Mekong River Commission
For Sustainable Development

TECHNICAL GUIDANCE

for the Protection and Restoration of Key Fish Habitats of Regional Importance

Technical Guidance for the Protection and Restoration of Key Fish Habitats of Regional Importance

December 2023

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Mekong River Commission
Documentation and Learning Centre
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Telephone: +856-21 263 263 | E-mail: mrcs@mrcmekong.org | www.mrcmekong.org

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AUTHORS

Management
Mr Socheat Hak and Mr Phetsamone Khanophet, Directors of Environmental Management Division, the Mekong River Commission Secretariat
Dr So Nam, Chief Environment Management Officer

Technical Expert
Dr Lai Tung Quan and Dr Phattareeya Suanrattanachai, Fisheries Management Specialist,
Vanna Nuon, Fisheries and Aquatic Ecology Officer

International Technical Expert
Prof Ian G. Cowx, Aquatic Resources Management Consultant, United Kingdom

Other Contributors
This publication was prepared under the guidance of the MRC Regional Expert Group on Environmental Management and based on the expert technical input from national consultants, relevant line or implementing agencies, and National Mekong Committee Secretariats in each Member Country.

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ABBREVIATIONS AND ACRONYMS

BFMS	Basin-wide Fisheries Management and Development Strategy
DPSIR	Driver-Pressure-State-Impact-Response
EIA	Environmental Impact Assessment
EMMP	Environmental Management and Monitoring Plan
FADM	Fish Abundance and Diversity Monitoring
FCZ	Fisheries conservation zone
GIS	Geographic Information System
IUCN	World Union for Conservation of Nature
JEM	Joint Environment Monitoring
LMB	Lower Mekong River Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NGO	Non-governmental organization
NMCS	National Mekong Committee Secretariat
OAAs	Other aquatic animal
OCEMs	Other effective area-based conservation measures
SMART	Specific, measurable, attainable, relevant and time-bound
TbEIA	Transboundary Environmental Impact Assessment

EXECUTIVE SUMMARY

Background

The Mekong River system is one of the most diverse and prolific inland fisheries in the world. Capture fisheries are important for livelihoods and food security. However, these fisheries and aquatic resources are under considerable pressure from rapid economic development. As a consequence, it was recognized that there is a need for additional guidance to improve the conservation and sustainability of fish species, populations, communities, as well as OAAs, in the Lower Mekong River Basin. To meet this need, the MRC promoted the preparation of this *Technical guidance for the protection, restoration and improvement of key fish habitats of regional importance* (*Technical Guidance*) to secure healthy ecosystems across transboundary areas in the LMB.

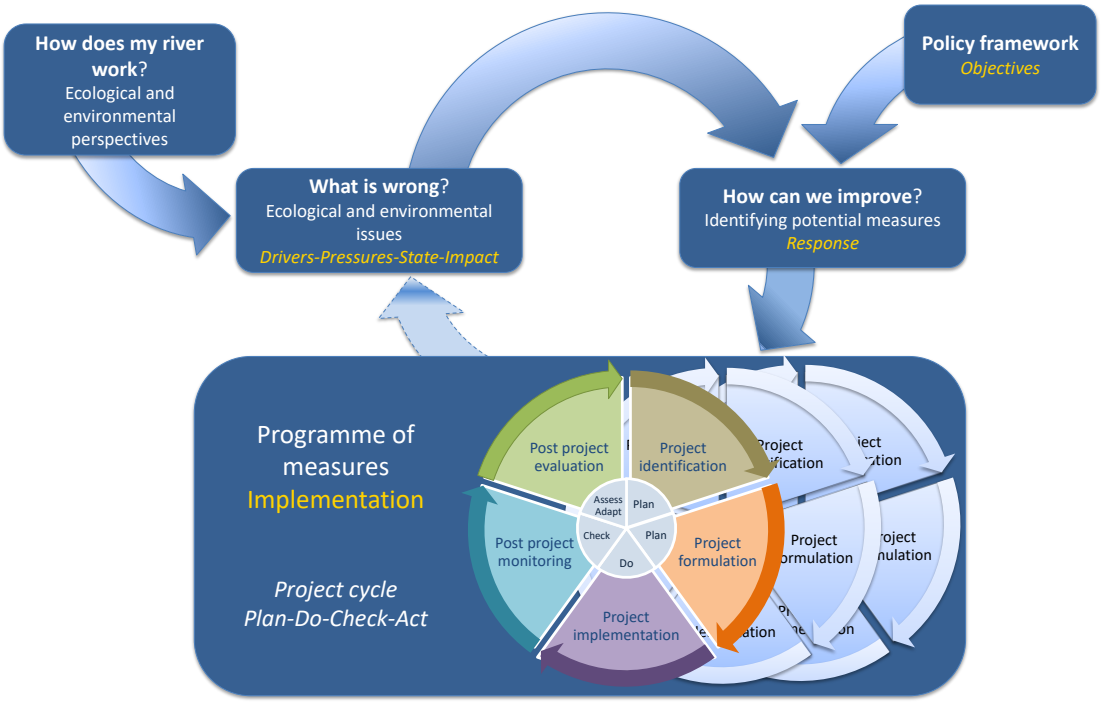
Overview of fish habitat restoration and protection in the LMB

The first section of the Technical Guidance reviews the issues affecting inland fisheries globally and the main measures used to maintain and improve inland fisheries. It reviews the measures currently undertaken in the Lower Mekong River Basin (LMB) based on independent reports for each country, with a particular reference to protecting and restoring key habitats for fish and aquatic biota. The country reports provided an inventory of protected areas, fish conservation zones (FCZs) and sanctuaries in the LMB, but there was limited information on the measures taken to restore key fish habitats. It was indicated that emphasis should also be placed on local fisheries and habitat management perspectives related to protection and enhancement practices, especially restoration of ecosystem functioning and habitat quality. However, to improve the long-term prospects of sustainable fisheries, efforts should focus on measures that have transboundary benefits and linking them with local measures.

The Technical Guidance is process that identifies the different levels of information, data collection and processing required, and presents critical decision levels, as show below.

It is broken down into three stages linked to the Drivers–Pressures –State –Impact–Response (DPSIR) approach. The information acquired from the assessments of “How the river works” to support fisheries and other living aquatic resources (Stage 1) and “What is wrong with the river” (Stage 2) feeds in a project planning approach to identify, formulate, implement and undertake post-project monitoring and evaluation of the restoration or protection project (Stage 3).

Stage 1 evaluates the key hydrological and geomorphological variables that drive fisheries in the LMB. This information is used to assess: (i) the distribution and migration patterns of fish species and guilds; (ii) habitat needs of different life stages in different zones of the LMB; and (iii) the extent and distribution of key habitats. Geographic Information System (GIS) modelling should then be used to map the extent of different habitat types in the LMB and link them to the key habitats, especially floodplain and wetlands systems.



Stage 2 makes use of the DPSIR process to examine the main drivers (agricultural development, deforestation, hydropower development, mining, sand mining, urbanization, industrial development and climate change) acting on the river form and function and the impacts on aquatic fauna. The various drivers crucially induce various pressures on the ecosystem that lead to the degradation of the form and function of the system. These drivers of change should be mapped and overlaid on GIS maps of fish distribution and abundance, including migratory pathways, to identify key areas that need protecting, or where they have been degraded, or where floodplain and wetland habitats have been disconnected, and ultimately the habitats that need to be restored.

The information acquired from the assessments of "*How the river works*" (Stage 1) and "*What is wrong with the river*" (Stage 2) feeds into the project planning approach to identify, formulate, implement and undertake post-project monitoring and evaluation of the restoration or protection actions (Stage 3). This stage is broken down into seven steps following the project cycle framework, as shown below.

In the first step, project identification, the **basic information** gathered in Stages 1 and 2 is used to understand the current status of the ecosystem functioning and ecosystem services in the management zone to establish the baseline against which to develop any project to restore or protect the key habitats. All possible information is collated and analysed, including existing policy frameworks and legislation, to provide a comprehensive overview of the ecological status and resource use patterns, and should be set in the context of the habitat requirements needed to complete life cycles of fish and other aquatic animals (OAAs). Particular environmental characteristics that need to be examined include hydrology and limnology, and their modifications, water quality, land use changes, habitat degradation and other impacts from different resource uses. In the second aspect of the identification phase, the **relevant policy issues** identified in Stage 1 need to be considered in relation to the desired policy objectives of the restoration or protection action.

The objectives for habitat restoration or protection measures identified in Step 1 are clearly defined in Step 2 and must adopt a river basin-wide approach. They should be developed from high priority regional and national policy objectives and should include conservation as well as food security and livelihoods objectives. The logical project approach is used to characterize project needs and set out the design of the restoration or protection project in a clear and logical way so that any weaknesses that exist can be brought to the attention of the planners. Critically, the endpoint or target of the restoration or projection activity is defined to focus on successful outcomes.

Projects to restore or protect key habitats (Step 3) are formulated by comparison of the status of the aquatic ecosystem (Step 1) and the overall regional and national policy objectives (Step 2). The assessment relies heavily on available information or expert (local) knowledge, and requires a thorough evaluation of all available information collected in Stages 1 and 2. A decision tree is provided to determine the current status of the zone (local and or transboundary) and the potential options available to address the problems. Once the various issues have been reviewed, the sites should be prioritized to ensure that key fish habitats of regional importance are selected for appropriate restoration or protection actions.

Once the priority sites have been identified, the most appropriate measures to restore the key habitats are selected. A wide range of measures are highlighted to address the main problems arising from different sectors (drivers) that have degraded the habitat. Criteria and references to guidelines for selecting the most appropriate measures are provided. Specific approaches to selecting priority habitats to be established as protected areas for conservation purposes are also provided.

An essential component of any habitat restoration or protection project formulation is to understand the risks and uncertainty associated with implementing the project. Step 4 is formulated to assess the scale of risk, with the degree of uncertainty, of any habitat restoration or protection project proposed. The assessment procedure is based on a comparison of the potential risks posed from the outcomes of the different options to restore or protect key habitats against the current situation or where no project or activity has been undertaken.

Once the identification, preparation and appraisal steps have been completed and the measures for restoration or habitats to be protected are decided, arrangements need to be made between the management team and stakeholders to commit to implementation (Step 5). Typical arrangements for implementation include negotiating budgets to construct the infrastructure for the protected area or to install the restoration measures, and establishing local regulations and co-management arrangements to monitor and maintain the integrity of the restored or protected habitat. Key measures to successfully implement projects are described. Contingency measures and budgets may be required to adapt the project to ensure that it meets its desired objectives and achieves a successful outcome.

The final steps (Steps 6 and 7) are project monitoring and evaluation. Monitoring and evaluation play key roles because they determine whether the restoration project is successful, or the establishment of a defined protected area meets its objectives. It is recommended monitoring design and indicators should be based on those outlined in the MRC Joint Environment Monitoring Guidance. These indicators should be employed to provide evidence that successful outcomes have been achieved. Some of the most common problems or reasons for failure of a restoration programme or project to establish a protected area are highlighted.

Throughout the Technical Guidance, call-out boxes are provided to help the user collect and interpret the key information to identify the main issues, design, implement and monitor the most appropriate actions (i.e. follow the project cycle). Throughout the process, engagement with and feedback to local stakeholders and agencies is critical to ensure that the stakeholder's ownership over the measures is recognized and maintained.

1. BACKGROUND

The Lower Mekong River Basin (LMB) is one of the world largest and most productive inland fisheries (MRC, 2019). The Mekong aquatic biodiversity is characterized by an estimated 1,148 species of fish, many of which are endemic to the river, plus numerous other aquatic plants and animals. Among these are 80 species that are assessed as threatened on the World Union for Conservation of Nature (IUCN) Red List (Annex 1), although it should be noted that many species have not been evaluated or are data-deficient, and thus the number could be much higher.

The LMB is of enormous importance to nearly 60 million people, where 70 percent of communities are rural, and rice farming and fishing are the main occupations. Fisheries resources, including fish and other aquatic animals (OAAs), make a vital contribution to regional food security and nutrition, cash income and employment, and have strong cultural and religious significance. More than 2.3 million tonnes of fish and a further 0.6–0.9 million tonnes of OAAs, valued at an estimated $11 billion, were estimated to be harvested annually from the LMB in 2010 (Nam et al., 2015; MRC, 2019). In 2020, this harvest dropped to 1.51–1.71 million tonnes of fish and 0.44 million tonnes of OAAs, worth an estimated US$ 7.69–9.11 billion annually (MRC, 2023).

Average per capita consumption of wild captured fish in the LMB is estimated at 33.4 kg, with Cambodia having the highest level at 53.6 kg/capita/year, followed by Thailand (37.0), Lao PDR (36.2 kg/capita/year) and Viet Nam (16.1 kg/capita/year), although Viet Nam has a high additional consumption of fish sourced from aquaculture (Nam et al., 2015). This is similar to the Southeast Asian rate of 51 kg/capita/year and significantly higher than the world rate of 24 kg per person (Funge-Smith, 2018). In the lowland areas of the LMB, protein from fisheries resources ranges from 40 percent to more than 80 percent of the total animal protein intake.

These fisheries and aquatic resources are under considerable pressure from rapid economic development, especially agriculture, hydropower, industrial expansion and mining, a growing human population and climate change (MRC, 2019). For example, according to the Council Study (MRC, 2017a) the size of the migratory fish resource at risk from dams on the Mekong mainstream alone has been estimated at 0.7–1.6 million tonnes per year (i.e. approximately 30–60 percent of the annual catch in the Mekong). This is a conservative estimate, because it does not consider the economic benefits that flow from the trade and processing of fish products. When other pressures on the river ecosystem are considered, the prospective for sustaining the massive contribution that the fisheries sector (fish and OAAs) make to food security and livelihoods is of concern.

These developments, especially the expansion of hydropower and irrigated agriculture in the Basin, are having a direct negative impact on the economic productivity of the natural resource sectors on which many people in the Basin depend. In particular, fish yields are exhibiting a long-term decline or shift to smaller, less valuable species (MRC, 2019). There are difficulties in accurately estimating the economic contribution of natural resources, such as wetlands, sand mining, timber forests and capture fisheries, leading to uncertainty regarding the values of these resources. Nevertheless, maintaining or improving their contribution to

the gross national product, food security, livelihoods and prevention of biodiversity loss is fundamental to fulfilling global initiatives such as the United Nations Sustainable Development Goals (SDGs) or Aichi biodiversity targets.

Currently most of the actions to sustain the fisheries and aquatic resources are focused on fishing regulations, establishing protected areas and conservation zones, and fish stocking activities. In addition, there are a small number of projects to improve fish migration in rivers (e.g. the building of fish passes) and reconnecting floodplain systems and irrigated areas (e.g. Baumgartner et al., 2014, 2018, 2021). However, many of these activities have been carried out in isolation and using historical modes of operation with little consideration of the outcomes of the activities or wider sustainability of fisheries and aquatic resources, and maintaining biodiversity for future generations.

There is a need for additional guidance to improve the conservation and sustainability of fish species, populations, communities, as well as OAAs, in the LMB, particularly with respect to the protection, restoration and improvement of key habitats at the regional level to maintain healthy ecosystems across transboundary areas. For example, agriculture and land use changes are the main threats to fisheries yields in rainfed habitats, but it may be possible to sustain or even increase fisheries yields by maintaining water depths, improving connectivity, developing refuge ponds and promoting integrated pest management (MRC, 2019).

The objective of this Technical Guidance to guide Member Countries in identifying, formulating and implementing projects related to the protection and restoration of key fish to secure health ecosystems across transboundary areas in the LMB. This objective is in line with the following strategic priorities and actions of the MRC (2017b) Basin-wide Fisheries Management and Development Strategy (BFMS) 2018–2022:

- monitoring of key indicators of: (i) fish diversity, abundance and ecology; (ii) socio-economics, livelihoods; (iii) food security and nutrition; and (iv) gender. This aims to observe and document changes and impacts in capture fisheries sector and other sectors;
- **management-related priorities**, where the BFMS 2018–2022 promotes proactive regional engagement (conservation of key habitats, fisheries enhancement, fisheries co-management and transboundary fisheries managemen**t**); and
- **priorities related to development (fisheries and fish-friendly irrigation and agriculture)**, aquaculture, water resources development and the adaptation of fisheries to climate change.

The guidance specifically targets the BFMS priority 2.5.3, Fisheries Enhancement (restocking or habitat enhancement) to "*significantly strengthen the human and institutional capacity of MRC Member Countries in conducting good practices of fish-stock enhancement for sustainable management and utilisation of inland fish resources contributing to national food security and nutrition and livelihood of fishers*" and the priority actions to:

- conduct in-depth country investigation into status and key issues/constraints for effective and responsible fish-stock and habitat-enhancement activities in all four Member Countries;

- translate existing international norms and standards and successful experiences related to inland fish stock and habitat enhancement to a regional technical guideline for MRC Member Countries.

It also covers, in part, the following elements for conservation under BFMS priority 2.5.9, Water Development and Fisheries:

- the maintenance and restoration of longitudinal and lateral connectivity in rivers in the interests of conserving fish-migration patterns through removal of transversal (dams) or lateral (levees) obstructions or the provision of fish-pass mechanism;
- the maintenance or restoration of main channel diversity in rivers, including meanders, point bars, bottom structure and vegetation;
- the maintenance or restoration of floodplains and riverine wetlands. This need not be continuous along the river, but provision should be made for reserves at intervals along the river where normal flood regimes are maintained;
- the removal and control of all point-sources of pollution, including industrial, urban and mining wastes. Control of diffuse pollution, particularly of nutrients, into lakes and rivers; and
- the control of processes at the basin level, particularly deforestation, mining operations in rivers and changes in agricultural practice that can lead to massive siltation, which can shorten the lives of lakes and reservoirs, and destabilize river channels and floodplains.

2. MEASURES FOR THE PROTECTION AND RESTORATION OF KEY FISH HABITATS IN INLAND WATERS

2.1 Introduction

Fishing is a major source of food and income for society globally, as well as in the LMB. However, the importance of inland fisheries has not evolved in line with other food production systems, such as rice, and is often considered a subsistence activity, especially in rural areas (FAO, 2019). This ignores the massive contribution that inland fish and fisheries and production from other aquatic organisms make to food and nutritional security, livelihoods and biodiversity targets.

As a result of the increasing exploitation of inland aquatic resources, both in terms of services delivered from other sectors such as agriculture and hydropower, and from the fisheries and aquatic biota they support, there is growing need to maintain, improve, protect and restore the quality of fish habitat and consequently output from fisheries in terms of biodiversity and yield.

The following section reviews the issues affecting inland fisheries globally, and the main measures used to maintain and improve inland fisheries, and reviews measures currently undertaken in the LMB, with particular reference to protecting and restoring key habitat for fish and aquatic biota.

2.2 Fish habitat protection and restoration activities – the global context

2.2.1 *Issues affecting inland fisheries*

For any management regime to function, there is a need to understand the issues and problems relating to the resource that needs to be managed. For fisheries and aquatic biota, this can be broken down into fishery-related issues, environment or watershed-related issues, and inter-sectoral conflicts.

In developing countries, inland waters are largely exploited by small-scale or artisanal fishing or subsistence fishing by local residents supplementing their food supply (Welcomme, 2001). In many cases, fisheries show signs of overexploitation, typically declines in catch per unit, capture of small-sizes of fish, reduction of larger-sized species, and change in exploitation to smaller, less economically valuable fish species (FAO, 2019). While the changes in the stock structure can often absorb increased amounts of effort, either as labour or improved technology, the size of fish caught declines and recruitment of larger-sized fishes is compromised. In these cases, the general response is to modify the fish assemblages further through stocking and introductions to support expanding fisheries (Cowx, 1994, 1999). A more appropriate strategy would be to address, if possible, the recruitment bottleneck either through more traditional fishery management regulations or restoration of the water body.

Pollution is one of the biggest threats to the freshwater environment (Moss, 1998; Reid et al., 2019). This is because effluent discharge into fresh waters is a convenient mechanism for disposal, and the capacity of large water bodies to accommodate such wastes is high. However, with the growing human population, the pressures exerted on rivers and lakes have become intolerable, and many inland water bodies have become contaminated, which in turn has resulted in deterioration of fish stocks and fisheries. Pollutants include organic wastes, nutrients, metals, poisons, suspended solids and cooling water from urban, industrial and agricultural sources. These can act directly on the fish, for example, due to the toxicity on the chemicals, which may have an acute or chronic affect, depending on concentrations of chemicals concerned, or indirectly, by changing water quality parameters, and consequently the suitability of the habitat for fish. Under these conditions, only a few species of organisms are able to survive, although they may do so in populations with very high numbers of individuals. If this species change replaces favoured species with less desirable species, the increased levels of production may not be seen to be advantageous.

In inland waters, and especially in the LMB, one of the major constraints to the sustainability of inland fish and fisheries is from inter- and cross-sectoral interactions. Aquatic resources are subject to numerous anthropogenic perturbations, such as: pollution discharge from agricultural, domestic and industrial sources; eutrophication; deforestation; river channel modification; damming for power generation and water supply; and urbanization (Figure 2.1). These have resulted in a shift in the status of the fisheries and a general decline in yield; under these circumstances, fisheries are not considered of sufficiently high priority or value.

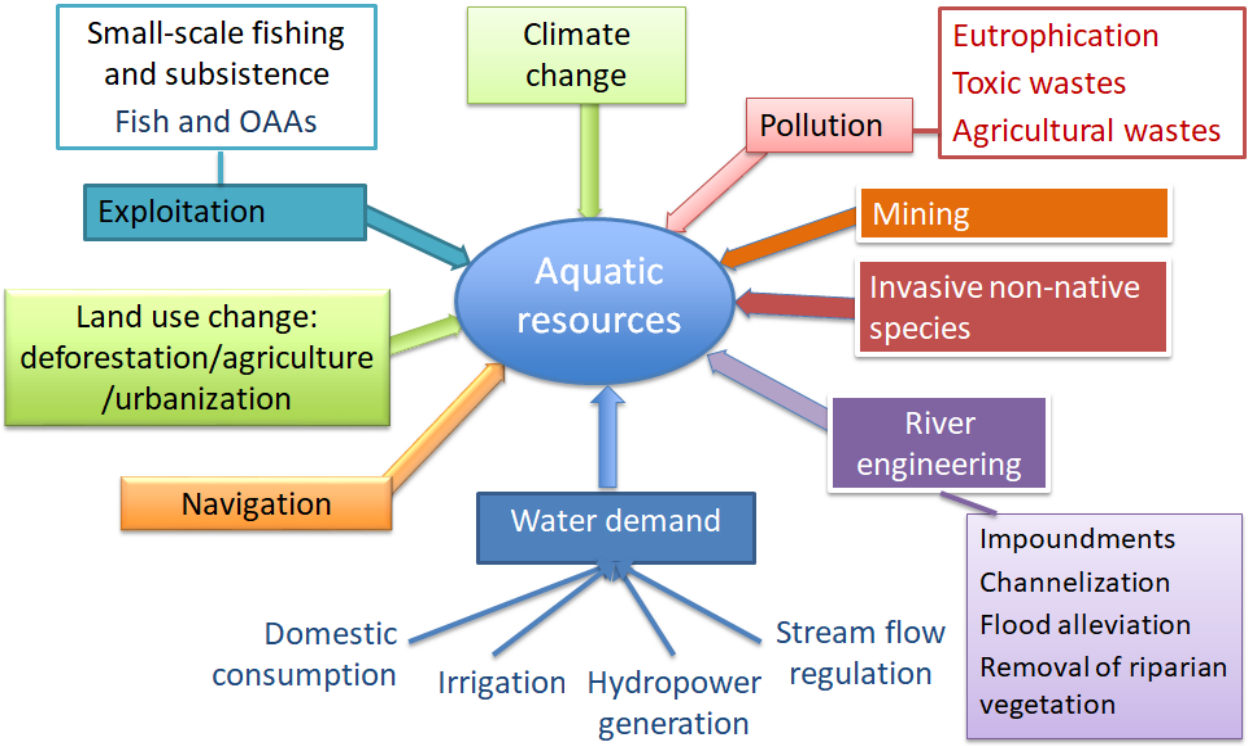


Figure 2.1. Summary of different impacts on fresh waters, with particular reference to the LMB

Engagement with other wider cross-sectoral users and stakeholders, both locally and in a transboundary context, is fundamental to ensuring fisheries improvement of protection actions are successful.

2.2.2 *Fish enhancement, habitat protection and restoration activities*

There are numerous approaches to managing inland fish and fisheries globally, which can essentially be broken down into: enhancing the fish assemblages (stocking and introductions); managing the fishery (fishery regulations and protected areas); and managing the environment (restoration and protection) (Welcomme & Bartley, 1998). Typically, as the water body becomes degraded (through a series of pressures), society and management respond with a series of interventions (measures). The measures taken nowadays reflect the evolving concepts of fisheries improvement that have shifted from a focus on managing species directly through stock enhancement and fisheries regulatory frameworks, to working with natural processes and ecosystem functioning, and ultimately to optimizing ecosystem services benefits from protection and restoration practices (Figure 2.2).

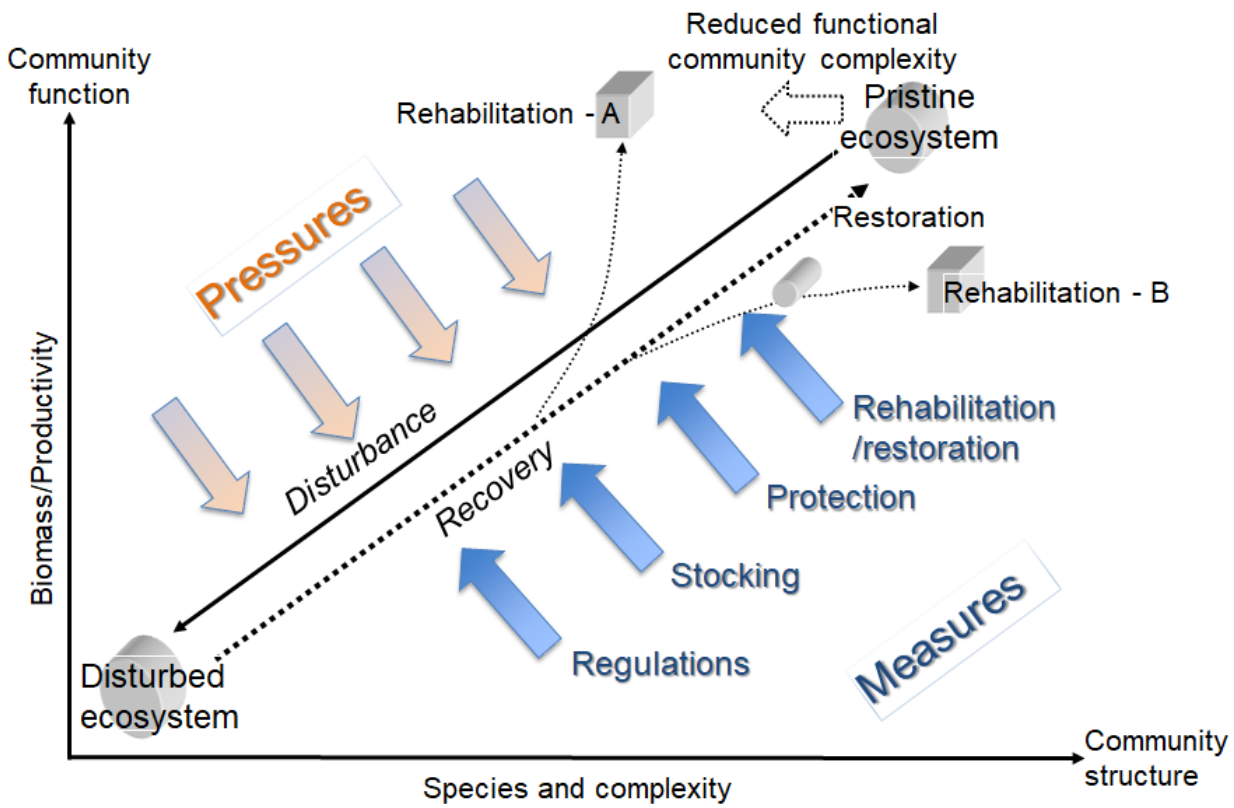


Figure 2.2. Processes of habitat and environmental degradation (pressures), and mechanisms for recovery of aquatic habitats and fish stocks

The enhancement of fisheries through the stocking of individuals or the introduction of species is a practice frequently used by fisheries owners, managers and scientists. It is not discussed further here because it has been fully addressed in the FAO (2015) *Responsible stocking and enhancement of inland waters in Asia*, and MRC (2015) *Guidelines for better fish stock enhancement practices in the Lower Mekong River Basin.* Justification for these activities

is acceptable, for example, to compensate for loss due to environmental interventions, such as pollution, or to enhance fish yield in water bodies that have limited recruitment or poor species diversity, thus to exploit the available ecosystem to the fullest. Stocking programmes are more likely to succeed if bottlenecks to natural recruitment are removed, but concerns have been expressed about the potential risks associated with stocking of fish, particularly with respect to ecological imbalance and change in community structure, and loss of genetic integrity (see Cowx, 1994).

In addition to direct interventions on the fish populations/communities, fisheries are usually controlled by enforcing various regulatory constraints to prevent the overexploitation of the resources and maintain a suitable stock structure. These generally involve technical measures to increase selectivity and lower efficiency of fishing gears through larger mesh sizes, imposing annual catch quotas and protecting spawning areas, as well as enforcement of regulations (Welcomme, 2001). These various measures and their expected outcomes are similar to those imposed on major marine commercial fisheries, and in many cases are not applicable or are difficult to enforce. This is because inland fisheries are often open access, highly dispersed, small-scale or subsistence, and are secondary livelihoods thus making them difficult to regulate.

The establishment of protected areas and restoration of key habitats are important tools in managing ecosystems to ensure their continued functioning and the provision of the many services they provide to society. The strategies, risks, constraints and procedures to maximize the benefits from protected areas and restored habitats have been summarily reviewed in a global context in Annex 1, but a number of critical issues must be addressed when determining the measures to restore or protect key habitats:

- Whenever establishing protected areas or restoring habitats, the aims and specific objectives of the actions must be clearly defined.
- A national inventory of key fish habitats, including deep pools, wetlands, fish sanctuaries, Ramsar sites, national parks and conservation zones, should be established as a precursor to choosing protected areas and key habitats for restoration to benefit from existing conservation areas and build on the networking of protected restored habitats.
- Before projects to establish protected areas or restore key habitats are undertaken, a thorough evaluation of the reasons for the action should be appraised, and alternative approaches to maintaining, improving or developing the aquatic habitat and associated resources (e.g. habitat offsetting or better fisheries management) should be considered and/or discounted.
- The strategy for any project to establish a protected area or restore key habitats should be carefully tailored to the species/biota in question, taking into account its entire suite of ecological prerequisites, so as to maximize the chances of success.
- The actions must be cost-effective and address the bottlenecks impacting the target biological elements. If they have been comprised beyond repair, the outcome of any restoration or protection measure will likely be unsuccessful.
- For protected areas, it is critical that the habitat being protected is intact and has all of the environmental characteristics to function sustainably.

- Regulators must consider the potential long-term implications of projects to establish protected areas or restore key habitats on the ecosystem. The entire catchment and any adjacent water bodies must be taken into account when considering the proposals.
- All projects to establish protected areas or restore key habitats are properly formulated and planned before implementation to avoid conflicts with other water resource sectors or within the fisheries sector.

2.3 Fish habitat protection and restoration activities in the Lower Mekong River Basin – A regional context

As highlighted, the fisheries and aquatic resources of the LMB are under considerable stress from multiple pressures (Figure 2.1) and are in decline because of alteration to, or disruption of, ecosystem processes. Overriding many of these pressures is climate change, which is having considerable impact on the Mekong hydrological regime and compounding many of the effects of flow regulation by hydropower and agricultural practices.

To support the development of this *Technical Guidance,* a series of national reviews of fisheries protection and restoration activities in the MRC Member countries was carried out. Each country recognized the importance of protecting key habitats that ensure that the fisheries of the LMB are maintained and improved, especially the important migratory species, which contribute to a major part of the fish catches.

The key messages from these reviews are presented in Annexes 2.2–2.5 and summarized below to identify common issues and recommendations for addressing them, and to underpin this Technical Guidance for the protection, restoration and improvement of key fish habitats of regional importance in the LMB.

Efforts have been made to protect fisheries and aquatic resources in the LMB through legislation and establishment of protected areas, FCZs and fish sanctuaries.

Protected areas are well established in the LMB (Figure 2.3), but are rarely related to the protection of key species or life stages of fish or key habitats that support recruitment dynamics and survival of fish or other aquatic organisms. Most existing protected areas are also not specifically orientated around riverine or aquatic environments, and few have fish as their primary species group to protect. As a first step to understanding the role of protected areas in supporting conservation of fish and key fish habitats, each country produced lists of national inventories of key fish habitats. conservation zones and sanctuaries, and the role of other conservation areas in protecting fisheries assets (summarized in Annexes A2.2–2.5).

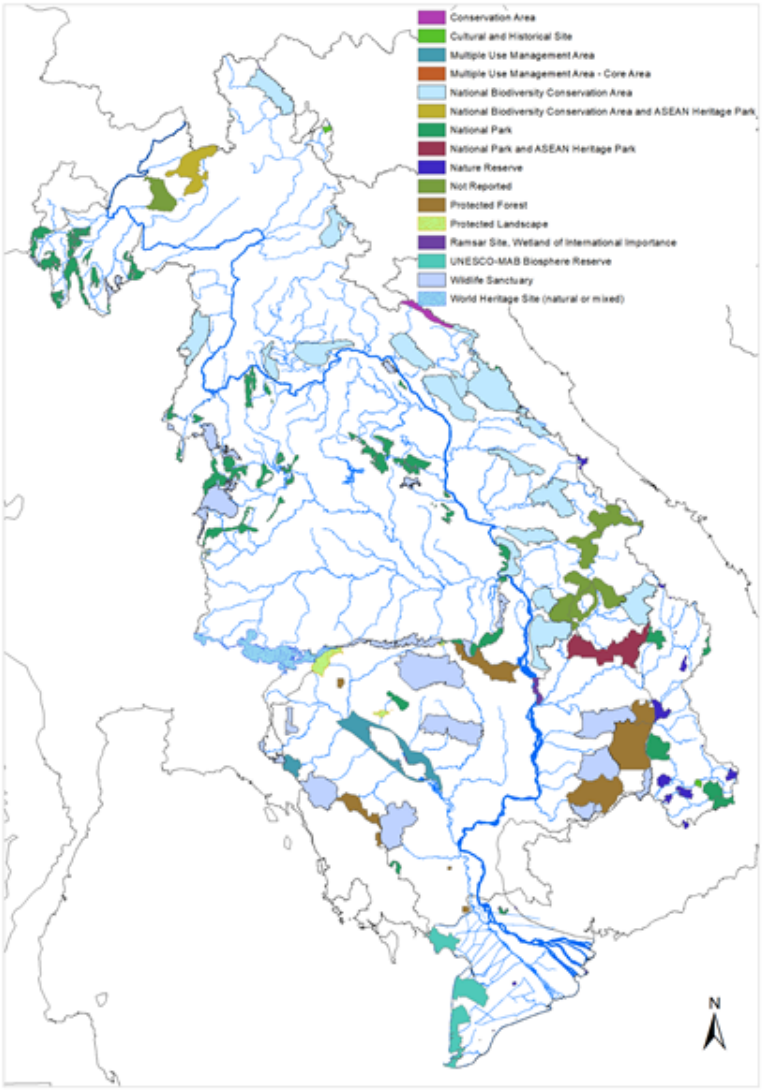


Figure 2.3. Location of Protected Areas in the LMB

These country reports summarized the location of protected and conservation areas, the habitat types, and main species protected by the area (note: many of the habitats are not specifically established to protect fish species). They also identified additional key fish habitats that will potentially contribute to the objectives to support further protection and conservation of key species regarding present and future threats.

This important information should be collated into a central database that ranks key conservation areas according to their consistency with medium- and long-term sustainability of the basin ecosystem. There is also a need to assess and catalogue the efficiency of existing protection and conservation measures for key conservation and threatened species regarding present and future threats. This is important given there are many fish species classified as threatened under the International Union for Conservation of Nature (IUCN) Red List.[1]

[1] IUCN Red List. www.iucnredlist.org/search/list?query=mekong&searchType=species

In this context, considerable attention should be placed on the importance of known key fish spawning habitats, and floodplain and wetland areas in the LMB. See, for example, MRC maps of major wetlands (Figure 2.4) and the 12 prioritized environmental assets in the LMB (Figure 2.5) that contribute to sustaining the abundance and biodiversity of fish and aquatic biota. These habitats, and floodplain and wetland areas then need to be categorized and expanded to account for critical areas for the protection and/or restoration for fish to help support future efforts and designations that also take due account of fish as key assets to rural livelihoods, food security, and importantly, endemic species biodiversity in the Basin.

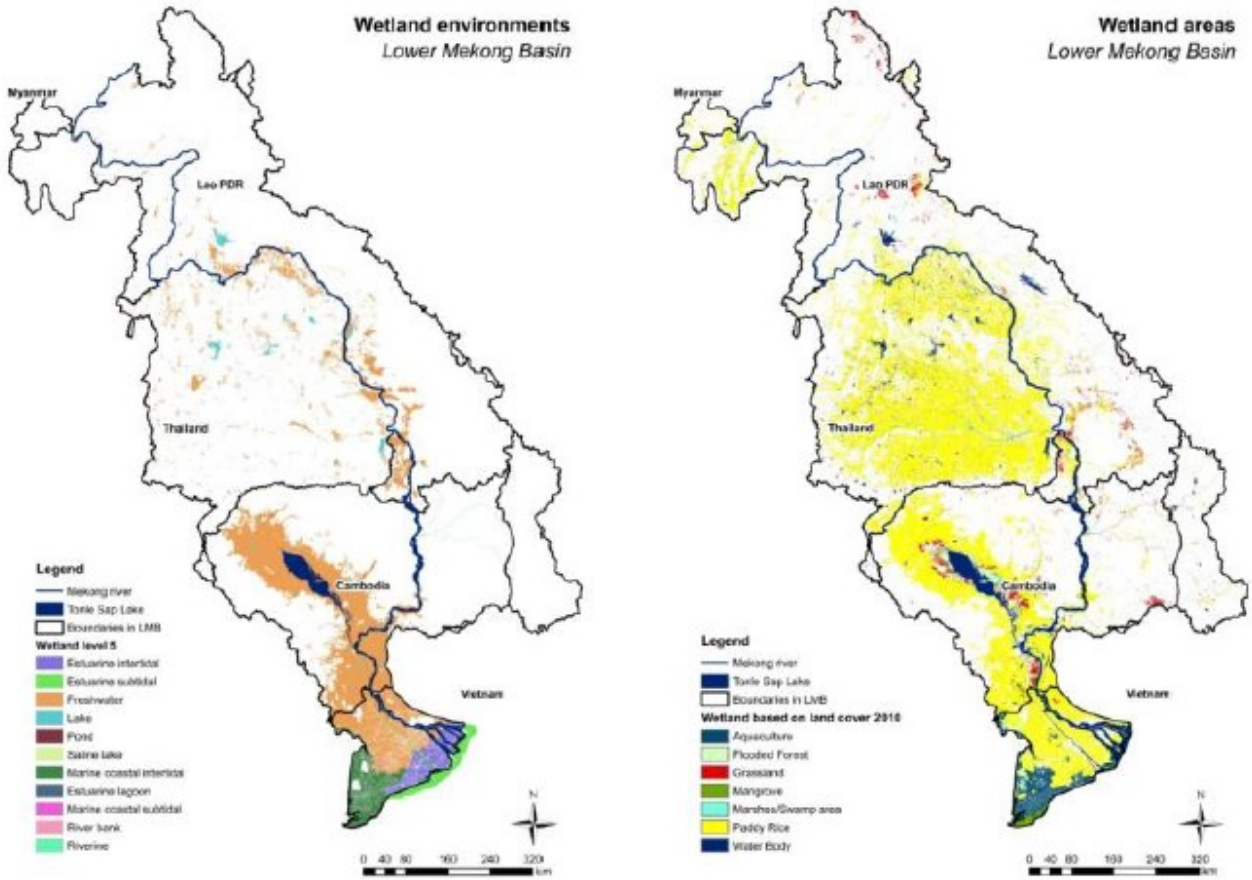


Figure 2.4. Map of (a) wetland types based on habitat; and (b) wetland areas determined by landcover analysis for 2010 in the LMB (Source: MRC, 2019)

There are also numerous FCZs and fish sanctuaries established throughout the LMB. They are usually established in small, often isolated, areas that do not encompass the wider habitat needs to complete the full life cycle of the species of concern, in particular maintaining connectivity between spawning and nursery habitats and feeding and refuge habitats. There is first a need to determine whether the existing protected areas and conservation zones provide the habitat needs of the main fish species and species groups (guilds, Annex 4) that are found in the region. Particular attention needs to focus on the connectivity between habitats needed for different life stages and whether the protected areas provide the full suite of habitat needs of the species to maintain and improve their population status. This is critical so these habitats can be integrated into a catchment-wide network of protected areas that cover all species of conservation concern. This should be combined with the inventory of deep

pools in the Mekong (Figure 2.6) that are recognized as key habitats for fish, with their protected status and legislative frameworks (national or local). Then, there is a need to determine whether appropriate activities are being implemented to connect deep pools or other critical habitats to ensure that fish species can complete their life cycles. This is essential to protect the pathways between key habitats as much as the habitats themselves.

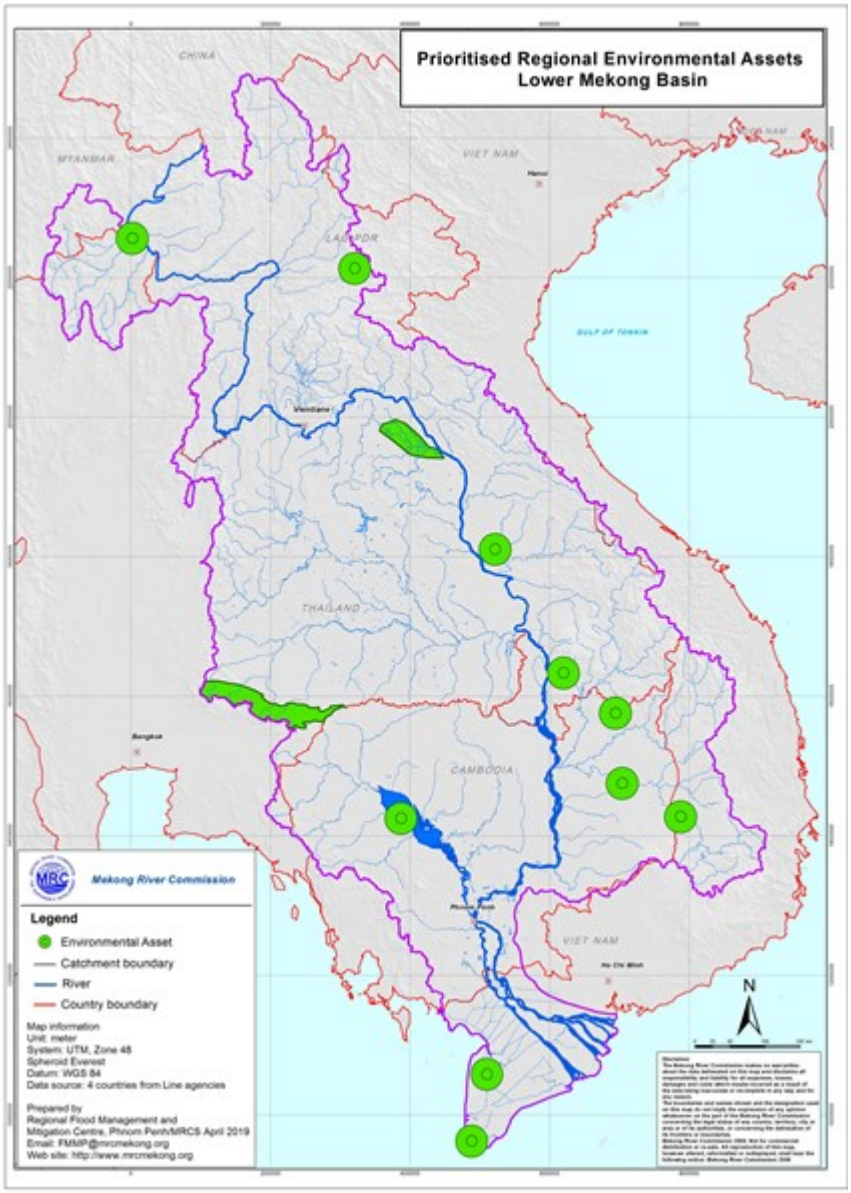


Figure 2.5. Map of 12 prioritized environmental assets of regional importance in the LMB

Less effort has focused on rehabilitation and restoration of habitats, which is mostly directed towards fish passage easements at water irrigation infrastructure, with some efforts to reconnect floodplain systems. Fish passes have been installed at a small number of major dams in the LMB, and fish easement facilities have been installed at some water control/irrigation structures (Figure 2.6). In addition, fish passes have been installed at a number of floodplains disconnected for irrigated rice production (e.g. Papeun Reservoir, Paksan district, Boilkhamxay Province; Sui Reservoir, Savannakhet Province; and water control structures on the Nam Kam River, Thailand; see Figure 2.7). In addition, there has been some replanting of mangroves along flood banks in the Mekong Delta. A full inventory of restoration

and remediation actions that have been carried out in the LMB, with their objectives; outcomes and legislative frameworks should be produced as a catalogue for stakeholders to use as reference for future restoration activities.

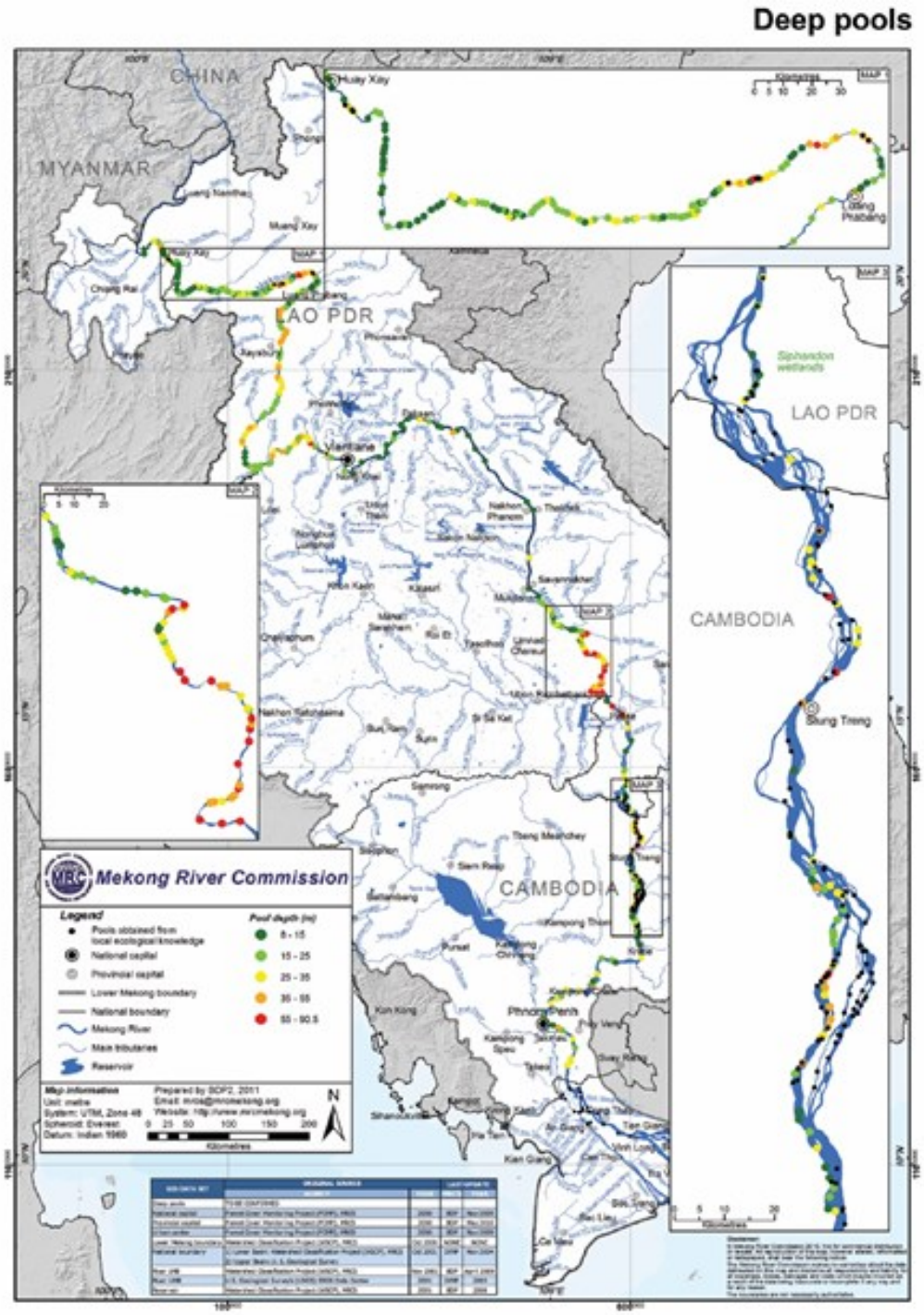


Figure 2.6. Location of deep pools in the Lower Mekong River Basin

Fish passage at Papeun Reservoir, Paksan district, Boilkhamxay Province

Fish passage at Sui Reservoir, Savannakhet Province

Thoranit Naruemit fish pass: the most downstream fish pass through the Nam Kam River system

Figure 2.7. Illustrations of fish restoration activities in the LMB

A number of transboundary projects have been implemented to support fisheries management processes. These projects are largely linked to Integrated Water Resources management and sustainable use of fisheries resources. They do not explicitly deal with fisheries enhancement. but can be used as the foundation of fisheries enhancement actions.

There seems to be appropriate legislation and regulations in all countries to support management of the fisheries, but there is limited capacity for institutional enforcement. Implementation is largely carried out through community-based management interventions with local fishing communities.

In summary:

- The country reports have provided an inventory of protected areas, FCZs and sanctuaries in the LMB, but there is a need for an inventory of existing measures taken to restore key fish habitats in the LMB.
- There is a broad understanding of the pressures on the fisheries and aquatic resources, and viable measures to mitigate or improve fisheries productivity, yield

and biodiversity. However, there is a need to link these pressures on key fish habitats that have been identified as requiring further protection or restoration to viable measures to meet the broad objectives of sustainable fisheries and protecting biodiversity.

- Emphasis should also be placed on local fisheries and habitat management perspectives related to protection and enhancement practices, especially restoration of ecosystem functioning and habitat quality, i.e. the establishment of institutional frameworks for enhancement activities;
- Throughout the development and implementation of any projects to protect, enhance or restore key habitats of importance for the fish and aquatic biota, it is critical that stakeholders are involved in the planning and execution since projects are largely enacted through community management initiatives.

Finally, as part of the developing the Technical Guidance, it is recommended that information on key fish habitats with regional importance in the national reports and other MRC reports (MRC Council Study BioRA documents, the MRC Wetlands Inventory, MRC Deep Pools database, MRC Priority Environmental Assets Inventory) be updated with descriptions of river restoration activities to support the application of the Technical Guidance in the LMB. This should be compiled into a central database or spreadsheet that can be used to formulate future restoration and protection measures, as detailed in Section 3. Particular attention should be paid to reviewing the outcomes (success or otherwise) of existing protected areas and restoration activities to enhance fisheries and aquatic biodiversity, including documenting institutional arrangements for managing habitats. The structure of the database or spreadsheet should have at least the following column headings:

- Coded Reference no: P= protected area; CZ = conservation zone; S = sanctuary; DEP = deep pool; R restoration measure
- Main river name:
- Catchment, sub-catchment or wetland name:
- Key habitat site name:
- Geographical reference location: GPS location
- Country:
- District:
- Water body type:
- Length of river or area of wetland:
- Pressures on selected habitat:
- Restoration or protection measure:
- Objective of restoration or protection measure:
- Fish species and aquatic organisms targeted:
- Expected or reported outcomes of measure:
- Governance framework:
- Monitoring activities:
- Reference material: links, reports, papers, videos, social media outputs.

3. TECHNICAL GUIDANCE ON PROTECTION AND RESTORATION OF KEY FISH HABITATS

3.1 Rational for the protection and restoration of key fish habitats

The Mekong River Basin is subject to considerable development pressures, especially from hydropower aggregate extraction, urban development and agricultural expansion. To ensure that the River will continue to provide the multiple services to millions of people, many of whom live in rural poor communities, it is essential that environmental conditions and ecosystem processes in the River are maintained and protected.

Currently, the main focus of fisheries enhancement in the LMB is on stocking and protected areas (Annexes 3.23.5). In addition, the main reasons for the deterioration of fisheries and aquatic resources are overexploitation, degradation and modification of habitats, which include a loss of connectivity between habitats, pollution and flow regulation (Figure 2.1). Thus, there is a need to promote wider environmental management actions, such a river restoration (nature-based solutions), integrated water resource management and habitat protection, which address the wider pressures on the LMB ecosystem. In particular, there is a need to relate ***pressures*** (stresses) on the environment's structure and functioning, and develop ***responses*** that will ameliorate these problems, but with specific ecological, conservation, economic or policy targets/objectives (Figure 3.1).

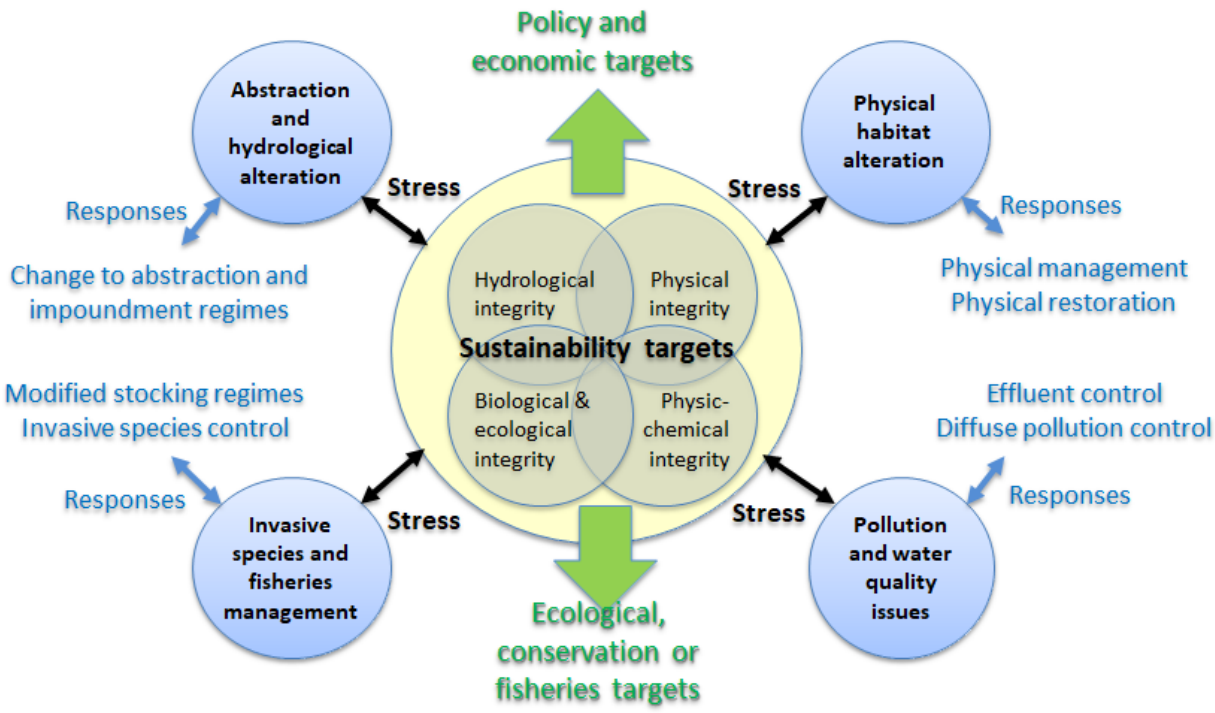


Figure 3.1. Components of sustainability targets for freshwater habitats and links to key remedies

This Technical Guidance draws on these different strategies and adopts an integrated perspective accounting for both living aquatic resources-related components and externalities acting on the biota. The Technical Guidance has been explicitly developed to improve the protection or restoration of key habitats for fish and OAAs in the LMB, but is equally applicable for other aquatic habitats in tropical and semi-tropical regions. The approach is interactive and must engage all stakeholders to address wider issues, such as biodiversity conservation, beyond those related to a single activity and decision-making regarding it and its likely effect on the environment and on other activities, or conversely, the likely effect of other activities on biodiversity.

3.2 Habitat restoration and protection processes

This Technical Guidance follows a logical project framework typically used in development projects, and river restoration and habitat protection planning globally. The procedure, outlined in Figure 3.2, is process-driven and makes use of various project planning tools, for example, Plan–Do–Check–Act (PCDA) DPSIR, conflict resolution and risk assessment, to:

- diagnose problems and produce a strategy for the restoration or protection of key habitats (Stages 1 and 2);
- provide knowledge of the technical policy and background to conflicts from multiple uses of resources (Stage 2);
- set objectives as defined by institutional, regional, national and global policies;
- identify measures to restore or protect key fish habitats, recognizing the need for an integrated approach to management of resources to minimize conflicts and optimize their use (Stage 3); and
- fully engage with stakeholders, especially from fisheries, conservation and other water-related sectors, such as agriculture and hydropower.

This approach covers specific technical issues targeting ecosystem functioning and services, and their effectiveness or limitations. It aims to address societal and prevailing ideals and values, and works within and accounts for regional institutional frameworks, i.e. fits within existing regulations and legislation. It is developed for resources and environmental entities whose physical boundaries are based on manageable limits, i.e. they can be managed at the local and district scales. The Technical Guidance provides the opportunity to consider the needs and aspirations of all resource users, thus enabling the opportunity to minimize conflicts and optimize resource use. Monitoring and evaluation, and participatory engagement, including full consultation with stakeholders, are embedded in the Technical Guidance.

The Technical Guidance identifies the different levels of information, data collection and processing required, and presents critical decision levels (Figure 3.2). It is broken down into three stages linked to the DPSIR approach (Box 1). The last stage is related to the project cycle, which comprises a series of steps to identify, formulate and implement measures to conserve, restore and enhance key fisheries habitats and protect them from the impacts of development pressure on the Mekong River system.

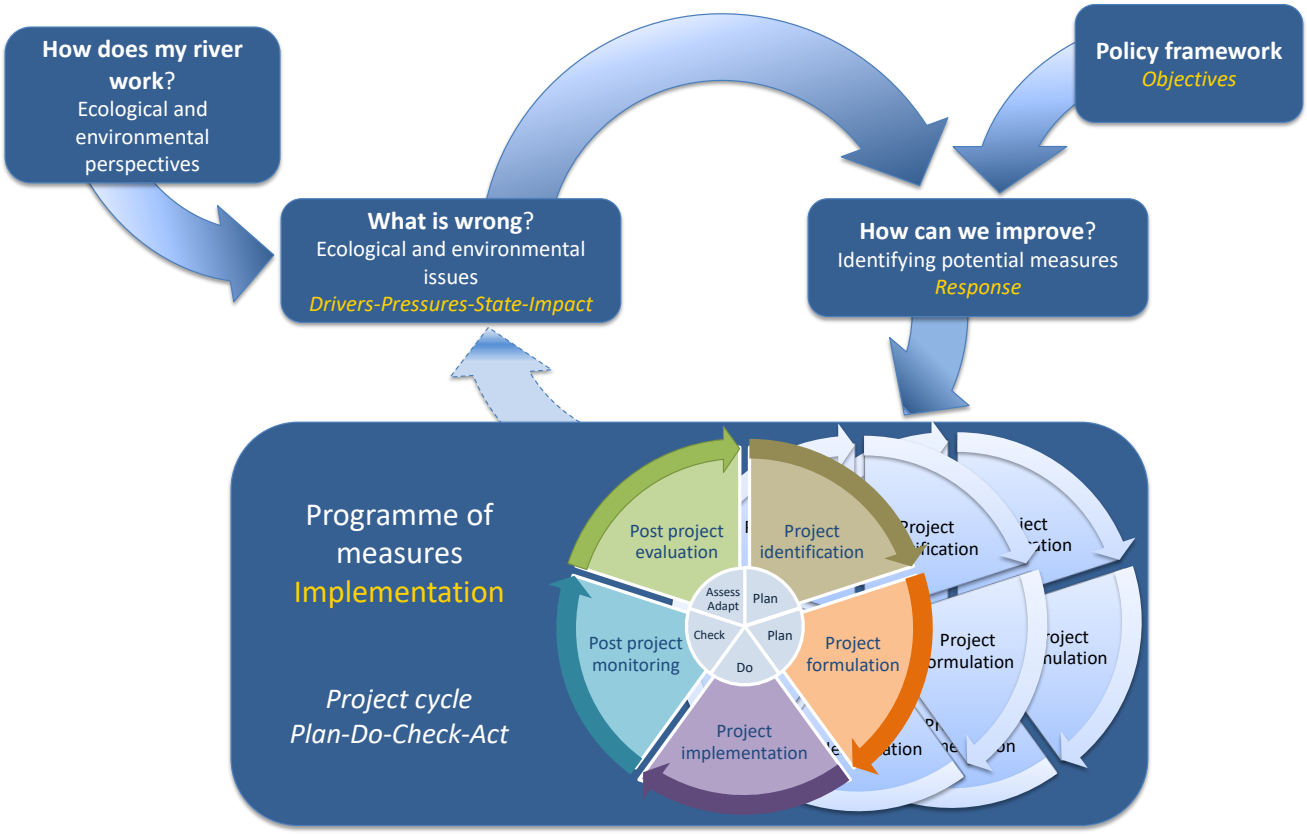


Figure 3.2. Guidance for identifying and formulating projects for the protection and restoration of key fish habitats (modified from Cowx et al., 2013)

Note: See Figure 3.3 for details of the project cycle.

The three stages of the Technical Guidance are:

Stage 1: How does the river work? (State)
Stage 2: What is wrong with the river: Identify issues affecting fisheries and aquatic resources: (Pressures- State-Impact)
Stage 3: How can we restore or protect the key fish habitats? (Response)

The information gained from the assessments of "How the river works" [Stage 1] and "What is wrong with the river" (Stage 2) feeds in a project planning approach to identify, formulate, implement and undertake post-project monitoring and evaluation of the restoration or protection project (Stage 3) (Figure 3.3). In Stage 3, it should be recognized that there may be more than one solution to address the problem and an options analysis using risk analysis and cost benefit tools should be carried out to decide on the most appropriate solution. Throughout this stage, it is critical that stakeholders are engaged in the decision-making so that they are not compromised by the interventions and are willing to adopt the solutions to protect or restore key fish habitats and the connectivity between them.

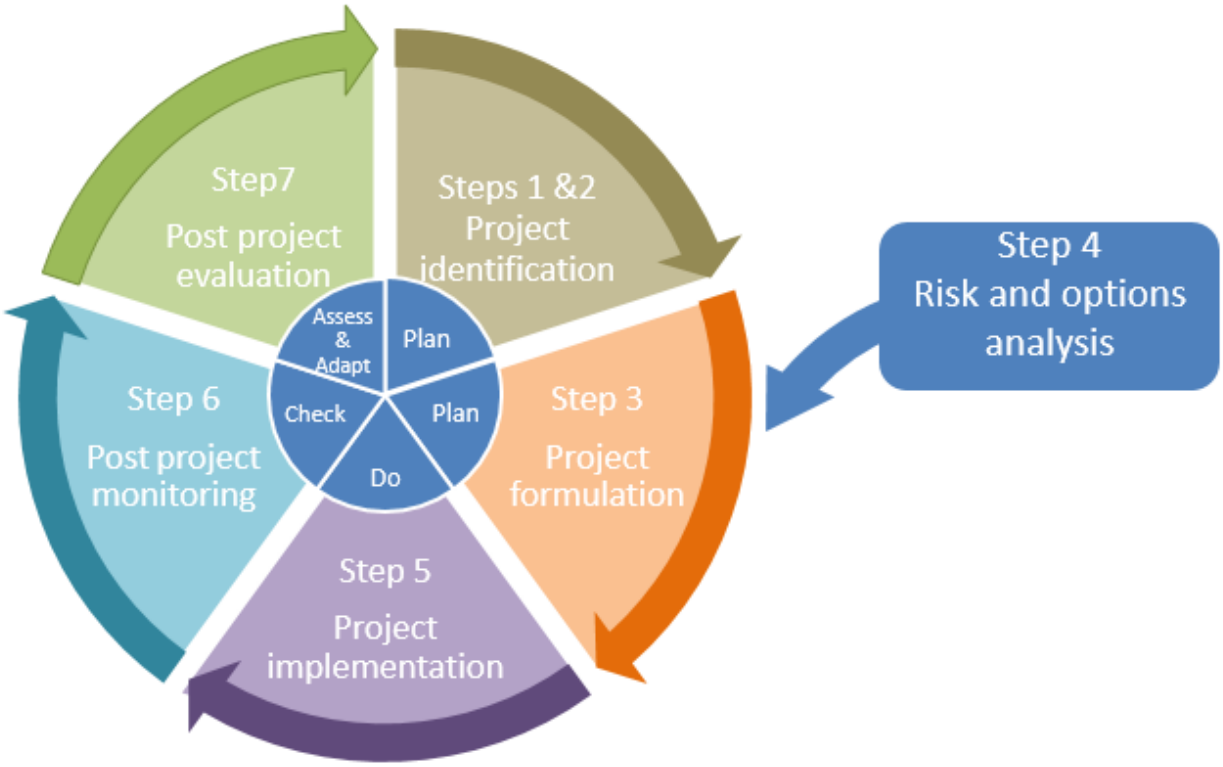


Figure 3.3. Project cycle approach to identify, formulate, implement and undertake post-project monitoring and evaluation of the restoration or protection project

Specifically, the Guidance aims to overcome the limitations of planning and to:

- promote and implement programmes and projects aimed at achieving defined objectives;
- develop programmes and projects that conform to national, regional and international policies and agreements, in addition to satisfying the objectives of funding agencies;
- benefit a wide cross-section of society; and
- directly or indirectly contribute positively to the economic, social, cultural, environmental and institutional development of the state.

Full consultation and engagement with all aquatic user groups throughout the project life cycle are essential to promote optimal, sustainable use of the water body while meeting river basin management targets.

Box 1. The Drivers–Pressures–State–Impact–Response approach

The **Drivers–Pressures–State–Impact–Response (DPSIR**) framework is a holistic approach that identifies key relationships between societal development and the environment (Figure 3.4). It supports managers in their decision-making, especially to structure and communicate policy-relevant protection, rehabilitation or enhancement projects (Atkins et al., 2011). DPSIR should be used within the project identification phase of the planning approach to reconcile conflicting interests between societal and the ecological needs of ecosystems (in this case, the Mekong River), in addition to land use changes.

Drivers are the key demands by society, such as agricultural and urban land use for food production and housing, flood protection, inland navigation and hydropower production. Governance, economic incentives and legislation are indirect but significant drivers with respect to balancing competing demands for freshwater resources, especially since each driver tends to be biased towards its own requirements, leading to significant environmental impacts on the natural functioning of inland water ecosystems, and thus habitats and fisheries.
These drivers are responsible for **Pressures** that cause biological and abiotic **State** changes and further **Impacts** within the river system (EEA, 2012). Natural variability, invasive species and climate change are indirect pressures arising from external sources, which can also cause changes in the river state; combined with pressures resulting from the main human activities associated with development, they can intensify impacts on the ecosystem. For instance, climate change has resulted in extremes in both high and low rainfall events. Increased flooding occurrences have resulted in an increased number of flood protection schemes (**Drivers**) that result in channelization of the river (**Pressure**), which simplifies the channel by straightening and steepening the riverbanks (**State**), subsequently removing the natural floodplain and reducing lateral connectivity (**Impact**).

The DPSIR approach disentangles these issues and identifies protection or restoration measures (**Responses**) to address the impacts on ecosystem services and ecosystem function. These measures include the application of river habitat improvement and protection activities to prevent or improve state changes in the environment for key fish habitats. A feedback loop between human responses (river restoration or protection) and pressures highlights the need to assess the chosen method to address the impact, and the risk and uncertainty of that measure being ecologically effective.

A DPSIR table can be created to help practitioners identify technically feasible and economically viable restoration or protection measures at the river basin and/or reach scales. The user should list all drivers present, the pressures they create, the resulting state changes, subsequent impacts and potential restoration measures (Table 3.1).

Table 3.1. Example of how the DPSIR table can be used to aid decision-making in the planning stages for river restoration

Driver	Pressure	State–Impact	Response
Example: Flood protection	Channelization	Steep banks and simplification of the channel. Loss of lateral connectivity.	Reconnect the floodplain by setting back the levees, reconnecting rice fields or allowed controlled flooding

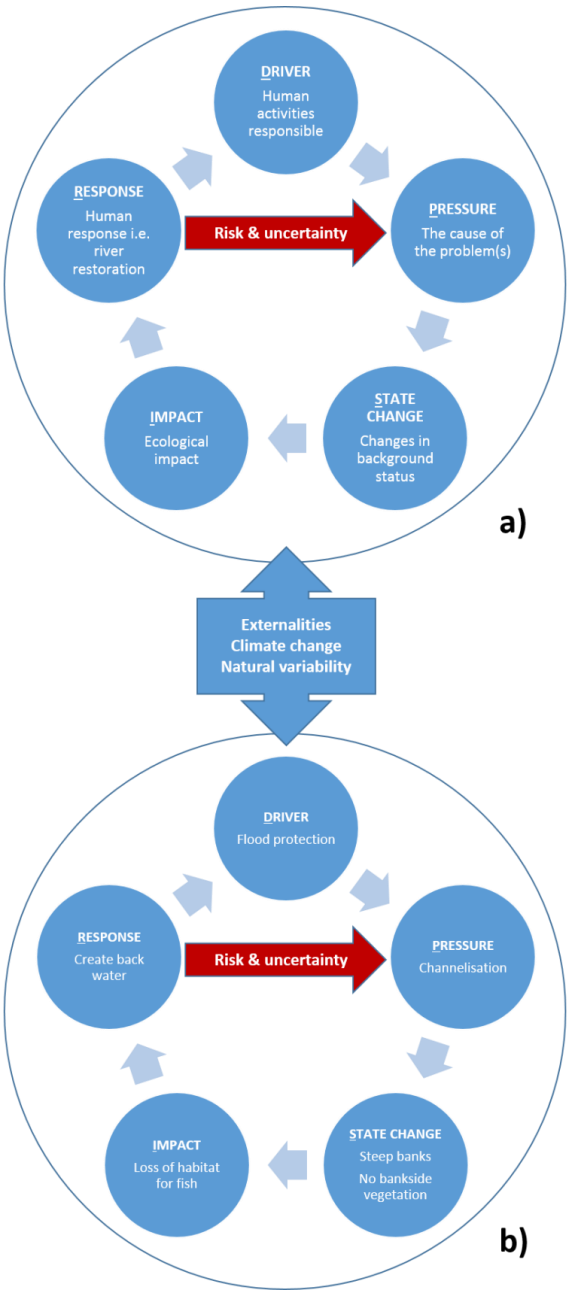


Figure 3.4. The DPSIR approach as a cyclic system, a) explanation of the different stages, and b) example of the DPSIR approach for river restoration

3.3 A stepwise approach to protection and restoration of key fish habitats

Stage 1: How does the river work? An ecological characterization of aquatic biodiversity in the LMB

Knowing how a river works is essential for achieving success in river restoration or establishing protected areas. It should be the first step in any restoration action or establishing protected areas, and is the basis for river basin management planning.

The primary activity for this step is hydromorphological characterization, i.e. looking at the river from a perspective of the relevant processes and forms. Hydromorphological characterization aims at capturing and explaining the complexity of hydrological, geomorphological and ecological processes that interact at many temporal and spatial scales. This is the key step in developing a fuller understanding of how a river functions physically, as a foundation for evaluating river conditions and developing a programme of restoration and protection measures. Hydromorphology in the context of river restoration is mainly associated with the hydrological cycle – and associated flow dynamics – and sediment processes, and how they influence ecological processes.

It is well established that the fisheries of the Mekong are intrinsically linked to the River's hydrological cycle (Figure 3.5). It is known that fish of different species groups (i.e. guilds) migrate up and downstream, or laterally to the floodplain during different periods of the flood cycle, while others occupy permanent floodplain habitats and wetlands. These flooding patterns are also critical for OAAs and biota and need to be maintained to protect biodiversity or to support restoration activities. The first step in determining key habitats for restoration is understanding the ecological characteristics of aquatic biodiversity in the LMB and the relationships between species of concern and their habitat needs and associated hydrological drivers.

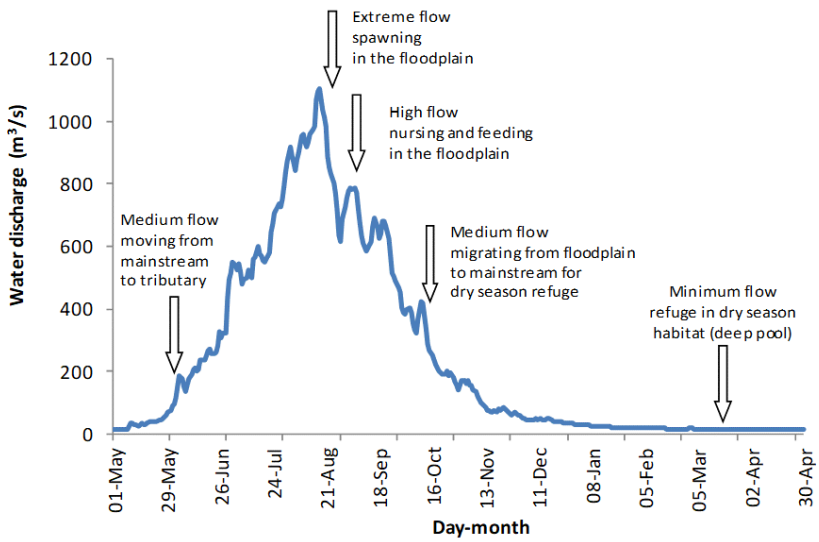


Figure 3.5. Typical natural hydrograph for the LMB illustrating key links to the characteristics of fish life cycles

The key hydrological and geomorphological variables that need to be considered in any evaluation of their importance to fisheries are indicated in Table 3.2, together with the relationships that need to be explored.

Table 3.2. Hydrological and geomorphological variables to be related to fisheries

Variable	Measurement units	Relationship
Change in extent of habitat connected to floodplain inundated and duration	hectares and number of days/weeks flooded	Correlated with fish species abundance and standing crop (biomass)
River flows volumes	m^3/s	Correlated with fish biomass, fish yield and species composition
Change in extent of salinity intrusion	hectares	Correlated with species diversity and catch, and aquaculture production type
Timing and duration of annual floods	onset/offset times	Related to fishery practices and species catch composition
Timing and duration of low flow periods	onset/offset times	Related to fishery practices and species catch composition
Extent of coastal mangrove area	hectares	Related to fishery recruitment dynamics
Changes in river sediment deposition and consequent nutrient loading	g/m^2/day and mg/L	Relate to fisheries productivity and standing crop
Change in habitat inundation depths	meters	Related to fishery practices and species catch composition
Extent of coastal sediment plume	km^2	Related to coastal fisheries catches

There is considerable information available in the MRC fisheries databases (FADM) and reports, and external peer-review and grey literature to understand these relationships. These information sources can be used to assess the following:

- distribution and migration patterns of fish species and guilds (Annexes 3 and 4);
- habitat needs of different life stages in different zones of the LMB;
- extent and distribution of key habitats, typically main river spawning and nursery habitats, and feeding and refuge habitats;and
- drivers of fish population dynamics including cues for migration and spawning, timing of movements with respect to the hydrological cycle.

A summary of source information and key characteristics is provided in Annex 3.

Against this backdrop, GIS modelling, such as that established for the fish yield modelling (Hortle & Bamrungrach, 2015; MRC, 2023; Figure 3.6) should be used to:

- map the extent of different habitat types the LMB and links between fisheries and the key habitats; and
- map key aquatic habitats and their role in supporting the sustainability of different fish species and guilds, as well as yield from the fisheries (MRC, 2023).

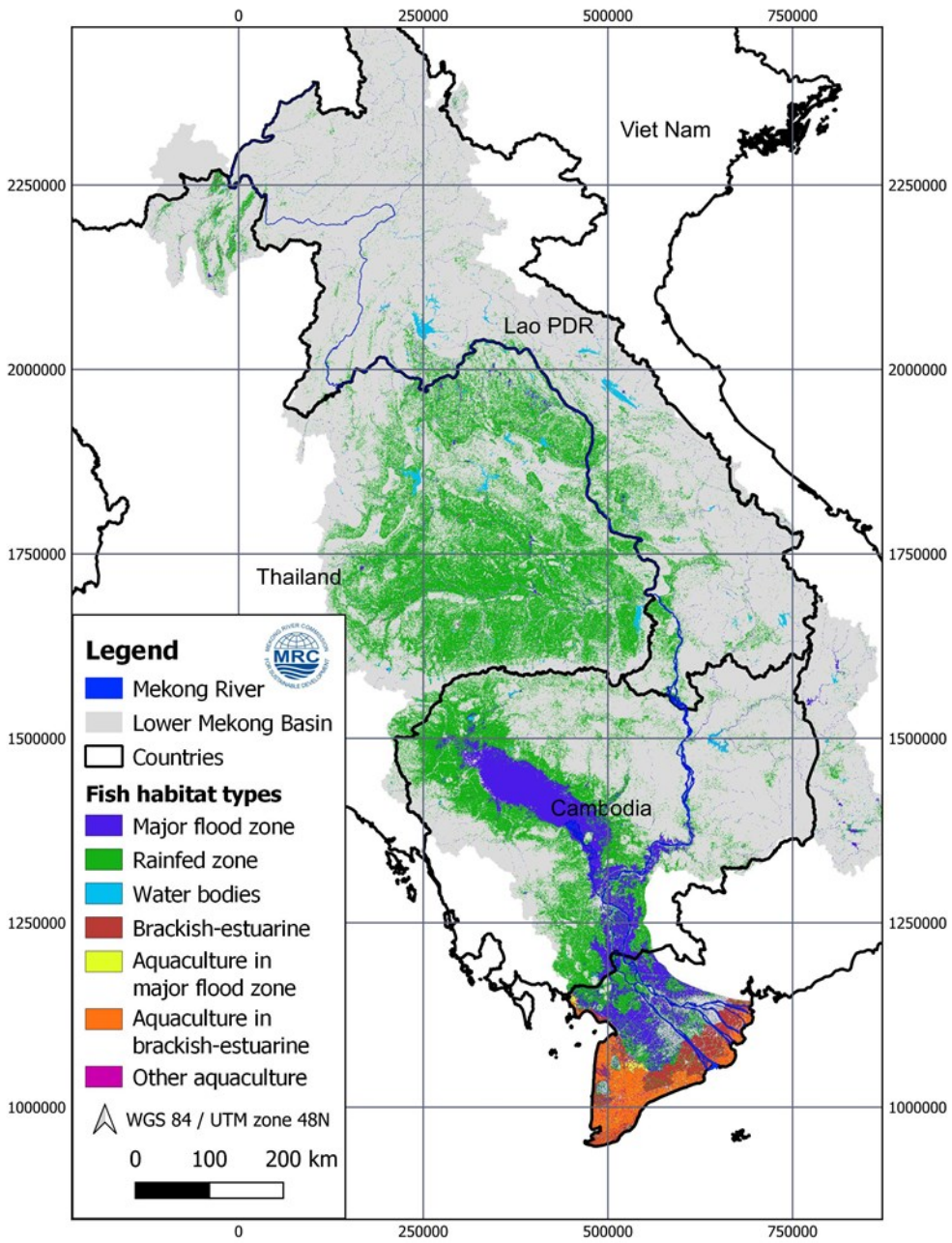


Figure 3.6. GIS mapping of different wetland habitats in the LMB, 2020

Of particular importance in the mapping stage is the distribution of floodplain and wetland systems that will be critical to fish population and community dynamics (Figure 2.4) and thus require protecting, or where degraded or disconnected for the river system can be instated to the original form and function.

Stage 2: Identify issues affecting fisheries and aquatic resources: Pressure–State–Impact

Stage 2 examines "*what is wrong with the river or reach of the river*". The impact of development on fisheries in the LMB has been well described in the context of hydropower (Campbell & Barlow, 2020; Dugan et al., 2010), but less well developed than other drivers, such as agricultural development (Vu, Hortle & Nguyen, 2021), mining, pollution or climate

change. The MRC Council Study (MRC, 2017a) explored the impacts of multiple drivers on ecosystem functioning and aquatic biota across the LMB as well as the cumulative and transboundary impacts of different sectors, but especially hydropower and climate change. The Vietnamese Delta study (DHI, 2016) further examined the impact of multiple drivers on the Vietnamese Delta area and Cambodian floodplain; however, little attention was paid to the impacts in Lao PDR and Thailand.

Stage 2 employs the DPSIR process (Box 1) and examines the main drivers (agricultural development, including massive expansion of rice farming, deforestation, hydropower development, mining, sand mining, urbanization and industrial development and associated pollution) to determine the current status and functioning of the river and the impacts on aquatic biota. The various drivers crucially induce various pressures on the ecosystem that lead to the degradation of the structure and functioning of the system (Table 3.3). It is these pressures that need to be addressed in any restoration project, or avoided when establishing protected areas. These pressures, where habitats have been degraded or where floodplain and wetland habitats have been disconnected, should be mapped and overlaid on GIS maps of fish distribution and abundance, including migratory pathways, to identify key areas that either need protecting or restored. For example, the distribution of water control structures in the LMB (Figure 3.7) clearly shows the potential impact on both longitudinal and lateral fish migration pathways. Similarly, Figure 3.8 shows the problem of levees designed to control flooding of rice production areas in the Delta and the lack of connectivity between the main river and remaining floodplain and the rice fields.

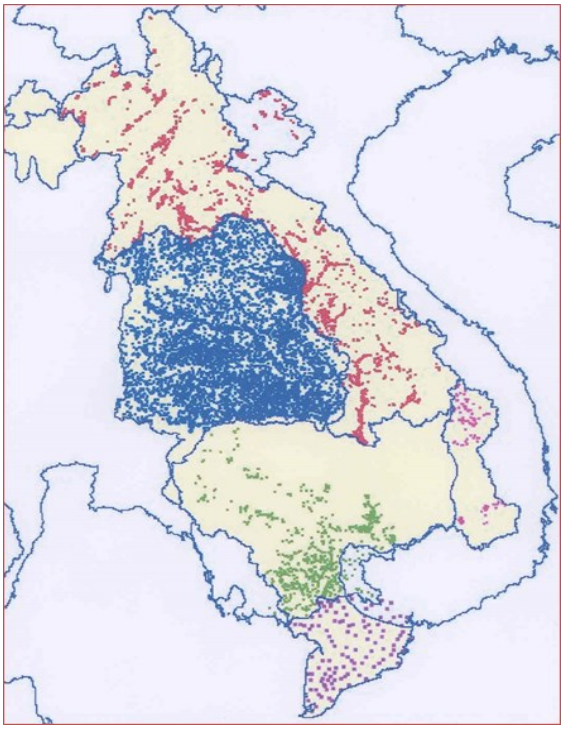


Figure 3.8. Location of water control structures across the LMB illustrating the scale of issues related to water resource management

Figure 3.7. Example of a disconnected floodplain

The impacts arising from these developments and interventions should be identified, specifically at the local scale in the immediate vicinity of the problem, and also at a regional and transboundary scale. It is recommended that interviews be carried out with local stakeholders and fishing communities to identify local issues (see Annex 5 for examples of semi-structured interviews). These impacts are then used to determine the potential management responses to address the problem (see Box 2 for Pressure–State–Impact assessment). It should also be recognized that climate change is affecting the hydrological regime and has the potential to override all other factors in the future, although climate variability and the likelihood for more extreme events, such as floods and droughts, is currently prevalent.

Box 2. Pressure–State–Impact

To understand the pressures-state-impact relationships, each must be understood in isolation. The various drivers crucially induce various pressures on the ecosystem that lead to the degradation of the form and function of the system (Table 3.3). It is these pressures that need to be addressed in any restoration project, or avoided when establishing protected areas.

State changes are hydromorphological or ecological process changes resulting from sector pressures, which are usually a degradation of physical habitat characteristics and the subsequent impacts on biota, in particular, macrophytes, macroinvertebrates and fish. These changes include:

- Flow alteration (regulation) and greater propensity of extreme events (droughts and floods)
- Habitat fragmentation
- Habitat homogenization
- Alteration of sediment erosion deposition processed or sediment reduction
- Riparian degradation/encroachment
- Floodplain disconnection/degradation
- Pollution/physio-chemical variables
- Loss of fish species diversity, reduction in catches, species composition or size of fishes in catch
- Loss of aquatic biodiversity and harvest of such resources.

All of these impacts can affect habitat availability for fish and their different life stages, and result in lost productivity and change in species composition.

This information on the impact of the main pressures in the LMB on aquatic fauna and habitats, together with possible management responses, is summarized in Table 3.3. This table can be used as the basis for focussing future projects to restore or protect key fish habitats.

Table 3.3. Summary of the impacts of main interventions in the Mekong River Basin on the aquatic environment, flora and fauna

Nature of change (State change)	Effect on aquatic fauna (Impact)	Management options (Responses)
Dam construction		
Transverse blocking of river channel	Blocking of longitudinal connectivity; interference with sediment and nutrient transport along channel. Shortening and disruption of migratory pathways and fish recruitment.	Construction of fish passage facilities.
	Shift from flood pulse to lake type environment upstream. Reduction in productivity upstream and downstream of dam.	Preparation of fishing communities for the transient nature of fisheries.
Alteration in flow regime	Reduction in flooding of floodplains and increased low flows. Decreased flow, which produces shifts from riverine to lentic fish communities. Increased phytoplankton production in main channel and increased planktivorous fish species.	Identification and mitigation of social and economic effects.
Disturbance of flow regimes downstream of dam	Inappropriate stimulus for fish breeding, leading to shifts in population away from seasonal spawners and towards those with more flexible spawning habits.	Cooperation with reservoir management authorities to ensure minimal flows and timely flood discharges.
Trapping of sediments	Incision of the downstream river channel, which reduce flooding of floodplains.	Identification and mitigation of social and economic effects.
Formation of reservoir upstream	Depletion in populations of riverine fish and change from lotic to lentic fish species. The destruction of aquatic vegetation and fish breeding areas due to the effects of drawdown and refilling.	Stocking of fish species that are better adapted to growth and reproduction in the reservoir environment. Stocking with young fish where recruitment is seen as a limiting factor.
Alteration of the thermal profile downstream of reservoir	Loss of thermal cues and a reduction in the growth potential and reproductive potential of aquatic organisms.	Mixing of surface water with hypolimnial water to minimize shifts in temperature regime.
Disconnection of floodplains for agriculture		
Construction of levees and flood control gates.	Interference with lateral nutrient interchanges reduces overall productivity of aquatic and terrestrial systems.	Control flooding of agricultural land, especially at the onset of the flood season.
Blocking of lateral movement and migrations	Denial of fish access to floodplains and side arms of rivers.	Construct fish passes to enable movements of fish into and away from agricultural areas, especially rice fields. Selective management of flood control systems

Prevention of lateral flooding and isolation of floodplain lakes and other water bodies.	Denial of fish access to floodplains and side arms of river. Disappearance of obligate floodplain spawners. General loss of habitat diversity.	Instal in-stream structures to create artificial breeding environments. Instal artificial in-stream habitat structures.
Channelization for flood control and navigation		
Simplifies channel diversity	Removal of habitats such as secondary channels and dead arms, changing nutrient dynamics and removes habitat for breeding, feeding and refuge; reduces numbers and biomass of food organisms..	Reinstate of river habitats.
Increases flow rate in channel	The consequent loss of rheophilic fish species due to young fish drifting past suitable areas for colonization.	Create off-stream nursery habitats and backwaters.
Dredging and gravel extraction		
Excavates channel bed and isolates channel from floodplain.	Prevention of lateral flooding Increased sedimentation, which interferes with nutrient and microorganism interchanges between main water column and substrate. Destruction of spawning substrate Diminished production of fish food organisms.	Regulate aggregate extraction activities in known spawning and nursery areas. Reinstate spawning substrata by deposition of gravels, encourage growth of in-stream vegetation.
Deforestation		
Increases in silt loading leading to changes in channel and floodplain morphology. Increases amplitude between high and low water discharges, may lead to desiccation of portions of river channel.	Reduction of habitat and community diversity. Choking of substrates, loss of food organisms and spawning sites for psammophil and lithophil fish. Makes habitats unsuitable for some or most fish.	Re-create habitat diversity. Clean substrata. Update legislation to ensure appropriate buffer zone is maintained along river margin.
Effluent discharge		
Point source pollution from industry, urbanization, mining and agricultural intensification.	Local mortalities of fish species; elimination of most sensitive species. Accumulation of heavy metals, pesticides and other harmful substances in the flesh of fish and in alluvial deposits.	Improve legislative controls to minimize discharge to acceptable levels. Installation of treatment facilities. Divest discharge to more appropriate water body.
Increases in nutrient loading leading to eutrophication.	Phytoplankton blooms in large slow flowing rivers and surviving backwaters Changes in fish population towards less sensitive ('r' selected) species.	Improve legislative controls to minimize discharge to acceptable levels. Control fertilizer application in the vicinity of water courses. Develop buffer zones to reduce nutrient run-off.

When undertaking this Pressure-State-Impact assessment, additional information must also be collected on the possible impacts of different development sectors (pressures), such as water resource management, flood protection, inland navigation and hydropower, on each other (cross-sectoral impacts), which have amplified the replacement of naturally occurring and functioning systems with highly modified and human-engineered systems (Table 3.4). The potential cross-sectoral interactions are identified (Table 3.4). Water resource development, for example, results in the construction of dams and irrigation channels, the construction of river embankments to improve navigation, drainage of wetlands for flood control, and the establishment of inter-basin connections and water transfers, all of which regulate the natural hydrograph and simplify river processes to meet human needs.

Table 3.4. Linkages between drivers and pressures

Pressures	Sectors – Drivers										
	Fishing	Agriculture	Urban land use	Water resource development	Flood	Navigation	Hydropower	Aquaculture	Forestry	Aggregate	Mining
Pollution and deterioration of water quality		■	■			■		■	■	■	■
Water abstraction		■	■	■			■	■			■
Impoundment, artificial barriers		■	■	■	■	■	■				
Flow regulation, hydropeaking				■		■	■				
Embankment, levees or dikes		■	■	■	■	■	■	■			
River fragmentation		■	■	■	■	■	■	■			
Alteration of instream habitat		■	■	■	■	■	■	■	■	■	
Sediment input		■	■						■	■	■
Sand and gravel extractions, dredging			■		■	■				■	
Deforestation		■	■	■	■	■	■	■	■		
Invasive species	■	■						■			
Climate change											

Restoration options, as described in Stage 3, can then be selected, but this will primarily depend on which sectors (drivers) are present, the level of impact they have on hydromorphological characteristics, ecosystem functioning and biota necessary to support a healthy ecosystem and the period of endurance.

Stage 3: How can we restore or protect key fish habitats?

Development activities within the Mekong have the potential to alter four important physical characteristics, hydrology, sediment, water quality, and connectivity (or physical barriers caused by the presence of the dams or flood protection levees). These physical changes can cause, or drive, impacts on aquatic resources in the immediate area of the development and further afield (transboundary effects). These can cause numerous changes to the physical and biological systems in the LMB, which could directly and indirectly affect the natural environment and ecosystem functioning, with implications for aquatic ecology, fisheries, including OAAs, and biodiversity. Changes to these resources can then impact on economic conditions in the impacted area and the livelihoods of local residents. The impacts of the main development activities have been highlighted in Stage 2, and should be used to determine measures to restore key habitats for fish or which areas to protect.

This assessment requires the considerable information on the key ecosystem elements of hydrology and hydraulics, sediment, water quality, aquatic ecology and fisheries collated in Stage 2 in order to formulate actions to protect or restore habitats. This information will contribute to understanding which elements of the habitat are altered and need remediation, or which elements need protecting. This assessment will provide knowledge on the technical policy and a background on conflicts of multiple users of common resources. It will also allow to compare the status of fisheries resources against overall policy objectives and the needs of local stakeholders.

Basically, the information acquired from the assessments of "*How the river works*" (Stage 1) and "*What is wrong with the river*" (Stage 2) feeds into the project planning approach to identify, formulate, implement and undertake post-project monitoring and evaluation of the restoration or protection project (Figure 3.3). Planning of individual river restoration projects sets project objectives to improve ecological status of key habitats at a local scale, but must consider the project in a river basin or catchment context. The project cycle (Figure 3.3) follows the basic Plan, Do, Check, Act structure, but includes more detailed planning phases that are described in the following steps and summarized in Annex 6 with example criteria and information. The initial project identification and formulation phases can be linked to the DPSIR approach (see Box 1).

By using this approach, it is important to recognize that each project to restore or protect key habitat should be treated individually because no situation is alike; *however*, each project should be linked to existing or other proposed new schemes to ensure the fisheries and aquatic resources benefit from the synergistic interactions of existing and proposed projects. This Technical Guidance allows the proposal to be evaluated at different levels and stages, and will effectively curtail a proposal at an early stage should that proposal be potentially impractical or unviable or not achieved the desired goals. Details on each step are given in the following subsections.

Step 1: Project identification

Project identification is the stage at which the initial proposal to restore or protect the key habitats is conceived and formulated. This identification phase is divided into two fundamental aspects. First the concept of the habitat restoration or protection project is considered in relation to:

- the overall status of the aquatic ecosystem functioning and the ecological status or potential;
- the regional or national policy and conservation priorities;
- local and national legislative frameworks to ensure benefits are accrued.

The first step provides an understanding of the current status of the ecosystem functioning and ecosystem services in the management zone to establish the baseline against which to develop any project to restore or protect the key habitats (Step 1 is equivalent to the DPSIR State assessment). The **basic information** required is gathered in Stages 1 and 2, and includes:

- background geography and landscape topography, political domains, climate, and general infrastructural development;
- habitat modification and geomorphological alteration;
- hydrology, including modifications to flow regulation, abstraction and other water uses;
- flood defence;
- fisheries, recreation and conservation;
- water quality;
- land use/navigation and mineral extraction;
- urban, agricultural and industrial development.

All possible information is collated and analysed to provide a comprehensive overview of the ecological status and resource use patterns. The ecological characteristics of the fisheries and aquatic biodiversity should be set in the context of habitat requirements to complete their life cycles and ensure successful recruitment to support sustainable fisheries, as well as improve the conservation status of endangered species.

Key to this evaluation is the assessment of the inter-relationships between human activities (cross-sectoral interactions) and environmental factors that drive the ecosystem functioning and provision of services (Step 2), as well as how they will be impacted by the different sectors individually and synergistically. Assessing the **potential impacts** requires several major inputs, including the following:

- baseline conditions for selected key indicators of river system flows and velocities, sediment loading and transport, and water quality;
- baseline conditions for key indicators of current status of aquatic ecology fisheries, OAAs and biodiversity;
- changes that have occurred in the key indicators of river flows and velocities, sediment loading and transport, and water quality that have degraded the environmental quality and capacity to support fish and fisheries. This is achieved by comparing the current state with corresponding baseline (reference or historical) conditions; and
- changes that have occurred in key ecological indicators as a result of the numerous pressures on the LMB ecosystem.

Particular environmental characteristics that need to be examined include hydrology and limnology, and their modifications, water quality, land use changes, habitat degradation and other impacts from different resource uses. This information is available in the MRC State of the River Basin Report (MRC, 2020) and online resources (MRC Data Portal). This information should be supplemented by information from local sources, and critically, by discussions with stakeholders. Field visits and surveys of key habitats and associated features should be part of this step, including semi-structured interviews (Annex 5) with fishing communities, riverine communities and local administrative officers regarding setting up any proposed measure, governance structure and expected outcome of the measures. In addition, walk-over surveys should be carried out around the target area to identify problems with the water body form and functioning, and to discuss opportunities to protect or restore key habitat. This is effectively a visual assessment of the state of the target aquatic ecosystem and key habitats, and an identification of the main issues preventing it from delivering services.

In addition to an assessment of the aquatic resources, equal attention should focus on socio-economic and institutional frameworks. These frameworks influence the way the resources are exploited and managed, their role in society and thus the performance of provisioning services in regional economies. The capacity of the institutional arrangements to manage and enforce legislation is fundamental to implementing habitat restoration or protection actions developed within a plan. Much of this information is provided in the country reviews that underpin this Technical Guidance. Similarly, knowledge of the socioeconomic status and pressures is critical to developing a sustainable habitat restoration or protection plan and the associated actions. Finally, it is critical that full consultation with stakeholders and those likely to be affected by the habitat restoration or protection scheme be carried out at this stage, and the needs and aspirations of all people and communities included in the decision-making. At this stage, it is also particularly important to engage with local stakeholders and people likely to be affected as they need to adopt and potentially manage any new assets. These factors set the proposed habitat restoration or protection project in the context of policy issues.

In the second aspect of the identification phase, the **relevant policy issues** from Stage 1 need to be considered in relation to the desired policy objectives of the proposed action, notably:

- the overall justification for the project (perspectives, development objectives);
- the likely target groups and beneficiaries, as well as those who might be adversely affected;
- the key factors influencing the likely success and failure of the project;
- local and national legislative frameworks that support project development, implementation and management.

Step 2: Setting project objectives

Objectives for habitat restoration or protection should be clearly defined and adopt a river basin-wide approach. They should be developed from high priority regional and national policy objectives (equivalent to the DPSIR drivers assessment), as described in Box 3.

Typical policy **objectives** include:

- Ensure effective conservation and efficient exploitation of resources
- Contribute to species conservation objectives
- Create regional employment and maximization of social benefits
- Establish regional development (regional and multilateral cooperation)
- Establish legal and administrative framework for regulation
- Assess environmental, economic and social impacts
- Maximize ecosystem health.

Box 3. Setting project objectives

Establishing project objectives that relate to the functional aspect of the ecosystem is central to successful river restoration, and should be the first step within the Technical Guidance. The specific, measurable, attainable, relevant and time-bound (SMART) approach is recommended to establish objectives. The achievement of the objectives should benefit biotic communities while enhancing understanding of how communities respond to changes in physical habitat over time. For example, the needs of individual fish species, size classes and guild structure should be considered to establish the degraded habitat and identify the habitat improvement measures required.

Key questions to consider include:

1. Is the main aim of the project to improve the physical processes of the river or to increase biological diversity in defined areas?
2. If the focus is to improve river form and processes, what will be the ecological benefits, i.e. to the specific fauna and flora, and where appropriate, life cycle stage(s)?
3. If the focus is to increase ecological (habitat) diversity for a range of fauna and/or flora, which parts of the life cycle are being targeted to restore, and what physical river features are expected to improve to support this goal?
4. Are the objectives SMART:
   - Clear (Specific)?
   - Quantifiable (Measurable)?
   - Achievable, Realistic and Time-bound?
5. Have quantitative or qualitative indicators been established that provide a simple and reliable means to measure achievement, reveal the changes connected to an intervention, or help assess the performance of an organization against the stated target.

It is recommended that the logical project approach (Box 4) be used to characterize project needs. The approach sets out the design of the restoration or protection project in a clear and logical way so that any weaknesses can be brought to the attention of the planners. Any deficiencies likely to arise in implementation can then be identified and remedied at an early stage, or if insuperable, the habitat restoration or protection project may be discounted. The logical project framework approach emphasizes the value of choosing measurable indicators or endpoints, which can be assessed throughout the life of the project, and also instructs the planners to carefully assess the risks and assumptions on which the project is based. Mechanisms for setting endpoints against which the success of the project can be measured are defined in Box 5.

Box 4. The Logical Project Approach

Once the project objectives have been determined (see Box 3), these outputs can be used to formulate the best restoration measures to achieve the desired goal, or the best location of the protected area to meet the conservation objectives. Since there is likely to be more than one option (measure) or a combination of options to resolve an issue, or different locations of protected areas, the advantages and disadvantages of each should be considered and their interlinkages explored. In addition, this analysis should include the feasibility of achieving the outcome of the stated option both from a technical as well as a financial perspective, and also to identify win-win scenarios. If necessary, an alternative solution may need to be sought. Critical in formulating objectives is identifying institutions and stakeholders responsible for implementing any action arising from the options analysis. This procedure can be developed using the project framework format (Table 3.5) that might be adopted at the outset of a restoration project. Starting with the aim of the project, a series of objectives, outputs and inputs are developed in the first column at the left-hand side of the page, "Project structure". The second column provides the indicators (endpoints) that have been determined at the outset of the project, and how they can be verified as the project is developed further through the various phases of the project approach. The final column assesses the risks and assumptions that underpin the elements described in the first two columns. As the restoration project develops, the logical project framework will be modified to take into account new information likely to affect the project elements.

Table 3.5. The Logical Project Framework approach for design restoration or protection projects

Project structure	Measurable indicators	Means of verification	External factors / assumptions
Goal: Sectoral objectives			
Purpose: Specific objective			
Outputs			
Activities		Inputs	

Box 5: Setting benchmarks and endpoints

Setting benchmarks and endpoints that are linked to clearly defined project goals is a valuable approach to help determine the measure of success within river restoration or protection projects. They place a level of quality to project outcomes that can be used as a standard when comparing other aspects against which to measure performance.

Benchmarks are measurable targets for restoring degraded sections of a river to protect key habitats. They are representative sites with similar characteristics within the same river or catchment, but differ from the degraded sections by having the required ecological status and being relatively undisturbed. Setting benchmarks draws on the assessment of catchment status and identifies restoration needs before selecting appropriate restoration or protection actions to address those needs.

Endpoints are target levels of restoration or protection actions. They can be ecological, social or hydromorphological, and are usually linked closely to project objectives. Given that benchmark standards cannot always be achieved, especially on degraded river sections, endpoints will assist in moving restoration efforts towards benchmark standards through application of the SMART objectives approach (see Box 3).
The process of benchmarking can be broken down into a number of steps:

- **Reference condition**: Establishing reference conditions according to a multiscale framework for hydromorphological river flow characters;
- **Expectation:** Establishing endpoints for characteristics of concern that reflect the overall restoration or protection goals;
- **Baseline condition:** Identifying hydromorphological or habitat conditions and processes that constrain recovery, and exploring the restoration or protection potential to establish endpoint target conditions.

Once the endpoints have been established, these restoration-protection targets need to be integrated into wider catchment-based restoration or protection activities to deliver win-win scenarios, taking due account of the cost and benefits, specifically in relation to ecosystem services delivery.

Where possible, the endpoints should define the target groups, quantities, quality, time and location. The section of the project devoted to the risks and conditions of the logical project framework is concerned with establishing realistic parameters of the environment in which the development project is to function and the likelihood of the project meeting its objectives.

Step 3: Project formulation

Habitat restoration or protection measures should be planned at a catchment scale and has five main components:

1. River characterization and condition assessment, including understanding of existing measures;

2. Potential for river restoration or protected areas
3. Selection of key habitats and priority sites;
4. Selecting appropriate measures for restoration or protection of key habitats; restoring specific habitats is more important than merely increasing habitat diversity; and
5. Project appraisal, i.e. determining the trade-offs between small restoration projects or individual protected areas/conservation zones against large-scale transboundary projects with long-term objectives.

The formulation of projects to restore or protect key habitats naturally falls out of comparison of the status of the aquatic ecosystem and the overall regional and national policy objectives (Figure 3.9). The assessment relies heavily on existing information or expert (local) knowledge, and requires a thorough evaluation of all available information, and where information is limited, it may require addition surveys prior to any decisions about setting up a protected area or implementing a restoration action. All information is collected in Steps 1-3 and decisions on the type of project that best fits the objectives can realised by following the decision tree in Figure 3.9.

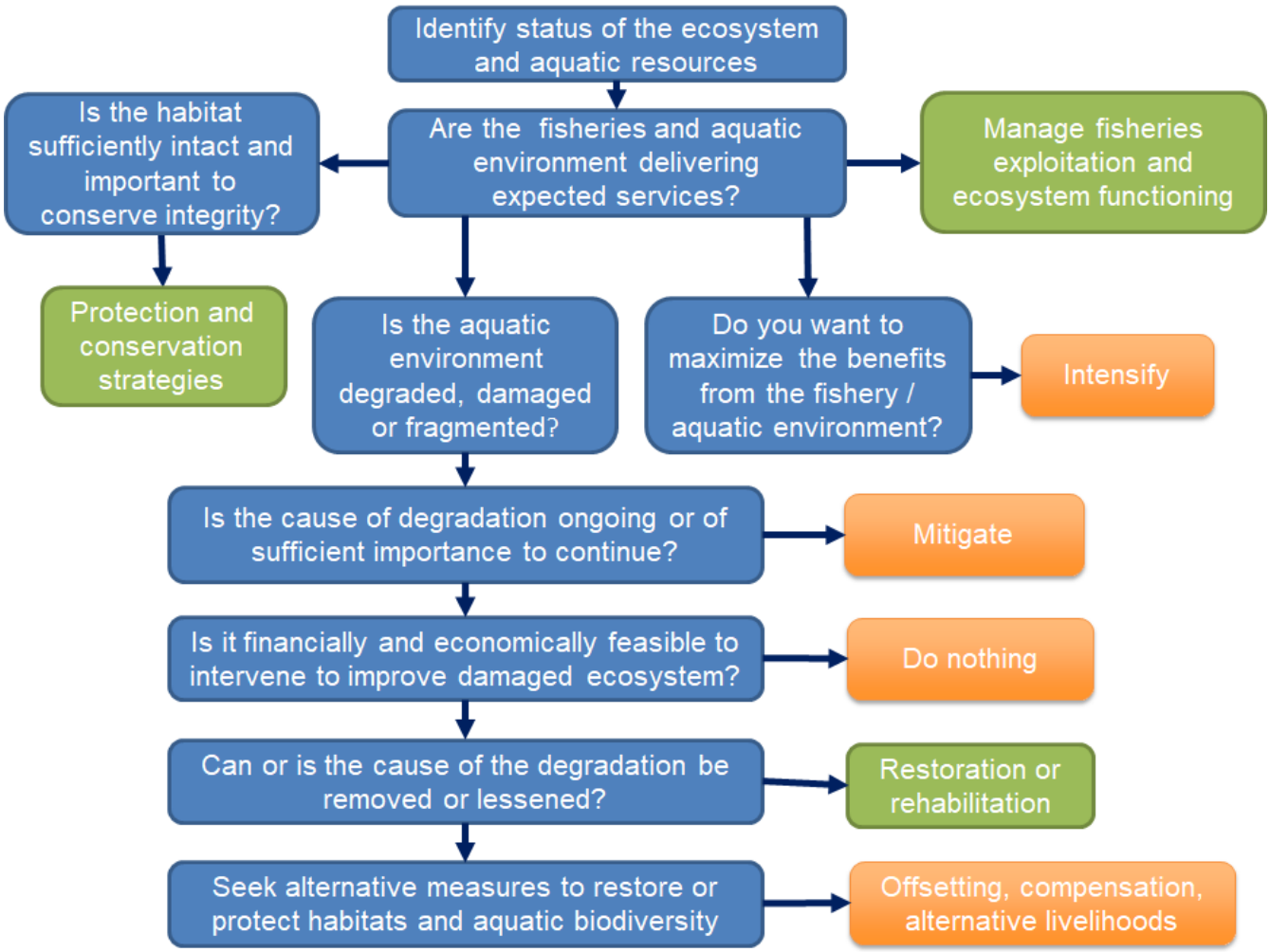


Figure 3.9. Choice of strategies for restoration of key habitats or establishing protected areas

This assessment highlights the dichotomy between current status and functioning of the ecosystem, as well as aspirations for the water body. Accordingly, it draws out the aspects of

the water body that will need to be maintained, improved and developed, and identifies the issues and constraints to achieving the target. Typical areas to assess are:

- maps that demarcate key habitats in the LMB ecosystem and rank key conservation areas, including spawning grounds, according to their consistency with medium- and long-term sustainability of the basin ecosystem;
- the natural resources of current and/or potential economic importance;
- the extent to which effective natural resources management is currently achieving objectives and future proposals in the light of technical and institutional capabilities;
- management options and legislation as the basis for restoration or habitat protection strategies;
- externalities that impact on the ecological status and responses to these externalities;
- economic and functional linkages between restoration and habitat protection actions and between other sectors (e.g. hydropower and navigation);
- the potential for combining activities to optimize resources or increase benefits;
- actual and perceived conflicts and ways to alleviating them;
- how legal frameworks add or detract from successful economic performance;
- monitoring and enforcement of management regulations;
- social issues regarding restoration or protected area objectives;
- capacity of research institutions and institutional frameworks for dissemination of information; and
- existing skills and aptitudes that can be developed to generate increased benefits.

Figure 3.9 illustrates a decision tree to determine the current status of the zone (local and or transboundary) and the potential options to address the problems. This decision tree has utility because it avoids expending efforts in restoration projects or establishing protected areas when they clearly will not achieve their desired goals. Within this stepwise process there is a specific pathway for defining and establishing protected areas (see Specific approach to selecting priority habitats to be established as protected areas for conservation purposes in the Mekong, p. 39). This option should technically only be available where the river zone is functional and delivering the desired ecosystem services.

Once the various issues have been reviewed, the sites should be prioritized to ensure that the key fish habitats of regional importance are selected for appropriate restoration or protection actions. Criteria for prioritizing sites are given in Box 6. Again, it is important to visit the potential habitats that will be restored or protected, and check potential factors that may conflict with other water resource users and stakeholders, and reduce the likelihood of the measure achieving its objectives. It is imperative that local communities are engaged and participate in the formulation of the project at this stage.

Box 6. Criteria for selecting key fish habitats of regional importance for restoration or protection

- contain natural or near-natural habitats that support vulnerable, endangered, or critically endangered species, or threatened ecological communities;
- support a significant proportion of indigenous or endemic fish subspecies, species or families, life-history stages, species interactions and/or populations;
- support populations of fish and other aquatic animal (OAA) species that are important for maintaining food security and rural livelihoods;
- support critical stages in the life cycles of target fish or aquatic animal species, or provide refuge during adverse conditions;
- are important feeding areas, spawning grounds and nursery areas, and/or represent key migration pathways on which fish stocks and OAAs depend;
- maintain the biological diversity of a particular biogeographic region;
- are sites of hydrological and geomorphological importance to aquatic biodiversity; and
- are sites hydrologically intact or suitable for remediation, reconnection or flow management;
- are sites support important ecosystem services (benefits to people); and
- are sites provide significant contribution to improving sustainable outcomes, i.e. sustaining overall ecological balance and functioning.

This information should include the transboundary nature of fish life cycles and must be used to inform the planning, formulation and implementation of protection and restoration measures.

When defining the sites for restoring or protecting the key habitat, due recognition should be given to existing protected areas, including the 12 prioritized regional environmental assets, RAMSAR sites, fish conservation zones and sanctuaries, and those already designated under international agreements as international and/or regional importance. It is critical to determine whether these habitats provide the needs of the target fish or aquatic organisms, or whether they can be built into the proposed network of sites to be restored or protected. The aim is not to focus on existing protected areas, but rather to build on their legacy.

Once the priority sites have been identified, the most appropriate measures to restore the key habitats need to be selected. A wide range of measures are available to address the main problems arising from different sectors (drivers) that have degraded the habitat and thus should be suitable to improving the priority habitats identified (Figure 3.10). Criteria for selecting the most appropriate measures are given in Box 7. In this context, a catalogue of potential measures that will be effective in the Mekong region under different scenarios should be produced, including the likely success of the measures under different environmental conditions, including: accounting for climate change; and clearly defining the most effective protocol for deciding whether or not an action should take place, how it should be implemented, and the potential impacts of such activities on other activities.

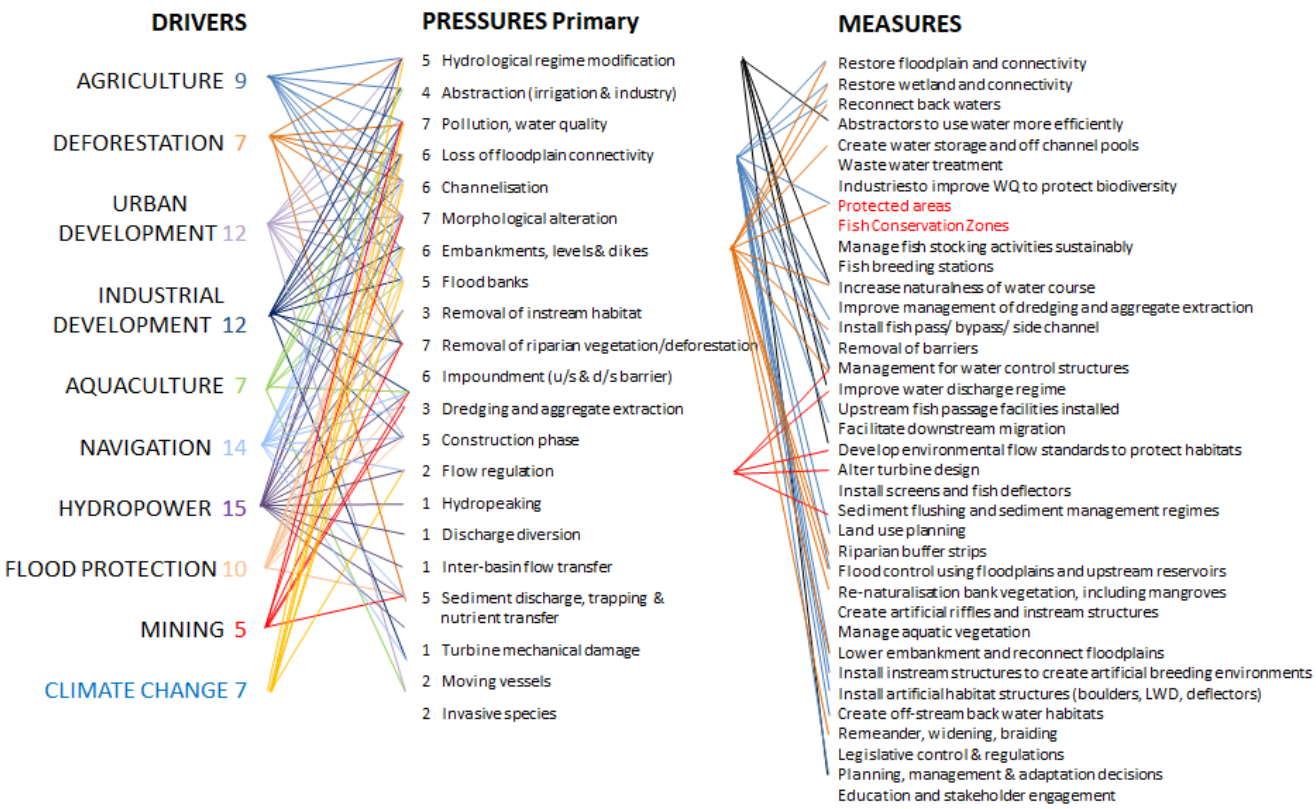


Figure 3.10. Summaries of the main potential measures available to respond to the main pressures found on river system

Note: These summaries can be found on a number of online sources including: REstoring rivers FOR effective catchment Management (REFORM – http: //wiki.reformrivers.eu/index.php/Main_Page); River Restoration Centre (RRC) Manual of River Restoration Techniques (www.therrc.co.uk/manual-river-restoration-techniques); the European Centre for River Restoration (ECRR) manual of restoration projects (www.ecrr.org/River-Restoration/RiverWiki-Projects-Database/userId/12937); and the US National Fish Habitat Partnership's National Fish Habitat Assessment (www.fishhabitat.org/)

As part of the appraisal of prospective restoration projects, there is a requirement for consultation through the planning and implementation phases to ensure that all stakeholders have a say in the development and engage with the project. As part of this consultation, an evaluation should also be carried out on the current and future conflicts, both real and perceived, between the project activities and outcomes, and other user groups.

To assist in the resolution of conflicts it will be necessary to identify a lead organization to chair the discussion and drive uptake of the proposed restoration measures or protected areas. If possible, the lead organization should be from one of the local user groups or agencies that assist in regulating the use of the aquatic resources. This local devolvement of management is essential to the overall success of the activity because it immediately removes the distrust often associated with politically appointed agencies.

Box 7. Criteria to select the most appropriate measure(s)

- **Suitability:** How well does the measure fit into the system, landscape or biophysical and socioeconomic context? Will it help restore or protect key habitat characteristics that support the life cycle needs of the target species?
- **Feasibility:** How easy will it be to design and construct, or retrofit the restoration or protection measure? Are the appropriate conditions available to ensure that the measures are sustainable and will not be impacted on by future development scenarios, including climate change?
- **Costs**: Are the financial instruments in place to cover the capital and recurrent costs of the measures implemented? Can cheaper options be found that deliver similar outcomes?
- **Effectiveness:** How effective will the measures be towards achieving the objectives, including the protection or enhancement of biodiversity, and the provision of opportunities to improve fish population and community dynamics linked to sustainable productivity?
- **Cross-sectoral impacts:** Do the restoration or protection measures have implications for water allocation and uses? Can trade-offs be established between users to optimize the benefits of water use and allocation? Do the measures have other environmental or social impacts?
- **Management requirements:** Do the proposed habitat restoration of protection measures have specific management requirements for both water resources and fisheries? Are these resources available as required? Are the appropriate technical skills and capacity available to manage the project over the duration of the project? Can they be linked to suitable co-management or community management arrangements?
- **Social dimensions:** Are the measures proposed acceptable to the local user groups and those who derive livelihoods from the area of influence? What changes in user behaviour are needed to facilitate adoption of the proposed measures?

Specific approach to selecting priority habitats to be established as protected areas for conservation purposes in the Mekong

Establishing protected areas, conservation zones and sanctuaries within the Mekong requires specific dialogue, because there are already a number of 'protected areas' (now termed 'other effective area-based conservation measures' [OCEMs]) in the form of formalized FCZs, fish sanctuaries, and zones defined for protecting the fisheries under religious beliefs, typically deep pools throughout the Mekong mainstem (Section 2.3 and Figure 2.5). While the PAs may help protect fisheries and aquatic resources, most are not set up with fisheries in mind; rather, they are based on local beliefs or have been established where there is a willingness or desire to help protect the functionality of the river or specific species of conservation value, support improved productivity from the system, or a combination of these. Thus, any actions should first explore the existing network of protected areas, FCZ and sanctuaries, and determine whether they are suitable for meeting the fisheries conservation objectives or improve yield/production.

To achieve this, the existing OECMs network should be mapped and explored in the context of whether they are providing pristine habitat, protection of habitats of importance to ecosystem functioning, or protection/conservation of priority species (Figure 3.11).

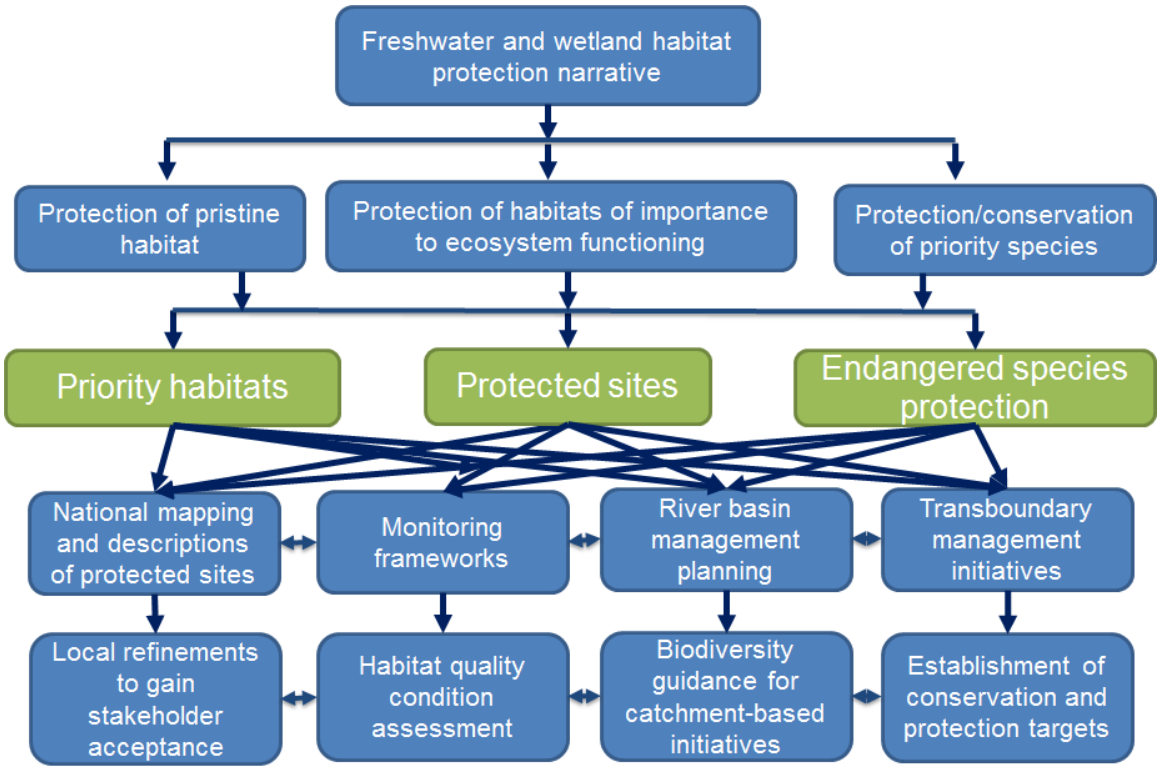


Figure 3.11. The role of freshwater and wetland habitat protection narrative in underpinning approaches to protected sites and priority habitats

In particular, there is a need to:

- assess and catalogue the efficiency of existing protection and conservation measures of key species, including high economic value migratory and endangered fish species, in relation to present and future threats;
- understand the potential for co-management arrangements or community-based management in the management and conservation of key habitats, based on regional experiences; and
- include management and conservation of key habitats in transboundary fisheries management arrangements.

The above has been partly done in the country reviews (Section 2.3), but needs to be re-examined to check if the "protected areas" can be redesignated for fish and aquatic biota, especially where they have been set up for terrestrial species/habitats. Once carried out, the "protected areas" should be checked to see if they meet all the habitat needs of the species of conservation concern and whether the pathways between the protected areas have been disrupted. The minimum distribution range of migratory species should be delineated from historical information of fish species in the Basin and the relationship to various habitat needs for the target species to meet its life history requirements (see Annex 3). The latter habitat requirements can be derived from GIS sources and related to species habitat quality and critical habitats mapped from indigenous knowledge collected during Fish Abundance and

Diversity Monitoring (FADM), Joint Environment Monitoring Guidance (JEM), Core River Monitoring Network (CRMN) and other ongoing MRC monitoring activities. In doing this, it should be recognized that there are multiple species migrating through the whole of the Mekong and within sub-basins when identifying migration zones; thus, connectivity assessments should also be carried out on a larger scale and should consider the hydro-geomorphological complexity of all river sections or whole rivers.

Once the assessment is conducted, it is feasible to define whether the network of "protected areas" is sufficient and where it will be most appropriate to establish new Protected Areas or FCZs of strategic value to sustaining fisheries and aquatic resources. This then follows the the project approach described in Figure 3.2.

Step 4: Risk assessment

An essential component of any habitat restoration or protection project formulation is to understand the risks and uncertainty associated with implementing the project. The objectives of the habitat restoration or protection project, as defined in Step 1, are put in perspective with the overall fish/aquatic biodiversity conservation and exploitation objectives pre- and post-intervention. The latter should be expressed not only in terms of maintaining ecosystem function and associated ecosystem services, but also in terms of conservation of threatened species, additional fish production or livelihood benefits, especially for more marginal groups with limited livelihood options.

There are two important sources of uncertainty in any habitat restoration or protection project: uncertainty about predictions of outcomes, and uncertainty about the preferences of affected stakeholders. For stakeholders, it is not only difficult to ascertain their own preferences and to be able to quantify them, but also to understand their own risks from the intervention. Clearly separating scientific predictions and societal valuations is an essential element of any decision support procedure.

Uncertainty about scientific predictions can be addressed by undertaking risk analyses and predicting the likelihood of outcomes achieving the desired objectives such as in the MRC Council study (MRC, 2017) and in the various Prior Consultations for mainstream dams carried out to date and described in Box 8. Uncertainty about stakeholder preferences is often better addressed by sensitivity analyses of the ranking of the predicted outcomes arising from different options to address the same problem. Communication of the uncertainty is critical to maintain the trust of the stakeholders in scientists and managers making the final decisions.

Assessment of hazards and risks of habitat restoration and protection activities

To assess the scale of risk, with a degree of uncertainty, of any habitat restoration or protection project, there is the need to undertake a risk assessment. The risk assessment analyses the major biological and environmental benefits to regional economies, and if necessary, accounts for them (Box 8).

The assessment is based on a comparison of the predicted outcomes of the different options to restore or protect key habitats against the current situation, or against where no project or activity has been undertaken. Potential outcomes and hazards include:

- a reduction in loss of species of conservation concern or improvement in their threatened status;
- key habitat form and function reinstated to support fisheries and biodiversity;
- the wild fish population characteristics in the target water body (specifically the natural production cycle) improved with associate improvements in catch dynamics;
- improvements in fish and aquatic biodiversity community structure and dynamics of the target water body;
- the environment of the target water body improved or reinstated; and
- improved governance of extant fisheries.

It is the potential interactions between these elements that may pose risk to the outcomes of the wild stocks. Priorities of action will be defined according to the perspectives of multiple stakeholders, including those dependent of the resources for their livelihoods.

Box 8. Assessment of hazards and risks of habitat restoration and protection activities

Risk assessment is used to determine the likelihood that an event may occur and what the consequences of such an event will be. A risk management framework operates by establishing the context (i.e. habitat restoration or protection measure), identifying the risks to the existing situation (consequence and likelihood), and assessing and treating them.

The level of risk of any project can be defined using risk matrix (Table 3.6). The matrix typically considers the probability or likelihood of occurrence of a project having an impact (positive or negative) against the category or scale of *consequence* (impact). The rating refer to the probability (*likelihood*) of the impact (*consequence*) occurring as the result of a habitat restoration or protection measure on the defined attributes of the ecology of the species and the environment where the action is implemented.

The *likelihood* of an event occurring is defined according to the rating in Table 3.6. An example of a risk matrix to define impact of restoration or protection measures is given in Table 3.7. The *consequence* refers to the scale of the potential impacts based on knowledge of ecological interactions between the habitat restoration or protection measure and the changes that occur in the target water body. The rating are, where possible, based on scientific evidence; otherwise, expert judgment is required. The latter introduces a level of uncertainty into the assessment procedure that must be accounted for. As a consequence, there is a need to introduce a further layer to the matrix that accounts for uncertainty in the knowledge base or processes in nature (Table 3.8). Where knowledge is deficient or uncertainty is high, the precautionary approach should be applied to prevent unforeseen impacts. It should also be recognized that the risks associated with stock enhancement can be reduced by mitigation actions, such as quarantining fish before stocking or stocking with reproductively sterile fishes (e.g. triploids). If applied, these procedures should be weighted into the overall assessment.

Table 3.6. Example of a risk matrix for use define impact of restoration or protection measures

			Consequence		
Likelihood	**Insignificant**	**Minor**	**Moderate**	**Major**	**Significant**
Rare	N	L	L	M	M
Unlikely	N	L	M	H	H
Possible	N	L	H	H	E
Likely	N	M	H	E	E
Almost certain	N	M	E	E	E

Note: N = negligible; L = low, M = moderate; H = high; E = extreme.

Table 3.7. Likelihood rating

Likelihood	Description	%
Rare	Event will only occur in exceptional circumstances	<5
Unlikely	Event could occur but not expected	25
Possible	Event could occur	50
Likely	Event will probably occur in most circumstances	75
Almost certain	Event is expected to occur in most circumstances	>95

Table 3.8. Weighting to account for uncertainty about potential risks from restoring or protecting key habitats

Degree of certainty	**Description**	**Weighting**
High	Well-established knowledge from existing habitat restoration or protection programmes	0.5
Medium	Knowledge from limited habitat restoration or protection programmes supported by documented ecological and environmental studies	1.0
Low	Little or no previous knowledge from habitat restoration or protection programmes and little or no supporting ecological and environmental studies	3.0

Note: Weightings are arbitrarily defined in this example and should be set to reflect the scale of risk likely to arise from the proposed activity.

Step 5: Project implementation

Once the identification, preparation and appraisal steps have been completed and the measures for restoration or habitats to be protected are decided, arrangements need to be made between the management team and stakeholders to commit to implementation.

Typical arrangements for implementation entail:

- negotiating the budget to construct the infrastructure for the protected area or to install the restoration measures;
- establishing local regulations to protect the restored habitat or protected area for future degradation;

- making local co-management arrangements to monitor and maintain the integrity of the restored or protected habitat;
- providing appropriate budgets and manpower to support local management, including time commitments by local stakeholders and community groups; and
- minimizing targeting of the fish or aquatic biodiversity that the habitat is designed to protect, especially during vulnerable life stages.

However, the project(s) may still face problems no matter how positive it is evaluated in the early stages of the assessment. Therefore, certain features of the project, should they become adverse, could render cost-effective implementation impossible, for example, long-term shortage of water of the correct quantity and quality, or extreme and adverse changes in land use that affects sedimentation and erosion processes, or climate changes that lead to extreme drought or flooding events. Contingency measures are required for these circumstances as well as options to adapt the project to ensure that the desired objectives can be achieved. Those who implement the project may find that, although the development objectives of the project are constant, implementation will often deviate from originally envisaged. The problems range over less severe scheduling and underestimating costs, to issues involving difficulties in land use change and project inflexibility causing further degradation of resources (e.g. fish stocks, water quality).

This phase may also prove difficult if the costs of the project, both capital and recurrent, increase, because new external impacts emerge, resulting in conflicts with other water resource users. To overcome this, the implementation phase needs detailed work plans and financial arrangements, which may have to be refined several times since the identification step. These should be translated into activity schedules, including targets for success, roadmaps (i.e. milestones) for delivery and quantifiable indicators of achieving steps in the delivery process. Disbursement of project funds into budget heads should be established, and all the monitoring and control mechanisms should be in place. Economic assessments of this type can help avoid problems with the implementation because they take into consideration the opinions of the user groups. Problems may also arise from introducing legislation and regulations. This is best achieved through the consultation process and devolving enforcement to the local communities.

Key to successful implementation are the following:

- agreements and commitments of those who is affected by the project (*stakeholders*);
- devolution of responsibility for the project management and the benefits gained from the project to the local communities (*third sector involvement and community engagement*);
- stakeholder *engagement* through the design and implementation phase to understand and address stakeholder concerns;
- open dialogue and active conflict resolution seeking *compromise* between competing and conflicting demands – with smaller, less influential, sectors of society having equal say in the decision and implementation phases; and
- continuous *communication* between project managers/implementing agencies and stakeholders.

Restoration and protection plans should not be based just on technical issues and their effectiveness or limitations but must involve:

- regional policy frameworks;
- societal and prevailing ideas and values; and
- institutional frameworks aligned with regulations and legislation, and endorsed and recognized by district or province-level water resource, agriculture and fisheries agencies.

It should be recognized that inputs to this phase of the planning will vary depending on the scale of the restoration project. Small individual projects such as revegetating the riverbank with mangrove trees to provide riparian cover and stabilize the riverbanks will require less investment in the planning process than reconnection of large wetlands or building a fish pass. To support the implementation of measures to restore or protect key habitats for fish, there is a need to:

- build databases of all protected areas in the region, and indicate why they were established and the characteristics of their operation;
- collate a database of habitat restoration activities undertaken in the LMB and other rivers in the region to provide a knowledge base for selecting future restoration measures;
- develop regional and local training programmes to build capacity to apply the procedures outlined in the technical guidelines; and
- develop a series of pilot projects to demonstrate the procedures and processes outlined in these Technical Guidelines.

Steps 6 and 7: Project monitoring and evaluation

Monitoring and evaluation play key roles within the project cycle approach because they determine whether the restoration project is successful, or if the establishment of a defined protected area meets its objectives. Pre-monitoring helps identify restoration or protected area goals, while restoration or habitat protection goals help define specific monitoring objectives to guide the development of a monitoring and evaluation programme. Among the monitoring indicators discussed in Box 4, the ones that respond to the restoration or protected area action and that address the questions outlined in the programme objectives should be chosen. Monitoring design and indicators should be based on those outlined in the MRC Joint Environment Monitoring Guidance (JEM) (MRC, 2022), and include hydromorphological indicators such as those outlined in Table 3.2, or for fisheries, as defined in the JEM protocol, or as defined in Table 3.9. These indicators should be employed to provide evidence, in statistical terms, that endpoints (Box 5) have been reached. A variety of impact assessment techniques are available to detect environmental change for restoration projects and determine the success of establishing protected areas and the data collection methods, which will differ spatially and temporally. A replicated Before-After-Control-Impact (BACI) design is the most powerful one because it includes replication in both space and time, and this is therefore recommended.

The evaluation phase for a project to restore or protect key aquatic habitats for fish, which has undergone the initial stages of the project approach, assesses the overall project effects (intentional and unintentional) and the sectoral impact of the project. Evaluation is only possible where a series of measurable indicators or endpoints has been established for the

project, hence the value of establishing and updating the logical project framework throughout. The evaluation phase will use the indicators to gauge how far the restoration or habitat protection project has developed with respect to the initial objectives and defined endpoints. Again, the analysis will return to the logical project framework, which was established at the outset and has been subsequently refined through the preparation and appraisal phase. It is the indicators in this framework that are used to monitor the habitat restoration or protection project during implementation. In addition, the implementation criteria will be used in ex-post evaluation that takes place some years after completion of the habitat restoration or protection project.

Table 3.9. Indicators to monitor impacts of restoration or protection of key fish habitats on fish and fisheries

Indicator	Units	Impact measures to be monitored and evaluated
Yield total	tonnes	Total yield can be determined using GIS methodologies that will detect general trends in catches and shifts in species to replace any loss in white fishes due to disruption in migration.
Yield of economically important species	tonnes	Shifts in species composition towards black and grey fish species as a result of disruption of migration patterns caused by the barrier effect of dams rather than by hydrological change.
Species richness	no. of species	Total numbers of species caught by all methods.
Fish catch diversity	percentage of total catch	The contribution of migratory white fish species will decline and other species guilds (black and grey fish) will increase, which will be detected as contribution to catch.
Catch per unit effort	kg/gear/day	Reduction in catch per unit effort (CPUE) of main commercial gears, especially those targeting migratory species. CPUE in backwater and off-channel habitats are unlikely to be detectable and to discriminate impact from changes in land use practices.

Some of the most common problems or reasons for failure of a restoration programme or a project to establish a protected area are:

- not addressing the root cause of habitat degradation;
- upstream processes or barriers to connectivity and habitat degradation that affect ecosystem functioning and habitat functionality;
- not establishing reference condition benchmarks and successful evaluation endpoints against which to measure success;
- failure to obtain adequate support from public and private organizations;
- failure to engage with the key stakeholders who will likely be impacted by the project;
- lack of or an inconsistent approach for sequencing or prioritizing projects
- poor or improper project design;
- inappropriate uses of common restoration techniques due to lack of pre-planning (one size fits all);
- inadequate monitoring or appraisal to determine project effectiveness; and
- improper evaluation (i.e. real cost-benefit analysis) of project outcomes.

Assuming that all goes well and the project is implemented, the evaluation phase should

provide steady feedback of information and results, which will be useful in other habitat restoration or protection project situations. Progress reports should be formally produced and assessed, focusing on the key indicators of the project, in order that lessons may be learned, and problems avoided in future habitat restoration or protection programmes.

3.4 Concluding remarks

The Mekong River has been subjected to an increasing array of human development activities since the 1950s (MRC, 2017) and, given the growing human population in the region and demand for economic growth, will likely be subject to further degradation in the foreseeable future. This, combined with increasing problems arising from climate change extremities in floods and drought, are likely to impact on the aquatic ecosystem, resulting in loss of diversity and fish production. It is therefore essential that efforts be made to protect and restore key habitats to maintain these valuable services. To achieve this, it is imperative that fisheries and aquatic biodiversity are fully integrated in basin planning and given the attention they deserve due their importance in rural livelihoods and food security in the region (MRC, 2023). This will ensure that economic development can take place alongside sustainable use of the fisheries resources and protection of the unique biodiversity found in the LMB.

4. DEFINITION OF TERMS

Artificial water body or Impoundment: Water body created by human intervention for supply of water, irrigation, hydropower development, or other human use.

Conservation: The protection, improvement and use of natural resources according to principles that will assure their highest economic or social benefits for humans and their environment, now and in the future.

Country of origin: The Member Country under whose jurisdiction a proposed project is intended to take place.

Drivers–Pressures–State–Impact–Response (DPSIR): A holistic approach that identifies key relationships between society and the environment. It supports managers in their decision-making, especially in order to structure and communicate policy-relevant protection, rehabilitation or enhancement projects. *Drivers* are the key demands on inland waters by society, such as agricultural and urban land use, flood protection, natural resources extraction including sand mining and fishing, navigation and hydropower. They are responsible for *pressures* that cause biological and abiotic *state* changes, and further *impacts* in the river ecosystem. *Response* is the application of river habitat improvement and protection measures to prevent or improve state changes in the environment for key fish habitats.

Environmental Impact Assessment (EIA): A national procedure for assessing the likely impacts on biophysical, social and economic aspects of a proposed project.

Habitat enhancement: A fishery management tool with the sole purpose of providing better environmental conditions for desired species of fish or aquatic organisms.

Habitat restoration/rehabilitation: Typically, methods that increase available habitats and/or access to key habitats for at least some life stages of a target species.

Member Country(ies): The signatory country(ies) to the 1995 Mekong Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin.

Potentially Affected Country(ies): The Member Country(ies) likely to be affected by potential transboundary environmental and/or fisheries impacts of a proposed project.

Proposed project: Any project or activity proposed by the Proponent in the Country of Origin which is subject to national environmental impact assessment of the Country of Origin.

Protected areas in freshwater systems: Mainly established with fish conservation objectives as the driver rather than related to fisheries enhancement.

Rehabilitation: Interventions to restore functionality to the system once an ongoing impact has ceased.

Restoration: Actions to bring a damaged ecosystem back into a pristine or wilderness condition.

Risk: The probability that something undesirable will occur. (It should be noted that when a technical definition in a decision theoretic framework is needed, it would be appropriate to use the terms expected loss or average forecasted loss, not risk.)

Stakeholders: Any person, group or institution that has an interest or 'stake' in the intervention (here, protected area or restored habitat in a project). This includes both intended beneficiaries and intermediaries, those positively affected, and those involved and/or those who are generally excluded from the decision-making process.

Stock enhancement: Raising the total production or the production of selected elements of a fishery beyond a level that is sustainable through existing natural processes. For the LMB, stock enhancement may entail: introducing only native species; stocking natural and artificial waterbodies, including with material originating from aquaculture installations; and altering species composition, including the elimination of undesirable species or constituting an artificial fauna of selected species.

Transboundary environmental impact: Significant environmental impacts/changes, both negative and positive, originating within the territory of one Member Country that potentially affect other Member Countries. The transboundary impacts can occur both downstream of the project location (i.e altered flow regime) and upstream (e.g. reduced fish migration).

Uncertainty: The incompleteness of knowledge about the state or processes of nature.

5. REFERENCES

Abell, R., Allan, J.D., & Lehner, B. (2007). Unlocking the potential of protected areas for freshwaters. *Biological Conservation,* 134, 48-63. https: //doi.org/10.1016/j.biocon.2006.08.017

Acreman, M., Hughes, K.A., Arthington, A.H., Tickner, D., & Dueñas M.-A. (2019a). Protected areas and freshwater biodiversity: A novel systematic review distils eight lessons for effective conservation. *Conservation Letters*. https: //doi.org/10.1111/conl.12684

Acreman, M.C., & Duenas-Lopez, M.A. (2019b). How effective is protected area designation for the conservation and restoration of freshwater biodiversity? Final Report to WWF-UK. Hydro-Ecology Consulting Ltd, Wallingford, UK. 20 April 2019 https: //www.wwf.org.uk/protectedareasforfreshwaterbiodiversity

Angelopoulos, N.V., Cowx, I.G. & Buijse, A.D. (2017). Integrated planning framework for successful river restoration projects: upscaling lessons learnt from European case studies. *Environmental Science and Policy* 76, 12-22. https://doi.org/10.1016/j.envsci.2017.06.005

Aparicio, E., Vargas, M.J., Olmo, J.M., & de Sostoa, A. (2000). Decline of native freshwater fishes in a Mediterranean watershed on the Iberian Peninsula: a quantitative assessment. *Environmental Biology of Fishes* 59, 11–19. https: //doi.org/10.1023/A: 1007618517557

Atkins, J.P., Burdon, D., Elliott, M. & Gregory, A.J. (2011). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. *Marine Pollution Bulletin,* 62, 215–226. https: //doi.org/10.1016/j.marpolbul.2010.12.012

Baumgartner, L. J., Deng, D.Z., Thorncraft, G., Boys, C. A., Brown, R. S., Singhanouvong, D., and Phonekhampeng, O. (2014). Perspective: Towards environmentally acceptable criteria for downstream fish passage through mini hydro and irrigation infrastructure in the Lower Mekong River Basin. *Journal of Renewable and Sustainable Energy* 6, 012301. https: //doi.org/10.1063/1.4867101

Baumgartner, L.J., Boys, C.A., Marsden, T., McPherson, J., Ning, N., Phonekhampheng, O., Robinson, W.A., Singhanouvong, D., Stuart, I.G. and Thorncraft, G. (2018). Comparing fishway designs for application in a large tropical river system. *Ecological Engineering*, 120, pp.36–43. https: //doi.org/10.1016/j.ecoleng.2018.05.027

Baumgartner, L. J., Barlow, C., Mallen-Cooper, M., Boys, C., Marsden, T., Thorncraft, G., Phonekhampheng, O., Singhanouvong, D., Rice, W., Roy, M., Crase, L., and Cooper, B. (2021). Achieving fish passage outcomes at irrigation infrastructure; a case study from the Lower Mekong Basin. *Aquaculture and Fisheries,* 6(2), pp. 113–124. https: //doi.org/10.1016/j.aaf.2018.12.008

Baran, E., Baird, I.G. & Cans, G. (2005). Fisheries bioecology at the Khone Falls (Mekong River, Southern Lao PR). *WorldFish Center*. Phnom Penh, Cambodia.

Bower, S.D., Lennox, R.J., & Cooke, S.J. (2015). Is there a role for freshwater protected areas in the conservation of migratory fish? *Inland Waters* 5, 1–6. https: //doi.org/10.5268/IW-5.1.779

Buijse, A. D., Klijn, F., Leuven, R. S. E. W., Middelkoop, H., Schiemer, F., Thorp, J. H., & Wolfert, H. P. (2005). Rehabilitation of large rivers: references, achievements and integration into river management. *Archiv fur Hydrobiologie Supplement*, 155, 715–738

Caddy, J.F. (2000). A fisheries management perspective on marine protected areas in the Mediterranean. Environmental Conservation, 27, 98-103. https: //doi.org/10.1017/S0376892900000138

Cambray, J.A. (2002). Conservation needs of *Sandelia bainsii*, an African anabantid. In: M.J. Collares-Pereira, I.G. Cowx & Coelho M.M. (eds) *Conservation of Freshwater Fishes: Options for the Future*. Oxford: Fishing News Books, Blackwell Science, pp. 90-97.

Campbell, I & Barlow, C. (2020). Hydropower Development and the Loss of Fisheries in the Mekong River Basin. *Frontiers in Environmental Science*, 8, 566509. https://doi.org/ 10.3389/fenvs.2020.566509

Collares-Pereira, M.J. & Cowx, I.G. (2004). The role of catchment scale environmental management in freshwater fish conservation. *Fisheries Management and Ecology, 11*, 303-312. https: //doi.org/10.1111/j.1365-2400.2004.00392.x

Cowx, I.G. (1994). Stocking strategies. *Fisheries Management and Ecology, 1*, 15-30. https: //doi.org/10.1111/j.1365-2400.1970.tb00003.x

Cowx, I.G. (1999). An appraisal of stocking strategies in the light of developing country constraints. *Fisheries Management and Ecology, 6*, 21-34. https: //doi.org/10.1046/j.1365-2400.1999.00139.x

CowxX I.G. & Collares-Pereira M.J. (2002) Freshwater fish conservation: options for the future. In: Collares-Pereira M.J., Cowx I.G. & Coelho M.M. (eds) *Conservation of Freshwater Fish: Options of the Future*. Oxford: Fishing News Books, Blackwell Science, 443-451 pp.

Cowx, I.G. & Welcomme, R.L. (eds) (1998). *Rehabilitation of Rivers for Fish*. Oxford: Fishing News Books, Blackwell Science.

Cowx, I.G., Angelopoulos, N., Noble, R.A., Slawson, D., Buijse, T. & Wolter, C. (2013). Measuring success of river restoration actions using end-points and benchmarking. Deliverable D5.1 EU FP7 project restoring rivers FOR effective catchment Management www.reformrivers.eu

Crivelli, A.J. (2002). The role of protected areas in freshwater fish conservation. In: M.J.

Collares-Pereira, I.G. Cowx & Coelho M.M. (eds) *Conservation of Freshwater Fishes: Options for the Future*. Oxford: Fishing News Books, Blackwell Science, pp. 373-388.

Day, J., Dudley, N., Hockings, M., Holmes, G., Laffoley, D., Stolton, S., Wells, S. & Wenzel, L. (eds) (2019). *Guidelines for applying the IUCN protected area management categories to marine protected areas*. Second edition. Gland. Switzerland: IUCN.

DHI. (2016). *Mekong Delta study*. DHI/DHR report to VNMC.

Dugan, P.J., Barlow, C., Agostinho, A.A., Baran, E., Cada, G.F., Chen, D., Cowx, I.G., et al. (2010). Fish migration, dames, and loss of ecosystem services in the Mekong Basin: *AMBIO*, 39, 344-348. https: //doi.org/10.1007/s13280-010-0036-1

Eden, S. & Tunstall, S. (2006). Ecological versus social restoration? How urban river restoration challenges but also fails to challenge the science - Policy nexus in the United Kingdom. *Environment and Planning C: Government and Policy, 24*, 661-680. https: //doi.org/10.1068/c0608j

EEA (European Environment Agency). (2012). *European waters-assessment of status and pressures*. Office for Official Publ. of the European Union. https: //www.chj.es/Descargas/ProyectosOPH/Consulta%20publica/PHC-2015-2021/ReferenciasBibliograficas/PlanificacionHidrologica/EEA,2012.European_waters_assessment_of_status_and_pressures.pdf

FAO (2008). *Rehabilitation of Inland Waters for Fisheries*. FAO Technical Guidelines for Responsible Fisheries. No. 6 Suppl. 1, Rome, FAO. https: //www.fao.org/3/i0182e/i0182e.pdf

FAO (2015). *Responsible stocking and enhancement of inland waters in Asia*. FAO Regional Office for Asia and the Pacific, Bangkok. RAP Publication 2015/11. http: //www.fao.org/3/a-i5303e.pdf

FAO (2019) *Review of the state of world fishery resources: inland fisheries.* FAO Fishery and Aquaculture Circular C942 Revision3. http: //www.fao.org/3/CA0388EN/ca0388en.pdf

Findlay, S.J. & Taylor, M.P. (2006). *Why rehabilitate urban river systems? Area, 38*, 312–325. https: //doi.org/10.1111/j.1475-4762.2006.00696.x

Filipe, A. F., Cowx, I. G., & Collares-Pereira, M. J. (2002). Spatial modelling of freshwater fish in semi-arid river systems: A tool for conservation. *River Research and Applications*, *18*(2), 123–136. https: //doi.org/10.1002/rra.638

Francis, R.C., Hixon M.A., Clarke M. E., Murawski S.A. & Ralston S. (2007). Ten commandments for ecosystem-based fisheries scientists. *Fisheries* 32(5), 219–233. https: //doi.org/10.1577/1548-8446(2007)32[217: TCFBFS]2.0.CO;2

Frissell, C. A. and Ralph, S. C. (1998). "Stream and watershed restoration". In Naiman, R.

J. and Bilby, R. E. (eds) *River ecology and management: lessons from the Pacific Coastal Ecoregion*. New York: Springer, pp. 599–624.

Frissell, C.A. & Nawa, R.K. (1992). Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. *North American Journal of Fisheries Management, 12*, 182–187. https: //doi.org/10.1577/1548-8675(1992)012<0182: IACOPF>2.3.CO;2

Funge-Smith, S. (2018). *Review of the state of world fishery resources: inland fisheries.* FAO Fisheries and Aquaculture Circular No. C942 Rev.3, Rome. 397 pp. In FAO Fisheries Circular. https: //doi.org/10.1098/rspb.2006.3735

Halls, A.S., Paxton, B.R., Hall, N., Hortle, K.G., So, N., Chea, T., Chheng, P., et al. (2015). *Integrated Analysis of Data from MRC Fisheries Monitoring Programmes in the Lower Mekong Basin*. MRC Technical Paper No. 33, Mekong River Commission, Vientiane. https: //doi.org/10.52107/mrc.ajgsd2

Hannah, L., Costello, C., Elliott, V., Owashi, B., So, N.., Oyanedele, R., Cheaf, R., Vibolg, O., Phenh, C. & McDonald, G. (2019). Designing freshwater protected areas (FPAs) for indiscriminate fisheries. *Ecological Modelling, 393,* 127–134. https: //doi.org/10.1016/j.ecolmodel.2018.12.006

Hermoso, V., Pantus, F., Olley, J., Linke, S., Mugodo, J., & Lea, P. (2012). Systematic planning for river rehabilitation: integrating multiple ecological and economic objectives in complex decisions. *Freshwater Biology* 57, 1–9. https://doi.org/10.1111/j.1365-2427.2011.02693.x

Hodder, K.H., Douglas, S., Newton, A.C., Bullock, J.M., Scholefield, P., Vaughan, R., Cantarello, E., Beer, S. & Birch, J. (2010). *Analysis of the costs and benefits of alternative solutions for restoring biodiversity*. Report to Defra December 2010 - WC0758/CR0444. https: //nora.nerc.ac.uk/id/eprint/523760/1/N523760CR.pdf

Hogan, Z., Baird, I.G., Radtke, R., & Vander Zanden, M.J. (2007). Long distance migration and marine habitation in the tropical Asian catfish, Pangasius krempfi. Journal of Fish Biology, 71, 818-832. doi:10.1111/j.1095-8649.2007.01549.x

Hortle, K.G. and Bamrungrach, P. (2015). Fisheries Habitat and Yield in the Lower Mekong Basin. MRC Technical Paper No. 47. MRC Secretariat: Phnom Penh. https: //doi.org/10.52107/mrc.ajg82r

ICEM (2014). *USAID Mekong ARCC Climate Change Impact and Adaptation Study for the Lower Mekong Basin on Protected Areas*. Prepared for the United States Agency for International Development by International Centre for Environmental Management. Bangkok: USAID Mekong ARCC Project. www.mekongarcc.net/resource

IUCN (1994). *Guidelines for Protected Areas Management Categories*, CNPPA, WCMC, IUCN – The World Conservation Union, Gland and Cambridge.

Jennings S. & Kaiser M.J. (1998). The effects of fishing on marine ecosystems. *Advances in Marine Biology, 34,* 201–352. https: //doi.org/10.1016/S0065-2881(08)60212-6

Kingsford, R.T., Biggs, H.C. & Pollard, S.R. (2011). Strategic adaptive management in freshwater protected areas and their rivers. *Biological Conservation*, *44,* 1194–1203. https: //doi.org/10.1016/j.biocon.2010.09.022

Loury, E. (2020). *Establishing and managing freshwater fish conservation zones with communities: A guide based on lessons learned from Critical Ecosystem Partnership Fund grantees in the Indo-Burma Hotspot*. Critical Ecosystem Partnership Fund. Arlington, VA.

Loury, E.K., Ainsley, S.M., Bower, S.D., Chuenpagdee, R., Farrell, T., Guthrie, A.G., Heng, S., Lunn, Z., et al. (2017). Salty stories, fresh spaces: Lessons for aquatic protected areas from marine and freshwater experiences. *Aquatic Conservation-Marine and Freshwater Ecosystems, 28,* 485–500. https: //doi.org/10.1002/aqc.2868

May, R. (2006). ''Connectivity'' in urban rivers: Conflict and convergence between ecology and design. *Technology in Society, 28,* 477–488. https: //doi.org/10.1016/j.techsoc.2006.09.004

Moss, B. (1998). *Ecology of Fresh Waters*. 3rd edition. Oxford: Blackwell Science.

MRC (2015). *Guidelines for fish stock enhancement practices in the Lower Mekong Basin*. Vientiane: MRC Secretariat.

MRC (2017a). *The Council Study Biological Resource Assessment Interim Technical Report 1. Vol 1 Specialists' Report*. MRC Secretariat.

MRC. (2017b). *Basin-wide Fisheries Management and Development Strategy (BFMS) 2018–2022*. Vientiane: MRC Secretariat. https: //doi.org/10.52107/mrc.ajg6oo

MRC. (2019). *State of the Basin Report 2018*. Vientiane: MRC Secretariat. https: //doi.org/10.52107/mrc.ajg4wl

MRC (2022). *Joint Environmental Monitoring Programme at two Mekong Mainstream dams: The Don Sahong and Xayaburi hydropower projects*. Vientiane: MRC Secretariat. https: //doi.org/10.52107/mrc.aqrs7o

MRC (2023). *Fisheries Yield Assessment by Habitat Type at The Landscape Scale in The Lower Mekong River Basin 2020*. MRC Secretariat.

Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., Carr, J., Clayton, S., et.al. (2005). Standards for ecologically successful river restoration. *Journal of Applied Ecology, 42,* 208–217. https: //doi.org/10.1111/j.1365-2664.2005.01004.x

Poulsen, A.F., Ouch, P., Viravong, S., Ubolratana, S. & Nguyen, T.T. (2002). *Fish migrations of*

the Lower Mekong River Basin: implications for development, planning and environmental management. MRC Secretariat. https: //doi.org/10.52107/mrc.akbo9o

Poulsen, A.F., Hortle, K.G., Valbo-Jorgensen, J., Chan, S., Chhuon, C.K., Viravong, S., Bouakhamvongsa, K., et.al. (2004). *Distribution and ecology of some important riverine fish species of the Mekong River Basin*. MRC Secretariat. https: //doi.org/10.52107/mrc.ak8j7v

Reid, A.J., Carlson A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J., Kidd, K.A., et.al. (2019). Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*. https: //doi.org/10.1111/brv.12480.

Roni, P., & Beechie, T. (2013). *Stream and watershed restoration: a guide to restoring riverine processes and habitats*. Wiley-Blackwell.

Roni, P., Hanson, K., Beechie, T., Pess, G., & Pollock, M. (2005). *Habitat rehabilitation for inland fisheries: Global review of effectiveness and guidance for rehabilitation of freshwater ecosystems*. FAO Fisheries Technical Paper.

So., N., Phommakone, S., Vuthy, L., Samphawamana, T., Hai Son, N., Khumsr, Mi, Peng Bun, N., Sovanara, K., Degen, P., & Starr, P. (2015). Lower Mekong fisheries estimated to be worth around $17 billion a year. *Catch and Culture, 21(3)*, 4-7. www.mrcmekong.org/assets/Publications/Catch-and-Culture/CatchCultureVol-21.3.pdf

Sverdrup-Jensen, S. (2002). *Fisheries in the Lower Mekong Basin: Status and perspectives*. MRC Secretariat. https: //doi.org/10.52107/mrc.akbogh

Vu, V.A., Hortle, K.G. & Nguyen, D.N. (2021). Factors driving long term declines in inland fishery yields in the Mekong Delta. *Water*, 13(8), 1005; https: //doi.org/10.3390/w13081005

Ward, J.V. (1989). The four-dimensional nature of lotic ecosystems. *Journal of the North American Benthological Society 8*, 2–8. https: //doi.org/10.2307/1467397

Welcomme, R.L. & Bartley, D.M. (1998). Current approaches to the enhancement of fisheries. *Fisheries Management and Ecology, 5*, 351-382. https: //doi.org/10.1046/j.1365-2400.1998.550351.x

Welcomme, R.L. (2001). *Ecology and Management of Inland Fisheries*. Blackwell Science: Oxford.

Welcomme, R.L., Winemiller, K.O. & Cowx, I.G. (2006). Fish environmental guilds as a tool for assessment of ecological condition of rivers. *Rivers Research and Applications, 22*, 377-396. https: //doi.org/10.1002/rra.914

ANNEXES

Annex 1: Native species in the LMB classified as threatened by the International Union for Conservation of Nature (IUCN) Red List

No	Species Name	Common Name	Family	IUCN Red List Status
1	*Schistura leukensis*		Balitoridae	Critically Endangered
2	*Schistura spiloptera*		Balitoridae	Critically Endangered
3	*Schistura tenura*		Balitoridae	Critically Endangered
4	*Sewellia breviventralis*	Butterfly Loach	Balitoridae	Critically Endangered
5	*Aaptosyax grypus*	Mekong giant salmon carp	Cyprinidae	Critically Endangered
6	*Catlocarpio siamensis*	Giant barb	Cyprinidae	Critically Endangered
7	*Cyprinus barbatus*		Cyprinidae	Critically Endangered
8	*Epalzeorhynchos bicolor*	Redtail sharkminnow	Cyprinidae	Critically Endangered
9	*Scaphognathops theunensis*		Cyprinidae	Critically Endangered
10	*Urogymnus polylepis (Himantura chaophraya)*	Freshwater whipray	Dasyatidae	Critically Endangered
11	*Datnioides pulcher*	Siamese tiger perch	Datnioididae	Critically Endangered
12	*Pangasianodon gigas*	Mekong Giant Catfish	Pangasiidae	Critically Endangered
13	*Pangasius sanitwongsei*	Giant pangasius	Pangasiidae	Critically Endangered
14	*Pristis microdon*	Largetooth sawfish	Pristidae	Critically Endangered
15	*Ceratoglanis pachynema*	Club-barbel sheatfish	Siluridae	Critically Endangered
16	*Oreoglanis lepturus*		Sisoridae	Critically Endangered
17	*Hemitrygon laosensis*	Mekong Freshwater Stingray	Chondrichthyes	Endangered
18	*Schistura bairdi*		Balitoridae	Endangered
19	*Schistura bolavenensis*		Balitoridae	Endangered
20	*Schistura nudidorsum*		Balitoridae	Endangered
21	*Schistura quasimodo*		Balitoridae	Endangered
22	*Sewellia patella*		Balitoridae	Endangered
23	*Ambastaia sidthimunki*	Ladderback loach	Botiidae	Endangered
24	*Yasuhikotakia sidthimunki*	Dwarf botia	Cobitidae	Endangered
25	*Cyprinus chilia*		Cyprinidae	Endangered
26	*Laubuca caeruleostigmata*	Leaping barb, Flying Minnow	Cyprinidae	Endangered
27	*Luciocyprinus striolatus*		Cyprinidae	Endangered
28	*Poropuntius bolovenensis*		Cyprinidae	Endangered
29	*Poropuntius consternans*		Cyprinidae	Endangered
30	*Poropuntius deauratus*		Cyprinidae	Endangered
31	*Poropuntius lobocheiloides*		Cyprinidae	Endangered
32	*Poropuntius solitus*		Cyprinidae	Endangered
33	*Probarbus jullieni*	Isok barb	Cyprinidae	Endangered
34	*Probarbus labeamajor*	Thicklip barb	Cyprinidae	Endangered
35	*Dasyatis laosensis*	Mekong stingray	Dasyatidae	Endangered
36	*Himantura chaophraya*	Freshwater whipray	Dasyatidae	Endangered
37	*Himantura krempfi*	Marbled freshwater whip ray	Dasyatidae	Endangered
38	*Fluvitrygon oxyrhyncha*	Marbled whipray	Dasyatidae	Endangered
39	*Fluvitrygon signifer*	White-rimmed stingray	Dasyatidae	Endangered
40	*Rhinogobius lineatus*		Gobiidae	Endangered

41	*Terateleotris aspro*		Odontobutidae	Endangered
42	*Scleropages formosus*	Asian bonytongue	Osteoglossidae	Endangered
43	*Pangasianodon hypophthalmus*	Striped catfish	Pangasiidae	Endangered
44	*Pterocryptis inusitata*		Siluridae	Endangered
45	*Oreoglanis siamensis*	Siamese bat catfish	Sisoridae	Endangered
46	*Hemitrygon laosensis*	Mekong stingray	Dasyatidae	Endangered
47	*Scaphognathops bandanensis*		Cyprindae	Vulnerable
48	*Mystus bocourti*		Bagridae	Vulnerable
49	*Hemimyzon confluens*		Balitoridae	Vulnerable
50	*Nemacheilus banar*		Balitoridae	Vulnerable
51	*Schistura atra*		Balitoridae	Vulnerable
52	*Schistura kaysonei*		Balitoridae	Vulnerable
53	*Schistura susannae*		Balitoridae	Vulnerable
54	*Schistura tubulinaris*		Balitoridae	Vulnerable
55	*Sewellia lineolata*		Balitoridae	Vulnerable
56	*Tenulosa thibaudeaui*	Mekong herring	Clupeidae	Vulnerable
57	*Serpenticobitis cingulate*		Cobitidae	Vulnerable
58	*Yasuhikotakia nigrolineata*		Cobitidae	Vulnerable
59	*Yasuhikotakia splendida*		Cobitidae	Vulnerable
60	*Balantiocheilos melanopterus*	Tricolor sharkminnow	Cyprinidae	Vulnerable
61	*Bangana behri*		Cyprinidae	Vulnerable
62	*Bangana musaei*		Cyprinidae	Vulnerable
63	*Cirrhinus microlepis*	Small scale mud carp	Cyprinidae	Vulnerable
64	*Devario apopyris*		Cyprinidae	Vulnerable
65	*Epalzeorhynchos munense*	Red Fin Shark	Cyprinidae	Vulnerable
66	*Hypsibarbus lagleri*		Cyprinidae	Vulnerable
67	*Labeo pierrei*		Cyprinidae	Vulnerable
68	*Mystacoleucus lepturus*		Cyprinidae	Vulnerable
69	*Oxygaster pointoni*		Cyprinidae	Vulnerable
70	*Poropuntius speleops*		Cyprinidae	Vulnerable
71	*Pseudohemiculter dispar*		Cyprinidae	Vulnerable
72	*Rhodeus laoensis*		Cyprinidae	Vulnerable
73	*Scaphognathops bandanensis*		Cyprinidae	Vulnerable
74	*Tor ater*		Cyprinidae	Vulnerable
74	*Troglocyclocheilus khammouanensis*		Cyprinidae	Vulnerable
76	*Datnioides undecimradiatus*	Mekong tiger perch	Datnioididae	Vulnerable
77	*Rhinogobius albimaculatus*		Gobiidae	Vulnerable
78	*Betta splendens*	Siamese fighting fish	Osphronemidae	Vulnerable
79	*Osphronemus exodon*	Elephant ear gourami	Osphronemidae	Vulnerable
80	*Pangasius krempfi*		Pangasiidae	Vulnerable

Source: World Fish Center. www.fishbase.org, Accessed 4 March 2021.
* IUCN 2018. IUCN Red List of Threatened Species. www.iucnredlist.org; www.iucn.org/sites/dev/files/content/documents/freshwater_kbas_lower_mekong_final_report.pdf

Note: Additional species: Near Threatened (NT) – 17 species; Least Concern (LC) – 322 species; Data-Deficient –132 species; Not Evaluated – 197 species.

Annex 2. Fish habitat protection and restoration practices in a global context

A2.1 Protected areas

The principle and practice of protected areas to create nature reserves or sanctuaries is well established in nature reserves) and marine (Marine Protected Areas) systems (Bower, Lennox & Cooke, 2015; Loury et al., 2017), but to date, few have been designated specifically for freshwater fishes (Crivelli, 2002; Acreman et al., 2019a; Hannah, et al., 2019; Loury et al., 2017). Protected areas in freshwater systems are mainly established with fish conservation objectives as the driver rather than for fisheries enhancement (Bower, Lennox & Cooke, 2015; Hannah et al., 2019; Loury et al., 2017). They are usually created to minimize human pressures on the habitats to maintain or restore natural balance and dynamics. In this way, short and long-term natural processes can function and maintain a breeding stock of target species that will ensure the survival of the species within the protected area and potentially facilitate colonization of unprotected surrounding areas (Acreman & Duenas-Lopez, 2019b).

Despite increasing efforts towards establishing freshwater protected areas, their effectiveness in inland aquatic systems is questioned (Bower, Lennox & Cooke, 2015; Cambray, 2002), especially in rivers, and freshwater biodiversity continues to decline. Their role in the enhancement of stocks, especially migratory species, for exploitation is also open to debate (Bower, Lennox & Cooke, 2015). There are many reasons for this poor effectiveness (Filipe et al., 2002; Cowx & Collares-Pereira, 2002; Acreman & Duenas-Lopez, 2019b):

- Protected areas are often planned without scientific bases and monitoring and chosen on basis of natural beauty and low economic value.
- Protected areas are rarely set up for fish as the target organism for conservation.
- A lack of consideration of freshwater biodiversity needs when designing and declaring protected areas: area designated may not provide needs for all life stages;
- There is a lack of knowledge about the distribution, abundance and habitat relationships of the target species.
- Protected areas are usually localized with no recognition of upstream, downstream, or wider catchment problems that may affect fish in protected areas.
- There is poor understanding of complex management problems beyond the limits of the protected area, and traditional notions of protected areas translate imperfectly to the freshwater realm.
- Fewer resources are devoted to freshwater conservation management than to other actions, resources to enforce legislation are lacking; thus, freshwater fishes are not always afforded the protection they are designated under law.
- Fish are given low priority in development projects – there is a weak integration of conservation in water resource management planning.
- There is an inadequate awareness of conservation issues by the public.

In marine systems, the main cause for declines of many fish species/stocks is intense fishing pressure. Thus, the management methods widely used in marine systems is the creation of protected areas for spawning, for the protection of juveniles, or for efforts in rebuilding breeding stocks (see Jennings & Kaiser, 1998; Caddy, 2000; Hannah et al., 2019; Loury et al., 2017). In inland waters, the factors responsible for decline are mostly external to the fishery,

such as water pollution, dams, river engineering or the introduction of non-native species. The impacts of these pressures thus often spread into or through the protected area and limit the efficacy of the protected area or the regulations in force. Aparicio et al. (2000) also concluded that the current system of nature reserves does not offer protection to threatened fish species or communities, because the protected areas were almost all in the headwaters and not in the lowlands where sites with highest priorities for protecting fish species are located. The designated areas are also often too small to protect the fish stocks from degradation, or to provide the habitat to ensure the fish species can complete their life cycle (Collares-Pereira & Cowx, 2004). Developing protected areas that encompass critical life-stages is fundamental to their success. This is particularly important for migratory species that must protect fundamental habitat, such as spawning and nursery areas, migratory corridors and feeding zones, and the connectivity between them to ensure that ecological and evolutionary processes are maintained (Bower, Lennox & Cooke, 2015).

The challenge for establishing protected areas for freshwater fishes is that the effects of protection measures usually vary from one protected area to another, and from one species to another, and are difficult to determine. It is generally agreed that parallel policies taken in areas outside individual reserves or networks of reserves are also required to ensure the conservation of aquatic habitats and their resources, including fisheries (Abell et al., 2007). With freshwater aquatic ecosystems, there is thus a need to identify the limits of ecosystems that support fisheries and integrate them into the protected area, i.e. the catchment (also referred to as the basin, drainage or watershed, Figure A2.1). Each catchment should be regarded as a separate, potentially manageable ecosystem unit, relatively isolated from adjacent catchments. The concept of integrated catchment management coupled with ecosystem-based fisheries management strategies must therefore be applied. The size of the protected area(s) will depend on the size of the catchment, characteristics of the fish communities in question, the mobility of the species in the community, and the heterogeneity of the environment. Increasing human populations in the catchment are the driving force for environmental degradation; therefore, the catchment approach cannot exclude human activities, values and priorities, but must include them in such a way that catchment functioning is maintained.

An ecosystem management or ecosystem-based management approach is certainly more difficult to put into practice than the creation of protected areas, but it is the only one that can conserve the fish communities in the long term (Francis et al., 2007). It also has the advantage of protecting not only fish, but also other aquatic organisms such as invertebrates, plants, riverine forests and amphibians living in the catchment. This approach does not preclude protected area approaches being undertaken within the catchment as a complementary measure. In essence, the designation of watersheds, including all the catchment (land and water) upstream (Filipe et al., 2002; Cowx & Collares-Pereira 2002; Crivelli, 2002), is necessary and must be negotiated.

Appropriate authorities and institutions should also engage with stakeholders to set up or extend the network of protected areas to ensure buy-in to the concept and not compromise the livelihoods and food security of the rural populations that are most likely affected by the setting up of the protected areas.

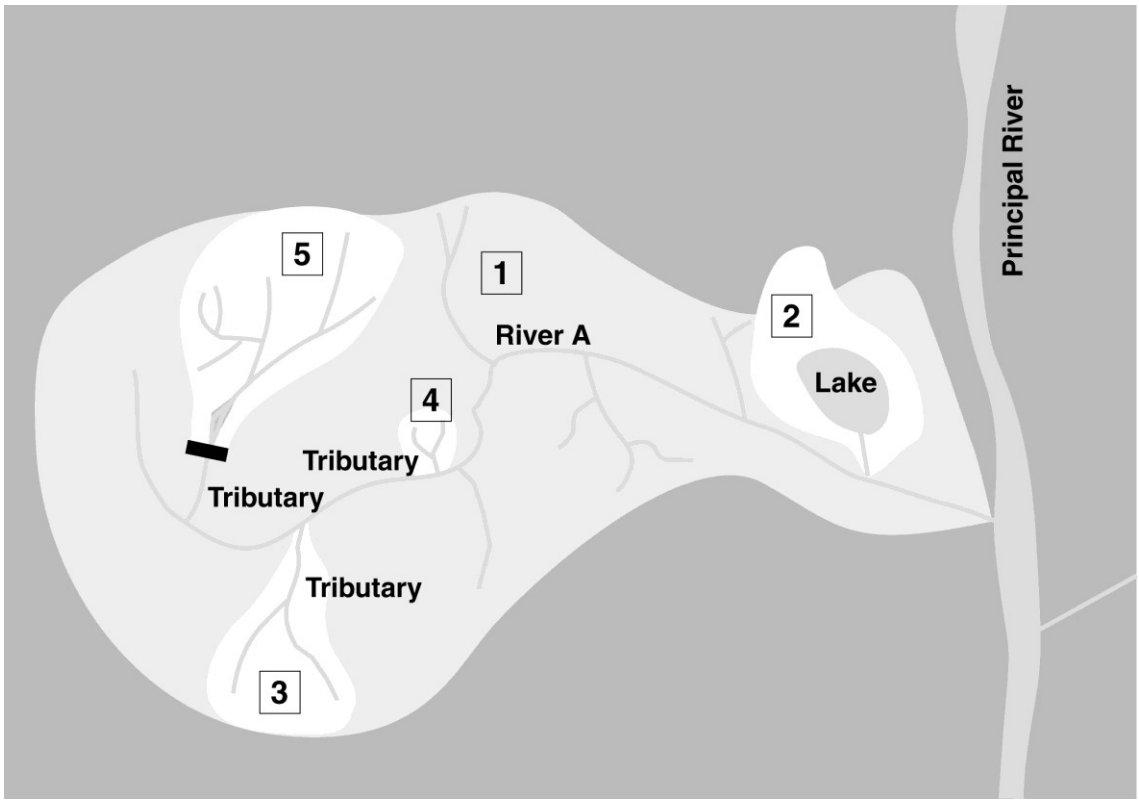


Figure A2.1. The catchment-level approach to establishing protected areas

Note: 2,3, 4 and 5 represent the scale of the protected areas that should be established to protect specific tributaries or habitats.

These criteria described above are similar to the following lessons to enhance protected area effectiveness proposed by Acreman (2019a) and Acreman & Duenas-Lopez (2019b) based on a review of the appropriateness of protected areas in freshwater ecosystems:

- Lesson 1: Monitoring and research to understand effectiveness should be built into the management of protected areas.
- Lesson 2: Protected areas need to be of sufficient size and configuration to connect diverse elements of the waterscape and maintain their biodiversity.
- Lesson 3: Areas designated to protect terrestrial ecosystems can contribute to freshwater biodiversity protection if they are located, designed and managed appropriately.
- Lesson 4: Incorporating conservation of aquatic habitats, including hydrological regime, water quality and riparian vegetation, into protected area strategies is vital to maintaining freshwater biodiversity.
- Lesson 5: Protected areas should be free of external and internal pressures from inappropriate, illegal, or unregulated land and water management.
- Lesson 6: Well-managed protected areas can provide a refuge for native species against invasive non-native species.
- Lesson 7: Meeting socioeconomic protected areas objectives, such as grazing, tourism and recreation, may result in a trade-off against biodiversity.
- Lesson 8: Laws and regulations associated with protected areas need to be enforced, but regulation activities should engage local communities.

Given the above lessons, a number of guidelines are available for identifying and establishing

protected areas for fish in inland waters (IUCN, 1994; Saunders et al., 2002; Kingsford et al., 2011; Day et al., 2019; Loury, 2020). They make use of classic management frameworks, typically the DPSIR and the Project Cycle to establish protected areas, but are largely targeting the conservation of threatened species rather than the enhancement of fisheries potential (Suski & Cooke, 2007). Hannah et al. (2019) provided an example of a formulation of protected areas for fisheries enhancement in the Tonle Sap region of the Mekong. However, the methodology is data-hungry and focuses more on defining where the protected areas are established. Protocols specifically for the Mekong region (ICEM, 2014; Loury, 2020) are also available and have been used when drafting this technical guidance for protecting fish habitats in the Mekong context.

A2.2 Rehabilitation or restoration of freshwater ecosystems

'Rehabilitation' or 'restoration' of the physical habitat in rivers and lakes has received little attention in developing countries and those with emerging economies. In the context of rivers, although the two terms are often interchanged, 'restoration' refers to the restoration of the water body to its original state, which is rarely practical and/or may not be acceptable. For example, nations with large areas of relatively unoccupied land may choose to restore wildness and natural functioning of rivers over part of the territory. Other nations, where population pressures are severe, would find this process impossible. Rehabilitation, by contrast, does not necessarily involve returning the river to its original state (form and function), but rather creating the conditions that correspond to societal needs. Habitat rehabilitation/restoration typically refers to methods to increase available habitats and/or access to key habitats for at least some life stages of a target species (see Cowx & Welcomme, 1998). These approaches may range from increased connectivity along a river (fish passage facilities) through the reconstruction of the habitat to the installation of artificial habitats (such as low weirs or groynes).

For the purposes of this Technical Guidance, the term 'restoration' is generally used to avoid confusion, but it should be recognized that returning the river or wetland to its original state will likely not be possible because it has been modified beyond recovery. Further, any actions are unlikely to rehabilitate it to a form suitable for societal needs or to remediate any of its degraded characteristics to improve the environmental form and function. This approach is only practical when pressures from other users have eased or as a mechanism to address a bottleneck in the fishery recruitment processes. For example, prior to considering any restoration action, it is critical that water quality and any pollution problems are addressed through: prior treatment of industrial and domestic effluents before discharge; diversion of effluents; banning of the use of environmentally damaging industrial practices, such as the use of mercury in gold mining; banning of the use of persistent pesticides; reduction of the excessive use of fertilizers; or control of the effluents from intensive aquaculture.

Before implementation of restoration actions, it is necessary to define the objectives of the restoration project, and in developing projects for remediation, the following must be taken into consideration:

- The requirements of society. These may include conservation goals such as the general protection of entire faunas, or of a particularly rare species, or use-oriented

goals such as the maintenance of particular types of fauna for recreation or food fisheries exploitation.

- The development of the river or lake basin. No restoration project can be considered in isolation from its basin. Activities upstream of the target water body that increase sediment loads, change discharge rates, and impede migrations can counteract any efforts at a local level. Furthermore, many species are migratory and have distinct feeding and breeding grounds. In such cases, both feeding and breeding areas will need to be restored and connectivity maintained between them.
- The minimum area necessary for restoration. When the area to be restored is limited to the target species or community, restoration will increase their number and wellbeing. However, as greater areas are restored, other factors may intervene to limit the fish population. For example, a project to restore spawning gravels may well increase populations until the availability of food stops further population growth. Similarly, where floodplains are necessary for many species, the carrying capacity of the environment at low water may be such that only a small proportion of fish spawned can survive to the next year. In such cases, only a small amount of the plain needs to be restored for an adequate fish stock.

Technical measures for the restoration of rivers tend to emphasize recreating structural diversity and connectivity. Rivers worldwide suffer from damming and channelization, which have transformed the channels into straightened, embanked reaches isolated by dams and weirs. They have also been separated from their floodplain through drainage and land reclamation programmes.

For more details the reader may consult the following key references: Cowx and Welcomme (1998) and Roni et al. (2005), FAO (2008) and Roni and Beechie (2013).

Readers are also referred to key institutional URL websites that relate to aquatic habitat improvement activities such as: REstoring rivers FOR effective catchment Management (REFORM – www.reformrivers.eu) and associated River Restoration WIKI on Guidance and tools for hydromorphological assessment and physical restoration of rivers and streams in Europe (http://wiki.reformrivers.eu/index.php/Main_Page); River Restoration Centre (RRC) Manual of River Restoration Techniques (www.therrc.co.uk/manual-river-restoration-techniques) the European Centre for River Restoration (ECRR) manual of restoration projects (www.ecrr.org/River-Restoration/RiverWiki-Projects-Database/userId/12937); and US National Fish Habitat Partnership's National Fish Habitat Assessment (www.fishhabitat.org).

One final point to make is that although rehabilitation/restoration is becoming popular, evaluation of its effectiveness is generally lacking (Angelopoulous et al., 2017). Thus, many of the restoration projects presented in the literature or on websites have not been evaluated; hence, expert knowledge will be required to decide on the most appropriate interventions in any restoration project. This report provides appropriate technical guidance to support this essential input.

A2.3 Catchment planning for restoring or protecting key habitats

The concept of returning a river to a pristine or pre-existing state by use of mitigation measures to overcome degradation is unrealistic and dated, especially due to the irreversible

changes in catchment boundary conditions, for example, land use change, hydrology, vegetation cover (Findlay & Taylor, 2006). Freshwater river ecosystems are intrinsically linked and have a natural habitat continuum between river and landscape (May, 2006). Broad-scale processes and interactions between adjoining ecosystems consist of a set of hierarchically nested physical, chemical and biological processes operating at a widely varying space and timescales, thus add further complexity (Hermoso et al., 2012).

As a consequence, it is difficult to conserve a small reach of river by simply using restoration actions at a local level; furthermore, impacts in one place may be the result of events or management decisions elsewhere (Findlay & Taylor, 2006). Therefore, the question of 'scale', and its significance in the way rivers function, needs to be addressed and catchment scale approaches need to be employed. The importance of scale in river conservation and management has grown over the past 20 years, advancing from Ward's (1989) 'four dimensional nature of lotic ecosystems', to more recent advances in integrated catchment management (ICM). However, most river restoration project goals often only address problems on single rivers at a small scale, have limited impact on catchment-scale processes and can often be more destructive than constructive (Frissell & Nawa, 1992; Buijse et al., 2005; Eden & Tunstall, 2006).

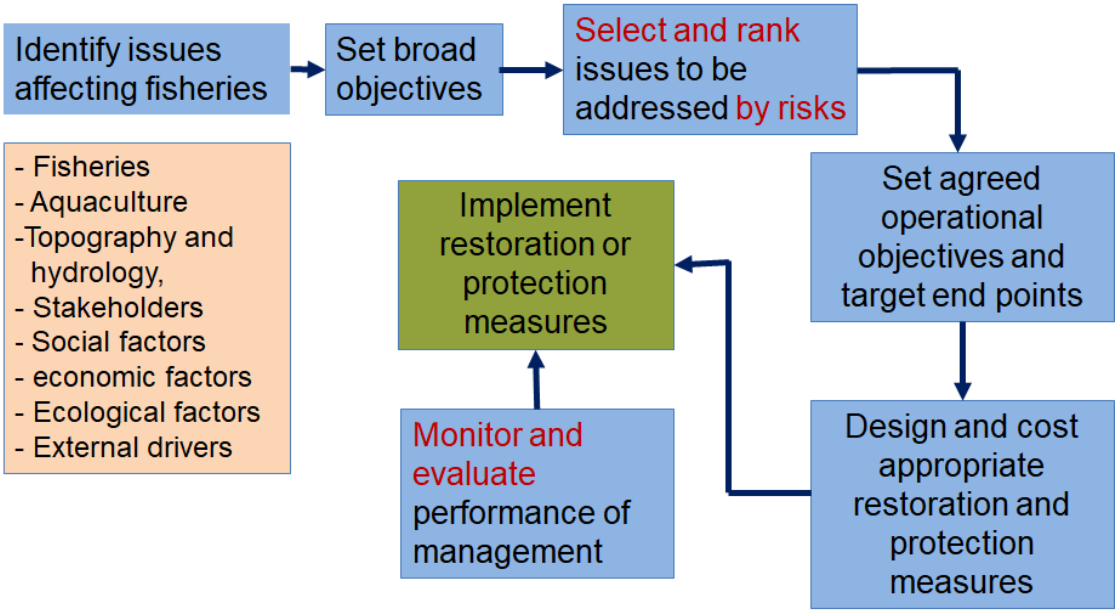


Figure A2.2. Steps in establishing catchment-based approaches to river restoration and practices

Nonetheless, the potential benefits of implementing river restoration and conservation at a catchment scale are being increasingly recognized as an essential component of future restorative practices (Hodder et al., 2010). These practices aim to combine catchment-scale understanding across a range of aquatic ecosystems to improve ecological status within specific river basins (Figure A2.2). Although the development of catchment-scale management is applied, it is often constrained by inadequate funding sources and will therefore influence restoration priorities leading to single, small-scale actions being the most frequently employed, with no association to catchment plans at a larger scale. Small-scale restoration is cheap, easy to apply and is quick to accomplish. As a consequence, it becomes important to understand how to apply small-scale restoration to benefit at a larger scale and to integrate

this approach at a catchment scale. Thus, project planning of a restoration scheme should incorporate habitat unit (small-scale) and reach (mid-scale), in addition to river basin scales (large-scale) when determining the scale of river degradation, selecting the type of restoration action when monitoring the rivers biotic and abiotic response to improvement works (Frissell & Ralph, 1998; Roni et al., 2005). Nevertheless, there are good examples of rehabilitation projects (see www.reformrivers.eu; and www.ecrr.org/River-Restoration/RiverWiki-Projects-Database/userId/12937) that have been conducted at a catchment scale, and emphasis must be drawn on the procedure of these good examples to draw lessons from them for future benefit. Planning and implementing scales of river rehabilitation do not necessarily have to be the same, provided that the individual restoration scheme is integrated at the whole catchment scale (Hermoso et al., 2012).

As a consequence, there is a need for more large-scale catchment programmes where river basin-wide assessment will enable prioritization of restoration sites (Buijse et al., 2005) and in some instances, assessment will identify large pressures where restoration at small scale, single reaches may not be an appropriate approach (Palmer et al., 2005). Catchment planning requires long-term planning over a number of years adapted over time that should be able to be adapted to changes to ensure that the best rehabilitation methods are being applied at all times.

A2.4 Summary

Establishment of protected areas and restoration of key habitats are important tools in the management of ecosystems to ensure their continued functioning and provision of the many services they provide to society. However, maintaining the integrity of many ecosystems, especially aquatic systems, is complex because they are prone to pressures from multiple sectors that degrade the ecosystem structure and functioning. To address these problems in a sustainable manner, it is recommended that the strategic planning approach to protection and restoration of key habitats for fish and fisheries be adopted**.** This will draw the attention of sectoral managers, decision makers, stakeholders and owners to the many problems that must be resolved within a wider aquatic resource sector context before habitat protection and restoration programmes are likely to achieve their objectives. As part of this approach, a number of aspects should be considered at an early stage:

- Whenever establishing protected areas or restoration of habitats, the aims and specific objectives of the actions must be clearly defined and be the focus of the action. The potential economic and environmental benefits should be demonstrated, although it is recognized that in some situations (e.g. protected areas for conservation purposes) there may be no well-defined economic benefits. These should be matched against any disadvantages or conflicts that may ensue.
- A national inventory of key fish habitats, including deep pools, wetlands, fish sanctuaries, Ramsar sites, national parks and conservation zones, should be established as a precursor to choosing protected areas and key habitats for restoration to benefit from existing conservation areas and build on the networking of protected restored habitats.
- The national inventory should be upscaled to provide a regional inventory to account for transboundary and regional needs for fish and biodiversity, and ensure that all requirements for them to complete their life cycles are included in any planned protected areas or restoration projects.

- Before projects to establish protected areas or restore key habitats are undertaken, a thorough evaluation of the reasons for the action should be appraised and alternative approaches to maintaining, improving or developing the aquatic habitat and associated resources (e.g. habitat offsetting or better fisheries management) should be considered/discounted.
- If it is possible to remove or minimize the causes of decline in target aquatic resources or biodiversity, this course of action should be taken first, and the aquatic biota and habitat may then recover without intervention. In this context, habitat improvement is considered a desirable option because it should lead to long-term, sustainable improvements with minimal deleterious ecological impacts, whereas protected areas maintain the status quo in terms of habitat quality and ecosystem functioning and only protect and conserve the existing resources in the area of concern.
- The wider issues and constraints that are likely to affect the long-term success of projects to establish a protected area or restore a key habitat should be reviewed and considered in the design of project and in the context of river basin management planning.
- Projects to restore key habitats should be considered mainly for systems that have not been degraded to a point where there is no possibility for recovery or re-establishing a functional ecosystem.
- Protected areas should be considered mainly for water bodies that are still largely intact, and aquatic resource use can be managed and/or regulated commensurate with the objective of the protected area. Due consideration must be given of potential upstream and downstream impacts on the functioning of the protected area, and measures taken to minimize and potential adverse effects.
- When evaluating projects to establish protected areas or restore key habitats as possible management interventions, the relative benefits and costs of all options should be considered. The 'do nothing' option should not be disregarded but should be considered as fully as any of the other options under discussion, despite possible pressure to adopt short-term solutions such as stocking.
- Regulators must consider the potential long-term implications of projects to establish protected areas or restore key habitats on the ecosystem. The entire catchment and any adjacent water bodies must be taken into account when considering the proposals.
- The strategy for any project to a establish protected area or restore key habitats should be carefully tailored to suit the species/biota in question, taking into account its entire set of ecological prerequisites, so as to maximize the chances of success.
- The potential adverse impacts of projects to establish protected areas or restore key habitats on other sectors should be considered fully. Stakeholder engagement should be adopted where other sectors or elements of society are likely to be impacted.
- Large-scale proposals to establish protected areas or restore key habitats, existing as well as proposed, should be evaluated by an independent review panel of scientists familiar with ecological principles and aquatic systems, especially in the Mekong region, to ensure that the wider environmental, ecological and socio-economic issues have been thoroughly reviewed.

- All projects should have in place the methodology to enable adequate monitoring of progress and, ultimately, success or failure. This should include a mechanism for disseminating the outcomes to minimize the risks of any unforeseen conflicts.

When assessing the viability of projects to establish protected areas or restore key habitats, an evaluation of the most cost-effective options regarding the expected benefits should be undertaken. All too often the strategy is to adopt measures from industrialized countries, whereas a little forward planning may improve the outcome considerably.

It is recommended that all projects to establish protected areas or restore key habitats beproperly formulated and planned before implementation to avoid conflicts with other water resource sectors or within the fisheries sector. The expected outcome for particular projects to establish protected areas or restore key habitats should be compared with wider aquatic resource sector objectives, and constraints that are likely to prevent a successful outcome should be considered in all appraisals. To this end, practical guidance to establish protected areas or restore key habitats in a range of water body types to meet specific objectives should be made available through government agencies and international advisory bodies.

Annex 3: Fish habitat protection and restoration activities in the Lower Mekong Basin – National report summaries

A3.1 Background

Fish production from inland capture fisheries and aquaculture in Southeast Asia, and the Mekong in particular, is progressively increasing but under threat from multiple pressures. Fish are freely harvested from natural waters when the fisheries resources are abundant. Despite the importance of inland fisheries, there are clear warning signs that fisheries in the Lower Mekong River Basin (LMB) are under considerable stress from both fishing activities (legal and illegal) and external pressures (e.g. hydropower, aggregate extraction, pollution, agricultural development, urbanization), and the predicted impact of climate change.

Currently overall catch is stable but a decline in the landings of large, late-maturing species and smaller average size of several commercial species are being observed. While aquaculture development can produce food fish to support the increased demand to some extent, wild capture fisheries play a crucial role in food security, especially to support the rural poor.

Fisheries management and enhancement in the region are achieved through traditional law enforcement, fish stock enhancement (stocking), habitat protection, and to a limited extent, restoration. Stocking is the most popular and widely used approach for fisheries enhancement in the LMB, and regional guidelines have been developed by the MRC in conjunction with the Food and Agriculture Organization of the United Nations (FAO) to support responsible stocking and enhancement of inland waters in Asia (FAO, 2015). While these stocking guidelines are available, they only deal with one aspect of fisheries enhancement, and it is now widely recognized that guidance is needed for other aspects of fisheries protection and restoration in the LMB beyond stocking practices.

To support the development of this *Technical Guidance for the Protection and Restoration of Key Fish Habitats of Regional Importance,* a series of national reviews of fisheries protection and restoration activities in the MRC Member Countries was carried out. Each country recognized the importance of protecting key habitats that ensure that the fisheries of the LMB are maintained and improved, especially for the important migratory species that contribute to a major part of the fish catches.

The key messages from these reviews summarized below is subsequently used to identify common issues and recommendations for addressing them, and for the preparation of this Technical Guidance.

A3.2 Cambodia

Cambodian fisheries resources play a very important role in contributing to national food and nutritional security, the national economy and people's livelihoods. Inland fisheries and aquatic animal species are under threat from habitat degradation and overexploitation. The fisheries are very much dependent on migratory species. Fish migrations occur in the lower part of the Mekong system between deep pools of the Mekong mainstream in Kratie-Stung Treng reach (also known as dry-season refuge and spawning, especially for white fishes) and the floodplain of the Tonle Sap Lake (TSL), and floodplain areas south of Phnom Penh, together known as flood-season rearing and feeding habitats.

Key areas of biodiversity have also been recognized by the International Union for Conservation of Nature (IUCN) and are mainly situated in the Tonle Sap River and Lake and the Cambodia Mekong-3S system (Table A3.1). In addition, fish sanctuaries or conservation areas have been established, particularly in the lower floodplain (TSL and area southern Phnom Penh) and the Cambodian mainstem Mekong, such as the dolphin conservation areas and wetlands of global ecological significance in Stung Treng. These areas are known to be critical habitats for fish rearing and feeding as well as dry season refuge and spawning. In the lower floodplain, fish sanctuaries mostly cover parts of the productive fishing areas previously under the commercial fishing concessions; the 'fishing lots'. Some of these conservation areas were mainly established after the abolition of the fishing lots in the first and second waves of the inland fisheries reforms in 2000 and 2012.

Table A3.1. Prioritized environmental assets of regional importance and additional recommended key fish habitats in Cambodia

Name of site	Status
Prioritized environmental assets of regional importance in Cambodia	
Tonle Sap Multiple Use Area	Fish sanctuaries (conservation areas), Ramsar wetlands (Prek Tuol and Boeung Chmar), IUCN's key biodiversity areas (KBAs), community fisheries (Cfi) conservation zones.
Virachey National Park	There is likely no existing/reliable data on key critical fish habitats studied. A new survey may be necessary.
Sre Pok Wildlife Sanctuary	There is likely no existing/reliable data on key critical fish habitats studied. A new survey may be necessary.
Additional key fish habitats recommended in the Cambodia national report	
Prek Toal Ramsar Site	Prek Taol Ramsar site, fish sanctuaries (former fishing lot areas), CFi conservation zones.
Mekong River and its tributaries in Stung Treng province	Deep pools in those river reaches (also known as dry-season refuge and spawning ground, especially for white fishes).

There are 167 deep pools in the Mekong River in Cambodia, particularly south of Khone Falls. These are recognized as critical habitats for the fisheries conservation in the Mekong. As a result, some community fisheries along the Mekong River in Cambodia have established community fish conservation zones to protect the Mekong fishes and/or set specific internal rules of their fishing practices.

Community fish refuge ponds (CFRs) are also among the current fisheries policy focus for the inland fish catch enhancement in the Cambodia inland waters. A CFR is a form of stock enhancement or a fish conservation measure that is intended to improve the productivity of rice field fisheries. The idea behind fish refuge ponds is to create dry season refuge or sanctuaries for brood fish in seasonally inundated rice fields.

The biggest challenges to enhance fisheries in Cambodia are considered to be related to the impact of hydropower dam development affecting the hydrological cycles and intensity. This is compounded by water infrastructure development (e.g. irrigation dams, flood prevention dykes) and large-scale flooded forest clearance, which are now becoming widespread to support agricultural expansion and intensification, causing irreversible changes to the lower floodplain habitats. In addition, disruption of flood cycles (both lateral and longitudinal connectivity) is having profound effects on fish migration patterns that play pivotal roles to sustain fish life cycles between spawning and refuge habitats, and the feeding and rearing

habitats, and is seriously affecting fisheries production and biodiversity. Intensive fishing pressure is also likely a key challenge to fisheries enhancement in Cambodia.

Recommendations for future activities

Critical habitats, connectivity among those habitats and fish fauna using these habitats should be effectively protected and conserved. Priority should be given to these key critical fish habitats where fishes breed, feed and seek refuge.

Robust environmental impact assessments and transparency are needed during all stages of hydropower dam development in the Mekong Basin as well as other infrastructure development in the Cambodian floodplain, to ensure the sustainability of critical habitats. Proper sub-national, national and regional management plans need to be prepared and effectively implemented to conserve these critical habitats and the fish resources.

Formal institutions should be strengthened and enabled to fulfil their mandates, such as: fisheries sector administrations; fisheries communities or fisheries associations; and the LMB transboundary fisheries management bodies, which have been established in the form of community-based fisheries management and joint mechanisms for transboundary fisheries management by the LMB national governments and the MRC.

A3.3 Lao PDR

People living within the Mekong Basin in Lao PDR are highly dependent on fisheries for food security and livelihoods, although often as a source of secondary or supplemental employment. Fisheries in Lao PDR are, however, under considerable pressure due to population growth and high market demand for fish; fishers have increased their fishing effort, sometimes illegally, and compete to capture larger fish for brood stock. As a result, larger fish species stocks are declining and replaced by small-sized fish species. The development and expansion of hydropower and irrigated agriculture is expected to have a negative impact on fisheries productivity, but agriculture and land use, especially in rainfed habitats, is considered the main threat to fisheries yields; nevertheless, it may be possible to maintain or even increase fisheries yields by maintaining water depths, improving connectivity, developing refuge ponds, and promoting integrated pest management. There is therefore a need to sustainably conserve and use fisheries resources in the LMB. Stock enhancement through formal stocking programmes is generally recognized as an important tool to compensate for the loss of productivity and diversity. Further actions include rehabilitation and conservation of the key important habitats. Fisheries management should be incorporated into Integrated Water Resources Management and should focus on Regional Transboundary Fisheries Management Frameworks.

There are a number of key fish habitats in the Mekong River in Lao PDR, including national parks (Table A3.2), fish conservation zones (FCZs), fish protected areas and fish refuges. Of particular importance are the many deep pools (337 identified in Lao PDR, of which 172 were more than 20 m deep), on which rural people rely heavily for subsistence and income generation. Although these deep pools are known to be important key habitats for many Mekong fish species, especially during the dry season, little is known about their functioning or how they contribute to overall fisheries production and yield. There are over 1,000 FCZs throughout Lao PDR, not only located on the Mekong River, but also on the important

tributaries, including the San, Kading and Theun Rivers. These FCZs are closed zones and prohibit fishing all year round or during the fish breeding seasons.

Table A3.2. Prioritized environmental assets of regional importance in the LMB and additional recommended key fish habitats: Lao PDR

Names of sites	Status
Prioritized environmental assets of regional importance in Lao PDR	
Nam Et Phoulei National Park	Important for biodiversity, ecology, hydrology, known for their rareness and uniqueness, providing ecosystem services, and recognized for their global importance
Bueng Kiat Ngong Wetland	Ramsar site with an area of 2,360 ha and consisting of lakes, swamps, marshes with established fishery conservation areas
Xe Chanphone Wetland	Ramsar site important for the conservation of the Siamese crocodile, occurrence of specific wetland habitats and the support it brings to local livelihoods
Additional key fish habitats recommended in the Lao PDR national report	
Nong Nga Wetland	Important wetlands for fisheries
Nong Fah	Volcanic crater lake

Efforts have been made to rehabilitate fish habitats in Lao PDR, most notably the reconnection of rice production areas in the centre region, for example, Pak Peung fishway in Borlikhamxay, and fishways on the Xe Bang Fei in Khammouane provinces.

Over the last three decades, there have been increasing numbers of reports from local people suggesting a decline in available aquatic resources in Lao PDR. The reasons for these declines are complex, perhaps interrelated, and as yet poorly understood. To address this, the 2009 Fishery Law provides a framework for implementing, managing, monitoring and inspecting capture fisheries and aquaculture. It aims to promote aquaculture, conserve and protect fisheries resources for sustainable development, and ensure the availability of fish and OAAs for food security, contributing to the socio-economic development of the nation. The law provides for community fisheries management and control measures, indicating the right of local communities to manage and utilize their resources. In addition, the law empowers communities to establish village or community fisheries management committees for specific water-bodies.

The key challenges facing fisheries include:

- poverty amongst rural people and their strong dependence on fisheries resources for food security;
- declining catch rates and changes to species composition in the main fishing ground, including deep pools;
- rural people fishing fish in the deep pools all year round, in particular in the dry season when fish aggregate in deep pools;
- increasing (excessive) fishing effort to meet market demand and fishing for trade;
- Illegal fishing activities, such as electrofishing, poisoning and using dynamite in deep pools in remote areas;
- many deep pools altered due to development projects (navigation, sand mining, hydropower) and climate changes;

- weak or ineffective enforcement of fisheries laws leading to declining fish catch and yield; and
- limited funds to support local communities to implement their fishery management plans.

Lao PDR is in a strong position to promote fisheries enhancement: fisheries regulations and laws already in place; FCZs have been established throughout the country, mostly in deep pools, with many more planned; local people recognize the importance of deep pools and FCZs as refuge habitats for fish; transboundary fisheries management projects have been implemented (Bokeo-Chieng Ria; Champasak-Stung Tung) and can be used as starting point for deep pools management.

Recommendations for future activities

- Significant deep pools in the main zones throughout the four zones in the Mekong in Lao PDR should be prioritized to ensure that migration patterns and refuge areas are not disrupted, This can be done within the framework of existing transboundary fisheries management projects (Bokeo-Chieng Ria and Champasak-Stung Treng).
- Since local communities depend on fisheries resources to support their livelihoods, there is a need to explore options for livelihood diversification such as aquaculture and eco-tourism to supplement the food and income of the local people that may affected from restrictions to fish in significant deep pools.
- Education and awareness campaigns on fisheries laws for the sustainable use of fisheries resources and biodiversity conservation are needed, including awareness of laws and regulations on fishing activities.
- Further assessment of significant deep pools in Champasak Province is recommended. Since different deep pools are inhabited by different fish species as local habitat or during migration cycles, it is important to map those pools, link them with fish species inhabited, gear uses and management arrangements. This information is important baseline data for management and decision-making regarding fisheries enhancement actions.

A3.4 Thailand

The Mekong Basin in Thailand comprises 98 km of main river in the Chiang Saen to Wiang Kaen, Chiang Rai Province, which includes many small rapids and deep pool areas that are important fish spawning grounds and refuge habitats in dry season periods. It also includes 860 km of main river in the northeast of the country, including Chiang Khan, Loei Province to Khong Chiam, Ubon Ratchathani Province. The later includes many large tributaries that have been disconnected by hydropower and irrigation infrastructure, the exception being the Songkhram River and its floodplains.

The intense use of wetlands in the Mekong River Basin in Thailand and elsewhere has had serious negative impacts on the ecosystems. Such threats, whether from adjacent areas, surrounding areas or within the wetlands, have resulted in pollution, eutrophication, siltation and reduction of water quantity, a decrease in numbers of aquatic animals, reduction of wetland size, and destruction of vegetation. Effected wetlands need to be conserved and protected. There are threats from: encroachment from agriculture and settlements; illegal fishing, which contributes to a reduction in the number of aquatic animals; inappropriate

water allocation, causing lack of water in the dry season and flooding in the rainy season; a proliferation of aquatic plants, such as water hyacinth; and invasion of non-indigenous species such as the golden apple snail and giant mimosa. As a result, a large number of wetlands in Thailand have been either lost or degraded.

There are 39 important wetland sites covering an area of 1,601,082 ha in the Mekong River Basin of Thailand, of which at least 15 are internationally important (Table A3.3) and 5 nationally important.

Table A3.3. Prioritized environmental assets of regional importance in the LMB and additional recommended key fish habitats: Thailand

Name of site	Status
Prioritized environmental assets of regional importance in Thailand	
Nong Bong Kai, Wiang Nong Lhom and mainstream Mekong of Chiang Rai	RAMSAR
Lower Songkhram River and its floodplains	RAMSAR site for a wide range of Mekong mainstream and Songkhram resident fish species
Dong Phayayen-Khao Yai Forest Complex	World Heritage Site for the conservation of globally threatened and endangered mammal, bird and reptile species
Additional key fish habitats recommended in the Thai national report	
Bung Khong Long Wildlife Non-Hunting Area	RAMSAR – birds and some fish
Koot Ting	RAMSAR – birds and some fish
Confluence of the Mun and Chi Rivers	Important wetlands for fisheries
Mun River flooded forest alongside Kaeng Tana National Park	
Lower Nam Mong Basin (Mekong River Tributaries)	Important wetlands

The current fisheries management practices in the inland waters including the tributaries of the Mekong River have been implemented through the legal and local institutions. Specific attention is given to the roles and responsibilities of government agencies, as well as to the division or, in some cases, overlap of jurisdiction among them. The Royal Ordinance on Fisheries B.E. 2558 (2015) is the official legislation regulating fishing activities.

A range of activities is practised in Thailand, which targets fisheries enhancement, as follows:

- establishment of fish conservation zones (FCZs);
- management of fisheries dry season refugia;
- restocking and stock restoration;
- habitat diagnosis and restoration; and
- habitat rehabilitation and installation of fish shelters.

The establishment of FCZs is one the primary activities established by many local communities for managing their own fisheries resources in the area. Critical habitats are selected to be FCZs, based on generations of local knowledge. Most local people believe that the impact of fish harvesting can be reduced by banning or significantly limiting fishing activities in key areas that serve as dry season refuges and sometimes spawning grounds for fish.

Recommendations for future activities

The key challenges in restoring and enhancing fish stocks in important habitats along transboundary areas in the Mekong River Basin include building a portfolio of effective habitat rehabilitation activities and human resources and institutional capacities on co-management approaches.

To effectively implement a restoration and enhancement programme for fish stocks, it is necessary to formulate an integrated fisheries and habitat management plan. The plan should involve many stakeholders, such as fishers, representatives from local and/or at times central government, non-governmental institutions, academics and other fisheries user groups (traders, cage culture farmers). Co-management may be an appropriate approach that encourages links between parties and between human and natural ecosystems.

Substantial investment is required in the form of time and human and institutional resource capacities to meet human and institutional capacity development needs, coupled with an understanding of the responsibilities of government and the local people. But both parties can play crucial roles in:

- avoiding further damage to the key habitats by limiting development activities in the areas,
- diminishing the impacts of development activity on the ecosystem by retaining some of the natural diversity (physical and biological aspects) by limiting certain activities in transboundary areas, and
- restoring habitats re-establishing the ecosystem structure and functions that existed prior to the initiation of development activities.

A3.5 Viet Nam

The Mekong Delta ecosystem is driven by both seasonally flooded wetlands and daily tidal cycles. These wetlands provide important habitats for indigenous flora and fauna, including many fish species that seasonally migrate to wetlands for spawning or feeding, or to take refuge or to occupy permanent habitat. Wetlands, therefore, are very important for the conservation of biodiversity and abundance of fisheries resources and OAAs. The wetlands have been heavily degraded by pollution (e.g. agrochemicals, industrial and urban wastes), the loss of mangroves, channelization for flood control, and dyke building, particularly to upscale rice production. The fisheries are also vulnerable to the accidental introduction of non-native species that have become invasive, including the freshwater golden snail (*Pomacea canaliculata*), sucker fish (*Pterygoplichthys disjunctivus*) and the red-eared turtle (*Trachemys scripta*), and are a serious threat to many fish habitats in the Mekong Delta.

The most important fish habitats identified in the Mekong Delta are hotspot wetlands, some of which have been designated as Ramsar sites because of their ecological values and biodiversity (Table A3.4). There are 23 deep pools in the Mekong and Bassac reaches in the Mekong Delta: the maximum depths range from 13 m to 44 m and areas range between 4 ha and 95 ha. Most of the deep pools there are common fishing grounds during dry season. Protected areas in the delta region are subjected to considerable pressures from an increasing human population living in the region.

Table A3.4. Prioritized environmental assets of regional importance in the LMB and additional recommended key fish habitats: Viet Nam

Protected areas	Status
Prioritized environmental assets of regional importance in Viet Nam	
U Minh Thuong National Park	Ramsar Wetland site Conservation of primitive Melaleuca forest Located in the core zone of Kien Giang UNESCO Biosphere Reserve. U Minh Thuong National Park is also recognized as an ASEAN Heritage Park
U Minh Ha and Mui Ca Mau National Park	Mui Ca Mau National Park designated as a Ramsar Wetland site
Yok Don National Park	Focused on the conservation of biodiversity of the terrestrial landscape; no fisheries-related action.
Additional key fish habitats recommended in the Viet Nam national report	
Tram Chim National Park	Ramsar Wetland site Conservation of the biodiversity of primitive Plain of Reeds Conservation of water birds, especially the Sarus Crane
Lang Sen Wetland Reserve	Ramsar Wetland site Wetlands reserve to protect the remains of the primitive Plain of Reeds.
Lung Ngoc Hoang National Reserve	Action plan mainly targets conservation of Melaleuca ecosystem and its wetland landscapes
Tra Su National Reserve	Focused on the protection of the Melaleuca ecosystem and prevention of fire risks
Thanh Phu National Reserve	Management and protection of mangrove forest ecosystem for conservation of biodiversity and natural habitats of wild animals such as water birds for ecotourism; no fisheries-related actions
Bac Lieu Bird Sanctuary National Reserve	Bird sanctuary
Bung Binh Thien Lagoon	Open access area for local communities and fishers
Yok Don National Park	Focused on the conservation of biodiversity of the terrestrial landscape; no fisheries-related action.

The fish habitats of these protected areas are composed of seasonally inundated Melaleuca forest and grassland, swamp and floodplains affected by Mekong River flows. They provide breeding, nursery and feeding grounds for floodplain grey fish in wet season and primary habitat for black fish all year round, but are replenished during the wet season. Therefore, most key fish habitats in the Mekong Delta are strongly affected by the hydrological regime, as well as other local and basin-wide social economic development. The Mui Ca Mau National Park, Thanh Phu Natural Reserve and Bac Lieu Bird Sanctuary provide favourable habitats for marine and estuarine fish guild and some anadromous Mekong catfishes. The area of the Sesan River Basin located in the Viet Nam highlands has mostly been impacted by hydropower developments on the mainstream, and these water bodies are under Hydropower Management Authorities.

A legal framework related to fish habitat management has been promulgated by the Government of Viet Nam through the Law on Fisheries (2017), the Law on Biodiversity (2008) and Law on Environmental Protection (2014). Presently, these protected areas, including fish habitats, are under the management of governmental institutions and focuses on the conservation of natural landscapes, biodiversity of wild animals (Sarus crane and water birds) and protection of Melaleuca forest, and development of ecotourism, but not much on fish biodiversity and fisheries.

There has been limited investment in research surveys on fish habitats, assessment of biodiversity and abundance, as well as management measures and most information is out of date and needs to be updated for further planning and effective management, as well as habitat and environmental rehabilitation and enhancement.

Recommendations for future activities

- conducting an inventory of key fish habitats in the Mekong Delta with updates of information on biodiversity and abundance of fisheries resources;
- carrying out research on the measures to improve fish habitat functionality, linked with other sectors such as agriculture, irrigation, aquaculture, navigation, hydropower;
- conducting training, research, monitoring and assessments of fish habitat management;
- conducting a review of and improving regulations for the management of freshwater protected areas to ensure that fish habitats are integrated into management plans; and
- setting up basin-wide cooperation in the development of technical guidelines for the effective management of fish habitats and the enhancement of their biodiversity and abundance, as well as sharing information and experience.

Annex 4: Ecological characteristics of aquatic biodiversity in the LMB

One of the key inputs required to identify, formulate and prioritize restoration or protection measures is a thorough understanding of the ecological requirements of the fish and other aquatic animals (OAAs) in the Mekong. The Mekong is characterized by a high diversity of fish species with many exhibiting complex life cycles that involve migration between different areas of the river, particularly upstream migration to spawning areas and downstream drift of migration to nursery, feeding and refuge habitats.

The general understanding of migration patterns in the Mekong is that there are three main groupings: the lower migration system (from the Delta up to Khone Falls), the middle migration system (from Khone Falls up to Vientiane) and the upper migration system (from Vientiane up to China) (Figure A3.1, adapted from Poulsen et al., 2002). However, there are also a number of species that migrate between these zones, and some species (possibly as many as 30 and often commercially valuable white fishes) that migrate longer distances. For some species, migration patterns extend over long distances upstream, at least as far as Luang Prabang (*C. lobatus* and *H. siamensis*, *P. proctozystron*, *P. malcolmi*, *C. harmandi*, *P. conchophilus* and *P. pleurotaenia*).

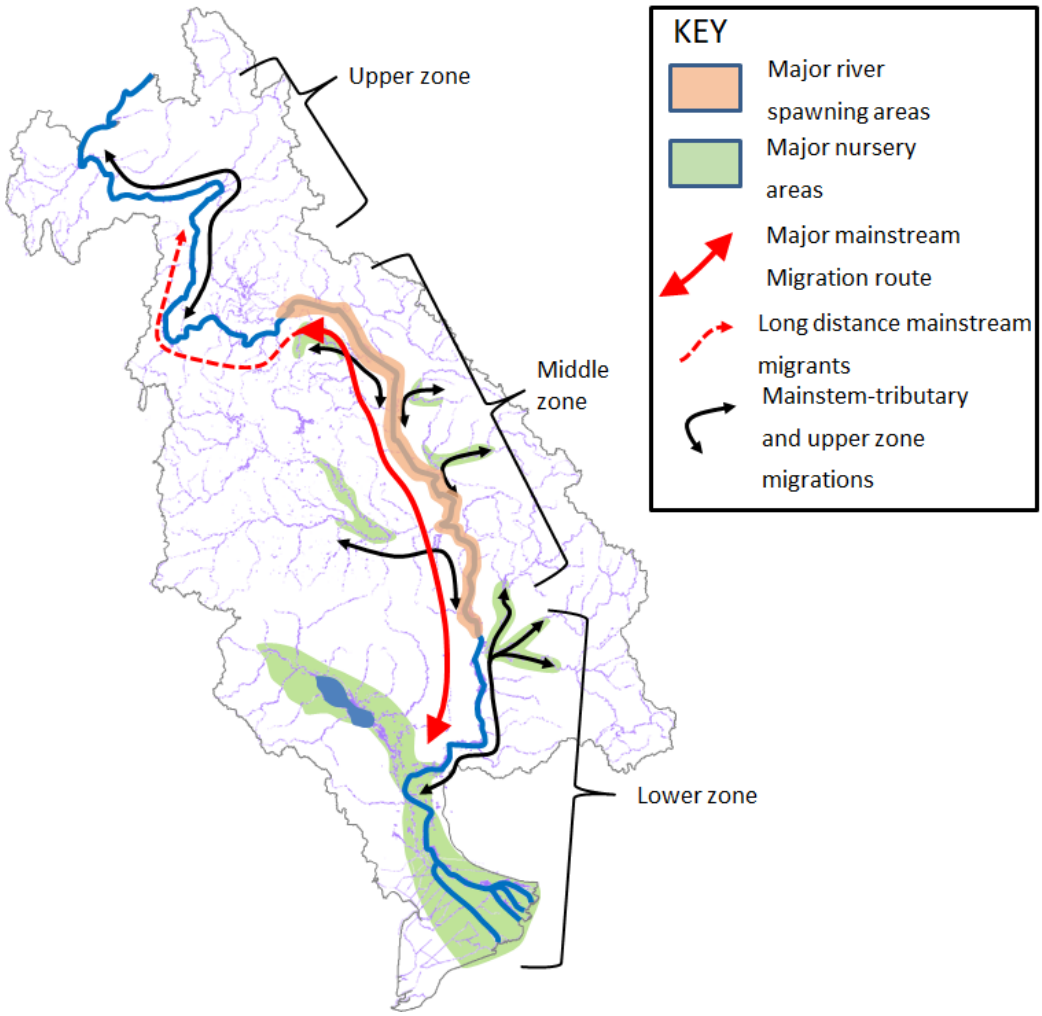


Figure A3.1. Generalized migration systems in the Lower Mekong Basin (modified from Poulsen et al., 2002)

Pangasius krempfi, an important commercial species, spends a part of its life at sea and in the brackish water of the Mekong Delta before returning to spawn in fresh water. This anadromous fish travels at least 720 km to Khone Falls, and possibly further upstream (Vu, Hortle & Nguyen, 2021; Hogan, Baird, Radtke & Vander Zanden, 2007), including into the 3S system. Other species such as *C. microlepis* and *P. larnaudii* appear to undertake less intensive migrations. *Y. modesta*, which is abundant in the Tonle Sap system, appears to be less migratory than previously believed (Poulsen et al., 2004, Halls et al., 2015). According to Poulsen et al. (2002), at least one-third of Mekong fish species need to migrate between downstream floodplains where they feed and upstream tributaries where they breed (see, for example, the migration patterns of *Cirrhinus* spp and *Pangasius krempfi;* Figure A3.2 from Poulsen et al., 2004).

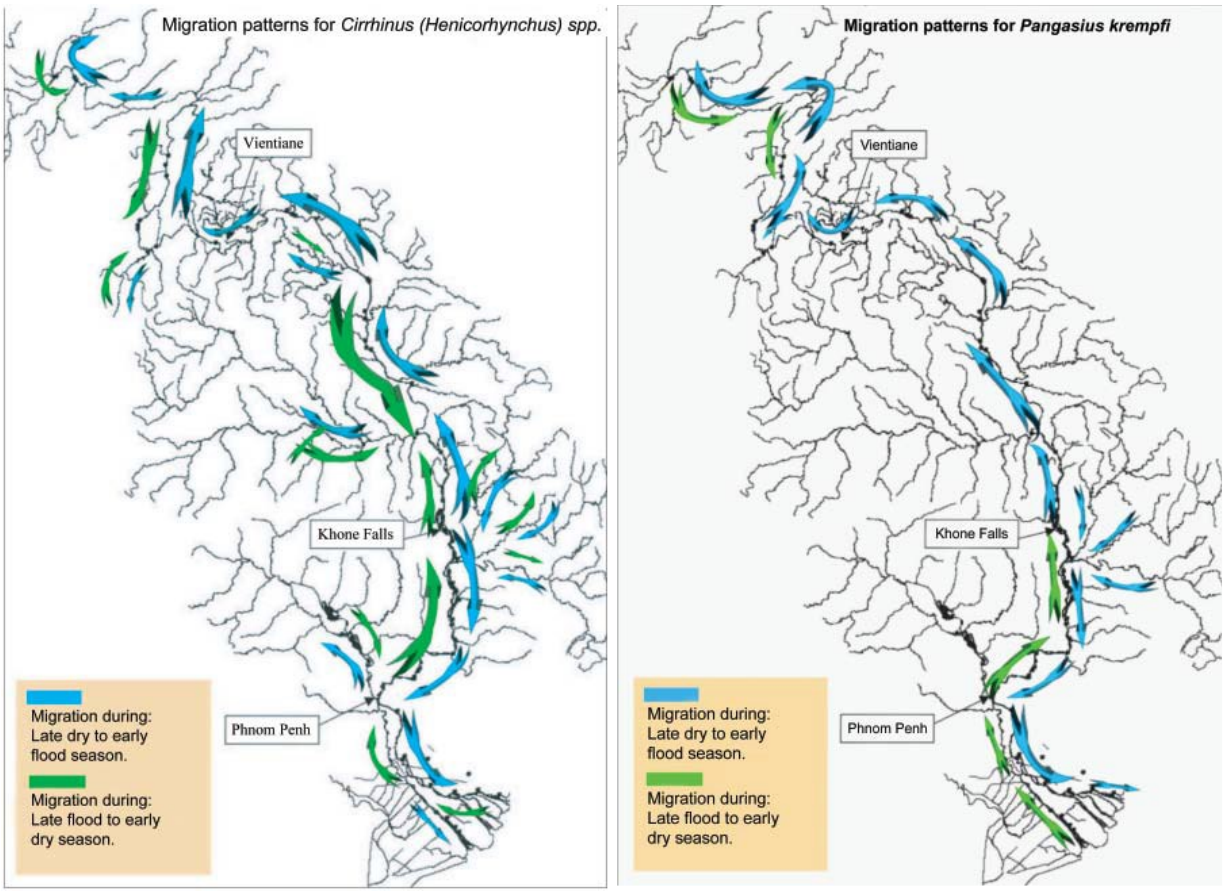


Figure A3.2. Typical migration patterns of key species in the LMB to illustrate the importance of connectivity between the Mekong mainstem and the 3-Ss (from Poulsen et al., 2004)

Importantly, migration of fish in the region occurs throughout the year. The different species utilize different aspects of the hydrograph for both upstream and downstream migration. In addition, eggs and larval life stages drift downstream to recolonize/restock the lower Cambodian floodplain and delta. **This raises the issue that upstream and downstream migration must be maintained throughout the year if the fisheries are not to be compromised, and more importantly, restoration measures should be designed to ensure all habitats for all life stages are restored and migratory pathways between them are maintained at all times.**

Although little is known about spawning requirements for most Mekong fishes, spawning habitats are generally believed to be associated with: (i) rapids and pools of the Mekong mainstream and tributaries; and (ii) floodplains (e.g. among certain types of vegetation, depending on species). River channel habitats are, for example, used as spawning habitats by most of the large species of pangasiid catfishes and some large cyprinids such as C*yclocheilichthys enoplos, Cirrhinus microlepis*, and *Catlocarpio siamensis* that then rely on particular hydrological conditions to distribute the offspring (eggs and/or larvae) to downstream nursery rearing habitats. For other fishes that spawn in main river channels, such as *Pangasius* spp., *Probarbus* spp. and *Chitala* spp., spawning is believed to occur in stretches where there are many rapids and deep pools, e.g. (i) the Kratie–Khone Falls stretch; (ii) the Khone Falls to Khammouan/Nakhon Phanom stretch; and (iii) from the mouth of the Loei River to Bokeo/Chiang Khong. Kratie-Khone Falls stretch and the stretch from the Loei River to Luang Prabang are particularly important for spawning (Poulsen et al., 2002). Floodplain habitats are used as spawning habitats mainly by black-fish species (Poulsen et al. 2002).

To complete these migrations unobstructed passage upstream is required, as well as the capacity for adults, larvae and juveniles to migrate or drift downstream. The timing of these upstream and downstream migrations is variable, depending on fish life cycles, but importantly, there appears to be continuous spawning in the river with peaks, during the spring (February – March) as the most important, followed by the onset of the flood (June – July) and then when the water is receding (November) (Sverdrup-Jensen, 2002). Many of the abundant species caught in the lowlands of the Mekong River system spawn around the beginning of the flood season. This behaviour has been strongly selected for in the monsoonal 'flood-pulse' environment. Flood-related spawning results in the fish larvae and fry growing at a favourable time, when the available aquatic habitat is expanding and zooplankton (the essential food for most fish larvae) is becoming abundant. The primary cause for the differences in upstream migration is adaption to the differences in discharge during each period of year. The small- to medium-sized species, i.e. less than 25 cm and 50 cm of total length (TL), are highly sensitive to discharge, and peak in catches range between 2,000 m^3/s and 4,000 m^3/s. In addition, the large-sized species (> 60 cm TL) are medium-sensitive to discharge at a rate over 5,000 m^3/s, when catches of these large sized species are generally maximized (Baran, Baird & Cans, 2005). This characteristic should be taken into consideration when designing fish restoration measures. These spawning periods are associated with continuous capture of larval and juvenile life stages in drift samples (although the main peaks were observed around the onset of the flood season) taken as part of the MRC identification of spawning grounds in the LMB (RIS) project, and therefore highlight the need to enable downstream drift throughout the year.

Annex 5: Major guild types in the Lower Mekong Basin and their vulnerability to dam development

Guild	Migratory guild name	Typical characteristics	Relative effect of mainstream dams on migration	Relative effect of change in flow regime on fish production
1	Rhithron resident guild	• Resident in rapids torrents, rocky areas and pools in the rhithron.	Little or no impact from mainstream dams (however, there are potentially high in upland storage dams)	Little or no impact from mainstream dams (however, there are potentially high in upland storage dams due to possible exposure of riffle areas and inundation of habitats upstream)
	Indicator groups and/or species **Notopteridae**: *Chitala blanci* (main channel with rocky only), **Cyprinidae:** *Gara* spp., *Brachydanio* spp., *Devario* spp., *Poropuntius* spp., *Tor* spp., *Neolissocheilus* spp., *Osteochilus waandersii*, *Raiamas guttatus*, *Opsarius* spp., *Lobocheiros* spp., *Onychostoma* spp.(Lao PDR), *Scaphidonuchthys acanthopterus* (Lao PDR), *Mekongina erythrospila* (Stuntreng-3S, Lao PRD), *Mystacoleucus* spp., **Balitoridae:** all species (e.g. *Homaloptera* spp., *Balitora* spp., etc.), **Nemacheilidae:** all species (e.g. *Nemacheilus* spp., *Schistura* spp.), **Akysidae:** all species (e.g. *Akysis* spp., *Pseudobagarius* spp.), **Sisoridae:** *Gryptothorax* spp., *Bagarius* spp. (main channel), **Datnioididae:** *Datnioides undecimradiatus* (main channel only), **Channidae**: *Channa gachua,* **Osphronemidae**: *Osphronemus exodon,* **Gobiidae:** *Rhinogobius mekongianus* (above Stuntreng), **Tetraodontidae**: *Pao baileyi* (main channel only), *P. turgidus*			
2	Migratory main channel (and tributaries) resident guild	• Long-distance migrants spawning in the main channel, and sometimes in the upper zone of the Mekong upstream of adult feeding habitat in the main channel • May migrate to refuges (deep pools) in the main channel during the dry season. • Pelagophilic members have drifting pelagic eggs or larval stages returning to adult habitat using backwaters and slacks as nurseries. • Adults do not enter floodplain and may be piscivorous.	Very high	High: flow variation may affect the passability at Khone Falls and other natural barriers, and delayed flooding disrupt migratory cues
	Indicator groups and/or species **Cyprinidae:** *Cirrhinus microlepis*, *Cyclocheilos enoplos*, *Cosmochirus harmandi*, *Probarbus jullieni* **Pangasiidae**: *Pangasianodon hypophthalmus* (all places), *Pangasius larnardii* (all places), *P. mekongensis* (DT-PP-TS only), *P. bocourti* (except the Tonle Sap system), *P. concophilus* (except TS system)			
3	Migratory main channel spawner guild	• Spawning occurs in the main channel, tributaries or margins upstream of floodplain feeding and nursery habitat, often with pelagic eggs or larval stages.	Very high	Very high: loss of connectivity and flooding of spawning and nursery habitat

Guild	Migratory guild name	Typical characteristics	Relative effect of mainstream dams on migration	Relative effect of change in flow regime on fish production
		• Adults and drifting larvae return to floodplains to feed. • May migrate to refuges (deep pools) in the main channel during the dry season.		
	Indicator groups and/or species **Clupeidae:** *Clupeichthys aesarnensis* (all places), *Clupeoides borneensis* (all places), *Corica laciniata* (DT-PP-TS), **Cyprinidae:** *Cirrhinus prosemion*, *C. jullieni*, *Hypsibarbus* spp., *Puntioplites falcifer* (above Kratie), *P. proctozysron* (below Kratie till DT)., *Labeo chrysophekadion, L. pierrei*, *Sikukia* spp., *Incisilabeo behri*, *Scaphognathops* spp. (above Kratie), *Barbichthys laevis*, *Leptobarbus rubripinna, Amblyrhynchichthys micracanthus,* **Botiidae:** all species (*Syncrossus* spp., *Yasuhikotakia* spp.), **Pangasiidae:** *Pangasius macronema, Pseudolais pleurotaenia, Helicophagus leptorhynchus,* **Siluridae:** *Walago attu, Phalacronotus* spp., *Kryptopterus* spp., **Bagridae:** *Hemibagrus* spp., **Cobitidae:** *Acantopsis* spp., *Acanthopsoides* spp. (prefers sandy bottom), **Gyrinocheilidae:** all species, **Tetraodontidae:** *Auriglobus nefastus*			
4	Migratory main channel refuge seeker guild	• Migrates from floodplain feeding and spawning habitat to refuges (deep pools) in the main channel during the dry season. • Spawning occurs on the floodplain and main channel used as refuge during dry season.	Medium	High: loss of connectivity and flooding of spawning and nursery habitat
	Indicator groups and/or species **Cyprinidae:** *Barbonymus altus*, *B. schwanefeldii*, *Cyclocheilichthys* spp., *Rasbora* spp., *Paralaubuca* spp., *Parachela* spp., *Thynnichthys thynnoides,* **Cobitidae:** *Pangio* spp., **Siluridae:** *Ompok siluroides;* **Bagridae:** *Mystus* spp., **Pristolepididae:** *Pristolepis fasciata*, **Ambassidae:** *Parambassis wolfii*, *P. apogonoides,* **Sciaenidae:** *Boesemania microlepis* (d/s Stuntreng common, above Khone Falls very rare now), **Tetraodontidae:** *Pao cambodgiensis*, *P. suvattii* (above Khone Falls only)			
5	Generalist guild	• Limited non-critical migrations in mainstream. • Highly adaptable, mobile and static elements in their genome make them highly adaptable to habitat modification.	Little or no impact	Medium: loss of connectivity and reduced flooding of floodplain
	Indicator groups and/or species: **Notopteridae:** *Notopterus notopterus*, *Chitala ornata*., **Cyprinidae:** *Gymnostomus* spp., *Barbonymus gonionotus*, *Systomus orphoides*, *Crossocheirus* spp. *Osteochirus vittatus*, *O. microcephalus*, *Hampala* spp., *Labiobarbus* spp., *Cyclocheilichthys* spp. **Syngnathidae:** *Doryichthys boaja* (below Kratie to DT-TS), *D. deokhatoides* (below Kratie to DT-TS), *D. contiguus* (confirmed between Vientiane-Ubonratchathani, but does not exist below Khone falls), **Mastacembelidae:** *Mastacembelus* spp. (e.g. *M. favus*, *M. armatus*), **Ambassidae:** *Parambassis siamensis,* **Eleotridae:** *Oxyeleotris marmorata*			
6	Floodplain resident guild (Blackfish)	• Limited migrations between floodplains pools, river margins, swamps, and inundated floodplains. • Tolerant to low oxygen concentrations or complete anoxia.	Little or no impact	Medium: loss of connectivity and reduced flooding of floodplain

Guild	Migratory guild name	Typical characteristics	Relative effect of mainstream dams on migration	Relative effect of change in flow regime on fish production
	Indicator groups and/or species: **Cyprinidae:** *Esomus* spp., **Cobitidae:** *Lepidocephalichthys hasselti,* **Clariidae:** all species (e.g. *C. macrocephalus*, *C.* cf *batrachus*), **Adrianichtyidae:** *Oryzias siamensis*, *O. minutillus,* **Hemiramphidae:** *Dermogenys siamensis,* **Channidae:** *Channa striata*, *C. lucius*, **Anabantidae:** *Anabas testudineus,* **Osphronemidae:** *Trichopodus* spp., *Trichopsis* spp., **Synbranchidae:** *Monopterus albus,* **Mastacembelidae:** *Macrognathus* spp., **Tetraodontidae:** *Pao cochinchinensis*			
7	Estuarine resident guild	• Limited migrations within the estuary in response to daily and seasonal variations in salinity.	Little impact (if dam is upstream of estuary and does not influence salinity dynamics in estuary).	Little or no impact
	Indicator groups and/or species **Plotocidae:** *Plotosus canius* (DT), **Ariidae:** all species (DT), **Adrianichthidae:** *Oryzias haugiangensis* (DT), **Gobiidae:** *Glossogobius* spp. (DT-TS-PP), **Polynemidae:** *Polynemus* spp. (DT-TS-PP), **Cynoglossidae:** all species (DT-PP-TS), **Soleidae:** *Brachirus* spp. except *B. harmandi* and *B. siamensis*			
8	Anadromous guild	• Enters fresh/brackish waters to breed. • Enters freshwaters as larvae/juveniles to use the area as a nursery, either obligate or opportunistic.	High (for dams located in river mouths or lower potamon).	Little or no impact
	Indicator groups and/or species **Pangasiidae:** *Pangasius krempfi*, *P. elongates* (mainstream only), Ariidae: all species (DT-PP)			
9	Catadromous guild	• Reproduction, early feeding and growth at sea. • Juvenile or sub-adult migration to freshwater habitat, often penetrating far upstream.	Very high	Very high: loss of connectivity to feeding and nursery habitat
	Indicator groups and/or species **Angullidae:** *Anguilla marmorata, A. bicolor* (all nodes), **Ophichthidae:** *Pisodonophis boro* (DT-PP-TS)			
10	Marine visitor guild	• Enters estuaries opportunistically	Little or no impact	Little or no impact
	Indicator groups and/or species **Scombridae:** *Scomberomorus sinensis* (DT-PP), **Gerreidae:** all species (DT), **Ambassiidae:** all species except *Parambassis* spp. (DT), **Terapontidae:** *Terapon jarbua,* **Sciaenidae:** all species except *Boesemania,* **Gobiidae:** *Pseudapocryptes elongatus, Periophthalmodon schlosseri*			
11	Non-native		Little or no impact	Little or no impact
	Indicator groups and/or species, **Cyprinidae:** *Labeo rohita, Cirrhinus cirrosus*, Cyprinus *rubrifuscus*, **Serrasalmidae:** *Piaractus brachypomus*, **Clariidae:** *Clarias gariepinus*, **Loricariidae:** *Pterygoplichthys* spp., **Cichlidae:** *Oreochromis* spp.			

Source: Based on Welcomme, Winemiller & Cowx, 2006, and MRC Council Study BioRA report 1.
Note: Grey shading highlights most vulnerable guilds.

Annex 6: Semi-structured interviews for field visits

SEMI-STRUCTURED INTERVIEWS: Non-fisheries stakeholders

Describe the local status and conditions of the aquatic environment

- What is the main area that is used by the stakeholder?
- What is the catchment area of the aquatic system under control?
- What is the land use in the catchment area?
- What is the nearest large urban area?

Ownership and management

- Who is the owner/manager of the water body?
- What is the primary and secondary use of the water body?
- What management regime exists for the water body?
- Water resources management
- Other activities

Fisheries

- Is there any integrated resource management/co-management arrangement?
- What fisheries exist in the target water body and associated key habitat?
- Describe by species or species groups
- Commercial fishing
- How many fishers and what is the exploitation?
- Subsistence fishing licences
- How many fishers and what gears?
- Is there any stocking?
- Are there any access problems for fishing?

Identify issues affecting the river system, habitat form and function, fisheries catch and biodiversity, and your livelihoods

- Habitat fragmentation
- Habitat alteration – how and what is the impact?
- Water level modification
- Extreme droughts and floods
- Water quality issues
- Sedimentation
- Illegal fishing
- Alien species
- Algal blooms/ eutrophication
- Conflicts between users
- Commercial fisheries v subsistence fisheries

- Fisheries and agriculture, urban development, hydropower, barriers, channelization

Options for development

- Fisheries
- Recreation
- Other uses

  Who should manage development?
  What sources of investment are available?

SEMI-STRUCTURED INTERVIEWS: Fisheries stakeholders

Demography

- Age of fisher Sex
- Family dependents

Fishing operations

- How long have you been fishing?
- How long on this water body?
- What gears to you use?

  Type, number and mesh size
- What is your target species?
- Full-time or part-time fishing

  What is the contribution of fisheries to livelihoods (contribution to income)?
  What is the contribution of fisheries to food security (proportion of animal protein)?
- What other livelihoods do you carry out?

  Source of income during the closed season

Catch

- Species caught

Is there seasonal variation?

- Describe trends in catches

  Seasonal
  Long-term annual
  Size of catch
  Size of fish caught
- What is your understanding of fishing regulations?
- What are the management arrangements for fisheries?

  Explain co-management arrangements if any

Markets

- Where do you sell your fish?

- How much do you consume?
- What are the issues with fisheries and fishing?

  Declining catches

    Catch in species composition
    Competition and poaching
    Other resource users
    Water levels
    Access

Issues are prevalent that affect the river system, habitat form and function, fisheries catch and biodiversity and your livelihoods

- Questions as for non-stakeholder interviews
- What are the options for development?

  Management of fisheries
  Establishment of protected areas
  Implementation of habitat improvement measures
  Stocking
  Aquaculture development

Annex 7: Stage 3 – How can we restore or protect key fish habitats from the impacts of hydromorphological pressure

	Stage of protocol	Possible methodological approach	Output	Explanation	Example of aactions
Step 1: Project identification					
Step 1(1)	Review current status of water body and/or other aquatic resources	DPSIR (current *state*)	List of all water bodies that have key fish habitats that are good quality and need protecting, or have hydromorphological (HyMo) issues and need restoration	Draw on information from MRC State of the Basin (SOB) to define the current status of the aquatic environment, determine pressures on the system and evaluate impact of resource users. (Information collated in Technical Guidelines Stage 1 and 2)	Ex. A water body may not be performing well because of poor water quality due to high nutrient loads or has been disconnected from the floodplain for irrigated agriculture. If the source of nutrients is poor farming practices, there may exist HYMO restoration potential to intercept nutrients. If the system has been completely disconnected and natural flooding is not possible to allow fish to move between habitats, potential restoration actions are limited and investment should move elsewhere.
Step 1(2)	Identify regional policy objectives	DPSIR (*drivers*)	List of all water bodies that have key fish habitats that are good quality and need protecting, or have HYMO issues and need restoration, including those listed in the Mekong fisheries management plan.	The MRC SOB report and country reviews provide lists, actions and protected areas, and indicate why they were established. These outputs should be compared with international, regional and local policy objectives to see how restoration might be connected to other projects and future planning, and how protected areas can be linked to achieve sustainable development and conservation goals. The SOB may have already identified certain rivers, river reaches or river types as priorities for restoration and or protection. Issues of ownership, politics, finances, and cultural resources may eliminate some sites from the list of potential projects.	Ex. Restoration potential or efficacy of protected areas is also dependent on river basin management. Ongoing development may impact on the likelihood of success of the project and thus external factors from other sectors need to be considered in the identification of projects.
Step 2: Setting project objectives					
Step 2(1)	Identify water body goals and specific objectives	DPSIR (reference *state*)	List of water bodies and their characteristics that can provide reference conditions to be compared with the water bodies selected in Step 1 and what should be achieved.	Identify one or more reference rivers/reaches and the key habitats and HyMo processes that will serve as reference condition benchmarks. These rivers/reaches will be used in Steps 3 and 4 to assess potential restoration sites or protected areas to identify causative issues affecting the impaired water body and the effective actions to restore in Steps 3 and 4. The aim is to provide the monitoring framework and/or serve as a monitoring control in Step 6.	Ex. Identify key habitats of importance to fisheries analysis of the current status and expected outcomes to define endpoints and establish the objectives of the restoration actions to achieve policy objectives. Objectives are defined in TG Box 3.

Step 2(2)	Compare water body status with policy objectives	DPSIR (*impacts*)	Analysis of ecological elements of the ecosystem that has been degraded to identify restoration measures or define good quality habitats that need protecting. This is determined by comparing Step 3 reference sites with Step 2 potential rehabilitation sites or protected areas.	Analyse the bottlenecks in quality elements resulting in poor status of the habitat and the need for restoration. A restoration deficit analysis should be completed using the benchmarking reference conditions for the relevant quality elements. For selecting protected area, the key habitat should provide all the necessary quality elements to ensure ecological and hydromorphological process are functioning at a high level to ensure ecosystem integrity.	
Step 2(3)	Identify issues affecting the water body both directly and indirectly	DPSIR (*pressures*)	List of causes and effects for the ecological elements of ecosystem that have been degraded to identify deficits for water bodies	Examine both basin hydrology and in-stream hydraulics for the causes and effects of ecological degradation, and identify which causes must be addressed to restore the habitat to good quality. There is need to include potential human activity changes (land uses), and impacts of climate change and invasive species, without which a restoration project will fail or not achieve the expected outcome. Issues of time and spatial scales must be addressed at this point. External factors that may impact the suitability of a protected area should be identified, and alternative sites and/or objectives for habitat need to be established.	
Step 2(4)	Identify appropriate HYMO process restoration actions or habitat protection needs	DPSIR (*responses*)	List of types of restoration actions to achieve each acceptable endpoint or target for restoration, or identify key habitat types to be protected to ensure the species are able to complete their life cycles	After determining causes and effects (Step 2(2) and 2(3)), identify what processes must be addressed and what endpoints are acceptable for restoration the status and quality of the target habitat. Select the hydrological and hydraulic processes and morphological changes to be considered for restoration actions to achieve these objectives. Spatial scale issues should be addressed. Criteria for setting objectives are defined Technical Guidelines Box 3. These should be liked to developing a Logical Project framework for	

				designing the proposed project to be implemented (TG Box 4)	
Step 3: Project formulation					
Step 3(1)	Review and select appropriate HYMO restoration actions or habitat protection needs	Specific, measurable, attainable, relevant and timebound (SMART) (*specific)*	Report on specific HyMo restoration actions to achieve each acceptable endpoint or target for restoration, or identify key habitat types to be protected to ensure the species are able to complete their life cycles	For each HyMo action there is a plurality of implementation techniques, each with a specific design and engineering effort, cost, operation and maintenance requirements, spatial and temporal requirements, and efficiency. Criteria for selecting key fish habitats of regional importance for restoration or protection are provided in Technical Guidelines Box 6.	Ex. Floodplains may be reconnected using a variety of techniques, including fish passes, breaching of flood protection levees, management of flood gates to support fish migration should be evaluated. If there is insufficient desire to reconnect wetlands, a constructed floodplain might be considered, which may address 2 or more of the deficits.
Step 3(2)	Design monitoring programme (BACI/BA/CI) and key indicators	SMART (*measurable*) Benchmarking and endpoints	Establish a programme of key indicators and a monitoring protocol for each restoration site or protected area.	Design the monitoring programme prior to implementation of the restoration project or establishing the protected area. Data from controls or reference sites may be needed for engineering design and "before" monitoring must begin at least 1 year before changes are made. Set benchmarking and endpoints (see Technical Guidelines Box 5). Depending on the type of changes proposed, a considerably longer "before" monitoring programme may be required. Time and spatial scales of monitoring should be carefully considered.	Ex. A "before" monitoring programme should include understanding the fish catch dynamics and characteristics before intervention. In addition, a complete hydrogeomorphological (walkover) study is needed of the river/wetland and riparian areas. If sediment transport and stream flow data are needed, the studies should start several years before implementation. If a reference reach is being used for channel design purposes, the hydro-geomorphological study of the reference channel must be done in advance of any engineering design, cost determination, or permitting. Stability of the reconfigured channel or wetland may need to be monitored over several decades depending on flood recurrence.
Step 4: Risk assessment					
Step 4	Prioritization of restoration actions or habitat protection needs with justification	Risk analysis	Carry out a risk analysis of cost-effective technique(s) and costs for each project site	Carry out a risk and cost benefit analysis – including integration of multiple objective scenarios carried out (Technical Guidelines Box 8). Highly engineered techniques tend to be very costly and may require costly operation and maintenance efforts. Success monitoring may require high tech installations and expertise. The costs (damage, legal, replacement, etc.) of failure may also be high (e.g. flooding.). Impacts on fishing communities and other users has been evaluated.	EX. A reconnecting floodplain could impact on agricultural production or increase flooding. These changes in resource use and impact on other stakeholders must be accounted for in formulation – requires considerable engagement with all stakeholders and establishment of local management committees.

Step 5: Project Implementation					
Step 5	Implementation		Select rehabilitation sites and watersheds. Select protected areas defined and established in local and national law,	Completed restoration project or protected area established. Most rehabilitation projects have several parts, some of which should be implemented consecutively and some simultaneously. The temporal scales of disturbance and recovery must be considered	Ex. New protected area limits defined and co-management arrangements in place. Ex. Fish pass constructed or floodplain reconnected to main river and natural flooding reinstated.
Steps 6 and 7: Project monitoring and evaluation					
Step 6	Monitoring	SMART- (*relevant, time-bound*) wise approach or participation ladder	Periodic monitoring results reports Rehabilitated site(s) and appropriate parts of the watershed,	Key indicators (Technical Guidelines Table 3.9) are all monitored at appropriate temporal and spatial scales to understand whether the restoration action or protected has achieved its objectives.	Ex. The "after" monitoring programme included real-time water quality (nutrient, turbidity) and fish catch monitoring. Fish catch CPUE maintained but size of fish caught was reduced; thus, the acceptable EP was not reached. The expected maintenance of catch diversity did not occur.
Step 7 (a)	Evaluation	SMARTER (*evaluate*)	Report of success or failure of rehabilitation project and proposed corrections	Most projects experience a mix of success and failure. At times, corrections are easily identified. Monitoring and subsequent evaluation should be conducted	Ex. Better recruitment to fish population but fishing pressure remained high. Management of the protected area needs adjustment. Ex. Recruitment to fishery not maintained because of fragmentation of habitat caused by changes in flow regimes disconnecting floodplain. Need to consider mechanisms to connect isolate habitats. Corrections are proposed to overcome problems.
Step 7(b)	Update goals and restoration management actions	SMARTER (re-evaluate)	Revised restoration goals and management actions. Redefine protected area and fisheries management regulations.	Updating goals and revising management actions are iterative processes, and periodicity will depend on HYMO processes, monitoring results, changing patterns of human activity, etc	Ex. Expand protected area and impose stricter fishing regulations. Reconnection of floodplain not functioning because of changes in flow regimes. If the end point is not reached, reconfiguration of channel geometry and floodplain will be considered

Mekong River Commission Secretariat

P. O. Box 6101, 184 Fa Ngoum Road, Unit 18 Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR

Tel: +856 21 263 263| Fax: +856 21 263 264 www.mrcmekong.org