How to set **priorities** for **restoring fish migration** across existing **barriers**

The MRC develops a set of guidelines to identify high-priority barriers in the Lower Mekong Basin that are most suitable for rehabilitation works to create fish-friendly irrigation structures

The Lower Mekong Basin has tens of thousands of irrigation and flood-control structures, especially in northeast Thailand. These structures, ranging from dams and weirs to regulators, floodgates and road crossings, may be too high for fish to pass, blocking their access to spawning areas, new habitats such as refuges and food resources. Such barriers can therefore have a significant impact on fish migration, affecting the successful completion of life cycles and leading to over-harvesting of fish that accumulate below the structures. Given that most Mekong fish species migrate up and down the river throughout the year and onto the floodplain during the wet season, the cumulative impact of these structures is large and has long-term implications for fisheries productivity.

Fishways can restore fish migration with rehabilitation works that allow fish to pass

Process suitable for catchments throughout the Lower Mekong Basin

The process used in the guidelines has succeeded in trials in two smaller catchments in the Lower Mekong, the Xe Champhone catchment in southern Lao PDR (see page 26) and the Nam Ngum catchment near Vientiane. The trials showed that it is suitable for catchments throughout the basin. The design and construction process has been used successfully in rehabilitating fish passage in Australia and more recently at the the Pak Peung regulator in central Lao PDR (see *Catch and Culture*, Vol 21, No 2, and box on opposite page). The prioritisation process ensures that limited information and resources are efficiently used to identify barriers with the greatest impact on fish migration. Priorities are based on a scoring and ranking technique used in Europe, the United States and Australia but also include broad concepts derived from optimisation techniques used in highly developed countries. In this way, the process keeps the simplicity of scoring and ranking but uses the re-evaluation power of the optimisation system.

Prioritisation takes into account limited information for catchments. GIS data to assess the priority of a barrier often uses proxy information about biology that is not directly available. For example, information about fish communities in every stream is difficult to collect. But many studies have shown that highly degraded habitats have reduced fish communities. Such degradation is related to the intensity of land use in the catchment, which can be easily identified by land use types in GIS. Intensity of land use can therefore be used as a substitute for the condition of fish communities, with conditions in pristine undisturbed catchments highly likely to be better than those in intensively developed catchments. In this way, mapping characteristics assessed by GIS can stand in for characteristics that are difficult to collect and represent spatially.

At the same time, thousands of potential barriers can be assessed before visiting sites. An initial desktop study employs the efficiency and unique decision-making capabilities of an automated GIS system to assess wide-ranging temporal and spatial habitat characteristics associated with each potential barrier. This approach allows limited resources to be directed towards assessing the highest ranking potential barriers after the initial GIS stage, rather than a more arbitrary approach of visiting unknown and often less critical barriers based on limited local knowledge.

Australia launches new five-year project to quantify impacts of fishways in Lao PDR

Australia launched a five-year project in April to quantify the biophysical and community impacts of improved fish passage in Lao PDR. The project is among the largest fisheries projects since the Australian Centre for International Agricultural Research (ACIAR) began its first Lao fisheries project on indigenous species in 1997. It is also the fifth ACIAR project in eight years to address the use of fishways to boost Lao fish production in areas where barriers to fish migration have been built.

Mr Khamphiew Phimmathad, Director General of the Bolikhamxay Provincial Agriculture and Forestry Office, said development of Lao infrastructure, especially roads and irrigation systems, had occurred rapidly in recent years. "These benefits will greatly benefit agriculture but may impact to fish migration and lead to decreased wetland fish production," he told a workshop launching the project in Pak San District on April 1. "The construction of suitable fishways can allow fish to migrate and also support sustainable development," Mr Khamphiew said, noting that many countries had developed fishways over the years. "It is possible to have food, water and energy production but only if designed in the best possible way ... Fish passage in Laos is an emerging scientific discipline," the director general said, underlining the importance of basing fishway designs on data for Mekong species. "Lao PDR is rapidly developing water resources for many purposes. Therefore study on fish passage for utilisation in Laos is necessary, especially for including fish-passage outcomes into irrigation and development policy."

Mr John Williams, the Australian ambassador to Lao PDR, told the workshop that Australia was proud to support the work through ACIAR, "drawing on all our experiences over the past 20 years in the Murray-Darling River Basin". He noted that cost-effective fish passage technology to bring fish back to the wetlands was a vital effort in the ongoing story of Lao PDR's economic development.

The first ACIAR fishway project, from 2008 to 2009, focused on developing criteria for floodplain species in central provinces. This was followed by a second ACIAR project from 2010 to 2015 to develop fishway technology to boost fisheries production in the floodplains of the Lower Mekong and the Murray-Darling basins in Australia. During the second project, more than 8,000 barriers to fish migration were identified in just three tributary catchments of the Mekong – Xe Bang Hieng, Xe Champone and Nam Ngum. The third project, from 2012 to 2013, was a pilot study to develop design criteria for fish-friendly irrigation and mini-hydropower projects in the two river basins. The fourth, launched in 2014 and scheduled to be completed in 2018, aims to improve the design of irrigation infrastructure.

Mr Khamphiew (right) speaking at the workshop in Pak San District in Bolikhamxay Province on April 1 with Australian Ambassador John Williams (left)

PHOTO: JARROD MCPHERSON/CHARLES STURT UNIVERSITY

Although these projects showed that fishways could be effective for Mekong fish species, feedback was that the scope of the work should be expanded to show and quantify their impact. ACIAR therefore commissioned the Institute for Land, Water and Society at Charles Sturt University to carry out the new project from 2016 to 2020, which aims to make it easier to adopt fishway technology to rehabilitate declining fisheries.

The new project aims to evaluate the colonisation of species in seasonal wetlands and quantify whether there has been annual increases in fish production at sites where fishways have been built. It also aims to quantify, in social and economic terms, options for building fishways at barriers on rivers and promote the uptake of project outputs. "We're keen for other donors to add to the outcomes by building more fishways," said Dr Chris Barlow, the ACIAR Fisheries Program Manager. The former manager of the Mekong River Commission Fisheries Program said ACIAR also hoped outcomes could be taken to "other countries" in the region. Dr Barlow explained that the new project was part of ACIAR's "strategic research" in which benefits might take more than five years to be realised – unlike its "applied research" which focuses on improving livelihoods and income security in less than five years.

Rehabilitating fish-passage barriers

Prioritisation

1. Identification Use available information and satellite imagery on all potential fish-migration barriers including fixed-crest weirs, gated weirs, dams, regulators, flood gates and bridges

2. Remote assessment Conduct GIS analysis of five attributes of potential barriers

3. Field appraisal Record physical attributes of high-priority potential barriers

4. Biological assessment Conduct GIS analysis of five properties of the barrier and site

5. Socio-economic assessment Consider four factors

Rehabilitation

6. Selection

7. Design

8. Construction

9. Operation and maintenance

10. Evaluation

Attributes (range of possible scores)

(i) Stream type (0-10)

(ii) Intensity of land use (1-5)

(iii) Upstream habitat (1-5)

(iv) Number of barriers downstream (1-7)

(v) Sub-catchment characteristics (1-7)

(vi) Can fish pass the barrier? (0-5)

(vii) Stream condition (1-5)

(viii) Stream flow and water hole performance (1-5)

(ix) Instream habitat for migratory species upstream of barrier (1-5)

(x) Importance to local community of fishing at barrier (1-5)

(xi) Estimated cost (1-5)

(xii) Technical viability (1-5)

(xiii) Effectiveness (1-5)

(xiv) Productivity benefits (1-5)

Recommendations

Rankings are not definitive. Significant barriers not necessarily of the highest priority may be preferable for fishways in areas that can be used as demonstration sites to generate community interest.

Team should include biological, engineering and irrigation experts. Collate as much existing site data as possible, conduct meeting, site visit and workshop, develop concept design and detailed design.

Refer any design changes to design team. Biologist should conduct at least one inspection before completion. Biologist and engineer should also inspect near or upon completion and when commissioned.

Plan should be developed during design phase and might include operating rules, a maintenance programme, contingency plans, a process for timely repairs and status reporting procedures.

Fishway monitoring (sampling with traps at entrance and exit of fishway), catchment fish community monitoring, local fishing community monitoring and tracking of fish movements.

through small steps along the barrier or slower water velocity that is more easily negotiated by fish. Building fishways, however, is a significant undertaking and requires a focus on high-priority sites. Determining which sites are the most important for building fishways is the focus of a new report that spells out guidelines for identifying and assessing all barriers to fish migration in the basin. Facilitated by the MRC Fisheries Programme and the MRC Agriculture and Irrigation Programme, the guidelines have been developed by Australian consultants, including Australasian Fish Passage Services, the Murray Darling Freshwater Research Centre of Latrobe University and a research fellow at the Faculty of Agriculture at the National University of Lao.

In addition to outlining steps to identify and prioritise existing barriers to fish migration, the guidelines offer advice on how to design, build and maintain fish passes and how to monitor their effectiveness. The aim is to promote informed investments in structures that have the greatest chance of improving fisheries productivity if passage is restored.

Barrier prioritisation

The prioritisation is run over a comprehensive five-stage process that identifies barriers and evaluates the fishery and ecosystem improvement, economic cost and social benefit of barrier repair (see opposite). The focus is on identifying barriers affecting the entire fish community. The authors of the guidelines note that this is different from assessment criteria biased towards particular fish families, economically important fish species or specific river reaches. Subjective prioritisations, particularly those focused on primarily high-value species, are seen as inadvertently creating environmental conditions unsuitable for some sections of the fish community, either by upsetting the balance of predator-to-prey relationships or by disadvantaging fish species that occupy specialised trophic niches fundamental to aquatic ecosystem functioning. Barrier prioritisations that only investigate particular river reaches or sub-sections of catchments are seen as having the potential to neglect or inadequately investigate downstream barriers. This is particularly pertinent as a single downstream barrier may be preventing or delaying sections of the fish community from reaching upstream habitats.

The score and rank system uses the five stages of assessment with an automated GIS process. The system takes into account the importance of various migration patterns and the likelihood of localised extinctions caused by the barrier. As a result, the process is designed to favour barriers close to the Mekong River or the South China Sea. Such barriers will affect a greater number of species by preventing fish from migrating upstream to feed or breed. A large portion of recruits to a population can be lost if adults cannot find suitable spawning habitats and juveniles are unable to find suitable nursery habitats. If fish passage is prevented year after year, fish populations can be severely diminished and over time lead to localised species extinction. The impact of barriers on the large fish communities close to the Mekong River or South China Sea is considered to be more critical than their effect on the smaller fish communities in the headwater streams. Additionally these headwater streams have much greater gradients that can create natural barriers to fish movement.

Adjustment of scores or weighting of attributes

As individual regions will have different priorities for the rehabilitation of fish passage, as well as unique conditions that may bias the results of the prioritisation process, the adjustment and/ or weighting of scores may be appropriate. The guidelines outline a scoring regime that is suitable across most of the Mekong Basin. However, individual countries or regions may need to score some attributes differently.

An example where the adjustment of scores may be appropriate can be found in the two parts of the Mekong Basin in Viet Nam. In the Central Highlands, many of the structures are very large due to the steep gorges of streams in the area. In the Mekong Delta, however, barriers are unlikely to be very large as the area is very flat. In this example, the small barriers are likely to block large migrations just as effectively as high barriers and should therefore be scored similarly. In this case, the score can be adjusted so that smaller barriers score that same as large barriers.

An example of where the weighting of attributes might be appropriate would be where a regional committee believes that the productive benefit to

Continued on page 26 ...

Design options for Mekong fish species

Recent research in Lao PDR has established several fishway designs suitable for local fish. A combination of designs is often the most suitable option. Designs that can be used to rehabilitate fish passage at new and existing structures include:

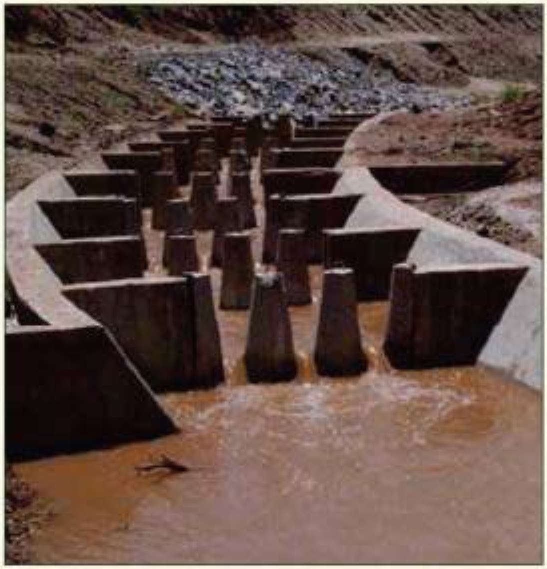
Rock ramp fishways, commonly used for low barriers up to about two metres high. They are essentially a series of rock ridges placed immediately below a barrier, creating a low slope pool and step that simulates a rocky stream bed. Larger boulders are placed in ridges across the rock ramp, creating pools of low flow and low turbulence. Each of the ridge rocks has a gap between it and the ridge rock beside it, through which the water flows, allowing fish to move from pool to pool and over the weir.

Cone fishways, designed on a similar principle to rock ramp fishways but with concrete to create the ridges. This design is particularly suitable for sites where the supply of rock is limited. The concrete cones create a series of ridges that provide small steps and pools of low turbulence and velocities through which fish can ascend. This design has recently been installed on the Pak Peung regulator near Paksan in Boxhimalay Province, Lao PDR and has been successfully assessed in the 2014 wet season. Monitoring indicates that the design is successfully passing fish.

Culvert baffle fishways, consisting of a set of vertical protrusions from the walls of a culvert that break up the water flow, slow the water down adjacent to the culvert walls and provide

Rock ramp fishway, Echuca Weir, Campaspe River, Central Victoria, Australia

PHOTO: TIM MARSDEN



Cone fishway, Pak Peung Wetland, Bolikhamxai Province, Central Lao PDR   Photo: Tim Marsden

Culvert baffle fishway, Aims Creek, Central Queensland, Australia
Photo: Tim Marsden

Vertical slot fishway, Gooseponds Creek, Central Queensland, Australia   Photo: Tim Marsden

resting areas and migration pathways for fish. The baffles are usually made of steel and fixed to the wall with suitable materials. They work on the same principal as other fishways, in that they break up the fast flow in to a series of small steps with manageable velocities for fish. They are most suitable for application at floodgates where culverts are often used in association with the gates.

Vertical slot fishways, consisting of a concrete channel extending from the top of the weir (headwater) to the base of the weir (tailwater). Within the channel, baffles are inserted at regular intervals along the length of the channel to slow the velocity of the water. Within each baffle there is a vertical slot through which water is transferred to the next pool downstream. This creates a series of pools and small steps, with low velocities that fish are able to swim through easily. This is one of the most successfully applied designs worldwide, but can have high capital costs.

Further reading

Baumgartner, L. J, Marsden, T, Singhanouvong, D, Phonekhampheng, O, Stuart, I.G. and Thorncraft, G. 2012. Using an experimental in situ fishway to provide key design criteria for lateral fish passage in tropical rivers: A case study from the Mekong River, Central Lao PDR. River Research and Applications. Volume 28, Issue 8, pages 1217–1229

How the guidelines succeeded in the Xe Champhone catchment

To identify potential barriers, data in the form of satellite imagery and aerial photography were used in GIS software. Due to poor imagery in some areas, Google Earth imagery was also used. Stream and road data were then acquired from the MRC. Data was then imported into both GIS software and Google Earth.

After remote assessment of five attributes, 798 potential in-stream barriers to fish migration were identified.Initial elimination removed 243 barriers on small intermittent streams with minimal fishery value, leaving 555 barriers to be analysed further. The highest score of 28 was achieved by the first potential barrier on the Xe Champhone upstream from the Mekong mainstream. Other highly ranked barriers were generally clustered around the lower Xe Champhone wetlands and mainstream channels higher in the system.

Field appraisal involved ground-truthing 105 top-priority barriers by a small team of fisheries biologists and students from the National University of Laos. Potential barriers were located and then accessed via vehicle or on foot. Barriers determined to have no impact on fish passage were removed. Others were assessed further on ecological, social and physical criteria.

For the biological assessment, all barriers were scored on "how well" they answered the criteria for five questions. A total of 105 potential barriers were validated in the field during this stage. Of these, 61 were identified as barriers to fish migration and 43 as non-barriers. The 61 barriers were then priority ranked in accordance with the ecological and physical criteria.

The socio-economic assessment involved analysing the top 61 barriers with several economic, social and technical criteria. Barriers were then prioritised in accordance with the scoring system, leaving a top priority list of 26 ranked barriers requiring future remediation (see table). Several barriers had equal scores.

A report detailing the top-priority structures was well received by the local government and non-governmental organisations. Several barriers are being investigated for remediation. Plans have been drawn up for the installation of a fishway on Hou Souy, ranked sixth on the list but providing a high-profile demonstration site due to its proximity to a large number of villages and its popular status as a recreation location.

The design at Hou Souy weir has been in conjunction with the World Bank, with site visits and surveys as well as a design process involving engineers, biologists and local agriculture and irrigation officials. The detailed design phase provides for a dual bank cone fishway providing fish passage over the majority of flows encountered at the site.

... from page 23

local villages should be the highest priority within the scoring system. As such, the committee may determine that a 100% weighting to the productive benefit score (thereby doubling the score) will ensure that this aspect is given the correct consideration within the scoring system. In this way the committee can ensure that projects with the most benefit to the local community will be considered the highest priority.

The adjustment of scores or the weighting of different attributes can allow the local project officers to refine the priority list to reflect the unique circumstances in their local area or of concern to local communities. However, it should be recognised that overuse of the score adjustment or attribute weighting can have a detrimental impact on where rehabilitation works are undertaken and as such should be used sparingly and with caution.

Rehabilitation

The guidelines also recommend a process for designing and building fishways, particularly important stages as any mistakes will lead to ineffective fish passage. Any design or construction errors are extremely hard to rectify at the site and can derail support for further fish passage infrastructure. It is therefore important to

Top 26 barriers for future remediation

Rank	Stream	Type	Height	Option	Est Cost
1	Xe Xangxoy	Medium weir	2.0 m	Vertical slot fishway	$200,000
1	Xe Xangxoy	Low weir	1.3 m	Vertical slot fishway	$75,000
3	Unnamed	Drop-board weir	1.8 m	Vertical slot fishway	$75,000
3	Hou Makmi	Regulator	2.0 m	Vertical slot fishway	$75,000
3	Xe Champone anabranch	Low weir	1.3 m	Vertical slot fishway	$75,000
6	Hou Souy	Medium weir	2.5 m	Concrete cone fishway	$85,000
7	Hou Kalang	Drop-board weir	1.3 m	Baffles	$5,000
8	Hou Lat	Drop-board weir	1.3 m	Baffles	$5,000
8	Hou Salongkhiang	Drop-board weir	2.5 m	Vertical slot fishway	$150,000
8	Hou Sala	Medium weir	1.5 m	Vertical slot fishway	$75,000
11	Unnamed	Medium weir	1.5 m	Concrete cone fishway	$100,000
11	Hou Payong	High weir	3.3 m	Concrete cone fishway	$150,000
11	Hou Makmi	High weir	3.5 m	Concrete cone fishway	$150,000
14	Wetland Kengkok-Dong	Wetland bund	0.8 m	Rock ramp fishway	$10,000
14	Hou Souy anabranch	Bund wall & reg	3.0 m	Concrete cone fishway	$150,000
16	Hou Kalang	Medium weir	1.8 m	Concrete cone fishway	$45,000
16	Hou Souy anabranch	Bund wall & reg	4.0 m	Concrete cone fishway	$150,000
16	Hou Bak	Regulator	5.0 m	Vertical slot fishway	$150,000
19	Hou Pakho	Drop-board weir	2.8 m	Concrete cone fishway	$150,000
20	Hou Payong	Medium weir	3.5 m	Concrete cone fishway	$150,000
20	Hou Thouat	High dam	20.0 m	Concrete cone fishway	$450,000
22	Hou Chelamong	Medium weir	2.2 m	Concrete cone fishway	$100,000
22	Unnamed	Wetland bund	4.0 m	Concrete cone fishway	$200,000
22	Unnamed	Wetland bund	2.5 m	Concrete cone fishway	$100,000
22	Unnamed	Wetland bund	1.2 m	Rock ramp fishway	$10,000
22	Unnamed	Wetland bund	3.0 m	Concrete cone fishway	$100,000

get the design and construction process correct to ensure long-term and effective fish passage at priority sites.

Operation and maintenance are also significant factors in the success of a fishway. Fishways that are not maintained or operated incorrectly are also likely to lead to ineffective fish passage. Installing and implementing correct procedures and plans after the completion of construction is therefore vital to the long-term operation of the fishway.

To determine if all steps have been undertaken successfully requires monitoring fish use. The authors note with surprise how many projects assume that their constructions are successful and fail to conduct any monitoring. To determine if a fishway has increased fisheries productivity, they suggest a rigorous monitoring programme to assess the performance of the fishway and how it is affecting fish communities of the surrounding catchment. The guidelines provide options for detecting the success of any fish passage installation that can be tailored to the scale of the project.

Further reading

Marsden, T., L. Peterken, L.J. Baumgartner and G. Thorncraft (2015) Guideline to prioritising fish passage barriers and creating fish-friendly irrigation structures. Mekong River Commission, Phnom Penh.