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Research paper

Fish for whom?: Integrating the management of social complexities into technical investments for inclusive, multi-functional irrigation

Nicolette Duncan [a,*], Sanjiv de Silva [b], John Conallin [a], Sarah Freed [c], Michael Akester [c], Lee Baumgartner [a], Matthew McCartney [b], Mark Dubois [c], Sonali Senaratna Sellamuttu [b]

[a] Institute for Land, Water and Society, Charles Sturt University, 386 Elizabeth Mitchell Drive, Thurgoona, New South Wales 2640, Australia
[b] International Water Management Institute, 127, Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka, Postal Address: P.O. Box 2075, Colombo, Sri Lanka
[c] Worldfish, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Pulau Pinang, Malaysia

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ABSTRACT

Irrigation represents a long-standing water sector investment in South East Asia. However, despite the undeniable benefits of food production, an irrigation/rice-centric strategy is insufficient in a multi-dimensional conceptualisation of development. The Sustainable Development Goals (SDGs) challenge us to re-think traditional ways of achieving food security. Central to this challenge is how we can retain multi-functionality within landscapes. We explore the often negatively correlated relationship between irrigation and inland fisheries through a literature review and interviews with key informants, focusing on examples from Myanmar and Cambodia. We found that whilst technical options exist for minimizing irrigation impacts on fisheries, there is a fundamental disconnect between the technical application of such 'solutions', and distribution of benefits to the marginal groups that SDGs 1, 2, 3 and more target. We found that insufficient recognition of the social contexts in which solutions are applied underpins this disconnect. This means that technical infrastructure design needs to be organised around the question, 'Who do we want to benefit?', if investments are to go beyond rice/fish production and deliver more on socially inclusive food security and livelihood opportunities. This paper is a call to extend the framing and financing of irrigation investments beyond technical parameters to include investing in the social processes that enable both multi-functionality and inclusive growth, to enhance the role of irrigation in adapting to a changing climate, while maintaining landscape integrity and multi-functionality so necessary for a sustainable future.

1. Introduction

According to Nobel prize winner Amartya Sen, development is the "process of expanding the real freedoms that people enjoy" (Félix & Belo, 2019). Inclusive development then, with "roots in social justice… (is) focused on the participation, human rights and social demands of the most marginalized people and communities" (Pouw & Gupta, 2017). Following seminal works by Johnston and Mellor (1961) and Schultz (1964), international aid organisations and governments have aimed to address poverty faced by rural communities in developing countries by investing heavily in rural development and infrastructure in South East Asia (SEA), where agriculture forms the backbone of multiple national economies (Grabrowski & Self, 2020). Irrigation in SEA has mainly targeted rice agriculture since the Green Revolution, which has reduced poverty and improved food security for many (Hussain & Biltonen, 2001). However, despite its status as a dietary staple and the benefits of greater food security, rice nutrient content is insufficient to meet human nutrition requirements (Youn et al., 2014). Moreover, the consolidation of rice agriculture into large-scale irrigated operations (Vicol, Pritchard, & Htay, 2018) adversely impacts naturally occurring food systems such as inland capture fisheries, well beyond the command area of a given irrigation scheme, by fragmenting landscapes and changing water flow regimes (Conallin et al., 2019; Mahood et al., 2020). The same approach inadequately addresses social justice concerns of ensuring participation

* Corresponding author at: Institute for Land, Water and Society, Charles Sturt University, 386 Elizabeth Mitchell Drive, Thurgoona, New South Wales 2640, Australia.

E-mail addresses: ndunenvir@gmail.com (N. Duncan), s.s.desilva@cgiar.org (S. de Silva), jconallin@csu.edu.au (J. Conallin), S.Freed@cgiar.org (S. Freed), M.Akester@cgiar.org (M. Akester), lbaumgartner@csu.edu.au (L. Baumgartner), M.McCartney@cgiar.org (M. McCartney), M.Dubois@cgiar.org (M. Dubois), s.senaratnasellamuttu@cgiar.org (S. Senaratna Sellamuttu).

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and distribution of benefits to disadvantaged groups, resulting in marginalisation of smallholder farmers (Jepsen, Palm, & Bruun, 2019; Loughlin & Milne, 2020; Snoxell & Lyne, 2019), despite efforts to engage local stakeholders in participatory irrigation management (Matsuno et al., 2013). Such marginalisation further concentrates wealth and power in the hands of a relative few, hardening and lengthening the gap between rich and poor (Ingalls et al., 2018). Li (2010) goes so far as to say that in this way, the poorest are 'let die' through this process of exclusion which displaces people from their land and livelihoods. These negative trade-offs of large-scale mainly irrigated rice production, combined with an overly technocratic design and implementation process, risk detracting from the livelihood and dietary improvement objectives of poverty reduction (Adger, 2000; Al Mamun, Nasrat, & Debi, 2011; Cramb, 2020), meaning time and resource investments by governments and donors may not achieve their full potential.

Global discourses which embrace multi-dimensional development, such as the United Nations' Sustainable Development Goals (SDGs), challenge us to re-evaluate 'growth', by recognising the social and environmental trade-offs of GDP focussed development (Bebbington & Unerman, 2018; Scholte & Söderbaum, 2017). The SDGs are reflected in global development organisations and donor strategies, including those of the World Bank (WB - Sen & Pookayaporn, 2018) and Asian Development Bank (ADB - Helble & Shepherd, 2017), as well as national policy. While they offer little guidance on best-practice approaches, the SDGs posit an inclusive development model, including in SDG 1 (No poverty), 2 (Zero hunger) 3 (Good health), 10 (Reduced inequalities) and 16 (Just, peaceful and inclusive societies) amongst others. Inclusive development calls for the potential benefits and consequences of development be considered with equal weight given to economic, environmental and social goals (Pouw & Gupta, 2017). According to Pouw and Gupta; "the underlying argument is that social inequality reduces opportunities for enhancing human wellbeing while reducing the resource base" 2017, p. 104).

This need to re-balance development interventions is demonstrated with examples of rice and fisheries production from Myanmar and Cambodia. In both countries, rice and fish are the mainstays of the national diet, especially for the poorest among the population (Dubois et al., 2019). Rice irrigation and associated water controlling infrastructure (WCI) negatively impact inland fisheries, which provide critical dietary micronutrients and are a common pool resource relevant to millions of livelihoods (Dubois et al., 2019). However, as elsewhere in the world, inland fisheries are simultaneously threatened by irrigation, hydropower, WCI, land conversion, population growth and overfishing, which have altered hydrological flows, fragmented and degraded aquatic habitats and accelerated fishery decline (Conallin et al., 2019). In Myanmar and Cambodia, the impact of WCI on fisheries is often unacknowledged (Lynch et al., 2017), although traditionally in these countries people have relied on diverse natural and ecologically functional food systems (Vicol et al., 2018). Thus, we argue that insufficient attention to inland fisheries represents an associated disregard for those who depend on them, especially rural poor and landless people. To safeguard the food and nutrition security provided by inland fisheries, the scope of project design should expand to focus not only on production but also to reducing negative socio-ecological trade-offs of agriculture (McCartney, Whiting, Makin, Lankford, & Ringler, 2019; Rasul, 2016), by ensuring appropriate institutional arrangements are in place (Matsuno et al., 2013) so that benefits are widely available.

In this paper, we contribute to the discourse on how more sustainable and socially inclusive development, and thereby several SDGs, could be achieved. Focussing on irrigation and fisheries, we argue that while technical solutions may maintain or increase fish availability, the challenge, as with irrigation, of serving often heterogeneous communities, stratified, for example, by class, gender, ethnicity or occupation, is often underestimated. We argue that consequently, a fundamental gap in current development approaches is that individuals, households and even entire communities are excluded not only from accessing natural resources and agricultural development infrastructure, but from partaking in setting the development agenda in the first place (Sobhan, 2010). We argue that this critical gap is typified in cookie-cutter development approaches which risk increasing inequities, where those with a greater capacity for resource extraction (whether fish, water or land) are at an advantage, unless rules and participatory governance arrangements to mediate this imbalance are also invested in (Choe & Yun, 2017; Ostrom, 1990; Saunders, 2014).

Our argument is framed by a social-ecological systems approach, adapted from Bronfenbrenner's (1979) ecological model, outlined in Fig. 1, which highlights the plural forces which underpin individuals' behaviour, or in our context, livelihood outcomes. This adapted version of Bronfenbrenner's (1979) Socio-Ecological Model illustrates the complexity of the social context into which development initiatives are deployed. An individual's or household's access to the benefits of development investments are shaped not only by personal circumstances, but also the local and larger scale power structures which determine who is represented in and who is excluded from development and natural resource decision making.

We thus argue, and seek to demonstrate, that while improving multifunctionality within irrigated landscapes may optimize use of scarce natural resources, it will not translate into livelihood improvement for those who need it most unless social contexts are accounted for through grounded, systematic institutional development. We investigate the potential benefits of fish passage and aquaculture as investments aimed at mitigating WCI impacts and enhancing fisheries within irrigated landscapes, as well as the consequences of each if social inequalities are not considered. We question whether the community and policy environments in Myanmar and Cambodia are conducive to multifunctional, inclusive agricultural development, and show that in both countries water (and fisheries in Myanmar) governance operates to the disadvantage of poor and marginal households. Finally, we examine the case study of Cambodia's rice field fisheries (RFFs) supported by community-managed fish refuges (CFRs), which demonstrate the advantages of developing multifunctional irrigated landscapes and investing in institution building.

Fig. 1. *Individuals are nested in a social ecology. Note:* Adapted from "Using the Socio-Ecological Model to Frame Agricultural Safety and Health Interventions" by B.C. Lee, C. Bendixsen, A. K. Liebman and S. S. Gallagher, 2017, *Journal of Agromedicine,* 22(4), p. 298–303. https://doi.org/10.1080/1059924X.2017.1356780. Copyright 2017 by Taylor and Francis.

2. Methodology

Through a literature review, approximately 200 English language documents were examined to reflect the richness of available material on both countries and read around the topic more broadly. The reviewed literature included peer-reviewed journal articles, book chapters, technical publications, donor reports, national policies and grey literature, sourced through Google Scholar and institutional and personal networks, including WorldFish, International Water Management Institute (IWMI) and the United Nations Food and Agriculture Organisation (FAO). The reviewed literature covered: discourse on irrigation and fisheries; development policy and fisheries in Myanmar and Cambodia; social heterogeneity and common pool resource governance. Search terms included, but were not limited to: aquaculture, access, Cambodia, conflict, development, elite capture, equity, exclusion, fish passage, governance, inland fisheries, inclusion, inclusive, irrigation, landless, land tenure security, land use, Mekong, Myanmar, nutrition, participation, political economy, pro-poor, rice fish, South East Asia and common pool resource governance. Relevant documents from the literature were uploaded to NVivo (released by QSR in March 2020). Documents were read and sections of the text were coded to themes arising from the literature review that linked to our research focus. Text search and tree map analyses were conducted across the 200 coded documents to observe the ways in which key terms were discussed and related to each other.

Concurrently, virtual interviews were held with 12 key informants (KIs) to gain a diversity of perceptions and deeper understanding of specific themes. KIs were identified through institutional and personal networks of the authors, and the literature, for their expertise on Cambodia and/or Myanmar fisheries and/or irrigation. Prior written informed consent was obtained from each KI. The KIs are distributed across government, academic, practitioner and donor categories although several KIs transcended these labels. Overall, five KIs were interviewed regarding Cambodia (3 academics; 1 practitioner and 1 government official) and four in Myanmar (3 academics; 1 practitioner) respectively. Three other KIs not specifically linked to either country, but a donor representative and practitioners knowledgeable on the overall topic, were also interviewed.

Ethical approval was obtained from the IWMI. Informed consent forms were sent to all KIs prior to the arranged meeting, along with a copy of the questions that would form the basis of the conversation. Interviews were conducted via video call, in English, guided by a semi-structured questionnaire, covering common themes including KI's views on the paper's primary argument; national policy; governance characteristics; the nature of social contexts and associated political economies in Cambodia and/or Myanmar and how these impact the role of fish in the livelihoods of rural households. Written notes were taken during each interview, and later uploaded and coded thematically in NVivo. Tree map and word cloud analyses were conducted to compare interview responses with literature review texts.

3. Fisheries in Myanmar and Cambodia's development contexts

Fish are the leading source of animal protein in Myanmar (Belton et al., 2015) and Cambodia (Golden et al., 2019). Both Myanmar and Cambodia encompass vast freshwater resources with highly productive inland fisheries (Orr et al., 2012). The extent of inland fisheries in Myanmar and Cambodia has made them a traditionally accessible and affordable common pool resource of social and economic importance (de Silva et al., 2014). Yet in recent years, inland fisheries have experienced significant declines due to extensive exploitation of freshwater ecosystems through water (Halls & Hortle, 2021; Tezzo, Belton, Johnstone, & Callow, 2018), fish (KC et al., 2017) and vegetation extraction and land conversion (Mahood et al., 2020) to agriculture and land development.

In Myanmar, the agriculture sector contributes 25% to 30% of export earnings (FAO, 2019). Agriculture, livestock and fisheries account for nearly 37.8% of GDP and about 70% of employment (FAO, 2019). Irrigation supplies about 15 million rural people and 2.78 million hectares (23.4% of the net sown area in 2015–2016) of agricultural land (Than, 2018). Further investments are likely for climate change adaptation (Ministry of Natural Resources and Environmental Conservation, 2017). Hydropower provides almost 75% of Myanmar's electricity and hundreds of small and medium hydropower plants are earmarked for potential construction by 2030 (Emmerton et al., 2015). Fishing contributes to approximately 15 million livelihoods (McCartney & Khaing, 2014), while consumption is estimated at 22–34 kg per capita per year and fish are consumed at almost every meal (FAO, 2003). The rural poor have inadequate access to food and nutrition and suffer from micronutrient deficiencies (Organisation for Economic Co-operation and Development [OECD], 2015; Ministry of Health and Sports, 2018). Stunting affects 29.4% of children (Blankenship, Cashin, Nguyen, & Ip, 2020), above the developing country average of 25% (Global Nutrition Report, 2020). Estimates indicate that between 41% and 57% of the population is landless (Lwin, Ikuko, & Koichi, 2020; Pritchard, Rammohan, & Vicol, 2019) and more likely than landholders to be food insecure (Lwin et al., 2020).

Inland fisheries are structured primarily around leasable and open fisheries systems, which account for 21% and 6% of total recorded fish catch annually. Leasable fisheries auction productive fishing areas to the highest bidder, granting exclusive fishing rights, subject to regulations on species, season and gear. There are over 3,500 leases in operation today. Open fisheries relate to licenced fishing in all inland waters except leasable fisheries. Open fishing grounds are specified, and gear is regulated. Aquaculture is mainly freshwater and operated by the private sector in large pond-based culture, the majority of which occurs in the Ayeyarwady Delta (van Beijnen, 2018). Small-scale aquaculture is also widespread, although policy prohibits conversion of rice-fields to other uses (Belton et al., 2015).

Cambodia's fisheries provide full-time, part-time and seasonal employment for approximately 35% of the population and contributes 25.4% of GDP, behind 54.8% from agriculture (Royal Government of Cambodia [RGC], 2010). The Proposed loan, grant, and administration of grant Kingdom of Cambodia (2019) reports 32% of rice is irrigated. Irrigation development including refurbishment is earmarked for further investment, which it is hoped will reflect a commitment by the RGC to enhance multifunctionality of structures needing repair (McCartney et al., 2019). External pressures from Mekong River hydropower development and a warming climate contribute to changing flood cycles. Altered water availability and flow regimes will ultimately affect not only inland fisheries, but water intensive agriculture, including rice and aquaculture (Teh et al., 2019). Fish constitutes 70% of animal protein intake (Bann & Sopha, 2020), 37% of the total protein, and total iron intake, along with other micronutrients (Council for Agricultural and Rural Development, 2014). However, one in three Cambodian children is estimated to experience stunting (Karpati et al., 2020).

Over 30% of Cambodia's landmass consists of either permanent or seasonal wetlands. It is the fifth largest inland capture (wild) fishery in the world, producing 58.8% of total national fish catch in 2018 (Bann & Sopha, 2020). The Tonle Sap Lake is the main production area and is home to highly diverse aquatic species (Chan, Brosse, Hogan, Ngor, & Lek, 2020). Most of Cambodia's almost 17 million people are engaged in fishing for some, or all, of the year, indicating the importance of healthy inland waterways to livelihoods (Nasielski, KC, Johnstone, & Baran, 2016). A shift from privately leased fish lots (akin to leasable fisheries in Myanmar) to co-managed community fisheries (CFis) in 2012, attempted to strengthen access and management rights for communities and support rural poverty reduction, food security and better habitat management. Today, all fisheries are technically accessible to all fishers, although 35% of the former lot area around Tonle Sap is now reserved for conservation and fishing is prohibited (KC et al., 2017). Important

inland fisheries include rice field fisheries, supported by co-managed Community Fish Refuges (CFRs), which produce approximately 30% of inland fish catch (Bann & Sopha, 2020). During monsoon floods, rice field fisheries are a common pool resource for communities, including the landless. Water bodies designated as CFRs allow fish populations to persist locally during the dry season and migrate to spawn and feed in the flooded rice fields during the monsoon. Aquaculture production (including marine) is relatively low, contributing one sixth of fisheries production (FAO, 2021). The sector is set to grow as the current level of exploitation in the Tonle Sap is thought unsustainable (Teh et al., 2019).

4. Under-representation of fisheries in policy. Irrigated landscape planning points to systemic dissonance between technical and social dimensions of development

The literature review and informant responses reflected an "invisibility" of fish within irrigation developments (Lynch et al., 2017), as well as a poorly developed or expressed understanding among donors and implementers of how heterogeneous social contexts influence the livelihood improvement impacts of development investments (Sheng et al., 2017). As one key informant put it; "governments are less interested in the social aspects; they are after the bio-physical solution. They take the view of a homogenous society" (International Rice Research Institute [IRRI] informant). With numerous major river infrastructure developments are earmarked for construction in Cambodia and Myanmar, there is a danger that a technocratic approach to design will miss important opportunities to resolve the social shortcomings of business-as-usual development.

Myanmar and Cambodia each have a poorly coordinated and fragmented water sector, where the needs of multiple water users are governed independently of each other (McCartney et al., 2019; Sithirith, 2017). In both countries, fisheries operate in isolation to other water sector departments (McCartney et al., 2019; Sithirith, 2017), are rarely consulted on river infrastructure development (two WorldFish informants), and multi-sectoral collaboration spaces are limited (informants from Gembloux AgroBio Tech, FiA & Mekong River Commission [MRC]). Inland fisheries are an afterthought in irrigation investments and action to mitigate negative impacts is reactive (MRC, Gembloux AgroBio Tech & FiA informants). As an informant from WorldFish put it; "the way the money flows to different ministries has a large influence on the relative power of those ministries". As it stands, the relative influence of irrigation far exceeds inland fisheries in both Myanmar and Cambodia, resulting in political, financial, technical underrepresentation.

In Myanmar on the one hand, household food and nutrition security (Ministry of Agriculture, Livestock and Irrigation [MoALi], 2014) and increasing incomes especially for agrarian households (Ministry of Health, 2011) are central policy goals. The Multi-sectoral National Plan of Action on Nutrition (MS-NPAN, 2018/19-2022/23) additionally highlights micronutrient deficiencies among women and children particularly in poor rural households as a development priority (Ministry of Health and Sports, 2018). Thus, while agriculture is positioned as a primary driver to improve rural livelihoods (MoALi, 2018), fisheries are recognised as a vital element in a more integrated and nutritious food production system (Ministry of Health and Sports, 2018; Ministry of Forestry, 2009).

Other aspects of the policy sphere however systematically work against poor and marginalised groups by excluding them from land and water resources (Lee, Bendixsen, Liebman, & Gallagher, 2017). 53.84% of the MoALi's budget for 2016–2022 is earmarked for irrigation, compared to only 13.53% for fisheries (MoALi, 2018). Customary land rights are rarely upheld, especially for minorities (WorldFish informant). Myanmar's National Sustainable Development Strategy (NSDS - Ministry of Forestry, 2009), for example, allows for the granting of land without a legally recognised title (termed 'vacant, fallow and virgin land') to private entrepreneurs for commercial-scale fish culture, even though these lands may constitute multi-use common pool resources for local communities. Aquaculture moreover remains an expensive pursuit only available to those with the power and resources to control land and invest in the associated inputs.

Similarly, the country's leasehold inland fisheries management system ensures only the most powerful can control productive inland fishing grounds, excluding small-scale fishers and driving youth out of freshwater fisheries. Until recently, community collectives were deemed illegitimate by the government (WorldFish informant), undermining the scope for building locally appropriate, participatory resource management institutions. The attention given to inland fisheries in Myanmar's development policies is yet to see significant reforms to the Freshwater Fisheries Law, which so far remains focused on the provisioning of fishing licenses (Khin et al., 2020) with no space for participatory fisheries management.

The negative impact of irrigation has been especially high in the Ayeyarwady Delta where some of the highest rates of landlessness occur, at approximately 32.6% (Htway, Phyo, Grünbühel, & Williams, 2014). More than 580 irrigation structures already exist in Myanmar (Than, 2018). Myanmar's National Water Policy and Strategic Plan for Irrigation Development, although focused on food security and poverty reduction, fail to recognise these negative impacts resulting from WCI, or of inland fisheries contribution to diets and livelihoods (National Water Resources Committee, 2014; Rosegrant, 2018). An awareness of the contribution of fish to nutrition security is however reflected in articles published on the NWRC website (Linn, 2020). Further threats to aquatic systems loom with plans to increase access to electricity via new small and medium hydropower plants (Emmerton et al., 2015 Tezzo et al., 2018). These are expected to have major negative impacts to Myanmar's inland fishery, as similar developments have had on the Mekong (Baran et al., 2018, p. 39).

The Cambodian context is not much different. Poverty reduction and inclusive, sustainable development are stated as core themes across development policies, with agriculture a major driver for achieving economic growth, poverty reduction and SDGs (Yu & Diao, 2011; World Bank, 2019). The Strategic Planning Framework for Fisheries (SPFF, 2010–2019) and National Strategy for Food Security and Nutrition (NSFS – RGC, 2014) recognize that fisheries improve nutrition, contributing to reductions in extreme poverty, hunger and child mortality (Royal Government of Cambodia [RGC], 2010). Smallholder production systems and sustainable use of common property fishery systems are highlighted as means to increase access to food and income for the poor and food insecure. Rice field fisheries and aquaculture are expected to contribute to growth in fisheries productivity (Fisheries, 2011).

However, agriculture receives a much larger budget share than fisheries, both of which are managed under the Ministry of Agriculture, Forestry and Fisheries (MAFF- WorldFish informant). Funding for irrigation infrastructure and human capacity development is a priority of the Royal Government of Cambodia (RGC), while donors including the World Bank (WB) and Asian Development Bank (ADB) prioritize support to the Ministry of Water Resources and Meteorology (MoWRAM); the main government agency responsible for water management (Sithirith, 2017). Water is redirected for use in large-scale irrigated farms and hydropower. This trades off against inland fisheries users who face declining fish populations, and in some cases are left without a local viable livelihood alternative, being forced to either migrate to other territories for food or income or starve (informant Gembloux AgroBio Tech; Lawreniuk & Parsons, 2020).

Moreover, Cambodia's most productive fishery, the Tonle Sap, is dependent upon the hydrological flow regime of the Mekong River, which is increasingly altered by the river infrastructure development, especially hydropower (Hecht, Lacombe, Arias, Dang, & Piman, 2019). Dam developments upstream in Lao PDR and China have drastically reduced flow (Lovgren, 2020). These changes to flow, coupled with consecutive years of drought (Lovgren, 2020; WorldFish informant)

have compounded the effects of flooded forest conversion to agriculture, all issues which are managed separately and with very little regard to fish (WorldFish informants).

That the purported policy focus on smallholder poverty reduction and nutrition security has not permeated the management of the sectors which affect fisheries most (agriculture, irrigation and energy) reflects the systemic dissonance of the irrigation/agriculture development bias. Discourse about the trade-offs of irrigation and energy to aquatic ecosystems is lacking, symptomatic of an entrenched sectoralism that undermines integrated development planning in both countries and overlooks the role of social contexts which mitigate the extent to which individuals can participate and benefit from development investments.

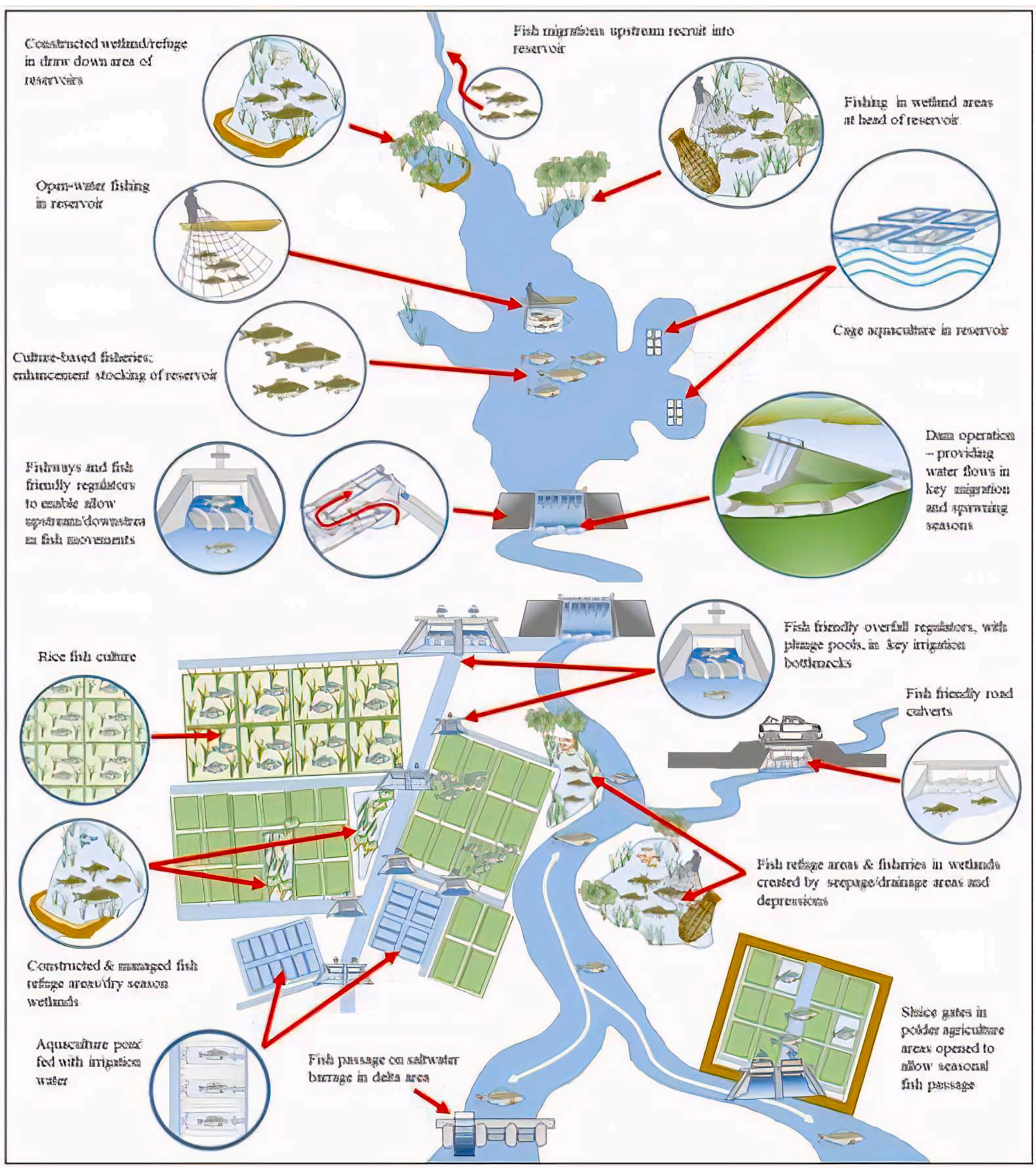

Fig. 2. *Technical fisheries mitigation and enhancement intervention possibilities across an irrigated landscape. Note.* Figure reproduced from *"An ecosystem approach to promote the integration and coexistence of fisheries within irrigation systems"* by R. Gregory, S. Funge-Smith and L. Baumgartner, 2018, FAO Fisheries and Aquaculture Circular (1169). Copyright 2018 by FAO. Reproduced with permission.

5. Enhancing irrigated landscapes through technical-based solutions to reintegrate fish: Fish passage, aquaculture and fish refuge technology

Negative environmental impacts of WCI include fragmentation of free-flowing rivers which prevents fish from accessing habitat for feeding, spawning and dispersing and can lead to significant declines. In the context of growing human demands and increasing environmental volatility, the importance of agricultural sectors in meeting development targets in Myanmar and Cambodia as elsewhere (Zirbel, Grman, Bassett, & Brudvig, 2019; Raiten & Combs, 2019) is underlined. Maintaining freshwater biodiversity and habitat connectivity through 'fish-friendly' infrastructure and practices (Baumgartner et al., 2016; McCartney et al., 2019) could present a more food secure, environmentally sustainable and economically equitable way forward (Freed et al., 2020). Efforts to ameliorate WCI's negative impacts have focused on technical solutions, such as the installation of fish passages in the Lower Mekong (Baumgartner, Boys, Barlow, & Roy, 2017), which allow fish to bypass dam infrastructure and re-enter formerly unobstructed landscapes (Baumgartner et al., 2021; Conallin et al., 2019). Other technologies such as aquaculture have been introduced partly to compensate for undermined natural fisheries (Golden et al., 2017). Both are technical solutions which work in combination with WCI. Both require significant capital investment however and livelihood improvement for marginalised groups is not guaranteed (Rajee & Mun, 2017).

Food production has been identified as the single most influential sector in improving socioecological outcomes and achieving SDGs (Willett et al., 2019). Presently, accounting for existing wild aquatic food systems in irrigation planning is an afterthought in rural development efforts (McCartney et al., 2019). Integrating fisheries through infrastructure modification, operational changes and value adding enterprises has been shown to measurably increase fish numbers within irrigated areas and present an alternative to the current rice-centric approach (Dubois et al., 2019; McCartney et al., 2019), increasing irrigated agriculture's long-term viability (McCartney et al., 2019). Gregory, Funge-Smith, and Baumgartner (2018) illustrate several methods of integrating fish friendly design into irrigated landscapes (Fig. 2), underlining that an integrated and holistic approach is needed to maintain a key aspect of aquatic ecology; connectivity. Rarely is such an approach taken however, as there are few examples worldwide of where fish-friendly design was implemented from inception (Conallin et al., 2019). This highlights a common problem where fisheries are considered after the fact and are usually only discussed in irrigation planning when fishery decline occurs, and the resource base is impacted.

5.1. Fish passage

Fish passage design is focussed on ensuring fish can move through WCI to complete essential life history processes. It is a globally recognised technical solution currently being applied in SE Asian rivers, including in Lao PDR (Baumgartner et al., 2018). The type and location of fish passage can have diverse outcomes for different social groups within the same irrigation area. For example, providing fish passage on river mainstreams in Myanmar may benefit leaseholders who typically control river fisheries, whereas natural wetlands are more often utilised by landless fishers. Reinstating connectivity to natural wetlands and ponds may therefore better serve poorer sectors of the community, and, as these habitats are important nursery areas for economically important fish, flow on effects to other fishing groups could be realised. The type of fish passage may also influence the distribution of benefits as leaseholders typically target large fish, while small-scale fishers more often rely on small-bodied species. Fish passage that allows for both sizes of fish to travel through may provide wider benefits, at an economic cost depending on the type of passage built.

In Myanmar, initiatives to re-instate connectivity for migratory fish species are beginning, with fish passage being designed for at least one key site and landscape connectivity focus and a regional approach to river connectivity are being applied (Conallin et al., 2019). In Cambodia, the technology is also being implemented, although it's still in its infancy (Baumgartner et al., 2017). Within both countries these initiatives were originally technical performance-based remediation projects, with an emphasis on fish biomass and cost-benefit attributes of the fish passage at key sites to ensure minimal impact on existing irrigation infrastructure. The assumption that more fish equals pro-poor outcomes forms the basis of these initiatives, but presently, there are orders of magnitude more structures which do not contain fish passages, than those that do. Prioritisation is a key factor. More needs to be done to have fish passage considered a "mainstream" part of decision making, and to have governance mechanisms to achieve social benefits included within fish passage initiatives. Often this technology is seen as an unnecessary cost, despite benefits being better-defined in recent times (Cooper, Crase, & Baumgartner, 2019).

5.2. Aquaculture

Recognition that capture fishery production cannot be substantially increased to match human population growth has made aquaculture an attractive proposition to guarantee fish through intensified production (Reverter et al., 2020). When fish are cultured concurrently with rice, land productivity can be doubled (Dubois et al., 2019), and aquaculture has been found to create jobs, with better wages, including for women (Belton, Filipski, & Hu, 2017; Stevenson & Irz, 2009), all while increasing production of fish for human consumption. Sector profitability has been demonstrated in the region, with Vietnam, Thailand and Bangladesh consuming and exporting large amounts of farmed fish (Belton et al., 2015). However, the substantial investments needed for profitable operations represent a barrier to entry for low-income households (Belton et al., 2017; Chertkov, 2020). Some socio-ecological impacts are described in Fig. 3 (Stevenson & Irz, 2009).

In Myanmar, aquaculture is primarily freshwater, concentrated in the Ayeyarwady Delta, and controlled by approximately 100 large farms (van Beijnen, 2018). Small-scale aquaculture occurs throughout the Delta, much of this illegally due to restrictive land use policy (Belton et al., 2015). Unlike in Cambodia where the industry is relatively low technology and inefficient (Joffre, Pant, Somony, Chantrea, & Viseth, 2019), aquaculture accounts for 35% of all catch in Myanmar (FAO, 2020). Several investments have been made to date, including MYCulture (Akester, 2019), GIFT (Chertkov, 2020) and WISH ponds (Karim et al., 2020). Government-led efforts to demarcate riparian and riverine areas of the Ayeyarwady Delta for aquaculture development have resulted in displacement of many (Hein & Belton, 2017; WorldFish informant), and where scheme design is singularly oriented to fish production and maximum profit (WorldFish informant), poor and landless can experience a double inequity: being simultaneously excluded from land, water and fishery resources and barely supported by investments (Pasgaard & Chea, 2013). In Cambodia, where formerly abundant freshwater capture fisheries are declining, aquaculture is gaining traction (MRC informant), however strong competition from already established aquaculture industries in neighbouring Vietnam and Thailand, limited access to quality seed, expensive imported feed, poor biosecurity and inadequate training and support have restricted the industry (Panha, 2018).

5.3. Fish-Rice systems

Rice-field fisheries (RFFs) are an important common pool resource in Cambodia which occurs within irrigated landscapes naturally containing wild fish and other aquatic species. RFFs are facilitated by the variety of aquatic habitats within rice agroecosystems, the seasonal inundation of rice fields and overflow of perennial water sources, which allow fish to disperse across the landscape to spawn and feed in shallow, nutrient

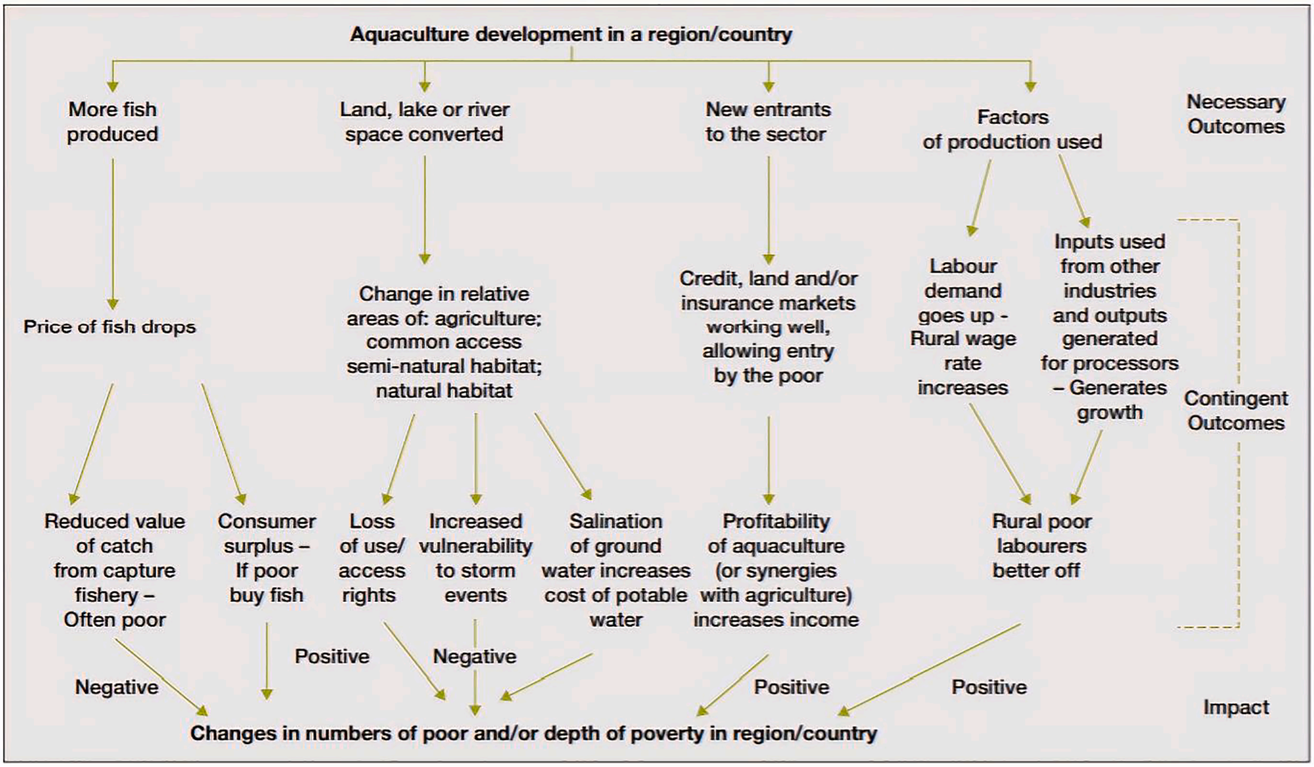

Fig. 3. *Aquaculture and poverty reduction: potential impact pathways. Note.* Reproduced from "*Is aquaculture development an effective tool for poverty alleviation? A review of theory and evidence*" by J. Stevenson and X. Irz, 2009, Cahiers Agricultures, 18, 292-299. https://doi.org/10.1684/agr.2009.0286. Copyright 2014 by CIRAD. Reproduced with permission.

rich, flooded rice paddies (Freed et al., 2020). RFFs are supported by water storage infrastructure such as canals, ditches and household ponds, and purpose-built community fish refuges (CFRs). Rice-fish culture; the practice of raising fish stocks in privately owned ditches, canals and ponds, for personal nutritional and economic benefit (Halwart & Gupta, 2004), also occurs. Conflicts can occur between agriculture focussed and fish focussed water users (Sithirith, 2017) during dry periods when landless people trespass on to private property to access fish (Dey et al., 2005).

6. Discussion

6.1. The challenge of inclusive development within unequal social landscapes

While fish passages, aquaculture and other technical investments can enhance fish populations within landscapes, neither the infrastructure nor increased fish biomass guarantees socially inclusive development unless social inequalities are concurrently addressed to secure equitable benefit distribution. Limited representation and agency of marginalised groups in the shaping of interventions and benefit sharing arrangements can lead to poorly targeted development projects and exacerbate issues of access to fish and water resources, prompting the question, fish for whom?

6.2. Social inclusion and distributive and procedural justice

In considering social inclusion in the context of the SDGs, Gupta et al. (2014) note that social goals tend to be marginalized in the implementation of sustainable development while economic growth is prioritized, such that many development challenges are essentially issues of distribution. Rawls' (1971) view of social justice emphasizes the need for fairness in the distribution of goods and opportunities with respect to wellbeing and participation to ensure that the least advantaged in society are not marginalised. Similarly, based on social justice ideology, Gidley et al. argue that increasing social inclusion "is about human rights, egalitarianism of opportunity, human dignity, and fairness for all", where "its primary aim is to enable all human beings to participate fully in society with respect for their human dignity" (2010, p. 9). Safeguarding the engagement and participation of all societal groups is therefore key to inclusive development (Gidley, Hampson, Wheeler, & Bereded-Samuel, 2010). One approach to this could be through procedural justice, or the fairness of the decision-making process (Venot & Clement, 2013), where who participates in and influences decision-making is shaped by recognition, in turn determined by social identity, linked to the heterogeneity of identities in a community. Social and procedural justice are important in our context with respect to both ensuring equitable access to irrigation and fish resources, and mitigating trade-offs between irrigation development and aquatic ecosystems, since it appears that disadvantaged groups lack adequate institutional capacity and legitimacy to participate in natural-resource decision making in Myanmar (WorldFish informants) and Cambodia (WorldFish & Gembloux AgroBio Tech informants).

6.3. Social inclusion in the context of heterogeneity, marginalisation and multi-scalar complexity

In general terms, heterogeneity can be understood as being diverse in character or content. In the context of irrigation or other common-pool resource use, social heterogeneity is the result of intersections between features of a particular collection of people such as a village or larger society and is strongly embedded in social identity. Intersecting factors may include economic, social and cultural, or other characteristics. For example, while gender norms and hierarchies shape nature-society interrelations (Agarwal, 1994; Leach et al., 2007), the experience of gender inequalities is impacted by other axes of vulnerability such as

class, race, religion, ethnicity, age, or disability. Social and cultural rules, norms and practices determine that reliance on, access to, use and control of natural resources varies significantly. For example in Myanmar, Angeles, Barbesgaard, and Franco (2019) demonstrate gendered impacts of development interventions for women and men in labour participation, community roles and access to resources, where women are often "invisible and unacknowledged" (2019, p.75) as fisheries is perceived as a male domain despite women's crucial role in fishery value chains. The land rights claims of marginalised ethnic groups are likewise known to be ignored or dismissed when demarcating formerly commons wetlands to private commercial aquaculture (WorldFish informants). Landless people are excluded all together from the direct benefits of irrigation, though they may indirectly benefit from lower food prices (Royal University of Agriculture Cambodia, WorldFish & MRC informants). The plurality in interests, needs, vulnerabilities and agency of diverse groups therefore unfold in different ways in spaces, such as the household, community and the "commons", which are therefore complex, dynamically evolving spaces (Clement, Harcourt, Joshi, & Sato, 2019). Moving beyond social factors, Bardhan and Dayton-Johnson (2002) point out that locational differences in landholding can provide different strategic opportunities (and disadvantages). This would apply in the case of upstream–downstream irrigators or fishers with access rights linked to specific locations. When correlated with wealth, fishers with more or better equipment will enjoy greater capacity to extract fish and capture a larger portion of the resource.

These interactions between social, economic and other factors cause a plurality of values and interpretations of social problems (Bardhan and Dayton-Johnson, 2002), which can impede cooperation and inclusion in the use and sharing of resources, which undermines irrigation performance unless appropriate management institutions are adopted. Moreover, Howarth, Nott, Parajuli, and Dzhailobayev (2007) note that approaches dominated by engineering and infrastructure activities that "glossed over the mixed livelihood strategies of water users, the nature of relationships in socially heterogeneous communities" and that it is the "particular interests and relationships" of local stakeholders that underpin the mixed performance of community-based irrigation management (2007, p.2). These weaknesses arise because irrigation management and water distribution problems are often perceived to be technical, and hence requiring only technical solutions.

Problems of commons management are, moreover, not simply "local" problems. Wider economic, social and political contexts shape social and environmental conditions and challenges in different ways (Fig. 1). Put together, this matrix of inequalities co-determines marginalization and vulnerability. For example, since water governance is polycentric, (nested at multiple jurisdictional levels), with multiple centres of decision making (Aligica & Tarko, 2012), intra-community relationships have both horizontal (local) and vertical (larger scale) characteristics (Berkes, 2006; Pellow, 2017; Stewart, 2002). Polycentrism and historical narratives in which social relations are rooted (Agarwal, 2003; Saunders, 2014), add to the contextual complexity in which investments and actors are 'embedded'. Thus, root causes of inequality are deeply structural and hierarchical (Agarwal, 1994; Leach et al., 2007), and represent relations of power, privilege and (in)justice at scale (Fraser, 1996).

6.4. *The risk of elite capture in designing and implementing technical interventions*

A key manifestation of social heterogeneity impacting the outcomes of investments is elite capture. Schmidt and Theesfeld (2012) define elite capture as "the tendency of local elites – that is, local individuals or groups with disproportionate access to social, political, and economic power – to dominate or capture participatory projects." Such dominance gives rise to "local tyrannies" (Andersson & Ostrom, 2008) based upon the manipulation of rules by the powerful to suit their interests, often at the expense of other stakeholders. Elite capture and marginalisation can be articulated by the interrelated notions of distributive justice, procedural justice and recognition (Schlosberg, 2003; 2004).

Avoiding elite capture of natural resources and equitably distributing benefits to marginal groups has proven enormously challenging (Andersson & Ostrom, 2008; Dasgupta & Beard, 2007; Platteau & Gaspart, 2003). Inclusivity and access pathways are rarely considerations in the planning, implementation and evaluation stages of many irrigation, fisheries, and other rural development projects (Hein & Belton, 2017; Kaminski et al., 2020; Johnstone, 2016), as evidenced by the scarcity of examples from the literature and experiences of key informants. Externally conceived projects tend to ignore or oversimplify the social context in which technical solutions are applied, often failing to incorporate adequate management strategies for the human aspects of resource use (Saunders, 2014). Questions of benefit distribution are left to be determined by power relations within rural communities (Saunders, 2014), and evaluating livelihood improvement impacts of investment remains challenging (Béné et al., 2016; Kandulu & Connor, 2017).

Myanmar's leasable fisheries system exemplifies the way vertical laws and horizontal inequalities interact to enable local elites to capture the country's most productive fishing grounds (Box 1). The exclusive access rights granted to leaseholders for resource exploitation are designed for maximum rent extraction and are auctioned at a price which precludes small-scale fishers from competing with wealthy operators, even if resources are pooled (Khin et al., 2020). Leases are also used to reward specific individuals, who, although they may sublease the operation of the fishery, remain in control of the profits (Khin et al., 2020). It is not only disparities in wealth that disenfranchise small-scale fishers; government policy prioritizes revenue through low transaction cost resource exploitation models that are blind to the fishery's distributive potential.

6.5. *The way forward: Bridging the techno-social divide*

Without prior in-depth social research, development projects will be unable to sufficiently account for complex social landscapes and thus risk investments being 'captured'. Mitigating uneven access and benefit distribution is therefore highly relevant to investments' contextual relevance and ability to deliver benefits accessible to the cross-section of a community. The question that must be answered by governments and donors is how will the contextual inequalities that inhibit some groups' influence on decision-making, meaningful engagement in planning, and active participation in implementation be addressed?

To tackle deep-rooted, intersectional inequalities that exist at scale, we recommend that government, donors and development implementers firstly recognize that investments in manipulating landscapes for human development must address both ecological and human aspects of social-ecological systems. This should lead to investments that no longer treat technical innovation as the final solution, but rather as a midway point, to be strongly linked to action in the social domain. In fact, we suggest that technical investments be conceived, designed and implemented within specific social contexts, informed by co-creative processes to ensure that project planning adequately allocates time and resources to understand and reflect the social dimensions of an intervention. This should include integration of local knowledge and contextual appropriateness of infrastructure design and operation as well as mechanisms for inclusive and equitable access to benefits. Such attention to distributive and procedural justice will help project design and implementation move beyond rhetorical notions of participation to more robust, inclusive designs. Inclusion is fundamentally about managing the politics of context: understanding wider social, political and economic contexts, not just to understand how these shape structural inequalities in decision-making, but equally to understand the plural mandates and interests that shape resource access, management and benefit distribution. Box 2 presents a case study of community fish refuge (CFR) investment in Cambodia to illustrate this. Transforming structural barriers is key to addressing inequality in diverse groups

Box 1
. A case study on the exclusionary impacts of leasable fisheries in Myanmar

An examination of youth engagement in inland fisheries by the International Water Management Institute (Arulingam et al, in review) demonstrates how investments in irrigation (canals, sluice gates) and other WCI have decimated the productivity of the local inland fishery in Kyonkadun village in the Ayeyarwady Delta. In this case, the leasable fishery system has compounded the plight of landless and smallholder households by excluding them from the remaining productive fishing areas, illustrating how more inclusive community fisheries management initiatives are fettered by the monopolistic influence of the leasable fishery, whereby the landholding fishery leaseholders shut out small-scale fishers. Local youth report disenfranchisement, and are now seeking alternate livelihood options away from the village. The out-migration of this next generation will result not only in the loss of labour, but generational knowledge of the natural resources system, meaning the loss of local environmental custodians. The convergence of sector-driven WCI investments and exclusionary, rent-seeking fisheries management policy undermines multi-functional landscapes and the contribution of inland fisheries to local poverty reduction and nutritional diversity. Considered in the context of the more than 300 other existing sites of WCI in the Ayeyarwady Delta provides pause for contemplation as to the cumulative impacts across the Delta.

within and between households (de la Torre-Castro, 2019; Rao, 2017). This will require a shift in thinking and considerable investment.

While other mediating factors no doubt contributed, this short case study is one example where collective resource governance appears to have been achieved with benefits for ecosystems and associated human communities. Conscious of both horizontal and vertical actors, the Rice Field Fisheries Enhancement Project appears to have by and large overcome the challenges of operationalising CPR theory and design principles in local contexts where power is distributed unequally (e.g. Ostrom 1990, Saunders 2014). Accounting for the full range of stakeholders not only reduced conflict (Miratori et al., 2019), but brought to bear local knowledge derived from life-long experiences with the natural system in question, enriching problem analysis and promoting a context-relevant rules system (Andersson & Ostrom, 2008; Schmidt & Theesfeld, 2012). This reflects the application of 'adaptive governance' theory (Dietz, Ostrom, & Stern, 2003) and polycentric approaches (Aligica & Tarko, 2012) that link local level action to higher levels of governance. Moreover, awareness of social diversity and inequality enabled representation and more effective management through bottom-up, co-creative processes, where the project was the facilitator rather than the agenda and rule setter.

Mediating social heterogeneity will require institutions built through an iterative process of social engagement beginning in the goal setting phase. To illustrate how the principles of institutional co-creation can fit within technical investments, Fig. 4 represents a modified version of a figure from Lynch et al. (2019). In its original form, investments in increasing inland fish resources were assumed to automatically result in greater food security and nutrition. The original figure aptly illustrates the current conception of development investments as solely technical fixes. To bridge the techno-social divide, we recommend "Multi-scale, representative institutions to foster sustainable resource management, inclusive access to fish and equitable benefit flows" (Fig. 4). This is notably the reverse of external and top-down approaches. In addition to goals related to natural resource production, ensuring greater food security, nutrition and income for a wider range of stakeholders constitutes a key goal. The steps that follow move through analysis of the status quo considering the agreed goal(s), which includes explicitly acknowledging inequalities, power asymmetries and underlying drivers,

Box 2
. Community-managed fish refuges in Cambodia: An example of institution building to address the techno-social divide.

After Cambodia's Fisheries Administration (FiA) decided to designate CFRs to enhance productivity of rice field fisheries, the Rice Field Fisheries Enhancement Project (2012–2016), led by WorldFish, in collaboration with the FiA and financed by USAID, set out to pilot best management practices for the CFRs. Core objectives included local enhancement of fishery productivity; local poverty reduction and improved nutrition through greater access to fish. As co-management arrangements are used to govern Cambodia's fisheries, local communities were considered both the custodians and beneficiaries of well-managed CFRs. The CFRs were established on a theoretical framework that:

builds on the premise that common-pool resources such as community fish refuges are complex systems that are often treated as public and open resources that everybody has access to and community members' knowledge of and participation in their management is paramount to sustain such resources (Phala, Sarin, Suvedi, & Ghimire, 2019).

A systematic approach including investment in an inclusive institution (the Community Fish Refuge governing committee), networks, partnerships and fora to enable the inclusion of CFR issues within wider planning for local and provincial governance, was central to this framework's operationalization. Governance capacity-building for CFR committees focussed on five areas: appropriate institutional structure, inclusive planning and implementation, effective resource mobilization, networking with external stakeholders and equitable representation (de Silva et al., 2017). Engagement of local resource users, commune council members, fisheries officers, environment officers, military police, district officials and regional governors was enabled through sharing of responsibilities and recognition for achievements; helping to minimise negative impacts of power imbalance and the potential for governance traps (Suhardiman et al., 2017). Using the Tonle Sap region as the frame of reference encouraged groups to think beyond their immediate geography, promoting a multi-scalar awareness of challenges and options for their management (de Silva et al., 2017). The process of collective analysis and institutional design built project legitimacy amongst local and external stakeholders and represents an example of procedural justice.

This process of institutional co-creation has yielded promising results. Resource conflicts were reduced through negotiated and agreed upon limits to water exploitation in the CFRs and better coordination between water users (de Silva et al., 2017). In the second year of the project, fish production increased by 17%, worth USD 1.8–2.1 million (Brooks & Sieu, 2016). Phala et al. (2019) found households were catching 0.8 kg more fish per day, while the variability of catch among households reduced, suggesting CFRs contribute to income equalization among community members. Household savings and family expenditure had consequently increased significantly

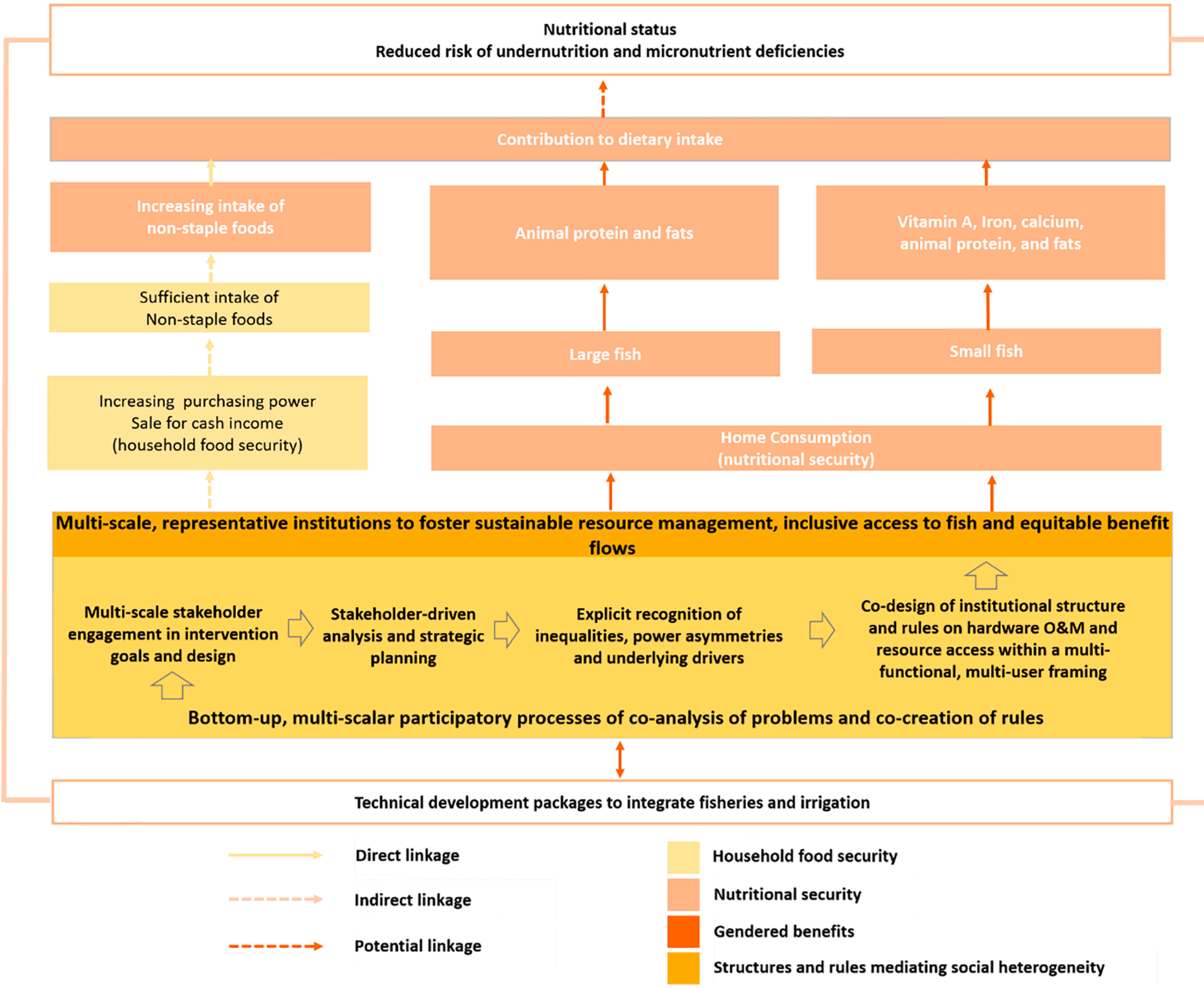

Fig. 4. *Development process components necessary to promote inclusive growth. Note.* Figure adapted from *"Speaking the same language: can the sustainable development goals translate the needs of inland fisheries into irrigation decisions?"* by A. Lynch et al., 2019, Marine and Freshwater Research, 70(9). doi:https://doi.org/10.1071/mf19176. Copyright 2019 by CSIRO. Adapted with permission.

enabling finally the design of contextually appropriate institutional structures, participation schemes, and rules fit for achieving desired goals.

7. Conclusion

Reintegrating fisheries can enhance landscape multi-functionality, contribute to agricultural and ecological resilience, and enhance food and nutrition security. However, as we have demonstrated, infrastructure alone is not enough to translate investments into these improvements, especially for marginalised groups, who compete from a position of disadvantage for resources and investment benefits. For inclusion to become reality within future development investments, gaining an appropriate understanding of social context, including incorporating local knowledge, prior to design and implementation, will aid greater customisation of investments such as fish passage, aquaculture and irrigation amongst others. We propose that institution building is of critical importance in bridging the techno-social gap that we argue currently exists, with Fig. 4 representing the social component that future investments must include.

We therefore call for the reconceptualization of water infrastructure to align with SDGs, arguing that WCI need perform not only bio-physically through fish/rice production, but socio-ecologically, which at present is poorly articulated in performance evaluation frameworks and investor strategies. This should result in more precise cost/benefit analysis disaggregated across predicted beneficiary groups and a reduction in unexpected or unintended social-ecological consequences. The development of frameworks for measuring performance against indicators of inclusive outcomes which go beyond binary, superficial statistics will likely require development design teams to become more multidisciplinary. Perhaps most importantly, political will to break away from the well-trodden path of business-as-usual is necessary. The onus is on donors and governments to recognize and account for this inextricable link between ecological and social systems in planning, designing and implementing development programs to ensure more equitable benefit distribution for those they are seeking to uplift.

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CRediT authorship contribution statement

Nicolette Duncan: Visualization, Investigation, Data curation, Formal analysis, Writing - original draft. **Sanjiv Silva:** Visualization, Investigation, Formal analysis, Writing - original draft, Supervision. **John Conallin:** Visualization, Investigation, Formal analysis, Writing - original draft, Supervision. **Sarah Freed:** Writing - review & editing. **Michael Akester:** Visualization, Writing - review & editing. **Lee Baumgartner:** Visualization, Writing - review & editing. **Matthew McCartney:** Visualization, Writing - review & editing. **Mark Dubois:** Visualization, Writing - review & editing. **Sonali Senaratna Sellamuttu:** Funding acquisition, Project administration, Resources, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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