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Final report

Project

Quantifying biophysical and community impacts of improved fish passage in Lao PDR and Myanmar

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2 Executive summary

Rising demand for irrigated agriculture and electricity has led to the widespread construction of dams and other infrastructure on many large tropical river-floodplain systems around the globe. Such infrastructure poses a major threat to the diverse and productive fisheries that occur in tropical river-floodplain systems, as it prevents access to vital feeding, spawning, and nursery habitat and subsequently constrains many species from completing their life cycles. The impacts of infrastructure development are of particular concern on the Mekong River, wherein lies the world's most productive inland fishery.

The current project progresses a program of work, which started as a proof-of-concept study (FIS/2006/183), before developing into a more comprehensive research and implementation phase (FIS/2009/041) and eventually into a monitoring/evaluation phase. The principal objective of this project was to assess whether fish pass technology in Mekong countries can be effectively applied to restore diminishing fisheries and to provide a mechanism for scale-out to Mekong countries and donor-funded programs.

This project has greatly enhanced fish passage restoration efforts in the Lower Mekong Basin. The benefits to fishery production are expected to be realised in terms of food security and livelihood improvements throughout the region over the coming years.

The early proof-of-concept studies (FIS/2006/183 and FIS/2009/041) led to the construction of the first 'test' fish pass on the Mekong River, at Pak Peung village in Lao PDR. FIS/2014/041 Variation 3 has built upon these studies by (1) monitoring and evaluating the socio-economic and ecological impacts of the Pak Peung fish pass, and (2) applying the new knowledge to inform the design and operation of other fish passes throughout South East Asia. Indeed, FIS/2014/041 Variation 3 has resulted in widespread knowledge uptake by high level government officials at many strategic workshops and other meetings; and millions of dollars of investment in fish passage research and implementation by agencies such as the Asian Development Bank, World Bank and USAID. Since the Pak Peung fish pass was built, the list of constructed or planned fish passes has been expanded to (so far) include 19 in Lao PDR, five in Cambodia, one in Myanmar, two in Thailand, and one in Vietnam. Other highlights have included the project team co-hosting the 2016 Lower Mekong Fish Passage and Fish Passage 2018 conferences; co-hosting four international fish passage masterclasses to train practitioners from Myanmar, Lao PDR, Thailand, Cambodia and Vietnam; and being awarded the internationally acclaimed "Distinguished Project Award" at the Fish Passage 2018 conference. The broader program of work has also resulted in a myriad of other scientific outputs, including 21 international journal papers, 24 reports, and 49 international conference papers.

The growing consideration of and investment into fish passage technologies throughout South East Asia is a strong testament to both the success of this program of work and what can be achieved when an integrated and long-term approach is applied to fish passage restoration efforts. The next phase of the work will focus on maximising the scale-out of fish passage restoration efforts throughout South East Asia by determining the impediments and drivers to achieving such outcomes.

3 Background

3.1 The socio-economic and ecological significance of the Mekong River fishery

The Mekong River is of immense economic and social importance to the people of South East Asia (Ziv et al. 2012, Nam et al. 2015). The 4800-km river is home to the largest inland fishery in the world, and its 800,000 km^2 basin supports approximately 65 million people distributed across six countries (China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam) (Ziv et al. 2012). The annual yield of the fishery in the Lower Mekong Basin (LMB — the part of the Mekong River Basin (MRB) located in Lao PDR, Thailand, Cambodia and Vietnam) makes up approximately 2% of the world's total and marine freshwater catch (Baumgartner et al. 2012), and has a first sale value of about US$17 billion (Nam et al. 2015). More than 80% of rural households in the Lao, Thai and Cambodian portions of the LMB are involved in capture fisheries, while up to 95% of rural households in the Vietnamese delta portion of the basin are also involved (Hortle 2009a). In food security terms, it has been estimated that the LMB fishery supplies between 47% and 80% of the animal protein intake of the local people (48% for Lao PDR, 47% for Thailand, 80% for Cambodia and 59% for Vietnam) (Hortle 2007). As a result, the fishery is considered to be critical for supporting both the livelihoods and nutritional needs of the neighbouring human populations (Baumgartner et al. 2012).

In addition to being of immense socio-economic importance, the Mekong River fishery is highly valuable from a biodiversity perspective (Hortle 2009a). Around 850 freshwater species occur in the system, or as many as 1100 species if coastal and marine species are additionally considered (Hortle 2009b). Nearly a quarter of these species (24%) are endemic to the Mekong (Hortle 2009a). Among these are a giant freshwater stingray (*Himantura chaophraya*) that can grow up to 600 kg, a critically endangered species of freshwater dolphin (*Orcaella brevirostris*), and a giant catfish (*Pangasianodon gigas*) that can reach up to 350 kg (Baumgartner et al. 2014).

It is estimated that 40–70% of the fish catch in the Mekong is comprised of migratory species (Barlow et al. 2008). These species must regularly undertake longitudinal or lateral migrations to access spawning, nursery, refuge or feeding habitat (Barlow et al. 2008). For instance, some species migrate from the main channel to floodplain wetlands and lakes during the wet season to access nursery habitat (Baumgartner et al. 2012), while others rely on being able to inhabit floodplain wetlands and lakes during the wet season and migrate to tributaries or the main channel during the dry season (Ferguson et al. 2011). If these fish cannot complete their migrations, they are unlikely to be able to undertake obligatory life-cycle processes such as spawning and recruitment, and this may ultimately result in large-scale population collapses (Roberts 2001). For example, Roberts (2001) reported that daily fish catches in reaches upstream of Pak Mun Dam (Mun River, Thailand) declined by 60–80% following the dam's construction.

3.2 Current threats to the Mekong River fishery

Weirs, floodplain regulators, hydropower dams and other structures are proliferating throughout the MRB to address increasing demand for irrigated agricultural resources (particularly rice) and power generation (Orr et al. 2012). Although such structures are seen as vital to progressing agricultural and energy production throughout the region, they have created physical barriers to fish spawning, nursery and feeding habitats, and therefore hindered migratory Mekong fish from being able to fulfil their life-cycle requirements (Pringle et al. 2000, Dugan et al. 2010). Because of these physical barriers, there have been major declines in the productivity and diversity of the Mekong fishery,

and these declines are expected to worsen as the amount of infrastructure development increases (Ziv et al. 2012, Winemiller et al. 2016).

Much of the infrastructure development in the LMB has involved the construction of low-level (generally less than 6 m) water regulation devices to regulate water flows between the river and floodplain (Daming and Kung 1997). Such water regulators can be used to enhance the production of floodplain crops like rice, by preventing them from being unintentionally flooded during the wet season and increasing water security for the dry season. However, the regulators may also prevent fish from being able to move between rivers and floodplains. Consequently, the proliferation of these structures has effectively reduced the habitat area available for the reproduction and recruitment of many Mekong fish species (Baumgartner et al. 2019b). It has also led to aggregations of pre-spawning fish forming below these barriers, leaving such fish highly vulnerable to overexploitation by fishers, disease and/or predation (G. Thorncraft pers. obs.).

3.3 The need for fish passage technologies

Fish passage technologies, such as fish passes, have been increasingly used in river-floodplain systems around the world in an attempt to improve fish passage where river infrastructure blocks migratory pathways (Clay 1995, Baumgartner et al. 2020). Fish passes are essentially channels around or through a physical barrier, which allow fish to pass without experiencing undue stress (Baumgartner et al. 2016). Such technologies have been successful in situations where an appropriate design has been used for the target species and local hydrological conditions (Baumgartner et al. 2020, Stuart and Marsden 2021). However, there is still a global trend where unsuitable designs are often been applied, resulting in sub-optimal fish passage outcomes. For instance, most early fish passes in tropical river-floodplain systems relied upon designs used for salmonids in temperate systems (e.g. pool-and-weir fish passes) (Stuart and Berghuis 2002). Not surprisingly, these fish passes yielded poor results, due to the fundamental differences in the movement ecology of temperate salmonids and tropical non-salmonids (Petts 1984, Welcomme 1985). In addition, there is still a deficiency of empirical knowledge on the effectiveness of fish passage technologies in tropical river-floodplain systems, and on the movement ecology of tropical riverine fishes in general. The deficiency of empirical assessments has been particularly notable for Mekong species (but see a few exceptions like Baumgartner et al. 2019, 2020). On the social side, there was also a need to demonstrate the economic benefits of fish passes and that fishers and villagers received tangible benefits from investment in this technology. These were needed to convince investors and donors that ecological and human benefits can arise from investment in fish passage solutions. As a result, project FIS/2014/041 arose from a pressing need to demonstrate the ecological and social benefits of fish passage technologies for Mekong species and conditions, and this need will only strengthen as the level of water management infrastructure development occurring in the Mekong region increases over time (Baumgartner et al. 2020).

4 Objectives

The aim of the project was to determine whether fish passage technologies could be applied in Mekong countries to restore diminishing fisheries. It advanced a program of work that started as a fish passage proof-of-concept study (FIS/2006/183), before developing into a more comprehensive research and implementation phase (FIS/2009/041) and then to a development and evaluation phase to empirically showcase impact (FIS/2014/041).

4.1 Objective 1: To evaluate the extent of fish migration barriers and the colonisation of riverine species in seasonal wetlands

While the extent of fish migration barriers in Lao PDR has been quantified (see Baumgartner et al. 2016), the extent of fish migration barriers and the efficacy of technical solutions in Myanmar was poorly understood at the commencement of this work. In addition, empirical studies were needed to evaluate the effectiveness of fish passage restoration, and the economic basis for such solutions, in both Lao PDR and Myanmar.

Consequently, Objective 1 was to firstly, evaluate the extent of fish migration barriers in Myanmar; and secondly, quantify whether riverine fish species were returning to wetlands in both Lao PDR and Myanmar. We aimed to sample the wetland, monitor the fish pass and survey fishers, and develop fish tagging methods to enhance sampling efficiency (Figure 1).

4.2 Objective 2: To quantify whether there is an annual increase in capture fishery production at sites where fish passes have been constructed

Objective 2 was to quantify whether there was an annual increase in capture fishery production at sites where fish passes have been constructed, by assessing the household capture fishery, and attempting to monitor fisheries improvements, at each site.

4.3 Objective 3: To quantify, in economic and social terms, the options for constructing fish passes at riverine infrastructure

Once both wetland fish colonisation (Objective 1) and household capture fishery production were quantified (Objective 2) in response to fish passage restoration, it was necessary to quantify the economic and social benefits of implementing various fish pass options. Objective 3 was to firstly, undertake a cost-benefit analysis for a range of management options available to remediate fish migration barriers; secondly, determine the benefits to household incomes and food security; and thirdly, assess the perceptions of locals regarding fish passage restoration efforts. The objective sought to calculate the “payback period” in terms of how quickly the investment in fish passage led to increases in fishery yield.

4.4 Objective 4: To promote the uptake of project outputs

The final objective of the project was to foster the uptake of the ecological and socio-economic outputs generated by the project under objectives 1, 2, and 3, in other countries. This involved the secondary objective of constructing a demonstration fish pass in Myanmar to serve as a model for scaling out fish pass technologies in that country; and monitoring this fish pass.

5 Overall approach and methodology

5.1 Overall approach and study area

Thirteen studies were undertaken to address the four objectives, and additional study locations were continually added over the course of the project as co-investment from other donor bodies grew through co-leveraging. Accordingly, we applied a hierarchical approach to present the complex structure of these studies in a logical and parsimonious manner (Figure 1, Figure 2). The hierarchical structure comprised of having the project 'objectives' at the highest level, followed by 'outcomes' for each objective, then 'locations' for each 'study'. This approach enabled us to build a body of evidence which demonstrated the ecological, social and economic benefits of fish pass installations at various sites in the Lower Mekong Basin.

Given the strong overlap between the activities involved in addressing objective's 1 and 2, we combined outcomes of these two for this report (Figure 1). Furthermore, the outcomes of Objective 4 (the uptake objective) were largely reported in the Impacts section (Section 8), for the sake of brevity and to minimise repetition.

The 13 studies yielded a series of scientific manuscripts, grey literature technical reports and policy briefs (to both governments and donors), which have been summarised in Section 7. The specific key results for each of the 13 studies have been summarised in Appendix II.

Most of the work funded by this activity was focused in northern, central and southern Lao PDR, and Myanmar. Although, through co-investment from other agencies, uptake activities extended into Thailand, Cambodia, and Vietnam; and some were not location-specific (see Section 8 for more details) (Figure 3). Since completing these activities, the team has also commenced a program of work in Indonesia. The outputs and communication activities from the project have resulted in an expanding demand for this work across the entire South East Asian region.

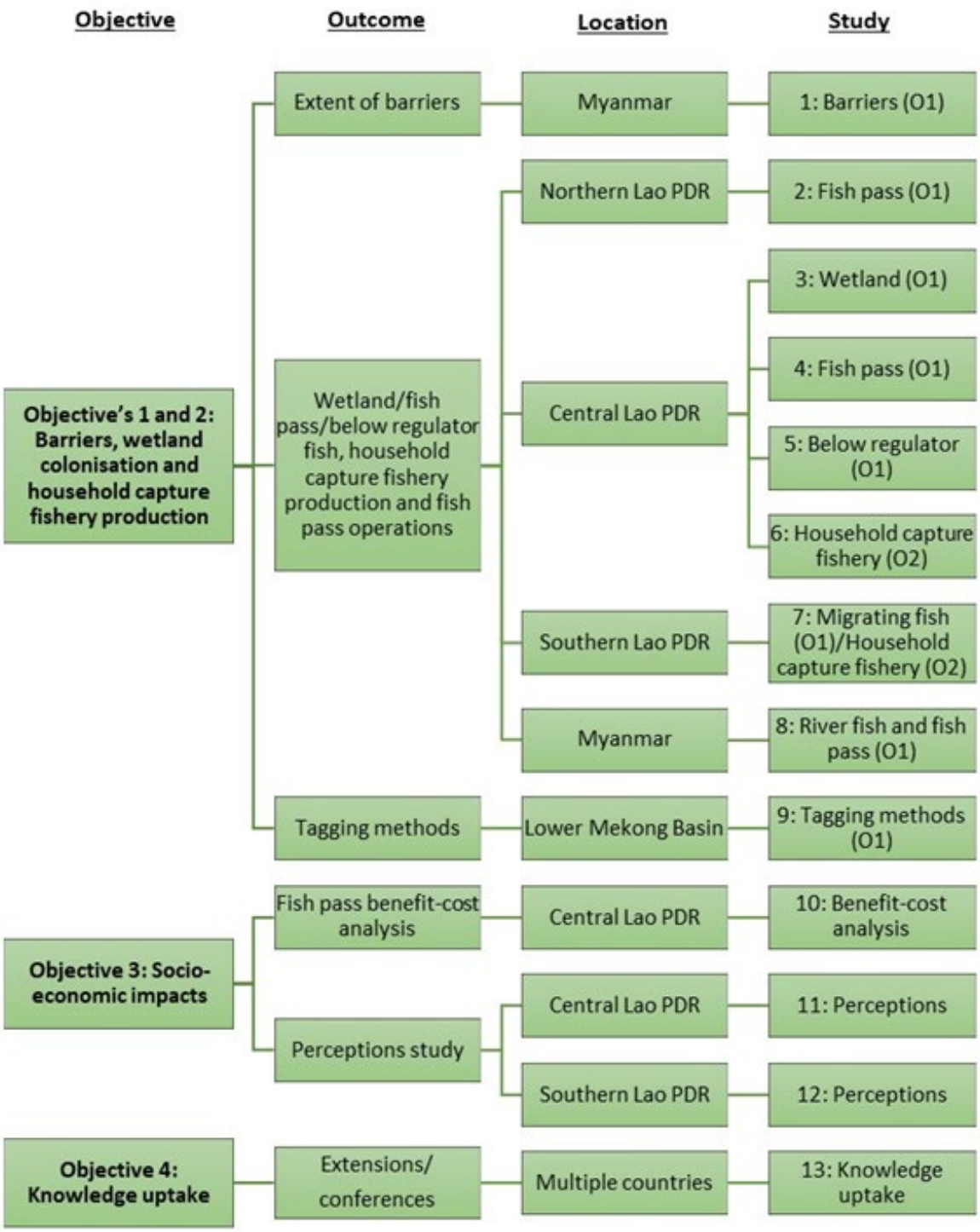

Figure 1. Organisational chart, showing the relationship between the four objectives and their 'outcomes', 'locations', and 'studies'. O1 = Objective 1, and O2 = Objective 2.

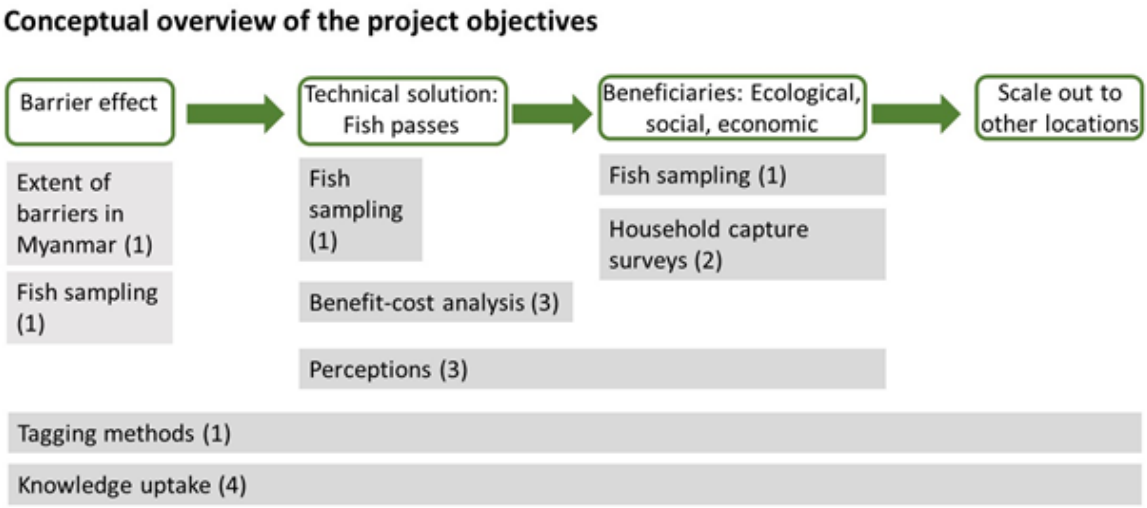

Figure 2. Conceptual overview of the project, showing how the studies for each objective assess the effectiveness of fish passage technologies to mitigate the effects of floodplain barriers, such as regulators. The objectives have been numbered in brackets next to each study/outcome (see the body of Chapter 4 for a description of the objectives).

Figure 3. Map of South East Asia, with the main locations studied during FIS/2014/041 represented by yellow stars (northern, central, and southern Lao PDR; and Myanmar) — as well as the countries where scale-out activities were undertaken represented by red stars (Thailand, Cambodia, and Vietnam).

5.2 Objective's 1 and 2: Barriers, wetland colonisation and household capture fishery production

Objective's 1 and 2 were addressed by undertaking nine studies:

1. Mapping extent of fish migration barriers in Myanmar (Study 1)
2. Assessing the effectiveness of a northern Lao PDR fish pass (Study 2)
3. Quantifying wetland fish improvements in central Lao PDR (Study 3)
4. Monitoring the Pak Peung fish pass in central Lao PDR annually (Study 4)
5. Monitoring fish aggregations below regulators in central Lao PDR (Study 5)
6. Documenting changes in central Lao PDR household fish capture (Study 6)
7. Documenting changes in southern Lao PDR fish/household capture (Study 7)
8. Assessing Myanmar river fish and designing a fish pass (Study 8)
9. Piloting tagging methods for wider application (Study 9)

5.3 Objective 3: Economic and social implications for constructing fish passes at riverine infrastructure

Three studies were undertaken to address Objective 3:

1. Defining fish pass value by undertaking a benefit-cost analysis (Study 10)
2. Assessing stakeholder motivations and perceptions in central Lao PDR (Study 11)
3. Assessing stakeholder motivations and perceptions in southern Lao PDR (Study 12)

5.4 Objective 4: The uptake of project outputs

To facilitate the uptake of project outputs, we undertook numerous extension activities over the life of the project, including:

1. Scaling out the uptake of fish passage technologies in other South East Asian countries beyond Lao PDR (i.e. Myanmar, Thailand, Cambodia, and Vietnam), using ACIAR and USAID financial support.
2. Hosting major international fish passage conferences and using these forums to share findings from the ACIAR 041 project.

The overall learnings and scale-out emanating from this work (Study 13) have been reported in the Impacts section (Section 8) to reduce repetition and maintain succinctness (see the project outputs summary of this report for the full list of extension activities). But these broadly translated to:

1. Provision of technical assistance (Extension Activity 1)
2. Dissemination at workshops/conference (Extension Activity 2)
3. Development and implementation of masterclasses (Extension Activity 3)
4. Design advice and construction supervision (Extension Activity 4)
5. Policy advice and guidance documents (Extension Activity 5)
6. Mentoring and staff development (Extension Activity 6)
7. Supporting regional and remote communities (Extension Activity 7)
8. Development of education material and curriculums (Extension Activity 8)
9. Establishment of demonstration sites (Extension Activity 9)

A summary of the methods for each of the 13 studies has been presented in Table 1.

Table 1. Summary of the methods for each study. Note, FP = fish pass, and XBF = Xe Bang Fei. Also, O1 = Objective 1, and O2 = Objective 2.

Objective	Outcome	Location	Study	Summary of methods
Objective 1 and 2: Barriers, wetland colonization, capture fishery production	Extent of barriers	Myanmar	1: Barriers (O1)	Applied our previously developed five-stage hierarchical decision-support framework (Marsden et al. 2014), to prioritise barriers for remediation based on fishery and socio-economic criteria in the Bago region in 2019
	Wetland/fish pass/below regulator fish, household capture fishery production and fish pass operations	Northern Lao PDR	2: Fish pass (O1)	Consultation and a masterclass to develop preliminary design options
		Central Lao PDR	3: Wetland (O1)	2016-17. 2 FP and no-FP paired sites compared, during early and late wet seasons. Standardised active and passive netting methods.
			4: Fish pass (O1)	2017-20. Once during wet season. Pak Peung. Trap set at entrance, exit and top of culvert for set time.
			5: Below regulator (O1)	2016-18. Early wet season. Pak Peung (FP) and Kadan (no-FP). Creel surveys.
			6: Household capture fishery (O2)	2016-19. Household surveys of early and late wet seasons for up- and downstream migrating fish. Pak Peung (FP) and Kadan (no-FP).
		Southern Lao PDR	7: Migrating fish (O1)/Household capture fishery (O2)	Effectiveness of nine fish-friendly floodplain structures (FFS's) in the XBF assessed 2019-20. Surveys of migrating fish undertaken early and late in the wet season. Also, fishers from 12 villages surveyed in the Lower XBF and Xe Champhone regions at the start and end of the wet season.
		Myanmar	8: River fish and fish pass (O1)	20 sites up-and downstream of Shan Gaing sluice 2019-20. Standardised netting methods. Only pre-fish pass river sampling data collected this far.
	Tagging methods	Lower Mekong Basin	9: Tagging methods (O1)	PIT tag retention experiments on 2 Mekong species. Assessed tag retention and mortality effects for chest, gut and shoulder locations.
Objective 3: socio-economics	Fish pass benefit-cost analysis	Central Lao PDR	10: Benefit-cost analysis	Decision support tool developed for doing benefit-cost analyses
	Perceptions study	Central Lao PDR	11: Perceptions	Five villages surveyed in Pak Peung, Paksan Nua, Phonesaat, Sisaat, and Nasammo (June/July 2020)
		Southern Lao PDR	12: Perceptions	Sampled households that fished in Houy Souy, Houy Papak, Houy Kae, Houy Khe and Houy Lo (Jan 2021)
Objective 4: uptake of project outputs	Extension activities/ conferences	Multiple countries	13: Knowledge uptake	Hosted numerous stakeholder engagement meetings and two international conferences, scaled out fish passage works to other SE Asian countries, mentored PhD students

6 Achievements against activities and outputs/milestones

Objective 1: To evaluate the extent of fish migration barriers and the colonisation of riverine species in seasonal wetlands

No.	Activity	Outputs/ Milestones	Completion date	Comments
1.1 a	Project inception activities (Lao PDR)	Inception meeting	Feb 2016	Completed
1.1 b	Project inception activities (Myanmar)	Inception meeting and scoping session	Sept 2017	Completed
1.1 c	Meet with World Bank and Asia Development Bank to scope opportunities	Agreed outcomes on a way forward	Nov 2017	Completed
1.1 d	Hold staff training session (Myanmar and Lao in Thailand)	Staff from Lao PDR and Myanmar are trained in barrier mapping and fish pass design principles	February 2018	Completed
1.2 a	Complete experimental design (Lao PDR)	During the inception meeting	Feb 2016	Completed
1.2 a		Document outlining the project workplan	Apr 2016	Document produced outlining the project workplan
1.2 a		Staff in agreement on the proposed methods	May 2016	Completed
1.2 b	Complete experimental design (Myanmar)	Agree on approach and way forward with Myanmar government officials	Aug 2017	Completed
1.2 c	Finalise experimental approach to assess success of existing fish passes	Finalise a terms of reference and work plan with World Bank	Nov 2017	World Bank agreed for ACIAR team to work on their structures. The ACIAR team mapped an agreed way forward with the World Bank.

1.3 a	Perform barrier mapping (Myanmar)	Generation of preliminary list of fish migration barriers in a catchment	Apr-June 2018	Completed
1.3 b		Correlation of preliminary list with actual field information on each barrier	Sep-Oct 2018	Completed
1.3 c		Generation of GIS-based maps and prioritisation list for fish pass construction	Dec 2018	A funding priority list was prepared for distribution to donor bodies.
1.4	Select suitable site for fish pass construction (Myanmar)	Approval gained through relevant authorities to undertake the work	Nov 2018	Shan Gaing sluice was chosen as the site for the demonstration fish pass. It was decided to opt for a more superior option than what was originally budgeted for, to generate better long-term outcomes. A full detailed design process was completed with IWUMD staff.
1.5 a	Annual trapping of fish pass and spillway gates (Lao PDR)	Construct assessment traps (Pak Peung and Soui reservoir)	Mar 2016	Completed. Implemented on schedule in April 2016 and 2017.
1.5 b		Implement trapping protocol (in central and southern Laos)	Apr 2016 then annually	Abandoned. Insufficient funds.
1.5 c		Data entry and preliminary analysis	Sep 2016 then annually	All data analysed and interpreted for this final report.
1.5 d		Build a database on annual fish movement into the wetland	Sep 2016 then annually	Database was prepared on annual fish movement into the wetland to permit annual calculation of productivity increases
1.5 e		Annual meetings with project team, district and province and government agencies	Nov/Dec each year	Annual meeting undertaken in May 2018 in conjunction with mid-project review. Project team met with the province and government agencies.
1.5f		Final analysis and report	Jun 2020	Competed and delivered on time.
1.6 a	Annually tag and release fish into Pak Peung wetland (Lao PDR)	Identify most suitable tagging method	Feb 2016	Completed. PIT tagging Honours study undertaken in 2016 by Bettina Grieve.

1.6 b		Seek district provincial approval	Apr 2016	Completed
1.6 c		Perform tag retention experiments to validate approach	Jun 2016	Completed. Two manuscripts were published (Appendix I).
1.6 d		Commence tagging activities and release fish into wetland	May-Jul 2017 then annually	Abandoned. Additional funding request was unsuccessful.
1.6 e		Monitor fish leaving the wetland	Jun-Sep 2017 then annually	Abandoned. Additional funding request was unsuccessful. But partially addressed under FIS/2012/100.
1.6f		Monitor fish pass for evidence of return migrations by migratory fish	May 2017 then annually	Abandoned. Additional funding request was unsuccessful. But partially addressed under FIS/2012/100.
1.6 g		Build database on annual fish movement into wetland	Ongoing	Annual fish movement into wetland was analysed as part of final report (see Objective 2)
1.6 h		Final analysis and report including manuscripts	Jun 2021	Final analysis for report was completed on time. Manuscripts from this project have been listed in the Appendix.

PC = partner country, A = Australia

Objective 2: To quantify whether there is an annual increase in capture fishery production at sites where fish passes have been constructed

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Project inception activities (Lao PDR)	Inception meeting	Feb 2016	Completed
2.2 a	Implement annual monitoring program (Lao PDR)	Meet with district and province staff to outline project	Feb 2016	Completed. Regular meetings undertaken with district and province staff. Work extended to Savannakhet in 2019.
2.2 b		Select four wetlands (Pak Peung, and three others) to study.	Feb 2016	Completed. Wetland sites chosen at Pak Peung and also near Soui Reservoir close to Savannakhet.
2.2 c		Workshop an appropriate experimental design	Apr 2016	Completed. Workshop undertaken to develop an appropriate experimental design to maximise benefits.

2.2 d		Implement monitoring protocol annually	From Jul 2016 but progress annually throughout the project	Monitoring protocol implemented from Jul 2016. Several sampling rounds undertaken, but efforts focused on sampling within the fish pass rather than in the wetland in 2019/20.
2.2 e		Database plotting changes in the trajectories of fisheries productivity	September 2016 and ongoing	Database prepared on annual fish movement into the wetland to permit annual calculation of productivity increases (see Objective 1.2).
2.2f		Final analysis, report and manuscripts	Jun 2021	Final report completed on time. Manuscripts listed in Appendix.
2.3 a	Implement annual monitoring program (Myanmar)	Meet with district and province staff to outline project	Mar 2018	Completed. Regular meetings undertaken with district and province staff.
2.3 b		Workshop an appropriate experimental design	Mar 2018	Completed
2.3 c		Implement monitoring protocol annually	From May 2019	Completed in 2019 and 2020
2.3 d		Database plotting changes in the trajectories of fisheries productivity	Jun 2020	Pre-demonstration fish pass data has been collected and analysed.
2.3f		Final analysis, report and manuscripts	Jun 2021	Final report completed on time. Manuscripts listed in Appendix.
2.4 a	Survey angler perceptions, catch and income after fish passes installed (Lao PDR)	Identify villages to target in the surveys	Feb 2016	Completed. Villages were identified for the surveys. Advice from the mid-project review was that our work is very ‘biodiversity-focused’. But to get maximum traction in SE Asia we need to be focused on how the fish passage has contributed to people’s lives, as well as the biodiversity aspects. So, the workplan was adjusted to include a measure of people’s perceptions to improvements following fish pass construction.
2.4 b		Develop standardised questions	Feb 2016	Completed. Standardised questions developed to survey angler perceptions, catch and income.

2.4 c		Implement annual survey	Commence Oct 2016; progress annually	All surveys completed (2016/17/18/19 pre-wet and post-wet). Analyses completed for final report.
2.4 d	Household study	Document fish catches and use among households	2019 and 2020	The mid-term review, and the decision support tool, required some more robust data on the importance of fish to rural households in Laos. Some structured surveys were designed and implemented to try and determine if the fish pass was important to how households accessed and used fish.
2.4 e	Perceptions study	Understand perceptions about the fish pass in 5 villages around Pak Peung	Dec 2020	The mid-term review identified a need to better-understand the qualitative perceptions of fish passage from villages around the wetland. So, we amended the workplan to include a qualitative perceptions study to document how people's lives have changed after the fish pass was built.
2.4f		Final analysis, report and manuscripts	Jun 2021	Final report completed on time. Manuscripts listed in Appendix.

PC = partner country, A = Australia

Objective 3: To quantify, in social and economic terms, the options for constructing fish passes at riverine infrastructure

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Project inception activities	Inception meeting	Feb 2016	Completed
3.2 a	Compare range of management measures that could be used to offset impacts of a migration barrier	Stakeholder meeting and workshop to identify alternative management strategies	Nov 2016	Completed. Stakeholder meeting and workshop undertaken to identify alternative management strategies.
3.3 b		List of estimated costs for alternative strategies	May 2017	The ACIAR team conducted a literature review on studies that have valued fish passes. We also established a database with values on ecological benefits of fish passes from existing studies.
3.4	Complete a fisheries productivity assessment at Pak Peung wetland	Field surveys at Pak Peung wetland	Dec 2019	Completed

3.5 a	Benefit-cost analysis of fish pass construction vs. other methods	Formal comparison of strategies relative to one another	Revised to Nov 2018	Request for extra funding to gather primary data unsuccessful. So, we instead developed a Decision Support Tool (DST) that will assist practitioners in their assessment of restoring/building new fish passes. The DST was presented at the Fish Passage 2018 conference in December 2018, and at the World Irrigation Forum in 2019.
3.5 b		Report and scientific manuscript	Jun 2018	Final report completed on time. A paper was published on the DST in 2019 (Appendix I).

Objective 4: To promote the uptake of project outputs

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1 a	Stakeholder analysis to determine key players in irrigation development	Engage appropriate communication specialist	May 2016	Completed. A communication specialist was engaged during project inception.
4.1 b		Complete stakeholder analysis. Review and update.	Aug 2016	Completed. The stakeholder analysis has been reviewed and updated.
4.2	Complete a communication and marketing strategy	Prepare draft report	Jul 2017	Re-structured. It was agreed between ACIAR/CSU that a far more pragmatic approach was to use the time available to proceed with the actual implementation of the strategy.
4.3	Construct a demonstration fish pass in Myanmar	Functional fish pass	Mar 2019	Delayed due to COVID-19 and contracting. Ongoing discussions with Myanmar staff are taking place. The aim is still to build the fish pass in the dry season of 2021/22 if extra funding can be sourced. The impacts of the fish pass will then be assessed as part of ACIAR FIS/2018/153.
4.4	Communicate project objectives and outcomes to national and international audiences	Attend at least one major domestic, regional or international conference/works every second year	These will be opportunistic and progressed as new events are planned	Eleven presentations given at 2018 Fish Passage conference and 6 presentations given at 2019 World Irrigation Forum including holding a focused workshop on fish passage (Appendix I)

4.5	Hold a major regional workshop on fish passage	Hosting a regional fish passage conference in Vientiane	Nov 2017	Completed - regional fish passage conference in Vientiane in Nov 2016. There is mounting support for a follow-up conference, but COVID-19 has delayed plans.
4.6	Hold a major international conference on fish passage	Fish Passage 2018 is an international event which will take place in Albury, NSW	Dec 2018	Completed - Fish Passage conference in Albury Nov 2018. There is mounting support for a follow-up conference, but COVID-19 has delayed plans.
4.7	Disseminate project information to a range of audiences	Final report, scientific manuscript, project fact sheets	Throughout the project.	Broader program has thus far resulted in 21 journal publications and more than 9 fact sheets (Appendix I). A website has also been drafted.

7 Key results and discussion

7.1 Migratory fishes in Myanmar rivers and wetlands: Challenges for sustainable development between irrigation water control infrastructure and sustainable inland capture fisheries

John C. Conallin[a], Lee J. Baumgartner[a], Zau Lunn[b,g], Michael Akester[c], Nyunt Win[d], Nyi Tun[d], Maung Moe Nyunt[e], Aye Myint Swe[e], Nyein Chan[b] and Ian G. Cowx[f] (2019). *Marine and Freshwater Research* 70(9): 1241-1253.

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[g]Present address: Biology Department, University of New Brunswick, PO Box 5050, 100 Tucker Park Road, Saint John, NB, E2L 4L5, Canada.

ACIAR objective(s) addressed: All four objectives

Source of data/knowledge: ACIAR FIS/2014/041

Overview: Irrigated agriculture and inland capture fisheries are both critical for food security in Myanmar, but there is currently little to no consideration for how both can be sustained without adversely impacting and/or hindering each other. This paper examined the threats presented by irrigation expansion to Myanmar's inland capture fisheries, and then explored options for managing these threats.

Contribution to knowledge: The paper reviews the main aspects of policy and governance, educational and institutional capacity, and technical and management-based practices required to better plan and integrate the needs of inland fisheries within irrigation infrastructure projects in Myanmar.

Application to management: It argues that the threats to Myanmar's inland capture fisheries could be alleviated by (1) increasing cross-sectoral collaboration between fisheries and irrigation department on irrigation projects; and (2) improving capacity, via research to bolster Myanmar's knowledge of the ecology of its migratory fish species, the trade-offs between irrigation and fisheries, and technical and operations-based mitigation options.

7.2 Fish Passage Report. ADB Grant No. 0534-LAO: Northern Rural Infrastructure Development Sector Project. August 2019

Garry Thorncraft[a], Lee Baumgartner[b], Phousone Vorsane[a], Wayne Robinson[b], Nathan Ning[b] (2019). Report.

[a]National University of Laos, PO Box 10864, Dongdok Campus, Vientiane, Lao Democratic People's Republic

[b]Institute for Land, Water and Society, Charles Sturt University, Elizabeth Mitchell Drive, Albury, New South Wales, Australia

ACIAR objective(s) addressed: Objective one

Source of data/knowledge: Northern Rural Infrastructure Development Sector Project (Asia Development Bank) and ACIAR FIS/2014/041

Overview: The aims of this study were to (1) visit Asian Development Bank (ADB)-funded weirs in the Beng and Houn districts of Oudomxay Province, Lao PDR, to provide an assessment and recommendations for the design of three fish passes, and construction of at least one fish pass at Nam Beng Weir, about 80 km WNW of Luang Prubang; and (2) undertake an assessment of the effectiveness of the fish pass at Nam Beng Weir in passing fish upstream during the 2019 wet season.

Contribution to knowledge: The Nam Beng fish pass successfully passed 23 species during the assessment period. This indicates that its construction, although not completely ideal for this site, will provide a benefit to upstream communities.

Application to management: The report recommends ADB take a more pro-active stance in achieving multi-objective outcomes at instream infrastructure modernisation projects. This includes the consideration of fish-related impacts at the business-case stage, rather than at the point of construction commencement. Designing fish passes at the concept stage, and constructing as part of the overall build, can lead to a 25% reduction in overall costs. Future projects should therefore consider fish passes at the business case stage, rather than as a retrofit after completion.

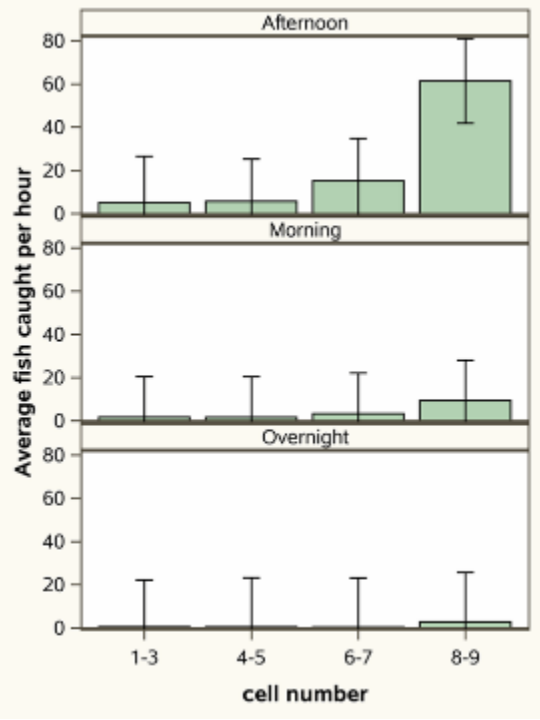

Figure 4. Fish movement rates through the new fishway at Nam Beng Weir in northern Laos (taken from the report).

7.3 Evaluating the placement of PIT tags in tropical river fishes: A case study involving two Mekong River species

Bettina Grieve[a], Lee J. Baumgartner[a], Wayne Robinson[a], Luiz G.M. Silva[a,d], Karl Pomorin[b], Garry Thorncraft[c], Nathan Ning[a] (2018). *Fisheries Research* 200: 43-48.

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[b]Karltek Pty Ltd, Sanctuary Lakes, Melbourne, Victoria, Australia

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[d]Universidade Federal de São João del-Rei, PPGTDS, PGE, Campus Alto Paraopeba, MG, Brazil

ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR FIS/2014/041

Overview: This study aimed to assess the effectiveness of PIT tagging in different body positions (chest, gut, shoulder) of Mekong fish species, with a view to informing future fish passage and fish migration studies. Two socially and economically important Mekong fish species that are migratory and vulnerable to the impacts of river development were studied. These were *Pangasianodon hypophthalmus* (Striped catfish) — a dorso-ventrally compressed, migratory, pangasiid catfish (So et al. 2006), and *Hypsibarbus malcolmi* (Goldfin tinfoil barb) — a laterally compressed, migratory, tropical cyprinid.

Contribution to knowledge: PIT tag retention rates did not differ whether the tag was inserted into the gut, shoulder or chest, and overall more than 90% of tags were retained. There was no mortality in Striped catfish, and less than 15% mortality in Goldfin tinfoil barb.

Application to management*:* The PIT tagging methods used can be applied to a large range of Mekong fish species.

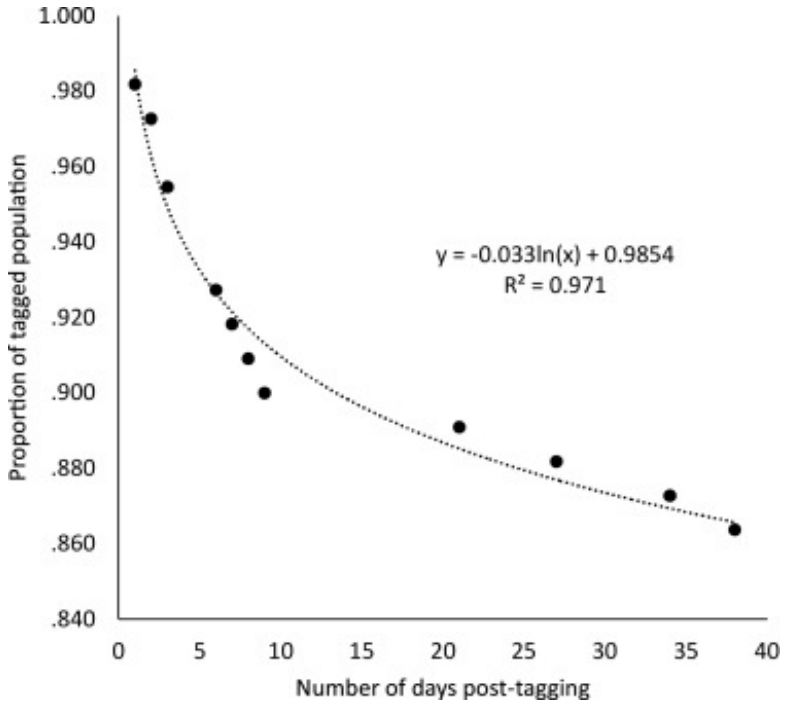

Figure 5. Tag survival for all species investigated. This work will later be very significant for FIS/2017/017, the Xayaburi assessment project (taken from the paper).

7.4 Flexible and non-invasive passive integrated transponder (PIT) tagging protocols for tropical freshwater fish species

Bettina Grieve[a], Lee J. Baumgartner[a], Wayne Robinson[a], Luiz G.M. Silva[a,d], Karl Pomorin[b], Garry Thorncraft[c], Nathan Ning[a] (2018). *MethodsX* 5: 299-303.

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[d]Universidade Federal de São João del-Rei, PPGTDS, PGE, Campus Alto Paraopeba, MG, Brazil

ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR FIS/2014/041

Overview: The paper provides a detailed description of the protocol for PIT tagging tropical freshwater fishes, which was developed in the previous paper (7.3) using Striped catfish (*Pangasianodon hypophthalmus*) and Goldfin tinfoil barb (*Hypsibarbus malcolmi*).

Contribution to knowledge: We explicitly outline the steps in our scientifically validated 'recipe' for PIT tagging Mekong fish species, so that the method can be used by other people, and potentially scientifically validated on other Mekong species.

Application to management: The PIT tagging approach described in this paper is a valuable tool for monitoring movement of fishes. Its application is in appraising the effectiveness of fishways and other mitigative measures designed to enable fish to complete vital life-cycle processes.

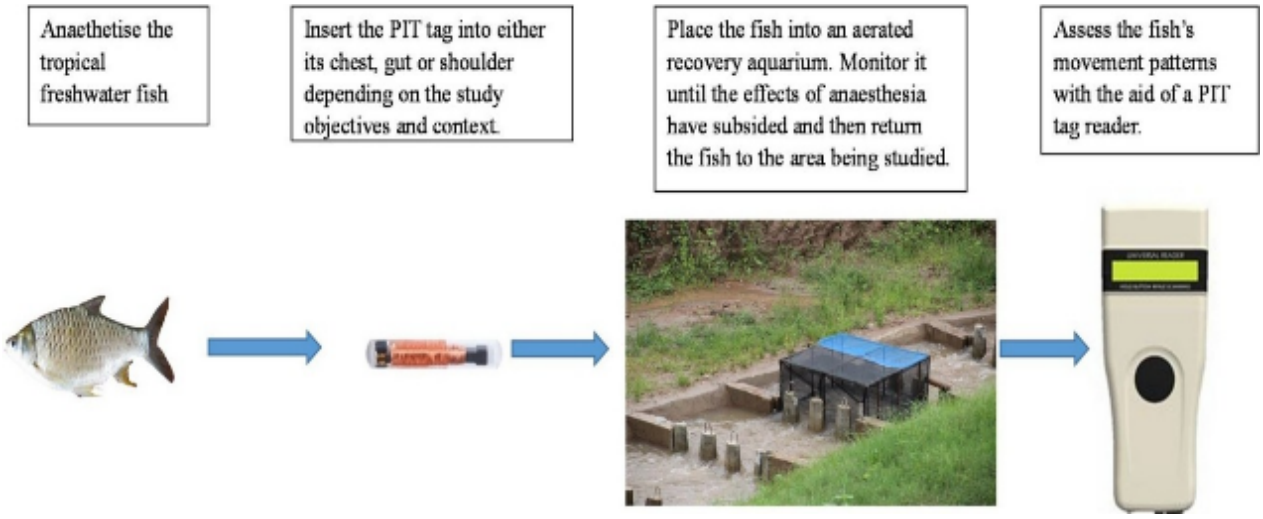

Figure 6. The standard methods for successfully tagging and releasing fish into the Mekong River were defined and published in open access format (taken from the paper).

7.5 Mekong Integrated Water Resources Management Project: Assessment of fisheries productivity and biodiversity changes following refurbishment of floodgates on floodplains of the lower Xe Bang Fei catchment

Wayne Robinson[a], Garry Thorncraft[b], Lee J. Baumgartner[a], Tim Marsden[c], and Nathan Ning[a] (2021). Report.

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ACIAR objective(s) addressed: Objective two

Source of data/knowledge: ACIAR FIS/2014/041 and Mekong Integrated Water Resources Management Project (M-IWRMP) (funded by the World Bank)

Overview: The M-IWRMP refurbished the downstream aprons and gates on nine floodgates of the floodplains of the Xe Bang Fei (XBF) catchment in Lao PDR in 2015 and 2016 to improve fish passage across the structures (Figure 7 and Figure 8). This study assessed the effectiveness of these refurbished structures (fish friendly regulating structures or FFRS's) at passing fish.

Contribution to knowledge: We found that 110 species of fish were able to ascend the revised floodgate aprons, but only in limited cases were they able to pass through the floodgate culverts and gate systems upstream into the adjacent floodplain wetlands.

Application to management: When refurbishing floodgates, making them more fish-friendly with a revised apron and gate operating system may be a short-term option for improving fish passage. Nevertheless, fishways designed specifically for both the immediate physical environment and local species composition will always be the best option on new and substantially modified floodgates.

Figure 7. Refurbishment works at one of the Xe Bang Fei (XBF) sites, Houy Papak, post 2015. The cone section below the culvert allowed upstream fish passage when the water level from the XBF in the channel below the structure had not yet reached the culvert (source: Wayne Robinson).

Figure 8. The fish friendly regulator structures (FFRS's) at the Xe Bang Fei (XBF) sites, Papak (a), Kae (b), Phine (c), Boun (d), Lo (e), Khe (f), Bankak (g), and Sadu (h). The FFRS at the ninth site, Sokbo, was decommissioned prior to this study, and thus not shown here (source: Wayne Robinson).

7.6 Estimating benefits and costs: A case of fish passages in Lao PDR and the development of the Lower Mekong Fishway support tool

Bethany Cooper[a], Lin Crase[a], Lee J. Baumgartner[b] (2019). *Marine and Freshwater Research* 70(9): 1284-1294.

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ACIAR objective(s) addressed: Objective three

Source of data/knowledge: ACIAR FIS/2014/041

Overview: Most of the current literature relating to fish pass development focuses on improving the design and operation of fish passes to maximise fish passage (Branco et al. 2013, Baumgartner et al. 2018), and few studies attempt to explicitly quantify the economic and social benefits and costs of constructing fish passes. Nonetheless, such analyses are vital for appraising the ecosystem services and economic benefits of improved fish passage throughout the Lower Mekong Basin (LMB). The aim of this paper was to develop a decision support tool (DST) that allows practitioners in the Mekong region to rapidly quantify the net benefit of constructing fish passes (i.e., the excess or deficit of benefits over costs expressed in dollar values).

Contribution to knowledge: Our DST, the Lower Mekong Fish pass Support Tool (LMFST), shows great potential for assessing the net benefits of investing in fish passage technologies throughout South East Asia. We tested the LMFST's application in a local context on the Pak Peung fish pass, and found that the fish pass would have a positive net present value and a short pay-off period, providing that excavation works were not excessive and additional costly structures were not needed.

Application to management: Following the design and construction of the DST, it was tested to assess the benefits and costs of the fish pass at Pak Peung village in central Lao PDR. Various design effectiveness scenarios were considered to generate benefit-cost analysis (BCA) outputs for each. Scenario 1 assumed that only half the wetland was affected and the fish pass was capable of passing 75% of the stock attracted, and the additional costs of both the excavation works and an overshot gate to facilitate the downstream movement of fish at the Pak Peung regulator were included; Scenario 2 had the same assumptions apart from the inclusion of the costs of the overshot gate and excavation works; and Scenario 3 again assumed that the costs of the overshot gate and excavation works were excluded, and that the whole wetland was affected and the fish pass was capable of passing 100% of the stock attracted.

The testing of the DST on the Pak Peung fish pass generated results for each scenario in line with those expected. Scenario 1 (where only half the wetland was affected; the fish pass was capable of passing 75% of the stock attracted; and the additional costs of both the excavation works and an overshot gate were included) led to total benefits for the project life of US$230 206. When the additional costs of the overshot gate and excavation works were excluded for Scenario 2, it greatly improved the feasibility of the fish pass project and led to positive net benefits totalling ~US$83 000 and a pay-off period of 11 years. Under Scenario 3 (i.e. which involved Scenario 2 being extended to assume that the whole wetland was affected and the fish pass was capable of passing 100% of the stock attracted), the fish pass project yielded even greater net benefits, with a net present value of more than US$283 000 and a pay-off period reduced to 5 years.

This quantitative economic modelling will be applied to future projects to assess the economic feasibility, from a fisheries improvement perspective, over the short and long term.

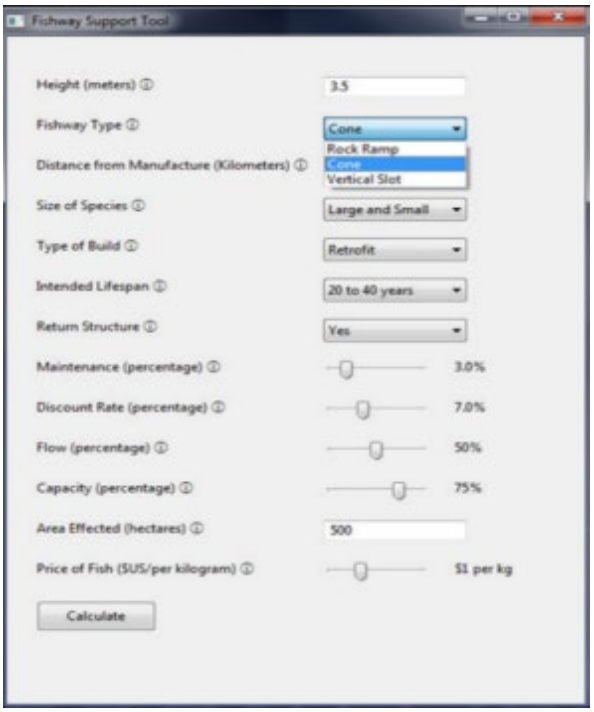

Figure 9. Screenshot of the 'input' parameters of the decision support tool (taken from the paper).

7.7 Lower Mekong Fish Passage Conference: Applying innovation to secure fisheries productivity

Lee J. Baumgartner[a], Craig A. Boys[b], Chris Barlow[a,c] and Mike Roy[d] (2017).
Ecological Management and Restoration 18(3): E8-E12.

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[c]Australian Centre for International Agricultural Research, Thynne Street, Bruce, ACT, 2601, Australia

[d]United States Department of the Interior, International Technical Assistance Program, 1849 C Street, NW, Washington, DC, 20240, USA

ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041

Overview: The first Lower Mekong Fish Passage Conference was held at Lao Plaza Hotel in Vientiane in November 2016. The conference was hosted by the ACIAR FIS/2014/041 project leader, Professor Lee Baumgartner (of the Inland Fisheries Research Group/Charles Sturt University), in collaboration with Dr Chris Barlow (of ACIAR at the time), Dr Craig Boys (NSW Department of Primary Industries) and Dr Mike Roy (US Department of Interior). It brought together 160 fish passage researchers and practitioners from 14 countries to share knowledge and experiences. Presentations were given on four key themes: (1) general fish ecology of the Lower Mekong Basin; (2) country updates and perspectives on the importance of fisheries; (3) mitigating impacts of low head barriers (i.e., irrigation diversion weirs and road crossings); and (4) mitigating impacts of high head barriers (i.e., hydropower dams).

Contribution to knowledge: Key messages from the conference were as follows: (1) best practice R&D approaches are crucial to effective fish passage; (2) concepts need to be tested and refined before solutions are applied; (3) demonstration projects are invaluable for facilitating large-scale adoption and acceptance; (4) partnerships among all levels of stakeholders are pivotal to success; and (5) we can learn from past mistakes to improve the future, and these lessons should be broadly applied.

Application to management: It was widely acknowledged that technology developed in other parts of the world, such as sensorfish, swim flumes, and PIT tags, could play a role in assessing the effectiveness of mitigation systems in the LMB.

Figure 10. Participants at the first Lower Mekong fish passage conference.

7.8 Global fish passage forum to include first symposium on hydropower and fish

Peter Starr[a] (2018). *Catch and Culture – Environment* 24(1): 38-40.

[a]Catch and Culture – Environment, The Mekong River Commission, Vientiane, Lao PDR

ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041

Overview: The First Symposium on Hydropower and Fish Management was held in conjunction with the International Conference on River Connectivity (Fish Passage 2018), in Albury, NSW, from 10-14 December, 2018. The joint meetings were hosted by the ACIAR FIS/2014/041 project leader, Professor Lee Baumgartner (of the Inland Fisheries Research Group/Charles Sturt University), in partnership with Dr Luiz Silva (Charles Sturt University at that time) and Dr Matthew Gordos (NSW Department of Primary Industries). They brought together 359 fish passage researchers and practitioners from over 30 countries to share knowledge and experiences relating to river connectivity issues for fish.

Contribution to knowledge: A total of 232 presentations were given, which covered a number of major themes, including (1) fish passage challenges in developing countries; (2) benefits of managed flows; (3) the importance of reconnecting rivers with floodplains and wetlands; (4) diversion screening technology to protect native fish from being removed from rivers; and (5) citizen science and its role in fish passage restoration.

Application to management: The joint conference facilitated the sharing of findings and expertise on fish passage issues and the building of connections between fisheries researchers and practitioners, to better utilise both skillsets to address fish passage concerns globally.

Figure 11. Senior international fish passage researchers and practitioners taking part in a pre-conference global fish passage workshop at Charles Sturt University (Albury) (source: Simone Engdahl).

7.9 ADB Policy Brief: Diversion weirs and fish passages for small-scale irrigation Lao People's Democratic Republic

David Salter[a], Niloofar Sadeghi[a], Garry Thorncraft[b], Lee Baumgartner[c], Wayne Robinson[c], Nathan Ning[c], Bethany Cooper[d], Lin Crase[d] (2020). Policy brief.

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[b]National University of Laos, PO Box 10864, Dongdok Campus, Vientiane, Lao Democratic People's Republic

[c]Institute for Land, Water and Society, Charles Sturt University, Elizabeth Mitchell Drive, Albury, New South Wales, Australia

[d]University of South Australia, School of Commerce, City West Campus, Adelaide, South Australia, Australia

ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041

Overview: This policy brief provides fundamental information on the significance and facets of fish passages and fishways for staff of the Asian Development Bank (ADB) involved in irrigation investments in addition to their development member country colleagues. It is designed to support ADB's Strategy 2030 and has been founded upon the successes of fish passage projects in Lao PDR.

Contribution to knowledge: The policy brief has now been distributed amongst ADB and associated development member country staff to educate them about the crucial importance of considering fish passage in any development projects, for maintaining both food security and livelihoods.

Application to management: In supporting the development of this policy brief, ADB have signalled their intention to ensure that their infrastructure projects pose no threat to inland fish populations. They have stated that effective fishway construction should be considered for any new ADB infrastructure projects, and potentially for any upgrades to existing structures.

Figure 12. Cover page of the ADB diversion weirs guidance document.

7.10 Sustainable fisheries and irrigation expansion in Lao PDR

Chris Barlow[a], Lee Baumgartner[b], Oudom Phonekhampheng[c], Garry Thorncraft[c], Douangkham Singhanouvong[d], Khampheng Homsombath[d], Tim Marsden[e], Craig Boys[f]. (2017). ACIAR. Policy brief. 8pp

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[c]National University of Lao, PO Box 7322, Vientiane, Lao PDR

[d]Living Aquatic Resources Research Centre, PO Box 9108, Vientiane, Lao PDR

[e]Australasian Fish Passage Services, 6 Spinifex Street, Fern Bay, NSW 2295, Australia

[f]New South Wales Department of Primary Industries, Narrandera Fisheries Centre, Post Office Box 182, Narrandera, NSW, 2700, Australia

ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041

Overview: This policy brief synthesises findings, outcomes, and recommendations from a number of fish passage research projects being undertaken by a consortium based in Australia and Lao PDR. The brief was provided at the request of Lao PDR's Ministry of Agriculture and Forestry.

Contribution to knowledge: The ACIAR fish passage program in Lao PDR has empirically demonstrated that fishways can be successfully applied to enhance fisheries productivity in areas impacted by irrigation infrastructure, and thus be used to achieve win-win outcomes for both irrigation and fisheries. These successes call for the development of management initiatives, policy changes and a broader development program that generate win-win outcomes for irrigation and fisheries on a larger scale throughout South East Asia.

Application to management: The policy brief outlines key actions that could significantly benefit fishers, farmers and communities if applied strategically. These include: (1) integrating the obligation to protect fish passage in current irrigation, energy and fisheries laws of Lao PDR; (2) considering fish passage from the outset in policy, guideline and budget discussions for any new infrastructures or upgrades; (3) supporting applied policy research to uphold development outcomes on food security; (4) promoting the sharing of crucial information on new technological solutions to support food security; and (5) endorsing a conducive business partnership environment to guarantee professional advice to developers and the Lao Government.

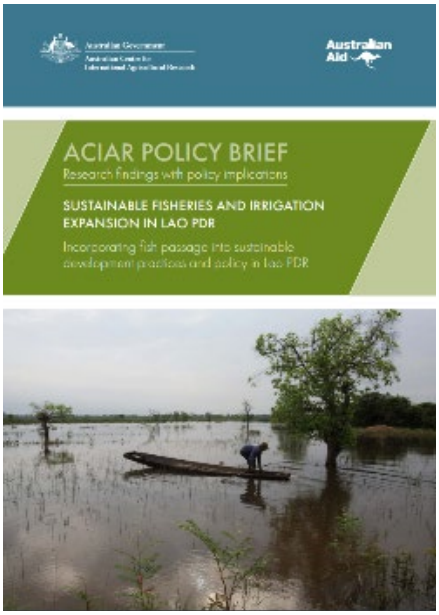

Figure 13. ACIAR fish passage policy brief which was prepared for the Lao government (taken from the brief).

7.11 Masterclass in Fish Passage Engineering Design, Construction, Ecology and Monitoring

Lee Baumgartner[a], Martin Mallen-Cooper[a], Tim Marsden[b], Bethany Cooper[c], Mike Roy[d], William Rice[d], Wayne Stancill[d] (2018). Report.

[a]Institute for Land, Water and Society, Charles Sturt University, Elizabeth Mitchell Drive, Albury, New South Wales, Australia

[b]Australasian Fish Passage Services, 6 Spinifex Street, Fern Bay, NSW 2295, Australia

[c]University of South Australia, School of Commerce, City West Campus, Adelaide, South Australia, Australia

[d]United States Department of the Interior, International Technical Assistance Program, 1849 C Street, NW, Washington DC, 20240, United States

ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041 and US Department of Interior

Overview: This report summarises the course outline of the Masterclass in Fish Passage Engineering Design, Construction, Ecology and Monitoring, which was hosted by members of the ACIAR FIS/2014/041 team and staff from the US Department of Interior. The overarching objective of this masterclass was to provide fishery managers and engineers from across the Mekong region with a grounding in the fundamentals of fishway design and fishway options. The students applied these learnings to prepare plans for designing, constructing and monitoring a fishway in their own country.

Contribution to knowledge: This was the first fish passage masterclass to be held in South East Asia, with 46 students attending (four from Myanmar, eight from Lao PDR, eight from Thailand, six from Cambodia, six from Vietnam, four from SEAFDEC, and 10 observers). The students from each country successfully obtained an improved understanding of migratory fish ecology, fishway design principles, and the importance of monitoring programs.

Application to management: The students have applied their learnings to design fishways in their home countries, and a number of these fishways are now in the formal planning and/or construction phases.

Figure 14. Participants at the first region-wide fish passage masterclass (source: Lee Baumgartner).

7.12 Myanmar Fish Passage Initiative. Masterclass in Fish Passage Engineering Design, Construction, Ecology and Monitoring

John Conallin[a], Lee Baumgartner[a], Tim Marsden[b], Martin Mallen-Cooper[a] (2019). Report.

[a]Institute for Land, Water and Society, Charles Sturt University, Elizabeth Mitchell Drive, Albury, New South Wales, Australia

[b]Australasian Fish Passage Services, 6 Spinifex Street, Fern Bay, NSW 2295, Australia

ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041

Overview: This report summarises the outcomes of the Myanmar Fish Passage Masterclass, which was hosted by members of the ACIAR FIS/2014/041 team. The primary aim of the masterclass was to provide fishery managers and engineers from Myanmar's Fisheries and Irrigation Ministries with the know-how to design and construct effective fish passes for migrating fish at irrigation infrastructures. A secondary aim was to initiate partnerships between irrigation and fisheries practitioners, so that they can work together effectively in achieving win-win outcomes for both sectors.

Contribution to knowledge: The Myanmar Fish Passage Masterclass successfully built baseline capacity within Myanmar's Department of Fisheries and Irrigation and Water Utilisation Management Department to independently design and construct effective fish passes.

Application to management: The trainees have so far applied their learnings to design a suitable fishway for three different priority barriers in the Bago River basin. One of those barriers is the chosen site for Myanmar's first demonstration fishway, Shan Gaing sluice (which is being completed as part of our follow-on ACIAR project, FIS/2018/153).

Figure 15. Field visit undertaken as part of the first Myanmar fish passage masterclass (source: Lee Baumgartner).

7.13 Addressing fish passage issues at hydropower and irrigation infrastructure projects in Indonesia

Lee J. Baumgartner[a] and Arif Wibowo[b,c] (2018). *Marine and Freshwater Research* 69: 1805-1813.

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ACIAR objective(s) addressed*:* Objective four

Source of data/knowledge: ACIAR FIS/2014/041, Research Institute for Inland Fisheries and Fisheries Extensions (Indonesia) and Inland Fisheries Resources Development and Management Department (Indonesia)

Overview: There are plans to greatly expand Indonesia's hydropower and irrigation infrastructure over the next two decades to meet the country's growing demand for energy and food resources. While this expansion promises to enhance food security and living conditions, it will have devastating consequences for the country's highly productive and diverse capture fisheries unless appropriate mitigation measures are put in place to protect these fisheries. The study reviews the impacts of hydropower and irrigation infrastructure projects on Indonesia's capture fisheries, and explores the role of fish passage technologies in alleviating these impacts.

Contribution to knowledge: There are currently only two fish passes in Indonesia — one at Poso Dam on the Poso River (Sulawesi island) and one at Perjaya Irrigation Dam on the Komering River (Sumatra island). The effectiveness of these structures has never been evaluated, and many other projects are proceeding that have not considered fish passage in any way.

Application to management: Indonesia's planned infrastructure refurbishments and upgrades over the next two decades offer a once-in-a-generation opportunity to ensure that migratory fish are managed sustainably into the future. The study recommends adopting a multifaceted approach to implementing fish passage technologies in Indonesia. This involves (1) monitoring the effectiveness of the two existing fishways and modifying them as required; (2) focusing research efforts towards better understanding the ecological life history traits and swimming abilities of target species; (3) using this knowledge to develop national standards to administer future fishway construction; and (4) guaranteeing that fish passage provision is incorporated into national policy for successful fishery-recovery programs.

Figure 16. Perjaya Dam, the site of the first Indonesian fish pass (source: unknown).

7.14 Challenges balancing fisheries resource management and river development in Indonesia

A. D. Utomo[a,b], A. Wibowo[a,b], R. A. Suhaimi[a,b], D. Atminarso[a,b,c] and L. J. Baumgartner[c] (2019). *Marine and Freshwater Research* 70: 1265-1273.

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ACIAR objective(s) addressed: Objective four

Source of data/knowledge: ACIAR FIS/2014/041, Research Institute for Inland Fisheries and Fisheries Extensions (Indonesia) and Inland Fisheries Resources Development and Management Department (Indonesia)

Overview: Indonesia has made the construction of new reservoirs a national priority as it faces increasing human population growth and associated demand for food and water resources. However, the construction of new reservoirs will place immense pressure on the country's capture fisheries via a number of stressors. This study reviews the impacts of reservoirs on the capture fisheries in Indonesia, and outlines a list of mitigation measures for these impacts.

Contribution to knowledge: The study identifies the main reservoir-related stressors on the capture fisheries in Indonesia as being sedimentation, reduced water flows/habitat alteration, eutrophication and overfishing.

Application to management: The study presents a range of possible actions to deal with the sedimentation, flow/habitat alteration, eutrophication, and overfishing impacts associated with reservoirs in Indonesia.

Number	Major reservoir	Location (island)	Altitude (m ASL)	Size (ha)	Maximum depth (m)
1	Cirata	Java	200	7300	62
2	Darma	Java	670	425	4
3	Gajah Mungkur	Java	140	8800	90
4	Jatiluhur	Java	111	8300	83
5	Kedung Ombo	Java	100	4500	46
6	Lahor	Java	270	260	2.6
7	Mrica	Java	200	1250	70
8	Saguling	Java	645	5300	53.4
9	Selorejo	Java	620	650	53.4
10	Sempor	Java	100	1380	4
11	Sutami	Java	270	1500	12
12	Palasari	Bali	66	No data	3
13	Wlingi	Java	163	No data	3.8
14	Koto Panjang	Sumatera	No data	12 000	83
15	RiamKanan	Borneo	No data	9300	100

Figure 17. There is significant river development in Indonesia and the size and frequency of large dams is increasing (taken from the paper).

7.15 Guideline to prioritising fish passage barriers and creating fish friendly irrigation structures

Tim Marsden[a], Claire Peterken[b], Lee Baumgartner[c], Garry Thorncraft[d] (2014). Report.

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ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR fish passage program

Overview: Fishery restoration strategies intrinsically depend on prioritising fish passage remediation efforts to achieve optimal ecological and socio-economic outcomes. A number of methodologies have been developed for assessing and prioritising the mitigation of fish passage barriers; however, they have been designed for developed countries where site data and/or other resources are often readily available. This report presents practical, low-cost basin-scale guidelines for assessing and prioritising the remediation of fish passage barriers in resource-deficient settings, like those typical of Mekong countries. It then outlines an approach to fishway design and construction, that will guide practitioners through the fishway development process for high priority barriers.

Contribution to knowledge: The prioritisation part of these guidelines consists of a five-stage hierarchical decision-support framework, to prioritise barriers for remediation based on fishery and socio-economic criteria. Stage 1 involves identifying all potential barriers within the target basin using satellite imagery; Stage 2 involves performing GIS analysis to rank the barriers for further investigation; Stage 3 involves field-validating the highest ranked barriers from Stage 2 to evaluate the GIS analysis results; Stage 4 involves identifying the highest ranked field-validated barriers affecting fisheries productivity; and Stage 5 involves further refining the list according to socio-economic considerations. The fishway design part of the guidelines then consists of another five stages following on from the prioritisation ones. These involve: (1) selecting sites for rehabilitation; (2) implementing a design process; (3) undertaking fishway construction; (4) operating and maintaining the fishway; and (5) appraising the success of the fishway.

Application to management: These guidelines provide practitioners with a practical stepwise approach to prioritise barriers and develop effective fish passages at the highest priority barriers within a river basin.

Figure 18. Prioritisation process output showing the top barriers to be fitted with fish passes in the Xe Bang Fei catchment (taken from the report).

7.16 Using an in-situ experimental fishway to inform key fishway design criteria: A case study from the Mekong River

L. J. Baumgartner[a], T. Marsden[b], D. Singhanouvong[c], O. Phonekhampheng[d], I. G. Stuart[e], G. Thorncraft[f] (2012). *River Research and Applications* 28: 1217-1229

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[e]Kingfisher Research, Melbourne, VIC 3089, Australia

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ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR fish passage program

Overview: This was one of the first published studies to empirically test the suitability of a demonstration fishway *in situ*, for providing lateral passage for fish wanting to access floodplain habitats from the Mekong River. Specifically, it examined the influence of fishway floor slope (1v:15h or 1v:7.5h) on fish passage effectiveness, to aid in establishing optimal design standards for the construction of vertical-slot fishways at barriers to fish passage.

Contribution to knowledge: The experimental *in situ* approach revealed that most fish preferred the vertical slot fishway when it was configured on a moderate hydraulic slope (1v:15h).

Application to management: This study suggests that vertical-slot fishways can support passage for a diverse range of LMB fish species, where the fish are moving laterally onto floodplains. It has also improved our understanding of the design criteria that are likely to achieve the most effective outcomes for LMB species.

Figure 19. Processing fish from Pak Peung fishway as part of the fish passage research (source: Jim Holmes).

7.17 Comparing fishway designs for application in a large tropical river system

Lee J. Baumgartner[a, b], Craig Boys[c], Tim Marsden[d], Jarrod McPherson[b], Nathan Ning[b], Oudom Phonekhampheng[e], Wayne Robinson[b], Douangkham Singhanouvong[f], Ivor G. Stuart[g], and Garry Thorncraft[e] (2018). *Ecological Engineering* 120: 36-4337.

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ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR fish passage program

Overview: Large tropical river-floodplain systems are well known for supporting highly productive and diverse fish communities that provide important socioeconomic and environmental benefits to their neighbouring human populations. However, they are being exploited to construct water control infrastructures which impact fish passage by preventing fish from accessing critical habitats to complete their life-cycles. This study experimentally examined the effectiveness of existing fishway designs for restoring fish passage in the LMB in Laos. We investigated the attributes of designs that had been previously used, including (1) vertical slot, (2) submerged orifice—150 mm square opening; and (3) submerged orifice—300 mm square opening fishways. The experiments were undertaken during both the day and night to consider the potential influence of variation in diel fish movement patterns.

Contribution to knowledge: The three fishway designs supported the passage of a similar abundance, biomass, species richness and size range of fish, during both the day and night. Nonetheless, the vertical slot design passed a different collection of fish species to that of the other two designs during the day.

Application to management: All three of these fishway designs could be used to effectively restore fisheries in the LMB and possibly other large tropical river systems with diverse migratory fish communities and variable hydrological features. Nevertheless, the vertical slot fishway offers superior design and operational flexibility over the submerged orifice designs, especially in tropical systems with intrinsically variable hydrology. The choice of fishway design will depend on the target fish species and size classes and the site-specific hydrological conditions.

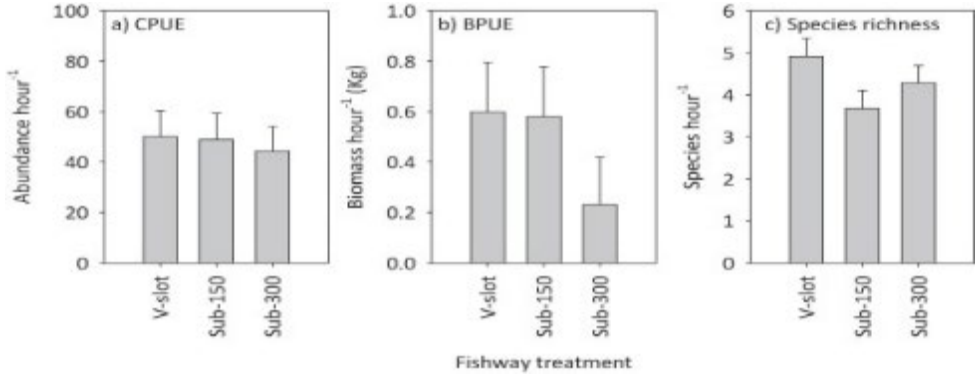

Figure 20. Key performance metrics of three fishways assessed for efficiency (taken from the paper).

7.18 A cautionary tale about the potential impacts of gated culverts on fish passage restoration efforts

Lee J. Baumgartner[a,b], Matthew Barwick[c], Craig Boys[d], Tim Marsden[e], Kate Martin[f], Jarrod McPherson[b], Nathan Ning[b], Oudom Phonekhampeng[g], Wayne Robinson[b], Douangkham Singhanouvong[h], Ivor Stuart[i] and Garry Thorncraft[h] (2019). *Journal of Ecohydraulics* 4(1).

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ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR fish passage program

Overview: This study assessed the lateral movement patterns of LMB fish, through a sequentially arranged fishway and sluice gate culvert facility located between the Mekong River and Pak Peung wetland in Lao PDR. The fishway-culvert facility was intended to enable fish to swim upstream from the Mekong River to Pak Peung wetland during the wet season.

Contribution to knowledge: The fishway-culvert facility successfully passed LMB fish when the culvert was only partially inundated and the culvert gate was fully open. However, during the subsequent period of complete inundation, when the inlet gate was partially closed to protect the downstream fishway, the passability of the culvert substantially decreased. These results support the hypothesis that the passability of the fishway-culvert facility at Pak Peung is greatly influenced by the regulating culvert at the upper end of the facility.

Application to management: To optimise fish passage, both culvert and fishway hydraulic functionality should be awarded equal consideration where they are arranged in sequence. Otherwise fish passage restoration efforts will most likely only be effective for a very limited range of hydrological conditions and/or local species.

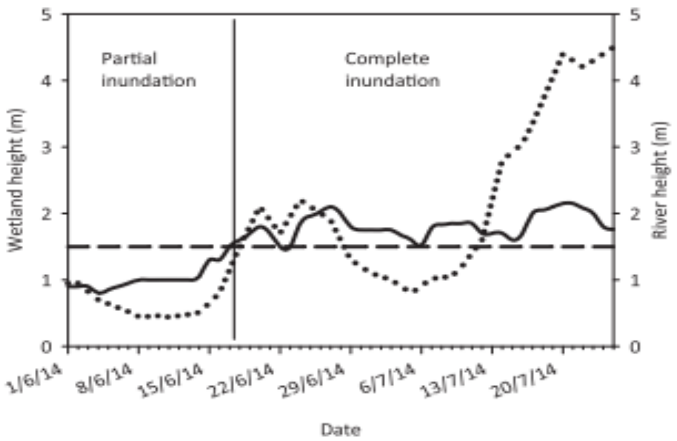

Figure 21. Wetland and river heights during our study. We learned that the culvert aspect of fish passage needs to be carefully considered to maximise success. Without a gap between the roof of the culvert and the water, fish passage is very difficult (taken from the paper).

7.19 A cone fishway facilitates lateral migrations of tropical river-floodplain fish communities

Lee J. Baumgartner[a,b], Craig Boys[c], Tim Marsden[d], Jarrod McPherson[b], Nathan Ning[b], Oudom Phonekhampheng[e], Wayne Robinson[b], Douangkham Singhanouvong[f], Ivor G. Stuart[g], and Garry Thorncraft[e] (2020). *Water* 12(2): 513.

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ACIAR objective(s) addressed: Objective one

Source of data/knowledge: ACIAR fish passage program

Overview: There is a mounting global need for innovative, cost-effective fish passage technologies to alleviate the obstructive impacts of irrigation and hydropower developments on migratory fish species. The study assessed the efficacy of a new cone fishway design for supporting lateral migrations of river-floodplain fish communities in the Lower Mekong Basin in Lao PDR, using the Pak Peung demonstration site.

Contribution to knowledge: Our results suggest that with further development, the cone fishway design has substantial potential for supporting the lateral movements of diverse tropical river-floodplain fish communities at low/medium head infrastructure, like those at Pak Peung.

Application to management: In addition to proving an alternative to other fishway designs, the cone fishway has the advantages of (1) being low maintenance and simple in design; (2) offering potentially lower average turbulence (energy dissipation) than the vertical slot design; (3) being built from pre-fabricated baffles to reduce the overall construction costs; (4) offering potentially safe human access and egress to better meet safety standards; and (5) preventing a headwater pool from being completely drained due to its fixed crest level.

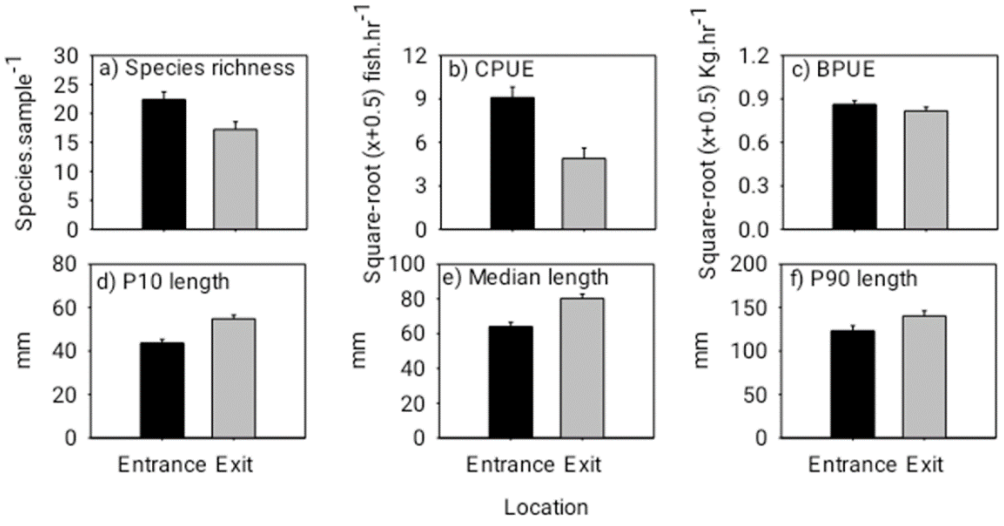

Figure 22. Biological metrics (species richness; catch per unit effort (CPUE); biomass per unit effort (BPUE); and 10th, median and 90th percentile lengths) associated with Pak Peung cone fishway performance (taken from the paper). The black bars represent the downstream fishway entrance and the grey bars represent the upstream exit.

7.20 Local perceptions of changes in the use and management of floodplain fisheries commons: The case of Pak Peung wetland in Lao PDR

Joanne Millar[a], Wayne Robinson[a], Lee Baumgartner[a], Khampheng Homsombath[b], Malavanh Chittavong[c], Thonglome Phommavong[c], Douangkham Singhanouvong[b] (2019). *Environment, Development and Sustainability* 21:1835-1852.

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ACIAR objective(s) addressed: Objective three

Source of data/knowledge: ACIAR fish passage program

Overview: The effectiveness of adaptive strategies to enhance fisheries co-management is strongly influenced by local perceptions of floodplain fisheries use and management; yet, these perceptions have not been considered thus far. This study investigated the perceptions of local people on changes in the use and management of floodplain fisheries, using Pak Peung wetland in Lao PDR as a case study.

Contribution to knowledge: Our surveys revealed that villagers perceived fisheries to have declined due to habitat destruction, population increase, irrigation development, and illegal fishing practices. Most villagers wanted tougher regulation and protection of fish conservation zones. A number of households reported catching fish species not seen in the wetland for many years post-fishway. As one fisher noted "*Before many trees, many small streams, Pak Peung reservoir was divided into (two streams called) Koud Hey & Koud Khao. Now it is all joined together because of the weir. After build weir not many trees in wetland, not many wildlife……many fish moved from the Mekong River. Big fish would come (Pa Khao, Pa Ngon, Pa Lart, Pa Khop,)".*

Application to management: The findings from this study suggest that regular patrolling and enforcement of fisheries rules would aid local communities in preserving their floodplain fisheries into the future.

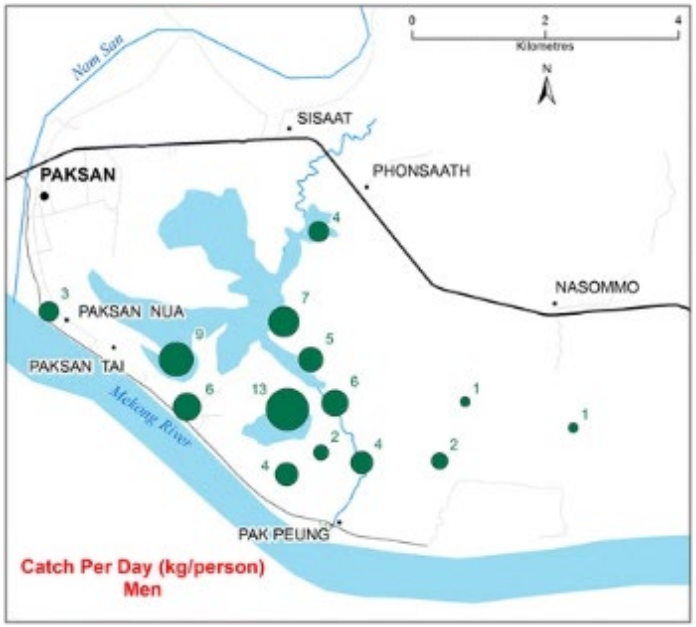

Figure 23. Daily catch rates of fishers in relation to Pak Peung village and the fishway (taken from the paper).

7.21 Achieving fish passage outcomes at irrigation infrastructure: A case study from the Lower Mekong Basin

Lee J. Baumgartner[a], Chris Barlow[a], Martin Mallen-Cooper[a], Craig Boys[a,b], Tim Marsden[c], Garry Thorncraft[d], Oudom Phonekhampheng[d], Douangkham Singhanouvong[e], William Rice[f], Michael Roy[f], Lin Crase[g], Bethany Cooper[g] (2018). *Aquaculture and Fisheries* 6(2): 113-124.

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ACIAR objective(s) addressed: All four objectives

Source of data/knowledge: ACIAR fish passage program and United States Department of the Interior Lao-based projects

Overview: This study synthesised the crucial facets of knowledge development and transfer from the ACIAR fish passage program in Lao PDR, within the context of river connectivity and fisheries management.

Contribution to knowledge: The success of the ACIAR fish passage program to date was found to be largely due to: (1) its long-term funding by ACIAR enabling proof-of-concept of the seasonally-natured and multilayered research in a developing country; (2) strong leadership and positive collaboration from both local and international leaders, (3) active engagement in scale-out by team members, underpinning commitment from donor agencies; (4) the holistic approach applied to fish passage remediation, which included consideration of the ecology of the target species in combination with the local hydrology, (5) remaining flexible and adaptive to be able to effectively navigate the local climatic, political and logistical constraints; and (6) the application of a demonstration site approach, which provided a facility at which the principles, benefits and public engagement with fish passages could be appreciated via direct observation.

Application to management: The successes from our Lao PDR can be applied to other Lower Mekong countries, to achieve long-term positive outcomes.

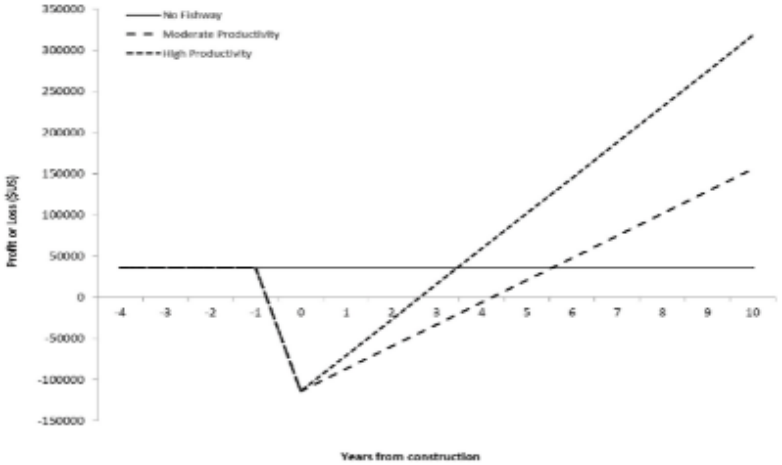


Figure 24. Estimated return on investment. Cost of fishway vs. estimated improvement in fisheries productivity (taken from the paper).

8 Impacts

8.1 Scientific impacts – now and in 5 years

Scientific advances

The science of fish passage is a complex and evolving field. It is extremely 'technical' and 'precise'. Attaining good outcomes requires close collaboration between engineers and biologists. But the ability to attain outcomes depends on the scale of application. The overall outcome from our work is to ensure that 'fish', and the people who depend upon fish, become an automatic consideration at future river infrastructure projects. The fact that river infrastructure impacts fisheries has been well-established and largely accepted. The fact that technical solutions exist and that there is a solid economic argument for their inclusion is accepted by some, but not all. So, at a fundamental level, the team worked hard to establish a scientific knowledge base which demonstrated that fish passes work. The ultimate gauge of scientific robustness is publication in scientific journals. So, ensuring our work was robust, defensible and publishable was deemed critical in order for the work to have credibility.

From that perspective, the FIS/2014/041 project generated a series of 'world firsts', including:

- *Defining the cost-benefits of fish pass construction in a local context*; we were the first team to demonstrate that investing in fish passage technology will have economic and nutritional benefits (Cooper et al. 2019).
- *Development of a decision support tool to guide fish passage investments*; the target audience for this tool was engineers and economists developing bankable projects. The tool can calculate the expected return on investment, which can then be incorporated into banking business cases.
- *Using the decision support tool to justify, and secure, donor investments into on-ground activities*; we worked with donors (specifically ADB) to calculate the expected return on investment for several fish passage projects as part of a Northern Lao infrastructure project. This was a key factor in the economic decision to invest in fish passes.
- *Scientifically defensible fish pass design criteria for Lao PDR;* we published the first design criteria for fish passes in Laos and demonstrated that the fish passes provided ecological and social benefits. These provide arguments that can be used to justify further scale-out.
- *Defining seasonal movements of Mekong fish into floodplain habitats;* we demonstrated that hundreds of species can use fish passes and the optimal operating and design criteria by which this can be achieved. We also demonstrated that villagers were benefitting from this improved passage by catching species that had returned to their fishing grounds.
- *Understanding local perceptions to fish pass construction;* we recognized that the beneficiaries (i.e., villagers and fishers) are critical stakeholders in the work. We worked hard to ensure that their perspectives were understood and communicated to investors.
- *Documenting sound governance and partnership processes required for fish passage to advance in South East Asia*; we mapped out the critical success factors that were gleaned from our involvement in many 'development' applications of our technology over several years. Reporting on the critical success factors offered a platform by which future benefits could be gained at other river infrastructure projects.

Scientific outputs

Defensible, peer-reviewed science was a focus for the team. The FIS/2014/041 project resulted in 21 papers being published in international scientific journals (Appendix I), and many others are being prepared and/or have been submitted for publication.

The outputs followed a strategic progression in terms of the relevance of this work for overall technological development:

1. Proof of concept: Where the efficacy of fish passes was assessed biologically and hydraulically through intense field testing
2. Opportunity scoping: Where GIS mapping and field validations were performed to determine the overall need for fish passage technology in target catchments
3. Capturing process: Where we attempted, as best we could, to capture the overall process required to successfully apply fish passes in a Lower Mekong context. This included both technical and process elements.
4. Capturing social benefits: There was a need to ensure that the 'human' side was understood, which extended to ensuring that nutritional and household benefits were captured.
5. Capturing economic benefits: There was a need to demonstrate that investing in fish passage was attractive in terms of 'return on investment' perspective
6. Scaling: It was necessary to ensure that the process by which scaling of outcomes to donor investments was captured
7. Information sharing: Rarely are events, such as conferences or major workshops reported on and outcomes publicly disclosed. We made a concerted effort to ensure that major regional workshops were reported in the scientific literature.
8. Capacity building: Fish passage is a highly technical discipline, which requires specific skills to implement correctly. The team put substantial effort into capturing the training requirements and reporting the outcomes publicly where possible.

The sub-total of the outputs (and outcomes) generated in these suites of publications then needed to be integrated into future projects. The project team initiated a series of additional research and development projects with both the World Bank in southern Laos, and Asia Development Bank in northern Laos. The results from these side projects have been presented in this final report, but were also reported in additional reports (final reports for ADB and quarterly reports for the World Bank). Further, additional funding has been approved to develop fish passage guidelines and an environmental flows strategy for Myanmar. This led to several papers being presented, and published in *Marine and Freshwater Research*, and these were launched at the World Irrigation Forum in 2019.

8.2 Capacity impacts – now and in 5 years

Overall / general capacity impacts

Often, a team of scientists and engineers will work on developing a solution at a single site. The team may or may not work together again at the next site (often engineering projects are implemented by separate teams). So, at the very basic level, there needs to be a knowledge base which is accessible to a broad range of engineering teams who may move from project to project. Thus, to apply a successful project at any site there needs to be a combination of local, and international, biology and engineering skills.

Recognising this need, the team partnered with ACIAR, US Department of Interior, the Mekong River Commission and the Crawford Fund to develop and deliver a masterclass approach to capacity building. In Myanmar, the goal of the masterclass was to provide engineers and fishery managers from Irrigation and Fisheries Ministries with the information needed to design and construct effective fish passes for upstream migrating fish at irrigation infrastructure. The second goal was to build connections between irrigation and fisheries practitioners, to better utilize both skillsets in fish pass design and construction. With both goals in mind, the students who participated in the masterclass actually spent four days collaborating to design a fishway.

Figure 25. Fishways constructed in Thailand (top left), Myanmar (design-only; top right), Vietnam (construction commenced, bottom right) and Cambodia (completed; bottom left). All of these fish passes emanated from the masterclass held in Bangkok in 2018.

The masterclass also benefitted donor banks. The Asia Development Bank sent a delegation of project staff to the Bangkok masterclass to learn about fish pass design. They were planning a major irrigation upgrade in the Pursat River in Cambodia. The team spent the four days with the engineering diagrams for the site and planned a concept for a vertical slot fishway.

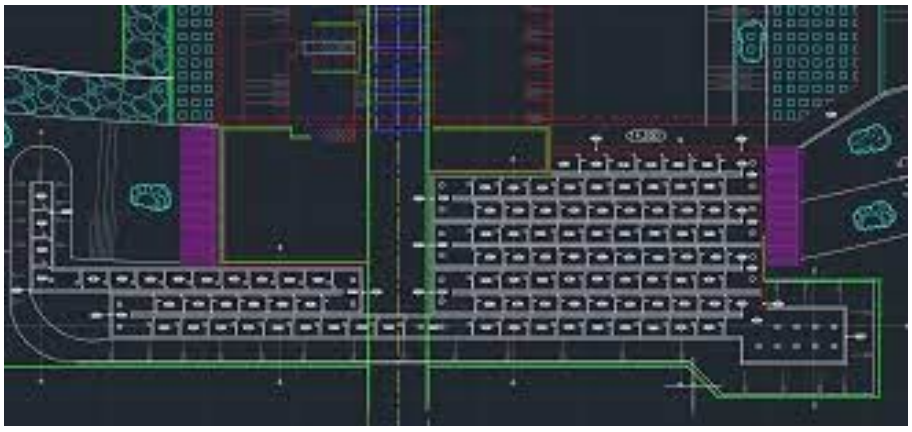


Figure 26. Concept for vertical slot fishway designed by the ADB/Cambodian project team at the Bangkok masterclass.

Figure 27. Final fishway constructed on the Pursat River in Cambodia which emanated from the masterclass activities.

The Bangkok masterclass therefore provided benefits for fisheries and irrigation agencies in all Mekong countries, and provided benefits to donor bodies seeking to increase environmental outcomes from investment programs.

The FIS/2014/041 project has built capacity in Lao research staff, fishery managers, irrigation officials, villagers; and Australian volunteers (Lauren Withers and Peter Collier).

The capacity has been built by involving each in project activities including fish sampling, fish pass construction and operation, and household fishing surveys.

Lao villagers can now communicate project benefits at the Pak Peung fish pass site, and have enough knowledge of the experimental approaches and fish pass hydraulics to operate the fish pass optimally on their own.

The World Bank projects have started to facilitate the uptake of the fish pass design criteria to other sites in southern Laos.

Our team's partnerships with the Asia Development Bank could also facilitate the construction of a further 26 fish passes in northern Laos.

The FIS/2014/041 project's capacity impacts at a broader geographic scale will be contingent on donor body acceptance and investment, which is more likely to transpire within a 10-year timeframe.

ADB

The ADB released their new fish passage strategy for Lao PDR on 7/9/20. It incorporates many aspects of the FIS/2014/041 project; including the decision support tool developed by our team. The strategy has now gone live on the ADB website and is a great example of FIS/2014/041's impact with donor agencies. The document concludes with a statement of how fish passage is relevant to poverty reduction strategies listed in the ADB 2030 strategy.

Specific examples of capacity-building activities leading directly to long-term impacts

- ACIAR team members and one PhD student obtained exposure and experience presenting their results at the 2019 World Irrigation Forum in Bali (see Appendix I). It also provided an opportunity to interact with investors and donors in the irrigation space.
- The Myanmar fish passage masterclass/design workshop (hosted by the ACIAR team members) provided Myanmar irrigation officials and fisheries managers with the expertise to design effective fish passes, using the Myanmar demonstration fish pass as a test case.
- Further fish migration and fish passage workshops took place with Myanmar irrigation and fishery managers in February 2020, to advance the design and implementation of the Myanmar demonstration fish pass.
- The ACIAR team partnered with the ADB to work on Phase 1 of the Northern Rural Infrastructure Sector Development Project (Thorncraft et al. 2019). Specifically, we:
  (a) provided recommendations pertaining to the modification of existing fish pass to improve fish passage on recently completed low-level irrigation weirs (two sites) in the Nam Beng catchment, Oudomsay Province, Lao PDR (Phase 1);
  (b) assessed the effectiveness of those modifications in the 2019 wet season; and
  (c) provided advice on future fish pass design for Phase 2 and 3 of the project (potentially another 90 plus sites) before construction started in November 2019.
- The team developed capacity in government officials and fisheries managers in Thailand, Cambodia, and Vietnam, for the ACIAR/USAID side project that is supporting the development of demonstration fish passes in those countries.
- The team was also engaged in an ADB-funded project, to advise on the design and construction of fish-friendly regulators just east of Vientiane.
- CSU student, Dwi Atminarso, upgraded his Master's enrolment to a PhD with an Australia Award scholarship, through CSU. His research will extend the ACIAR fish passage research into Indonesia.

8.3 Community impacts – now and in 5 years

8.3.1 Economic impacts

To address the third major objective of FIS/2014/041 (i.e., to 'quantify, in social and economic terms, the options for constructing fish pass at riverine infrastructure'), we developed the decision support tool (DST) for rapidly assessing the benefits of fish passage works. This DST will be essential for evaluating the ecosystem services and economic benefits of enhanced fish passage throughout the LMB.

Also, as part of the design and development of the DST, we:

- Undertook a productivity assessment on the scale of proposed benefits (in terms of hectares)
- Performed a basic assessment of nutritional needs of LMB children so that a nutrition factor could be calculated by the tool
- Performed a straightforward household and market analysis to predict the income-related benefits arising from increased fisheries production
- Assembled a list of known costs for fish passes constructed across the LMB.

The DST was introduced to the scientific and engineering communities at the World Irrigation Forum in Bali in 2019. The *Marine and Freshwater Research* paper describing the DST was published in a special irrigation issue of the journal in 2019 (see Appendix I). Fishery managers and irrigation officials have also been trained in how to apply the DST in fish passage masterclasses run by the team.

8.3.2 Social impacts

Overall / general social impacts

The scale out of fish pass technologies will enhance fisheries production, and subsequently improve incomes and food security for fishers and their families throughout the LMB. Furthermore, the handling of fish passes as community-managed assets, such as the Pak Peung one, will incentivise local co-operation and cohesion. Other expected benefits include:

Awareness raising and assurance to support fish migration and fish passage work in Myanmar: Fish migration and fish passage assessments are still fairly novel concepts for the Myanmar government and research agencies. The ACIAR team held numerous meetings with irrigation officials and fishery managers throughout this project to workshop the Myanmar demonstration fish pass concept and build capacity within the institutions responsible for informing decision makers.

Improved community co-management frameworks: Floodplain capture fisheries are largely regarded as a shared resource among villagers. In the Pak Peung region, seven villages are located at varying distances from the fish pass site; however, there is broad recognition within the community that the villages should benefit equally. To accomplish this goal, local, district and provincial officers are keen to establish a flexible community management framework that could simply be extended to include other sites.

Regional leadership on fish pass issues: Fish pass construction and capture fisheries restoration are being increasingly considered in Lao PDR, thanks to the significant ecological and socio-economic benefits that they can potentially generate. Lao fisheries and irrigation staff who have been previously involved in capture fisheries rehabilitation and fish pass construction have been gaining further experience and building capacity by partaking in extension activities in the southern Laos province of Savannakhet.

Greater community knowledge of floodplain fisheries: Fish pass construction and capture fisheries restoration are developing issues in Laos. Most local fishers only have a basic knowledge of the processes influencing fisheries ecology and productivity, mainly from the fish they regularly catch. At Pak Peung, more than 80% of the local villagers involved in fishing activities have not finished secondary school. Our ACIAR team endeavoured to address this challenge by involving locals directly in project activities so that they could obtain hands-on education and work experience in fisheries management and ecology.

Examples of specific social impacts

- Northern Laos – the ACIAR team has partnered on a project seeking to use irrigation to improve the livelihoods of 120 villages and 9,989 households. The team have produced concept notes for fish passes which have progressed.
- North-east of Vientiane – The ACIAR team has advised the ADB-funded side project, to build fish-friendly regulators (on Mekong outlet east of Vientiane) to restore fish passage and nutritional and economic benefits at That Luang Marsh. We applied the DST to estimate that a functioning fish pass would increase fisheries-related income from the wetland by over $US100,000 per year and benefit 19,000 people.
- Central Laos – under a scenario in which the whole of Pak Peung wetland was affected by the demonstration fish pass and the fish pass was capable of passing 100% of the stock attracted, the DST estimated that nearly 5.7 tonne of extra edible protein would be created annually, which would meet the dietary requirements of almost 1200 children under 3yo.
- Southern Laos – field trips to the XBF regulator sites in May 2020 have generated greater knowledge of fish pass operations and benefits to households.
- Indonesia – PhD student, Dwi Atminarso, has begun fish passage investigations at Perjaya Dam on Sumatra Island. He will include a component of his PhD to calculate the importance of inland fisheries to people on Sumatra Island (following the advice of FAO (Inland Fisheries)).

8.3.3 Environmental impacts

The results of our final report analysis for objective's 1 and 2 empirically indicate that the project activities from FIS/2014/041 (and the broader program of ACIAR fish passage projects completed since 2006) will progressively lead to the restoration of many South East Asian fisheries affected by dams and other infrastructure-associated barriers. Importantly, there will be no harmful environmental impacts. Evidence of environmental improvement included:

- In all years (except for the first year of fish pass operation – 2016), total household fisheries biomass became generally greater in the late wet season than in the early wet season at the Pak Peung fish pass site, and the opposite seasonal trend occurred at the Kadan no-fish pass site (see Appendix II).
- Over 100 species successful passing through the Pak Peung fish pass.
- Over 23 species ascending the Nam Beng fish pass in Northern Laos over two-weeks
- Over 50 species and 800,000 individuals passing through a newly constructed fish pass in Cambodia over a two-month period.
- New species appearing where they had not been seen for over 20 years.
- Reconnecting previously disconnected aquatic habitats.
- Multi-discipline contributions to better understanding the impacts and scale of irrigation development across the Lower Mekong Basin.

8.4 Communication and dissemination activities

8.4.1 Overview of communication activities

Communication and extension activities targeted towards end users

- Five presentations, and a special session, were given at World Irrigation Forum in Bali (Appendix I). The fish pass decision support tool (DST) was tested with an international audience comprising mostly irrigators and donors.
- Four masterclasses were hosted by the ACIAR team in the last three years:
  a. Thailand 2018 Barrier Prioritization and Fish Passage Masterclasses (Baumgartner et al. 2019a) (Appendix I). These masterclasses were co-hosted with the U.S. Department of Interior in Thailand, to train engineers and fishery managers from Myanmar, Lao PDR, Thailand, Cambodia, and Vietnam.
  b. Myanmar 2019 Fish Passage Masterclass (Conallin et al. 2019) (Appendix I).
  c. In July 2019, provided training to 24 practitioners from Myanmar Irrigation and Water Utilisation Management Department and Department of Fisheries on designing fish passages.
  d. Lao PDR 2020 Fish Passage Masterclass (Thorncraft et al. 2020) (Appendix I).
- Fish pass sampling training was given to staff from the District Agriculture and Forestry Office (DAFO) and local villagers at Pak Peung in 2019.

Hands-on training of fisheries scientists, managers and students in Asia and Australia

The ACIAR team supervised many Honours and postgraduate students. In summary:

- Completing honours projects on PIT tagging methods on Mekong species at LARREC, under the supervision of team members (Appendix I) (two journal papers were published from this work – Grieve et al. 2018a, b) (Appendix I).
- Students obtaining Australia Award scholarships on fish passage issues in Indonesia.

Also, the ACIAR team generated numerous media outputs (Appendix I). Some key examples:

- Project media interviews/releases to the Mekong River Commission Catch and Culture newsletter (Appendix I).
- Giving presentations about some of the Mekong ACIAR-funded research to Year 6 students in August 2019, as part of a university student experience day at CSU.

Figure 28. The ACIAR FIS/2014/041 team teaching irrigation and fisheries officials about fish passage design (a) and barrier mapping and prioritisation (b) at the two Thai masterclasses held in Bangkok in 2018 (source: Unknown).

The ACIAR project learnings being referenced in an Australian Parliamentary inquiry into dams and weirs (please click QR code)

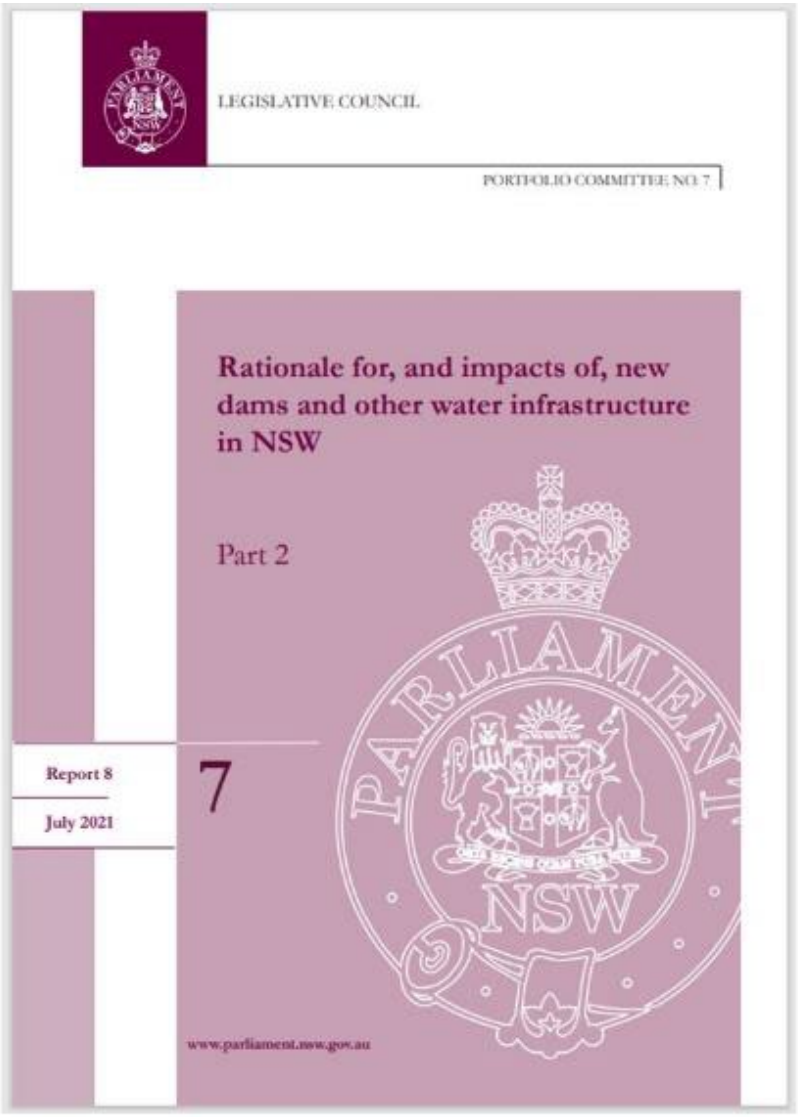
The learnings from the ACIAR fish passage program (i.e., FIS/2014/041 and its predecessor projects) were referenced in an Australian Parliamentary inquiry into dams and weirs (Figure 29). This is a great example of an ACIAR project providing benefit back to Australia in formulating better policy around our river connectivity challenges. Specifically, the committee noted the involvement of communities in the co-design of fish passage works. In fact, evidence was presented which outlined the role that the village chief played in the fish pass design. He noted that the first concept may be too dangerous for local children and he expressed concern that there may be a drowning risk. The design team worked with him to implement a solution which enabled children to play within the fish pass but have an easy way to access and egress the structure. The committee noted that they would like to see a similar design approach undertaken in NSW and made specific recommendations that government consider this moving forward.

8.4.2 Southern Lao PDR – World Bank communication/dissemination activities

2019 — We held stakeholder meetings with water management groups in Xaibouly and Nongbok districts. We used local villagers to aid in the preparation and painting of the structures prior to the wet season, and to encourage awareness of the project in advance of sampling.

2020 — In June 2020, we held a community stakeholder lunch and workshop in Xaibouly district that was attended by all Xaibouly gate operators, Niebahns and local DoI staff. This workshop reinforced the agreement reached during structure painting in May 2020 that all flaps and gates would be fully open for the start of the 2020 wet season. However, none of the gates were ever fully opened in 2020.

2021 — We held an end-of-project stakeholder meeting including a dissemination trip on 25 March, 2021. The meeting was held in Thakek and attended by local gate operators, water management group representatives, Niebahns, and District and provincial DoI irrigation and communications officers. We have provided at our own cost, 200 copies of an educational poster detailing gate operations that promote fish passage in Lao language. The posters will be put on display in DoI offices across Laos.



LEGISLATIVE COUNCIL

PORTFOLIO COMMITTEE NO. 7

Rationale for, and impacts of, new dams and other water infrastructure in NSW

Part 2

Report 8

July 2021

7

www.parliament.nsw.gov.au

Importance of community engagement

8.7 The committee heard evidence regarding the importance of engaging impacted communities in the development of water management policy.

8.8 Dr Baumgartner and Dr Mallen-Cooper told the committee about work they had been a part of in South-East Asia regarding the management of water systems. They described an approach that involved more community engagement, that was less 'top-down', and included 'co-design'.[346]

8.9 Dr Baumgartner gave an example of designing a fish ladder in Laos, and told the committee about the community involvement that was undertaken in establishing what was required, and what their needs were. He stated that:

> They knew exactly what we were going to do because we involved them in every step of the process. I would say that the big difference over there is that they want to be included in the decision-making process. They are actively included and at the end they want to take some ownership of the solution. That is probably a big difference for me.[347]

8.10 Dr Baumgartner and Dr Mallen-Cooper stated that this approach of involving impacted communities in the design of water management systems would be welcomed in NSW. Dr Baumgartner told the committee that basin communities would 'relish that opportunity', and noted that the desire to be involved throughout the entirety of the decision-making process had been expressed to them consistently in their work in impacted communities.[348]

Figure 29. The excerpt from an Australian Parliamentary inquiry into dams and weirs, which references learnings from the ACIAR fish passage program.

8.4.3 2016 Lower Mekong Conference

The ACIAR FIS/2014/041 project team hosted the Lower Mekong Fish Passage Conference at Lao Plaza Hotel in November 2016. Eleven members of the team presented project results at the conference (Appendix I); which was supported by the ACIAR launch fund program.

The format of the conference involved several initial presentations on the importance of regional fisheries sustainability and an understanding of migration ecology from each of the Lower Mekong countries. Presentations were then given regarding processes for developing design criteria for local species in the Lower Mekong Basin. Speakers then discussed how these criteria were adapted into permanent migration facilities. There was general agreement among participants that to successfully improve fish passage across the Lower Mekong Basin: (1) enhanced knowledge was needed on design criteria that can provide effective passage for local species in an upstream and downstream direction; (2) there was a strong need from developers and consent agencies for a clearly-defined set of acceptable biological criteria for upstream and downstream fish passage, which are proven to work for local species; (3) there was acceptance that technology developed in other parts of the world, such as sensorfish, acoustic tags and PIT tags, could play a role in helping document the success of mitigation systems; and (4) research outputs need to be urgently used to inform the development assessment process for new and existing works.

This conference gave villagers associated with the ACIAR project experience in hosting for one of the conference days. The Laos project collaborators also presented the results from the project at the American Fisheries Society conference in August 2017 and the 2018 Fish Passage conference in Albury (Appendix I).

Figure 30. Key collaborators at the first Lower Mekong fish passage projects conference.

8.4.4 2017 American Fisheries Society Conference in Tampa, Florida

The ACIAR team hosted a special session, obtained co-funding for partners and gave nine presentations at the 2017 American Fisheries Society Conference in Tampa, Florida (Appendix I).

8.4.5 2018 Fish Passage conference in Albury

These were captured in Objective 4 – uptake. But to recap, ACIAR launch funding supported:

- The Laos project collaborators imparted project-derived knowledge to international scientists and managers when they presented results at the 2018 Fish Passage conference in Albury, NSW (Appendix I).
- Our FIS/2014/041 project team gave eleven presentations at the conference, and received the Distinguished Project Award for the substantial international fish passage impacts achieved by the group.
- The Fish Passage 2018 conference also successfully fostered networking among the project members, and between the project members and staff from other organisations.
- This resulted in major collaboration opportunities, including between:
  a. Prof. Lee Baumgartner (CSU) and Dr Gordon O'Brien (University of Mpumalanga, South Africa), on fisheries concerns in Africa.
  b. ACIAR project team members (Lee Baumgartner, Craig Boys, Wayne Robinson) and eminent fisheries researchers from Germany (Juergen Geist and his team at Technical University of Munich). The Australian scientists partook in research exchange program with the German scientists on fish passage issues.
  c. Senior international fish passage researchers and practitioners. A workshop was held linking sustainable development goals (SDG's) with irrigation and fisheries. The workshop has resulted in the development of a publication and journal special issue on sustainable irrigation.

Figure 31. Lee Baumgartner giving the opening address at the Fish Passage 2018 conference (a), and team members of the ACIAR-funded Lao PDR fishway project receiving the Distinguished Project Award at Fish Passage 2018 (b) (source: Nikki Scott).

8.4.6. Scale out of learnings to Myanmar, Thailand, Cambodia and Vietnam (USAID/ACIAR-funded extension)

A USAID/ACIAR-funded extension was undertaken to:

- Scale out learnings from Lao fish pass research to Myanmar, Thailand, Cambodia, and Vietnam
- Carry out prioritization of barriers in each country (already reported for Myanmar in objective's 1 and 2 – Study 1)
- Design and build a demonstration fish pass in each country (as was done in Lao PDR).

Myanmar

ACIAR funded the formation of a partnership approach between Department of Fisheries (DoF), Irrigation and Water Utilisation Management Department (IWUMD) and Flora and Fauna International (FFI) to work together on assessing and providing a way forward for fish passage issues in the foodbowl district of Bago, where irrigation plays a key role in food security for the country. ACIAR funded the design of a double vertical slot demonstration fish pass for Shan Gaing sluice in Myanmar under Variation 3 of the project contract.

The general approach to scaling out the uptake of fish passage technologies in Myanmar consisted of:

- Prioritising barriers for remediation throughout focal catchments, using the barrier prioritisation method that was first developed in the ACIAR project, FIS/2009/041 (Baumgartner et al. 2016).
- Running a masterclass in country in July 2019 with 24 delegates (10 from IWUMD and 14 from DoF), to train key Myanmar DoF and IWUMD staff in fish passage design (Conallin et al. 2019).

This masterclass adopted a learning-by-doing approach, and was used to develop potential fish pass designs for real-world high priority barrier sites in the focal Myanmar catchments. The masterclass also led to the development of preliminary fish pass designs for Shan Gaing sluice, as well as a timeline with set actions for the various steps needed to get to the stage where the demonstration fish pass can be built. Our team has since been continuing to liaise with the IWUMD and DoF to refine and finalise the design with detailed drawings and costings.

Thailand/Cambodia/Vietnam

The scale-out components for Thailand, Cambodia, and Vietnam have been funded by USAID, and overseen by our ACIAR team and US Department of Interior officials, in partnership with irrigation and fisheries officials from each respective country. As per the approach in Myanmar, barrier mapping was initially undertaken in each country, followed by fish pass design and construction.

Key outcomes

Myanmar

- The Myanmar Fish Passage Masterclass built baseline capacity within DoF and IWUMD to be able to design a suitable fish pass for three different priority barriers in the Bago River basin, including the Sha Gaing sluice (Conallin et al. 2019).
- We are currently still negotiating on the design for the Myanmar demonstration fish pass at the Shan Gaing sluice, with engineers from IWUMD.
- The initial Shan Gaing vertical slot fish pass was costed at about $US500k, so we are looking for funders to assist with covering the higher-than-anticipated cost.
- In the meantime, we have designed and built four fish passes (and are currently exploring options for a flume), to scale out the uptake of fish passage technologies in Myanmar.
- The Australian Water Partnership (AWP) is currently interested in supporting the fish pass.
- We are aiming to build the fish pass during the 2021–22 dry season if funding can be secured.
- Monitoring/uptake will spill over into our recently initiated ACIAR governance project, FIS/2018/153.

Before the project started, Myanmar authorities (specifically DoF and IWUMD) had no knowledge of or experience in fish passage technology, and the two departments had not previously worked together. Although there is no requirement for IWUMD to consider fisheries within irrigation projects, the project has enabled a partnership to form between DoF and IWUMD to work together on integrating fisheries and fish passage within their irrigated landscapes in the Bago food bowl district. The approach has seen the Bago region mapped for barriers, staff trained in fish passage technology, a full design and costings for the Shan Gaing Sluice, and a replica demonstration fish pass built to be used in both DoF and IWUMD training centres. The approach now acts as a model for working at a regional scale and these partnerships will continue within the FIS/2018/153 project.

The approach and partnerships have also been incorporated into another AWP project looking at developing a regional fish passage strategy. This partnership approach has also led to one of the team members from IWUMD being awarded an Australia Award to come and study fish passage science, and two other colleagues from DoF and IWUMD to come to Australia and complete the Graduate Certificate in Fish Conservation and Management at CSU.

Vietnam

Barrier mapping was undertaken during February–March 2018.

A new fish pass (Ea Tul Fishway) was designed during 2018–19 with fisheries and irrigation departments, and this fish pass is currently being constructed.

Thailand

Barrier mapping was undertaken during February–March 2018.

A new fish pass (Wang Chan fishway) was constructed in 2020 (funded by the Thai government).

Cambodia

Barrier mapping was undertaken in the Pursat catchment during February–March 2018.

Two fish passes have since been completed in the catchment as part of an extension funded by USAID, under the guidance of our team members, and the Cambodian Inland Fisheries Research and Development Institute (IFReDI) and Cambodian Ministry of Water Resources and Meteorology (MOWRAM).

One of the fish passes, the Kbal Hong fishway, is a cone fishway on the Stung Pursat (Pursat River) — a southern tributary of the Tonle Sap Lake in Cambodia. The cone fishway has now been operational for two years and is passing many fish, which has greatly excited provincial officials. The local Cambodian fisheries and irrigation teams have been sampling the fishway regularly, with sampling over 43 days in the 2019 wet season resulting in over 505,000 fish from 115 different species being captured in the fishway. Sampling catch rates were highest in October corresponding with the highest river flows. Up to 20 kg of fish were sampled in the fishway over a 2-hour period at this time. This data will provide great insight into the migration patterns of fish in the tributary rivers of the Tonle Sap, which is one of the world's most productive freshwater fisheries.

Figure 32. Construction of the Kbal Hong fishway on the left bank was undertaken by local contractors in the dry season and was complete just before first flows of the wet season (source: Tim Marsden).

Figure 33. The Kbal Hong Fishway in operation on low flows. These flows typically had the smallest catches (source: Tim Marsden).

Figure 34. IFReDI staff were on hand to sort, measure and record all fish collected during fishway sampling (source: Tim Marsden).

8.4.7 Overall scale out of fish passes throughout South East Asia, resulting from the ACIAR fish passage program

To date, 28 fish passes have been planned and/or constructed throughout South East Asia, with input from the ACIAR fish passage program (i.e. FIS/2006/183 and FIS/2009/041, and FIS/2014/041) (Table 2) (see Appendix IV for more detailed descriptions of these fish passes).

- Most of the fish passes are in Lao PDR (19) and Cambodia (5).
- They consist of a wide variety of fish pass types, including rock ramp, cone, vertical slot and trapezoidal designs; in addition to culvert baffles and regulator gate modifications.
- They also vary greatly in terms of construction cost, with the cheapest being a $US1200 villager-built rock ramp fishway near Ban Simano in Lao PDR, and the most expensive being a $US350,000 vertical slot fishway near in Chheukrom in Cambodia (Table 2; Appendix IV).
- Ten of the fish passes were funded by the World Bank, eight by the Asian Development Bank, five by USAID, and two by ACIAR (Table 2; Appendix IV).

Table 2. Fish passes that have been planned and/or constructed throughout South East Asia thus far, with input from the full ACIAR fish passage team.

Country	Location	Site name	Design type	Construction cost	Funded by
Myanmar	Abyar-Shangaing tributary	Shan Gaing Sluice	Dual vertical-slot	Est. US$500,000	Seeking funding
Lao PDR	Houy Lo	Houy Lo (2015)	Flap gate crane and bank stabilisation	US$77,987	World Bank
	Houy Boun	Houy Boun (2015)	Upstream apron modifcation and bank stabilisation	US$62,041	World Bank
	Houy Phine	Houy Phine (2015)	Flap gate crane, apron modification, culvert baffles and bank stabilisation	US$53,370	World Bank
	Houy Kae	Houy Kae (2015)	Flap gate crane, apron modification, culvert baffles and bank stabilisation	US$54,656	World Bank
	Houy Papak	Houy Papak (2015)	Apron modification, culvert baffles and bank stabilisation	US$95,789	World Bank
	Houy Sadu	Houy Sadu (2016)	Flap gate crane, apron modification, culvert baffles and bank stabilisation	US$63,496	World Bank
	Houy Khe	Houy Khe (2015)	Flap gate crane, apron modification, culvert baffles and bank stabilisation	US$59,813	World Bank
	Houy Bangkak	Houy Bangkak (2016)	Apron modification, culvert baffles and bank stabilisation	US$86,012	World Bank
	Houy Souy	Houy Souy (2016)	Two cone fishway - one either side of weir	US$51,625	World Bank

Table 2 continued. Fish passes that have been planned and/or constructed throughout South East Asia thus far, with input from the full ACIAR fish passage team.

Country	Location	Site name	Design type	Construction cost	Funded by
Lao PDR	Houy Sokbo	Houy Sokbo (2015)	Modified slide gates and apron	US$85,420	World Bank
	Houy Nongpung (Peung)	Pak peung regulator (2016)	Overshot layflat gates	$90,000	ACIAR
	Houy Nongpung (Peung)	Pak peung fishway (2013)	Cone bypass fishway	$128,000	ACIAR
	Nam Met	Nam Met Weir and Fishway (2019)	Modified trapezoidal	$2,311	ADB
	Nam Beng	Nam Beng (2019)	Modified trapezoidal	$2,420	ADB
	Houy Van Varth	Houy Van Varth (2020)	Villager built rock-ramp with gate crane	US$2,800	ADB
	Houy Poun	Houy Poun (2020)	Villager built rock-ramp with gate crane	US$1,400	ADB
	Houy Xang Nam	Houy Xang Nam (2020)	Villager built rock-ramp with gate crane	US$1,200	ADB
	Nam Tong	Nam Tong	Rock ramp bypass	Planned – tendering in 2021. Est. at US$18,000	ADB
	Houy Mak Hiew	Houy Mak Hiew	Vertical slot	Awaiting project approval. Est. $432,000	ADB/ Netherlands
Thailand	Nam Chang	Wang Chang (2019)	Cone	US$70,000	USAID
	Nam Khom	Sang Khom (2012)	Rock ramp	US$500	Province
Cambodia	Mekong River south of Sambor village	Sambour Dam (prop)	Vertical slot (proposed)	US$80,000	USAID
	Stueng Ojik	Srey Snom (prop)	Cone and rock ramp (proposed)	US$50,000	USAID
	Stung Pursat	Kbal Hong fishway (2018)	Cone	US$78,000	USAID
	Stung Chinit	Makara Dam (2000)	Vertical slot	US$300,000	ADB
	Damnak Chheukrom Irrigation Scheme	Chheukrom (2021)	Vertical slot	US$350,000	ADB
Vietnam	Da Rang River	Ea Tul (under construction)	Vertical slot	US$78,000	USAID

9 Conclusions and recommendations

9.1 Conclusions

FIS/2014/041 has directly enhanced and fostered fish passage restoration efforts in the Lower Mekong Basin, and the benefits to fishery production are anticipated to begin translating to food security and livelihood improvements throughout the region over the coming years.

This project advances a program of work that originally began as a proof-of-concept study (FIS/2006/183), before progressing to a research and implementation phase (FIS/2009/041) and eventually to a monitoring/evaluation phase to validate impact.

FIS/2014/041 has built upon the work done during these preceding ACIAR projects by monitoring and evaluating the socio-economic and ecological impacts of the Pak Peung fish pass, and using the knowledge to inform the design and operation of other fish pass throughout Lao PDR and the broader South East Asian region.

Since the completion of the first Mekong fish pass at Pak Peung, the list of planned (or already constructed) fish pass has been scaled out to include 19 in Lao PDR, five in Cambodia, and one in Myanmar, two in Thailand, and one in Vietnam.

The project has led to widespread knowledge uptake by high level government officials at numerous strategic workshops and other meetings; and millions of dollars of investment in fish passage research and implementation by agencies such as the Asian Development Bank, USAID, World Bank, and Australian Water Partnership.

The broader program of work has also led to numerous other outputs, including 49 international conference papers, 21 international journal papers, 24 technical reports, an Honours thesis, and three pending PhD theses (see Appendix I).

Further highlights have included the project team co-hosting the 2016 Lower Mekong Fish Passage and Fish Passage 2018 conferences; co-hosting four international barrier prioritisation and fish passage masterclasses to train fisheries and irrigation officials from Myanmar, Lao PDR, Thailand, Cambodia and Vietnam; and winning the internationally acclaimed Distinguished Project Award at the Fish Passage 2018 conference.

9.2 Recommendations

Implementation of the project has indicated the importance of meaningfully incorporating local communities into activities.

It cannot be stated strongly enough that the involvement of locals (including village chiefs, PAFO and DAFO staff) was one of the critical factors in project success. Co-designing the concept with local staff, and societal leaders was essential for buy-in. This approach built a sense of ownership and pride but also ensured that the locals respected community co-management frameworks when they were implemented.

Communication strategies are important but need to be flexible

We had envisaged a strong communication plan and then a strategic implementation. But in reality, much of the communications needed to be adapted as the project progressed. Even after commencement, our stakeholder analysis became out-dated as other countries (i.e. Japan, Korea and the European Union) increased their investment into the Mekong region. So, a recommendation is that projects be agile, and flexible enough, to incorporate new partners and ways of working as the political situation evolves.

Volunteers bring additional effort and expertise, which can be focused for both their development and project activities.

Having staff in-country is a key factor in project success. This was a key learning and a strong recommendation for future projects. This does not, however, need to be paid (salaried) project staff. We were able to successfully integrate AVID volunteers into our workplans and these people, integrated into partner agencies, and were invaluable team members who provided high quality support to the project team. We have, so far, included six different AVID volunteers in our project teams and this has provided an on-ground link between Australian and international teams.

Australian scientists based in-country ensure project momentum and rapid clarification and resolution of problems.

The countries where we have experienced the most rapid and successful scale-out are where we have had Australian staff based in country for significant time periods. Laos is an exemplary situation where having (presently) two staff in country has provided much needed support to local teams, allowed knowledge to be imparted rapidly and accurately and allowed us to push through critical problems and situations with ease. This situation became most critical during the COVID-19 pandemic outbreak. Our workplan in Laos continued, largely uninterrupted, despite Australian-based staff being unable to travel. Our in-country staff remain critical for maintaining project operations during this period.

The critical value of programs of work should be recognised

It is recommended that programs of work (a series of projects) are recognized as essential to fully realise the outcomes and impacts of ecological research and development. Indeed, Figure 35 presents summarised timelines of the key outcomes resulting from the current ACIAR fish passage program of work (FIS/2006/183, FIS/2009/041 and FIS/2014/041) in Myanmar, Indonesia, Lao PDR, Thailand, Cambodia, and Vietnam. The timelines clearly demonstrate the importance of committing to long-term projects for effectively scaling out impacts throughout South East Asia.

Working with the right line agencies is important

A critical strategic miscalculation, early in the project, was that we partnered with fisheries and natural resource management agencies. It was an obvious ‘fit’ because clearly a fisheries project, which aimed to solve problems impacting the resource base, should be based here. However, most of the river development programs were being implemented by other line agencies (i.e., irrigation and engineering) who were largely unaware that their activities were impacting the resource base. So, in essence, we were communicating with fisheries line agencies who understood the problem well, but were relatively disengaged with decision making processes to influence the solution. It was only when we partnered with irrigation and energy agencies, and communicated the solutions, that traction commenced and scale out started occurring. We recommend that future projects include a thorough stakeholder analysis as part of project development processes. Having support of the right agencies from the outset could accelerate development outcomes emanating from the research.

Recognise that change can take time

Our program of work commenced in 2008 but it was not until our demonstration project was completed in 2012 that broad interest was generated. In fact, it was at the regional conference in 2016, where outcomes were discussed and disseminated, that momentum accelerated (Figure 35). Taking a long term approach, building and sustaining partnerships and being prepared to learn from setbacks were critical steps in the process. With the long term aspect considered, and the right partners now on board, the next decade looms as an incredibly productive decade for integrating fisheries solutions into river development programs.

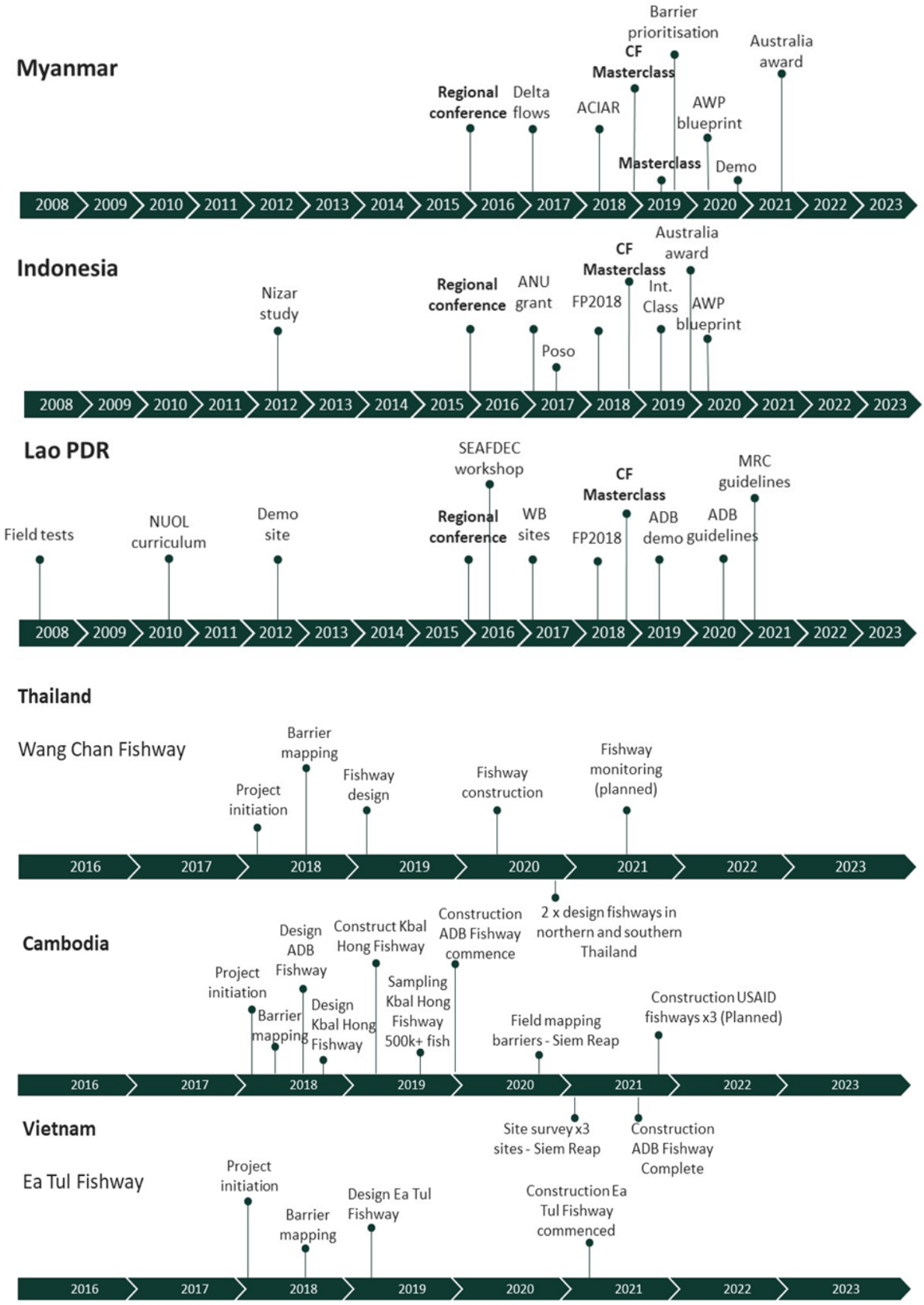


Figure 35. Timelines of key outcomes resulting from the ACIAR fish passage program (i.e. FIS/2006/183), FIS/2009/041 and FIS/2014/041).

Pathways to adoption of fish pass technology in Asian countries should be identified

A major learning from FIS/2014/041 (and its predecessor projects) was that research, policy, governance and institutional capacity all play key roles in wide-scale application, and will act as an implementation block within countries if they are not adequately considered and incorporated.

Therefore, to facilitate broad scale outcomes, we propose a three pillared approach that ensures existing research (Pillar 1) is used to drive institutional and future capacity (Pillar 2) which lead to fish passage being adopted in governance frameworks and policy agendas led by donors and government agencies (Pillar 3).

ACIAR FIS/2018/153 has just been started to address these needs, following on from the learnings arising during ACIAR FIS/2014/041.

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11 List of publications produced by project

Please see Appendix I for this list.

12 Appendices

12.1 Appendix I: Publications from this ACIAR program

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****Please see the FIS/2014/041 publications Excel sheet for the full list of all outputs from this project.**

12.2 Appendix II: Key results from the 13 FIS/2014/041 studies

For Objective 1, we successfully applied the barrier identification and prioritisation process originally used in Lao (in FIS/2009/041), in the Bago region of Myanmar. This enabled us to identify a suitable site for the first Myanmar demonstration fish pass (objective's 2 and 4).

For Objective 2 (and Objective 1 combined), our multiples lines of evidence approach revealed that household capture fishery biomass was generally greater in the late wet season than in the early wet season at the Lao PDR test fish pass site (Pak Peung), but the opposite trend was observed at its comparison no-fish pass site (Kadan).

Unfortunately, in central Lao PDR, we were unable to detect any evidence of concordance between the wetland results and those of the fish pass, below regulator, and household capture fishery results (objective's 1 and 2).

Objective 2 also resulted in the successful world-first testing and development of PIT tagging methods for Mekong species. These methods are now already being applied in other Mekong studies (e.g. ACIAR FIS/2017/017).

For Objective 3, we developed a benefit-cost analysis decision support tool (DST) to evaluate the benefits and costs of building fish pass technologies. We then applied this DST to model the ROI on the Pak Peung fish pass as a test case. The perceptions of villagers towards fish passes were also assessed — both in central and southern Lao PDR.

For Objective 4, the uptake of fish pass technologies was scaled out to Myanmar, Thailand, Cambodia, and Vietnam. Our team also hosted two major international conferences (The Lower Mekong Fish Passage Conference in 2016, and Fish Passage 2018), which united hundreds of delegates from over tens of countries. This is described in more detail in Section 8.

Table A2.1. Key results for each of the four objectives and their associated studies. O1 = Objective 1, O2 = Objective 2.

Objective	Outcome	Location	Study	Key results
Objective's 1 and 2: Barriers, wetland colonisation and household capture fishery production	Extent of barriers	Myanmar	1: Barriers (O1)	We identified 876 potential barriers in the Bago catchment, and then systematically assessed these barriers using GIS analysis, field validation, fishery and socio-economic filters to produce a prioritised list of 23 barriers for cost-effectively achieving optimal fishery and community benefits.
	Wetland/fish pass/below regulator fish, household capture fishery production and fish pass operations	Northern Lao PDR	2: Fish pass (O1)	On the back of FIS/2014/041, the ADB have agreed to fund a $US500K fish ladder at That Luang Marsh north of Vientiane. They have also released a new fish passage strategy for Lao PDR (2020), which includes our DST.
		Central Lao PDR	3: Wetland (O1)	High levels of variability in total and Black/White/Grey species abundance, biomass, and richness. Also, high levels of uniqueness at the region and wetland scales. Power analysis suggested that we would have needed more than 80 sites per wetland per sampling round to detect a difference in species richness as a significant change.
			4: Fish pass (O1)	The Pak Peung fishway passed between 0.8 Kg/day (in 2017) and 7.3 Kg/day (in 2019) on average, although fish passage rates of up to 76 Kg/day were observed in 2019. But no evidence of concordance with the other elements.
			5: Below regulator (O1)	For Bolikhamxay, most of the species approaching the wetlands from the Mekong in the early wet season were white species (long-range migrators), but more than two-thirds of the catch and up to half the biomass comprised of grey species (mid-range migrators).
			6: Household capture fishery (O2)	Total household capture fishery biomass was generally greater in the late wet season than in the early wet season at the test fish pass site (Pak Peung), whereas the opposite seasonal trend occurred at its comparison no-fish pass site (Kadan).
		Southern Lao PDR	7: Migrating fish (O1)/Household capture fishery (O2)	Our World Bank-partnered extension study on Fish Friendly Regulator Structures (FFRS's) in southern Lao PDR recorded 100 species of fish in the FFRS's. Subjective interpretation of wetland species catch by households suggests that FFRS's pass migratory fish into upstream wetlands if their associated culvert gates and flaps are operated in a fish migration-friendly. manner.

Table A2.1 continued. Key results for each of the four objectives and their associated studies. O1 = Objective 1, O2 = Objective 2.

Objective	Outcome	Location	Study	Key results
Objective's 1 and 2 continued: Barriers, wetland colonisation and household capture fishery production	Wetland/fish pass/below regulator fish, household capture fishery production and fish pass operations	Myanmar	8: River fish and fish pass (O1)	The pre-fish pass surveys indicated that site downstream of Shan Gaing had a markedly greater overall species richness (21 vs. 5), abundance (623 vs. 100) and biomass (1394 g vs. 271 g) of fish than the site upstream of Shan Gaing.
	Tagging methods	Lower Mekong Basin	9: Tagging methods (O1)	Our results showed that PIT tagging could serve as a valuable technique for assessing the movement ecology of Striped catfish and Goldfin tinfoil barbs — in the Mekong River. Specifically, the results indicated that PIT tags can be retained within both species, without impacting their growth or mortality, and regardless of whether the tag is positioned in the chest, gut or shoulder.
Objective 3: Socio-economic impacts	Fish pass BCA	Central Lao PDR	10: Benefit-cost analysis	We successfully developed and tested a decision support tool (DST) for assessing the socio-economic benefits and costs of building fish passage technologies. At Pak Peung, under the assumptions that only half of the wetland was affected and the fish pass was capable of passing 75% of the stock attracted, the DST indicated that the fishway would lead to positive net benefits totalling ~US$83 000 and a pay-off period of 11 years.
Objective 3: Socio-economic impacts	Perceptions study	Central Lao PDR	11: Perceptions	Locals are concerned about less fish being available, increased fishing pressure and recent increases in the use of illegal fishing methods. The community are generally aware of the fish pass and its intended effects (increased numbers of juveniles of migratory fish species), yet responses to earlier questions show these effects have not yet occurred. This is consistent with the lack of operating time of the fishway to date.
		Southern Lao PDR	12: Perceptions	The same as for central Lao PDR
Objective 4: Knowledge uptake	Extensions/conferences	Multiple countries	13: Knowledge uptake	We have hosted four international fish passage masterclasses to date; and the list of planned (or already constructed) fishways has been scaled out to (so far) include 19 in Lao PDR; five in Cambodia; one in Myanmar; two Thailand; and one in Vietnam. We also hosted two international conferences (the Lower Mekong Fish Passage Conference in 2016, Fish Passage 2018), which each attracted practitioners from 14+ countries.

12.3 Appendix III: Central Lao PDR perceptions study quotes

Some typical examples of responses from villagers (note, the word extinct can mean disappear or can mean electrofishing).

QN: If so, what are those changes to HP fishery from the fish pass?

“Fish Increase and more fish are laying eggs and juvenile Pa Khao and Pa Ern.”

“Increase small fish but that one juvenile large species.”

“Increase fish species but only small fish, and Juvenile big species e.g.: Pa Phia, Pa Khern, Pa Khao, Pa Ern deng.”

“Increase fish small size but big species e.g.: Pa Pak, Pa Phia,”

“A lot of fish moved to spawn every year. But this year not many fish moved to spawn because Water levels very low”

QN: Do U feel PP fish pass responsible for changes to your lifestyle?

“It used to take a long time to sow nets and shrubs, now it takes only one or two times to eat.”

“Rule from the government Do not use [extinct] fishing gear, No fishing at fish pass”

“Can caught fish never catch before e.g.: Pa Kherng, Pa Pak Namkhong, Pa Pak Na, Pa Phia, Pa Vienfai.”

“Go fishing enough to eat and sell. If you get a lot, share it with your relatives”

“If more water levels can caught more fish. If water levels low cannot caught more fish”

Discussion/Surveyors notes

“The fish pass should be kept in good condition forever. If there is no fish pass, the fish can't go up to lay eggs, especially small fish. Fish species caught: Pa Ern, Pa Khoun, Pa Khao, Pa Phia, Pa Sakang, Pa Vienfai, Pa Pak, Pa Nai.”

“After the fish pass was built, the number of fish increased significantly, Except if it does not rain seasonally. Like last year, very dry water caused the fish to become almost [extinct], Fish caught Such as Pa Ern, Pa Ngone, Pa Khoun, Pa Khao, Pa Phia, Pa Khop”

“10 years ago can caught big fish more than small fish. But now different.”

“Need to Release Breeder fish into reservoir for restore fish in stream”

“There should be a fish release To increase the breeder. There should be a reserve fund for patrols for [extinct] fisheries, such as haul net, backpack electro fishing.”

“If possible, have a fund To inspect [extinct] fishermen. Want to release fish in the Peung wetland.

“Want to DAFO have a check fishing gear”

“I would like to have a conservation area to preserve the breeding fish”

“Without fish pass, fish could become [extinct]”

“Want to be clean. Preserve the conservation zone so that in the future there will be aquatic animals for the children to eat”

“Need fish pass project continues support fund for management”

12.4 Appendix IV: South East Asian fish passes planned or completed so far, with input from the ACIAR team

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Cambodia** 382869E, 1387425N Stung Pursat	Kbal Hong fishway (2018)	Cone	US$78,000[T]	USAID	115[T,O]	13–560[T,O]	240[T,O]	50[T]	12,860[T]
	**Cambodia** 516073E, 1381695N Stung Chinit	Makara Dam fishway (2005)	Vertical slot	US$300,000[T]	ADB[T]	55[Sok,O]	77–315[Sok,O]	2.42[Sok,O]	70[T]	13,203[T]
	**Cambodia** 359613E, 1363665N Damnak Chheukrom Irrigation Scheme	Chheukrom (2021)	Vertical slot	US$350,000[T]	ADB	120[T,O]	13–560[T,O(F6)]	240[T,O(F6)]	50[T]	1,406[T]

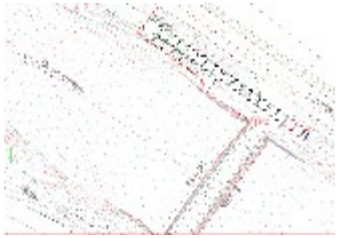
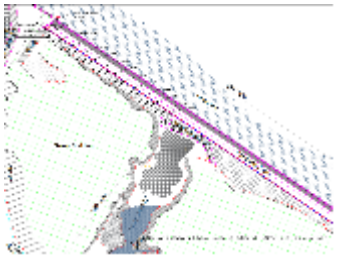
Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Cambodia** 327558E, 1492337N Sambor village	Sambour Weir (proposed)	Vertical slot (proposed)	US$80,000[T]	USAID	45[T,O]	13–560[T,O(F6)]	240[T,O(F6)]	500[T]	8,165[T]
	**Cambodia** 348422E, 1540560N Stueng Ojik	Srey Snom (proposed)	Cone and rock ramp (proposed)	US$50,000[T]	USAID	104[T,O]	13–560[T,O(F6)]	240[T,O(F6)]	100[T]	1,487[T]
	**Lao PDR** 478979E,1882392N Houy Lo	Houy Lo (2015)	Flap gate crane, slide gate refurbishment and bank stabilisation	US$77,987[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	6[LD]	1,527[LD]

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Lao PDR** 480781E, 1883826N Houy Boun	Houy Boun (2015)	Upstream apron modification, slide gate refurbishment and bank stabilisation	US$62,041[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	3[LD]	231[LD]
	**Lao PDR** 481719E, 1880154N Houy Phine	Houy Phine (2015)	Flap gate crane, slide gate refurbishment, apron modification, culvert baffles and bank stabilisation	US$53,370[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	4[LD]	504[LD]
	**Lao PDR** 483047E, 1885372N Houy Kae	Houy Kae (2015)	Flap gate crane, slide gate refurbishment, apron modification, culvert baffles and bank stabilisation	US$54,656[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	3[LD]	344[LD]

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Lao PDR** 482777E, 1878937N Houy Papak	Houy Papak (2015)	Flap gate crane, slide gate refurbishment, apron modification, culvert baffles and bank stabilisation	US$95,789[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	7[LD]	691[LD]
	**Lao PDR** 479171E, 1868931N Houy Sadu	Houy Sadu (2016)	Slide gate refurbishment, apron modification, culvert baffles and bank stabilisation	US$63,496[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	2[LD]	364[LD]
	**Lao PDR** 482633E, 1885695N Houy Khe	Houy Khe (2015)	Flap gate crane, slide gate refurbishment, apron modification, culvert baffles and bank stabilisation	US$59,813[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	2[LD]	212[LD]

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Lao PDR** 474553E, 1871629N Houy Bangkak	Houy Bangkak (2016)	Apron modification, culvert baffles and bank stabilisation	US$86,012[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	3[LD]	321[LD]
	**Lao PDR** 520675E, 1826346N Xe Champhone	Houy Souy (2016)	Two cone fishways - one either side of weir	US$51,625[G]	World Bank	42[W,O]	18–235[W,O]	4.56[W,O(F6)]	17[LD]	3,184[LD]
	**Lao PDR** 480958E, 1888577N Houy Sokbo	Houy Sokbo (2015)	Flap gate crane, slide gate refurbishment, apron modification, culvert baffles and bank stabilisation	US$85,420[G]	World Bank	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	6[LD]	1,767[LD]

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Lao PDR** 362253E, 2029253N Houy Nongunh (Peung)	Pak Peung regulator (2016)	Overshot layflat gates for downstream fish passage	$90,000[G]	ACIAR	114[B,O]	5–225[B.O]	40.65[B,W,O]	6[W]	1,008[W]
	**Lao PDR** 362253E, 2029253N Houy Nongung (Peung)	Pak Peung fishway (2013)	Cone bypass fishway	$128,000[G]	ACIAR	108[W,O]	12–805[W,O]	48.5[W,O]	6[W]	1,008[W]
	**Lao PDR** 791779E, 2259521N Nam Met	Nam Met Weir and Fishway (2019)	Modified trapezoidal	US$2,311[G]	ADB	23[Th,O]	29–314[Th,O]	10.3[Th,O]	1[G]	194[G]

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Lao PDR** 791843E, 2262569N Nam Beng	Nam Beng (2019)	Modified trapezoidal	US$2,420[G]	ADB	23[Th,O(F6)]	29–314[Th,O(F6)]	10.3[Th,O(F6)]	1[G]	194[G]
	**Lao PDR** 272408E, 1988611N Houy Van Varth	Houy Van Varth (2020)	Villager built rock-ramp with gate crane	US$2,800[LG]	ADB	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	1[G]	250[G]
	**Lao PDR** 273139E, 1988904N Houy Poun	Houy Poun (2020)	Villager built rock-ramp with gate crane	US$1,400[LG]	ADB	108[W,O(F6)]	25–313[W,O(F6)]	5.3[W,O(F6)]	1[G]	250[G]

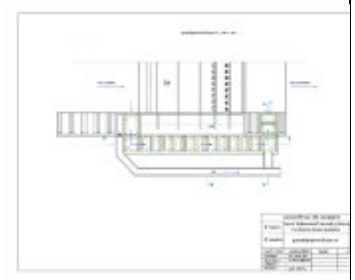
Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Lao PDR** 273701E, 1989080N Houy Xang Nam	Houy Xang Nam (2020)	Villager built rock-ramp with gate crane	US$1,200[LG]	ADB	108[W(F6)]	25–313[W(F6)]	5.3[W(F6)]	1[G]	250[G]
	**Lao PDR** 322473E, 2169082N Nam Tong	Nam Tong (2020)	Rock-ramp bypass	Tendering in 2021[G(F7)]	ADB	Not assessed yet	29–314[Th,O(F6)]	10.3[G]	3[G]	230[G]
	**Lao PDR** 278514E, 1991463N Houy Mak Hiew	Houy Mak Hiew	Vertical slot	Awaiting project approval[G(F8)]	ADB/ Netherlands	104[Ma]	Up to 800[Ma]	Unknown but expected to be high[Ma]	17[G]	7,000[G]

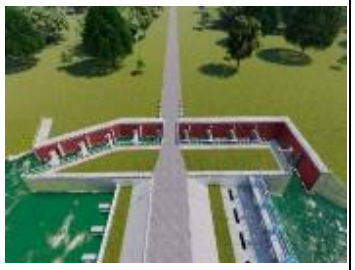
Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Myanmar** 270902E, 1927206N Abyar-Shangaing tributary	Shan Gaing Sluice	Dual vertical-slot	Estimated US$500,000[J]	Seeking funding	44[Co]	Expected 20–1,200[Co]	Unknown but expected to be high[Co]	6[Re]	51,136[Re]
	**Thailand** 297655E, 1970226N Nam Chang	Wang Chang (2019)	Cone	US$70,000[T]	USAID	108[W,O(F6)]	12–805[W,O(F6)]	48.5[W,O(F6)]	20[T]	-
	**Thailand** 293791E, 1972106N Nam Khom	Sang Khom (2012)	Rock ramp	US$500[T]	Province	110[W,O(F6)]	12–330[W,O(F6)]	4.56[W,O(F6)]	5[T]	-

Photo	Country	Site name	Design type	Construction cost	Funded by	Biological benefits			Social benefits	
						No. species[F1]	Fish length range (mm)[F2]	Migrating biomass (kg/day)[F3]	Upstream villages[F4]	Upstream households[F5]
	**Vietnam** 814340E, 1420252N Song Da Rang	Ea Tul (under construction)	Vertical slot	US$78,000[T]	USAID	55[T]	Expected < 300[T]	10.3[Th(F6)]	10[T]	-

TOTAL	**4**	**28**	**13**	**US$2,000,000** **AUD$3m (approx.)**	**6**	**-**	**-**	**-**	**904**	**82,666**

Appendix IV Footnotes

1. The estimated maximum number of species that are predicted to navigate the fish pass.
2. The estimated size range of fish that are predicted to navigate the fish pass.
3. The estimated maximum biomass of fish that are predicted to navigate the fish pass.
4. Approximate number of upstream villages potentially benefitting
5. Approximate number of upstream households potentially benefiting
6. Some estimates for species number, size range and biomass derived from adjacent similar sites where applicable.
7. Estimated cost US$18,000 (includes cost of fishway and new weir).
8. Estimated cost US$500,000. Design completed and approved; funding available, awaiting project construction tender in September 2021.

*Note: All biological data are relevant to the wet season

Funding agencies

Funding by	Full name	Country of Head Office
ADB	Asian Development Bank	Philippines
ACIAR	Australian Centre for International Agricultural Research	Australia
World Bank	World Bank	United States of America
USAID	US. Agency for International Development	United States of America
Netherlands	Netherlands Trust Fund under the Water Financing Partnership Facility	Netherlands

Sources of data

1. J = John Conallin unpub. data
2. T = Tim Marsden unpub. data
3. W = Wayne Robinson unpub. data
4. B = Boys, C., Pflugrath, B. D., Singhanouvong, D., Phonekhampeng, O., Thorncraft, G., Phommavong, T., Vorsane, P., Homsombath, K., Baumgartner, L., and Fowler, T. (2020). Improving the design of irrigation infrastructure to increase fisheries production in floodplain wetlands of the Lower Mekong and Murray Darling Basins (P. 44). FIS/2012/100.
5. Co = Conallin, J., Baumgartner, L., Marsden, T., and Mallen-Cooper, M. (2020). Shan Gaing Sluice Fishway: Proposed design criteria and concept. Charles Sturt University, Albury: Australia; 46pp.
6. Ma = Thorncraft, G., Baumgartner, L., Mallen-Cooper, M., Thew, P., Conallin, J., Phonekhampheng, O., Phommavong, T., Robinson, W., and Vorsane, P. (2020). Houay Maki Hiew Fishway: Concept design report. Charles Sturt University and National University of Laos. 38pp.
7. LD = Lao PDR DoI, Khammouane Province
8. LG = Department of Irrigation GMS Flood and Drought Risk Management and Mitigation Project - Supply of Fish-Friendly Structure (013/RFQWNPCO/2019).
9. Th = Thorncraft G, Baumgartner LJ, Vorsane P, Robinson WR, Ning N. (2019). Fishway options and performance. National University of Laos and Charles Sturt University. 29 pp.
10. Sok = Seyha, S. (2007). Migration and productivity of wild fish in Stung Chinit Reservoir, Kampong Thom Province. Masters, Royal University of Agriculture, Phnom Penh, Cambodia.
11. Re = Republic of the Union of Myanmar – The Population and Housing Census of Myanmar, 2014
12. O = unpublished data based on actual observations (rather than predictions).