



Hydropower Development and the Loss of Fisheries in the Mekong River Basin

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Development of large scale hydropower is proceeding rapidly in the Mekong basin without adequate consideration of the severe and cumulative impacts the dams and reservoirs will, and are already beginning to, have on biodiversity, livelihoods and the economies of the lower Mekong countries. Migratory aquatic species will be particularly affected, and global experience indicates that fishways proposed for large mainstream and tributary dams will not provide effective amelioration. An offset strategy of remediating small weirs, flood control devices, regulators and irrigation works on tributaries and flood plains is more likely to be an effective and economically efficient means of supplementing fisheries to compensate for the negative impact of mainstream dams. Mainstream hydropower developments may result in future stranded assets, high electricity costs and even threaten the sovereignty of lower Mekong countries.

Keywords: Mekong River, hydropower, fisheries, impacts, environmental offsets

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INTRODUCTION

Although the Mekong River system is known to support an extraordinary diversity of freshwater species and a globally significant fishery (Hortle, 2009a), development of hydropower in the basin proceeds apace (Geheb, 2018), with only scant consideration given to the biological resources being lost (Intralawan et al., 2018). In this commentary we outline key management issues and environmental consequences arising from the present trajectory for hydropower development in the Mekong basin. There are other environmental issues confronting the people of the Mekong basin which will also impact the river, including climate change, but at least over the next couple of decades the impact of dams already constructed and under construction is expected to far outweigh impacts arising from changing climate (Lauri et al., 2012; Ngo et al., 2016).

CHARACTERISTICS OF THE MEKONG SYSTEM

The Mekong is one of the most globally significant rivers (Campbell, 2009a). It is significant because of the large human population living in the basin and dependant on the river for their livelihoods both directly (e.g., fisheries, navigation, and water supply) and indirectly (e.g., the annual flood

pulse around which farming is based, soil fertility, cultural values). It supports a remarkable diversity of fish (Valbo-Jørgensen et al., 2009), and freshwater gastropods. The Mekong River is one of the 20 largest rivers in the world in terms of discharge. It arises in the Himalayas, and flows through six countries in a politically sensitive region.

The total number of fish species present in the Mekong system will likely never be known. New species are being discovered, taxonomy is being revised, and estimates for species numbers vary depending on the inclusion or otherwise of estuarine fishes. Hortle (2009b) estimated there are at least 850 freshwater fishes in the Mekong. More recently, the Mekong River Commission's Fish Species Database lists 1,144 species, which includes marine visitors and estuarine fishes, in the river (MRC, 2020). This makes the Mekong second to only the Amazon for the variety of fish species present. Included in that fauna are several unusual and charismatic species such as the giant species of catfish, barb and stingray (Hogan et al., 2004; Valbo-Jørgensen et al., 2009). In addition to the fish, the Mekong is known to have at least 285 species of freshwater snails (Attwood, 2009), which constitute over 7% of the globally described species of freshwater gastropods (Strong et al., 2008), as well as other high profile aquatic species (e.g., freshwater dolphins).

The riverine ecosystem has supported what is believed to be the largest riverine fishery in the world. The fishery is estimated to yield approximately two million tons per year (Hortle, 2007; Hortle and Bamrungrach, 2015) with an annual value of US\$11 billion (Nam et al., 2015). The annual fish harvest is equivalent to 17% of the annual global inland fisheries harvest of 12 million tons, and 2.4% of the global marine fish harvest of approximately 84 million tons (FAO, 2020).

Fisheries such as that of the Mekong have been difficult to describe in terms of economic importance, and are usually undervalued (Neiland and Béné, 2006; Baran et al., 2007). Most of the harvest is taken by subsistence fishers, who consume much of their own catch. When fish are traded it is partly through direct bartering with local people and partly through thousands of small local markets (Coates et al., 2003). Therefore, although large marine fisheries are conducted primarily by large fishing vessels operating through a relatively small number of well-established fishing ports allowing the catch to be comparatively easily documented and quantified, the Mekong is largely composed of artisanal fisheries. The full extent and importance of the fishery has only become evident as a result of extensive surveys and analyses conducted for the Mekong River Commission since 1995 (e.g., Hortle, 2007; Hortle and Bamrungrach, 2015) and meta-analyses of fish consumption data revealing the global "hidden harvest" from inland fisheries (Fluet-Chouinard et al., 2018).

IMPACTS OF HYDROPOWER DAMS ON THE MEKONG

The major impacts of dams, including hydropower dams, on riverine ecosystems have been well known for decades (Petts, 1984; Nilsson and Berggren, 2000; World Commission on Dams, 2000; Anderson et al., 2015). Generally, the two most important

sets of impacts arise from the dam acting as a barrier to the movement of sediment and aquatic organisms such as fish and crustaceans, and the alteration to downstream flows. However, dams may also affect water quality and, through inundation, eliminate flowing water habitats.

In a large river such as the Mekong, which carries a substantial sediment load, the trapping of sediment has two important consequences (Kondolf et al., 2014). Firstly, a reduction in the downstream sediment supply has serious consequences for systems downstream that may depend on that supply. That may include riparian and floodplain systems that derive part of their nutrient supply from deposited silt, and deltaic systems that may change from depositional to erosional systems when sediment supply is reduced or even eliminated completely. Within the Mekong system it has been estimated that, should the full suite of proposed dams be constructed at the proposed locations, the sediment load currently transported to the delta would be reduced by 96% (Kondolf et al., 2014). This would result in both increased erosion and reduction in the area of the delta (Schmitt et al., 2017).

The consequences of a dam as a barrier to fish and aquatic life depend in part on the extent to which the species present undergo obligatory migrations. Concerns about dams as barriers to fish first became prominent in relation to salmonid fisheries in North America when populations of anadromous salmon were devastated when their migratory pathways were blocked by dams (Ferguson et al., 2011; Brown et al., 2013). Similarly, in the Mekong, it is known that many species undergo annual long-distance migrations as part of their breeding cycles, so the potential for dams to disrupt the fishery is high (Halls and Kshatriya, 2009).

It should be noted that dams act as a barrier to both upstream and downstream movement. Upstream movement is blocked because the organisms such as fish may be unable to pass over the spillway or through the power station turbines because the velocity of the current is too high. Downstream movement is impaired because drifting larvae, and even adult fish, are unable to find their way through the standing water of the impoundment to locate the outlet (Pelicice et al., 2015). Moreover, adult and juvenile fish which attempt to pass through hydropower infrastructure experience severe mortality from shear forces, physical strikes from turbine blades, and barotrauma or changes in barometric pressure (Algera et al., 2020).

The second pathway by which dams can impact riverine ecosystems is by alteration of downstream flow patterns (Petts, 1984). Although single-use hydropower dams do not divert water from the river channel, the flow pattern is altered with water usually being retained during the wet season and released during the dry – so wet season flows are reduced and dry season flows increased. When newly constructed dams are filling downstream flows may be reduced in both dry and wet seasons. Both of these patterns have been encountered in the lower Mekong (Hecht et al., 2018; Eyler et al., 2020). Many riverine species of fish and invertebrates have life cycles synchronized to river flow regimes. For instance, eggs and larvae (which are unable to swim or are poor swimmers) of many species are present

during low flow periods when they are less likely to be washed downstream, so their life cycles and population recruitment are adversely affected when dry season flows are increased (Campbell, 2009b).

Thirdly, dams may alter the physical and chemical characteristics of the water downstream (Petts, 1984). Water released from the bottom of dams may be colder or contain lower concentrations of dissolved oxygen than normal river water. In addition, the impoundment of the dam, with still or slowly flowing warm clear water, may act as an incubator for algae which are then released downstream.

A final impact is the loss of habitat that occurs when a section of river is inundated and replaced by the standing water of the impoundment. In the case of the Mekong system a large number of dams have been constructed, and many more are under construction or planned (Greater Mekong Dams Observatory, 2020; **Figure 1**). Most of the hydropower systems proposed are “cascades” in which the pondage of each dam backs up virtually to the foot of the wall of the next upstream dam, eliminating riverine habitat entirely. The dam cascades under construction on the mainstream in Lao PDR, for example, will eliminate about 40% of the mainstream

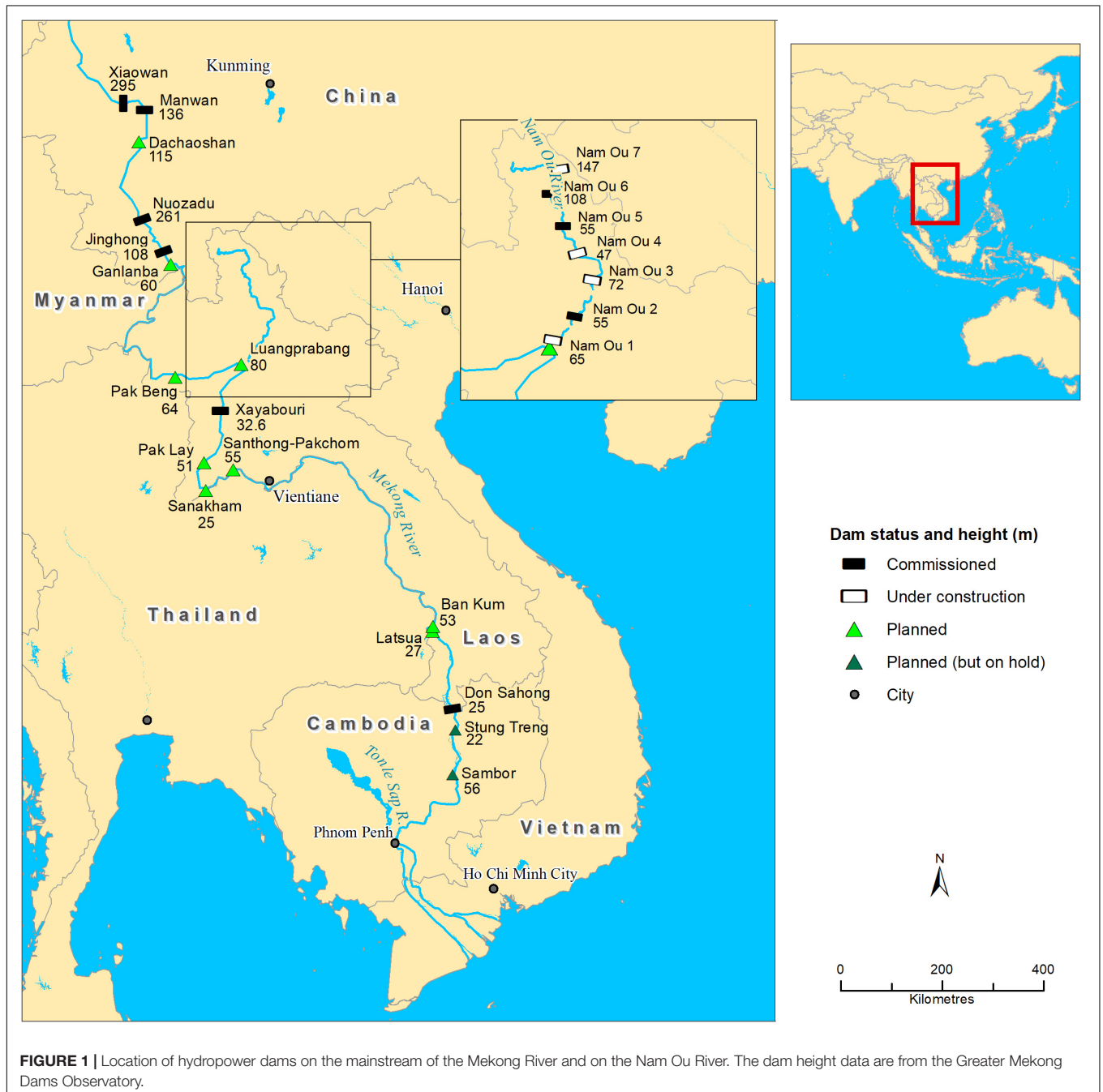


FIGURE 1 | Location of hydropower dams on the mainstream of the Mekong River and on the Nam Ou River. The dam height data are from the Greater Mekong Dams Observatory.

riverine habitat in Lao, which is about 25% of the mainstream habitat downstream of China. A similar cascade presently under construction is eliminating most of the mainstream habitat in China (Wei et al., 2017), and cascades are also flooding the habitats of the Nam Ou, the largest tributary in Lao PDR, and many other tributaries. The loss of habitat alone threatens many riverine species in the system.

The impoundments will support populations of fish and other aquatic species, but the species composition will be changed, and the size of the fisheries will be diminished. While newly created reservoirs often have productive fisheries in their first few years from excess nutrients resulting from decaying vegetation, the fisheries invariably decline to production levels less than the river fisheries which they replaced (Jackson and Marmulla, 2001).

VALUING HYDROPOWER AND FISHERIES

Analyses of the benefits of hydropower and the associated loss of ecosystem services have indicated negative economic consequences for the lower Mekong countries, especially Cambodia and Vietnam (Orr et al., 2012; Pittock et al., 2016; Intralawan et al., 2018; Yoshida et al., 2020), contrary to assessments undertaken by the Mekong River Commission (MRC, 2011). Intralawan et al. (2018) recommended that a new Lower Mekong Basin energy strategy be developed taking into account less hydropower income than previously anticipated, updated forecasts for LMB energy demand, and improved energy efficiency and renewable energy technologies (especially solar power). In light of these analyses, it is instructive to retrospectively examine the background to the relative importance given to hydropower development and fisheries by the governments of the lower Mekong countries.

The international consultants who were first involved in development proposals for the Mekong came predominantly from Europe and North America, where rivers and inland fisheries differed starkly from the Mekong. In those regions there were very few subsistence users of rivers, and the rivers primarily supported recreational fisheries. The only analogous situation in a developed region would be the rivers of north-western America that supported large salmon fisheries, and there the impacts of hydropower development had become highly controversial (Williams, 2008).

The Mekong fishery is diffuse, lacking large scale fishing ports, markets or processing plants, so consultants from developed countries making short term visits to the region largely failed to appreciate the importance of aquatic resources. However, since 1995, mainly because of the work of the fisheries program operated by the Mekong River Commission, more information has become available. For example, the value and importance of the fishery has been progressively identified, and that information has been published and passed to politicians and decision makers within governments in the region and international development agencies. Recent estimates by the MRC put the value of the capture fishery at US\$11 billion per year per year (Nam et al., 2015).

One approach to considering the economic impact of hydropower development in the lower Mekong is to consider the fisheries value of the river per unit of river length. Although it is not possible to measure the lengths of rivers precisely because they are fractal values (see Campbell, 2009a), an estimate of the length of the Mekong main channel length from the China-Lao border to the sea is about 2500 km, measured from Google Earth. The fishery is not constrained to the main channel, so including the large tributaries we estimate that there is probably in the order of 7500 km of large river channel in the lower Mekong.

While migratory species would be those most impacted by hydropower dams, not all of the value of the Mekong fishery accrues from migratory fish. Halls and Kshatriya (2009) estimated that 38.5% of the total weight of fish species caught in fisher catch surveys was migratory. This equates to a total value for the migratory fish resource of \$4.2 billion, or \$565,000 per kilometer. The relative value is higher in the downstream flood-plain reaches where there is more fish production than in the upper, mountainous reaches. Nevertheless, as a generalization, for a dam that inundates say 100 km of river (which is approximately the length of the Xayaburi Dam pondage), the economic benefit from the dam would need to exceed \$56 million per year before the dam produces a net positive economic value for the country.

Friend et al. (2009) discussed the reasons why the Mekong capture fisheries are undervalued in relation to hydropower. They identified four aspects: the fisheries were believed to be in an inevitable decline; that it was a marginal activity; that aquaculture could replace capture fisheries; and that there was a trade-off between fisheries and development.

We propose another issue to be considered is whether hydropower is overvalued in the Mekong. There are several reasons that suggest to us that this is a possibility. The first is the relentless sales campaigns that hydropower agencies have waged in the Mekong, and in other less developed regions with large rivers. Second, increasingly commonly proposed large hydropower projects in developed countries have been blocked as their environmental impacts were identified by local people resulting in intense political battles. Blocked in their own countries those organizations sought business elsewhere – often where people were not as aware of the issues and politicians were more tractable. Thirdly, independent analyses have found “overwhelming evidence that budgets are systematically biased below actual costs of large hydropower dams” (Ansar et al., 2014).

In the Mekong there has been a series of proposals dating back to organizations like the Tennessee Valley Authority from the United States, the Compagnie Nationale du Rhône from France (Mekong, 1994), the Snowy Mountains Engineering Corporation and Hydro Tasmania from Australia, and agencies from Canada, Norway, Thailand, and China. Hydro Tasmania started to seek other geographical regions where they could build hydropower dams following bitter political fights over Lake Pedder and the Franklin River in Australia. Similarly dam building companies in Thailand turned their sights to neighboring Mekong countries following political backlashes to proposed dams in southern Thailand, and the economic and public relations disaster of Pak Mun dam on a Thai

tributary of the Mekong (Roberts, 1993). In China, there is an increasing resistance to large dams since the completion of the Three Gorges Dam, which many regard negatively. Politicians in Lao PDR in particular have been the recipients of decades of “hard sell” about the benefits of hydropower projects from both private and semi-government corporations seeking future large projects.

In turn, governments in the Mekong countries perceive at least three benefits of hydropower projects. The first is that hydropower projects are considered an important step on a pathway of large-scale industrialization as the primary mechanism to raise incomes and living standards. Second, large-scale development projects are used as evidence of modernity and thus improved status of the country in international discourse. Finally, large infrastructure projects provide abundant opportunities for corruption (e.g., Wells, 2015; Locatelli et al., 2017), and senior decision makers, typically the elites within countries, are well positioned for personal benefit (Andersen et al., 2020).

THE FAILURE OF PLANNING AND DESIGN

The current hydropower developments on the Mekong River are, in part, the outcome of two failures in planning and design. The first is a failure to conduct a basin-wide strategic environmental impact assessment. The second is the application of the cascade model of hydropower development.

The Mekong River Commission instigated a strategic environmental impact assessment of hydropower in the Mekong in 2009 (ICEM, 2010). However, the investigation was constrained by the insistence by member countries that only mainstream dams could be considered, and by the mandate of the Commission being restricted to the river downstream of China. More importantly, the two main recommendations arising from the assessment were not implemented. These were: that decisions on mainstream dams be deferred for 10 years to allow for rigorous and broad assessment of benefits and costs; and that the Mekong mainstream should never be used as a test case for proving and improving full dam hydropower technologies. Nevertheless, we note that basin-wide planning in multi-jurisdictional contexts anywhere in the world present intractable issues, with a history of contested or failed experiences (Campbell, 2007; Campbell et al., 2013).

The model of hydropower development being pursued in the Mekong is cascades of dams, where each dam spills directly into the next downstream pondage. This model, widely applied in China, maximizes the potential electricity yield, but it also maximizes the negative environmental and social impact of dams. Inclusion of environmental and social impacts in assessments often results in a negative net benefit.

The cascade model of dam building also brings into question the basic argument for fishways (including any structure built to assist upstream or downstream movement of fishes past a barrier), namely that they are to maintain migratory routes along the river continuum to enable natural recruitment dynamics

(Lira et al., 2017). If connectivity and habitat availability is severely limited by multiple dams on a river, then the basic argument for fishways is devalued – fishways in these circumstances can become “ecological traps” (Pelicice and Agostinho, 2008). The rationale or need for fishways should be assessed on a systematic, basin wide scale, rather than on an individual dam basis (Lira et al., 2017; Birnie-Gauvin et al., 2018).

The overall impact of hydropower dams in the Mekong region needs to include consideration of both mainstream projects and those proposed for tributary streams. Tributary streams contribute a large proportion of the flow and sediment to the mainstream. They also contribute most of the habitat of fish and other aquatic organisms. One option for reducing the overall impact of hydropower developments would be to identify particular tributary streams to be maintained in an unregulated condition as refuges; and conversely, for other tributaries to be designated for hydropower development (Barlow, 2016). This approach was inherent in Ziv et al. (2012) analyses of the trade-offs between power generation and fisheries production for numerous combinations of dams on the mainstream and tributaries. They quantitatively demonstrated options for achieving specified power outputs while minimizing the loss of fisheries production, and that tributary dams in Lao and Cambodia would have graver impacts on fish biodiversity than the combined effects of the six mainstream dams above Vientiane.

Another approach for minimizing the impacts of hydropower development is to evaluate siting, design and operational features of proposed dams in conjunction with power generation, effectively giving equal footing to power output and ecological concerns. This approach was detailed for the proposed Sambor Dam in Cambodia, and could theoretically be coupled with basin wide planning to investigate acceptable boundaries around hydropower development and maintenance of riverine ecosystems (Wild et al., 2019). Presumably at least partly in response to the Wild et al. (2019) report, the Cambodian government has recently suspended plans for hydropower development on the mainstream of the Mekong in Cambodia (WWF, 2020).

WILL FISHWAYS HELP?

Fishways were first developed in the northern hemisphere as a means of reducing the impact of dams on commercially significant salmonid fishes (salmon and trout) (Katopodis and Williams, 2012; Birnie-Gauvin et al., 2018). All the anadromous species of Atlantic and Pacific salmon are strong swimmers, programmed to swim *en masse* to headwaters to spawn, with the progeny returning downstream as smolts or yearlings. Salmonids exhibit biological characteristics (predictable timing of runs upstream and downstream, powerful swimming ability, large size) which when coupled with supportive dam management (well-designed fishways, appropriate timing and quantity of water release, trapping and land transport of smolts past dams) have enabled them to successfully pass upstream and downstream of high dams. The fish passage technology has been developed

through decades of research, especially since the 1940s, and billions of dollars in funding. Yet while most populations have survived, they are invariably at a fraction of the size of pre-dam populations (Williams, 2008; Brown et al., 2013; Birnie-Gauvin et al., 2018).

The situation is far more complicated in tropical rivers where multiple fish species are involved, varying in size at maturity from a few centimeters to well in excess of 1 m, migrating at different times of the year in response to various but often unknown environmental cues, and none of which have upstream swimming abilities comparable with salmonids. Downstream migration is usually by passive drift of larvae and actively swimming small juveniles, which are vulnerable to physical damage while moving over or through dam infrastructure.

The problems compound where there are multiple dams along a river. In Lao PDR there is a cascade of six dams planned between Vientiane in central Lao PDR and the northern border with China. If, say, 50% of a fish population ascends each fishway, then only 1.6% of the initial population will pass the most upstream dam. The cumulative effect for downstream migration is similar, and the impact magnifies for each successive generation. Modeling of fish passage scenarios for selected Mekong fishes indicated that to maintain viable populations, small bodied fish would need at least 60–87% success rate for a single dam, rising to 80–95% for two or three dams (Halls and Kshatriya, 2009). Populations of large bodied fishes would be extirpated, as adults are particularly susceptible to mortality when migrating downstream through turbines or over spillways (Halls and Kshatriya, 2009).

Fishways have been built on many hydropower dams outside of salmonid ranges, but we cannot find any reports documenting their successful application in securing long-term viability of populations of target species. Reports of lack of success abound (see reviews by Bunt et al., 2012; Noonan et al., 2012). The numerous inter-related biological, engineering and governance issues constraining successful fish passage development for high dams have been reviewed by Silva et al. (2018). Given the complexity of these issues, the need for case by case testing and application, and the limited financial resources available for fishway experimentation, it is not realistic to expect that they will be resolved in the foreseeable future.

Nevertheless, we note the considerable effort that the two most advanced hydropower development projects on the Lower Mekong (Xayaburi and Don Sahong) are currently devoting to fish passage investigations (Baumgartner et al., 2017). Xayaburi Power Company in northern Lao has utilized European consultancies to design and construct a complex fish passage facility at the cost of more than US\$300 million. The company has now entered a public-private partnership with fish passage experts from Australia and the United States to monitor fish movements in the fishway and adapt operational measures to improve upstream and downstream passage.

The Don Sahong Power Company (DSPC – a Lao company) has contracted Sinohydro (a Chinese company) to build the hydropower dam on the Khone Falls in southern Lao. DSPC has published on its website many reports on social and biological aspects of the traditional fisheries in the area (DSHPP, 2020).

One of the main areas of investigation has been the opening of alternative fish migration routes through the 11 km wide Khone Falls, as the dam is built on, and thus blocks, the historically important route through the Hou Sahong channel (Baird, 2011). The company has improved fish passage at several sites in five other channels, and has supported a government of Lao committee to remove more than 500 large illegal fishing gears to reduce obstruction of fish passage through those channels (Hortle and Phommanivong, 2019).

Despite the lack of evidence for the efficacy of fishways at high dams (especially for non-salmonids), fishways continue to be proposed by dam proponents and governments in the Mekong region as the preferred means to ameliorate the impacts of dams on fish and fisheries resources. Fishways, particularly for upstream passage, seem to be the social license necessary for dam approval. They enable a counterargument to those outlining the impacts of dams on migratory fishes. Moreover, they indicate good-will and social conscience on the part of developers, and they are physically impressive structures that engender support from management agencies and influential observers.

INVESTING IN ECOLOGICAL OFFSETS AS AN ALTERNATIVE TO FISHWAYS ON HYDROPOWER DAMS

Hydropower dams are the focus of water management impacts on aquatic ecosystems in the Mekong basin, including fisheries. But for fish ecology and production, arguably the collective impact of the multitude of small weirs, flood control devices, regulators and irrigation works on tributaries and flood plains in the basin (see details in Hortle and Nam, 2017) is similarly deleterious to that of hydropower dams. All these water management structures constrain fish migrations to varying degrees, and thus restrict the ability of fishes to access spawning, nursery or feeding habitats (Baumgartner et al., 2012). Because the structures are not physically obvious (they are usually less than 6 m head height) and, we proffer, not implemented by multi-national corporations, they have received comparatively little attention in the public discourse on human-induced impacts on the ecological functioning of the Mekong River.

Since the mid-2000s, a multi-disciplinary research and development program in the Mekong Basin (summarized in Baumgartner et al., 2019a) has: documented the ubiquity of water management structures (Marsden et al., 2014); demonstrated methods for enabling fish to pass low-head barriers (Baumgartner et al., 2019b, 2020); outlined socio-economic benefits of improved fish passage (Millar et al., 2019); developed a decision making tool for assessing benefits-costs of fishways on low-head barriers (Cooper et al., 2019); and demonstrated scale-out of results through irrigation infrastructure rehabilitation projects in southern and northern Lao, funded by the World Bank and the Asian Development Bank, respectively (Baumgartner et al., 2019a). The program continues to generate data on the scale-out and cost-benefit of fishways to reconnect aquatic ecosystems in the Mekong, and more recently has initiated similar work in Myanmar and Indonesia.

The demonstrated success of such interventions for aquatic ecosystem restoration at low-head barriers, coupled with a history of poor results for fishways at hydropower dams, brings to the fore the alternative of offsets (ecological remediation at sites remote from the hydropower dams) or compensation (payments to downstream affected communities) for the impacts of hydropower dams. Offsets or compensation could take many forms, but all would have the specific aim of a better environmental outcome for the equivalent amount of expenditure that would be required to build a fishway at a hydropower dam. Hortle and Nam (2017) reviewed possible mitigation measures for the impacts of dams on fisheries, and suggested that offsets should be considered as part of the cost of dam development and/or funded through the income from hydropower production. By way of example, the relative expenditures for fishways at high- and low-head barriers are stark – US\$300 million for a fish passage facility at Xayaburi Dam, versus an outlay of US\$800,000 for refurbishment of 10 weirs and road culvert barriers, including incorporation of fishways, in southern Lao (World Bank, 2015).

THE LONGER TERM OUTCOMES FOR THE LOWER MEKONG COUNTRIES

Over the next few decades there are a number of predictable consequences that will arise as a result of the development of hydropower in the Mekong. First, hydropower is expensive power. Costs of generating electricity from wind and, especially, solar are falling, with recent generation costs of US\$ 0.03/kWh; while hydro generation is becoming more expensive with recent costs of US\$ 0.04/kWh (IRENA, 2018). Within the Mekong, if the lost fisheries value is also factored in, hydropower will be substantially more expensive. Pumped hydro as a means of energy supply smoothing is widely advocated (ARENA, 2020), but the dams in the Mekong are, for the most part, too low to be suitable for that purpose. In a region like the Mekong, where the population is dispersed and local energy requirements are not usually intense, solar generation, which can produce energy on site and therefore does not require massive investment in poles and wires, also has an advantage in lower distribution costs. Countries relying on hydro as their source of power for industry will be at a decided economic disadvantage compared with those using solar power, and under pressure to provide subsidies to support the industry.

Many of the hydro projects in Lao PDR are public private partnership projects. They are constructed by private companies which will then operate them for a fixed period before handing them over to the national government. In the case of the Nam Ou dams and others in Lao the period of private operation is 30 years (Xaypaseuth Phomsoupha, 2015). By the time these projects are handed to the Lao Government many of the dams will contain large amounts of sediment that will at best reduce their efficiency of operation and at worst render them non-functional (e.g., Rădoane and Rădoane, 2005). The costs of refurbishments will be borne by the government.

The impact on sovereignty is frequently a concern for countries sharing international river basins. Tensions between upstream and downstream countries are the most common. Negotiations between Ethiopia and Egypt over dams on the Nile River (Mbaku, 2020), and India with both Pakistan and Bangladesh over the Indus and Brahmaputra River systems, are well known examples which continue to cause international tensions (e.g., see Beach et al., 2000).

In the context of the Mekong sovereignty issues have also been of concern. The MRC member countries have not allowed the MRC to consider issues relating to tributary streams because of potential impacts on national sovereignty. It is also widely believed that part of the reason that China has declined to join the MRC, and is reluctant to share data on flows from the upper Mekong, the Lancang, is because of sovereignty concerns.

In any international river basin countries sharing the basin are influenced by the actions of the others. The most obvious pathway of influence is through upstream countries impacting downstream flows, but in the Mekong, for example, navigation from the sea to Cambodia must pass through Vietnam. Developing and facilitating navigation agreements has been an important role of the MRC.

The construction and/or operation of multiple large dams within or by external jurisdictions continues to be a concern of the Mekong countries. In the upper Mekong, the storage capacity of the six most downstream dams in China is sufficient to store over 40% of the annual Mekong discharge at Chiang Saen in northern Thailand. China therefore has the capacity, if it wishes, to cut off the entire dry season flow at Chiang Saen. Flows would continue from tributaries downstream, but because Chinese government-owned firms control all the dams on Nam Ou and have controlling interests in many of the large dams on other tributaries, even those have the potential to be compromised. Such an outcome has been viewed as fanciful, but recent data indicate that China is prepared to exercise its control at the expense of downstream countries (Eyler, 2020), a most disturbing development.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

Both authors made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Conflict of Interest: IC and CB were the sole owners of consulting companies Rhithroecology Pty Ltd., and Fish Matters Indo-Pacific Pty Ltd., respectively.

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