Not just for the wealthy: Rethinking farmed fish consumption in the Global South

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1. Introduction

Fish[1] is a rich source of vitamins, minerals, fatty acids and high quality protein, playing an essential role in the diets of billions of consumers, many of them poor, malnourished and living in low and middle income countries (Thilsted et al., 2016; HLPE 2014; Kawarazuka and Béné, 2011).

Fish are obtained from a continuum of production systems, ranging from the harvest of fish from naturally reproducing populations (capture fisheries), to breeding and farming under controlled conditions (aquaculture). Global capture fisheries output peaked in mid-1990s, and has plateaued or declined since (cf. FAO 2016a; Pauly and Zeller 2016). In contrast, aquaculture has boomed during the past three decades, growing at an average rate of 8.2% per annum, and now provides more than half of the fish destined for direct human consumption (FAO 2016b).

The growth trajectories of capture fisheries and aquaculture are often juxtaposed to make the case that sustained and rapid aquaculture development is vital to the future food security of fish dependent populations in Southern nations, and should be promoted as such (e.g. Barange et al., 2014).

Contrasting this positive outlook is a counter-narrative (which we term 'economic geography'), that holds that aquaculture largely fails to meet the needs of poor and undernourished Southern consumers. The narrative asserts that most farmed fish produced in Southern countries is destined for export to Northern markets (McIntyre et al. 2016; Ponte et al. 2014), and that farmed fish remaining in domestic markets is consumed primarily by wealthy urbanites (Beveridge et al. 2013; Bush 2004; Ahmed and Lorica 2002; Lewis 1997). A related argument is that aquaculture production is concentrated in Asia and does little to address the needs of malnourished populations in Africa (Hall et al., 2013; Golden et al., 2016).

Another pair of narratives sets up contrasting visions around aquaculture's supply side. The first emphasizes the predominance and desirability of, low intensity 'small-scale' farming that contributes directly to household food security and producer incomes (e.g. Bondad-Reantaso and Subasinghe, 2013). The second frames environmental degradation and social dislocation associated with the rise of 'industrial' export-oriented aquaculture as compromising the food security of communities in Southern producing nations (e.g. Nayak and Berkes, 2011; van Mulekom et al., 2006).

We argue that despite their influence in shaping science, policy and popular perceptions, none of these narratives adequately represent the current diversity of aquaculture in the Global South, nor its aggregate 'macro' effects on food security. The remainder of this paper makes this case.

First, we demonstrate that, contrary to the focus on international trade, farmed fish is overwhelmingly consumed domestically in Southern aquaculture-producing nations, and is increasingly widely available and readily accessible to poor urban and rural consumers in these markets. Second, we address supply side arguments by challenging the dominant narratives linking aquaculture and food security and the prescriptions for promoting aquaculture that arise from them. We conclude by highlighting the need for future research and policy to pay greater attention to existing patterns of aquaculture development and their contributions to Southern food security.

[1] The terms 'fish', 'aquatic animals' and 'seafood' are used interchangeably as a shorthand for edible aquatic animals. Aquatic plants, algae, non-edible aquatic animals (e.g. corals, sponges), and aquatic mammals, are excluded all calculations in the paper.

2 International trade vs. domestic consumption

Seafood is among the most highly internationally traded food commodities (e.g. Asche et al. 2015; Tveteras et al. 2012). Fish and shellfish exports from developing countries exceed the value of coffee, rubber, cocoa, tea, tobacco, meat, and rice combined (Smith et al, 2010) and trade in fish products accounts for 10% of all agricultural exports (Gephart et al, 2016). In 2012, 37% of global fish production was exported (Kobayashi et al, 2015), with an estimated value of $129 billion (HPLE, 2014).

The scale of the international seafood trade and its apparent tendency to move large quantities of fish away from poor food insecure southern consumers to wealthy food surplus countries renders it controversial (HPLE, 2014). For example, Smith et al. (2010) contrast the status of large net exporters of seafood (e.g. China, Indonesia, Vietnam, Thailand, India, and Myanmar) possessing moderate to high levels of undernourishment, with the largest net importing markets (e.g. the United States and European Union), which are wealthy and well-nourished.

Asche et al. (2015) and Béné et al (2015a) provide thorough synopses of the debate over whether international trade in seafood has positive or negative effects on consumption and poverty. Our intent in the present paper is not to contribute to the literature on seafood trade. Rather, we argue that an emphasis on international trade has obscured the contributions made by farmed fish to domestic food security in the main Southern aquaculture producing countries.

To demonstrate this point, we estimate the volume of fish originating from aquaculture and capture fisheries that are traded internationally, or remain in country for domestic consumption, for the ten largest aquaculture producing developing countries in the world - Bangladesh, Brazil, China, Egypt, India, Indonesia, the Philippines, Myanmar, Thailand and Vietnam (FAO, 2016a). Together these countries accounted for 87% of global production of farmed aquatic animals and 43% of global capture fisheries landings in 2013. They are also home to 51% of the global population, and 52% of all malnourished individuals (Table 1).

Table 1 about here

The trade component of the FAO Fishstat J database (FAO, 2016b), on which we base our analysis, does not specify whether internationally traded products originate from capture fisheries or aquaculture. Following the methodology set out by Bush et al. (2013), we estimated the share of internationally traded aquatic animal products derived from each source, working on the assumption that the share of farmed and wild fish species groups in the exports from each country is proportional to the share of farmed and wild fish of these species groups in national production[2].

National fish production is reported by FAO in live weight equivalents (the weight of freshly harvested fish prior to any processing). The quantity of fish products traded internationally is reported in nominal terms - i.e. as the volume of fish traded post-processing (if any). To estimate the live weight equivalent (LWE) of each internationally traded product listed in Fishstat J we assigned conversion factors for similar categories of product, obtained from published sources (FAO, 2015; Bush et al., 2013; European Commission, 2011; Tacon et al., 2006). For each country, reported aquaculture production was divided by the apparent LWE of aquaculture exports to estimate the

[2] At the country level, production data were categorized by the "ISSCAAP species groups" reported by FAO. Exports were categorized by "ISSCAAP commodity divisions". Species divisions and commodity divisions were then combined under five aggregate "ISSCAAP commodity groups" (crustaceans, freshwater and diadromous fishes, marine fishes, miscellaneous aquatic animals, molluscs (including cephalopods) to enable comparison across countries and product categories. The complete dataset used, including all calculations, is available for download (see xxxx. 2017).

share of farmed fish exported and the share remaining as domestic food supply. The same procedure was followed for capture fisheries production and exports.

Figure 1 here

Figure 1, reveals the extent to which an excessive focus on international trade in seafood has inflated perceptions of its significance. The vast majority of fish farmed and landed in some of the world's largest fish producing and consuming countries is not exported. Eighty-nine percent of the fish farmed in the ten most important Southern aquaculture producing nations is consumed in these same domestic markets. The share of capture fisheries landings exported is almost double that of farmed fish, and exceeds that of aquaculture exports in six of the ten countries, but is still relatively modest at 22%.

In eight of the ten countries, apparent domestic consumption of farmed fish equals or exceeds 90% of total national aquaculture production. Only in Thailand and Vietnam do aquaculture exports exceed domestic consumption. Both these countries are also major exporters of capture fisheries products, and have fish supplies per capita well in excess of the global average of 20.1 kg, at 24.8 kg/capita/year and 32.7 kg/capita/year, respectively (FAO, 2016a; 2016c). Their seafood exports are surplus to domestic consumption needs, and do not divert food away from consumers at home.

To address the possibility that extrapolating the proportion of aquaculture and capture production to exports could bias results, we provide an alternative calculation using the most conservative assumptions possible with respect to aquaculture's contribution to domestic fish supplies. For each country, we attribute 100% of exports to aquaculture in species groups where production of farmed fish exceeds exports. For species groups where export volumes exceed farmed fish production, we assume that 100% of farmed fish is exported, with capture fisheries making up the gap between farmed fish production and total exports. Our original and alternate estimates are presented together in Table 2. The alternate assumption has little impact on the overall results: domestic consumption of farmed fish equals or exceeds 90% of production in seven countries and stands at 84% in one more. Overall, only 15% of farmed fish produced by the ten countries is exported.

Table 2 here

These results are supported by data presented in FAO (2016a) indicating that freshwater fish (by far the most important category of fish produced in the ten selected countries) account for just 4.8% of international trade in fish by volume. Shrimp (the second most important species group produced in the ten countries) make up 6% of world trade. In contrast, marine fish, which originate overwhelmingly from capture fisheries, account for 68.7% of global trade.

3. New geographies of consumption

The 'economic geography' critique of aquaculture's contribution to food security is epitomized by Golden et al. (2016), who state that fish farmed in the Global South is, "mostly exported to the wealthy countries of Europe and North America, or consumed by the growing middle-classes in the megacities of these economies" (p. 318). Analysis presented above contradicts the first of these claims. The second claim is similar to that put forward by Beveridge et al. (2013, p. 1075), who hypothesize that "aquaculture producers in developing countries tend to target the production of larger-sized fish, aimed at middle-class urban regional and international markets, presumably in the expectation that the higher absolute and relative prices such fish command increase profits".

The next subsection challenges these latter claims; providing evidence that farmed fish produced for domestic markets are widely accessible to low-income rural and urban consumers, and examining the changing characteristics of urban and rural demand, and the effects of aquaculture on price stability and fish supply.

3.1 Access and availability

Contrary to the prevailing view, aquaculture produces a wide range of species of low or moderate market value. Reports from the early stages of aquaculture development in Bangladesh indicated a bias toward producing high value Indian major carps that were not accessible to the rural poor (Lewis 1997). But while Lewis' observation accurately reflected the situation in the mid-1990s, by 2011 three low value farmed species (pangasius, silver carp and tilapia) were each eaten in greater quantities in Bangladesh than rohu (the most popular Indian carp), or any species of fish originating from capture fisheries (Hernandez et al., 2017).

Low value farmed fish species now dominate or make large contributions to domestic fish supply in most of the 10 countries assessed above (e.g. tilapia and walking catfish in Thailand and Indonesia, silver carp in China, tilapia in Egypt, pangasius in India). At the same time, production of more expensive carnivorous species in these countries has often stagnated at low levels (e.g. barramundi and grouper in Thailand, Indonesia and Vietnam). Given that the vast majority of consumers in these countries belong to low or middle income brackets, such a pattern is to be expected. Aquaculture could not have sustained its extreme growth rate over the last three decades if it catered only to demand from a small wealthy segment of the domestic market.

Aquaculture's growth has driven down the real price of most farmed fish species produced in large volumes, making them increasingly accessible to lower income consumers. The tendency for supply to increase and production to remain profitable even as prices fall, is the result of productivity growth arising from improvements in efficiency (Asche et al., 2009). This pattern has been a defining feature of the global aquaculture boom for the past 30 years.

Examples of declines in the real price of farmed fish are numerous. In Egypt, from 2000 to 2010 inflation adjusted prices fell by 46% for catfish, 38% for tilapia, and 31% for mullet (Macfadyen et al., 2011). International prices for tilapia and pangasius fillets fell by around 40% from 1995-2007 and 2002-2007, respectively (Asche et al., 2009). Nominal prices received by carp farmers in India's main producing state, Andhra Pradesh, remained roughly constant from the mid-1980s to 2014, representing a huge reduction in real price (Belton et al., 2017).

Depletion of wild fish stocks has been another driver of aquaculture's growth. Pervasive habitat degradation and overexploitation of fish stocks have caused declines in the supply per capita of fish from inland and marine capture fisheries in major aquaculture producing countries. Non-farmed fish have become increasingly expensive, both in real terms and relative to farmed fish, often reversing their relative accessibility to consumers. For example, in Myanmar the price of snakehead and hilsa (two of the most important species harvested from inland and marine capture fisheries, respectively) increased at an average rate of 2.9% and 5.5% each year from 2008 to 2014. In contrast, the real price of rohu, the main species farmed, fell at an average rate of 0.5% per annum (Belton et al., 2015).

In Bangladesh, the average real price of fish from inland capture fisheries increased 4% between 2000 and 2010, while that of marine capture fish jumped 42%. The average price of farmed fish fell over this period, to become 10% cheaper than the inland capture fish that once dominated supply (Toufique et al., 2017). A similar pattern is illustrated in Figure 2. From January 2012 to June 2015 the nominal price of Bangladesh's four main farmed fish species remained fairly constant. In contrast, the price of two formerly cheap and abundant small fish species harvested from inland capture fisheries (*puti* and *mola*) rose, to exceed of all but one of the main farmed species by the end of the period. These trends resulted in a 35% reduction in the consumption of inland capture fish for extreme-poor households and 37% reduction for non-poor households in Bangladesh from 2000-2010. In contrast the consumption of farmed fish increased 152% and 88% for the same groups over this period (Toufique and Belton, 2014).

Figure 2 here

3.2 Urbanization and shifting patterns of demand

Contrary to assumptions implicit in the economic geography narrative, food security is no longer a solely, or even predominantly, rural concern. The share of urban dwellers already exceeds those in rural areas, and is expected to rise to 66% by 2050, fueling unprecedented urban demand for food (Chicago Council, 2016). Many urban inhabitants in Southern countries, even among the middle classes, occupy precarious positions. For example, sixty percent of Africa's 350 million strong middle class is considered vulnerable to slipping back into poverty, and thus food insecurity (Chicago Council, 2016). Results from the Gallup World Poll's 'Food Insecurity Experience Scale' survey reflect this urban precarity. Respondents in urban areas of Asia feel *more* food insecure than those in rural areas - a difference of about three percentage points for Asia as a whole (21% in rural areas versus 24% in urban), and eight percentage points in South Asia (FAO, 2016d).

Demand for non-staple foods in Southern cities is growing in line with 'Bennett's Law' - that the proportion of calories derived from starchy staples falls with rising income as consumers diversify the food consumption bundle to include higher-priced calories (Timmer et al., 1983). As a result, the share of food expenditure allocated to fruits, vegetables, meat, dairy and fish rises disproportionately with income (Reardon et al., 2014). By virtue of higher average urban incomes and the increasingly large share of urban inhabitants in the population, demand for food is highly concentrated in urban areas, which already account for 65% of the value of the entire Asian food economy (Reardon and Timmer, 2014). This means that demand for all fish - both farmed and wild - is greater in urban areas than rural.

However, the gap in consumption of animal proteins between urban and rural consumers is now smaller than is generally understood. Cross-country analysis of Bangladesh, Indonesia, Nepal and Vietnam shows that urban dwellers in all four countries consume approximately 50% more animal source foods (meat and fish combined) than rural dwellers (Reardon et al., 2014). In China, urban consumers in the poorest wealth quartile (i.e. the poorest 25% of the urban population) eat 40% more fish than poorest quartile rural consumers, while the difference between urban and rural consumers across the other quartiles ranges from 21% to 25% (calculated from Chui et al., 2013). In Bangladesh, the difference between urban and rural fish consumption is smaller still, with urban consumers eating 12% more farmed fish and 17% more fish from inland capture fisheries than those in rural areas (Toufique et al. in press).

Price elasticities for fish of all types tend to be high - estimated at 0.8 on average, with a range of 0.31–1.04 by Naylor (2016) - and are larger for poor consumers than for the better-off. For example, the price elasticity of farmed fish in Bangladesh is reported to range from 0.78 to 1.29 for non-poor and extreme-poor consumers, respectively (Toufique et al., 2017). The poor are therefore more responsive to increases (or decreases) in fish prices than the wealthy, as also demonstrated by Dey et al. (2008) in a cross-country analysis of consumption in Bangladesh, China, India, Indonesia, Malaysia, the Philippines, Sri Lanka, Thailand and Vietnam. Rural consumers (who are poorer on average than urban) therefore have most to lose from increases in the price of non-farmed fish that accompany the contraction of wild supply, and most to gain, proportionately, from declines in the price of farmed fish that accompany the expansion of aquaculture.

The income elasticity of demand for fish is also relatively high; reported as -0.64 by Naylor (2016), and ranging from -0.44 to -0.51 for non-poor and extreme-poor consumers for farmed fish in Bangladesh (Toufique et al. 2017). This tendency contributes to increasing demand for fish in economies where incomes are rising.

3.3 Price stability

The growth of aquaculture has stabilized fish prices. Food price stability is particularly important for the food security of poor consumers, for whom food expenditures constitute a large share of total income (Troell et al., 2014). Farmed fish prices are about half as volatile as those of wild fish on average, reflecting the seasonally variable and often unpredictable nature of fisheries, and the high degree of control over the timing of the production process that is possible in aquaculture (Asche et al., 2015). This pattern is illustrated by Figure 2, which shows much greater seasonal fluctuations in the price of two the non-farmed species than the four cultured ones.

As aggregate production from capture fisheries appears to have reached the maximum level that can be sustained, increasing demand for wild fish can only increase prices further. However, because the supply of fish from aquaculture has kept pace with demand, substitution has dampened price pressure on wild fish as demand has spilled over to farmed species, reigning in divergence in the prices of farmed and wild fish over time (Tveteras et al., 2012).

This finding has profound implications for food and nutrition security. Rashid et al. (2016) calculate that if aquaculture had stopped growing in 1980, fish supply per capita in 2013 would have been about half of the actual supply in that year, and 17% less than it was in 1980. As these authors note, "the consequences of such a scenario are easy to imagine: higher prices, lower consumption, and far greater pressure on marine and inland capture fisheries." The adverse consequences would have been particularly severe in Asia (Rashid et al., 2016, p. 1). In other words, the poor in our ten countries would eat far less fish *of any kind* - wild or farmed - were it not for the growth of aquaculture.

4. Transforming farmed fish supply

Production of farmed fish is as subject to misinterpretation as its consumption. Two narratives dominate aquaculture science and policy. The first extolls the benefits of low intensity 'small-scale' aquaculture for promoting food security. The second critiques the 'industrial' forms of production, particularly shrimp farming, for undermining it. Reducing aquaculture to the idealized binary categories of 'small-scale' and 'industrial' has obscured the contributions of a very large intermediate segment of producers, existing along a gradient between these two poles. This 'missing middle' class of producers has emerged in response to the changing patterns of demand and diet transformation outlined above, as part of a broader 'quiet revolution' in agri-food supply chains in most of Asia and parts of Africa (Hernandez et al., 2017). Failure to acknowledge the missing middle's existence has resulted in the perpetuation of ineffective prescriptions for food security focused aquaculture development.

4.1 Polarized production narratives

Promotors of small-scale aquaculture emphasize the cumulative impact and positive nature of the contributions such farms make to food security. For instance, the High Level Panel of Experts on Food Security and Nutrition (HPLE, 2014) asserts that 70-80% of aquaculture production originates from small-scale farming. Such pronouncements are commonplace (e.g. Tacon et al., 2010; De Silva and Davy, 2009) and form a central tenet of the conventional wisdom on aquaculture. But they are also unsubstantiated - there is no global database of fish farm sizes to provide an empirical basis for this claim.

Small-scale aquaculture is generally characterised in the literature as low intensity (utilizing limited external feed inputs), and/or integrated with other agricultural systems. As such, it is seen as ecologically efficient in terms of a reliance on low trophic level fish species, limited dependence on nutrient inputs, and integration with components of terrestrial farming systems (e.g. through use of crop processing wastes or manures available on farm as feeds or fertilizers, or the stocking of fish in rice fields) (Edwards et al., 2002). The contribution of small-scale aquaculture to food security is usually framed in terms of meeting the subsistence fish consumption needs of rural households, and the generation of supplemental incomes through sales of small marketable surpluses that may be spent on purchases of other food items (e.g. Ahmed and Lorica, 2002).

The 'small-scale' narrative has provided the basis for promotion of aquaculture by overseas development projects throughout the tropics for more than 30 years. The assumption that small-scale aquaculture is underdeveloped globally and should be supported as a key strategy for improving food and nutrition security in developing economies is persistent. Golden et al. (2016, p. 139) argue for instance that, "when explicitly planned to improve local well-being, aquaculture can be a crucial contribution to local diets and economies … less-intensive and more-diverse forms of aquaculture may have the most potential to meet the nutrition and food-security needs of the poor".

Literature at the opposite end of the narrative spectrum focusses on the role of intensive, industrial aquaculture in undermining local food security. Work on 'industrial aquaculture' emphasizes in particular the role that export oriented shrimp aquaculture has played in "threatening both domestic food security and the economic opportunities of local communities" (van Mulekom et al., 2006, p. 546). Studies of shrimp farming provide evidence of a variety of social and environmental impacts on local food security, including reduced agricultural production arising of the salinization of rice-dominated terrestrial farming systems (e.g. Paprocki and Cons, 2014); displacement of small-scale capture fisheries from coastal lagoons (Nayak and Berkes, 2011); and, destruction of mangroves (a critical nursery habitat for wild fish) to make way for shrimp ponds (e.g. Hamilton and Lovette 2015). These processes have been a recurrent feature of shrimp farm development in many locations, particularly during 'boom' periods.

However, both small-scale and industrial narratives have a tendency to confuse the specific characteristics of their subject matter with the generalized attributes of the entire aquaculture sector. The small-scale aquaculture narrative vastly overstates the importance of the idealized small, low input, integrated farm. Similarly, the industrial aquaculture narrative often extrapolates from negative food security impacts arising from local struggles over resources that characterize production of specific commodities in specific places and specific times, to divine the aggregate effects of global farmed fish production.

4.2 The missing middle

Contrary to the polarized narratives presented above, empirical evidence points to most global aquaculture output originating from a 'missing middle' segment of producers, characterized by five features. They are: (1) highly commercially oriented; (2) span a broad spectrum of scales of production; (3) utilize a diverse range of production technologies (but are increasingly intensifying through use of pelleted feeds); (4) produce multiple, predominantly low and medium value, species and; (5) have emerged in an unplanned manner in response to opportunities created by changing patterns of demand.

For example, Chinese farms producing carps and tilapia are almost entirely commercial, with more than 95% using manufactured feeds, and produce fish in polycultures that contain an average mix of four to six fish species (Chiu et al., 2013). In Andhra Pradesh, India, the location of the highest concentration of freshwater fish farms outside China, aquaculture is dominated by semi-intensive carp and pellet-fed pangasius polycultures, oriented entirely to the market and spanning a spectrum of farm sizes from small to very large (Belton et al., 2017). In Bangladesh, a recent survey of 2678 farms identified 14 distinct production technologies, all of them polycultures, producing a combined total of 54 different species of fish and crustaceans. Production is dominated by carps, tilapia and pangasius. While overwhelmingly below 2 ha in size, farms are strongly commercially oriented, generating large marketed surpluses (Jahan et al., 2015). In Egypt's Nile Delta, the mean size of tilapia farms is 6 ha, 94% of farms use branded pelleted feeds (applying an average of 12 t of feed/ha), and 100% of farms sell their product to domestic wholesale markets (Eltholth et al., 2015). Similar assessments would be applicable to many other Southern aquaculture producing countries. For example, a recent report synthesizing case studies from Bangladesh, Chile, Ecuador, Egypt, Indonesia, Mexico, Thailand, Viet Nam and Zambia, concluded that 'small-scale' aquaculture contributed less than 30% of farmed fish production in these countries (Phillips et al., 2016).

The missing middle segment of fish producers represented in all of the cases noted above differs markedly from the idealized small farms portrayed in developmentalist narratives. Although large numbers of households in South and Southeast Asia have benefited from enhanced nutrition and supplementary incomes generated by small farms of the traditional type, these can no longer be considered the dominant mode of production. For instance, even in Bangladesh, a country with more than 4 million small 'homestead ponds', two thirds of farmed fish output in 2010 originated from fully commercial farms (Belton and Azad, 2012). Moreover, even among the homestead pond farm segment the trend is one of intensification and commercialization, with 38% of farms in Bangladesh using pelleted feeds in 2014 (Hernandez at al. 2017).

Attempts to establish small-scale aquaculture in the traditional mold have largely failed outside of Asia. For example, concerted efforts by external development agencies in Malawi over several decades have been highly constrained by poor market development and, ultimately, the limited purchasing power of a still largely rural population (Brummett 2000; Brummett et al. 2008). Even where well-intentioned projects have demonstrated potential for subsistence orientated small-scale production (e.g. Dey et al. 2010), outcomes have rarely been sufficiently attractive to stimulate widespread adoption. Similar failures to establish viable, self-sustaining small-scale aquaculture have been repeated throughout a succession of African and Caribbean states (Leschen and Little, 2014). The potential of integrated rice-fish farming, promoted widely as a contributor to local food security, has also been overstated. Only 1% of the world's rice fields are deliberately stocked with fish, principally because returns to labor are often unattractive to farm households (Edwards 2015).

As Brummett et al. (2008) outline for Africa, the types of aquaculture that have become most successfully established and produce the greatest volumes of fish for domestic consumers have rarely received direct support from government or donors because they are not perceived to represent the poor, nor offer the possibility of generating export earnings. Despite this, 'immanent development' (Belton and Little, 2011) of fish farms – the unplanned supply response of large numbers of producers and supporting value chain actors to emergent opportunities presented by rising domestic incomes and diet transformation – is the global norm. Normative prescriptions for aquaculture 'planning' that continue to pervade the literature (e.g. Golden et al., 2016) are thus outdated and unlikely to be effective where implemented.

Aquaculture was once widely considered to have failed in Sub-Saharan Africa (SSA), but is now expanding rapidly in Nigeria, Uganda, Ghana, Kenya, Zambia, Madagascar and South Africa. Between 2004 and 2014 there was a seven-fold increase in farmed fish production in SSA, concentrated mainly in these countries, with an average annual growth rate of 21%. (Satia, 2017). The growth of aquaculture in this region parallels the recent emergence of a substantial middle class and their demand for more diverse diets (Tschirley et al., 2015).

Fish production serving this market was pioneered mainly by large vertically integrated farms, but the value chain infrastructure established to facilitate these operations (e.g. hatcheries, feed mills, cold storage) has allowed significant numbers of medium scale producers to emerge in some locations (see Kassam and Dorward, 2017). Poorly developed supply chains and logistics, and consequent difficulties in accessing inputs and end markets, remain a challenge in other areas of SSA (Naylor, 2016). However, where these hurdles have been overcome, the high value urban market segments targeted by large farms are starting to become saturated, leading to diversification into production and marketing of smaller, cheaper fish that are accessible to consumers in lower income brackets (see Kassam and Dorward, 2017 and Kaminsky et al. In press for examples from Ghana and Zambia, respectively). There is also a small but growing role for aquaculture exports from Southern nations to SSA, which is now ranked as China's second most valuable tilapia market after the U.S. (Mao, 2016).

As noted above, one of the overriding trends in aquaculture for the past two decades has been a shift toward intensive forms of production that utilize formulated pelleted feed diets to achieve higher levels of productivity per unit area of land. Although many extensive and semi-intensive production technologies will continue to remain viable over at least the medium term, there is no reason to expect that the trend will reverse in favor of widespread expansion of the less intensive production systems widely advocated in the interventionist literature (e.g. Golden et al., 2016; Thilsted et al., 2016).

Moving beyond interventionist approaches opens up food security questions that are more relevant in the context of the ongoing intensification occurring with the rise of aquaculture's 'missing middle'. Perhaps most important is the long running controversy over whether utilization of marine 'forage fish' in pelleted feeds diverts food that might otherwise be used for direct human consumption away from poorer consumers, thereby compromising their nutrition security (e.g. Tacon and Metian, 2013). The extent to which use of fish for animal feeds competes directly with the use of fish for human consumption remains unclear, however (Béné et al, 2015b).

Advances in the formulation of pelleted feeds mean that feed conversion ratios (an indicator of overall feed use efficiency), and fish-in fish-out ratios (a measure of the efficiency with which fish meal and fish oil are utilized) are improving (e.g. Sarker et al., 2013). Aquaculture is increasingly less dependent on marine ingredients in feeds, with rapid substitution for vegetable derived feed ingredients occurring (Roberts et al., 2015). Furthermore, an estimated 35% of all marine ingredients used in feeds are now sourced from fish processing byproducts, and aquaculture is itself becoming a major source of fishmeal and oil (Little et al., 2016). Partly as a result of these changes, the share of global fish production used as fishmeal declined from an average of 23% in the 1990s to 10% in 2012; a reduction of 10 million tonnes (HPLE, 2014).

Finally, considering the sustainability of the global food system as whole, evidence suggests that the environmental performance of intensive aquaculture, as measured through life cycle assessment, can be equal to or better than other animal source foods (Béné et al, 2015b). The question then, is how to build further efficiencies into aquaculture production by working with the missing middle.

5. Conclusion

The rapid rise of aquaculture in the Global South has drawn attention to the sector's potential to contribute to food security, as well as its perceived failures to do so. However, as demonstrated here, most science and policy in this sphere lags far behind current empirical realities and largely fails to recognize the scale and nature of contributions that aquaculture already makes to global food security. In fact, as we show, aquaculture development in the main fish farming countries of the Global South has already averted severe declines in food and nutrition security.

Part of the disconnect between narrative and reality stems from an excessive focus in the literature on the international seafood trade, and on farmed aquatic commodities produced for export. Export focused research has directed attention toward a relatively small and unusually problematic set of technologies and commodities, and away from a domestic demand led 'quiet revolution' in farmed fish production, in which huge improvements in the availability, accessibility, and stability of fish supply have been achieved.

Instead of emphasizing aquacultural reform based on outdated narratives about the planned development of extensive small-scale aquaculture, we argue for recognition that diverse and increasingly intensive forms of commercial fish farming already make important contributions to diet diversity for low and middle income urban and rural consumers in countries home to almost half the world's population. These latter forms of farming have the greatest potential to augment nutrient supplies from capture fisheries, and will continue to do so, whether or not much-needed improvements in capture fisheries governance and management are achieved. The transformation of fish supply, already far advanced in Asia, is now also beginning in several of the more populous and rapidly growing countries in Africa.

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Tables and Figures

Table 1. Population, undernourishment, and aquaculture and fisheries production for selected countries

Country	Population (millions)*	Prevalence of Undernourishment (% of population)*≠	Undernourished population (millions)†	Aquaculture production (t)‡	Capture fisheries production (t)‡	Aquaculture as a share of fish production (%)
Bangladesh	161	16	26	1,859,808	1,550,446	55
Brazil	208	5	10	472,829	765,287	38
China	1371	9	123	42,694,335	16,274,939	72
Egypt	92	5	5	1,097,544	356,858	75
India	1311	15	197	4,549,607	4,645,182	49
Indonesia	258	8	21	3,819,517	6,103,001	38
Myanmar	54	14	8	926,175	3,786,840	20
Philippines	101	14	14	815,008	2,335,004	26
Thailand	68	7	5	1,052,701	1,843,747	36
Vietnam	92	11	10	3,203,326	2,803,800	53
Subtotal	3714		418	60,490,850	40,465,104	60
World	7347	11	808	69,296,511	93,763,656	42
Subtotal as share of world (%)	51	n/a	52	87	43	n/a

Notes: *World Bank (2016); ≠ Undernourishment refers to the percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously; †Calculated from data in columns 2 and 3; ‡Production data for 2013 (FAO, 2016b)

Table 2 Estimates of aquaculture's contribution to domestic consumption and exports in selected countries (2011). Source: Authors' calculations from FAO (2016b)

Item	Bangladesh	Brazil	China	Egypt	India	Indonesia	Myanmar	Philippines	Thailand	Vietnam	Total
Total aquaculture production (million t)	1.52	0.44	38.62	0.99	3.67	2.72	0.82	0.77	1.20	2.85	53.59
	Exports (first estimate)										
Total aquaculture exports (estimated LWE) (t)	60,475	2,993	2,918,521	5,985	193,093	231,391	36,613	19,187	935,535	1,681,781	6,085,575
Share of exports in aquaculture production (%)	4	1	8	1	5	9	4	3	78	59	11
Share of aquaculture consumed domestically (%)	96	99	92	99	95	91	96	97	22	41	89
	Exports (second estimate)										
Total aquaculture exports (estimated LWE) (t)	130,071	5,782	4,005,385	10,820	361,248	429,382	66,510	40,070	837,868	1,895,821	7,782,956
Share of exports in aquaculture production (%)	9	1	10	1	10	16	8	5	70	67	15
Share of aquaculture consumed domestically (%)	91	99	90	99	90	84	92	95	30	33	85

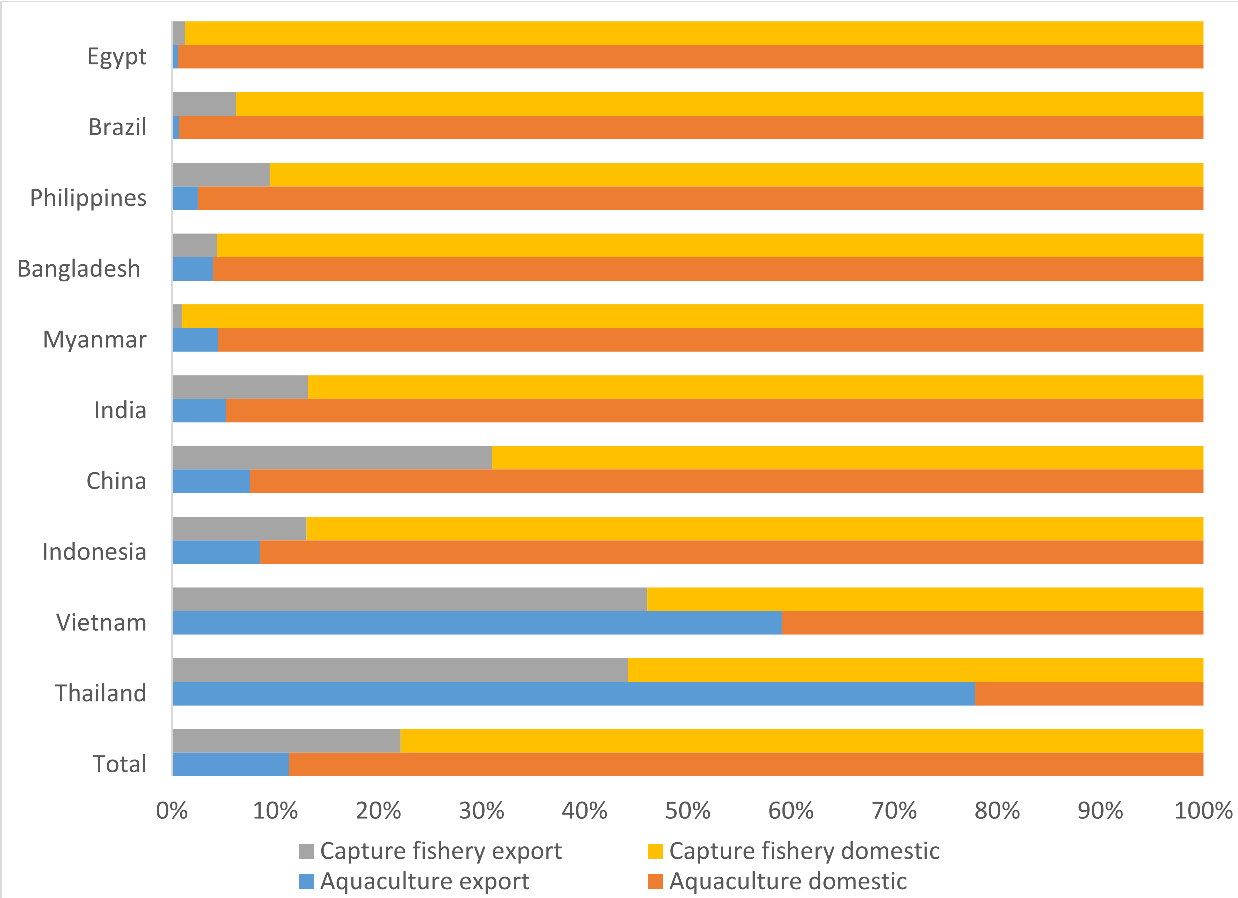

Figure 1. Aquaculture and capture fisheries exports and apparent domestic consumption in selected countries (2011). Source: Authors' calculations from FAO, 2016b[3]

[3] This analysis is based on data for 2011, the most recent year for which both production and trade data was available in the Fishstat J database.

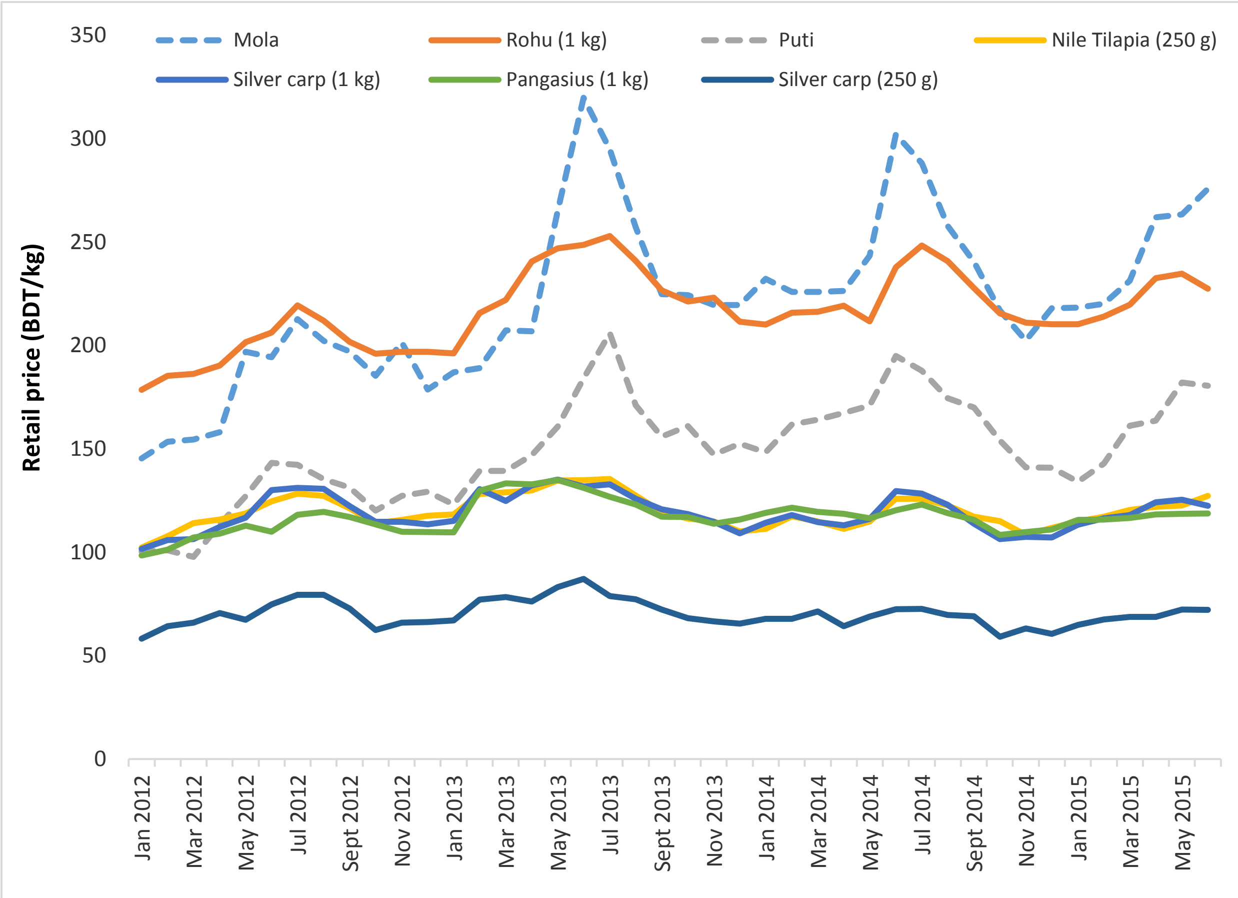

Figure 2. Monthly nominal retail prices of four farmed and two non-farmed fish species in Bangladesh, January 2012-May 2015. Note: Non-farm species identified by dashed line. Source: Unpublished data collected by WorldFish on a weekly basis from 25 rural and urban retail markets in six districts in South, Southwest, North and Northwest Bangladesh.