Innovations in capture fisheries are an imperative for nutrition security in the developing world

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This article examines two strands of discourse on wild capture fisheries; one that focuses on resource sustainability and environmental impacts, another related to food and nutrition security and human well-being. Available data and research show that, for countries most dependent on fish to meet the nutritional requirements of their population, wild capture fisheries remain the dominant supplier. Although, contrary to popular narratives, the sustainability of these fisheries is not always and everywhere in crisis, securing their sustainability is essential and requires considerable effort across a broad spectrum of fishery systems. An impediment to achieving this is that the current research and policy discourses on environmental sustainability of fisheries and food security remain only loosely and superficially linked. Overcoming this requires adoption of a broader sustainability science paradigm to help harness synergies and negotiate tradeoffs between food security, resource conservation, and macroeconomic development goals. The way society chooses to govern fisheries is, however, an ethical choice, not just a technical one, and we recommend adding an ethical dimension to sustainability science as applied to fisheries.

overfishing | small-scale fisheries

Within a few years, if it has not happened already, aquaculture's contribution to fish supply for human consumption will exceed that of wild capture fisheries. Given this imminent milestone, and the fact that world population now exceeds 7 billion, aquaculture is understandably receiving considerable attention as a source of food and economic development (e.g., ref. 1).

However, although aquaculture may be the new frontier for producing fish, wild capture fisheries (hereafter simply referred to as fisheries) remain significant for overall supply. Here we present an analysis that shows how this supply is especially important for food security in developing countries.

We then discuss this contribution in the light of the multiple threats to fisheries sustainability and the widely expressed concern that fishing, especially of our oceans, is profoundly damaging to aquatic ecosystems (2, 3). Finally, we offer some perspectives on how the research and policy discourse needs to evolve to help ensure fisheries' contribution to food and nutrition security.

We focus on the role of fisheries as a direct food provider to vulnerable and food insecure populations. Fisheries' role in providing income for sector participants to purchase other foods is not considered explicitly, nor the impact of revenues from trade, licensing, and access fees that may contribute to positive trade balances, enabling food imports (see for example refs. 4 and 5).

Important as these indirect benefits are, or could be, realizing them is likely to require tradeoffs against the direct food provisioning function of fisheries. With food and nutrition security currently a key global policy concern, it therefore behooves us to understand the actual and potential role of fish as food before we can make informed, ethical choices on the use of fish as just another trade commodity and fisheries as just another economic activity.

Results

To assess the contribution of fisheries to people who are food and nutrition insecure, we first consider the relationship between country wealth, measured as per capita gross domestic product (GDP), animal protein consumption (in grams per person per day), and the percentage of animal protein provided by fish (Fig. 1).

As one would expect, overall animal protein consumption increases with country wealth. Relatively few of the wealthier countries, however, rely on fish for a high proportion of this supply. This contrasts with poorer countries, for whom a subset has high dependence on fish for the animal protein in the diet.

Arbitrarily defining this subset as countries with a per capita GDP of less than $2,000 and a greater than 20% dependence on fish for animal protein supply, we can assess how much of this comes from wild capture fisheries. To do this we used per capita fish supply ("apparent consumption") at the national level as our starting point. This is conventionally calculated by the Food and Agriculture Organization of the United Nations (FAO) by combining data on domestic fish production with fish imports and exports. Because global trade statistics do not distinguish between aquaculture and wild capture sources, we examined the size and direction of the trade balance for each country and compared this with total domestic production and the proportion of this supplied by wild capture fisheries (Fig. 2). To provide a further perspective we also included the levels of undernutrition in the population as an additional variate.

Several features of these data indicate that fish from wild capture dominates domestic supply in these countries. First, for 10 of the 13 net fish exporters in our sample, fisheries contributed more than 90% of domestic production. Because domestic fisheries production also exceeds exports by a considerable margin one must conclude that fisheries supply the bulk of the fish in these populations' diets. The remaining three net exporting countries were Vietnam, Bangladesh, and Indonesia. For these, one cannot draw definitive conclusions about the relative importance of capture fisheries vs. aquaculture for domestic food from these data.

For the net importing countries, two types are apparent: those for whom net imports exceed domestic supply and those for whom it does not. Three countries are in the first category, all from West Africa: Nigeria, Benin, and Cote d'Ivoire. Another, Ghana, falls on the margin. The bulk of fish imported to Nigeria are frozen herring, mackerel, and croker, all of which are supplied from wild stocks (6). Fisheries are almost certainly also the source of the lower-value fish that constitute most other imports into the region, particularly in view of the well-documented and dynamic regional fish trade in Africa (7).

For all but 2 of the 12 net fish importers for which domestic production exceeds imports, more than 90% of this domestic supply comes from wild capture. For these countries, especially those where imports are relatively low, wild capture supplies are clearly of greatest importance to the local population.

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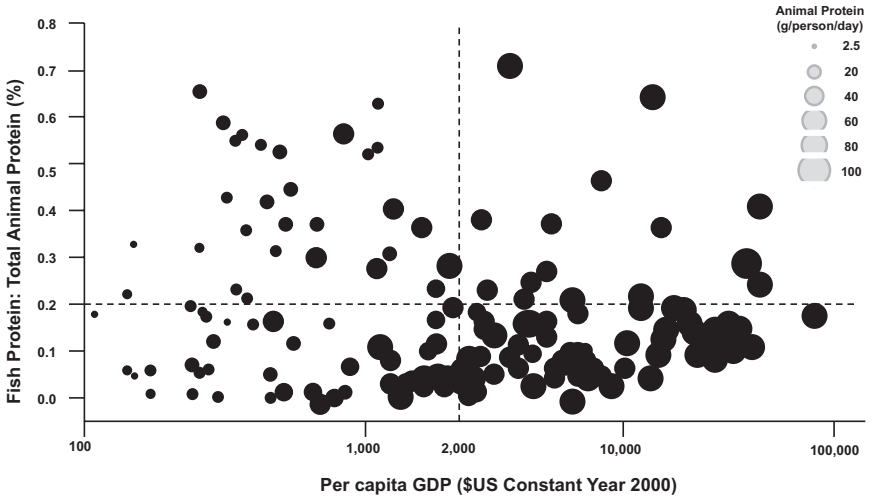

Fig. 1. Graph of fish protein in national diets as a proportion of total animal protein vs. national per capita GDP. Size of dots denotes the total animal protein in the national diet. Countries appearing in the upper left quadrant appear in the analysis shown in Fig. 2. Data sources: protein consumption, FAOStat Food Consumption Database (http://faostat.fao.org); GDP (constant 2,000 $US), World Bank (http://databank.worldbank.org). Data are for 2007.

Further evidence in support of the primacy of wild capture for providing fish to the food insecure comes from recent analyses for the small-scale fisheries—a sector for which official statistics often underestimate catches (8). This analysis sought to rectify this by undertaking 15 case studies covering 17 countries and adjusting global data on the basis of these findings.

Summarizing this work, Mills et al. (9) conclude that inadequate reporting in official statistics of the small-scale fishing sector in developing countries (designated as the countries identified as such in FAO FishStat) probably leads to underestimates of global marine catches by approximately 10% and freshwater catches by approximately 80%. Using local consumption data, for example, rescaled national production estimates for Vietnam rose by a factor of 5.7. Similarly, for Ghana, localized market surveys suggested that catch was five times national estimates (9).

Revised total estimates for capture fisheries production from developing countries were between 70 and 75 mt for 2006, compared with approximately 65 mt from official statistics. Of the revised figure, 40–46 mt was estimated to be for direct human consumption (9). Fig. 3 summarizes the origins (small or large scale, marine or freshwater) of this food supply.

It is significant that this study estimates that 94% of small-scale fisheries catch is consumed within the country of origin. Even if cross-border trade in fish reduces this estimate (e.g., ref. 7), much of this trade is among developing countries and does not substantially alter the conclusion that small-scale fisheries play a critical role in securing food for people in developing countries.

Discussion

Both our results and the recent study of small-scale fisheries described above point to two simple and related facts: (*i*) the

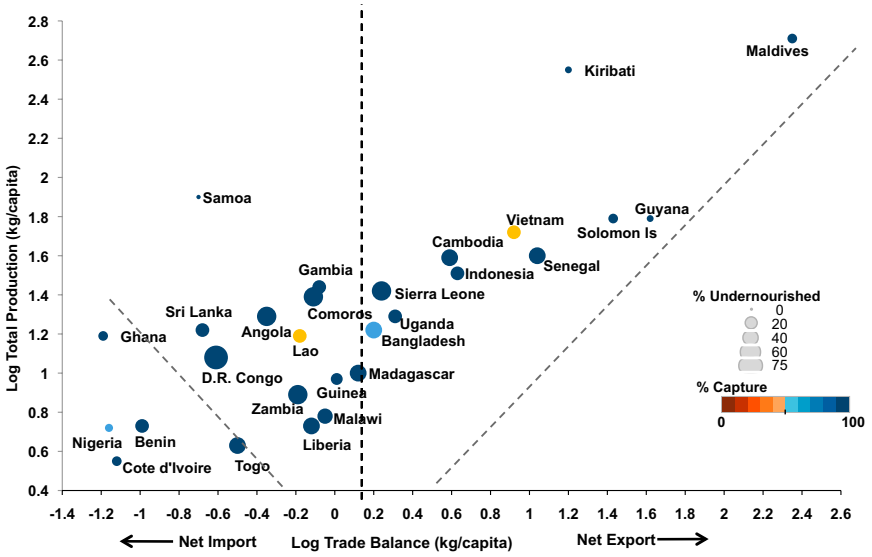

Fig. 2. Graph of log trade balance against log total domestic fish production. Colors of dots indicate the proportion of per capita domestic production from wild capture fisheries. Size of dots denotes the percentage of the population that is undernourished. Dotted lines denote equivalency of imports or exports with domestic production (e.g., for countries above the dotted line to the left of the midline, domestic production exceeds net imports). Data sources: fish production, FAO FishStat Fishery Commodities Global Production and Trade Database (www.fao.org/fishery/statistics/en); percent undernourished, table 1 in ref. 54.

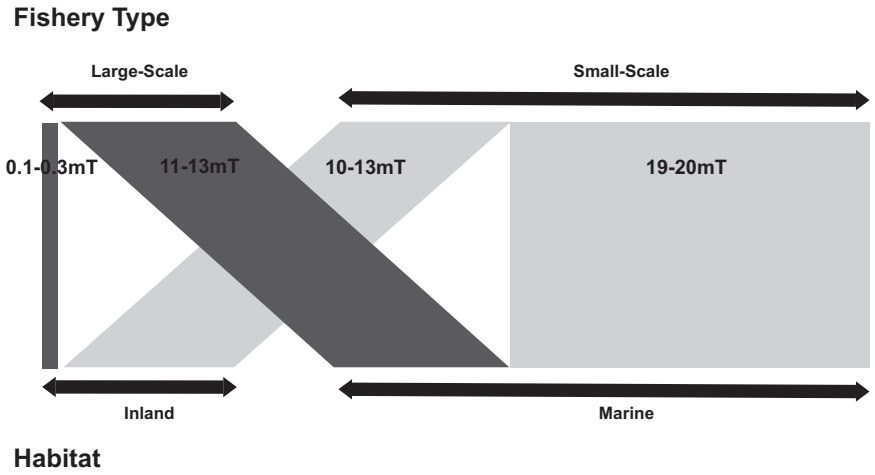

Fig. 3. Proportion of developing country fisheries catch destined for direct human consumption in 2008 derived from inland and marine systems and from small-scale and large-scale fisheries. Data source: table 1.1 of ref. 9. Figures indicate the upper and lower uncertainty bounds and are in millions of tons.

countries that depend most on fish for food and nutrition security rely primarily on catches from the wild, and (*ii*) most of those countries are in the developing world.

In many settings these fish represent the principal animal source food for the population, supplying both high-quality protein and essential micronutrients for maintaining health and well-being (10). This dependency is likely to persist for the foreseeable future because, for most of these countries, aquaculture remains a relatively small contributor to total supply. This is particularly true for most of the African and Small Island Developing States shown in Fig. 2. Although recent aquaculture growth rates for some of these countries are among the fastest in the world, the low base from which they are starting makes a major contribution to national fish supplies unlikely in the next 10–15 y, even under ideal conditions. There is no immediate prospect, therefore, that aquaculture will replace any losses of local wild fish supplies or meet future demand growth unless it is through imports of farmed fish—currently an unaffordable prospect for these countries. Given this circumstance, a key question, therefore, is the ecological sustainability of wild fish production, particularly in the developing world, and the limits to supply.

Status and Future of Fisheries. The most authoritative assessments of world fisheries status come from FAO. Using regional experts to assess 445 stocks, estimates of their status cover approximately 80% of FAO-estimated global catch. The most recent estimate states that 29.9% of stocks were overexploited, depleted, or recovering in 2009 (11), a slight decrease from 2008. Several other published estimates are also available and reach a broadly similar conclusion, albeit with differing methods, definitions of overexploitation, and geographic coverage (12–14).

Concerning trends, FAO assessment suggests a moderate increase in the proportion of overexploited stocks over the past 20 y from approximately 25% in 1999 to approximately 30% in 2009 (11). Others argue that the FAO assessment is highly conservative and that analysis of catch data shows much more dramatic increases (15). However, others argue that catch analyses are biased and that there is little evidence of a rise in the proportion of overexploited or collapsed stocks over the past 40 y (14).

Although these disputes remain unresolved, there remains considerable cause for concern. In particular, south, southeast, and east Asia are among several regions containing significant developing country sea fishing nations where the data to assess stock status have either not been collected or have yet to be adequately analyzed and included in global syntheses.

For marine fisheries it is fishing itself that, at a global scale, is the principle anthropogenic driver of changes in stock status. However, there are, of course, other drivers that affect marine fisheries sustainability. Changes in freshwater flow regimes that affect the productivity of coastal waters, nutrient enrichment and consequent anoxia and harmful algal blooms, coastal habitat destruction—all these affect the harvestable resource (16). More recently, the role of climate change in fisheries sustainability has also received considerable attention (e.g., ref. 17). The fact remains that fishing itself is usually the principle human driver of stock status for marine fisheries. Thus, improving the governance and management of fisheries exploitation is the principle means for securing these fisheries contributions to food security.

In contrast to marine fisheries it is external environmental pressures that normally represent the greatest threat in freshwater (18). This is especially true for river fisheries, which contribute more than half of the total inland catch. Dam construction, land-use changes, water abstraction, pollution, urbanization, and several other external drivers pose significant threats to major river fisheries throughout the world, suggesting the need for alternative kinds of research to inform policy (see below).

Notwithstanding the inevitable uncertainties in the status and trends of both marine and freshwater fisheries, few doubt that we are at, or close to, the limits of what natural systems can provide (11). Although improved fisheries and environmental management could increase yields to some degree (19–21), and despite the considerable prospects for avoiding spoilage and waste of the landed catch in many fisheries (22), any such increase in supply will be outstripped by increasing global demand (23).

Yet, although there may be relatively limited prospect for increasing wild fish catches, ensuring the long-term resource sustainability remains vital. Balanced against this, however, is the fact that hunting in the world's aquatic wildernesses generates societal concerns about the ecological effects of fishing—concerns that extend beyond issues of resource sustainability to encompass more fundamental nature conservation considerations.

Fishing, Nature Conservation, and Human Well-Being. For fisheries, concern about overfishing and its ecological costs dominate the popular press and public discourse; the more utilitarian concern of meeting human needs (or demands) for fish as food is less prominent. Similarly, in the scientific literature the fulcrum of debate lies between fisheries science and resource exploitation on one side and conservation science and wildlife preservation

and environmental values on the other. As a result, scientific debate is dominated by questions of whether or how data show that no-take marine protected areas help restore fisheries (e.g., ref. 24), particular fish stocks or bycatch species are destined for extirpation (e.g., ref. 25), or ecosystems are disintegrating as a result of our actions (e.g., ref. 26). These ecological sustainability concerns have recently been augmented by concerns over economic sustainability, with an emphasis on improving aggregate economic performance withdrawing subsidies, reducing excess catching capacity, and seeking to maximize resource rents (27).

In contrast, there is relatively little analysis of fisheries as a food supply system and the quantitative links between this and human well-being. Thus, in building the metaphorical "three pillars" of sustainable development (28), fisheries science and management has devoted most effort to the environmental, is currently attending to the economic, but largely neglects the social.

This omission is both surprising and puzzling. Surprising because, with few minor exceptions, the ultimate rationale for all fishing is to provide food. Puzzling, because it is difficult to explain why, given its instrumental value as a food source, efforts to understand the ecological relationships between fishing and ecosystems dwarf investment in understanding its interactions with socioeconomic systems generally and food systems in particular.

Even within socioeconomics, most fisheries analyses concern economic efficiencies, with very little linked explicitly to questions of food supply, food and nutrition security, or human welfare and social justice (29, 30). However, given the well-documented complexity of the links between food production, availability, entitlement, and access (31), these are surely also essential areas of inquiry; to pursue them, however, we must ask more specific questions on how food security (among other) benefits from fisheries might be derived and how these might be equitably distributed (4, 30).

For small-scale fisheries, for example, we need to ask when their primary function should be providing healthy, nutritious, and affordable food to those most in need of it, and who have least access to alternatives? We must also to ask whether and how best they can provide a source of livelihood to the landless rural poor, or a "safety net" income for those experiencing temporary or seasonal hunger or unemployment. Most of the 45 million or so people engaged directly in fishing are part-time fishers, and a further 6 million are estimated as occasional fishers or farmers (32). This makes fishing part of a highly diversified livelihood strategy for many—a reality often ignored in policy development.

This failure to better frame the fisheries discourse, and to integrate it with that on food security and livelihoods, is also highly problematic because it narrows the ethical dimensions of the debate. Public policy must balance and reconcile societal values and ethics, and achieving this balance requires us to lay out clearly the full panoply of issues—something that, with respect to the food provision and livelihood dimensions of fisheries, we often fail to do. This failure occurs for two reasons.

First, fisheries science, management, and development agendas have been driven by the concerns and viewpoints of its most powerful actors—governments of wealthy nations, major fishing companies and seafood buyers, international conservation organizations, and global and regional finance institutions (33). Food and livelihood security of the poor have been, until recently, minor concerns in this skewed vision of fisheries, which either excludes or misunderstands the "tropical majority" (34) or considers only the ecological threat and economic inefficiencies generated by their attempts to secure food and livelihood from open-access or poorly regulated fisheries.

Even the current advocacy of rights-based approaches remains partial in its vision. Leaving aside the potential for powerful actors to secure rights at the expense of the weak, there is no doubt that resource tenure and access rights are an essential element influencing livelihood security for fishers. However, approaches to fishery governance that only consider fishing rights when thinking about the development needs of the fishery sector may be ineffective if not combined with measures to address other, sometimes more fundamental, causes of livelihood insecurity (30).

Second, fisheries policy generally emerges from processes that are uninformed by explicit ethical description and analysis. There are some signs of growing interest by ethicists in using tools that make the societal debate on the ethical issues surrounding fisheries more inclusive and explicit (35), but they remain nascent. Such approaches, however, have the potential to surface more effectively, and resolve more equitably, for example, the many conflicts of interest between fishery types operating in the same water body (e.g., between large- and small-scale operators in coastal inshore waters).

Where to from Here? Nearly a decade ago, the World Summit on Sustainable Development called for rebuilding all exploited fish stocks to maximum sustainable yield by 2015 and for the creation of representative networks of marine protected areas by 2012 (36). These declarations indicate the international preoccupation with a largely resource management focus to fisheries. More recently, concerns to maximize the aggregate economic benefits of fisheries have also come to the fore, leading to emphasis on strengthening exclusive fishing rights, withdrawing subsidies, and enabling access to global markets (e.g., ref. 27).

Laudable and important as the commitments to improve resource management and economic efficiency are, however, the absence of concomitant development and food security focused goals for fisheries is disturbing at best. There is a strong case for including them and being more explicit in asking how we might better use fisheries to improve food security and reduce poverty. In doing so we need to ask what the implications are for reforms aimed at moving fish harvesting patterns toward higher sustainable yields or greater economic efficiency (29).

In several high-level documents, there is clear acknowledgment of this need. The New Partnership for Africa's Development Action Plan on Fisheries, for example, includes recommendations to strengthen consideration of inland, coastal, and marine fisheries "…in national and regional policies and actions on food security" (37). Such goals are, perhaps, especially relevant to the small-scale fisheries of developing countries upon which so many of the vulnerable depend.

However, agreeing on high-level goals is relatively easy; it is implementation that poses the greatest challenge, especially when the nature of the problem is highly context specific. Deciding how best to make the most of an inshore canoe fishery that spans 500 miles of remote coast and serves both local consumers and a regional trade will be quite different from deciding how to manage a lake fishery that dries out periodically, shows natural boom and bust cycles of fish productivity, and meets the needs of a wide range of part-time fishers, many of whom migrate to the region for the boom periods. Range these two examples against the, perhaps, simpler challenges posed by a large-scale offshore fishery with relatively few boats, all of which land in one of a few ports to provide cheap fish for urban markets, and one begins to appreciate the singularity of circumstance.

Even when the broad features of the ecology and economy of a fishery are homogeneous, other particularities can apply. For example, in the recently gazetted Draft Small-scale Fishing Policy in South Africa (38), which focuses on assigning rights and management responsibilities to defined community-based entities, consultations among stakeholders revealed that, although this sits well with the rural coastal villages of the Eastern Cape, it sits poorly with fishers in the Western Cape and the Cape Town metropole. This is because, in these latter areas, small-scale fishers often reside far from their operating ports, and their social

networks are not geographically bounded in ways that make the notion of a spatially constrained community workable (38).

To these complexities one must also add the wider political context of a fishery, in particular the breadth of the political power structure and the extent of public accountability. When poorly accountable elites dominate (who themselves may have insecure positions), incentives for them to promote, support, or care about fisheries reform to meet food security and development objectives for the populace will be weak (39).

Such high levels of context specificity are powerfully illustrated by the compendium of case studies on small-scale fisheries described in ref. 40, leading Jentoft et al. (41) to argue for a "dexterity principle" that demands sensitivity to the details that differ from one place to another. In a related vein we offer four key, mutually reinforcing, principles for how development agencies and other stakeholders might best navigate through the challenge of fisheries reform and partner with governments in helping their fisheries support food security objectives.

The first is to promote and support mechanisms that devolve responsibility for management and decision making to those for whom incentives to meet broader societal objectives are greatest. In well-functioning democracies this might legitimately remain with central government, whereas in many developing country contexts decentralization to regional or local government or community will often be best. [Arguing in a similar vein, Jentoft et al. (41) call for the same thing, calling it a subsidiarity principle.]

In advocating such a principle, however, we reiterate that context is everything and that local-level collusion among political or traditional authority elites can critically undermine the effectiveness of such decentralization (42). The key point here is the value of supporting formal analysis of incentive structures and institutional relationships to help decide on the appropriate level, rather than doctrinaire adoption of a particular decentralization model.

Particularly for reforms that require some form of devolution, one must also recognize that parallel efforts to build the requisite capacities and competencies among stakeholders will also be needed. Often this will need addressing first, before fisheries reforms are attempted. When literacy, empowerment, agency, and roles are weak among key constituencies, the prospects for achieving sound and durable reform are poor. Too often decentralization efforts have foundered because of failure to accept this (42).

Our second principle is to ensure there is effective and inclusive stakeholder dialogue over the goals of any fisheries reform, as well over as the policies for implementation. We use the term "dialogue" deliberately to invoke the need for genuine conversation directed toward collaborative exploration and resolution of problems. Although achieving such dialogue will often be difficult and demanding, efforts to do so will substantially increase the probability of successful outcomes. Too often policy development includes a "consultation" process structured to legitimize and adapt a preselected technical solution to a preconceived and poorly, or narrowly, specified problem—an approach that offers limited opportunity for the kind of interaction that genuine dialogue connotes. An excellent account of how effectively structured dialogue can help successfully reform a politically contentious developing country fishery is provided by Ratner et al. (43).

Such quality dialogue will be especially important for elevating food security considerations. When stakeholder concerns rest with feeding one's family adequately, or maintaining an option of fishing to cope with periodic food shortage or economic downturn, the parameters of the ethical debate around fisheries alter substantially. We do well to remember that such conditions prevail in many fishery systems and that giving voice to those whose well-being is most affected will help ensure that such benefits are not lost in a reform process.

Our third principle is to complement the usual fisheries resource data that inform policy dialogue with data on the patterns and dynamics of fish trade and end user consumption. To develop effective policies to increase fisheries' contributions to food and nutrition security, we must understand the fate of fish once they are landed. As noted above, it is not just fish production (landings) that matters. Failures of access and entitlement, and their consequences for health and well-being, especially by vulnerable groups (e.g., young children and pregnant or lactating mothers), must also be addressed. Dealing with these issues will require a much better appreciation of fish value chain structures and dynamics and the drivers of behavior by poor consumers. Recent work on the development of "nutrition sensitive value chain analysis" offers a valuable example of the direction that research in this area needs to take (44).

Our final principle is this: develop and support multisectoral perspectives and approaches. Decisions and external drivers associated with several other sectors have the potential to profoundly affect fisheries resource sustainability and the well-being of those who depend on them. In many settings immediate next steps toward solving "the fisheries problem" may lie outside of fisheries. As noted earlier, for example, addressing issues of stakeholder literacy and agency may be essential if decentralization efforts are to work. Similarly, issues relating to public health and security, local governance, social safety nets, or other broader rural development foci may be key blockers of reform efforts and need to be prioritized first. Addressing these considerations demands that we incorporate fisheries issues into the broader rural development policy dialogues and processes and that rural development considerations are factored into fisheries policy.

In essence, what we advocate is the further development of a "sustainability science" (45) in support of fisheries policy and governance reform. In its early evolution sustainability science was framed as a means to broadly apply science and technology to better meet sustainable development needs, as articulated in the Rio and Johannesburg World Summits (45). More recent articulation of sustainability science, however, indicates a greater concern for environment than for development, with a core research agenda to understand the structures and processes that shape human–environment interactions (46).

Indeed, although this journal, in particular, has highlighted the application of sustainability science to pressing social problems such as, for example, climate change vulnerability and adaptation (47), poverty reduction (48), and marine conservation (49), most of these analyses draw from the natural sciences and certain branches of economic thought (institutional economics, welfare economics).

Our analysis suggests a need to more explicitly consider the role of power in shaping the way markets work (and for whom) and the way science informs policy. In other words, we believe that if sustainability science is to chart an effective course toward both present-day and intergenerational justice, it needs to engage more effectively with political economy and moral philosophy. The participatory action research paradigm (50, 51) perhaps offers a valuable guidepost for how research efforts needs to evolve to engage those who are currently marginalized in both fisheries policy and fisheries science.

In this article we have shown that, for countries most dependent on fish to meet the nutritional requirements of their population, wild capture fisheries remain the dominant source of supply. Although, contrary to popular narratives, the sustainability of these fisheries is not always and everywhere in crisis, securing their sustainability—ecological, economic, and social—remains essential. In the short to medium term there is no prospect that increased aquaculture production can compensate for failing fisheries in these countries.

We then examined two strands of fisheries discourse: one that focuses on resource sustainability and environmental issues, the

other related to food security and human well-being. We argue that published research and policy debate on these issues are, for the most part, running on independent tracks, with only loose and superficial links between them. Although considering them together undoubtedly introduces inconvenient complexity for both researchers and policy makers, we believe that embracing this complexity is essential if durable solutions for fisheries are to be found. Protecting the environment and ensuring human well-being are intimately interlinked goals that can only be achieved by treating them within the same framework. We hope that this article has helped illustrate why this is so and stimulates debate on how best to proceed.

Methods

All data used in these analyses were sourced from publicly accessible datasets (see figure legends). We used 2007 data because this was the most recent year for which data on both consumption and production were available.

For our metric of nutritional dependence on fish we used protein consumption as a proxy for nutrition and used the ratio of fish protein to total animal protein, expressed as a percentage. Animal protein was chosen over total dietary protein as the denominator because there is good evidence that the micronutrient contributions of animal source foods (minerals, vitamins, essential amino acids, etc.) are especially important. Thus, even if eaten in small absolute quantities, animal source foods make a significant contribution to nutrition (52, 53).

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