Rev Fish Biol Fisheries (2021) 31:843–877
https://doi.org/10.1007/s11160-021-09664-w

REVIEWS

The ten steps to responsible Inland fisheries in practice: reflections from diverse regional case studies around the globe

Steven J. Cooke · Elizabeth Nyboer · Abigail Bennett · Abigail J. Lynch · Dana M. Infante · Ian G. Cowx · T. Douglas Beard Jr. · Devin Bartley · Craig P. Paukert · Andrea J. Reid · Simon Funge-Smith · Edith Gondwe · Emmanuel Kaunda · John D. Koehn · Nicholas J. Souter · Gretchen L. Stokes · Leandro Castello · Nancy J. Leonard · Christian Skov · Søren Berg · William W. Taylor

Received: 29 April 2020 / Accepted: 28 May 2021 / Published online: 15 July 2021

Abstract Inland fisheries make substantial contributions to food security and livelihoods locally, regionally, and globally but their conservation and management have been largely overlooked by policy makers. In an effort to remedy this limited recognition, a cross-sectoral community of scientists, practitioners, and policy makers from around the world convened a high-level meeting in 2015 at the Food and Agriculture Organization of the United Nations headquarters in Rome, Italy to develop recommendations for sustainable inland fisheries management. This meeting resulted in the production of the Rome Declaration, outlining ten key steps needed to achieve responsible inland fisheries. When the Ten Steps were conceived, they were framed in a global context because inland fisheries around the world face similar

S. J. Cooke (✉) · E. Nyboer · A. J. Reid
Fish Ecology and Conservation Physiology Laboratory, Department of Biology and Institute of Environmental and Interdisciplinary Science, Carleton University, 1125 Colonel By Dr, Ottawa, ON K1S 5B6, Canada
e-mail: Steven.Cooke@carleton.ca

S. J. Cooke · A. Bennett · D. M. Infante · D. Bartley · E. Gondwe · W. W. Taylor
Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, 1405 South Harrison Road, East Lansing, MI 48823, USA

A. J. Lynch · T. D. Beard Jr.
U.S. Geological Survey, National Climate Adaptation Science Center, Reston, VA 20192, USA

I. G. Cowx
Hull International Fisheries Institute, University of Hull, Hull HU6 7RX, UK

C. P. Paukert
U.S. Geological Survey, Missouri Cooperative Fish and Wildlife Research Unit, University of Missouri, Busch Natural Resources Building, 302 Anheuser, Columbia, MO 65211, USA

S. Funge-Smith
Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok 10900, Thailand

E. Kaunda
Department of Aquaculture and Fisheries Science, Lilongwe University of Agriculture and Natural Resources (LUANAR), P.O Box 219, Lilongwe, Malawi

J. D. Koehn
Applied Aquatic Ecology, Department of Environment, Land, Water and Planning, Arthur Rylah Institute for Environmental Research, 123 Brown St, Heidelberg, VIC 3084, Australia

challenges, and it was hoped that these large-scale and ambitious steps would draw the attention of regional or international bodies for greater investment in their proper management. Most inland fisheries, however, are managed at a local (often community, watershed, or waterbody) scale with the "on-the-ground" practitioners, managers, assessment biologists, and stewardship officers responsible for achieving the promise of the Ten Steps. Here, we reflect on the relevance of the Ten Steps to practitioners using six regional case studies from around the globe (North America, South America, Europe, Asia, Australia, and Africa) to identify the extent to which existing efforts align with the Ten Steps and where there are opportunities to do more. Learning what is effective from local/regional actions should better inform a more global "action plan" and provide tangible guidance for implementation recognizing that global guidance needs to be informed by and acted upon by local practitioners. We conclude by considering the common challenges, synergies, and other emergent properties that arise from these case studies, and use these as a path forward to advancing responsible management of inland fisheries through the Rome Declaration. Of particular importance is the need to balance the high-level aspirational goals of the Ten Steps with the local cultural, socio-economic, and institutional realities that ultimately influence how humans interact with fisheries resources and aquatic ecosystems. This assessment provides valuable information on how to refine and implement the Ten Steps recognizing that success will require coordinated efforts among on-the-ground practitioners, scientists, stakeholders, rightsholders and international decision makers.

Keywords Inland fisheries · Sustainable fisheries · Freshwater fisheries · Fisheries management

N. J. Souter
Greater Mekong Program, Conservation International, Adelaide, SA 5005, Australia

G. L. Stokes
School of Natural Resources and Environment, University of Florida, Gainesville, FL 32611, USA

L. Castello
Department of Fish & Wildlife Conservation, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA

N. J. Leonard
Pacific States Marine Fisheries Commission, 205 S.E. Spokane St., Suite 100, Portland, OR 97202, USA

C. Skov · S. Berg
Section for Freshwater Fisheries and Ecology, Technical University of Denmark, National Institute of Aquatic Resources, Vejlsøvej 39, 8600 Silkeborg, Denmark

Introduction

The lakes, rivers, and wetlands of the world are home to diverse assemblages of inland fishes and other aquatic organisms that generate a multitude of ecosystem services. Inland fisheries support livelihoods, provide a source of nutrition, maintain cultural connections, and create leisure opportunities for millions of people across the globe (Holmlund and Hammer 1999; Lynch et al. 2016). Indeed, inland fisheries are an essential source of income and food security for some of the most impoverished peoples on Earth, with 90% of inland fisheries production occurring in Africa and Asia (FAO 2019) and 43% in low-income food-deficit countries (LIFDCs) (Funge-Smith and Bennett 2019). In these regions, inland fisheries provide an essential source of macro- and micronutrients needed for survival and childhood development (Dugan et al. 2010; Youn et al. 2014). Inland fisheries also offer important livelihood opportunities (Smith et al. 2005), employing at least 17 million fishers and 8 million post-harvest workers, more than half of the latter being women (Funge-Smith and Bennett 2019).

However, the contributions of inland fisheries as both natural benefits and goods/services tend to be overlooked at all scales (e.g., from regional to global; Welcomme et al. 2010; Beard et al. 2011). There are several reasons why this is the case. First, the economic value of inland fisheries is difficult to quantify given that inland fisheries are highly dispersed, with products that are rarely exported, and often sold through informal markets or bartered through non-traditional food supply chains (Welcomme 2011). As such, the Food and Agriculture Organization of the United Nations (FAO) has struggled to accurately quantify the global inland fisheries harvest, a key metric needed for recognition and respect of the importance of these fishes and their fisheries in policy making. Although progress in this area has been made, inadequacies in the data reporting

are still prevalent (Welcomme 2011; Bartley et al. 2015; Fluet-Chouinard et al. 2018; Funge-Smith 2018). Given these challenges, estimates vary greatly; global inland fisheries harvest may be more than 50% higher than the 11.6 million tonnes reported to FAO in 2017 (Fluet-Chouinard et al. 2018; Ainsworth et al. 2018; Deines et al. 2017). Second, inland water resources provide multiple ecosystem services essential to the health and well being of nearby and distant human communities, including potable supply, hydropower, irrigation, and aggregate mining (Beard et al. 2011; Cooke et al. 2016b; Baumgartner et al. 2019). Such services have historically taken precedence over fisheries in policy decisions related to water resource use and development. Relatedly, inland waters are threatened (Vörösmarty et al. 2010; Reid et al. 2019) and their biodiversity is in decline (FAO 2019; Funge-Smith 2018; Harrison et al. 2018), which is likely to degrade healthy and productive fish populations and fisheries. Although overfishing can occur in inland waters (e.g., Allen et al. 2005; Irvine et al. 2019), many of the threats to inland fish and fisheries are external to the fisheries sector (Beard et al. 2011). Raising awareness of the contribution of these fisheries to local, regional, and global economies is necessary for highlighting common challenges faced in these systems (Lynch et al. 2016). Pinpointing local successes in their management, together with developing consistent and globally cohesive reporting and management procedures can improve fishery productivity and enhance the livelihoods of human communities that depend on inland fishes for income and food security.

A number of recent efforts have raised the profile of inland fisheries on regional and global stages to ensure their appropriate valuation and management. Various initiatives undertaken by FAO and collaborators (see Beard et al. 2011) provided the foundation for the first UN conference on global inland fisheries (co-sponsored by Michigan State University, USA), which was held at the FAO headquarters in Rome in 2015, and was titled "Freshwater, Fish and the Future: Cross Sectoral Approaches to Sustain Livelihoods, Food Security, and Aquatic Ecosystems" (Taylor et al. 2016). The conference brought together a diverse community of $>$ 200 scientists, practitioners, resource managers, and policy makers from around the world. Delegates took part in interactive discussions, panels, and workshops to identify issues specific to inland fisheries, highlight threats to sustainable use, and synthesize needs for sustainable approaches to inland fisheries management (Beard et al. 2016). The conference resulted in proceedings outlining key findings and recommendations that emerged from these discussions (i.e., Taylor et al. 2016; Cooke et al. 2016b), as well as a policy advisory document entitled "The Rome Declaration: Ten steps to responsible inland fisheries" (FAO and MSU 2016). The Rome Declaration contains ten key recommendations (hereafter referred to as the Ten Steps) that serve as a call-to-action for those working within inland fisheries to improve assessment, valuation, and governance of freshwater ecosystems and the fisheries they support (Table 1; Cooke et al. 2016b).

A recent perspective article (Lynch et al. 2020a) revealed mixed progress towards achieving the Ten Steps. When the Ten Steps were conceived, they were framed in a global context given the similar challenges faced by inland fisheries around the world. Like other voluntary guidance conceived at a global level, there is a considerable challenge to translate broad objectives and recommendations into concrete and context-specific improvements for countries, communities, fisheries and ecosystems. For example, the FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (FAO 2015) have been followed by a series of efforts toward awareness-raising, stakeholder empowerment, action at the science-policy interface, and implementation support (Jentoft 2014; Jentoft et al. 2017; http://www.fao.org/voluntary-guidelines-small-scale-fisheries/implementation/en/). The Ten Steps must follow a similar path in order to see initial efforts expand and develop into meaningful outcomes.

The Ten Steps are global and ambitious, because they are aimed at attracting the attention of regional or international bodies and influential groups, including policy makers, to drive initiatives for their implementation. However, most inland fisheries are managed by local practitioners, managers, resource biologists, and stewardship officers working within administrations that operate at the community, watershed, and/or waterbody scale. Thus the global guidance needs actions by local practitioners to collectively achieve the promise of these high-level Ten Steps. As fisheries and aquatic professionals move towards implementation of the Ten Steps, it is necessary to explore how existing regional actions align with the Ten Steps to

Table 1 Summary of the goals and recommendations of the Ten Steps derived from the *Rome Declaration*

The Ten Steps		Brief description and recommendations from the Rome Declaration
1	Improve the assessment of biological production to enable science-based management	**Goal:** Remedy the lack of accurate / complete information on biological production from inland fisheries
		Recommendations: Develop standardized assessment methods; develop novel and cost-effective data collection approaches; incorporate inland fisheries into agricultural statistical surveys; increase capacity of resource officers on the ground; establish minimum / practical data collection protocols
2	Correctly value inland aquatic ecosystems	*Goal:* Improve economic and social valuation of healthy inland aquatic ecosystems
		Recommendations: Recognize, respect, and support traditional customs, rights and ecological knowledge; assess ecosystem services for their contribution to ecosystem health and societal wellbeing; value ecosystem services along the entire value chain
3	Promote the nutritional value of inland fisheries	*Goal:* Fully appreciate the contribution of inland fisheries to food security, especially for children in the developing world
		Recommendations: Maintain/improve accessibility of fish in areas of traditionally high fish consumption; establish water management plans that prioritize nutrient-rich aquatic products
4	Develop and improve science-based approaches to fishery management	*Goal:* Promote better sharing of data and information about inland fisheries to support the assessment-management cycle
		Recommendations: Implement an ecosystem-based approach to inland fisheries; support governance arrangements and improve compliance with management regulations; if reducing fishing capacity is necessary, establish social safeguards/alternative livelihood options
5	Improve communication among freshwater users	*Goal:* Share information on the importance of inland fisheries with policy-makers, stakeholders, and the general public to promote political protection of these resources
		Recommendations: Disseminate information about inland fish, fishers, and fisheries; engage other users of freshwater resources to address conflicts among sectors
6	Improve governance, especially for shared waterbodies	*Goal:* Establish governance structures that are harmonized across national, international and transboundary jurisdictions
		Recommendations: Establish river/lake basin-wide authorities that strengthen the capacity of existing institutions; incorporate trans-boundary decisions into national government policy
7	Develop collaborative cross-sectoral integration in development agendas	*Goal:* Collaborate with non-fishery water resource users to ensure inland fisheries are not overlooked in management decisions, and to find mutually beneficial outcomes across water sectors
		Recommendations: Promote cross-sectoral discussions that consider inland fisheries equitably; strengthen platforms for multi-stakeholder decision-making; incorporate into 2015 SDGs
8	Respect equity and rights of stakeholders	*Goal:* Recognize the diverse livelihood practices of Indigenous people, inland fishers, and fish workers and ensure all groups' rights to access fishery resources
		Recommendations: Protect the cultural heritage of Indigenous peoples; ratify and implement human rights instruments
9	Make aquaculture an important ally	*Goal:* Use aquaculture wisely to complement capture fisheries through stocking, provision of alternative livelihoods, and providing food security, but avoiding introduction of invasive species, genes and diseases to natural populations, causing pollution, and restricting access to traditional fishing grounds
		Recommendations: Adopt an ecosystem-based approach to aquaculture management; promote synergies among fisheries, stock enhancement, and aquaculture; regulate use of non-native species in aquaculture
10	Develop an action plan for global inland fisheries	*Goal:* Bring together the above steps to ensure sustainability and responsible use of inland fisheries and aquatic resources for future generations
		Recommendations: Involve the international community, governments, civil society organizations, Indigenous peoples, industry, and all freshwater resource use sectors in the conversation

identify challenges and opportunities. Here, we reflect on the alignment of existing efforts with the Ten Steps using various regional case studies from around the globe (Fig. 1). From these case studies we also identify tangible actions needed to implement the Ten Steps from a local perspective and address deficiencies/needs for full implementation at the global scale. This reflective bottom-up approach is necessary to develop a more effective global "action plan"—something called for by Lynch et al. (2020a) and which will likely require refinement of the Ten Steps. We conclude by considering where there are consistent challenges, synergies, and other lessons that arise from the case studies as a path forward to advancing responsible inland fisheries through the Rome Declaration at the local, regional, national, and global level.

We acknowledge that an implicit assumption of this paper is that for fisheries management to be "successful," the case studies used should align well with the Ten Steps. In reality, some steps (or recommendations) are not relevant to all scenarios (or case studies). We also acknowledge that the Ten Steps have only been available for $\sim$ 5 years at the time that we wrote this article so there has been limited time for uptake. As such, the case studies we present here are coincident with the Ten Steps but not modeled after them. That does not diminish the value of this case study approach but rather reflects the reality that many fisheries practitioners were involved in developing the Ten Steps giving them high applicability for regional implementation. There is much that can be learned from reflecting on bottom-up examples of where the Ten Steps (or parts thereof) are already being operationalized in an effort to consider how the Rome Declaration and its Ten Steps can be shared and embraced broadly.

Case studies

Six case studies were selected, based on expert opinion and local experience of the coauthors, to span a diversity of internal and external issues affecting inland fisheries and to include representation from Africa, Asia, Australia, Europe, North America, and South America (See Fig. 1). Each case study comprises four sections, viz. (A) a brief summary of the fishery (e.g., scope, scale, characteristics), (B) a commentary on the extent to which existing efforts align with the Ten Steps or where they could be applied directly or indirectly (elaborated in Table 2, 3,

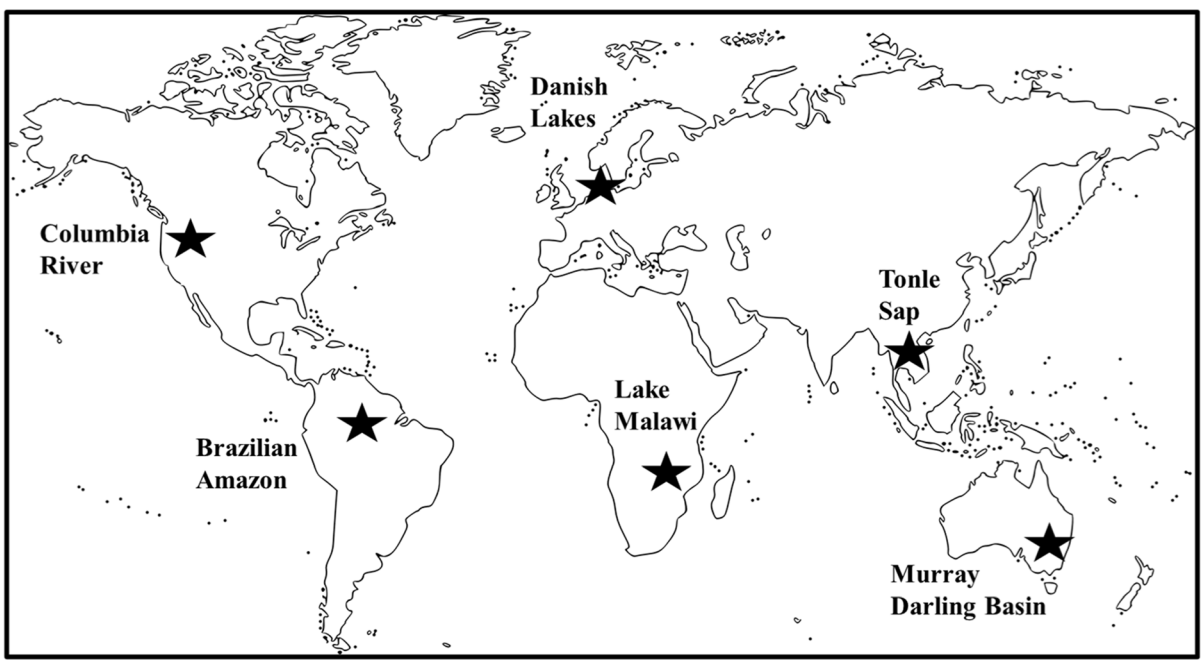

Fig. 1 Map illustrating the location of the focal case studies (stars) included in this paper

4, 5, 6 and 7; herein called Past Applications), (C) insights into successes and challenges in applying the tenets of the Ten Steps with the goal of informing activities in other regions, and (D) a description of what is needed to achieve the Ten Steps locally (i.e., Future Possibilities). Within each case study, we identify when a statement or idea is relevant to a specific step (or steps) for sections B, C, and D. Although we refer to the Ten Steps for the purpose of these bottom-up case studies, we exclude *Step 10* (i.e., develop an action plan for global inland fisheries) in that it is an inherently global initiative. However, we discuss *Step 10* at the end of the paper given that these bottom-up case studies have the potential to inform aspects of a global action plan that could be relevant for on-the-ground practitioners at all levels of governance. Not all case studies include references to all of the Ten Steps given the inherent regional variation in issues that extends throughout the selected case studies.

Lake Malawi fisheries in Malawi, Africa

Fishery overview

Lake Malawi is the 3rd largest lake in Africa and the 9th largest in the world, supporting nearly 14% of the world's freshwater fish species, over 90% of which are endemic (Wilson and Primack 2019; Weyl et al. 2010; Lyons et al. 2015). Lake Malawi is shared by three countries (Malawi, Tanzania, and Mozambique); however, the highest fishing effort and most catch data originate in Malawi (Weyl et al. 2010) so the information presented here refers primarily to the ~ 60% of the lake that is under Malawian jurisdiction. The lake is an important source of animal protein and livelihoods for local fishing communities (Banda et al. 2005) and provides water for irrigation and hydroelectricity. Small-scale fisheries in Malawi account for over 90% of the annual production (GoM 2018) using both traditional and relatively modern gears and watercraft (FAO 2005). The large-scale commercial fishery operates in the southern part of the lake, and consists of trawl vessels, purse seine and lift nets, targeting mostly tilapiine species and species of haplochromine cichlids, including groups locally known as Ndunduma, Chisawasawa, and Utaka (FAO 2005). Although overall capture fishery production from Lake Malawi has been increasing, the highly economically valuable Chambo fishery (consisting of a group of tilapia species including *Oreochromis lidole, O. squamipinis* and *O. karongae*) has declined in recent decades (Banda et al. 2005; GoM 2018; Irvine et al. 2019). Currently, less valuable small pelagic species of the Cyprinidae family, primarily Lake Malawi sardine (*Engraulicypris sardella*), constitute over 50% of the total catch (GoM 2018).

Past applications (See Table 2)

Lake Malawi fisheries in Malawi (both small- and large-scale) have been co-managed using a Participatory Fisheries Management (PFM) approach (Nunan 2015) in which democratically elected Beach Village Committees (BVC) represent fishers and residents of a beach/village in collaboration with the Department of Fisheries of the Government of Malawi (Njaya 2018; Hara 2011; *Steps 6,8*). Although the governments of Tanzania and Mozambique also use co-management approaches in fisheries governance (Weyl et al. 2010; Nunan et al. 2015), there is currently no intergovernmental fishery body established to formally discuss, develop, and manage aquatic resources in Lake Malawi (*Step 6*). The fisheries are governed in Malawi using the Ecosystem Approach to Fisheries and Aquaculture (EAFA) management plan (Njaya 2018), which seeks to develop and manage fishery resources in a holistic and participatory manner (*Step 7*). Nevertheless, the management approaches have not curbed overfishing, nor use of illegal gears (Njaya 2018; Limuwa et al. 2018). The lack of consistent stock assessment studies (*Step 1*) and limited analysis of fish value chains and valuation of fish resources (*Step 2*) undermines policy development, including setting national priorities, forming alternative policy options, and implementing effective freshwater ecosystems management programs (Hoggarth et al. 2006; Makwinja et al. 2019). High post-harvest losses persist, necessitating the development of nutrition-sensitive fisheries programs (Makawa et al. 2019; *Step 3*).

Table 2 The Ten Steps in practice: Lake Malawi Fisheries in Malawi, Africa

The steps	Past applications	Future possibilities
1. Improve the assessment of biological production to enable science-based management	Due to limited resources, assessment of fish stocks in the Malawi section of Lake Malawi fishery are undertaken sporadically, the last being more than a decade ago. Additionally, recent assessments have been confined to a small part of the lake. Assessments have mostly been supported through projects, such as the USAID funded FISH project that supported the recent Chambo stock assessment in southern Lake Malawi	Establish frequent and consistent stock assessment surveys which would play a critical role in zoning fishing areas for the fishery for both small and large scale fishers. The data would also be used to determine the number of fishing licenses to be issued to commercial fishers on the lake
		Investigate ways in which assessments can become cost effective using modern tools, such as satellite imaging and Geographic Information Systems
2. Correctly value inland aquatic ecosystems	The Lake Malawi fishery is not accurately valued (Makwinja et al 2019). Value of the inland systems is only based on beach prices for the landed fish (GoM 2018). No assessments are undertaken further to that. However, as noted by Mussa et al (2017), failure to account for other forms of value including that generated by informal trade underestimates the purported value of the fishery. There are currently no mechanisms to record informal fish trade data	Adapt methodologies that efficiently measure value of aquatic ecosystems and services including the landed amount of fish by conducting disaggregated market analysis and adopting a multi-stakeholder approach with key departments such as the Malawi Revenue Authority to estimate informal trade values
3. Promote the nutritional value of inland fisheries	Recognition of the role that fish plays in diets of Malawi is widely accepted (GoM 2018; Kurien et al. 2013; Nagoli et al. 2010). Attempts to increase the nutritional value of fish products through improved processing methods, such as solar driers and modern smoking, continue to be promoted (Makawa et al 2019), albeit with low adoption (Chiwaula et al 2019). Postharvest losses (quantity and quality) continue to persist, with limited quantifications and classifications of the various types of losses (Chiwaula et al 2019)	Adapt successful fish value-added products from the globe (e.g., fish-based chutney (designed for pregnant and lactating women) and a fish powder (designed for infants of complementary feeding age) developed in Bangladesh; complementary food (food using small dried fish) which was well accepted by mothers and children in Kenya; and small indigenous fish which were identified as an affordable alternative to milk to improve the nutritional quality of complementary foods in Cambodia (Bogard et al. 2015; Konyole et al. 2012; Skau et al. 2015
	Consumption of small fish, which are rich in important nutrients, has also not been widely popularized	Improve the value chains (e.g., to reduce fish waste and loss). In particular, fish drying operations using open-air drying racks experience high waste/loss during rainy seasons when fish spoil after becoming wet
4. Develop and improve science-based approaches to fishery management	Academic institutions in the country, led by Lilongwe University of Agriculture and Natural Resources (LUANAR), Fisheries Research Unit and others, have attempted to enhance human capacity for science-based approaches. However, low student enrollment in stock assessment and modelling studies have slowed this progress	Develop approaches and training that focus on scientific methods of conducting assessments as well as addressing overfishing of exploited and endangered species. Embrace global partnerships and scientific exchanges to enhance science-based approaches
5. Improve communication among freshwater users	Efforts have been made to establish networks and working groups to facilitate information flow among stakeholders (Department of Fisheries, Academia, NGOs, Fisheries associations and other related departments). In 2018, LUANAR and the Malawi Fisheries Department (Government of Malawi) co-hosted the Pan African Fisheries Association (PAFFA6), which attracted > 300 national and international delegates	Improve communication among users through establishment of formal communication channels and structures among stakeholders for improved harmonization of fisheries management plans
	Malawi also hosts the annual Malawi Fisheries Forum where scientists and other stakeholders present work being undertaken to enhance communication within the country. However, more consistent communication is crucial. An upcoming initiative to enhance information on fish biodiversity and related scientific research is currently underway where LUANAR seeks to establish a data portal to be supported by the Jacob Richard Schramm (JRS) Foundation	

Table 2 continued

The steps	Past applications	Future possibilities
6. Improve governance, especially for shared waterbodies	There continue to be challenges in the management of Lake Malawi fishery despite the current Participatory Fisheries Management (PFM) and Ecosystem Approach to Fisheries and Aquaculture (EAFA) that are currently being implemented (Njaya 2018). An integrated watershed management plan could potentially play an important role in ensuring that the fishery is conserved and sustained – something that is currently missing (Leon, 2003). There have been several projects and programs to improve governance of the fishery sector in Malawi, especially through NGO-supported projects. Challenges continue to persist in terms of adherence to the 2-month closed season, both among small scale and commercial fishers Transboundary governance arrangements for Lake Malawi between Malawi and Tanzania have to date not been resolved	Improve governance capacity of the sector through development of localized fisheries management plans Improve transboundary governance of the fishery by adopting integrated watershed management plans (Chidammodzi and Muhandiki 2015; Leon 2003; AFDB 2019). The framework proposed by Leon (2003) advocates for water quality improvement of Lake Malawi through connecting a watershed model, hydrodynamic model and water quality box model. Operationalization of this model could offer increased pathways for improving the fishery Implement large-scale management approaches that could result in more meaningful outcomes for the fishery. As one example, the AFDB project is funding a 5-year project on "Sustainable Fisheries, Aquaculture Development and Watershed Management" with an outcome of improving watershed management areas in fishing communities
7. Develop collaborative approaches to cross-sectoral integration in development agendas	The EAFA approach was used in the Chambo restoration strategy by FAO, albeit with limited success as stocks have still continued to decline despite the management framework (Njaya, 2018). There is hence a need to improve the current approaches to attain broader goals of management and sustainability	Use ecosystem-based management to better address drivers of unsustainability and the new commitments to ecosystem-scale sustainability (Cowan 2012)
8. Respect equity and rights of stakeholders	There have been calls for equal treatment between small scale fishers and commercial fishers, with small scale fishers demanding that commercial fishers be subjected to closed season restrictions to ensure they also play a role in the conservation measures of the fishing bodies	Establish protocols and guidelines on the roles and involvement of stakeholders in fisheries management plans. Engage in efforts to seek equity for different components of the fisheries sector
9. Make aquaculture an important ally	Aquaculture has the potential to supplement dwindling fisheries production, contribute to increased per capita fish consumption and support fishing communities (Limuwa et al, 2018). The revised Fisheries and Aquaculture Policy provides the legal framework for ensuring that aquaculture is incorporated as part of fisheries management plans (GoM, 2016). However, production has remained low at < 5000 MT per annum Challenges remain in accessing quality seed fish and feed continues to be imported from Zambia instead of being produced within Malawi. Limited success of previous programs is attributed to inadequate investments that are required to transform the sector (Limuwa et al, 2018). Potential for increasing output from the sector could be achieved through programs such as the African Development Bank "Sustainable Fisheries, Aquaculture Development and Watershed Management" (AFDB project) which will strengthen fish farmers and aquaculture institutions	Harness opportunities of improving farmed species by advancing work on genetic improvement programs. It is also necessary that investments in affordable but quality feed development be advanced to simulate the positive impacts that have been evidenced in the Zambia aquaculture sector provided that there are no negative effects on the wild capture sector

Successes and challenges

The EAFA management plan corresponds to the Ten Steps by increasing capacity for science-based management (*Step 4*) and improving governance with communities taking the centre stage (*Step 6*). Having a single comprehensive plan allows for all actors to be engaged and to work together towards common goals. It also addresses the common failure of 'top-down' management by considering a wide range of stakeholder perspectives, including local communities, and therefore presents the potential to balance the

competing objectives of resource sustainability, food security, and economic development (*Step 7*). The PFM approach has shown similar potential of positive impacts, but there is need for adequate funding to ensure that BVCs are empowered to carry out necessary functions (e.g., enforcement, monitoring) and to oversee both small and large-scale fisheries. Investment requirements to advance some of the steps can also be achieved by harnessing multilateral programs, such as the USAID and African Development Bank funded programs currently being implemented in the country. Other challenges include issues with equity between small- and large-scale fisheries.

Future possibilities (See Table 2)

For Lake Malawi fisheries, achieving the Ten Steps will require shifts in investment priorities by governments, increased intergovernmental action to establish a fishery management body on the lake (that considers transboundary issues), improved stakeholder engagement (*Steps 5, 6*), and increased research and stock assessment effort (*Step 1*), with the latter being addressed by projects funded in partnership by various development organizations. There is also opportunity to explore alternative management schemes including a zonal approach. A recent study identified fisheries as one of the top value chains with pathways of achieving poverty reduction, economic growth, and nutrition security in the country (Benfica et al. 2017; *Steps 2,3*), which is likely to encourage increasing investment in the sector. Wider engagement of the non-fishery sectors is needed to demonstrate the economic and social value of the Lake's fisheries (*Step 7*). For example, plans for crop development call for a doubling of production which would require withdrawing more water from the Lake. This increase in agriculture will surely negatively impact the health and productivity of current Lake Malawi fisheries and the local communities that depend on these fisheries for food, livelihoods and societal well-being. The aquaculture sector in and around Lake Malawi remains underdeveloped, with challenges in availability of quality and affordable input materials, such as feed (Limuwa et al. 2018). However, the number of fish farmers has increased recently, and continued focus on aquaculture extension services may enable growth in this sector *(Step 9)* (FAO, 2020).

Fisheries of the Murray-Darling Basin of Australia

Fishery overview

The Murray-Darling Basin (MDB) covers 1.1 million km^2 in semi-arid, south-eastern Australia. Native fish populations have suffered significant declines as a result of alterations to habitat, flow reductions, and invasive species, among other drivers, with populations estimated at less than 10% of pre-European settlement levels (Murray-Darling Basin Commission 2004; Murray-Darling Basin Authority 2020). Local extinctions have occurred (Lintermans 2007), and previously economically important commercial inland fisheries for Murray cod (*Maccullochella peelii*) and golden perch (*Macquaria ambigua*) have collapsed and closed (Rowland 2005; Reid et al. 1997). Native fishes have important nutritional, social, and cultural values for Indigenous peoples and European settlers, although reliance on these fishes for nutritional resources has declined over time (Rowland 2005; Ginns 2012). Currently, native species fisheries are primarily recreational and provide an important pastime, especially in rural areas where they make major economic contributions to regional tourism (Henry and Lyle 2003; Ernst and Young 2011).

Past applications (See Table 3)

The MDB is Australia's 'food bowl' with extensive irrigated agriculture (Meyer 2005). It is now one of the world's most regulated river systems (Nilsson et al. 2005), and infrastructure, flow regulation, and habitat modification are cited as major reasons for declines in native fishes and watershed integrity (Murray-Darling Basin Commission 2004; Davies et al. 2010, 2012). Hence, significant conflicts occur around the use of water for irrigation versus the need for water for fisheries and the environment (Koehn 2015; *Step 7*). Concerns regarding over-allocation of water to various sectors including agriculture and hydropower development (Lester et al. 2011) have been highlighted by the 1997–2010 'millennium drought' (Murphy and Timbal 2008), climate change predictions (CSIRO 2008), and the regular occurrence of fish kills (King et al. 2012; Baumgartner and Finlayson 2019), emphasizing the need for cross-sectoral cooperation on water management (*Step 7*).

Table 3 The Ten Steps in Practice: Fisheries of the Murray Darling Basin of Australia

The steps	Past applications	Future possibilities
1. Improve the assessment of biological production to enable science-based management	Regular assessment of river condition is undertaken through the Sustainable Rivers Audit (SRA) (and subsequent surveys; Davies et al. 2010, 2012) but while this does provide CPUE data there is no true assessment of fishery production	Include cultural values, recreational take, illegal take, capture efficiencies, and improved data analysis to provide more effective population estimates and trends, with feedback to management. Production must be linked to flows in this highly variable, semi-arid environment
2. Correctly value inland aquatic ecosystems	Only basic economic valuations have been conducted for recreational fishing (Ernst and Young 2011). No assessments for biodiversity, Indigenous values, or tourism	Conduct a full economic valuation of the ecosystem, the fishery and other stakeholder values, especially to local communities in order to enable comparative assessments
3. Promote the nutritional value of inland fisheries	Not really applicable, but recreational take (Henry and Lyle 2003) does contribute to nutrition as does cultural take that is known to occur in some areas	Include subsistence and cultural take as explicit values of the fishery
4. Develop and improve science-based approaches to fishery management	Existing data (SRA and angler catches) has not been fully utilised and comprehensively analysed to provide an assessment of a Total Allowable Catch (TAC) limit. Adaptive feedback loops to management are limited	Improve surveys (see *Step 1* above, including measure of angler take), data analysis, and the incorporation of predictive modelling with adaptive feedback loops into fishery management to provide a TAC. Link environment and river conditions (e.g., flows) to fishery production
5. Improve communication among freshwater users	Integrated communication between stakeholder agencies (e.g., water, natural resource management (NRM), fisheries) and from agencies to their user groups is somewhat piecemeal and not very effective in a holistic management sense	Include recreational fishers, and conservation, cultural, and social stakeholders. Develop a knowledge transfer and communication strategy from agencies to all user groups that covers all values
6. Improve governance, especially for shared waterbodies	Multi-jurisdictional (includes State, territory and National governments and some agencies) governance structures exist for water infrastructure and delivery but are less coordinated for water rules and auditing use, and limited for natural resource management (i.e., State fisheries and NRM agencies; Koehn 2015)	Include all voices and values (see above) on an equal basis within governance frameworks that engage State agencies, Indigenous representatives and other stakeholder groups
7. Develop collaborative approaches to cross-sectoral integration in development agendas	Formal, inter-jurisdictional committees exist for irrigation and water but are limited, non-formal and non-equal for fisheries, cultural and environmental interests	Establish multi-disciplinary and multi-jurisdictional governance frameworks for fishery, environmental and other non-water values. This includes multi-jurisdictional environmental watering plans and their impacts on these other non-irrigation values
8. Respect equity and rights of stakeholders	Irrigation currently drives most management such that many other stakeholders are not engaged in the process	Increase recognition of other values. Need to ensure that adequate water is allocated for non-irrigation values
9. Make aquaculture an important ally	Provides some native species for re-stocking. This is currently undertaken by State agencies, within their jurisdictional boundaries. Currently included in some fishery and recovery plans but this is mainly for larger, recreational species. This needs to expand to other threatened species for their recovery (Murray-Darling Basin Authority 2020)	Formally incorporate quality control of stocking procedures through licensing arrangements. Warrants coordination between States to provide a Basin-wide perspective. A valuable component of recreational fishery and threatened species management; this needs to include smaller, forgotten, non-recreational species

Successes and challenges

A Murray-Darling Basin Plan (Murray-Darling Basin Authority 2010, 2011) has proven to be politically controversial, being both expensive and difficult to implement (Koehn 2015; Murray-Darling Basin Authority 2010, 2011). It involves changing existing, long-entrenched views regarding unfettered access to water for irrigation, whilst largely ignoring other values such as socio-economic benefits (recreational fishing, tourism), biodiversity and conservation (including threatened species) and the cultural importance to Indigenous nations (Noble et al. 2016). It would be much more beneficial to incorporate all values (i.e., cultural, social, recreational, economic, biodiversity, conservation, agriculture, irrigation) as foundations of a more inclusive and sustainable management model which would better align with the Ten Steps (especially *Step 6,7*). While economic data for agricultural production are relatively easy to obtain, this is not so for other important sectors that rely on an intact MDB such as recreation and tourism (Koehn 2015). Initial assessments of the economic contribution of recreational angling to the MDB have indicated that they are up to AUS$1.7 billion annually (Ernst and Young 2011). It is anticipated that this value would increase substantially with the implementation of the Basin Plan (Colquhoun 2015; *Step 2*). The multi-jurisdictional framework of both the Basin Plan and the Native Fish Strategy (NFS) (Koehn and Lintermans 2012; Murray-Darling Basin Commission 2004) provide powerful governance structures that can effectively incorporate the views of all stakeholders. Strategies are needed to ensure that these views are transferred meaningfully to the political decision makers so that the diversity of voices in the MDB are heard when developing management strategies for the MDB (*Steps 5, 6*).

Future possibilities (See Table 3)

The Murray-Darling Basin Plan was developed to reduce the consumptive use of water and thereby provide additional water for environmental benefits such as fish (Murray-Darling Basin Authority 2010, 2011; *Step 7*). In addition to water allocation, a range of other threats to the MDB fish and fisheries were also identified that needed to be addressed for sustainable fisheries (e.g., barriers to movement, water quality, habitat condition, non-native species) (Koehn and Lintermans 2012; Baumgartner et al. 2019). Additionally, the NFS (no longer funded; Koehn et al. 2014), provides a more holistic approach, incorporating environmental flow and other actions to address multiple objectives (Murray-Darling Basin Commission 2004; *Steps 5, 7*). It also harnessed significant community support and engendered cooperation across jurisdictions, adding voices of other stakeholders, including Indigenous peoples and recreational fishers (Koehn and Lintermans 2012; *Step 8*). There is also need for ongoing fisheries assessments (*Steps 1, 4*) to inform management actions and allow for refinements.

Fisheries of the Tonle Sap Lake of Southeast Asia

Fishery overview

Tonle Sap located in Cambodia is the largest lake in Southeast Asia. This lake has a unique reverse flow system; during the monsoon wet season, it floods by up to 9 m depth which results in a six-fold increase in surface area (Kummu 2003), providing important habitat to approximately 300 species of fish. These species can be broadly characterised as those that migrate long distances throughout the Mekong River system, those which migrate short distances into local tributaries, and those which are local floodplain residents (Valbo-Jørgensen et al. 2009). The fishes are harvested by hundreds of different types of fishing gears exploiting the different life history strategies and habitat use of the fishes (Deap et al. 2003). Around one million people live on or around the Tonle Sap Lake, most of whom are dependent upon the fishery for their livelihoods and nutrition. Average annual fish production for the Tonle Sap Lake and its floodplain has been estimated to be approximately 350,000 tonnes (Mekong River Commission 2018).

Past applications (See Table 4)

Following the disbandment of the traditional lot licencing system in 2012, the Tonle Sap fishery is now essentially unregulated and indiscriminate (Ratner et al. 2014). Although the lot system was replaced with community management, this, along with government enforcement of fisheries law, has proven ineffective at a broad scale due to challenges with

Table 4 The Ten Steps in Practice: Fisheries of Tonle Sap Lake of Southeast Asia

The steps	Past applications	Future possibilities
1. Improve the assessment of biological production to enable science-based management	Considerable effort has been expended in expanding fish catch monitoring on the Tonle Sap lake, particularly focussing on measuring the daily and weekly catch of artisanal fishers. Longer-term datasets have also been extensively analysed, revealing new insights into the structure and dynamics of the Tonle Sap fishery. However, this effort is largely reliant on foreign funding	Scale up current efforts more broadly across the Tonle Sap system. Embrace new approaches such as eDNA and bioacoustics monitoring for supplementing current fisheries-dependent monitoring efforts. Secure sustainable funding to support the required broad scale biological assessment
2. Correctly value inland aquatic ecosystems	Various attempts have been made to estimate the economic value of the Tonle Sap lake fishery, whilst a consolidated assessment of its ecosystem services has not yet been made. However, when held up against other development activities (e.g., hydropower development) the economic, social and cultural values of the Tonle Sap fishery, and that of the Mekong as a whole, have been drastically undervalued in the decision-making process (e.g., Intralawan et al. 2018)	The ecosystem services provided by the Tonle Sap lake and its local catchment are currently being assessed using the Freshwater Health Index framework (Vollmer et al. 2018). Measure future changes against this assessment; use it to gain insight into services that are difficult to measure due to data gaps and to identify services that are under stress
3. Promote the nutritional value of inland fisheries	Fish are a vital source of nutrition in Cambodia (Vilain et al. 2016) and 37% of Cambodian's total protein and iron intake comes from fish (IFReDI 2012). Considerable work has gone into promoting the nutritional value of fish in Cambodia. Much of this has focussed on community level education programmes to ensure that people get the most nutritional value out of the fish they catch and consume	Ensure that relevant government bodies are aware of the immense nutritional value of inland fisheries resources. Relatedly, further expand community education programmes, which are largely led by NGOs, to improve Cambodians' knowledge of fish as a nutritious source of food and increase the value they place on the Tonle Sap Lake fishery
4. Develop and improve science-based approaches to fishery management	The Tonle Sap is a largely unregulated indiscriminate fishery. Whilst moves have been made to give control of the fisheries resources to local people with a government led 'deep fisheries reform' in 2012 (Cooperman et al. 2012), most communities lack the technical, management, financial, and enforcement capacity to manage their own community fisheries	A variety of NGOs, in collaboration with the Cambodian Government Fisheries Administration, are working to develop the capacity of Community Fisheries (CFis). Encourage long-term commitments of at least five years to build each CFis financial and human resources capacity so that they can effectively monitor their fishery and its resource base (e.g., flooded forest extent and condition)
5. Improve communication among freshwater users	The importance of the Tonle Sap Lake fishery is recognised both in the published literature and by the Cambodian Government Fisheries Administration (e.g., IFREDI 2012). Its importance is frequently highlighted by the Mekong River Commission (MRC) such as through the Catch and Culture newsletter, and the voluntary Mekong Fish Network. However, among the lake's fishing communities the impact of flooded forest destruction and degradation in causing declining fish catches is often underappreciated, as most people attribute the declines to overfishing and the impacts of upstream hydropower development (Eyler 2019). This reveals a lack of communication of current scientific knowledge to local communities	Invest in more efforts to disseminate relevant information to the lake's fishing communities in locally relevant and understandable formats. Due to low levels of literacy within fishing communities information is best delivered as flip chart or slide show presentations during community movie nights, backed up by simple infographic sheets with limited text in the Khmer and Vietnamese languages. A board game that simulates fishing activity and rewards sustainable practices has also proven useful. The opportunity also exists for communities to collect their own data through recording their daily fish catch. The rapid collection and collation of these data are becoming more feasible due to advances in digital technology. Importantly, it enables communities to understand trends in fish catch and inform government agencies of their local experience and needs

Table 4 continued

The steps	Past applications	Future possibilities
6. Improve governance, especially for shared waterbodies	Within the Tonle Sap, CFis manage local fisheries resources. The Cambodian Government's Tonle Sap Authority (TSA) coordinates the management, conservation, and development of the Tonle Sap Lake region. And the Cambodian National Mekong Committee (CNMC) plays a secretarial role in coordinating the management, study, conservation, and development of water resources in the Cambodia Mekong River Basin. Regionally, the Tonle Sap lake is covered under the 1995 Mekong Agreement	Improve capacity and increase resourcing for governance systems that are effective and inclusive. Use the transboundary impact of dams to provide an impetus for more transboundary cooperation. Ensure that China is involved in the development of the Lancang-Mekong Cooperation (LMC) sub-regional mechanism to improve transboundary cooperation, although there are grounds for scepticism as to whether this mechanism can improve environmental conditions (Biba 2018)
7. Develop collaborative approaches to cross-sectoral integration in development agendas	Despite the extensive efforts of the Mekong River Commission and others to determine the impact of hydropower development on ecosystem services—and inland fisheries in particular (ICEM 2010; Intralawan et al. 2018; MRC 2018)—the value and integrity of the Tonle Sap Lake fishery has been consistently traded-off in favour of dam construction	Continue to support existing institutions, such as the MRC, TSA and CNMC, to promote cross sectional discussions. These institutions, and potentially with the LMC, should continue to promote the value of inland fisheries in both the discussion of new dam developments, and also present the need to modify existing dam operations to provide environmental flows
	Clearance of the Tonle Sap flooded forest for agriculture, both by small holders and more powerful outsiders is seemingly undertaken either in ignorance or disregard of the forests value to the fishery (*cf* Eyler 2019)	Expand the successful Fisheries Coordination Team mechanism, which brings together fishing communities and district and provincial government officials to address fisheries issues, to all six provinces bordering the lake
		Engage in efforts to educate relevant actors about the role of land use activities on fish and fisheries
8. Respect equity and rights of stakeholders	Fishing communities who live on the Tonle Sap Lake are economically marginalized. Most are landless and have few livelihood options outside of fishing. The Tonle Sap Lake is an open access resource which many non-residents visit to fish (often using illegal methods) and exploit the flooded forest. This presents a management challenge to under-resourced CFis	Improve the capacity of CFis to manage their own natural resources; this will improve both their connection to the lake and the respect with which this relationship is treated. For example, CFis can be strengthened by improving their human capacity, which will improve governance; increasing their financial capacity, which allows greater patrolling of community protected areas; and increasing government engagement through the Fisheries Coordination Team mechanism which will improve both management and fisheries law enforcement
9. Make aquaculture an important ally	Aquaculture on the Tonle Sap lake is minimal compared to the wild capture fishery. However, the impact of current aquaculture practices on the Tonle Sap lake fishery are generally negative. Siamese crocodiles are grown in pens on the lake and are fed wild-caught fish and water snakes which have suffered population declines (Brooks et al 2007, 2010). The popular, although illegal, aquaculture fish, snakehead, is a voracious consumer of wild-caught fish. Large volumes of wild-caught fish are exported to the Mekong delta in Viet Nam to feed *Pangasias* aquaculture. Yet, poor practices often result in large volumes of fish spoiling in transit	Investigate and implement methods to reduce the impact of current aquaculture practices on the Tonle Sap's wild fishery. Aquaculture is seen as a solution to the continued decline in the Tonle Sap's wild caught fishery and is likely to expand. It is essential that future aquaculture developments be managed as part of an ecosystem-based approach. Obtain better data on how fish in Tonle Sap are either used directly for food or used as material for feeding fish in aquaculture and their relative environmental impacts (i.e., which one is better/worse from different perspectives)

implementation (i.e., a failure of *Step 6*). The resulting lack of a sustainable management program has impacted the fishery by reducing the catch of medium- to large-bodied species and increasing the catch of small-bodied species. Overall, the latter has compensated for the former with overall catch biomass remaining stable (Ngor et al. 2018). However, the ecological integrity of Tonle Sap is threatened by continued effects of heavy fishing, increasing degradation of the lake and its flooded forest ecosystems, upstream hydropower development that alters the lake's flooding regime and blocks migratory pathways, and stressors related to climate change (emphasizing need for *Step 7*).

Successes and challenges

The ability of local communities to understand and manage their own fisheries resources has been demonstrated in some cases (*Step 6*), albeit at a small scale. More broadly, however, fisheries declines have still been noted. A range of international and local NGOs have been working with Community Fisheries (CFis) and the Cambodian government Fisheries Administration to improve their management capacity given that current efforts could benefit from improvements (*Step 4*). These efforts should focus on improving governance, such as assisting with the development and implementation of management plans, conducting community patrols, and undertaking quantitatively reliable fish and wildlife monitoring programs to inform management (*Step 1*) and allow for better valuation (especially nutritional value; *Step 3*). This bottom-up approach can influence the two crucial needs identified above. By conducting patrols and reporting illegal activities to local authorities, some communities have observed increased compliance. Similarly, the establishment of Fisheries Coordination Teams, an initiative of local NGO ANKO and Conservation International (CI), has successfully brought together community fishery representatives and local authorities to collaboratively solve fisheries issues (*Step 5*), such as illegal activity within community fisheries. To address the need for funding, CI established US$ 5000 CFis mini-trust funds. CFis use the investment interest ($\sim$ US$ 350 per year) to partially fund their activities. This has been successful in attracting additional co-financing from both the government and the villagers themselves, but it is unclear if this funding is sustainable. Whilst these activities, along with a range of other community development and conservation programs implemented by NGOs, have proven successful to date, they have, to our knowledge, been implemented in less than 100 of the lake's 1200 villages.

Future possibilities (See Table 4)

As detailed in Cambodia's draft Strategic Plan for Fisheries Conservation and Management 2019–2028, the two crucial elements needed for sustainable management of Cambodia's fisheries are the political will to enforce compliance and sufficient funding for regulation and management. Significant scaling up of NGO-led efforts to support and improve community-based fisheries management (*Step 6*) may assist with achieving the Ten Steps. Currently, few CFis, including even those that have received NGO support, are self-sufficient; yet, under the current governance regime, community management is a vital component of sustainably managing the fishery. Dealing with the major changes in the fishery that have only just begun to emerge as a result of climate change, agricultural intensification, and hydropower development (Mekong River Commission 2018), which present significant challenges to the sustainable fisheries productivity of the Tonle Sap ecosystem (*Step 7*). Initiatives to tackle these difficulties are being developed by the Joint Environmental Monitoring programme established by the Mekong River Commission, which is making some progress towards alignment with *Step 7* (Mekong River Commission, 2018). Responsible aquaculture (*Step 9*) may serve as a means of reducing pressure on wild fisheries.

Arapaima fishery of the Brazilian Amazon

Fishery overview

A variety of fish species found within the Brazilian Amazon support large commercial and artisanal fisheries that provide food and income for millions of people (Junk et al. 2007). One fish of cultural and economic importance is arapaima (*Arapaima* spp.), which is traditionally harvested by harpooning when they surface to breathe air (Veríssimo 1895). Their large sizes (up to 200 kg and 3 m in length) and high market value stimulated increased fishing pressure

through the 1950s. Although formal stock assessment programs did not exist, perceptions of overfishing, concerns about food security, and failed attempts by government agencies to manage the fishery in the 1980s (Castello and Stewart 2010; Cavole et al. 2017) prompted the Catholic Church to begin a grassroots movement to improve community organization and management of floodplain lakes and their fisheries (Lima et al. 1999). As numbers of self-managing communities increased, a community-science model for arapaima community-based management (CBM) was developed by the Mamirauá Sustainable development Institute in collaboration with the regional fisheries agency (IBAMA) for implementation in protected areas where fishers have exclusive rights over fish resources. In this CBM model, trained fishers annually count the numbers of arapaima individuals in their lakes using a scientifically tested method (Castello 2004). Population count data are used to set harvest quotas, which are determined by fishing communities together with IBAMA (Castello et al. 2009). The effectiveness of this model, as shown by increases in arapaima populations and fishers' revenues (Castello et al. 2011b; Petersen et al 2016; Campos-Silva et al. 2016), has led to its implementation in some 450 communities in $\sim$ 25% of the Amazon Basin area. Its success warrants consideration of similar CBM approaches for other species. The use of fishers' knowledge and their involvement in monitoring to overcome data scarcity, and collaboration of fishing communities with NGOs and government agencies, are lessons that could be applied to other fisheries of the Basin to enhance their future viability and sustainability.

Past applications (See Table 5)

The development of the CBM model allowed fishers to assess fish populations (*Step 1*) and self-regulate harvest rates (*Step 6*). Local recognition of the economic and livelihood value of the arapaima fishery (*Steps 2, 3*) has prompted communication and collaborative work among stakeholders directly involved in arapaima fishing and management (*Step 5*) to sustainably manage stocks (*Steps 5, 6*). However, although arapaima populations are being managed in an increasing number of communities, there has been a near-complete lack of integration of arapaima CBM schemes with other fisheries and broader-scale intersectoral activities, stakeholders/rightsholders, and threats (e.g., hydropower planning and agriculture) (*Step 7*). There is also virtually no communication between arapaima stakeholders and stakeholders from other sectors (e.g., cattle ranching; *Step 5*) and few programs exist to discuss, reconcile conflicts about, and govern the shared use of water bodies (Crampton et al. 2004; McGrath et al. 2008). There is an urgent need to develop and implement multi-sector, region-wide, community-driven governance structures for shared management of Amazonian floodplains (*Steps 6, 7*). This must begin within individual communities, then be scaled up to increasingly larger jurisdictional scales. Widespread use of the CBM model across the Amazon will require improved biological knowledge of these fish in diverse habitats (*Step 1*), scaled up cross-sectoral collaboration (*Step 7*), and enhanced governance structures at multiple scales (*Step 6*), from fishing communities, to regions, to the whole Basin.

Successes and challenges

Conventional approaches to fisheries management based on collection of fisheries statistics and top-down rule enforcement often fail in tropical, developing countries without sufficient governmental capacity to manage diverse fish populations over large geographical areas. While CBM comes with unique challenges (e.g., leadership, patrolling, rule enforcement), the case of arapaima CBM demonstrates the importance of active fisher participation and investment for effective assessment (*Step 1*) and management (*Steps 4, 6*) of a tropical, developing country fishery. Fishers were only able to use their knowledge to develop sustainable arapaima fisheries because of community organization work done decades before, highlighting the importance of building social capital to enable fisheries management (*Step 8*). Fishers and their communities have much to contribute to fisheries science and management. Their contributions will accrue when governmental and non-governmental organizations collaborate with them to promote and facilitate their roles as integral components of fisheries management programs (*Steps 5, 6, 7*). Challenges remain with aquaculture production of which need to be overcome to potentially reduce pressure on wild stocks in some regions (*Step 9*).

Table 5 The Ten Steps in Practice: Arapaima Fishery of the Brazilian Amazon

The steps	Past applications	Future possibilities
1. Improve the assessment of biological production to enable science-based management	A scientifically tested, standardized procedure exists for population counts. Local fishers use visual and acoustic cues to count the number of individual fish at the time of their surfacing (required for respiration) for 20-min periods in lakes during the dry season (Castello 2004). Fishers and associated stakeholders (including the regional fisheries agency (IBAMA)) then jointly use the count data to determine conservative harvest quotas. The current approach incorporates some biological assessment (e.g., collection of scales for age-growth, population responses to management); however, key gaps include genetic work to understand the existence and distribution of species and subspecies, and cross-ecosystem variability in stock recruitment and age-growth estimation. Although arapaima populations are censused in thousands of floodplain lakes by fishers, region-wide fisheries statistics and formal stock assessments are lacking	Combine data from arapaima community-based management (CBM) schemes with stratified sampling of unmanaged fisheries to produce a regional assessment
2. Correctly value inland aquatic ecosystems	The value of freshwater ecosystems in the Amazon is widely acknowledged by local stakeholders; however, regionally there is a tendency to under-value their economic and ecological importance relative to terrestrial forested ecosystems and agro-ecosystems	Conduct comprehensive assessment of the services and economic value provided by Amazonian fisheries and the Amazonia freshwater ecosystem as a whole (Castello et al. 2013) with a focus on cultural and economic values of fisheries
3. Promote the nutritional value of inland fisheries	The nutritional value of fisheries in the Amazon Basin is undisputed, with mean per capita rates of fish consumption estimated to be on the order of 40–94 kg/yr (Isaac and Almeida 2011). As such, malnutrition is often of low concern. Little effort has been made to promote arapaima specifically for its nutritional value outside of rural fishing communities	Prioritize education on the health benefits of wild fish, particularly in rapidly developing river communities and urban cities; partner with NGOs to disseminate information widely and effectively
4. Develop and improve science-based approaches to fishery management	Despite the apparent effectiveness of current practices involved in the arapaima CBM model, improvements via investments in research could further promote the sustainability of the fishery in the region. Gaps include studies of biological or behavioral variability across diverse habitat types (e.g.,changes in breathing behavior, movement) to inform adaptive management	Improve understanding of biology and ecology of the fish and methodological procedures involved in fishers' assessments and harvest quota determinations. Apply emerging technologies (e.g., GPS tracking, eDNA, drones for habitat monitoring or monitoring for illegal fishing) to study arapaima in natural settings with non-invasive methods
5. Improve communication among freshwater users	Communication among stakeholders directly involved in arapaima fishing occurs at small scales but is hampered at larger geographical scales due to relative lack of means of communication and transport. NGOs and local protected area personnel promote cross-community engagement. However, competition for floodplain resources such as fish, land, and forests create many inter-sectoral conflicts, and are addressed via communication in only a few regions (McGrath et al. 2008)	Scale up communication from fishing communities to state and federal levels (e.g., regional fisheries agency, Brazilian Institute of Environment and Renewable Natural Resources, and agencies within the Ministry of the Environment and Ministry of Science and Technology). Such efforts are complex due to the remote locations of fishing communities and limited access to state or federal government

Table 5 continued

The steps	Past applications	Future possibilities
6. Improve governance, especially for shared waterbodies	Current management and conservation strategies include water resources legislation, protected areas, climate and land use policies, and environmental licensing of hydroelectric dams, which together have potential to protect Amazonian floodplains and their fish populations In the case of arapaima, fishing communities report their catches to the governing body for natural resources (Brazilian Institute of the Environment and Renewable Natural Resources) and jointly set harvest quotas	Develop a conservation framework similar to the multiple-use zoning framework proposed by Abell et al. (2007), which integrates various freshwater ecosystem use strategies occurring inside and outside protected areas into a whole basin-management strategy that balances human uses and ecosystem integrity. Such a framework is more likely to succeed if it is developed through collaborative partnerships involving science institutions, public management agencies, local communities, and the private sector (Poff et al. 2003)
7. Develop collaborative approaches to cross-sectoral integration in development agendas	There are no multi-sector, region-wide governance structures for shared management of Amazonian floodplains	Improve governance for arapaima through the formation of regional sub-committees (e.g., Purus River council). Mid-level governance is necessary to bridge local and federal governance decisions
8. Respect equity and rights of stakeholders	While the cultural values, beliefs, knowledge, social organization, and diverse livelihood practices of Indigenous people, inland fishers and their communities are relatively well understood, lack of governance structures for shared management of Amazonian floodplains impedes their proper accounting in management decisions	Build the bridge between formal state-led governance mechanisms and customary approaches to management of inland fisheries. Build on traditional ecological knowledge and traditional management approaches. Seek means to integrate recognition of traditional management into state-led management regimes and local governance frameworks. Cross-link to the guidance of the FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (VGSSF) and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries, and Forests (VGGT)
9. Make aquaculture an important ally	Many of the same characteristics that make arapaima suitable for CBM make them ideal fishes for aquaculture. This has spurred many aquaculture initiatives (e.g., lower Amazon, Santarem) that are increasingly taking over the market share of artisanal fishers. This market competition undermines the economic value that fosters arapaima CBM, thus threatening the only promising approach to conserve arapaima fisheries. Thus, current aquaculture practices cannot be considered an ally of wild arapaima fisheries management	Estimate total aquaculture production of arapaima in relation to wild-caught harvests and to understand the extent to which aquaculture arapaima is captive-bred or simply the product of wild-caught juveniles grown in tanks. It is also necessary to identify means to avoid or conciliate market competition between wild-caught and aquaculture products. This includes understanding deflation or decreased market values in CBM from aquaculture activities and potential for market diversification to reduce competition

Future possibilities (See Table 5)

There is a major need to build upon successful management strategies, such as the arapaima CBM model, to develop similar strategies for other fisheries (*Step 6*) as well as develop a multiple-use zoning framework in Amazon floodplains. Such a framework would need to integrate various freshwater ecosystem use strategies including fisheries into a whole Basin management strategy that balances human uses and ecosystem integrity (Castello et al. 2013; *Step 7*). Such a framework is more likely to succeed if it is developed through collaborative partnerships involving science institutions, public management agencies, local communities, and the private sector (Poff et al. 2003; emphasizing need for *Step 5*). The framework could be operationalized basin-wide under the Amazon Cooperation Treaty, which was signed by all Amazonian countries, in part to address freshwater ecosystem issues. Integrating local values and

knowledge into governance structures would be of great benefit (*Step 8*).

Pacific salmon fishery of the Columbia River of North America

Fishery overview

The Columbia River's present-day freshwater fishery consists of treaty-fisheries that are regulated by the Columbia River treaty Tribes (Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Warm Springs Reservation of Oregon, Nez Perce Tribe, and Confederated Tribes of the Umatilla Indian Reservation) and non-treaty commercial and recreational mainstem fisheries focused on anadromous salmonids (*Oncorhynchus* spp.) and white sturgeon (*Acipenser transmontanus*; e.g., Joint Staff Report 2018). There are also ceremonial and subsistence tribal fisheries in the mainstem and tributaries, including harvest of Pacific lamprey (*Entosphenus tridentatus*; CRITFC et al. 2018). Tributary recreational fishing occurs for anadromous salmonids and resident fish such as Kokanee (*O. nerka*) and various trout species (WDFW 2018). Most of the native fish species supporting fisheries (e.g., Pacific salmon) have declined since the early 1900s due to overharvesting, habitat modification, and development of hydroelectric dams, resulting in some fish being extirpated or listed under the U.S. Endangered Species Act (Leonard et al. 2015).

Past applications (See Table 6)

Management, mitigation, and recovery efforts of the Columbia River's fisheries and ecosystem are informed by science-based assessments (e.g., Leonard et al. 2015; HSRG 2009; ISAB 2018, ISRP 2018; *Steps 1, 4*). The importance of applying an ecosystem-based approach to management is recognized both legally and scientifically (Northwest Power Act, §839b(h)(1)(A)); ISAB 2011; Cosens and Williams 2012), and policy and management decisions frequently consider effects of proposed actions on multiple species (as opposed to single species approaches) (Leonard et al. 2015; TMT 2003). Despite growing collaboration among management entities, holistic, ecosystem-based management remains challenging partially due to the complexity of mixed stock fisheries, and because the responsibilities of the different management entities can be ambiguous, overlapping, and conflicting (*Step 7*). While ecosystem-based management remains imperfect in practice, it is the overarching goal in managing Columbia River fisheries and their habitat (NPCC 2014; Leonard et al. 2015). An important shortcoming in assessments of the Columbia River fisheries is the paucity of information on their economic, cultural (especially for Indigenous communities), nutritional, and social values (*Step 2*), although there are ongoing efforts to compile this information throughout the Columbia River Basin (e.g., IFR 1996; WDFW 2011; Flores et al. 2017). Commitment to regular assessment and communication of these valuations to stakeholders/rightsholders (*Step 5*) and policy makers would garner support for mitigation efforts and increase investments in improving fisheries management tools (*Step 4*). From a political perspective, there are several international, federal, state, and tribal legal agreements that inform governance of water use, hydroelectric dam operations, and management of fisheries on the Columbia River. This complexity necessitates consideration of the diversity of values held by the rights holders (Harrison 2018; PEB 2008; Cosens and Williams 2012; *Step 8*), and the implementation of collaborative approaches (including extensive communication among stakeholders/rightsholders; *Step 5*) to achieve sustainable management of these resources (Woods 2008; Coordinated Assessments 2018; TMT 2003; State of Washington et al. 2018).

Successes and challenges

The construction and operation of hydroelectric dams on the Columbia River have, along with other factors (e.g., land use change), significantly impacted native anadromous and resident fish species (Leonard et al. 2015). Although there have been significant advances in biological assessments of fish populations following hydropower construction (Ferguson et al., 2011), more can be done to assess potential impacts before development occurs. For example, the development of the hydroelectric system without accounting for the value of the Columbia River's fisheries (USBOR 1938) resulted in negative impacts to fisheries, economic losses, the violation of cultural and social values of diverse stakeholders/rightsholders, and the loss of access to Tribes' first foods (e.g., IFR 1996;

Table 6 The Ten Steps in Practice: Pacific Salmon Fishery of the Lower Columbia River of North America

The steps	Past applications	Future possibilities
1. Improve the assessment of biological production to enable science-based management	Assessments of freshwater salmon and steelhead are well developed, using a variety of assessment approaches and tools including drones, remote-sensing, genetic tagging, eDNA, PIT-tag array detection at dams and in tributaries, and life-stage specific modeling. Assessments of other freshwater species do not have the same level of investments but do benefit from advances from salmon/steelhead work. Recent focus is on improving the delivery of data from field to databases and on coordinating reporting indicators	Increase investment in advancing assessments of resident fish species, white sturgeon, and Pacific lamprey. Improve and maintain investments in regional databases for biological assessment data. Further support collaborative coordinated assessments that recognize participants equally (not defer to the major funding entity) to inform reporting indicators used in decision-making
2. Correctly value inland aquatic ecosystems	The importance of fisheries, fish, and their ecosystem is recognized under the Northwest Power Act which effectively drives decision-making to consider both the value of hydroelectricity and natural resources in the Columbia River Basin (NPCC 2014). Assigning a value to these resources to inform decisions tends to be limited to individual federal, state, and some tribal agencies assessing the economic value of fisheries for their portion of the river or species within their jurisdiction (e.g., WDFW 2011). The cultural and social values associated with these fish species cannot be captured by economics alone, nor the impacts of declining access to the Tribes' first foods; efforts to measure these are ongoing (e.g., Flores et al. 2017)	Work with the federal, state, and tribal agencies to regularly summarize the economic benefits from direct and in-direct use of the Columbia River fisheries, water, and habitat to provide a more balanced discussion among water-user sectors (e.g., hydropower, agriculture) Achieve a shared understanding and recognition of the cultural and social values of fish species and their ecosystems that go beyond their economic value Incorporate fisheries and ecosystem services in the current negotiations of the Columbia River Treaty between the United States and Canada that guides cooperative development and operation of Columbia River water for flood control and power would contribute to conveying the value of the ecosystem along with that of flood risk management and hydroelectricity (CRS 2019)
3. Promote the nutritional value of inland fisheries	Individual federal, state, and tribal agencies promote fishing and communicate nutritional value along with food advisory consumption (e.g., Oregon Health Authority's Fish and Shellfish Consumption)	Improve access to fish that are safe to consume by addressing the contaminant sources and decreasing the need for consumption food advisory. Broaden support for non-native fish suppression programs and make these fish available for human consumption
4. Develop and improve science-based approaches to fishery management	Current fishery management in the Columbia River are founded in science-based approaches, utilizing the best available monitoring technology and adapting as new information/technology becomes available (Leonard et al. 2015)	Advance consideration of climate change impacts on Columbia River fisheries Improve the digital capture and transfer of data from field to regional repositories for informing decisions, especially for shared fisheries or fish species listed under the Endangered Species Act
5. Improve communication among freshwater users	There is an ongoing effort to provide easily understood information to all interested parties about the status of habitat, fish, and fisheries. Federal, states, and Tribes have been improving online access to their information in an easily understood and accessible format leveraging ESRI dashboards, story maps, infographics, and social media (e.g., Coordinated Assessments 2018; Yakama Nation Fisheries 2019)	Improve access to derived fish, habitat, and fisheries reporting indicators in a format easily understood by the public; this would enhance understanding of the role of fisheries in the Pacific Northwest Target outreach and education to sectors that impact freshwater resources (e.g., agriculture, hydropower) to improve recognition of fisheries and their ecosystem in their decision making and identify win–win scenarios

Table 6 continued

The steps	Past applications	Future possibilities
6. Improve governance, especially for shared waterbodies	Inland fisheries management is well coordinated within the Columbia River where jurisdictions overlap. Agreements exist to guide management activities between federal, state, and tribal authorities (e.g., *United States v. Oregon*, Civil No. 68–513-MO (D. Or.)) Management of water flows through Columbia River federal dams is coordinated between federal agencies and federal/state/tribal fisheries management agencies through the Columbia River Regional Forum's Technical Management Team (TMT 2003)	Leverage existing interstate compacts and expand represented managers and other stakeholders to reflect sectors impacting/relying on water resources (e.g., agriculture, hydropower); this would enhance communication among water sectors to coordinate governance of water users and enhance understanding of trade-offs which would allow for more fully informed decision making
7. Develop collaborative approaches to cross-sectoral integration in development agendas	Collaboration between Washington and Oregon, USA in their common boundary along the Columbia River dates back to when these two states (territories) were created by Congress in 1853. The need for consistent fishing regulations to improve fisheries governance in the Columbia River arose in the early 1900s leading to Congress ratifying The Columbia River Fish Compact between Washington and Oregon in 1918. The 1918 Compact is a public forum that reviews technical information, considers testimony, and provides an opportunity to agree on consistent fishery regulations for the waters over which these states have concurrent jurisdictions, which has enhanced significantly policy coordination, sharing of technical resources, and enforcement. In 1969, *United States v. Oregon Civil N. 68–513* provided regulations for treaty Tribes under the Columbia River Compact (Wood 2008) The 1980 Northwest Power Act mandates the Northeast Power Coordinating Council (NPCC) to consider the needs of fish and their habitat while addressing the demand for affordable hydroelectricity in the Columbia River Basin (NPCC 2014). At a finer scale, the Technical Management Team informs in-season hydroelectric dam operations to provide flows for migrating fish (TMT 2003). More broadly, a recent task force established by the National Oceanic and Atmospheric Administration (NOAA) to collaboratively agree upon salmon/steelhead objectives engages stakeholders from NGOs, Tribes, states, the navigation sector, ports, ranchers, fishermen, and others that rely on the Columbia River for their livelihoods/operations to discuss feasible options for achieving the fish objectives (CBPTF 2019)	Expand decision making to be more inclusive of other water-based sectors and agencies to provide a more comprehensive approach to discussing options and trade-offs to benefit society while more deliberately considering the needs of fish and their ecosystem

Table 6 continued

The steps	Past applications	Future possibilities
8. Respect equity and rights of stakeholder and tribal treaty-rights	Legal court case decisions, tribal treaty-rights, and strong lobby groups have provided a strong voice for the rights of affected Columbia River Tribes' rights, commercial fishing industries, recreational fishers, and other stakeholders, as well as the mitigation obligations of hydroelectricity ratepayers and their rights to affordable electricity, and other societal water-related rights (e.g., NPCC 2014; CBPTF 2019)	Improve recognition of fish losses in the upper portion of the Columbia River and its tributaries and invest in mitigating for these losses by investigating options that mitigate closely for the native fish and fisheries historically present Achieve broader understanding of the importance of these fish to Tribal culture, ceremony, spiritual tradition, subsistence, and role in tribal economies, in addition to the non-tribal economic, social, and cultural importance of commercial and recreational fishing. Important to include stakeholders and rightsholders in decision making
9. Make aquaculture an important ally	The role of aquaculture science in regard to stock enhancement (artificial propagation) is recognized in the Columbia River as an important ally for supporting declining fish populations (conservation) and providing harvest opportunities to support commercial, recreational, and cultural rights-based fishing where dams and other factors have resulted in decreased fish abundance (e.g., NPCC NPCC, Leonard et al. 2015). Many of the Columbia River artificial propagation programs are tied to mitigation obligations, Tribal treaty rights and endangered species are intertwined in Columbia River fishery management (e.g. *United States v. Oregon*, Civil No. 68–513-MO (D. Or.))	Improve communication of the value of stocking to the local economy, cultural identity, and nutrition; this would be beneficial to balance the information provided to the public and decision-makers who more frequently learn about the negative impacts of stocking programs

Flores et al. 2017). Given the massive costs of the mitigation investments to address these impacts (US$16.8 billion from 1981 to 2018; NPCC 2019a), it would have been more effective to have used an approach that considered the effects of hydropower development on fisheries prior to their construction, as is now outlined in the 1970 National Environmental Policy Act and 1980 Northwest Power Act. Identifying affected sectors and stakeholders/rightsholders and including them in the decision-making process (*Steps 5, 6, 8*) may be a way to avoid lengthy and expensive litigation (e.g., United States v. Oregon court case, Civil No. 68-513-MO (D. Or.)), which ultimately undermines the capacity for effective collaboration among groups (noting that in this case the legal system provided a strong legal voice for the affected Indigenous communities). The importance of advanced planning to minimize impacts is a lesson that the region (and other regions such as in South America and Asia where large-scale hydropower development is underway) continues to act on, as illustrated by existing agreements to reduce impacts of hydroelectric dam operations on resident fish (e.g., Montana Operations at Libby and Hungry Horse Dams) and weekly in-season water management decisions coordinated by federal dam operators and fish managers through the Technical Management Team (TMT 2003). More recently, the importance of collaboration among sectors to achieve healthy fisheries is demonstrated in the multi-year commitment of the Columbia Basin Partnership Task Force (CBPTF) to collaboratively develop fish abundance objectives and understand the trade-offs for impacted water-sectors (CBPTF 2019; *Step 7*). Challenges remain with accounting for climate change in management to ensure long-term resilience (*Step 4*).

Future possibilities (See Table 6)

The Columbia River fisheries' management approach, valuation, and inclusion in cross-sectoral decisions reflects some of the principles of the Ten Steps; however, further implementation would require an increased focus on leveraging the role of existing interstate compacts as a forum for coordinated ecosystem-based management and cross-sectoral decision making. A dedicated commitment to producing, at least biennial, detailed economic analysis of the Columbia River fisheries and its ecosystem would support more informed decision-making related to mitigation efforts (*Step 2*). Lastly, continued and enhanced investment in the development and maintenance of regional repositories for reporting accepted indicators of fisheries status is critical for informing proper policy and fisheries management decisions.

Lake fisheries of Denmark

Fishery overview

Fisheries in freshwater lakes in Denmark have undergone drastic changes since the 1950s from being mainly small-scale, commercial fisheries (today only performed in < 10 lakes) to recreational fisheries, which are dominated by the angling sector (Skov et al. 2019). Key targeted species are piscivores including northern pike (*Esox lucius*), European perch (*Perca fluviatilis*), and pikeperch (*Sander lucioperca*). Angling in most public lakes is open access apart from the mandatory state angling license. In privately owned lakes, which cover 75% of the total lake area in Denmark (Søndergaard et al. 1999), a fee must typically be paid to the owner as well. Often, only angling from boats is possible due to local nature protection rules (i.e., ban on walking in the littoral zone to protect submerged macrophytes and nesting birds) and landowner rights (i.e., no trespassing on private land). All fisheries are regulated by the national Fisheries Act (Jacobsen et al. 2004) but it is worth noting that social norms and pressures also play an important role in regulating behaviour.

Past applications (See Table 7)

Sustainable management of fisheries is stated as a primary goal of the Fisheries Act in Denmark and aligns with the conservation and improvement of aquatic environments, typically under obligation to the European Union Water Framework Directive (EU WFD). Despite this, basic knowledge on fish population structure and production is limited for most Danish lakes (*Step 1*). Data on aquaculture production are collected and catches for the few remaining commercial fisheries are recorded; however, there are no data collected systematically on the prevalence or frequency of angling, and updated knowledge on the socioeconomic value of recreational lake fisheries is lacking. Management aims to be science-based (even though data are often incomplete; *Step 4*), promote communication among users (*Step 5*), and respect rights of stakeholders (*Step 8*). The rights of landowners are especially strong; ownership of land is guaranteed in the constitution, and the Fisheries Act stipulates that fishing rights cannot be separated from land ownership. Thus, some of the Ten Steps (e.g., *Steps 5, 8, 9*) are relatively well established in management of Danish lake fisheries while the others are not fully met at present.

Successes and challenges

There are some examples where existing activities align with the Ten Steps. For example, the Danish Fisheries Act has a strong focus on sustainability, stating: "The purpose of the Act is to ensure a sustainable basis for commercial fisheries and possibility for recreational fishing, through management that ensures the protection and enhancement of living resources in salt and fresh water, as well as the protection of other animal and plant life" [Ministry of Environment and Food (2019a), author's translation]. In addition, management of inland waters focuses on habitat restoration (as opposed to stocking), emphasizing a recognition of foundational ecological principles, but also aligning with the EU WFD. Moreover, the development of aquaculture facilities that reduce environmental impact (e.g., recirculation systems, purification of runoff, fewer escapees) is progressing rapidly (*Step 9*). Collectively, these regulatory frameworks and strategies provide a foundation of principles needed to achieve healthy and productive ecosystems and fisheries. There is also evidence that the communication paths between research and management are relatively easy to navigate and integrate science into policy decisions (Koed et al. 2020). Finally, EU WFD

Table 7 The Ten Steps in Practice: Lake Fisheries of Denmark

The steps	Past applications	Future possibilities
1. Improve the assessment of biological production to enable science-based management	Estimates of catch per unit effort (CPUE) based assessment of number, biomass, and planktivore/piscivore ratio have been obtained from a few selected lakes for environmental quality management purposes (EU Water Framework Directive (WFD) implementation). Otherwise, there has been no catch/effort monitoring of fisheries	Implement a combination of CPUE based assessment and catch/effort monitoring. Currently an app-based angler catch log system (Venturelli et al. 2017) is being tested and evaluated, and could potentially be added as a supplement to traditional catch/effort monitoring in the future
2. Correctly value inland aquatic ecosystems	A general assessment of the economic and societal value of Danish angling (all fisheries – marine and freshwater combined) was performed in 2010. However, no specific assessment of the economic and social value of single or multiple lakes has ever been conducted	Conduct economic impact analyses and/or site choice studies focused on freshwater systems (e.g. Hunt et al. 2019)
3. Promote the nutritional value of inland fisheries	There is no promotion of the nutritional value of inland fisheries. This is likely because of Denmark's long coastline and proximity to the sea as well as habitual and traditional mechanisms of Danish people to eat dominantly marine fish. Moreover, catch-and-release angling has grown in popularity among anglers, implying an orientation towards recreation rather than consumption. An exception is European eel (*Anguilla anguilla*), which is both currently and traditionally popular to eat fried or smoked. However, due to the drastic population declines of the European eel, its commercial and nutritional importance is rapidly declining	Currently not applicable to Danish lakes for several reasons. For example, it is debatable whether actions in this context would be in accordance with nature protection objectives (e.g. EU WFD implementation), especially when it comes to harvest of predatory fish. Moreover, the biomass of freshwater fish that could be harvested in Danish lakes is relatively small compared to the market for fish products
4. Develop and improve science-based approaches to fishery management	Current regulation of lake fisheries is a mix of rules enforced for biological reasons (i.e., science based) and rules enforced for cultural (historic) or social reasons (e.g., to distribute the resource) Partly based on research showing low success of fish stocking, using this technique as a management tool in lakes is less important than it was previously	Collect site-specific data on fish populations and catch/effort monitoring to secure a stronger science-based approach for local waters Build management structure to implement the use of data reported and to secure sufficient reporting by anglers
5. Improve communication among freshwater user	Implementation of the EU WFD has promoted the formation of so-called regional advisory (municipality level) water councils in 2013. These comprise representatives of all NGO user associations like anglers, farmers, and ornithologists, and have the opportunity to give input to the WFD implementation process. The water councils have facilitated and improved communication among these stakeholders	Maintain the water council structure beyond the WFD implementation period (ends 2027) and expand the duty of the councils to also cover fisheries management

Table 7 continued

The steps	Past applications	Future possibilities
6. Improve governance, especially for shared waterbodies	Fisheries management in Denmark is governed at the national level only. Environmental management of lakes is shared between national and municipality levels and focused on EU WFD implementation. Water bodies shared between two or more municipalities cooperate on EU WFD issues. However, communication between the management bodies of fisheries and management bodies of the environment is scarce	Integrate management of environment and fisheries including active stakeholder involvement in the management process, e.g., through the water councils described under *step 5* In addition, specific action plans could improve implementation of *step 6*
7. Develop collaborative approaches to cross-sectoral integration in development agendas	Historically, inland fisheries in lakes have tended to be marginalised in water resource development. However, exceptions exist where water use development has benefitted lake fisheries, albeit unintentionally (e.g., irrigation using surface water is not allowed; this rule promotes natural water level fluctuations that benefits lake fish reproduction). Industrial development plans in the vicinity of lakes are in most cases hindered by the Nature Protection Act (Ministry of Environment and Food 2019b). Recently, several shallow lakes have been established to increase denitrification, which can create new lake fisheries but inflict a negative impact on diadromous fish species passing the new lake (Schwinn et al. 2019)	Nature conservation issues due to international obligations (like the EU WFD) will most likely continue to be superior to other ways of using lakes in Denmark including inland fisheries However, due to cultural and societal agendas, it is often promoted to regulate water level fluctuations in lakes, especially in lakes near urban areas. Emphasizing the importance of not only restoring water clarity during lake restoration but also restoring natural hydraulic variability would greatly benefit target species like pike and perch in lake fisheries
8. Respect equity and rights of stakeholders	Fishing rights in Denmark are typically owned by the nearest landowner, unless the state or municipality is in charge of a lake. Fishing rights owned by landowners cannot be sold without the adjacent land, and fishing rights cannot be taken from the landowner without full compensation. Thus, the right is fundamental and solid. However, regulation of fisheries enforced by national authorities can affect how the right can be executed Other rights (to sail, swim etc.) are not constituted by law and can be regulated or removed without compensation	Consider if the cultural heritage of different fishing sectors should be maintained during the present period where there is emphasis on expanding angling at the expense of small-scale inland commercial fisheries
9. Make aquaculture an important ally	Although there is no aquaculture directly in Danish lakes, aquaculture is an important business in Denmark with rainbow trout (*Oncorhynchus mykiss*) being the most important species produced. The trend in fisheries management is to focus on habitat restoration rather than compensatory stockings. Hence, producing fish (e.g., brown trout, salmon, and eels) for stocking programmes is a small and diminishing part of this industry	Promote the present trend of applying recirculation technology to fish farms to reduce the need for surface water intake to fish farms, and also reduce the risk of increased nutrient load leading to eutrophication and unintended fish introductions from farms through escape. This trend has apparently already improved the reputation and acceptance of the aquaculture industry in the inland fisheries sector

initiatives linked to Water Councils supports forums for stakeholder involvement (*Steps 5, 6*). The EU WFD states as its main purpose that by 2027 all surface waters and groundwater within the European Union should fulfill the goal of having "good ecological quality". Thus, it is the obligation of all EU member states to assess the ecological quality of all surface waters and, if necessary, initiate actions to fulfill the goal unless the waterbody is classified as "heavily modified."

Future possibilities (See Table 7)

The inland fisheries of Denmark require more assessment of the status and trends of fish populations, along with improved catch and effort monitoring of recreational and commercial fisheries (*Step 1*). Assessments of the human dimension aspects are also necessary, including updated economic impact and valuation studies of recreational fisheries (*Step 2*). Locally, the lack of robust assessment is a major hindrance for science-based fisheries management (*Step 4*) and, in some cases, cross-sectoral integration (*Step 7*). The lack of political engagement can also explain the absence of a specific action plan.

From global to local—the ten steps in practice

At the global scale, the Ten Steps provide a best-practice framework for securing sustainable inland fisheries. By articulating these recommendations in an accessible document (i.e., the Rome Declaration), it was hoped that national and local governments could use this tangible guidance to implement at least some of the suggested steps. However, to date there have been no documented initiatives of coordinated efforts to pro-actively implement the Ten Steps at regional or national levels. Nonetheless, there are examples of ongoing initiatives and actions conducted by regional bodies, governments, and communities that align with the Ten Steps. Across these case studies, there are certain elements of the Ten Steps that are commonly applicable to local management (See Table 8), but, to date, this has tended to be prior to and often coincidental with the existence of the Ten Steps, rather than inspired by them. Moving from 'coincidental alignment' to 'conscious implementation' will require global bodies concerned with inland fisheries to work with regional bodies to promote awareness of the Ten Steps and support efforts to operationalize them. Because local managers and practitioners played an active role in developing the Ten Steps during the 2015 FAO meeting, it is likely that these recommendations will be intuitive to practitioners who have not yet heard of the Ten Steps, and that they will be highly relevant when applied to a wide variety of local management problems. It is noteworthy that none of the case studies presented here engaged in actions that spanned all the Ten Steps. This is unsurprising given that inland fisheries are diverse and disparate, and that application of the Ten Steps requires specific expertise and resourcing requirements. Indeed, given local context varies so much, it is unreasonable to assume that all of the Steps are relevant or necessary in all situations/regions. Actions that align with Steps 2, 7 and 9 have been poorly implemented relative to others but it is unclear why that is the case (e.g., is it because of lack of relevance to a given context, or is it because of a need for funding, capacity building, or other resources?). This underscores the importance of down-scaling the Ten Steps in a way that is relevant to the local context. We are unaware of any strategic initiatives, at any level discussed here, that have pro-actively designed actions to implement the Ten Steps, highlighting the need for sensitization and awareness raising.

Analyses of these case studies revealed that, on a local scale, there were several common actions that aligned with some of the Ten Steps. This was the case for the realms of biological assessment (the foundation of effective management; *Step 1*), improved communication among users (*Step 5*), and better governance, particularly through co-management arrangements (*Step 6*). The reason that these actions (steps) were most common across case studies presumably reflects the fact that in many ways these are the minimal aspects of any science-based fisheries management program. For example, biological assessment informs management which is best achieved through co-management and communication among stakeholders and rightsholders which demands established and effective governance systems. This does not mean that those are the only actions needed but we argue those are the Steps that are most widely recognized as essential. Indeed, for decades these hallmarks of inland fisheries management have been championed by organizations such as the FAO with extensive

Table 8 Extent to which each of the case studies demonstrates how individual Steps have been addressed recognizing that successes are often due to coincidental alignment of local activities with the Ten Steps

	The Ten Steps	Lake Malawi	Murray Darling Basin	Brazilian Amazon	Columbia River	Tonle Sap	Danish Lakes
1	Improve the assessment of biological production to enable science-based management						
2	Correctly value inland aquatic ecosystems						
3	Promote the nutritional value of inland fisheries						
4	Develop and improve science-based approaches to fishery management						
5	Improve communication among freshwater users						
6	Improve governance, especially for shared waterbodies						
7	Develop collaborative cross-sectoral integration in development agendas						
8	Respect equity and rights of stakeholders						
9	Make aquaculture an important ally						

Open (white) boxes indicate negligible progress or alignment, black (filled) boxes indicate significant progress or alignment, and grey boxes indicate moderate progress or alignment. *Step 10* is excluded (i.e., Develop global action plan) given that this is not the task of individual jurisdictions

capacity building and training related to those Steps. However, there is a larger suite of approaches that could be implemented through utilising the global relevance of the Ten Steps to promote a more cohesive approach to inland fisheries management at regional, national and specific-fishery level. For example, the Ten Steps framework can help promote quantitative target setting with measurable indicators of progress toward achieving sustainable, equitable, and socio-economically valuable fisheries. In many ways, the Ten Steps ensure that fisheries are managed in ways that have the greatest potential benefits to a variety of actors and outcomes (ranging from food security to social justice).

Our case studies reveal opportunities where the implementation of the Ten Steps would be of great benefit. For example, within the realm of biological assessment (*Step 1*), there is evidence of little assessment in Lake Malawi and for the lakes in Denmark, while in the Tonle Sap there is some promising progress towards alignment through initiatives such as the Joint Environmental Monitoring programme developed by the Mekong River Commission. Beyond that, quantitative targets and indicators of progress fit squarely into existing instruments and processes

related to aquatic biodiversity (e.g., Aichi targets, Post-2020 biodiversity framework), environmental and water management (e.g., EU WFD, Murray-Darling Basin Plan), agricultural best practice (International Water Management Institute smallholder agriculture water management (AWM)), and the energy sectors (e.g., International Hydropower Association (IHA) guidelines). The identification and tracking of mutually agreed upon indicators to meet defined targets, as suggested by Lynch et al. (2020b), would ensure that inland fish and fisheries are accounted for and incorporated into broader water and landscape management frameworks. These indicators can be identified globally and targets applied locally. What is apparent is that although the Ten Steps may provide useful guidance, in each case they will need to be tailored to be implemented locally for future actions. There is also an assumption that fisheries management is proactive (i.e., planned), yet most of the examples that we share here are reactive, which decreases the likelihood of using frameworks such as the Ten Steps to help guide management. Any efforts to incorporate fisheries management into longer planning cycles and be more engaged and proactive would be useful strategies (Pauly et al. 2003).

More broadly, a key strategy globally is the meaningful integration of inland fisheries into existing international frameworks and initiatives such as the Sustainable Development Goals, the Convention on Biological Diversity, and the UN Decade on Ecosystem Restoration. This must extend generalized catch-all statements of protecting or sustaining freshwater ecosystems to meaningful actions that could be applied locally, recognizing that the local capacity and governance systems vary dramatically among jurisdictions. Here, we are not advocating that inland fisheries are treated as separate entities with their own targets and provisions, but instead that they are recognised as important components of integrated food systems, can support sustainable livelihoods and local economies, and provide leisure and cultural opportunities, like those derived from marine fisheries (e.g., SDG 14) and other ecosystem services provided by freshwater ecosystems (see Lynch et al. 2020b).

From local to global—the Ten Steps in practice

At a local scale, the lessons learned by comparing the case studies show that, although there is a broad diversity of issues facing inland fisheries across the globe, there are commonalities among them that can allow solutions and initiatives in one location to be applicable elsewhere in the world. As implementation and action plans for the Ten Steps are developed, having success stories to draw upon that demonstrate how the Steps can be effectively applied in practice will be important. One of the most obvious areas of consistency across the diverse case studies is that human dimensions must be at the center of discussions on practicing the Ten Steps for responsible fisheries (Kaplan and McCay 2004; Hilborn 2007). For example, the outcomes of the Fisheries and Aquaculture Management session at the conference entitled Strategy for Conservation and Sustainable Development of the African Great Lakes Region in a Changing Climate, held in Entebbe, Uganda (Cowx and Ogutu-Ohwayo 2019) recognised "…that people are the problem, and people are the solution. Different sectors (i.e., activities external to the fisheries sector) a need to understand the motives, modes of operation, and reward systems of other spheres of society to maintain delivery of ecosystem services and help achieve the SDGs."

The case study on arapaima management in the Amazon emphasized the value of community-based initiatives that involved key stakeholders and rightsholders in governance. Co-management arrangements are now becoming common practice in the management of fish stocks at the local level, but caution is needed as these systems do not necessarily lead to desired outcomes of sustainable harvest and management of stocks (e.g., the Tonle Sap case study; Obiero et al. 2015), or they do not function as planned, often due to financial and personnel instability or changing values of the different sectors. Of particular importance is the establishment of appropriate governance and management structures that help include diverse values and voices (especially from rightsholders as per the UN Declaration on the Rights of Indigenous Peoples) in the overall management framework (i.e., the spirit of *Step 6* with support from and relevance to *Step 5* and *Step 8*). This is consistent with an ecosystem approach and recognizes the influence of humans on fisheries systems as well as the influence of

fisheries systems on society at all levels of governance (Beard et al. 2011).

It was also clear that there is a need to recognise that all threats that impact specific fisheries will also influence their ability to implement remedial actions. As outlined by Welcomme (2001) and Collares-Pereira and Cowx (2004), fisheries planning must recognize and account for the threats (e.g., fragmentation, invasive species, pollution, habitat degradation, water resource development, changing climate) and include strategies that mitigate them (e.g., fishways, pollution control measures, alien species management, habitat restoration, screening of abstraction pumps).

Relatedly, an overwhelming theme was the need to think and act in an integrated and holistic manner (i.e., the spirit of *Step 4* but also the rationale for developing an Action Plan—i.e., *Step 10*). Although some case studies provide examples of holistic ecosystem-based approaches (e.g., Lake Malawi, the Columbia River), challenges or deficiencies were noted in these and other case studies. Failing to think holistically will most certainly result in failure to achieve long-term fisheries management and broader societal or environmental objectives. Admittedly, the Ten Steps by virtue of how they are organized, break down what is needed into specific steps but in reality, it is the "whole" (i.e., all Ten Steps) that need to be embraced to achieve sustainable inland fisheries (recognizing that there are some systems for which some Steps may not apply).

We see no need to reinvent the wheel; if a lesson learned in one fishery can be applied to another, there is no need (or desire) to stumble through a similar process to reach the same recommendation when it can be applied immediately. We can learn how "bright spots" (Bennett et al. 2016; Krueger et al. 2019; Jeanson et al. 2021) in inland fisheries management can be applicable in other contexts to inform global actions, or, where challenges have arisen and failures have occurred; this will allow us to tease out the cause and determine affirmative actions to address the problem in the target system. Similarly, by acknowledging what is unique about each local context, we can ensure that management initiatives do not try to "fit a round peg in a square hole." For example, the arapaima example benefits from the fact that the target species are air breathers so their abundance can be assessed by counting surfacing events. Most biological fisheries assessment, however, requires more sophisticated methods and technology (Lorenzen et al. 2017).

Implementation will always have to occur at a local level, although involvement of higher-level management will ensure compliance with national and international governance frameworks; an understanding of what can be applied from global recommendations saves management effort that can be put to better use focusing on specific, local issues. There are inherent challenges to connect these scales. This will undoubtedly require community, stakeholder, rightsholder, and political support at a variety of levels (Cooke et al. 2013). There may be benefit of engaging more directly with regional fisheries management entities (rather than global or local) to help contextualize the Ten Steps given regional variation in culture, socio-economic conditions, governance, and ecosystem properties. Failure to be proactive and thus be prepared for unanticipated events puts entire fisheries, aquatic ecosystems, and human communities at risk. The local case studies presented here serve to provide real examples of the consequences of management challenges and failures and can be used to help stimulate the international community of global thinkers and decision makers to engage, given the manifold impacts of a fisheries collapse on livelihoods, nutritional security, and cultures (Ainsworth et al. 2018).

Conclusions

The Rome Declaration and its Ten Steps provide a global framework for promoting responsible inland fisheries. Although the Declaration is very much a high-level, global initiative, effective implementation benefits from direct engagement from on-the-ground practitioners in its development. It is therefore not surprising that the case studies explored here revealed many instances where regional actions (some of which have been ongoing for decades before the Ten Steps were developed) align with the Ten Steps. Examining this suite of diverse case studies shows that, although there were no instances where regional actions addressed all the Ten Steps, each case study had various actions that aligned well with some of the Ten Steps. We submit that learning from these "successes" will inspire others to embrace the Ten Steps and

modifying them as necessary to adjust to practical implementation will ultimately lead to the "future we want" (UN 2012) with respect to responsible inland fisheries, locally and globally. The case studies presented here both highlight the extent to which bottom-up actions can help to achieve the Ten Steps while also emphasizing how the top-down actions and activities need to align with the reality of practitioners and stakeholders/rightsholders.

Clearly, there is no single path to achieving responsible inland fisheries. Rather, it will require the collective efforts of individuals, organizations, and governments working locally, regionally, nationally, and internationally to come together around a common goal (i.e., sustainable fisheries). This paper provides insights on how that process can progress, and complements efforts to ensure that the Ten Steps are considered when discussing the global state of inland fisheries management, its success, and failures (Lynch et al. 2020a). Moreover, there may be a need to revisit or refine the Ten Steps to address deficiencies identified here (e.g., the need for more holistic approaches to assessment and management; the explicit need for co-management or other participatory frameworks) to enhance their implementation. Finally, it is evident from all case studies is that there is a strong need for political awareness and political ownership of the Ten Steps to encourage explicit involvement in their implementation at all levels. This is a pre-requisite for the additional work needed to enhance awareness about the Ten Steps at the level of the on-the-ground practitioner. It is also clear that some of the Ten Steps are less relevant in some contexts than in others. Thus, there is need for broad communications and engagement with various levels of government and fisheries professionals around the globe. Regional workshops will be needed to build capacity and operationalize the Ten Steps in a manner that respects cultural, socio-economic, political, and ecosystem realities. We submit that the time is right to embark on development of a Global Action Plan complete with the development of culturally sensitive and regionally or locally developed implementation plans.

Acknowledgements Authors are members of the international InFish Research Network (http://infish.org/). Cooke, Kaunda, and Bartley are Robin Welcomme Fellows in Inland Fisheries at Michigan State University. Cooke is further supported by the Natural Sciences and Engineering Research Council of Canada and Genome Canada. Nyboer is supported by a Fonds de recherche du Québec – Nature et Technologies grant from the Government of Quebec, Canada. Berg and Skov received funding from the Danish Rod and Net Fishing License Funds. We appreciate the input provided on an earlier draft of the Columbia River case study by Zachary Penney, Kate Self, Mike Matylewich, Matt Boyer, Bill Tweit, Tucker Jones, and Guy Norman. This manuscript has been internally reviewed by Bo Bunnell (Great Lakes Science Center) for the U.S. Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

References

Abell R, Allan JD, Lehner B (2007) Unlocking the potential of protected areas for freshwaters. Biol Conserv 134(1):48–63

AFDB (2019) Malawi—Sustainable Fisheries, Aquaculture Development And Watershed Management Project—Project Appraisal Report. https://www.afdb.org/en/documents/malawi-sustainable-fisheries-aquaculture-development-and-watershed-management-project-project-appraisal-report

African Union (2015) Agenda 2063: The AFRICA We Want. "A shared strategic framework for inclusive growth and sustainable development & a global strategy to optimize the use of Africa's resources for the benefit of all Africans". Framework Document. Addis Ababa, Ethiopia. September 2015

Ainsworth RA, Funge-Smith SJ, Cowx IG (2018) Chapter 10.3: Assessing Inland fisheries at basin level. In: Funge-Smith SJ (eds), Review of the state of world fishery resources: Inland fisheries. FAO Fisheries and Aquaculture Circular No. C942 Rev. 3. (pp. 317–334). Rome, Italy: Food and Agriculture Organization of the United Nations.

Allan JD, Abell R, Hogan ZEB, Revenga C, Taylor BW, Welcomme RL, Winemiller K (2005) Overfishing of inland waters. Bioscience 55(12):1041–1051

Banda M, Jamu D, Njaya F, Makuwila M, Maluwa A (2005) The Chambo restoration strategic plan. WorldFish Centre Conference Proceedings 71

Bartley DM, De Graaf GJ, Valbo-Jørgensen J, Marmulla G (2015) Inland capture fisheries: status and data issues. Fish Manage Ecol 22:71–77

Baumgartner LJ, Finlayson CM (2019) A good plan to help Darling River fish recover exists, so let's get on with it. The Conversation. https://theconversation.com/a-good-plan-to-help-darling-river-fish-recover-exists-so-lets-get-on-with-it-110168 (Accessed 2.06.19)

Baumgartner LJ, Deng ZD, Ning N, Conallin J, Lynch AJ (2019) Irrigation, fisheries and Sustainable Development Goals: the importance of working collaboratively to end world hunger and malnutrition. Mar Freshw Res 70(9):i–iii

Baumgartner LJ, Gell P, Thiem JD, Finlayson C, Ning N (2020) Ten complementary measures to assist with environmental watering programs in the Murray–Darling river system, Australia. River Research and Applications rra.3438. doi:https://doi.org/10.1002/rra.3438

Beard TD Jr, Arlinghaus R, Cooke SJ, McIntyre PB, de Silva S, Bartley D, Cowx IG (2011) Ecosystem approach to inland

fisheries: Research needs and implementation strategies. Biol Let 7:481–483. https://doi.org/10.1098/rsbl.2011.0046

Benfica R, Thurlow J (2017) Identifying Investment Priorities for Malawian Agriculture. Project Report. https://pim.cgiar.org/files/2017/04/IFPRI-IFAD-PIM-Malawi-Presentation.pdf

Biba S (2018) China's 'old' and 'new' Mekong River politics: the Lancang-Mekong Cooperation from a comparative benefit-sharing perspective. Water Int 43(5):622–641. https://doi.org/10.1080/02508060.2018.1474610

Bogard JR, Hother AL, Saha M, Bose S, Kabir H, Marks GC, Thilsted SH (2015) Inclusion of small indigenous fish improves nutritional quality during the first 1000 days. Food Nutrit Bull 36(3):276–289. https://doi.org/10.1177/0379572115598885

Brooks SE, Allison EH, Reynolds JD (2007) Vulnerability of Cambodian water snakes: Initial assessment of the impact of hunting at Tonle Sap Lake. Biol Cons 139(3–4):401–414

Brooks SE, Allison EH, Gill JA, Reynolds JD (2010) Snake prices and crocodile appetites: aquatic wildlife supply and demand on Tonle Sap Lake. Cambodia Biol Conserv 143(9):2127–2135

Campos-Silva JV, Peres CA (2016) Community-based management induces rapid recovery of a high-value tropical freshwater fishery. Sci Rep 6:34745. https://doi.org/10.1038/srep34745

Carvalho F, Power M, Forsberg BR, Castello L, Martins EG, Freitas CEC (2018) Trophic ecology of Arapaima sp. in a ria lake-river-floodplain transition zone of the Amazon. Ecol Freshw Fish 27:237–246. https://doi.org/10.1111/eff.12341

Castello L (2004) A method to count pirarucu Arapaima gigas: Fishers, assessment, and management. North Am J Fish Manag 24:379–389. https://doi.org/10.1577/m02-024.1

Castello L (2008) Lateral migration of Arapaima gigas in floodplains of the Amazon. Ecol Freshw Fish 17:38–46. https://doi.org/10.1111/j.1600-0633.2007.00255.x

Castello L, Viana JPJ, Watkins G, Pinedo-Vasquez M, Luzadis VA (2009) Lessons from integrating fishers of Arapaima in small-scale fisheries management at the Mamirauá Reserve, Amazon. Environ Manage 43:197–209. https://doi.org/10.1007/s00267-008-9220-5

Castello L, McGrath DG, Beck P (2011a) Resource sustainability in small-scale fisheries in the Lower Amazon. Fish Res 110:35–365

Castello L, Stewart DJ, Arantes CC (2011b) Modeling population dynamics and conservation of arapaima in the Amazon. Rev Fish Biol Fisheries 21:623–640. https://doi.org/10.1007/s11160-010-9197-z

Castello L, McGrath DG, Hess LL, Coe MT, Lefebvre PA, Petry P et al (2013) The vulnerability of Amazon freshwater ecosystems. Conserv Lett 6(4):217–229

Castello L, Arantes CC, McGrath DG, Stewart DJ, Sousa FS (2015) Understanding fishing-induced extinctions in the Amazon. Aquat Conserv Mar Freshwat Ecosyst 25:587–598. https://doi.org/10.1002/aqc.2491

Cavole LM, Arantes CC, Castello L (2015) How illegal are tropical small-scale fisheries? An estimate for arapaima in the Amazon. Fish Res 168:1255–1265. https://doi.org/10.1016/j.fishres.2015.03.012

CBPTF (Columbia Basin Partnership Task Force) (2019) Phase 1 Report of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee. NOAA Fisheries and the Marine Fisheries Advisory Committee, Portland, Oregon. Available: https://www.fisheries.noaa.gov/vision-salmon-and-steelhead-goals-restore-thriving-salmon-and-steelhead-columbia-river-basin

Chiwaula LS, Kawiya C, Kambewa PS (2019) Evaluating economic viability of large fish solar tent dryers. Agric Res. https://doi.org/10.1007/s40003-019-00416-8

Collares-Pereira MJ, Cowx IG (2004) The role of catchment scale environmental management in freshwater fish conservation. Fish Manage Ecol 11:303–312

Colquhoun E (2015) Measuring the economic value of recreational fishing at a national level. Report 2012–214. Canberra, Australia.: http://www.frdc.com.au/Archived-Reports/FRDC Projects/2012–214-DLD.pdf. Accessed 20.06.19.

Cooke SJ, Lapointe NWR, Martins EG, Thiem JD, Raby GD, Taylor MK, Beard TD Jr, Cowx IG (2013) Failure to engage the public in issues related to inland fishes and fisheries: strategies for building public and political will to promote meaningful conservation. J Fish Biol 83(4):997–1018. https://doi.org/10.1111/jfb.12222

Cooke SJ, Bartley DM, Beard TD, Cowx IG, Goddard C, Fuentevilla C, Leonard N, Lynch AJ, Lorenzen K, Taylor WW (2016a) From Ideas to Action: Ten Steps to Responsible Inland Fisheries that Support Livelihoods, Food Security, and Healthy Aquatic Ecosystems. In Goddard C, Leonard N, Taylor WW, Bartley D (Eds). Freshwater, Fish, and the Future: Proceedings of the Global Cross-Sectoral Conference. American Fisheries Society, Bethesda, pp 343–351.

Cooke SJ, Allison EH, Beard TD, Arlinghaus R, Arthington AH, Bartley DM, Cowx IG et al (2016b) On the sustainability of inland fisheries: finding a future for the forgotten. Ambio 45:753–764

Cooperman MS, So N, Arias M, Cochrane TA, Elliott V, Hand T et al (2012) A watershed moment for the Mekong: newly announced community use and conservation areas for the Tonle Sap Lake may boost sustainability of the world's largest inland fishery. Cambodian J Nat Hist 2012:101–106

Coordinated Assessments (2018) Coordinated Assessment Five Year Plan. Pacific States Marine Fisheries Commission-StreamNet and Pacific Northwest Aquatic Monitoring Partnership. https://www.streamnet.org/data/coordinated-assessments

Cosens BA, Williams MK (2012) Resilience and water governance: adaptive governance in the Columbia River Basin. Ecology and Society 17: 3–17. http://www.ecologyandsociety.org/vol17/iss4/art3/. Accessed 9 January 2013.

Cowan JJ, Rice JC, Walters CJ, Jilborn R, Essington TE, Day JW, Boswell KM (2012) Challenges for implementing an ecosystem approach to fisheries management. Mar. Coast. Fish. Dyn. Manag. Ecosyst. Sci 4(1):496–510

Cowx IG (2015) Characterisation of inland fisheries in Europe. Fish Manage Ecol 22:78–87

Cowx IG, Ogutu-Ohwayo R (2019) Towards sustainable fisheries and aquaculture management in the African Great Lakes. Fish Manage Ecol 26:397–405

Crampton WGR, Castello L, Viana JP (2004) Fisheries in the Amazon várzea: Historical trends, current status, and factors affecting sustainability. In: Silvius K, Bodmer R, Fragoso JMV (eds) People in nature: Wildlife conservation in South and Central America. Columbia University Press, New York, New York, pp 76–95

CRITFC (Columbia River Inter-Tribal Fish Commission) (2014) Spirit of the Salmon—WY-KAN-USH-MI WA-KISH-WIT. CRITFC, Portland, Oregon, Available CRITFC (Columbia River Inter-Tribal Fish Commission).

CRITFC (Columbia River Inter-Tribal Fish Commission) (2018) Master Plan: Pacific Lamprey Artificial Propagation, Translocation, Restoration, and Research—Conceptual Phase to Address Step 1—Master Plan Review Elements. CRITFC, Portland, Oregon. https://www.critfc.org/wp-content/uploads/2018/04/20180327-Master-Plan-Pac-Lamprey.pdf. Accessed 7 July 2019

CRS (Congressional Research Service) (2019) Columbia River Treaty Review, updated June 21, 2019. CRS Report R43287, version 22. https://fas.org/sgp/crs/misc/R43287.pdf

CSIRO (2008) Water availability in the Murray-Darling Basin. Summary of a report from CSIRO to the Australian Government. Canberra: CSIRO. 11 pp. http://www.csiro.au/files/files/pna0.pdf. Accessed 20.06.19.

Davies PE, Harris JH, Hillman TJ, Walker KF (2010) The sustainable rivers audit: assessing river ecosystem health in the Murray-Darling Basin, Australia. Mar Freshw Res 61:764–777

Davies PE, Stewardson MJ, Hillman TJ, Roberts JR, Thoms MC (2012) Sustainable Rivers Audit 2: The ecological health of rivers in the Murray-Darling Basin at the end of the Millennium Drought (2008–2010). Murray-Darling Basin Authority, Canberra.

Deines AM, Bunnell DB, Rogers MW, Bennion D, Woelmer W, Sayers MJ, Grimm AG, Shuchman RA, Raymer ZB, Brooks CN, Mychek-Londer JG, Taylor W, Beard TD (2017) The contribution of lakes to global inland fisheries harvest. Front Ecol Environ 15:293–298

DFID (2017) Sector Analysis Studies for the Commercial Agriculture for Smallholders and Agribusiness Programme Malawi—Country Value Chain and Market Analysis Report 10 November 2017. UK Department for International Development.

Doran PJ, Medard M, Apsec CD (2017) The 2017 African Great Lakes Conference: Conservation and development in a changing climate. J Great Lakes Res 44:1137–1141

Dugan P, Delaporte A, Andrew N, O'Keefe M, Welcomme R (2010) Blue harvest: inland fisheries as an ecosystem service. The WorldFish Center Working Papers.

Ernst and Young (2011) Economic contribution of recreational fishing in the MDB. Victoria: Department of Primary Industries. 19 pp. http://www.fishingworld.com.au/files/dmfile/EconomicContributionofRecFishingintheMDBFinalReport08_08_20112.pdf. Accessed 20.06.19.

Eyler B (2019) Last days of the mighty Mekong. Zed Books Ltd, London, UK

FAO (2005) Fishery and Aquaculture Country Profiles. Malawi .Country Profile Fact Sheets. In: FAO Fisheries and Aquaculture Department [online]. Rome. Updated 1 April 2005. [Cited 18 November 2019]. http://www.fao.org/fishery/Government of Malawi. 2018. Annual Economic Report. Malawi.

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

FAO (2019) The State of the World's Aquatic Genetic Resources for Food and Agriculture. FAO Commission on Genetic Resources for Food and Agriculture assessments, Rome

FAO (2020) Fishery and Aquaculture country profiles: Malawi (2018). Country Profile Fact Sheets [online]. In: FAO Fisheries Division. Rome. Updated 30 October 2020.

FAO, MSU (2016) The Rome Declaration: ten steps to responsible inland fisheries. Food and Agriculture Organization and Michigan State University. Rome. http://www.fao.org/inland-fisheries/resources/detail/en/c/1142047/

Ferguson JW, Sandford BP, Reagan RE, Gilbreath LG, Meyer EB, Ledgerwood RD, Adams NS (2011) Bypass system modification at Bonneville Dam on the Columbia River improved the survival of juvenile salmon. Trans Am Fish Soc 136:1487–1510

Fernandes CC (1997) Lateral migration of fishes in Amazon floodplains. Ecol Freshw Fish 6:36–44. https://doi.org/10.1111/j.1600-0633.1997.tb00140.x

Flores L, Mojica J, Fletcher A, Casey P, Christin Z, Armistead C, Batker D (2017) The Value of Natural Capital in the Columbia River Basin: A Comprehensive Analysis. Earth Economics, Tacoma, WA. https://secureservercdn.net/104.238.71.140/b63.d34.myftpupload.com/wp-content/uploads/2017/12/ValueNaturalCapitalColumbiaRiverBasinDec2017.pdf

Fluet-Chouinard E, Funge-Smith S, McIntyre PB (2018) Global hidden harvest of freshwater fish revealed by household surveys. Proc Natl Acad Sci USA 115:7623–7628

Funge-Smith SJ (2018) Review of the state of world fishery resources: inland fisheries. FAO Fisheries and Aquaculture Circular No. C942 Rev. 3. Rome, Italy: The Food and Agriculture Organization of the United Nations.

Funge-Smith S, Bennett A (2019) A fresh look at inland fisheries and their role in food security and livelihoods. Fish Fish 20(6):1176–1195

Ginns A (2012) Murray cod- creator of the river. RipRap 34: 42–43. http://australianriverrestorationcentre.com.au/riprap-magazine/. Accessed 20.06.19

Government of Malawi (2018) Annual Economic Report. Malawi.

Government of Malawi (2016) National Fisheries and Aquaculture Policy. https://www.unpei.org/sites/default/files/event_documents/FISHERIES%20POLICY%20FINAL%2013.11.2012.pdf

International Center for Environmental Management (ICEM). MRC Strategic Environmental Assessment (SEA) of Hydropower on the Mekong Mainstream: Final Report; ICEM: Hanoi, Vietnam, 2010

Isaac VJ, De Almeida MC (2011) El consumo de pescado en la Amazonía brasileña. COPESCAL. Documento Ocasional (13), I

Hara M (2011) Community response: Decline of the Chambo in Lake Malawi. In: Jentoft S, Eide A (eds) Poverty mosaics:

realities and prospects in small-scale fisheries (pp 251–273). Amsterdam: Springer. Hara M, Jul-Larsen E (2003) The "Lords" of Malombe; An analysis.

Harrison J (2018) Columbia River history. Portland, Oregon: Northwest Power and Conservation Council. https://www.nwcouncil.org/reports/columbia-river-history

Henry GW, Lyle JM (2003) The National Recreational and Indigenous Fishing Survey. Final Report. Canberra: Australian Government Department of Agriculture, Fisheries and Forestry.

Hilborn R (2007) Managing fisheries is managing people: what has been learned? Fish Fish 8(4):285–296

Hoggarth DD, Abeyasekera S, Arthur RI, Beddington JR, Burn RW, Halls AS, Kirkwood GP, McAllister M, Medley P, Mees CC, Parkes GB, Pilling GM, Wakeford RC, Welcomme RL (2006) Stock assessment for fishery management—A framework guide to the stock assessment tools of the Fisheries Management Science Programme (FMSP). FAO Fisheries Technical Paper. No. 487. Rome, FAO.

Holmlund CM, Hammer M (1999) Ecosystem services generated by fish populations. Ecol Econ 29(2):253–268. https://doi.org/10.1016/S0921-8009(99)00015-4

HSRG (Hatchery Scientific Review Group) (2009) Columbia River Hatchery Reform System-Wide Report. USA: Hatchery Scientific Review Group, 278 pp. http://www.hatcheryreform.us/hrp/reports/system/welcome_show.action accessed 15 November 2012

Hunt LM, Camp E, van Poorten B, Arlinghaus R (2019) Catch and non-catch-related determinants of where anglers fish: a review of three decades of site choice research in recreational fisheries. Rev Fish Sci Aquacult 27(3):261–268

IFR (The Institute for Fisheries Resources) (1996) The Cost of Doing Nothing: The Economic Burden of Salmon Declines in the Columbia River Basin. Report No. 1 of 3, October 1996. Eugene, Oregon: The Institute for Fisheries Resources, Northwest Regional Office. Available https://pcffa.org/wp-content/uploads/2016/10/CDNReport-Columbia.pdf

IFReDI 2012: Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia. Synthesis report of the FiA/Danida/WWF/Oxfam project "Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia". Inland Fisheries Research and Development Institute, Fisheries Administration, Phnom Penh, Cambodia. 44 pp.

Intralawan A, Wood D, Frankel R, Costanza R, Kubiszewski I (2018) Tradeoff analysis between electricity generation and ecosystem services in the Lower Mekong Basin. Ecosyst Serv 30:27–35

Irvine K, Etiegni CA, Weyl OLF (2019) Prognosis for long-term sustainable fisheries in the African Great Lakes. Fish Manage Ecol 26:413–425. https://doi.org/10.1111/fme.12282

ISAB (Independent Science Advisory Board) (2018) Review of the Comparative Survival Study (CSS) Draft 2018 Annual Report. Portland, Oregon, Northwest Power and Conservation Council. Available: https://www.nwcouncil.org/fish-and-wildlife/project-reviews-and-recommendations

ISAB (Independent Science Advisory Board) (2019) A review of predation impacts and management effectiveness for the Columbia River Basin. Portland, Oregon: Northwest Power and Conservation Council. https://www.nwcouncil.org/isab2019-1

ISAB (Independent Scientific Advisory Board) (2011) Using a Comprehensive Landscape Approach for More Effective Conservation and Restoration. Document Number ISAB 2011–4. Portland, OR: Northwest Power and Conservation Council, 191 pp. http://www.nwcouncil.org/library/report.asp?d=640 accessed 15 November 2012

ISRP (Independent Science Review Panel) (2018) 2018 Research Projects: Progress Review. Portland, Oregon, Northwest Power and Conservation Council. Available: https://www.nwcouncil.org/fish-and-wildlife/project-reviews-and-recommendations

Jacobsen L, Berg S, Skov C (2004) Management of lake fish populations and lake fisheries in Denmark: history and current status. Fish Manage Ecol 11:219–224

Jeanson AL, Lynch AJ, Thiem JD et al (2021) A bright spot analysis of inland recreational fisheries in the face of climate change: learning about adaptation from small successes. Rev Fish Biol Fisheries 31:181–200. https://doi.org/10.1007/s11160-021-09638-y

Jentoft S (2014) Walking the talk: Implementing the international voluntary guidelines for securing sustainable small-scale fisheries. Maritime Stud 13(1):16

Jentoft S, Chuenpagdee R, Barragán-Paladines MJ, Franz N (2017) The small-scale fisheries guidelines: global implementation. Springer, Berlin

Joint Staff Report (Joint Columbia River Management Staff; Oregon Department of Fish & Wildlife; Washington Department of Fish & Wildlife) (2018) 2018 Joint Staff Report: Stock Status and Fisheries for Fall Chinook Salmon, Coho Salmon, Chum Salmon, Summer Steelhead, and White Sturgeon. https://wdfw.wa.gov/sites/default/files/publications/02005/wdfw02005.pdf

Junk WJ, Soares MGM, Bayley PB (2007) Freshwater fishes of the Amazon River basin: their biodiversity, fisheries, and habitats. Aquat Ecosyst Health Manage 10(2):153–173

Kaplan IM, McCay BJ (2004) Cooperative research, co-management and the social dimension of fisheries science and management. Mar Policy 28(3):257–258

King AJ, Tonkin Z, Lieschke J (2012) Short-term effects of a prolonged blackwater event on aquatic fauna in the Murray River, Australia: considerations for future events. Mar Freshw Res 63:576–586

Koed A, Birnie-Gauvin K, Sivebæk F, Aarestrup K (2020) From endangered to sustainable: Multi-faceted management in rivers and coasts improves Atlantic salmon (Salmo salar) populations in Denmark. Fish Manage Ecol 27(1):64–76. https://doi.org/10.1111/fme.12385

Koehn JD (2015) Managing people, water, food and fish in the Murray-Darling Basin, southeastern Australia. Fish Manage Ecol 22:25–32. https://doi.org/10.1111/fme.12035

Koehn JD, Lintermans M (2012) A strategy to rehabilitate fishes of the Murray-Darling Basin, south-eastern Australia. Endangered Spec Res 16:165–181

Koehn JD, Lintermans M, Copeland C (2014) Laying the foundations for fish recovery: the first 10 years of the Native Fish Strategy for the Murray-Darling Basin. Aust Ecol Manag Rest 15(S1):3–12

Konyole SO, Kinyuru JN, Owuor BO, Kenji GM, Onyango CA, Estambale BB, Friis H, Roos N, Owino VO (2012)

Acceptability of amaranth grain-based nutritious complementary foods with dagaa fish (Rastrineobola Argentea) and edible termites (Macrotermes Subhylanus) compared to corn soy blend plus among young children/mothers dyads in Western Kenya. J Food Res 1(3)

Krueger C, Taylor W, Youn SJ (2019) From catastrophe to recovery: Stories of fishery management success. American Fisheries Society, Bethesda

Kurien J, Javier LR (2013) Flavouring fish into food security. Report/Rapport: SF-FAO/2013/14. August/Aout 2013. FAO-SmartFish Programme of the Indian Ocean Commission, Ebene, Mauritius.

Leon LF, Lam DC, McCrimmon C, Swayne DA (2003) Watershed management modelling in Malawi: application and technology transfer. Environ Model Softw 18:531–539

Leonard NJ, Fritsch MA, Fazio JD, Harrison J, Grover T (2015) The challenge of managing the Columbia River Basin for energy and fish. Fish Manage Ecol 22(1):88–98

Lester RE, Webster IT, Fairweather PG, Young WJ (2011) Linking water-resource models to ecosystem-response models to guide water-resource planning—an example from the Murray-Darling Basin, Australia. Mar Freshw Res 62:279–289

Limuwa MM, Singini W, StorebakkenIs T (2018) Fish farming an illusion for lake Malawi Riparian communities under environmental changes? Sustainability 10:1453. https://doi.org/10.3390/su10051453

Lintermans M (2007) Fishes of the murray-darling basin: an introductory guide. Canberra: Murray-Darling Basin Commission. 157 pp.

Lynch AJ, Cooke SJ, Deines A, Bower S, Bunnell DB, Cowx IG, Nguyen VM et al (2016) The social, economic, and ecological importance of inland fishes and fisheries. Environ Rev 24:115–121

Lynch AJ, Bartley DM, Beard TD Jr, Cowx IG, Funge-Smith S, Taylor WW, Cooke SJ (2020a) Examining progress towards achieving the ten steps of the rome declaration on responsible Inland fisheries. Fish Fish 21(1):190–203

Lynch AJ, Elliott V, Phang SC, Claussen JE, Harrison I, Murchie KJ, Steel EA, Stokes GL (2020b) Inland fish and fisheries integral to achieving the Sustainable Development Goals. Nat Sustain 3:579–587

Lyons RP, Scholz CA, Cohen AS, King JW, Brown ET, Ivory SJ, Johnson TC, Deino AL, Reinthal PN, McGlue MM, Blome MW (2015) Continuous 13-million-year record of East African hydroclimate, and implications for patterns of evolution and biodiversity. Proc Natl Acad Sci 112(51):15568–15573. https://doi.org/10.1073/pnas.1512864112

Makawa Z, Kaunda E, Kapute E (2019) Wood utilization efficiency and acceptability of fried and smoked fish from lake Malawi. Afr J Food Agric Nutr Dev 19(2):14432–14457. https://doi.org/10.18697/ajfand.85.17205

Makwinja R, Kosamu I, Kaonga C (2019) Determinants and values of willingness to pay for water quality improvement: insights from Chia Lagoon. Malawi Sustainability 11(17):4690. https://doi.org/10.3390/su11174690

McGrath DG, Cardoso A, Almeida OT, Pezzuti J (2008) Constructing a policy and institutional framework for an ecosystem-based approach to managing the Lower Amazon floodplain. Environ Dev Sustain 10:677–695. https://doi.org/10.1007/s10668-008-9154-3

Mekong River Commission (MRC) (2018) The Council Study WUP-FIN IWRM Scenario Modelling Report. Vientiane, Lao PDR.

Meyer WS (2005) The Irrigation Industry in the Murray and Murrumbidgee Basins. CRC for Irrigation Futures Technical Report No. 03/05. www.clw.csiro.au/ImageGallery/. Accessed 7 May 2019]

Ministry of Environment and Food (2019a) Order of the Fisheries and Fish Farming Act (Fisheries Act). Ministry of Environment and Food. LBK no 261 of 21/03/2019 https://www.retsinformation.dk/Forms/R0710.aspx?id=208281 (in Danish). Date of access: 05 Nov. 2019.

Ministry of Environment and Food (2019b) Order of the Act of Nature Protection. Ministry of Environment and Food. LBK no 240 of 13/03/2019. (in Danish) https://www.retsinformation.dk/Forms/R0710.aspx?id=207969 (Date of access: 05 Nov. 2019).

Murphy BF, Timbal B (2008) A review of recent climate variability and climate change in southeastern Australia. Int J Climatol 28:859–879

Murray-Darling Basin Authority (2010) Guide to the Proposed Basin Plan: Overview. Canberra: Murray–Darling Basin Authority, p 262. www.download.mdba.gov.au/Guide_to_the_Basin_Plan_Volume_1_web.pdf. Accessed 20.06.19.

Murray–Darling Basin Authority (2011) Plain english summary of the proposed basin plan—including explanatory notes. Canberra: Murray–Darling Basin Authority, p 138. http://download.mdba.gov.au/proposed/plain_english_summary.pdf. Accessed 20.06.19

Murray–Darling Basin Authority (2020). Native Fish Recovery Strategy. Working Together for the Future of Native Fish. Murray-Darling Basin Authority, Canberra. https://www.mdba.gov.au/node/5971/. Accessed 23 June 2020.

Murray-Darling Basin Commission (2004) Native Fish Strategy for the Murray-Darling Basin 2003–2013. Canberra: Murray-Darling Basin Commission, p 64. http://www2.mdbc.gov.au/NFS.html Accessed 20.06.19.

Mussa H, Kaunda E, Chimatiro S, Banda L, Nankwenya B, Nyengere J (2017) Assessment of informal cross-border fish trade in the southern africa region: a case of Malawi and Zambia. J Agric Sci Technol 7:358–366. https://doi.org/10.17265/2161-6264/2017.05.009

Nagoli J, Holvoet K, Remme M (2010) HIV and AIDS vulnerability in fishing communities in Mangochi district. Malawi African Journal of AIDS Research 9(1):71–80. https://doi.org/10.2989/16085906.2010.484575

Nilsson C, Reidy CA, Dynesius M, Revenga C (2005) Fragmentation and flow regulation of the world's large river systems. Science 308(5720):405–408. https://doi.org/10.1126/science.1107887

Njaya F (2018) Ecosystem approach to fisheries in southern Lake Malawi: Status of the fisheries co-management. Aquat Ecosyst Health Manage 21(2):159–167. https://doi.org/10.1080/14634988.2018.1472504

Noble M, Duncan P, Perry D, Prospe K, Rose D, Schnierer S, Tipa G, William E, Woods R, Pittock J (2016) Culturally significant fisheries: keystones for management of freshwater social-ecological systems. Ecol Soc 21(2):22. https://doi.org/10.5751/ES-08353-210222

NPCC (Northwest Power and Conservation Council) (2014) Columbia River Basin Fish and Wildlife Program. Portland, Oregon: Northwest Power and Conservation Council. https://www.nwcouncil.org/reports/2014-columbia-river-basin-fish-and-wildlife-program

NPCC (Northwest Power and Conservation Council) (2019a) 2018 Columbia River Basin Fish and Wildlife Program Costs Report—18th Annual Report to the Northwest Governors. Council Report 2019–5. Portland, Oregon: Northwest Power and Conservation Council. https://www.nwcouncil.org/sites/default/files/2019-5_0.pdf

NPCC (Northwest Power and Conservation Council) (2019b) Draft 2020 Addendum—Columbia River Basin Fish and Wildlife Program 2014. Council document 2019–6. Portland, Oregon: Northwest Power and Conservation Council. https://www.nwcouncil.org/fw/program/2018-amendments

Nunanará M, Onyango P, F (2015) Institutions and co-management in East African inland and Malawi fisheries: A critical perspective. World Dev 70:203–214

Obiero KO, Abila RO, Njiru MJ, Raburu PO, Achieng AO, Kundu R, Lawrence T (2015) The challenges of management: Recent experiences in implementing fisheries co-management in Lake Victoria, Kenya. Lakes Reserv Res Manag 20:139–154

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. Global Environ Chang 22(4):925–932. https://doi.org/10.1016/j.gloenvcha.2012.06.002

Pauly D, Alder J, Bennett E, Christensen V, Tyedmers P, Watson R (2003) The future for fisheries. Science 302(5649):1359–1361

PEB (Permanent Engineering Board) (2008) Columbia River treaty. Portland, Oregon: Columbia Basin Water Management Division, Civil Works and Management Directorate, Northwestern Division, U.S. Army Corps of Engineers. http://www.nwd-wc.usace.army.mil/PB/PEB_08/index.htm

Petersen TA, Brum SM, Rossoni F, Silveira GFV, Castello L (2016) Recovery of Arapaima sp. populations by community-based management in floodplains of the Purus River. Amazon J Fish Biol 89:241–248. https://doi.org/10.1111/jfb.12968

Poff NL, Allan JD, Palmer MA, Hart DD, Richter BD, Arthington AH, Rogers KH, Meyer JL, Stanford JA (2003) River flows and water wars: Emerging science for environmental decision making. Front Ecol Environ 1:298–306. https://doi.org/10.1890/1540-9295(2003)001[0298:RFAWWE]2.0.CO;2

Reid DD, Harris JH, Chapman DJ (1997) NSW Inland Commercial Fishery Data Analysis. FRDC Project No. 94/027. Sydney. http://www.frdc.com.au/Archived-Reports/FRDC Projects/1994–027-DLD.pdf. Accessed 20.06.19.

Reid AJ, Carlson AK, Creed IF, Eliason EJ, Gell PA, Johnson PT et al (2019) Emerging threats and persistent conservation challenges for freshwater biodiversity. Biol Rev 94(3):849–873

Rowland SJ (2005) Overview of the history, fishery, biology and aquaculture of Murray cod (Maccullochella peelii peellii). In: Lintermans M, Phillips B (eds). Management of Murray Cod in the Murray-Darling Basin: Statement, Recommendations and Supporting Papers. 3–4 June 2004. Canberra: Murray-Darling Basin Commission and Cooperative Research Centre for Freshwater Ecology, pp 38–61. http://publications.mdbc.gov.au/ Accessed 20.06.19.

Schwinn M, Baktoft H, Aarestrup K, Koed A (2019) Artificial lakes delay the migration of brown trout Salmo trutta smolts: a comparison of migratory behaviour in a stream and through an artificial lake. J Fish Biol 94(5):745–751. https://doi.org/10.1111/jfb.13950

Skau JKH, Touch B, Chhoun C, Chea M, Unni US, Makurat J, Filteau S, Wieringa FT, Dijkhuizen MA, Ritz C, Wells JC, Berger J, Friis H, Michaelsen KF, Roos N (2015) Effects of animal source food and micronutrient fortification in complementary food products on body composition, iron status, and linear growth: a randomized trial in Cambodia. Am J Clin Nutr 101(4):742–751. https://doi.org/10.3945/ajcn.114.084889

Skov C, Berg S, Eigaard OR, Jessen TK, Skov PV (2019) Danish fisheries and aquaculture: past, present, and future. Fisheries 45(1):33–41. https://doi.org/10.1002/fsh.10330

Smith LED, Khoa SN, Lorenzen K (2005) Livelihood functions of inland fisheries: policy implications in developing countries. Water Policy 7:359–383

Søndergaard M, Jeppsen E, Jensen JP (1999) Danish lakes and their restoration. TEMA-rapport fra DMU 24/1999. National Environmental Research Institute (in Danish).

State of Washington (1999) Statewide Strategy to Recover Salmon – Extinction is not an Option. Washington State Joint Resources Cabinet, September 21, 1999. Olympia, Washington. Available: https://www.digitalarchives.wa.gov/GovernorLocke/gsro/strategy/strategy.htm#long

State of Washington, State of Oregon, State of Idaho, United States, the Shoshone Bannock Tribes, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, and the Confederated Tribes and Bands of the Yakama Nation (2018) 2018–2027 United States v. Oregon Management Agreement. United States v. Oregon, Civil No. 68–513-MO (D. Or.), Case 3:68-cv-00513-MO. https://www.fws.gov/lsnakecomplan/Reports/USvOregon/FINAL.2018-%202027%20USvOR%20Management%20Agreement%20with%20Signature%20Feb%202018%20.pdf

Taylor WW, Bartley DM, Goddard CI, Leonard NJ, Welcomme RL (Eds.). (2016) Freshwater, fish and the future: Proceedings of the global cross-sectoral conference. Bethesda, MD: American Fisheries Society, Food and Agriculture Organization of the United Nations, and Michigan State University.

Tenney J, Warf D, Tancreto N (2018) Columbia Basin PIT Tag Information System, 1/1/2017–12/31/2017 Annual Report, 1990–080–00. Pacific States Marine Fisheries Commission, Portland, Oregon. https://www.ptagis.org/docs/default-source/ptagis-program-documents/2017-annual-report-project-1990-080-00.pdf?sfvrsn=2

TMT (Technical Management Team) (2003) Guidelines for Technical Management Team. http://pweb.crohms.org/tmt/documents/wmp/2006/guidelines.pdf

USBOR (United States Bureau of Reclamation) (1938) The Grand Coulee Dam and the Columbia Basin reclamation

Project. United States Department of Interior Bureau of Reclamation. Available https://babel.hathitrust.org/cgi/pt?id=mdp.39015049235826&view=1up&seq=48

Venturelli PA, Hyder K, Skov C (2017) Angler apps as a source of recreational fisheries data: opportunities, challenges and proposed standards. Fish Fisheries 18(3):578–595. https://doi.org/10.1111/faf.12189

Veríssimo J (1895) A pesca na Amazônia. Livraria Classica de Alves, Rio de Janeiro

Vilain C, Baran E, Gallego G, Samadee S (2016) Fish and the nutrition of rural Cambodians. Asian J Agric Food Sci 4(1):26–34

Vollmer D, Shaad K, Souter NJ, Farrell T, Dudgeon D, Sullivan CA, Fauconnier I, MacDonald GM, McCartney MP, Power AG et al (2018) Integrating the social, hydrological and ecological dimensions of freshwater health: The Freshwater Health Index. Sci Total Environ 627:304–313

Vörösmarty CJ, McIntyre PB, Gessner MO, Dudgeon D, Prusevich A, Green P, Glidden PS, Bunn SE, Sullivan CA, Reidy-Liermann C, Davies PM (2010) Global threats to human water security and river biodiversity. Nature 467:555–561. https://doi.org/10.1038/nature09440

WDFW (Washington Department of Fish & Wildlife) (2018) Effective July 1, 2018-June 30, 2019 Washington Sport Fishing Rules. Olympia, Washington. Available https://wdfw.wa.gov/sites/default/files/publications/01998/wdfw01998.pdf (accessed July 7, 2019)

WDFW (Washington Department of Fish & Wildlife) (2011) Washington's Fish & Wildlife Mean Business and Jobs. Olympia, Washington, available https://wdfw.wa.gov/sites/default/files/publications/01160/wdfw01160.pdf

Welcomme RL (2001) Inland Fisheries: conservation and management. Blackwells, Oxford

Welcomme RL (2011) An overview of global catch statistics for inland fish. ICES J Mar Sci 68:1751–1756. https://doi.org/10.1093/icesjms/fsr035

Welcomme RL, Cowx IG, Coates D, Béné C, Funge-Smith S, Halls A, Lorenzen K (2010) Inland capture fisheries. Phil Trans R Soc B 365(1554):2881–2896. https://doi.org/10.1098/rstb.2010.0168

Weyl OLF, Ribbink AJ, Tweddle D (2010) Lake Malawi: fishes, fisheries, biodiversity, health and Habitat. Aquat Ecosyst Health Manage 13(3):241–254

Wilson JW, Primack RB (2019) Conservation Biology in Sub-Saharan Africa. Open Book Publishers, Cambridge. https://doi.org/10.11647/OBP.0177

Woods F (2008) The Columbia River Compact. Washington Attorney General's Office, Olympia, WA.

World Bank (2012) Hidden harvest: the global contribution of capture fisheries. World Bank, Washington DC. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2012/05/18/000427087_20120518142913/Rendered/PDF/664690ESW0P1210120HiddenHarvest0web.pdf

Yakama Nation Fisheries (2019) STAR Project—Status and Trends of Fish and Habitat. http://dashboard.yakamafish-star.net/

Youn SJ, Taylor WW, Lynch AJ, Cowx IG, Beard TD Jr, Bartley D, Wu F (2014) Inland capture fishery contributions to global food security and threats to their future. Glob Food Sec 3(3):142–148. https://doi.org/10.1016/j.gfs.2014.09.005