda, L., E. Bidone, A. Guimaraes, and W. Pfeiffer. 1994. "Mercury Concentrations in Fish from the Itacaiúnas-Parauapebas River System, Carajás Region, Amazon." *Anais da Academia Brasileira de Ciências* 66(3): 373–380.

Lam, V.W., W.W. Cheung, W. Swartz, and U.R. Sumaila. 2012. "Climate Change Impacts on Fisheries in West Africa: Implications for Economic, Food and Nutritional Security." *African Journal of Marine Science* 34(1): 103–117.

Lim, S.S., T. Vos, A.D. Flaxman, G. Danaei, K. Shibuya, H. Adair-Rohani . . . K.G. Andrews. 2012. "A Comparative Risk Assessment of Burden of Disease and Injury Attributable to 67 Risk Factors and Risk Factor Clusters in 21 Regions90–2010: A Systematic Analysis for the Global Burden of Disease Study 2010." *The Lancet* 380(9859): 2224–2260.

Longley, C., S. Haraksingh Thilsted, M. Beveridge, S. Cole, D. Banda Nyirenda, S. Heck, and A.-L. Hother. 2014. "The Role of Fish in the First 1,000 Days in Zambia." *IDS Special Collection, September 2014*.

Majluf, P., S. De la Puente, and V. Christensen. 2017. "The Little Fish That Can Feed the World." *Fish and Fisheries*.

Moll, R., and B. Davis. 2017. "Iron, Vitamin B 12 and Folate." *Medicine*.

Mozaffarian, D., and E.B. Rimm. 2006. "Fish Intake, Contaminants, and Human Health: Evaluating the Risks and the Benefits." *JAMA* 296(15): 1885–1899.

Naylor, R.L. 2016. "Oil Crops, Aquaculture, and the Rising Role of Demand: A Fresh Perspective on Food Security." *Global Food Security* 11: 17–25.

Neumann, C., D.M. Harris, and L.M. Rogers. 2002. "Contribution of Animal Source Foods in Improving Diet Quality and Function in Children in the Developing World. *Nutrition Research* 22(1): 193–220.

Norman-Lopez, A. 2009. "Competition between Different Farmed and Wild Species: The US Tilapia Market." *Marine Resource Economics* 24(3): 237–251.

OECD (Organisation for Economic Co-operation and Development). 2017. *Policy Coherence for Sustainable Development 2017: Eradicating Poverty and Promoting Prosperity.* Paris: OECD Publishing.

Oken, E., A.L. Choi, M.R. Karagas, K. Mariën, C.M. Rheinberger, R. Schoeny . . . S. Korrick. 2012. "Which Fish Should I Eat? Perspectives Influencing Fish Consumption Choices." *Environmental Health Perspectives* 120(6): 790.

Ottaviani, D., C. De Young, and S. Tsuji. 2016. Assessing Water Availability and Economic, Social, and Nutritional Contributions from Inland Capture Fisheries and Aquaculture. FAO Fisheries and Aquaculture Technical Paper 602. Rome: Food and Agriculture Organization of the United Nations.

Ottolenghi, F., C. Silvestri, P. Giordano, A. Lovatelli, and M. New. 2004. Capture-based Aquaculture: The Fattening of Eels, Groupers, Tuna and Yellowtails. Rome: Food and Agriculture Organization of the United Nations.

Paddock, J.R. 2017. "Changing Consumption, Changing Tastes? Exploring Consumer Narratives for Food Secure, Sustainable and Healthy Diets." *Journal of Rural Studies* 53: 102–110.

Palacios, C., and L. Gonzalez. 2014. "Is Vitamin D Deficiency a Major Global Public Health Problem?" *The Journal of Steroid Biochemistry and Molecular Biology* 144: 138–145.

Pauly, D., and D. Zeller. 2017. "Comments on FAO's State of World Fisheries and Aquaculture (SOFIA 2016)." *Marine Policy 77*: 176–181.

Pinca, S., A. Vunisea, F. Lasi, K. Friedman, M. Kronen, R. Awira . . . F. Magron. 2008. *Solomon Islands Country Report: Profiles and Results from Survey Work at Nggela, Marau, Rarumana and Chubilopi.* Pacific Regional Oceanic and Coastal Fisheries Development Programme, New Caledonia.

Powell, B., S.H. Thilsted, A. Ickowitz, C. Termote, T. Sunderland, and A. Herforth. 2015. "Improving Diets with Wild and Cultivated Biodiversity from Across the Landscape." *Food Security* 7(3): 535–554.

Raine, A., J. Portnoy, J. Liu, T. Mahoomed, and J.R. Hibbeln. 2015. "Reduction in Behavior Problems with Omega-3 Supplementation in Children Aged 8–16 Years: A Randomized, Double-blind, Placebo-controlled, Stratified, Parallel-group Trial." *Journal of Child Psychology and Psychiatry* 56(5): 509–520.

Roos, N., C. Chamnan, D. Loeung, J. Jakobsen, and S.H. Thilsted. 2007. "Freshwater Fish as a Dietary Source of Vitamin A in Cambodia." *Food Chemistry* 103(4): 1104–1111.

Roos, N., M.M. Islam, and S.T. Thilsted. 2003. "Small Indigenous Fish Species in Bangladesh: Contribution to Vitamin A, Calcium and Iron Intakes." *The Journal of Nutrition* 133(11): 4021S–4026S.

Roos, N., M.A. Wahab, C. Chamnan, and S.H. Thilsted. 2007. "The Role of Fish in Food-based Strategies to Combat Vitamin A and Mineral Deficiencies in Developing Countries." *The Journal of Nutrition* 137(4): 1106–1109.

Roos, N., M.A. Wahab, M.A.R. Hossain, and S.H. Thilsted. 2007. "Linking Human Nutrition and Fisheries: Incorporating Micronutrient-dense, Small Indigenous Fish Species in Carp Polyculture Production in Bangladesh." *Food and Nutrition Bulletin* 28(2_suppl2): S280–S293.

Ruel, M.T. 2003. "Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities." *The Journal of Nutrition* 133(11): 3911S–3926S.

Smith, M.D., C.A. Roheim, L.B. Crowder, B.S. Halpern, M. Turnipseed, J.L. Anderson . . . A. Khan. 2010. "Sustainability and Global Seafood." *Science* 327(5967): 784–786.

Sumaila, U.R., A. Dyck, and W.W. Cheung. 2013. "Fisheries Subsidies and Potential Catch Loss in SIDS Exclusive Economic Zones: Food Security Implications." *Environment and Development Economics* 18(4): 427–439.

Sumaila, U.R., A.S. Khan, A.J. Dyck, R. Watson, G. Munro, P. Tydemers, and D. Pauly. 2010. "A Bottom-up Re-estimation of Global Fisheries Subsidies." *Journal of Bioeconomics* 12(3): 201–225.

Sushchik, N.N., A.E. Rudchenko, and M.I. Gladyshev. 2017. "Effect of Season and Trophic Level on Fatty Acid Composition and Content of Four Commercial Fish Species from Krasnoyarsk Reservoir (Siberia, Russia)." *Fisheries Research* 187: 178–187.
Swanson, D., R. Block, and S.A. Mousa. 2012. "Omega-3 Fatty Acids EPA and DHA: Health Benefits throughout Life." *Advances in Nutrition: An International Review Journal* 3(1): 1–7.
Szuwalski, C.S., M.G. Burgess, C. Costello, and S.D. Gaines. 2016. "High Fishery Catches through Trophic Cascades in China." *Proceedings of the National Academy of Sciences* 201612722.
Tacon, A.G.J., and M. Metian. 2009. "Fishing for Feed or Fishing for Food: Increasing Global Competition for Small Pelagic Forage Fish." *AMBIO: A Journal of the Human Environment* 38(6): 294–302.
Teh, L.S., V.W. Lam, W.W. Cheung, D. Miller, L.C. Teh, and U.R. Sumaila. 2016. "Impact of High Seas Closure on Food Security in Low-Income Fish-Dependent Countries." *PloS One* 11(12): e0168529.
Thilsted, S.H., A. Thorne-Lyman, P. Webb, J.R. Bogard, R. Subasinghe, M.J. Phillips, and E.H. Allison. 2016. "Sustaining Healthy Diets: The Role of Capture Fisheries and Aquaculture for Improving Nutrition in the Post-2015 Era." *Food Policy* 61:126–131.
Tiemeier, H., H.R. Van Tuijl, A. Hofman, J. Meijer, A.J. Kiliaan, and M.M. Breteler. 2002. "Vitamin B12, Folate, and Homocysteine in Depression: The Rotterdam Study." *American Journal of Psychiatry* 159(12): 2099–2101.
UN (United Nations). 2015a. *The Millennium Development Goals Report.* New York: United Nations.
———. 2015b. *Transforming Our World: The 2030 Agenda for Sustainable Development.* New York: United Nations.
———. 2017. *Progress towards the Sustainable Development Goals: Report of the Secretary-General.* E/2017/66. New York: United Nations.
UN DESA (UN Department of Economic and Social Affairs). 2009. World Population Prospects: The 2008 Revision, Highlights, Working Paper No. ESA/P/WP.210. New York: United Nations, Department of Economic and Social Affairs, Population Division.
———. 2013. World Population Prospects: The 2012 Revision, Volume II, Demographic Profiles. ST/ESA/SER.A/345. New York: United Nations, Department of Economic and Social Affairs, Population Division.
———. 2017. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. Working Paper No. ESA/WP/248. New York: United Nations, Department of Economic and Social Affairs, Population Division.
Valderrama, D., and J.L. Anderson. 2010. "Market Interactions between Aquaculture and Common-Property Fisheries: Recent Evidence from the Bristol Bay Sockeye Salmon Fishery in Alaska." *Journal of Environmental Economics and Management* 59(2): 115–128.
Van Dolah, F.M. 2000. "Marine Algal Toxins: Origins, Health Effects, and Their Increased Occurrence." *Environmental Health Perspectives* 108(Suppl 1): 133.
Villasante, S., D. Rodríguez, M. Antelo, M. Quaas, and H. Österblom. 2012. "The Global Seafood Market Performance Index: A Theoretical Proposal and Potential Empirical Applications." *Marine Policy* 36(1): 142–152.
Wang, H.-X., Å.Wahlin, H. Basun, J. Fastbom, B. Winblad, and L. Fratiglioni. 2001. "Vitamin B12 and Folate in Relation to the Development of Alzheimer's Disease." *Neurology* 56(9): 1188–1194.
Wang, T.J., M.J. Pencina, S.L. Booth, P.F. Jacques, E. Ingelsson, K. Lanier . . . R.S. Vasan. 2008. "Vitamin D Deficiency and Risk of Cardiovascular Disease." *Circulation* 117(4): 503–511.
Watson, R.A., R. Nichols, V. Lam, and U. Sumaila. 2017. "Global Seafood Trade Flows and Developing Economies: Insights from Linking Trade and Production." *Marine Policy* 82: 41–49.
Wei, S.-Q., H.-P. Qi, Z.-C. Luo, and W.D. Fraser. 2013. "Maternal Vitamin D Status and Adverse Pregnancy Outcomes: A Systematic Review and Meta-analysis." *The Journal of Maternal-Fetal and Neonatal Medicine* 26(9): 889–899.

Welcomme, R.L., I.G. Cowx, D. Coates, C. Béné, S. Funge-Smith, A. Halls, and K. Lorenzen. 2010. "Inland Capture Fisheries." *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 365(1554): 2881–2896.

Wessells, K.R., and K.H. Brown. 2012. "Estimating the Global Prevalence of Zinc Deficiency: Results Based on Zinc Availability in National Food Supplies and the Prevalence of Stunting." *PloS One* 7(11): e50568.

West Jr, K.P., J. Katz, S.K. Khatry, S.C. LeClerq, E.K. Pradhan, S.R. Shrestha . . . R.P. Pokhrel. 1999. "Double Blind, Cluster Randomised Trial of Low Dose Supplementation with Vitamin A or βcarotene on Mortality Related to Pregnancy in Nepal. *BMJ* 318(7183): 570–575.

WHO (World Health Organization). 2008. Indicators for Assessing Infant and Young Child Feeding Practices. Conclusions of a Consensus Meeting Held 6-8 November 2007 in Washington, D.C. Geneva: World Health Organization.

———. 2009. Global Prevalence of Vitamin A Deficiency in Populations at Risk 1995–2005. WHO Global Database on Vitamin A Deficiency. Geneva: World Health Organization.

Wilson, A., R. Platt, Q. Wu, D. Leclerc, B. Christensen, H. Yang . . . R. Rozen. 1999. "A Common Variant in Methionine Synthase Reductase Combined with Low Cobalamin (Vitamin B 12) Increases Risk for Spina Bifida." *Molecular Genetics and Metabolism* 67(4): 317–323.

World Bank. 2011. World Development Report 2012. Gender equality adn development. Washington, DC: World Bank.

———. 2012. *Hidden Harvest: The Global Contribution of Capture Fisheries.* Report No. 66469-GLB. Washington, D.C.: The World Bank.

———. 2013. Fish to 2030: *Prospects for Fisheries and Aquaculture.* World Bank Report Number 83177-GLB. Washington, D.C.: The World Bank.

World Bank, FAO, and WorldFish. 2012. *Hidden Harvest: The Global Contribution of Capture Fisheries*. Report No. 66469-GLB. Washington, DC: World Bank.

WorldFish. 2011. Aquaculture, Fisheries, Poverty and Food Security. Working Paper 2011-65. Penang, Malaysia: The WorldFish Center.

Youn, S.-J., W.W. Taylor, A.J. Lynch, I.G. Cowx, T.D. Beard, D. Bartley, and F. Wu. 2014. "Inland Capture Fishery Contributions to Global Food Security and Threats to Their Future." *Global Food Security* 3(3): 142–148.

Zeller, D., S. Booth, G. Davis, and D. Pauly. 2007. "Re-estimation of Small-scale Fishery Catches for US Flag-associated Island Areas in the Western Pacific: The Last 50 Years." *Fishery Bulletin*.

Zeller, D., S. Harper, K. Zylich, and D. Pauly. 2015. "Synthesis of Underreported Small-scale Fisheries Catch in Pacific Island Waters." *Coral Reefs* 34(1): 25–39.

Zeller, D., M. Palomares, A. Tavakolie, M. Ang, D. Belhabib, W. Cheung . . . K. Zylich. 2016. "Still Catching Attention: Sea Around Us Reconstructed Global Catch Data, Their Spatial Expression and Public Accessibility." *Marine Policy* 70: 145–152.

Zhao, L., J. Sun, Y. Yang, X. Ma, Y. Wang, and Y. Xiang. 2016. "Fish Consumption and All-Cause Mortality: A Meta-analysis of Cohort Studies." *European Journal of Clinical Nutrition* 70(2): 155–161.

Zhou, S., A.D. Smith, and E.E. Knudsen. 2015. "Ending Overfishing While Catching More Fish." *Fish and Fisheries* 16(4): 716–722.

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