Global Environmental Change 47 (2017) 167–173

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Perspective

Inland fisheries – Invisible but integral to the UN Sustainable Development Agenda for ending poverty by 2030

A.J. Lynch[a,*], I.G. Cowx[b], E. Fluet-Chouinard[c], S.M. Glaser[d], S.C. Phang[e], T.D. Beard[a], S.D. Bower[f], J.L. Brooks[f], D.B. Bunnell[g], J.E. Claussen[h], S.J. Cooke[f], Y.-C. Kao[i], K. Lorenzen[j], B.J.E. Myers[a], A.J. Reid[f], J.J. Taylor[f], S. Youn[i,1]

[a] U.S. Geological Survey, National Climate Change and Wildlife Science Center, 12201 Sunrise Valley Drive, MS-516, Reston, VA 20192, USA
[b] Hull International Fisheries Institute, University of Hull, Hull HU6 7RX, United Kingdom
[c] Center for Limnology, University of Wisconsin-Madison, 680 North Park St., Madison, WI 53706, USA
[d] Secure Fisheries program, One Earth Future, 525 Zang Street Suite A, Broomfield, CO 80021, USA
[e] Department of Evolution, Ecology and Organismal Biology, The Ohio State University, 318 West 12th Avenue, Columbus, OH 43210, USA
[f] Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental Sciences, Carleton University, 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada
[g] U.S. Geological Survey, Great Lakes Science Center, 1451 Green Road, Ann Arbor, MI 48105, USA
[h] Illinois Natural History Survey, 1816 S. Oak Street, Champaign, IL 61820, USA
[i] Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, 1405 South Harrison Road, Suite 115 Manly Miles Building, East Lansing, MI 48823, USA
[j] Fisheries and Aquatic Sciences, School of Forest Resources & Conservation, University of Florida, 7922 NW 71st Street, Gainesville, FL 32653, USA

ARTICLE INFO

Keywords:
Inland fisheries
Livelihoods
Poverty
Sustainable Development Goals

ABSTRACT

The United Nations' (UN) 2030 Agenda for Sustainable Development defines the formidable challenge of integrating historically separate economic, social, and environmental goals into a unified 'plan of action for people, planet, and prosperity.' We highlight the substantial contribution inland fisheries can make towards preventing increased poverty and, in some cases, alleviating poverty (i.e. addressing Sustainable Development Goal [SDG] 1: No Poverty) as an opportunity to inform the next set of development agendas and their associated budgets and priorities. Overlooking the contribution of inland fisheries to poverty prevention and alleviation may undermine the capacity to successfully meet the development goals, especially in rural communities in Low-Income Food-Deficit countries. Inland fisheries are essential for food and economic security as the vast majority are small-scale operations or subsistence, predominantly used by poorer groups. Protecting inland fisheries from diverse threats from other water users and associated sectors requires robust, multi-sectoral, and multinational policies that can be brought about by global initiatives like the SDGs. Without such protection, their vital contribution towards sustainable livelihoods and poverty issues becomes uncertain. Further, integrating inland fisheries into sustainable development frameworks strengthens the likelihood of achieving the UN Agenda for Sustainable Development. In this perspective article, we posit that including inland fisheries in national policy statements and programs can prove beneficial to promoting economic and social growth for the poor, preventing further poverty, and achieving SDG 1 and other SDG targets, especially those related to food security.

1. Introduction

The United Nations' (UN) 2030 Agenda for Sustainable Development tackles the formidable challenge of integrating historically separate economic, social, and environmental goals into a unified 'plan of action for people, planet, and prosperity' (UN, 2015). The effort to consider all factors necessary to achieve the Sustainable Development Goals (SDGs) is understandably a daunting task. We

* Corresponding author.
E-mail addresses: ajlynch@usgs.gov (A.J. Lynch), i.g.cowx@hull.ac.uk (I.G. Cowx), fluetchouina@wisc.edu (E. Fluet-Chouinard), sglaser@securefisheries.org (S.M. Glaser), phang.6@osu.edu (S.C. Phang), dbeard@usgs.gov (T.D. Beard), shannondbower@gmail.com (S.D. Bower), jillbrooks85@gmail.com (J.L. Brooks), dbunnell@usgs.gov (D.B. Bunnell), juliec@illinois.edu (J.E. Claussen), StevenCooke@cunet.carleton.ca (S.J. Cooke), kaoyc@msu.edu (Y.-C. Kao), klorenzen@ufl.edu (K. Lorenzen), bjmyers@usgs.gov (B.J.E. Myers), andreajane.reid@carleton.ca (A.J. Reid), jessjtaylor16@gmail.com (J.J. Taylor), younsoju@msu.edu (S. Youn).
[1] Second through fifth authors contributed equally to this work and are listed alphabetically. The twelve subsequent authors contributed equally to this work and are listed alphabetically.

https://doi.org/10.1016/j.gloenvcha.2017.10.005
Received 29 March 2017; Received in revised form 18 October 2017; Accepted 20 October 2017
Available online 09 November 2017
0959-3780/

highlight the substantial contribution inland fisheries make to livelihoods and emphasize their potential for preventing increased levels of poverty (i.e., addressing SDG 1 [No Poverty]). Through this perspective article, not a traditional research article, we seek to add to the established work on the contribution of inland fisheries to other SDGs (e.g., SDG 2 [No Hunger]; see Béné et al., 2016) and the Millennium Development Goals before them (see Heck et al., 2007) and inform ongoing discussions to implement the SDGs and the associated next round of development agendas. Overlooking inland fisheries in sustainable development planning may pose a serious risk to the services they provide and diminishes capacity to make progress towards SDG 1, which is scheduled for review by the UN High-Level Political Forum in 2017.

'Inland fisheries' refers to the harvesting of aquatic organisms from inland waters, lakes, rivers, streams, canals, reservoirs, and other landlocked waters (FAO, 2014). While inland fisheries alone will not eradicate poverty, they can play an integral role in multi-dimensional efforts to alleviate poverty and prevent further poverty escalation. Inland fisheries are typically perceived and managed as a common pool resource, with ease of access and low barriers to entry facilitating their utilization by poor communities (Béné et al., 2010; Béné and Friend, 2009). Individuals can relatively easily begin fishing because basic equipment needs (e.g., nets, hooks, traps) are generally inexpensive and do not require substantial skill to operate or maintain. Despite being 'low-tech,' and inexpensive, these approaches can be highly effective at catching large amounts of fish and are used extensively in inland fisheries around the globe (Welcomme et al., 2010). Ephemeral exploitation of inland aquatic resources can provide a 'safety net' in times of stress for transitional, vulnerable cohorts that fall into poverty (e.g., from economic displacement or market collapse; Béné et al., 2007). However, despite the perception of being a 'poverty trap' (see Béné, 2003), well-managed inland fisheries can also contribute to poverty alleviation and income growth (Campos-Silva and Peres, 2016; Eggert et al., 2015; Smith et al., 2005). This multifaceted contribution at different socioeconomic levels strengthens the impact of inland fisheries to society and compounds the need to protect them.

2. Drivers of poverty and unsustainable inland fisheries

Poverty is driven by a range of complex political, cultural, environmental, and economic factors (see Hulme et al., 2001), and these factors shape the links between poverty and inland fisheries (Fig. 1).

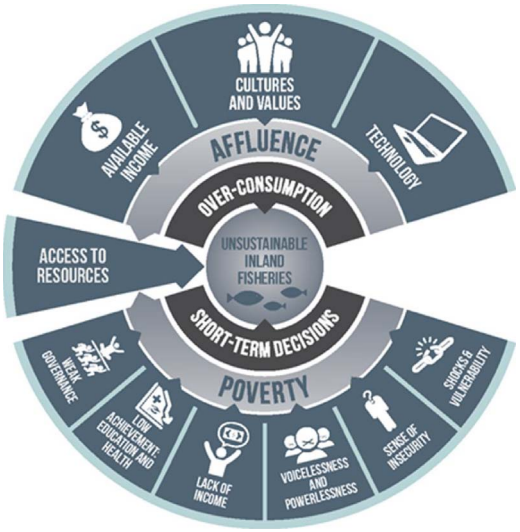

Fig. 1. Characteristics of affluence and poverty (*outer ring*) can lead to unsustainable choices (*inner ring*). When coupled with access to resources, affluence can lead to over-consumption and poverty can lead to short-term decisions that result in unsustainable practices for inland fisheries.

Sustainability of inland fisheries is challenged by heavy exploitation driven by demand for fishery products from both poor and affluent populations (Allan et al., 2005), as well as external water resource users (Welcomme et al., 2010). The poor face inadequate education and health facilities, vulnerability to economic shocks, and ineffective governance structures, problems exacerbated by limited technical capacity and access (Lélé, 1991). This scenario often leads to short-term, unsustainable decision making. The affluent, with greater access to finance and advanced technologies, can drive demand for products that contribute to the over-consumption and degradation of inland fisheries. Furthermore, the affluent are often geographically or socio-economically removed from the place of exploitation and less aware of or vested in the health of the resource (Parikh, 1996).

In both cases, the costs of unsustainable fisheries harvest are borne primarily by poorer, more vulnerable populations that rely on inland fisheries for their livelihoods and nutrition (Béné, 2006; Béné et al., 2010; Smith et al., 2005; Youn et al., 2014). These impacts reduce resilience of the poor and exacerbate poverty. Rural poor communities are hit hardest because of limited access to alternative natural resources, employment opportunities, and basic infrastructure (e.g., electricity, sanitation, health clinics; Cowx et al., 2004).

3. Inland fisheries' role in addressing vulnerability to poverty

We highlight the growing evidence that inland fisheries have disproportionate importance for impoverished countries (Fig. 2). The paucity of data presents a major challenge to evidencing the role of inland fisheries; not because inland fisheries do not contribute, but rather, because their contributions are not easily quantifiable (Lorenzen et al., 2016). Inland fisheries resources are often taken for granted (e.g., as an assumed immediate food source following a disaster; see Westlund et al., 2007). The highly dispersed nature of these fisheries means assessment is not common in poor regions and the status of the resources is often unknown. Where data do exist (e.g., Lake Victoria: Mkumbo and Marshall, 2015; Mekong River: Nam et al., 2015), we observe clear contribution from inland fisheries to SDG 1 relevant targets like resilient livelihoods, gender, governance, and addressing global poverty (see Table 1). For example, women typically occupy half (sometimes much more) of the workforce associated with all fish harvest and post-harvest subsectors (de Graaf and Garabaldi, 2014; World Bank, 2012; Fig. 2-**Africa inset**). Ignoring or overlooking the role of inland fisheries in development agendas misses an important mechanism for achieving progress towards SDG 1 (Cooke et al., 2016).

A majority of people who live on less than US$2 per day reside in Low-Income Food-Deficit (LIFD) countries; this group is targeted by SDG 1 for poverty reduction efforts. Many of these countries are located in Sub-Saharan Africa and Southern Asia where inland fisheries play essential roles in food and economic security because reliance on them is greater among poorer groups (Kapetsky, 2003). The percentage of the population engaged in inland fisheries and their per capita fish catch tend to be higher in countries with a per capita income below the US$2 per day poverty threshold (Fig. 2-**Map**). In Asian countries, fish make up a larger proportion of household expenditures in low income households (e.g., Dey et al., 2005; Fig. 2-**Asia inset**). In more developed countries, a transition from food-based (subsistence) fisheries towards recreational fisheries has altered the contribution of inland fisheries to rural economies and livelihood opportunities (Arlinghaus et al., 2016). A similar transition in the developing world can bolster progress on SDG targets (it is already occurring across large parts of South America: see Freire et al., 2012 and southern Africa: see Potts et al., 2009). Overlooking the role and contribution of inland fisheries to reducing poverty (both prevention of further poverty escalation and promotion of economic and social growth) may make reaching that goal even more challenging, particularly in LIFD countries.

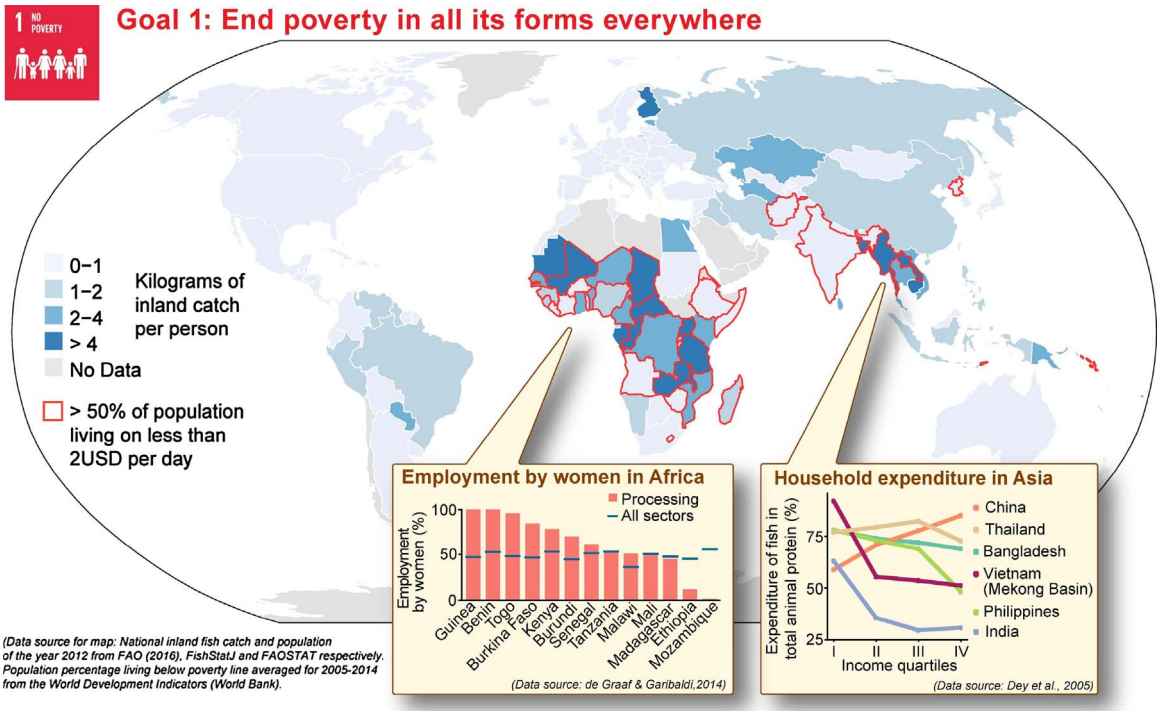

Fig. 2. ***(Map)*** Global overlap of inland fish harvest per capita and poverty prevalence by country averaged for the period 2005–2014. Countries with high inland fisheries catch and large fraction of the population under the international poverty line coincide in Africa and Asia. ***Africa inset:*** Employment in post-harvest processing of inland fisheries in many African countries is occupied by women at a higher rate than in the labor force in general. ***Asia inset:*** Apart from China and Thailand, among countries shown, lower income households spend more of their budget for animal protein on fish than do higher income households. Household expenditure presented includes all fish sources (inland, aquaculture, marine) as data on inland fish consumption and contribution to poverty alleviation are sparse and often cannot be separated from other sources, particularly aquaculture production.

4. Inland fisheries' role in resilient livelihoods

The contribution of inland fisheries to resilient livelihoods, those which are buffered against difficult situations, is multifaceted and, consequently, difficult to evaluate (Smith et al., 2005). Inland fisheries in LIFD countries are often part of a diversified livelihood strategy (Allison and Ellis, 2001; Martin et al., 2013; Nasielski et al., 2016), exacerbating the tendency for them to be overlooked and undervalued (Cooke et al., 2016; Welcomme, 2011). Preserving inland fisheries means protecting their role as a livelihood buffer for the poor who are already challenged by fewer resources and capital to absorb variability in income or cope with external economic shocks (see Table 1).

Prioritizing conservation and sustainable use of inland fisheries and protection of their environment can prevent further poverty escalation and promote economic and social growth. For example, fishing in the Lower Mekong Basin, the largest inland fishery in the world, buffers

Table 1
Examples of inland fisheries contributions to Sustainable Development Goal 1–No Poverty targets (FAO, 2011, 2014; Béné et al., 2007, 2010; Béné, 2006; Turpie et al., 1999; Kolding and van Zwieten, 2011; World Bank, 2012; Medard et al., 2001; Geheb et al., 2008; Lynch et al., 2016a,b; Martin et al., 2013; Nasielski et al., 2016).

Poverty Reduction & Prevention (SDG target 1.1)	Improved Governance (SDG targets 1.A&B)
Income from inland fisheries: • Low-Income Food-Deficit countries account for 38% of reported inland fisheries harvest (FAO 2011). • Inland fisheries contribute to local economies through income and employment multiplier effects (Béné et al., 2007) and can be considered a "bank in the water" (Béné, 2006). • Inland fishing can play a critical role in cash generation (e.g., Turpie et al. 1999), particularly when other income generating activities fail (Kolding and van Zwieten, 2011).	**Governance strategies can address broader issues of fisheries and other water uses:** • Inland fisheries generate income and contribute to local economic growth given the right governance context (Béné et al., 2010). • Interjurisdictional fisheries, in some cases, can lead to improved cooperation and governance (Lynch et al., 2016b). • Competing water uses often lead to policy trade-offs impacting inland fisheries (Lynch et al., 2016a).
Fish and Gender (SDG target 1.2)	**Resilient Livelihoods (SDG target 1.5)**
Women constitute a large fraction of inland fish workers (e.g., harvest, trade, or processing): • Woment typically occupy half of the harvest and post-harvest workforce (World Bank, 2012), and in regions such as Lake Victoria, greater than 70% (Medard et al., 2001). • Selling fish can provide extra income and offset other household needs, such as childcare, because selling fish can be done outside the home (Geheb et al., 2008).	**Inland fisheries serve as primary and secondary employment:** • >21 million people are reported to engage in inland fisheries and >36 million in post-harvest as primary employment (FAO, 2014). • Inland fisheries as a sole livelihood is rare and is often associated with high occupational diversity (Martin et al., 2013). Households engaging in fishing often do not report it as an occupation (e.g., Nasielski et al., 2016).

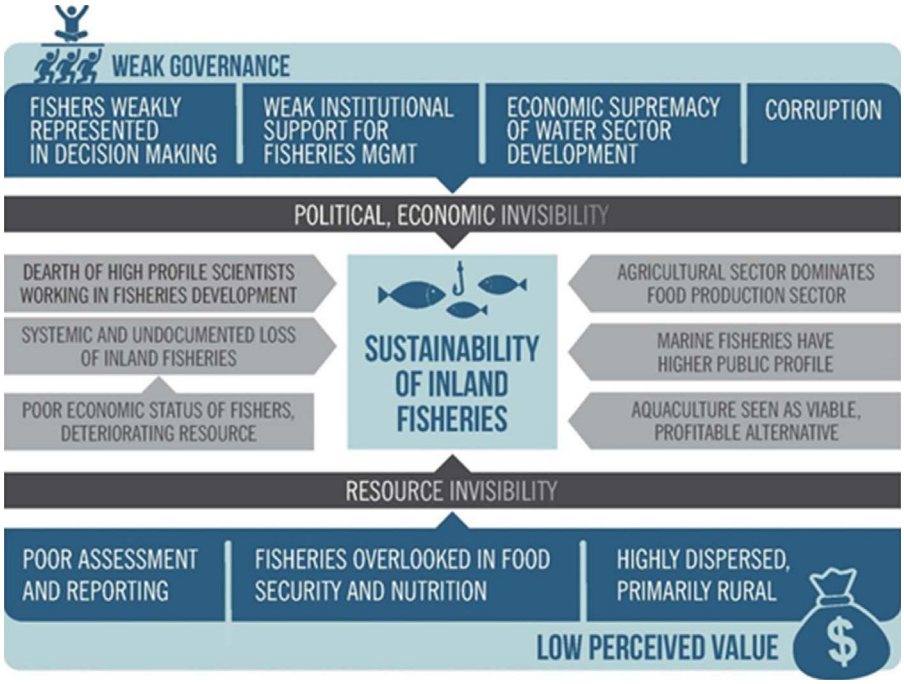

Fig. 3. Conceptual model of issues affecting inland fisheries sustainability. The discrete and external factors contribute to a visibility problem which impacts the sustainability of inland fisheries. Weak governance and institutions make inland fisheries invisible to political and economic projects. Low perceived value of inland fisheries make them invisible to many sustainable development agendas.

poverty escalation by generating US$11 billion (Nam et al., 2015). Inland fisheries also provide food security, nutrition, and livelihoods for more than 60 million people in the basin (Orr et al., 2012). Reliance on fish for food in this region is amongst the highest in the world at an estimated 43–75 kg/person/year (Hortle, 2007). However, these fisheries are under considerable threat from external pressures, such as hydropower and agricultural development (Coates et al., 2003). Up to 50% of the annual fisheries yield could be compromised if uncontrolled development continues in the basin (DHI and HDR, 2015). Replacing this lost food base may lead to further degradation of the river environment already stressed by external pressures and may intensify poverty. For supplementary case studies of inland fisheries and resilient livelihoods, please visit the interactive map at http://infish.org/sdg-storymap/.

5. Sustaining inland fisheries

Preserving resilient inland fisheries livelihoods requires ecosystems resilient to development, climate change, and other external perturbations, plus the sustainable exploitation of their resources. This approach necessitates an ecosystem perspective to management that integrates fish habitat, water quantity and quality, and the impacts of harvest (Beard et al., 2011). Freshwater ecosystems support approximately 42% of all known fish species, yet they are among the most threatened ecosystems in the world (Vörösmarty et al., 2010). Over 90% of the reported global riverine fish catch comes from highly stressed river basins (McIntyre et al., 2016).

Threats ranging from human population growth to changes in water regimes, including less predictable precipitation patterns, flooding extent, and dry season flows, pose a great risk to inland fish habitat and inland fisheries production (Dudgeon et al., 2006). These risks are further amplified by other water users, such as the agricultural sector, which can abstract surface water for irrigation and create levees or other flood-control structures that may obstruct fish spawning migrations (Agostinho et al., 2008; Marmulla, 2001; Nguyen Khoa et al., 2005; Welcomme et al., 2010). The challenges facing inland fisheries are more complex than in marine systems, where the dominant impacts are principally driven by fisheries exploitation and require global-level, multi-sectoral policy initiatives, like the SDGs, for effective management (Cooke et al., 2014).

Conflict in management can arise between conserving freshwater fish biodiversity and promoting inland fishery production. Balancing inherently exploitative fisheries with preservation of biodiversity and habitat for long-term fisheries production is a serious challenge. Fishers are often keenly aware of the negative impacts of fishing, but given their reliance, and a lack of alternatives, they are often left with few options other than continued fishing (for Chinese example, see Xu and Zhang, 2013). Faced with immediate food insecurity, fishers often favor short-term gains rather than long-term sustainability (Fiorella et al., 2014). Indeed, the complex interplay between poverty and fishery exploitation must be considered within the frame of local, regional, and even global socio-economics and trade (Smith et al., 2005).

The diffuse nature of inland fisheries makes centralized management and enforcement difficult; as a result, local community and co-management are common strategies (Almeida et al., 2009; Castro de and McGrath, 2003; Garaway et al., 2006). Active management of inland fisheries through regulation of fishing and/or technical interventions, such as habitat restoration or stocking of hatchery-reared fish, can increase productivity and sustainability (Almeida et al., 2009; Amilhat et al., 2009; Lorenzen, 2014), yield substantial socio-economic benefits, and contribute to poverty alleviation (Campos-Silva and Peres, 2016; Eggert et al., 2015; Garaway et al., 2006). However, active management is not always realistic, or even desirable, where open access is crucial to sustaining people suffering from abject poverty (Kolding and van Zwieten, 2011; Smith et al., 2005).

Despite their value, inland fisheries are mostly neglected in governance processes (Fig. 3). They face political and economic isolation and invisibility, caused by governance in which fishers are weakly represented in decision making, there is little institutional support for fisheries management, other water users take precedence, and there is widespread mismanagement of resources (erring on corruption). The dispersed, rural nature of most inland fisheries means they are often overlooked in food security and nutrition discussions (Cooke et al., 2016). Invisibility is perpetuated because there is a systematic and undocumented loss of inland fisheries, the field has not received adequate academic interest, and fishers tend to have a poor economic status. These factors are compounded by agriculture being the dominant food production sector, marine fisheries having a higher public

profile, and aquaculture seen as a viable, profitable substitute. However, these sectors are not appropriate alternatives for many inland fishers given that agricultural products do not provide the same micronutrients, marine fisheries are not accessible to most inland fishers, and aquaculture is not often a feasible alternative livelihood.

We suggest that global development agendas can play an essential role in directing governance to consider the wider welfare impacts of inland fisheries. By devising poverty alleviation plans that integrate aquatic ecosystems effects and management plans that consider fishing access and extraction, governance strategies can address the broader issues impacting inland fisheries. Reliable technical guidance exists for approaches to conserve, restore, and enhance fisheries under the influence of competing uses of land and water resources, such as irrigated agriculture, hydropower development, and urbanization (Cowx and Welcomme, 1998; Lorenzen et al., 2007; Marmulla, 2001).

6. Potential and limits of aquaculture

Aquaculture is often cited as way of increasing inland fisheries production and possibly substituting for capture fisheries production and livelihoods as wild harvest declines. Indeed, aquaculture can play a key role in reducing global poverty and improving resilience (Toufique and Belton, 2014). Over 18 million people – 33% of all people involved in fish production worldwide – were engaged in aquaculture in 2014 and, by 2025, fish from aquaculture farms will represent 52% of all fisheries production; of that, 60% of aquaculture production will be freshwater species (e.g., carp, catfish, tilapia, trout) and 95% will be produced in developing countries (FAO, 2016). Some forms of aquaculture can be closely integrated with capture fisheries in fisheries enhancement or capture-based aquaculture (Amilhat et al., 2009; Lorenzen, 2014). But, while aquaculture production has increased fish supply and dampened increases in relative fish prices and volatility, access to fish by poor consumers has not necessarily risen (Beveridge et al., 2013). Furthermore, aquaculture can be capital intensive (e.g., feed and seed are not negligible expenses) and exclude poorer sectors of society (Lynch et al., 2016a). Additionally, in cases where high-value piscivorous fish are cultured and their feed requires fish from capture harvest, inland aquaculture may not add to the overall availability of fish protein (Tacon and Metian, 2008) but redirect protein that would traditionally be consumed by the rural poor into fish feed.

The evidence linking aquaculture to poverty reduction, consequently, is mixed. In developing countries, aquaculture is one option from a relatively limited pool of economic opportunities, and it can serve as both a subsistence and cash crop (Bostock et al., 2010; Brummett et al., 2008). Small-scale aquaculture can provide viable alternatives to land-based farming to increase household income and typically offers higher return than alternative agriculture activities (e.g., Ahmed and Lorica, 2002; Toufique and Belton, 2014). While intensive aquaculture of some species (e.g., *Pangasius* catfish) can have transformational impacts on household income, commercial aquaculture development can disproportionately exclude poorer fish farmers (Lynch et al., 2016a). Rural fish farmers have difficulty accessing the necessary resources and training, while wealthier farmers in the rural-urban transition zone have greater access to feed, fish stocks, credit sources, information, and ownership or rental of land and water resources (Béné et al., 2016).

Increasing vertical market integration and consolidation of aquaculture investment and profits generally exclude the poor (Béné et al., 2016). Power asymmetries in the value chain mean small-scale producers, fishers and fish farmers alike, often receive less benefit than other actors in the value chain. Increasingly, lower value freshwater aquaculture products are entering export markets (e.g., tilapia and *Pangasius*; Asche et al., 2009). While they may contribute to national GDP and export earnings of the exporting country, the increasing supply of relatively inexpensive farmed fish (e.g., tilapia from China) may decrease the profitability of local aquaculture efforts and even depress prices of inland fishery products in importing countries, further stressing the livelihoods of poor inland fishing communities (Béné et al., 2016).

7. Conclusion

The role of inland fisheries in meeting challenges faced by individuals, society, and the environment is often underappreciated or ignored despite its importance (Lynch et al., 2016b). Inland fisheries can be a significant contributor to poverty alleviation and prevention of poverty escalation, where they are a primary livelihood, a secondary livelihood, or even as a subsistence source of nutrition (e.g., Martin et al., 2013; Musumali et al., 2009). In many cases, food, income, and livelihoods provided by inland fisheries cannot be easily replaced by alternatives. For both capture fishers and fish farmers, training and capital investments are often cost-prohibitive for many to transition successfully to alternative livelihoods (Smith et al., 2005), and may result in increased levels of poverty if aquatic resources are degraded.

The omission of inland fisheries from the SDGs illustrates how their value has yet to be recognized and underlines the need to raise their importance in policy discussions and decisions. Furthermore, the challenges facing inland fisheries are sufficiently different from marine fisheries and require distinction. Visible and impactful marine initiatives (e.g., the Global Ocean Commission, Our Ocean, Sea Around Us) have increased awareness, political will, and funding for marine issues, while a noted lack of similar initiatives exist for inland systems despite attempts to raise the profile in international arenas (Taylor and Bartley, 2016). Elevating the status of inland fisheries in policy discussions is vital to ensure that these important, often invisible, resources are not lost (Cooke et al., 2016). Without properly addressing the sustainability of inland fisheries and the externalities that threaten their continued delivery of services, their positive contribution to poverty alleviation, now and in the future, will likely be compromised. Replacing this lost food, employment opportunity, and revenue source would be difficult and costly as there are few viable alternatives in the poorest regions for the poorest segments of society.

Sustainable development agendas provide an opportunity to enhance the visibility and safeguard against losses in inland fisheries by promoting sustainable inland fisheries as both a means for economic and social growth as well as a ‘safety net’ to prevent further poverty escalation. Countries and Non-Governmental Organizations can integrate inland fisheries into their sustainable development frameworks to help achieve the UN’s 2030 Agenda for Sustainable Development. Including inland fisheries alongside marine fisheries in national policy statements and programs can prove beneficial to promoting economic and social growth, preventing further poverty, and achieving SDG 1 as well as many other SDG targets, such as those related to food security.

Declaration of interest

The authors declare no conflict of interest related to this work.

Funding

The joint activities of this group have been funded by the U.S. Geological Survey’s National Climate Change and Wildlife Science Center.

Acknowledgements

We thank Carleton University and Queen’s University Biological Station for hosting the ‘InFish’ workshop from which this manuscript resulted (http://infish.org/). We also thank William W. Taylor (Michigan State University) for conducting an internal USGS peer review and Andres Cuan for graphics assistance. For supplementary case studies of inland fisheries and resilient livelihoods, please visit the

interactive map at http://infish.org/sdg-storymap/. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

Agostinho, A., Pelicice, F., Gomes, L., 2008. Dams and the fish fauna of the Neotropical region: impacts and management related to diversity and fisheries. Braz. J. Biol. 68, 1119–1132. http://dx.doi.org/10.1590/S1519-69842008000500019.

Ahmed, M., Lorica, M.H., 2002. Improving developing country food security through aquaculture development—lessons from Asia. Food Policy 27, 125–141. http://dx.doi.org/10.1016/S0306-9192(02)00007-6.

Allan, J.D., Abell, R., Hogan, Z., Revenga, C., Taylor, B.W., Welcomme, R.L., Winemiller, K., 2005. Overfishing of inland waters. Bioscience 55, 1041–1051. http://dx.doi.org/10.1641/0006-3568(2005)055[1041:OOIW]2.0.CO;2.

Allison, E.H., Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. Mar. Policy 25, 377–388. http://dx.doi.org/10.1016/S0308-597X(01)00023-9.

Almeida, O.T., Lorenzen, K., McGrath, D.G., 2009. Fishing agreements in the lower Amazon: for gain and restraint. Fish. Manag. Ecol. 16, 61–67. http://dx.doi.org/10.1111/j.1365-2400.2008.00647.x.

Amilhat, E., Lorenzen, K., Morales, E.J., Yakupitiyage, A., Little, D.C., 2009. Fisheries production in Southeast Asian farmer managed aquatic systems (FMAS). Aquaculture 296, 219–226. http://dx.doi.org/10.1016/j.aquaculture.2009.08.014.

Arlinghaus, R., Lorenzen, K., Johnson, B.M., Cooke, S.J., Cowx, I.G., 2016. Management of freshwater fisheries: addressing habitat, people and fishes. In: Craig, J.F. (Ed.), Freshwater Fisheries Ecology. Wiley, Oxford, UK, pp. 557–579.

Asche, F., Roll, K.H., Trollvik, T., 2009. New aquaculture species – the whitefish market. Aquac. Econ. Manag. 13, 76–93. http://dx.doi.org/10.1080/13657300902881641.

Béné, C., Friend, R.M., 2009. Water, poverty and inland fisheries: lessons from Africa and Asia. Water Int. 34, 47–61. http://dx.doi.org/10.1080/02508060802677838.

Béné, C., Macfayden, G., Allison, E.H., 2007. Increasing the contribution of small-scale fisheries to poverty alleviation and food security. FAO Fisheries Technical Paper. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. http://dx.doi.org/10.1017/CBO9781107415324.004. http://www.fao.org/docrep/009/a0965e/a0965e00.HTM.

Béné, C., Hersoug, B., Allison, E.H., 2010. Not by rent alone: analyzing the pro-poor functions of small-scale fisheries in developing countries. Dev. Policy Rev. 28, 325–358. http://dx.doi.org/10.1111/j.1467-7679.2010.00486.x.

Béné, C., Arthur, R., Norbury, H., Allison, E.H., Beveridge, M., Bush, S., Campling, L., Leschen, W., Little, D., Squires, D., Thilsted, S.H., Troell, M., Williams, M., 2016. Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. World Dev. 79, 177–196. http://dx.doi.org/10.1016/j.worlddev.2015.11.007.

Béné, C., 2003. When fishery rhymes with poverty: a first step beyond the old paradigm on poverty. World Dev. 31, 949–975. http://dx.doi.org/10.1016/S0305-750X(03)00045-7.

Béné, C., 2006. Small-scale fisheries: assessing their contributions to rural livelihoods in developing countries. FAO Fisheries Circular No. 1008. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. http://www.fao.org/3/a-j7551e.pdf.

Beard, T.D., Arlinghaus, R., Cooke, S.J., McIntyre, P.B., De Silva, S., Bartley, D., Cowx, I.G., 2011. Ecosystem approach to inland fisheries: research needs and implementation strategies. Biol. Lett. 7, 481–483. http://dx.doi.org/10.1098/rsbl.2011.0046.

Beveridge, M.C.M., Thilsted, S.H., Phillips, M.J., Metian, M., Troell, M., Hall, S.J., 2013. Meeting the food and nutrition needs of the poor: the role of fish and the opportunities and challenges emerging from the rise of aquaculturea. J. Fish Biol. 83, 1067–1084. http://dx.doi.org/10.1111/jfb.12187.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., Little, D., Ross, L., Handisyde, N., Gatward, I., Corner, R., 2010. Aquaculture: global status and trends. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 365, 2897–2912. http://dx.doi.org/10.1098/rstb.2010.0170.

Brummett, R.E., Lazard, J., Moehl, J., 2008. African aquaculture: realizing the potential. Food Policy 33, 371–385. http://dx.doi.org/10.1016/j.foodpol.2008.01.005.

Campos-Silva, J.V., Peres, C.A., 2016. Community-based management induces rapid recovery of a high-value tropical freshwater fishery. Sci. Rep. 6, 34745. http://dx.doi.org/10.1038/srep34745.

Castro de, F., McGrath, D.G., 2003. Moving toward sustainability in the local management of floodplain lake fisheries in the Brazilian Amazon. Hum. Organ. 62, 123–133. http://dx.doi.org/10.17730/humo.62.2.9bkh58xeekj6bg0m.

Coates, D., Poeu, O., Suntornratnana, U., Nguyen, T.T., Viravong, S., 2003. Biodiversity and Fisheries in the Mekong River Basin, Mekong Development Series. Mekong River Commission (MRC), Phnom Penh, Cambodia. http://www.mrcmekong.org/assets/Publications/report-management-develop/Mek-Dev-No2-Mek-River-Biodiversityfiisheries-in.pdf.

Cooke, S.J., Arlinghaus, R., Bartley, D.M., Beard, T.D., Cowx, I.G., Essington, T.E., Jensen, O.P., Lynch, A., Taylor, W.W., Watson, R., 2014. Where the waters meet: sharing ideas and experiences between inland and marine realms to promote sustainable fisheries management. Can. J. Fish. Aquat. Sci. 71, 1593–1601. http://dx.doi.org/10.1139/cjfas-2014-0176.

Cooke, S.J., Allison, E.H., Beard, T.D., Arlinghaus, R., Arthington, A.H., Bartley, D.M., Cowx, I.G., Fuentevilla, C., Leonard, N.J., Lorenzen, K., Lynch, A.J., Nguyen, V.M., Youn, S.-J., Taylor, W.W., Welcomme, R.L., 2016. On the sustainability of inland fisheries: finding a future for the forgotten. Ambio 45, 753.

Cowx, I.G., Welcomme, R.L. (Eds.), 1998. Rehabilitation of Rivers for Fish. European Inland Fisheries Advisory Commission of FAO, Rome, Italy.

Cowx, I.G., Almeida, O., Bene, C., Brummett, R., Bush, S., Darwall, W., Pittock, J., van Brakel, M., 2004. Value of river fisheries. In: Welcomme, R.L., Petr, T. (Eds.), Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries (Volume 1). FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. p. 20.

de Graaf, G., Garabaldi, L., 2014. The value of African fisheries. FAO Fisheries Circular No. 1093, Rome, Italy. http://www.fao.org/3/a-i3917e.pdf.

Dey, M.M., Rab, M.A., Paraguas, F.J., Piumsombun, S., Bhatta, R., Ferdous Alam, M., Ahmed, M., 2005. Fish consumption and food security: a disaggregated analysis by types of fish and classes of consumers in selected Asian countries. Aquacult. Econ. Manag. 9, 89–111. http://dx.doi.org/10.1080/13657300590961537.

DHI, HDR, 2015. Study of the impact of mainstream hydropower on the Mekong River. Final Report. Hanoi, Viet Nam. https://www.scientists4mekong.com/wp-content/uploads/2016/04/mds-final-project-report-18jan16.pdf.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I.I., Knowler, D.J., Leveque, C., Naiman, R.J., Prieur-Richard, A.-H.H., Soto, D., Stiassny, M.L.J., Sullivan, C.A., 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev. 81, 163–182. http://dx.doi.org/10.1017/s1464793105006950.

Eggert, H., Greaker, M., Kidane, A., 2015. Trade and resources: welfare effects of the Lake Victoria fisheries boom. Fish. Res. 167, 156–163. http://dx.doi.org/10.1016/j.fishres.2015.02.015.

FAO, 2011. Guidelines for the Ecolabelling of Fish and Fishery Products from Inland Capture Fisheries. FAO, Rome, Italy.

FAO, 2014. CWP Handbook of Fishery Statistical Standards Section G: Fishing Areas – General. FAO, Rome, Italy.

FAO, 2016. The State of World Fisheries and Aquaculture – 2016 (SOFIA). FAO, Rome, Italy.

Fiorella, K.J., Hickey, M.D., Salmen, C.R., Nagata, J.M., Mattah, B., Magerenge, R., Cohen, C.R., Bukusi, E.A., Brashares, J.S., Fernald, L.H., 2014. Fishing for food? Analyzing links between fishing livelihoods and food security around Lake Victoria, Kenya. Food Secur. 6, 851–860. http://dx.doi.org/10.1007/s12571-014-0393-x.

Freire, K.M.F., Machado, M.L., Crepaldi, D., 2012. Overview of inland recreational fisheries in Brazil. Fisheries 37, 484–494. http://dx.doi.org/10.1080/03632415.2012.731867.

Garaway, C.J., Arthur, R.I., Chamsingh, B., Homekingkeo, P., Lorenzen, K., Saengvilaikham, B., Sidavong, K., 2006. A social science perspective on stock enhancement outcomes: lessons learned from inland fisheries in southern Lao PDR. Fish. Res. 80, 37–45. http://dx.doi.org/10.1016/j.fishres.2006.03.012.

Geheb, K., Kalloch, S., Medard, M., Nyapendi, A.T., Lwenya, C., Kyangwa, M., 2008. Nile perch and the hungry of Lake Victoria: gender, status and food in an East African fishery. Food Policy 33, 85–98. http://dx.doi.org/10.1016/j.foodpol.2007.06.001.

Heck, S., Béné, C., Reyes-Gaskin, R., 2007. Investing in African fisheries: building links to the Millennium Development Goals. Fish Fish. 8, 211–226. http://dx.doi.org/10.1111/j.1467-2679.2007.00251.x.

Hortle, K.G., 2007. Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No. 16. Mekong River Commission (MRC), Vientiane, Lao PDR. http://www.mrcmekong.org/assets/Publications/technical/tech-No16-consumption-n-yield-of-fish.pdf.

Hulme, D., Moore, K., Shepherd, A., 2001. Chronic Poverty: Meanings and Analytical Frameworks. Chronic Poverty Research Centre (CPRC), Manchester, UK. http://www.chronicpoverty.org/uploads/publication_files/WP02_Hulme_et_al.pdf.

Kapetsky, J.M., 2003. Review of the State of World Fishery Resources: Inland Fisheries. FAO Fisheries Circular No. 942, Rome Italy. Romeftp://ftp.fao.org/docrep/fao/006/J0703e/j0703e00.pdf.

Kolding, J., van Zwieten, P.a.M., 2011. The tragedy of our legacy: how do global management discourses affect small scale fisheries in the south? Forum Dev. Stud. 38, 267–297. http://dx.doi.org/10.1080/08039410.2011.577798.

Lélé, S.M., 1991. Sustainable development: a critical review. World Dev. 19, 607–621. http://dx.doi.org/10.1016/0305-750X(91)90197-P.

Lorenzen, K., Smith, L., Nguyen Khoa, S., Burton, M., Garaway, C., 2007. Guidance Manual: Management of Impacts of Irrigation Development on Fisheries. International Water Management Institute, Colombo, Sri Lanka.

Lorenzen, K., Cowx, I.G., Entsua-Mensah, R.E.M., Lester, N.P., Koehn, J.D., Randall, R.G., So, N., Bonar, S.A., Bunnell, D.B., Venturelli, P., Bower, S.D., Cooke, S.J., 2016. Stock assessment in inland fisheries: a foundation for sustainable use and conservation. Rev. Fish Biol. Fish. 26, 405–440. http://dx.doi.org/10.1007/s11160-016-9435-0.

Lorenzen, K., 2014. Understanding and managing enhancements: why fisheries scientists should care. J. Fish Biol. 85, 1807–1829. http://dx.doi.org/10.1111/jfb.12573.

Lynch, A.J., Beard, T.D., Cox, A., Zarnic, Z., Phang, S.C., Arantes, C.C., Brummett, R., Cramwinckel, J.F., Gordon, L.F., Husen, M.A., Liu, J., Nguyen, P.H., Safari, P.K., 2016a. Drivers and synergies in the management of inland fisheries: searching for sustainable solutions. In: Taylor, W.W., Bartley, D.M., Goddard, C.I., Leonard, N.J., Welcomme, R.L. (Eds.), Freshwater, Fish and the Future: Proceedings of the Global Cross-Sectoral Conference. American Fisheries Society Press, Bethesda, Maryland, pp. 183–200.

Lynch, A.J., Cooke, S.J., Deines, A.M., Bower, S.D., Bunnell, D.B., Cowx, I.G., Nguyen, V.M., Nohner, J., Phouthavong, K., Riley, B., Rogers, M.W., Taylor, W.W., Woelmer, W., Youn, S.-J., Beard Jr., T. Douglas, 2016b. The social, economic, and environmental importance of inland fishes and fisheries. Environ. Rev. 24, 1–7. http://dx.doi.org/10.1139/er-2015-0064.

Marmulla, G., 2001. Dams, Fish, and Fisheries: Opportunities, Challenges, and Conflict Resolution. Fisheries Technical Paper 419, Rome, Italy.

Martin, S.M., Lorenzen, K., Bunnefeld, N., 2013. Fishing farmers: fishing, livelihood

diversification and poverty in rural Laos. Hum. Ecol. 41, 737–747. http://dx.doi.org/10.1007/s10745-013-9567-y.
McIntyre, P.B., Reidy Liermann, C.A., Revenga, C., 2016. Linking freshwater fishery management to global food security and biodiversity conservation. Proc. Natl. Acad. Sci. U. S. A. 113, 12880–12885. http://dx.doi.org/10.1073/pnas.1521540113.
Medard, M., Sobo, F., Ngatunga, T., Chirwa, S., 2001. Women and gender participation in the fisheries sector in lake Victoria. World Fish Cent. 155–168.
Mkumbo, O.C., Marshall, B.E., 2015. The Nile perch fishery of Lake Victoria: current status and management challenges. Fish. Manag. Ecol. 22, 56–63. http://dx.doi.org/10.1111/fme.12084.
Musumali, M.M., Heck, S., Husken, S.M.C., Wishart, M., 2009. Fisheries in Zambia: an undervalued contributor to poverty reduction. World Fish Cent. Policy Br. 1913, 16.
Nam, S., Phommakone, S., Vuthy, L., Samphawamana, T., Son, N.H., Khumsri, M., Bun, N.P., Sovanara, K., Degen, P., Starr, P., 2015. Lower Mekong fisheries estimated to be worth around $17 billion a year. Catch Cult. 21, 4–7.
Nasielski, J., Kc, K.B., Johnstone, G., Baran, E., 2016. When is a fisher (not) a fisher? Factors that influence the decision to report fishing as an occupation in rural Cambodia. Fish. Manag. Ecol. 23, 478–488. http://dx.doi.org/10.1111/fme.12187.
Nguyen Khoa, S., Lorenzen, K., Garaway, C., Chamsinhg, B., Siebert, D., Randone, M., 2005. Impacts of irrigation on fisheries in rain-fed rice-farming landscapes. J. Appl. Ecol. 42, 892–900. http://dx.doi.org/10.1111/j. 1365-2664.2005.01062.x.
Orr, S., Pittock, J., Chapagain, A., Dumaresq, D., 2012. Dams on the Mekong River: lost fish protein and the implications for land and water resources. Glob. Environ. Change 22, 925–932. http://dx.doi.org/10.1016/j.gloenvcha.2012.06.002.
Parikh, J., 1996. Consumption patterns: the driving force of environmental stress. In: May, P.H., Seroa da Motta, R. (Eds.), Pricing the Planet: Economic Analysis for Sustainable Development. Columbia University Press, New York, N.Y, pp. 39–48.
Potts, W.M., Childs, A.R., Sauer, W.H.H., Duarte, A.D.C., 2009. Characteristics and economic contribution of a developing recreational fishery in southern Angola. Fish. Manag. Ecol. 16, 14–20. http://dx.doi.org/10.1111/j.1365-2400.2008.00617.x.
Smith, L.E.D., Khoa, S.N., Lorenzen, K., 2005. Livelihood functions of inland fisheries: policy implications in developing countries. Water Policy 7, 359–383.
Tacon, A.G.J., Metian, M., 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. Aquaculture 285, 146–158. http://dx.doi.org/10.1016/j.aquaculture.2008.08.015.
Taylor, W.W., Bartley, D.M., 2016. Call to action – the Rome declaration: ten steps to responsible inland fisheries. Fisheries 41, 269. http://dx.doi.org/10.1080/03632415.2016.1183993.
Toufique, K.A., Belton, B., 2014. Is aquaculture pro-poor? Empirical evidence of impacts on fish consumption in Bangladesh. World Dev. 64, 609–620. http://dx.doi.org/10.1016/j.worlddev.2014.06.035.
Turpie, J., Smith, B., Emerton, L., Barnes, J., 1999. Economic Value of The Zambezi Basin Wetlands, Zambezi Basin Wetlands Conservation and Resource Utilization Project. International Union for Conservation of Nature (IUCN), Cape Town, South Africa. http://dx.doi.org/10.1017/CBO9781107415324.004. https://portals.iucn.org/library/sites/library/files/documents/1999-098.pdf.
UN, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development (A/RES/70/1). UN, New York, USA.
Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R., Davies, P.M., 2010. Global threats to human water security and river biodiversity. Nature 467, 555–561. http://dx.doi.org/10.1038/nature09440.
Welcomme, R.L., Cowx, I.G., Coates, D., Béné, C., Funge-Smith, S., Halls, A., Lorenzen, K., 2010. Inland capture fisheries. Philos. Trans. R. Soc. B-Biol. Sci. 365, 2881–2896. http://dx.doi.org/10.1098/rstb.2010.0168.
Welcomme, R.L., 2011. An overview of global catch statistics for inland fish. ICES J. Mar. Sci. 68, 1751–1756. http://dx.doi.org/10.1093/icesjms/fsr035.
Westlund, L., Poulain, F., Bage, H., van Anrooy, R., 2007. Disaster response and risk management in the fisheries sector. FAO Fisheries Technical Paper 479. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy. http://www.fao.org/docrep/010/a1217e/a1217e00.htm.
World Bank, 2012. Hidden Harvest: The Global Contribution of Capture Fisheries. World Bank, Washington, D.C.
Xu, B., Zhang, J., 2013. The predicament of Lake Poyang fisher families (in Chinese). Man. Biosph. 85, 26–27.
Youn, S.-J., Taylor, W.W., Lynch, A.J., Cowx, I.G., Beard, T.D., Bartley, D.M., Wu, F., 2014. Inland capture fishery contributions to global food security and threats to their future. Glob. Food Sec. 3, 142–148. http://dx.doi.org/10.1016/j.gfs.2014.09.005.