MEKONG RIVER COMMISSION SECRETARIAT	
Office of the Secretariat in Vientiane 184 Fa Ngoum Road, Ban Sithane Neua, P.O. Box 6101, Vientiane, Lao PDR Tel: (856-21) 263 263 Fax: (856-21) 263 264	**Office of the Secretariat in Phnom Penh** 576 National Road, No. 2, Chak Angre Krom, P.O. Box 623, Phnom Penh, Cambodia Tel: (855-23) 425 353 Fax: (855-23) 425 363
mrcs@mrcmekong.org	*www.mrcmekong.org*

MRC Initiative on Sustainable Hydropower (ISH)

IMPROVED ENVIRONMENTAL AND SOCIO-ECONOMIC BASELINE INFORMATION FOR HYDROPOWER PLANNING

ISH11 PHASE 2 REPORT: Fisheries Annex

20 December 2013

Abbreviations and Acronyms

BDP	Basin Development Plan (of the MRC)
CPUE	Catch per Unit Effort
DLF	Department of Livestock and Fisheries
DoF	Department of Fisheries, Thailand
EP	Environment Programme (of the MRC)
FAO	Food and Agriculture Organisation (of the United Nations)
FiA	Fisheries Administration (Cambodia)
FP	Fisheries Programme (of the MRC)
HH	Household
IFReDI	Inland Fisheries Research and Development Center
IKMP	Information and Knowledge Management Programme (of the MRC)
ISH	Initiative on Sustainable Hydropower (of the MRC)
IWRM	Integrated Water Resource Management
LARReC	Living Aquatic Resources Research Center (Lao PDR)
LECS	Lao Expenditure and Consumption Survey
LEK	Local Ecological Knowledge
LMB	Lower Mekong Basin
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
Mt/yr	Million tonnes per year
NMC	National Mekong Committee
OAA	Other Aquatic Animal
PNPCA	Procedures for Notification, Prior Consultation and Agreement (under the 1995 Mekong Agreement)
PDG	MRC Preliminary Design Guidance for proposed LMB mainstream dams
PDR	People's Democratic Republic
QA/QC	Quality Assurance / Quality Control
RAFC	Rural, Agricultural and Fisheries Census
RIA2	Research Institute for Aquaculture No. 2 (Viet Nam)
SEA	Strategic Environmental Assessment
SIMVA	Social Impact Monitoring and Vulnerability Assessment
SoB	State of the Basin
SOP	Standard Operating Procedure

SPM	Suspended Particulate Matter
ToR	Terms of Reference
TSS	Total Suspended Solids – old term for SPM
WI	Work Instructions
WWF	World Wide Fund for Nature

Table of Contents

List of Figures

List of Tables

1 Context of Fisheries within the ISH11 Study

This ISH11 Phase 2 Fisheries Annex updates the ISH11 Phase 1 Fisheries Annex of 31 March 2013.

The ISH11 Phase 1 Fisheries Annex was based upon information on existing fisheries monitoring provided during meetings with the MRC FP and EP, discussions and guidance during an inception meeting (27 Nov 2012), a first regional consultation (6 March 2013), background information from published and grey literature, and information as provided by the FP and the LMB countries for the 2010 State of the Basin Report.

Since March 2013 the activities included national and regional consultations (refer to ISH11 Phase 2 Main Report), further meetings with the MRC FP and a partial review of FP databases, review of additional publications and reports as noted in this report, and a workshop on Standard Methods development (Vientiane 16 Oct 2013). Meetings were also held to review the SIMVA study and provide advice on questions related to fisheries for a follow-up survey. Attachment 2 shows responses to some of the points raised during consultations regarding fisheries as well as the contributions from ISH11 national consultants. Attachment 3 provides an overview of the materials presented and discussed at the Standard Methods Workshop. Attachment 4 provides an updated bibliography of key fisheries references for this project.

Fisheries is one of the five specialist disciplines under ISH11. It is appropriate that fisheries receives a high level of attention during the ISH11 study for several reasons:

1. Fisheries are very important in the LMB for nutrition and livelihoods; virtually all of the basin's 60 million inhabitants eat inland fish and other aquatic animals and most rural households go fishing or collect other aquatic animals at some time. Capture fisheries yield about two million tonnes per year and the LMB is widely recognised as supporting the world's largest inland fishery (Mattson and Jutagate 2005, Hortle 2009, IFREDI 2012).
2. There are many developments in progress in the basin that will alter the environment. Among these, hydropower has a high profile and hydropower dams will generally cause negative effects on river-floodplain fisheries, with some increased production in new reservoirs and new opportunities for aquaculture (Hortle 2010, IFREDI 2012). There are also likely to be effects on the delta, depending upon changes in flow and salinity intrusion (WUP/EP 2006).
3. While the importance of fisheries is increasingly recognised, e.g. during the PNPCA, and BDP Scenario Assessment processes in 2010-11, there is little agreement on the magnitude of impacts of hydropower development (e.g. Friend 2009). The unavailability of timely and focused information from fisheries monitoring in the LMB prevents accurate impact prediction and causes polarisation of views, an undesirable situation in which constructive dialogue becomes highly constrained. The ISH11 study is very useful way to improve monitoring and the level of dialogue on fisheries issues and hydropower impacts, management and mitigation.
4. Surveys and monitoring of fisheries by hydropower developers are site-specific and generally neither publically available nor provided to the MRC. The MRC is the only organisation mandated to carry out coordinated monitoring of fisheries at the basin level, a desirable scale given the importance of migrations of fish within the system, similarities of habitat over long reaches of the river, and likely scale of impacts from extensive development of hydropower dams. The existing fisheries monitoring carried out by the MRC FP provides a good institutional framework established over many years for basin-wide fisheries monitoring. The FP currently invests about US$0.5 m per year directly in funding national agencies for fisheries monitoring, with additional fixed costs. The ISH11 study provides an opportunity to support an assessment of the existing monitoring to suggest improvements that will provide better-quality information in a more timely manner, particularly for the purposes of hydropower assessment and monitoring. The EP

SIMVA project also collects fisheries data through sampling of over two thousand households along the mainstream; as for the FP monitoring, the ISH11 study is an opportunity to improve the SIMVA activity for long-term implementation.

5. Various fisheries studies or monitoring are carried out in each of the LMB countries by national agencies. In general the methodologies are not readily available. The ISH11 study can assist the countries to improve their fisheries monitoring by developing standard approaches, writing SOPs, and through training and capacity development, so that national and MRC monitoring can be as well-aligned as possible, especially for national-level hydropower assessment and monitoring.
6. The importance of monitoring fisheries in their own right is recognised by the MRC, but standardised monitoring of fish and other aquatic animals can also meet separate objectives of categorising the condition of the river in terms of its health or biotic integrity, as is usual practice elsewhere. The ISH11 study offers an opportunity to develop, test and document standard methods for fish monitoring (as distinct from fisheries) and to develop indicators or metrics in line with best practice elsewhere, particularly as these would relate to hydropower impacts. Such standardised fish sampling would be a new activity for the MRC and a valuable outcome from ISH11 that would complement existing bio-monitoring. The standardised fish sampling would be supported by habitat assessment, as is usual elsewhere but not yet currently applied in MRC-sponsored activities. ISH11 can also support development of monitoring of the biological characteristics of fish (diet, reproduction, condition etc.), as well as stock status, all common elements of monitoring that are yet to be developed in the Mekong.

This report contains:

- an overview of best practice for fisheries monitoring programmes, with an emphasis on river fisheries (Section 2),
- a review of literature and state of knowledge, including current monitoring, and a summary of some key features of the fisheries of the lower Mekong Basin (LMB) as relevant for monitoring hydropower effects (Section 3),
- an analysis of gaps in current MRC fisheries monitoring (Section 4),
- a summary of the ISH11 study's recommended improvement proposals for Phase 3 (Section 5),
- conclusions (Section 6), references (Section 7) and Attachments.

Figure 1 – Downstream of Nam Ngum dam and hydroelectric plant in Lao PDR

This dam created a major reservoir which supports a large fishery. Since its closure in 1971 this dam has regulated the flow of the Nam Ngum River and causes various other downstream effects; monitoring information is needed to inform fisheries management and development of aquaculture.

2 Best Practice Monitoring for Fisheries

2.1 Introduction

Fisheries are complex systems involving biological production, harvest (catches), processing, distribution and consumption, supported by various industries, producing various wastes, and at the receiving end of all kinds of impacts from human activities and natural events. Each of the main elements of fisheries may be studied or monitored, each requiring particular approaches and producing various kinds of information. The main elements that can be monitored are as shown in Figure 2.

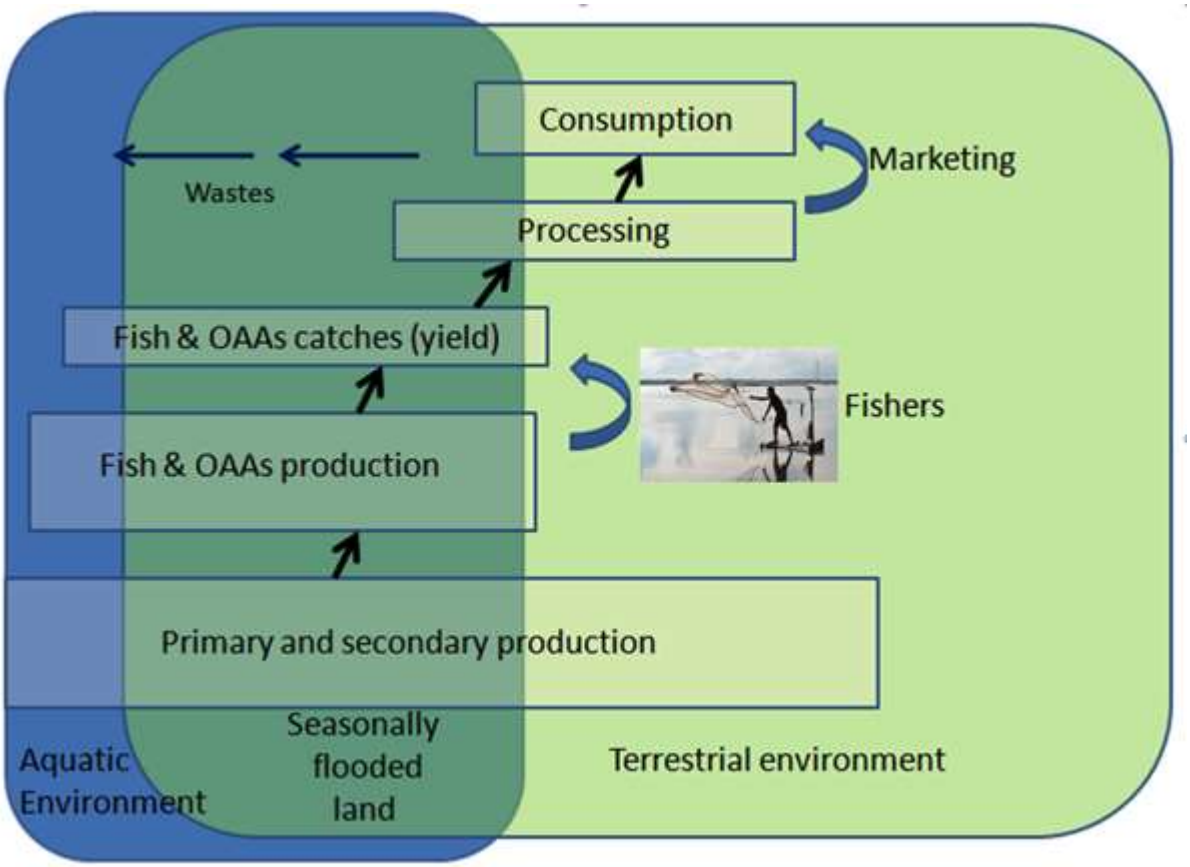


Figure 2 – Diagram of a fishery's main elements, each of which can be monitored

Seasonally flooded land is particularly important in the Mekong basin, and terrestrial processes all affect fisheries. Supporting industries are omitted for clarity.

A fishery may be monitored for two broad purposes:

(1) to describe changes in the fishery itself, or

(2) to use fish or fisheries as a way of monitoring the ecological status or health of the aquatic environment.

LMB fisheries are of great importance for livelihoods and nutrition. The main objective of MRC-sponsored monitoring is to describe and understand changes in fisheries in their own right (1), and this objective is the focus of the monitoring proposed and consistent with the objectives of the MRC Fisheries Programme (FP). However, some of the activities recommended will support (2) as changes

in fisheries in the Mekong are likely to be a result of natural environmental variation (e.g. in water and nutrient availability), environmental changes caused by development in other sectors, and fishing pressure. Hence interpretation of data from monitoring of inland fisheries requires ancillary supporting environmental data as well as data from other sectors that cause stress or pressure on fisheries. Interpretation of fisheries monitoring data also requires information on fishing pressure, to discriminate the causes of changes. As well as monitoring the quantities and value of fish and OAAs caught – the emphasis of the FP to date - the condition and quality of fisheries species must receive more attention.

Best practice monitoring of fisheries follows basic quality principles and generally established practices, suitably adjusted to take account of local conditions. Some best-practice approaches specific to fisheries include:

- following a documented process to select gears;
- consistent design of gears;
- consistent setting or use of gears by habitat and time;
- understanding and taking account of gear biases;
- accurate recording of sampling or fishing effort;
- accurate identification of fish and OAAs;
- accurately measuring lengths and weights; and
- reducing operator errors in large-scale surveys with many participants.

As shown in Figure 2, 'best practice' approaches can be defined for monitoring of each of the fisheries main elements, as provided for in the following sections. For all existing monitoring there needs to be good documentation of methods and use of SOPs, and where relevant chain-of-custody for samples, and a systematic and documented approach to data handling.

2.2 Monitoring of Hydropower Impacts on Fisheries

As fisheries are at the receiving end of many impacts, it will be difficult to categorically identify hydropower dams as the cause of any particular changes. However, large dams are known to cause various changes that are likely to be distinctive and greater close to a dam. These include changes to the environment which include barrier effects, and others which can be grouped under hydrology, water quality or habitat. These can lead to changes to the fish populations and changes to the behaviour and condition of individual fish, all of which lead to changes in fishing activities and the composition, abundance and biomass in catches or samples, which further affect marketing and the industries that support fisheries. Aquaculture tends to expand in hydropower reservoirs and downstream.

The parameters that could be monitored are summarised in Table 1, together with some of the features specified by Kusek and Rist (2004) for a monitoring plan. Other features which need to be considered include locations, responsibilities, costs, analytical needs, reporting, implementing agencies and users.

As shown in Table 1, data on a range of parameters should be collected during monitoring. Rather than analysing spatial or temporal patterns by species, Jutagate (2007) has outlined an approach to classify fish into 12 main guilds - groups based on similar behaviour, reproduction or habitat use. Fish within guilds are likely to respond in similar ways to hydropower impacts, simplifying analyses, as there are typically 200-300 species recorded at any site and about 850 recorded from the Mekong Basin (Hortle 2009).

Indicators of hydropower impacts would be generated from parameters based on well-established patterns from hydropower dams elsewhere, for example:

- changes in habitat types and extent, for example loss of pools, reduction in flooded area;
- changes in habitat quality, for example loss of snags as trees are trapped by dams;
- changes in the food chain, from a diversity of riverine and terrestrial food, especially insects, to a simplified food chain based on the zooplankton growing in reservoirs, with consequent changes in the fish community;
- declines in large migratory fish species;
- increases in generalist species;
- increases in planktivorous or filter-feeding fishes and OAAs such as clams;
- increases in some predatory species in reservoirs and immediately downstream of dams, including some fishes and predatory birds;
- increased mercury content in fish as a result of biomethylation in anoxic sediments in dams;
- other biological effects on fish, such as reduced condition and fecundity (egg production);
- changes in the fishery, such as increasing commercial fishing;
- flow-on effects to increased aquaculture production.

Indicators can be readily defined based upon these well-established effects.

There will usually be alternative explanations for any observed changes, so interpretation must rely upon likelihoods and weight-of-evidence approaches, and supporting environmental and pressure data will be necessary for interpretation.

Table 1 – Short list of parameters for monitoring of hydropower impacts on fisheries

Type of parameter or indicator	Examples of specific parameters	Relevance for hydropower planning
Habitat	Area of permanent and temporary water and features such as pools, riffles and sandbars. Areas of in-stream or in-reservoir habitat including vegetation, and areas and quality of riparian vegetation.	Dams lead to many kinds of changes in habitat extent and quality downstream and in reservoirs.
Fish and OAA populations	Abundance and weight of fish and OAAs in catches or in samples, species lists or occurrence data.	Fish and OAA species composition, abundance and biomass will be affected by changes in environmental conditions as a result of hydropower development.
Fish and OAAs biological features	Condition, growth rate, dietary and reproductive parameters, parasites and diseases.	Changes in hydrology, water quality and the food chain lead to changes in fish and OAA condition and growth rate, which ultimately lead to changes in fish and OAA populations.
Fish and OAAs population structure	Proportional makeup of subpopulations. Rates of gene flow.	Dams fragment populations, reducing or stopping gene flow between upstream and downstream river segments.
Fish and OAAs migration patterns	Species migration patterns and ontogeny from observation, tagging or isotope studies.	Dams may prevent or restrict fish migration.
Fish and OAAs contamination	Concentration of mercury and pesticides in fish and OAAs. Note: assumes supporting studies of sediments and water quality.	Reservoirs may increase methylation of mercury leading to biomagnification. Increasing pesticide use under agricultural intensification may lead to impacts that are unrelated to hydropower.
Fishing pressure	Number of fishers full-time, part-time and occasional, number and size and type of boats, number and dimensions of gears, time that gear is set or used.	Direct and indirect changes related to hydropower include in rivers up and downstream and in the new reservoir, leading to changes in fishing effort and overall fishing pressure
Fish stocking	Species, quantities and sizes, growth rate and percent recapture.	Reservoirs are often stocked as a mitigation or enhancement measure.
Aquaculture	Type of systems (cage, pond, cove), extent or capacity, species, production inputs and outputs.	Hydropower dams provide new opportunities for aquaculture development, but may also affect operations downstream through water quality changes
Fish processing and marketing	Market channels, market statistics including prices and quantities by species, employment and economic aspects.	Marketing and distribution of fishery products will change as a result of changes in capture fisheries and aquaculture and demographics and infrastructure.
Fish and OAA consumption	Household consumption of fish and OAAs.	Changes in production of the capture fishery and from aquaculture will lead to altered patterns of consumption.
Fisheries-supporting industries	Fishing gears and boats - types, quantities value.	There are many flow-on effects from changes in the fishery; some of these such as fuel, salt and ice are generic.

2.3 Ancillary Data on Hydrology, Water Quality, Bio-Monitoring and Habitat

Refer to separate ISH11 Annexes for reviews of Hydrology, Water Quality, Sediments and Geomorphology, and Aquatic Ecology, disciplines which can provide important ancillary environmental data for fisheries information.

Methods for mapping aquatic habitats have developed since the 1970s and are well-described by Bain and Stevenson (1999), DEP (2006) and Zale *et al.* (2013). Habitat mapping at sampling locations will generally include in-stream measurements of wetted width, slope, stream depth, turbulence, water velocity and substrate, as well as cover, which includes wood debris and aquatic vegetation. Other out-of-stream habitat measurements include stream-bank and shoreline condition, riparian vegetation extent and density, and barriers to fish movement. At the time of sampling, supplementary water quality data may be collected to relate to fisheries sampling efficiency (e.g. Secchi disc transparency or conductivity) or to understand 24-hour patterns (especially oxygen concentration) which are not evident from routine (2-monthly) data collection. Methods are well-described in standard texts, but will require testing and development for the Mekong. A high level of precision may not required where measurements are used only to classify sites or part of the river into broad categories, as is likely to be the case. General elements of best practice should be followed during development of methods.

2.4 Interviews for Collecting Fisheries Information

To establish the range of variation and trends in fisheries parameters of interest may require many measurements to be taken over years or even decades. As a result, “best practice” monitoring has increasing emphasis on accessing local ecological knowledge (LEK) by interviews of fishers (e.g. Haggan *et al*. 2007, Bao *et al.* 2001, Friend 2009) on the assumption that LEK integrates many years of prior observations by many people. At a minimum, such interviews can provide considerable background information that is useful for design of more conventional sampling as is proposed for this ISH11 study, and ideally provide more quantitative data on catches and/or consumption. Socio-economic surveys using standardised interviews have provided a great deal of fisheries information and are the only feasible way to assess the characteristics and size of inland fisheries over large scales for inland fisheries such as in the LMB (see discussion in Hortle 2009). Some surveys in the LMB are discussed by Hortle (2007), MRC (2010) and Bouapao *et al.* (2012). Best practice in this context is not fisheries-specific, but includes survey design, the science of asking questions and correctly formulating questionnaires (e.g. Schaeffer and Presser 2003), as well as reducing ‘operator error’ (differences between observers). Operator error should be covered by the piloting and training processes set up, for example under the SIMVA process.

An important aspect that requires attention is calibration of interview results against monitoring data so that biases are understood. Elsewhere, there is a considerable literature on dietary monitoring (daily food records) compared with interviews based on recall, with both methods having some inherent biases, and improvements continue to be made (e.g. Fiedler *et al.* 2012, Lazarte *et al.* 2012).

2.5 Fisher Catch Monitoring

Fisher catch monitoring is a common practice worldwide that may be carried out at various scales and with more or less involvement of experts as data recorders. At one extreme, fishers enter data in logbooks themselves (e.g. Cooke *et al.* 2000), as this is may be the only practical way to record data from many fishers; at the other, experts may systematically record representative data on major elements of fisheries (e.g. FAO 1999). Both approaches are used in the Mekong by the FP –

fisher catch monitoring using logbooks, and expert monitoring of the dai fishery and the large lee trap and gill net fisheries at Khone Falls.

Figure 3 – Lift nets are a common small-scale gear in the Mekong basin

Fisher catch monitoring can only cover a small proportion of the many gears and habitats; interviews are necessary to get broad coverage. Photo on a tributary, Huai Mong, northeast Thailand.

2.6 Standardised Sampling of Fish

Many background documents on fisheries sampling methods were consulted in developing the following information on best practice fish sampling, including Backiel and Welcomme (1980), Bonar *et al.* (2009), CEN (2005), Deap *et al.* (2003), DEP (2006), FAO (1999), Potter and Pawson (1991), USGS (2002), TVA (2010) and Zale *et al.* (2013).

Non-capture methods: Fish and OAAs may be in some situations be directly observed, identified and counted, a common practice where rivers or lakes are clear, but one that could not generally be applied in the Mekong, which is too large and often turbid. Indirect counting measures use mechanical, electrical or hydro-acoustic instruments. Of these, hydro-acoustics is becoming commonly used in large open water-bodies such as lakes, where there are few interferences and where the method can be calibrated against other removal-based methods. This method has been trialled in the Mekong (Viravong *et al.* 2006) and has some application to certain habitats such as deep pools or reservoirs at certain times, but cannot be used across a range of sites and habitats throughout the year. It is also complex and requires specialised and ongoing maintenance and operator training.

Capture methods: Sampling of fish by capture using various standard methods is common in developed countries as one element in monitoring fisheries or as a way of characterising ecological health of inland waters. Generally such sampling seeks to provide information on the number and biomass of fish in a water-body. Standard sampling produces statistics on either absolute or relative abundance. Absolute abundance (e.g. kg or number of fish per hectare) may be estimated by

pumping out a water-body, by depletion sampling or by mark recapture; all are problematic in large open systems like the Mekong. In this situation, the best practice approach would aim to produce relative estimates of abundance as catch per unit effort, which are assumed to be related to underlying population abundance and biomass.

To develop appropriate sampling methods, it is usual to compare various gears to understand their limitations and biases, with long-term monitoring usually employing one or a few gears and methods.

The FAO defines 11 main types of gear, of which there are hundreds of variants in use in the Mekong system:

- Surrounding nets (including purse seines)
- Seine nets (including beach seines and Boat, Scottish/Danish seines)
- Trawl nets (including Bottom: Beam, Otter and Pair trawls, and Midwater trawls: Otter and Pair trawls)
- Dredges
- Lift nets
- Falling gears (including cast nets)
- Gill-nets and entangling nets (including set and drifting gillnets; trammel nets)
- Traps (including pots, stow or bag nets, fixed traps)
- Hooks and lines (including hand-lines, pole and lines, set or drifting longlines, trolling lines)
- Grappling and wounding gears (including harpoons, spears, arrows, etc.)
- Stupefying devices (such as electro-fishers or poisons).

Gears commonly used for sampling in inland rivers include electro-fishers and rotenone (a poison) but these are not likely to be widely applicable in the Mekong, because (1) they are illegal, so permitting may not be possible or may cause copycatting by others; (2) as 'active' methods, they depend greatly upon operator skill and application; and (3) environmental variations (e.g. in water turbidity) directly affect capture efficiency, which confounds site and date comparisons.

Other common inland-river sampling methods that are likely to be the more applicable in the Mekong include seines, gill-nets and traps. These are also widely used by local fishers, which may allow direct calibration of standard gears against local gears. Gill-nets and traps may be used as 'passive' gears, which may reduce operator errors that could result when different field crews are operating in each country. Panel gill-nets have been successfully used in the Mekong basin in some other studies of intervention effects (e.g. Arthur *et al.* 2010, Lorenzen *et al.* 1998), based on the assumption that such gears catch a wide range of species and that their CPUE correlates with actual biomass of fish in a water-body. Gill-nets were also trialled by Lieng (2003) during testing for MRC bio-monitoring. He used six gill nets with stretched meshes of 2.5 to 10 cm set during the day at 11 mainstream sites, and recorded 59 species, a reasonable result where about 200 species are recorded over long periods by fishers using various gears. It is not clear why this work was not further developed to be included as a routine element of the EP's bio-monitoring. Lift-nets, a very common local gear, could also be adapted to be a useful standard method. Sampling with any of these gears may be easily replicated, an essential requirement to achieve required statistical power.

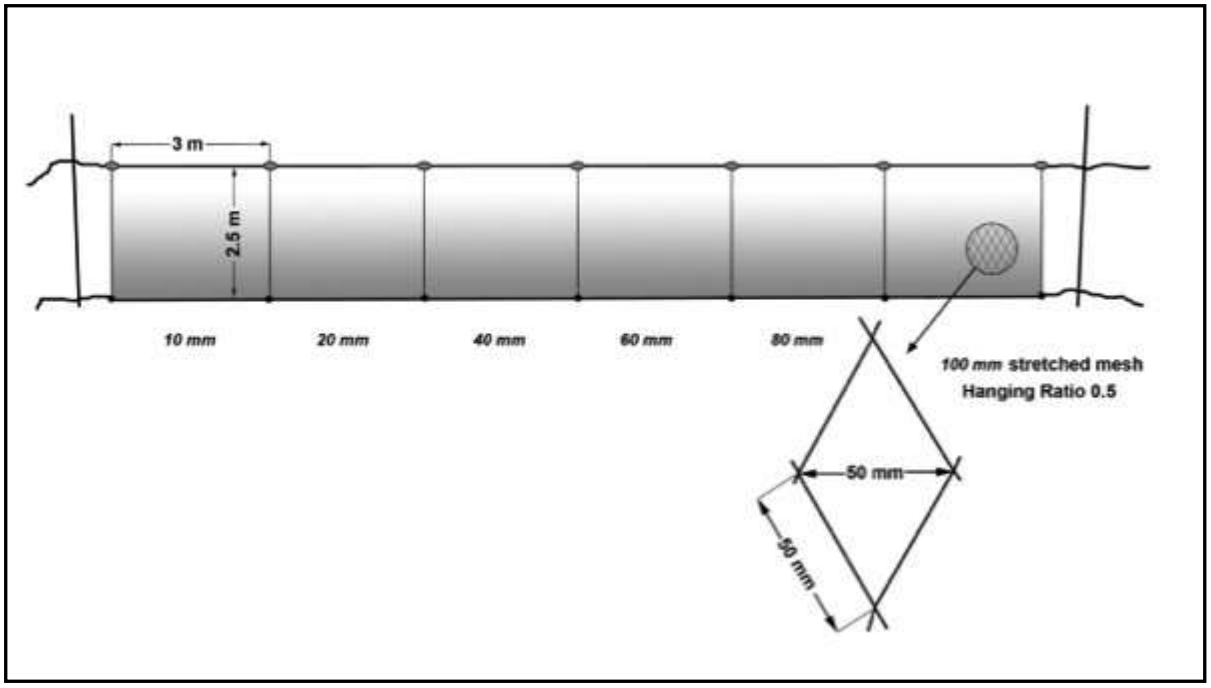


Figure 4 – Example of design for a possible standardised gear – a panel gill net

Standardisation of length, depth, hanging ratio (hung length/un-hung length), mesh sizes, floats, weights, and ropes is necessary to reduce variance in sampling results. Figures in italics are stretched mesh aperture dimensions. Float and weights are attached at one-metre intervals, omitted for clarity.

As mentioned above, to ensure consistent results over time, best-practice sampling must begin by testing and comparing proposed gears under different conditions (e.g. Growns *et al.* 1996; Neebling and Quist 2011), and it would also be useful to compare the results from standard gears with those from fisher catches. Fish and OAAs removed from gears must be identified, counted and measured, and the data recorded following standard approaches.

At present the only standard fisheries monitoring routinely employed in the Mekong by the FP is larval sampling, but monitoring of single gear types – the dais in the Tonle Sap, and lee trap and gill net monitoring in Lao PDR – are methods that are close to being standardised as the variability from year-to-year is not great and catch data can be adjusted for effort, which is recorded.

2.7 Biological Analyses of Fish

Best practice methods for examination of fish are detailed in Zale *et al.* (2013) and other standard references. Selected fish can be retained from the monitoring or catches, and taken to laboratories for processing. Various biological attributes can be assessed – diet, condition, growth rate, fat content, reproductive condition, concentrations of contaminants such as mercury, and presence of parasites and pathogens; these are all indicators that may change as ecological conditions change downstream of hydropower plants. Samples may also be taken for genetic analysis for long-term monitoring of stock structure.

2.8 Market Surveys of Fisheries Products

A survey of the quantities and prices of the main species in local markets is a useful element of fisheries monitoring that can provide several useful indicators of how a fishery is changing. Some indicators that could be affected by hydropower dams include quantities and price of large

migratory species, exotic fishes, and aquaculture fish by species, with origin where known. Best practice monitoring in this context includes defining representative markets at different levels (state to local), determining how these fit with selected zones or locations of interest for hydropower impacts, and taking account of several local factors that could have a large confounding effect on survey outcomes. Some examples include the following:

- In many markets, few fish are sold on Buddhist holidays.
- Market sellers are reluctant to talk with surveyors early in the day, until some sales have been made.
- About 80-90% of traders are women who may only be surveyed accurately by other women who speak their language.
- Bargaining is usual practice, so actual prices are less than asking prices.
- Fish prices are high in the morning and drop towards midday as sellers try to clear their stock, which affects the 'average' price for the day.
- Quality has a large effect on prices.
- Generally, aquaculture fish are cheaper than wild capture fish of the same species.

These and other characteristics and how to take account of them should be properly documented within 'best practice' SOPs for monitoring fisheries products in markets in the Mekong basin. Any market monitoring would use either interviews or logbooks, for which the merits and disadvantages should be weighed against objectives prior to implementation.

3 Literature Review and State of Knowledge

3.1 Information Sources

In the LMB there have been many surveys (once-off studies) of fish and fisheries, but there are relatively few monitoring data (i.e. that have been collected several times in the same way). Data are collected at national level by statistics agencies and by fisheries agencies; for the Mekong basin under MRC FP or EP direction, and in various surveys or studies of smaller areas. Various information and reports have been provided by the MRC FP and EP as well as from earlier projects such as the the WUP and BDP, as well as the MRC library and published references. ISH11 national consultants provided references as recommended during national consultations.

3.1.1 National Fisheries Data Collection

In the Mekong Basin, national censuses by statistics agencies include some useful fisheries data, much of it summarized in MRC (2010) and briefly reviewed below. Such data are are usually at too coarse a scale to indicate local impacts of a particular development, such as a hydropower dam, but would reflect development impacts over large areas, such as across an entire province where a large dam or several dams are built. These official national data collection systems could be built upon to provide useful long-term monitoring data.

National 'official' fisheries statistics as collected by fisheries agencies (e.g. as compiled by the FAO) are often questionable, with little information on how data were obtained Coates (2002). Inland fisheries are generally under-reported in official data and many components of catches are not reported at all.

Thailand

Thailand has well-established data collection systems implemented through a highly trained and relatively well-funded civil service. Most of the areas covered in north and northeast Thailand have already been extensively dammed so the data indicate the status of fisheries in a highly modified landscape. Most of the currently planned dams will not directly impact most of the current fishery in Thailand, but the experience, methods and available capacity should be utilised as much as possible for future monitoring in other parts of the basin.

Thai National Statistical Office – National Agricultural Census

National agricultural censuses have been carried out in 1950, 1963, 1978, 1993 and 2003. The 2003 census covered about 16,000 households nationwide and includes questions on fisheries as a primary activity (i.e. full-time or commercial fishers) and also whether people ever go fishing (i.e. subsistence, artisanal small-scale fishing); participation rates are useful indicators of the importance of fisheries. For example, the 2003 census showed that 18% and 32% of households in the north and northeast respectively were fishers. Various other questions could be included for the next census which would be very useful for monitoring development impacts.

Thai Department of Fisheries – National fisheries and aquaculture monitoring

Annual fisheries catch surveys provide production and value by species from landing sites in large water-bodies, including 17 large reservoirs. These data are collected by provincial fisheries officers and aggregated by the Fisheries Information Center of the DOF. Long-term data at some sites for more than 20 years appears to only reflect trends in commercial catches. The current estimated inland national catch of about 200,000 tonnes per year is a gross under-estimate; see below. This data collection system as currently implemented does not cover the main areas likely to be affected by new hydropower developments and does not cover the dominant small-scale catches.

Annual national household survey of catches

This census covers about 2000 fishing households of which about half are in the Mekong basin. It provides good quality data on catches and value by species, showing total national inland catches of about one million tonnes compared with 200,00 tonnes from fisheries surveys, the difference being coverage of small-scale catches (Lymer, 2008). The initial step to include only 'fishing' households based on the National Agricultural Census could exclude many households that fish or collect OAAs occasionally; the surveys also appear to not cover OAAs, and fish catches may be under-estimated or under-reported. Consumption data could be collected at the same time and might provide a higher estimate. The survey results along the Mekong River could provide very useful data for evaluating development impacts on catches and the methods. Since 2002, DOF has also monitored CPUE in selected reservoirs (two per province) that are stocked with various aquatic organisms to evaluate the success of stocking for put-grow-and-take fishing.

Annual household survey of aquaculture

Thai DoF carries out a random sample of several thousand households, which provides very good quality data by culture type on production and value by species.

Lao PDR

The Lao Expenditure and Consumption Survey (LECS) is carried out every 5 years by the National Statistics Center (1993, 1998, 2003, 2008, 2013), the latest survey covering about 8000 households. This is a very useful national study which demonstrates the importance of fisheries based on consumption values. In 2013 LECS has been expanded to include 5 extra fishing-related question – including fishing as primary and secondary occupations and also a question on fishing habitats and value of fish sold. Similar but more detailed questions are also being asked in the pending follow-up to the SIMVA study, for which advice was provided to the ISH11 socio-economist in Phase 2.

The LECS per capita consumption values for fish are much larger than those reported intermittently by the DLF, which have been based on crude estimates of catch per unit area and habitat areas. DLF also collects data on commercial landings at some locations, compiled at district levels, aggregated at provincial level and sent to DLF. The LECS coverage is generally adequate to show trends at a provincial level.

Cambodia

National fisheries statistics are collected by the Dept of Fisheries at district level, then amalgamated and provided to the FAO, but the data collection methods are not published. Other national population and socio-economic ~5-year censuses by the National Institute of Statistics could collect useful data on some indicators of development impacts.

Viet Nam

The General Statistics Office carries out a Rural, Agricultural and Fisheries Census (RAFC) every five years, the most recent in 2011. This survey only covers fisheries as a primary occupation; small-scale fishing by farmers is not covered, so the census grossly underestimates the size and value of fisheries.

The Ministry of Fisheries, Institute of Fisheries Economics and Planning collects data on landings at regular intervals at provincial level and these are reported to national level. Such data cover only cover some commercial fishers, including those operating in the Mekong delta. MRC-sponsored household surveys shows that in the delta the official catch figures are very similar to the estimated commercial catches; i.e. official figures do not include the large participation and production by many small-scale fishers. The RAFC could collect very useful data on fisheries as a secondary occupation.

Other national studies

Various other studies are carried out within each country; these are mostly once-off studies of particular issues with local relevance and do not qualify as monitoring. Among these, a recent biodiversity study sponsored by the NAGAO foundation supported agencies or universities in each LMB country to collect fish in the Mekong and Chao Phraya basins and properly identify and catalogue them; this study has produced very useful identification guides which would help overcome taxonomic issues with other studies. Can Tho University carries out monthly monitoring along the Bassac (Hau) River in the Viet Nam delta recording catches by gear type - species, abundance and biomass length and weight of individual fish. This study would be a worthwhile element in long-term monitoring. Ubon Ratchathani University (Thailand) also carries out various fisheries studies some of which may be useful starting points for monitoring.

3.1.2 MRC Fisheries Programme Data

The MRC has supported four long-term programs to monitor status and trends in the fisheries in the lower Mekong basin, as shown in Table 2 and Attachment 1 with a map of locations.

The Tonle Sap dai fishery, Cambodia (1994 – 2013)

Dais are large stationary trawls which are arranged in rows across the Tonle Sap (Figure 5). Catches are assessed through stratified random sampling during each 6-month fishing season, October – March. Dais are relatively non-selective and catch large quantities of fish so this fishery is probably a good integrator of the impacts of various changes in the Tonle Sap-Great Lake system and also in the Mekong upstream in Cambodia, where many fish spawn. Catches are strongly correlated with the strength of annual flooding, after allowing for variations in year-to-year recruitment. There are many methods and gears being used in the Tonle Sap at the same time as the dais, and further work is needed to understand how representative the dai catches are of total catches in this part of the system. It is noteworthy that in 2011-12 fishing season the total catch doubled after fishing lots were abolished upstream; demonstrating that competition between gears or fishers must be taken into account if results of any CPUE monitoring are to be interpreted correctly. The dai monitoring is most likely to show the effects of dams in Cambodia, especially if a mainstream dam were to be built at Sambor in the region where many fish spawn, and less likely to show the effects of more distant upstream dams.

Lee Trap and gill-net Monitoring at and upstream of Khone Falls, southern Lao PDR (1994 – 2013)

Khone Falls, a series of cascades, forms a natural barrier for fish migrating upstream, and is a focal point for intensive fisheries using many kinds of gear. Lee traps (Figure 6) are set in many of the cascades to catch migrating fish, and the catches from traps in one of the channels are monitored by random sampling in May and June each year. Many people fish upstream of the falls using gill nets and other gears. The 5-7 cm mesh gill net fishery is monitored at two villages upstream of Khone Falls. This monitoring is very selective, only covering a small proportion of gear types and in low numbers, but if carried out in the same way each year may indicate some underlying trends. Catches are highly variable each year, and against the high background variation only very major changes in catches are likely to be detectable (Figure 7, see also Halls *et al.*, 2013b). The two hydropower projects planned at Khone Falls are likely to affect fishing pressure directly; e.g. the Don Sahong

project aims to reduce fishing pressure on some channels to allow migrating fish to pass, which could lead to higher catches by other competing fishers at or upstream of the Falls. To be of value for detecting changes, long-term monitoring at this location would need to be expanded to be more representative.

Figure 5 – Catch from a single haul of a dai net on the Tonle Sap, Cambodia

Figure **6 – Lee traps at Khone Falls in Lao PDR**

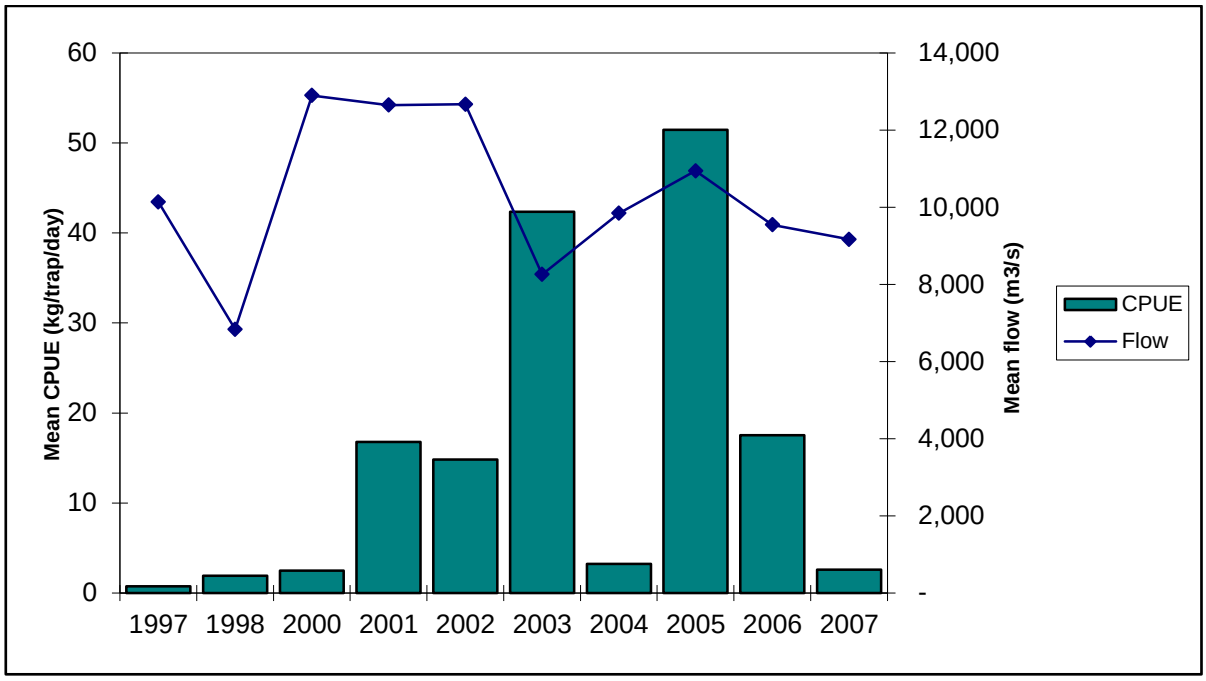


Figure 7 – Catch per unit effort for fish caught in the early wet season lee trap fishery at Hoo Som Yai, Khone Falls and estimated annual mean flows at Pakse

CPUE is based on 15-days sampling during May-June each year. This graph illustrates the problem of high variability in catches.

Figure 8 – Larvae sampling, Mekong River near Phnom Penh using large plankton nets

Fish Larvae Monitoring Programme, Cambodia and Vietnam (1999 - 2013)

Large numbers of fish larvae drift downstream from fish spawning along the Mekong in Cambodia. These larvae are sampled using plankton nets set in the Mekong and the Tonle Sap near Phnom Penh and in the Bassac and Mekong in Viet Nam a few kilometres from the border (Figure 8). This monitoring shows strong peaks in drift over short periods and significant changes in recruitment from year-to-year.

The representativeness of this sampling should be investigated, particularly the degree to which it reflects total larval drift at a site. The existing sampling should be rationalised to reduce the number of samples, and further review and analysis should take discharge into account. Interpretation would benefit from more information on the distance that larvae/fry are actually drifting to determine where impacts originate.

This monitoring requires specialised capacity for identifying the larvae and is relatively labour-intensive so could not be implemented routinely at many sites. However, it is a very useful indicator of recruitment strength from spawning along entire river reaches thereby integrating effects. At present the monitoring is downstream of Zones 4 and 5. Adding key sites at the downstream part of the MRC Zones 2 and 3 would provide an index of recruitment for each of the main river reaches and show the long-term incremental effect of development on recruitment from within those reaches.

Fisher catch monitoring (2003 – 2013)

Catches of commercial fishers were monitored at up to 40 sites along the Mekong mainstream from 2003 to 2010, with 36 sites monitored now (Attachment 1), including some large tributaries since 2007. The catches of 3 fishers are recorded daily at each site so 108 fishers are monitored in total. Gill nets are the main gears used (e.g. Figure 9), but the fishers also use cast nets, various kinds of traps, trammel nets and trawls and harpoons and spears. Two review reports have been published by the FP in 2013. Halls *et al.* (2013a) reviews all FP monitoring data from 1994 to 2010; within this period some datasets cover shorter time periods. Halls *et al.* (2013b) reviews in more detail monitoring of the Tonle Sap dai fishery from 1998 to 2008.

This monitoring aims to provide data for indicators of the state of fisheries along the Mekong and some tributaries. Logbook monitoring is attractive because of daily coverage and the fishers collectively providing data on millions of fish each year (MRC 2010). However, current coverage is not adequate to be representative of catches at any particular location, and many habitats and tributaries are not covered, so the absolute values of indicators cannot be taken as representative of the LMB. But assuming that the monitoring is carried out consistently (i.e. biases are constant over time) then it should indicate important temporal trends in key indicators; for example changes in the relative proportions of fish by guild.

There have been various problems such as use of un-calibrated or old balances, fishers not correctly identifying fish or not fully recording data, and errors in data transcription as well as various issues with databases (personal observations and presentation by Ngor Pengbun of FP on 30 August 2012); so some improvements in quality are required. The variation in gears between fishers and over time also increases variability in the data and hinders interpretation, as apparent differences of changes may simply reflect variation in gears or effort.

Figure **9 – Typical Mekong River gillnet fisher near Vientiane**

3.1.3 MRC SIMVA Study

The pilot Social Impact Monitoring and Vulnerability Assessment (SIMVA) in 2008-9 covered 1360 rural households in a 15-km corridor along the Mekong and Tonle Sap (M-TS), where about 34 million people or about half of the LMB population live (Figure 10). During 2011, the SIMVA study was repeated and expanded within the Mekong-Tonle Sap corridor, to cover 2720 households in 136 villages (20 HHs per village) (Bouapao *et al.* 2012). Because of its spatial coverage, level of replication, and statistical representativeness, the SIMVA project offers an excellent opportunity to obtain good long-term data on many socio-economic elements, including fisheries. SIMVA sampling was based on the MRC Mekong hydro-ecological zones, which would also tend to group other features of the natural and human environment. The sample size in each zone was not related to population size, but the need to compare between countries, zones, or Thai/Lao sub-zones in Zone 2 and 3. The resulting sample sizes over-represent the upper Mekong and middle Mekong Zones (2 and 3) and under-represent Zones 4 and 6 relative to their populations, and this may be a subject for further discussion.

The MRC hydro-ecological zones can also be partly related to the zones of the fish migration 'systems' proposed by Poulsen *et al.* (2002) (Figure 13 of this report). MRC Zones 2 and 3 coincide with the proposed Middle and Upper fish migration systems respectively, which are also likely to coincide broadly with habitats and species composition. The Lower Mekong fish migration system covers most of MRC Zones 4, 5 and 6, and this section of the river could be further subdivided (e.g. during analyses) into three fisheries zones to take into account the importance of marine and estuarine fish in the delta, and the separate populations of fish that migrate between the Tonle Sap-Great Lake and its tributaries (see also Mattson and Jutagate 2005). It should be noted that the classification of Poulsen *et al.* was based only on LEK survey findings for the more migratory fishes along the mainstream, so is only one element in classifying the Mekong into habitat zones for fisheries. That the LEK classification has some validity is confirmed by some studies of individual species that indicate a segregation of stocks that coincides to some extent with the postulated migration systems; e.g. for the common small cyprinid *Henicorhynchus siamensis* (Adamson *et al.* 2009).

The SIMVA approach of using structured interviews is probably the best way to obtain representative data on fisheries over large areas as many households are surveyed for relatively low costs. The SIMVA study addressed people's dependence on aquatic resources generally, which included a good deal of information on fisheries. For example, SIMVA confirmed the very high dependence of rural households on fish and OAAs, and showed high rates of participation in fisheries; it provided CPUE data (catch per fisher per hour), data on consumption and disposal of catches, habitats fished, and others.

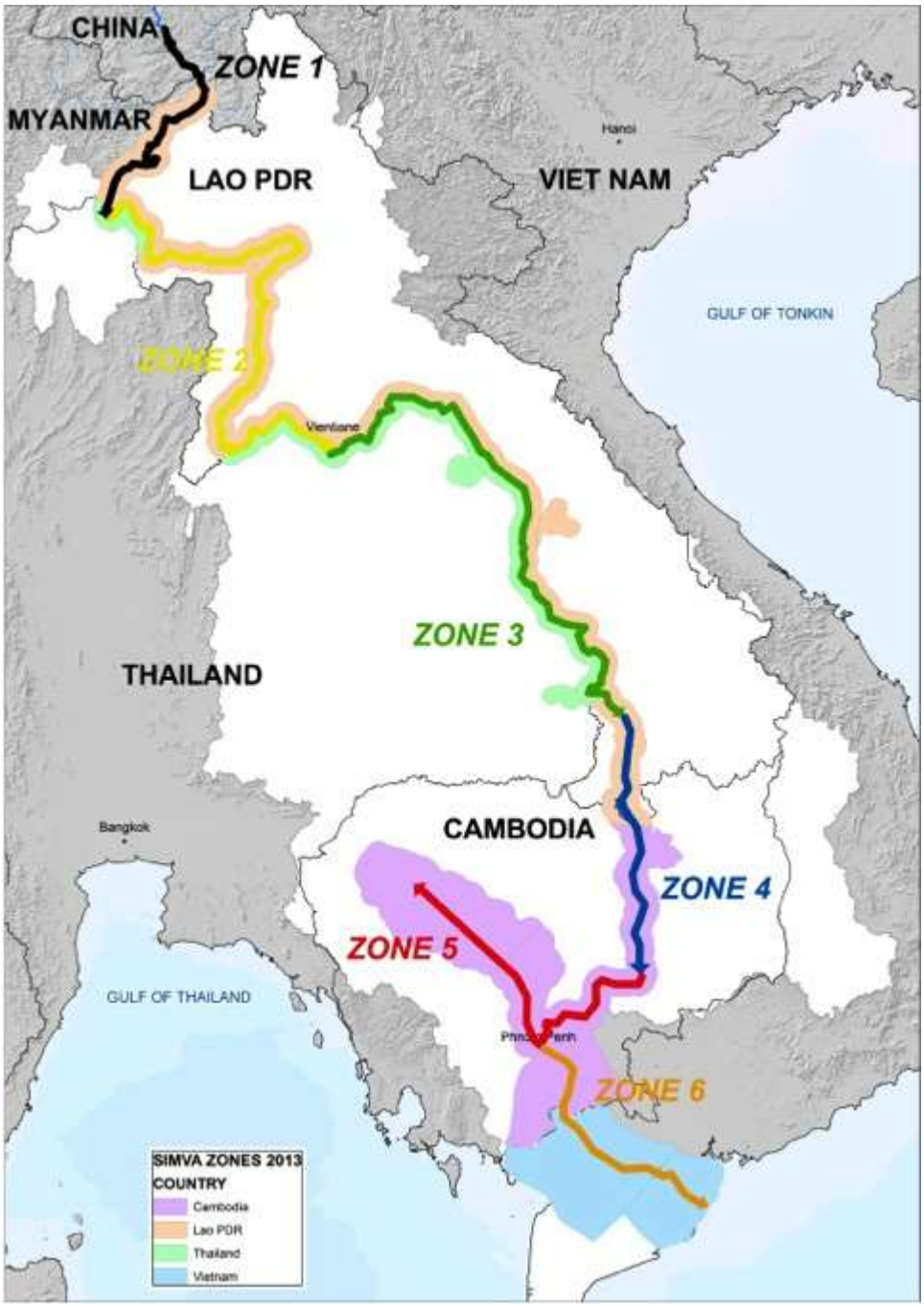


Figure 10 – MRC hydro-ecological and SIMVA zones 2013 along the Mekong mainstream and Tonle Sap

It is proposed to use the same or similar zones for design of monitoring of fisheries based on habitat, fish distribution and migration systems and stocks; see Figure 13 and also Jutagate (2007)

Table 2 – Ongoing fisheries monitoring by the MRC

See Attachment 1 for locations.

Lead agency	Implementing agencies	Type of monitoring	Locations	Duration	Frequency	Field methods	Examples of specific parameters	Funding in 2013	Comments	Relevance for hydropower planning
MRC FP	LARReC, Thai DOF, IFReDI, RIA2	Fisher Catch	36 locations, most on mainstream	2003-5, 2007-present	Daily	Logbooks by fishers	Abundance and weight of fish and OAAs in catches by species	$170,907	Needs quality improvements, calibration, and rationalisation of frequency	Fish and OAA species composition, abundance and biomass will be affected by changes in environmental conditions as a result of hydropower development.
	LARReC	Lee trap (1 site) and gill net (2 sites)	At (Lee trap) and upstream (gill nets) of Khone Falls	1994-present	3-4 per week during season	Observations by agency staff	Abundance and weight of fish and OAAs in catches by species	$16,052	Needs quality improvements and better coverage of gears	
	FiA	Dai	Tonle Sap	1994-present	Semi-random, more information required	Observations by agency staff	Abundance and weight of fish and OAAs in catches by species	$23,450	Needs quality improvements and possibly reduced sampling frequency	
	FiA, RIA2	Larvae sampling	Mekong and Tonle Sap nr Phnom Penh, Bassac and Mekong in upper delta	1999-present	4 per day for 4 months	Sampling by agency staff	Abundance and size of fish larvae by species	$44,107	Needs quality improvements, calibration, and rationalisation of frequency	Spawning and recruitment will be affected by hydropower dams.
	LARReC, Thai DOF, IFReDI, RIA2	Market Monitoring	In planning	2013 start	Annual	Sampling by agency staff	Prices of main species	$60,000	ISH11 project to review and comment when details are available	Marketing and distribution of fishery products will change as a result of changes in capture fisheries and aquaculture and demographics and infrastructure.
	LARReC, Thai DOF, IFReDI,	Aquaculture	In planning	2013 start	Annual?	Sampling by	No details yet	$120,000	ISH11 to review and	New dams will lead to increased

Fisheries

Lead agency	Implementing agencies	Type of monitoring	Locations	Duration	Frequency	Field methods	Examples of specific parameters	Funding in 2013	Comments	Relevance for hydropower planning
	RIA2					agency staff			comment when available	aquaculture

3.1.4 Other MRC Programmes Data

MRC hydrology monitoring

The area and volume of available water as well as short-term variability directly affect fisheries production in inland waters. For example, based on data from the Tonle Sap dai fisheries, the year-to-year variability in catches is well-correlated with flooded area, which explains about 70% of the variance in the data (Halls *et al.* 2013b; p. 107). Catches are also affected by fishing pressure along migration routes and conditions in dry season refuges which may be distant from the capture sites. Hydrology data as currently collected for the MRC are adequate in most cases to support fisheries data interpretation. At key sites along the Mekong and in some tributaries water level data are collected twice-daily manually and at 15-minute intervals automatically. These data are regularly converted to discharge data. Additional locations have been proposed in this ISH11 study, and hydrological indicators usually can be calculated based on simple relationships from the existing sites for the purposes of fisheries data interpretation (see ISH11 Phase 2 Main Report and Hydrology Annex).

MRC water quality and sediment monitoring

Water quality data are collected under the Environment Programme every two months at 54 key sites along the Mekong and in some tributaries. The list of parameters is quite extensive and generally adequate for supporting interpretation of data on fish and fisheries. The new IKMP sediment monitoring program provides more detailed data on quantities of sediment, but should include information on nutrients and organic material as sediment is a misnomer for complex particulates which may be more or less damaging or beneficial depending on their makeup. More intensive monitoring of some parameters such as dissolved oxygen would be useful near dam-sites, where concentrations may fluctuate greatly with diurnal operating regime. Additional sites have been proposed for this ISH11 study, and indicators usually can be calculated based on simple relationships from the existing sites for the purposes of fisheries data interpretation (see ISH11 Phase 2 Main Report and Water Quality Annex).

MRC Bio-monitoring

Data on benthic diatoms, zooplankton and macroinvertebrates are collected by standard sampling at 32 key sites along the Mekong mainstream and some tributaries (ISH11 Phase 2 Main Report and Aquatic Ecology Annex).The types of organisms present and biodiversity are used to create an index to classify sites as more or less 'healthy' relative to baseline sites which have good water quality. The bio-monitoring program produces some data that are directly useful in fisheries, for example, abundance of food items where fish diet is to be studied. Fish are routinely used as one element in bio-monitoring, so when the MRC program was established in 2003 fish sampling was trialled (Lieng 2003) but not further developed. The results from standard sampling of fish as suggested for this project (Section 5) will be a useful adjunct to other bio-monitoring.

3.2 State of Knowledge of Mekong Fisheries

Mekong fisheries have been reviewed by Pantulu (1986), Anonymous (1992), Sverdrup-Jensen (2002), van Zalinge *et al.* (2004), Mattson and Jutagate (2005), Hortle (2009) and MRC (2010), so are are quite well-described in general terms. By contrast, there is a general lack of coordinated and timely monitoring that can provide representative and up-to-date information as required for planning and management. Two recent reviews (Halls *et al.* 2013a; Halls *et al.* 2013b) have covered the most MRC FP monitoring data up to 2010.

Some particular features of the basin's fisheries that should be taken into account in planning of monitoring include the following.

Size and value. The total catch from wild capture fisheries is estimated at over two million tonnes per year worth about US$3-4 billion. The Mekong basin probably ranks first in the world for the size of its capture fishery. Some other large river systems such as the Amazon and Zaire are less productive per unit area or less intensively exploited.

Aquatic habitats. As well as productive river-floodplain fisheries (Figure 5 and 11), much of the catch in the basin is from rain-fed rice-fields and associated habitats (which are absent from most other large river basins), and from reservoirs (Figure 12). Fisheries productivity depends to a large extent upon flooding and inundation of seasonal habitats (Figure 12). Monitoring locations in rivers should take into account the positions of tributaries and the connections to nearby floodplains and other seasonally flooded land.

Figure 11 – The Mekong and its floodplain, upstream of Phnom Penh

Fish need to migrate along rivers and on and off floodplains, which drive much of the fisheries production.

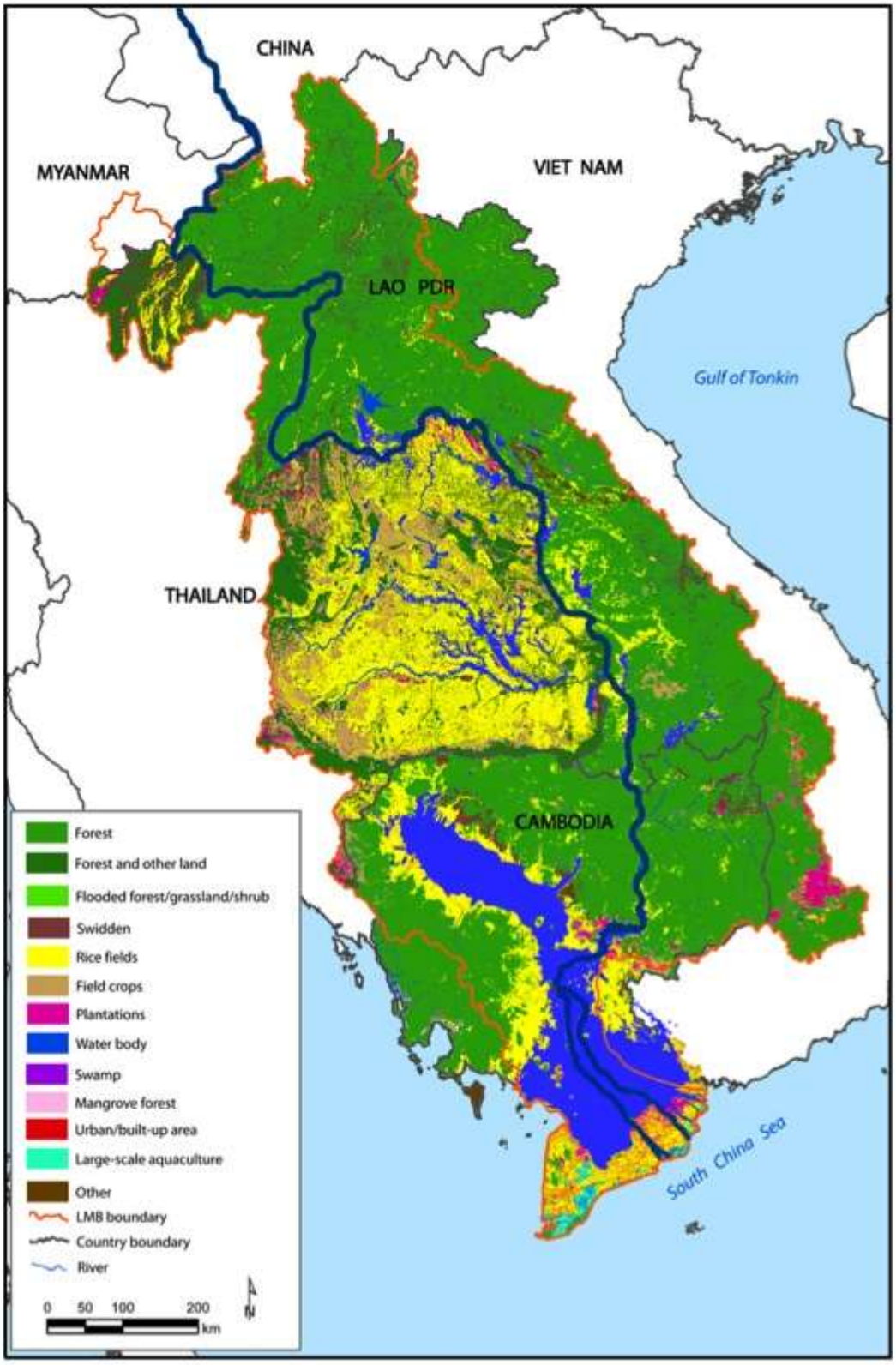


Figure 12 – Flooding and land-use in the LMB

Water bodies are mainly flooded land, as well as large reservoirs in Thailand and Nam Ngum Reservoir in Lao PDR. Flooding is modelled on the major Year 2000 flood. Rainfed ricefields are the most extensive wetlands. The Mekong River is exaggerated for clarity. (From Hortle and Bamrungrach, in press).

Migration. Fish migrate between feeding, spawning and resting habitats. In large monsoonal systems such as the Mekong, the extreme variability in water availability drives fish to migrate long distances, and migrating fish are heavily targeted by fishers, often causing strong peaks in catches over short periods. Three main migration systems for freshwater fish associated with the Mekong mainstream have been proposed by Poulsen et al. (2004) (see 3.1.3 above). The pattern of variability in catches must be understood prior to establishing any monitoring. While monthly or quarterly sampling is commonplace elsewhere, more frequent monitoring is required during migration periods, and sampling must be scheduled to take account of moon phase as a potentially confounding factor (Baird et al., 2003).

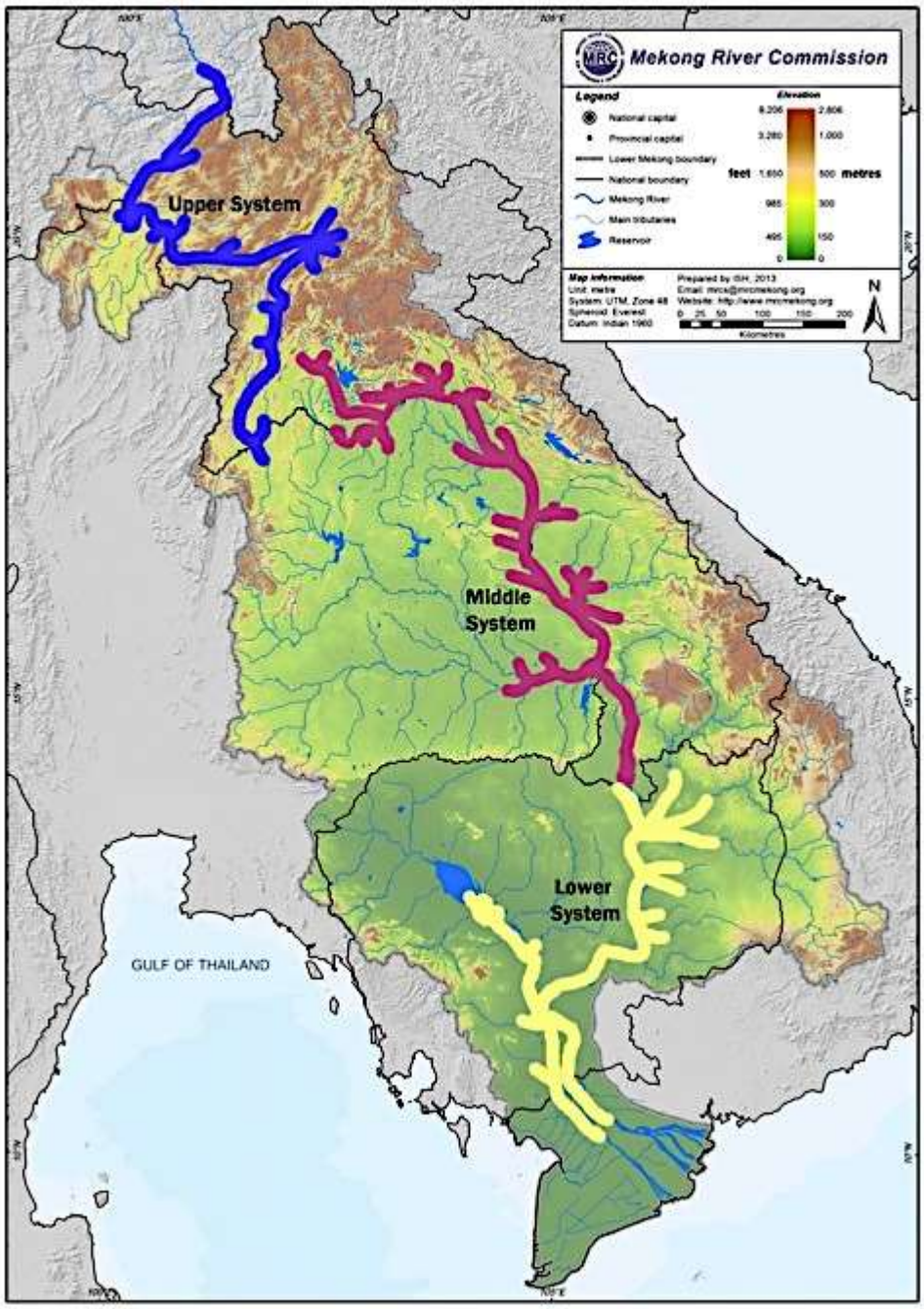


Figure 13 – The three general migration 'systems' of freshwater fish associated with the Mekong mainstream

Redrawn from Poulsen et al. (2004), refer to that reference for details.

Existing barriers. The effects of hydropower dams or any other developments will be limited to varying degrees by existing barriers, which are already preventing or restricting migration at many locations on Mekong tributaries or their tributaries. Monitoring design, particularly in tributaries, must take into account the presence and likely effect of existing barriers which may require separate field survey.

Diversity. The Mekong system hosts about 850 fish species, with more being described regularly. More than 200 fish species can be expected routinely in catches form large rivers in the lowlands. Correct identification of fish is an ongoing challenge and there is a need to improve field guides and to train and test scientists responsible for surveys.

Participation. Most rural households in the LMB go fishing or collecting OAAs at some time, and most of the catch is taken by small-scale artisanal fishers, who typically catch 1-2 kg of fish per day, retaining smaller low-value species for home consumption while selling larger more valuable fish. Relatively few fishers (5-10%) are full-time and commercial; they tend to use larger gears with larger meshes, motorised boats, and to fish more permanent habitats such as large river channels, hence their catches are not entirely representative of the fish community or catches at a location. Representative data on all catches and consumption can only be obtained through interview-based household surveys such as the SIMVA study. Monitoring of experienced commercial fishers (via logbooks) is however of value for providing long-term detailed data on composition and abundance in catches, but biases need to be understood for correct interpretation.

Fishing methods. More than 100 gear types are commonly used in various ways. The most common gears include gill nets, cast nets, traps and hook-and-line; illegal gears such as electro-fishers, poisons and explosives are also common. At any monitoring location, the types of gear and fishing methods should be first investigated as a guide to refining the design of standard gears for long-term monitoring.

Fishing pressure. As a result of fishing pressure LMB fisheries are experiencing 'fishing down', a process in which increasing effort leads to increasing total catches but smaller catches per unit effort (CPUE), including catch per fisher. Catches of larger fish and larger species - particularly carnivores – are declining, while catches of smaller species - particularly herbivores or omnivores – increase. Changes in fishing pressure lead to changes in the fishery itself, complicating interpretations of monitoring data, as impacts of dams or other developments could be easily confounded by the effects of changing fishing pressure. Changes in CPUE alone (e.g. in current FP monitoring) may indicate little about total catches, so data on fishing effort are also needed; these would typically include numbers of fishers, gear types used and time spent fishing.

Processing and marketing. In the LMB most of the catch is typically eaten by the fishers' households or sold locally in informal village markets, but an increasing proportion passes through well-regulated city markets where it is relatively easy to obtain accurate data on quantities, species and value and the source of fish and OAAs. Markets provide a simple means of monitoring broad changes in fisheries, such as variation in species and prices and relative supply from aquaculture, and markets at any location provide useful supplementary data to cross-check data from fishers or standardised sampling.

4 Gap Analysis with Respect to Guiding Framework

4.1 Needs

Data on fisheries and aquaculture are needed for information to inform hydropower development at various levels and time scales, as exemplified in Figure 14. Fisheries are addressed through several processes in the MRC and each of these can be progressively improved as more focused fisheries monitoring information becomes available. National governments can also benefit by reference to MRC monitoring data which will show the relative importance, size and value of fisheries in hydropower-affected areas. At local and project level, fisheries monitoring data are useful in EIA processes and development of fisheries and aquaculture opportunities.

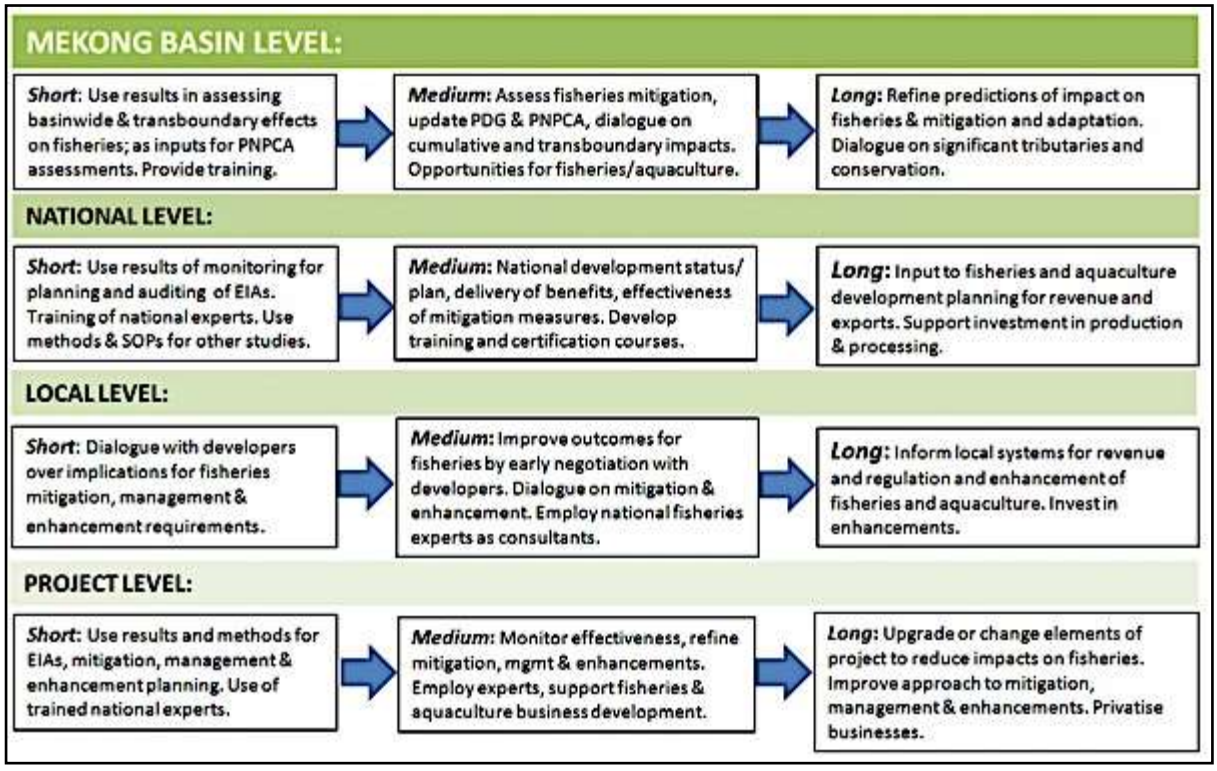


Figure 14 – Information needs to support hydropower planning

Some uses of data from monitoring of fisheries and aquaculture at different levels.

4.2 Status and gaps

The ISH11 study team's 'Guiding Framework for MRC Basin-Scale Information for Hydropower Planning and Management' has five main components: Locations, Parameters, Timing, Information Management and Information Use, against which fisheries information is discussed below.

4.2.1 Locations

The general criteria for selection of locations are shown in Section 2.2 of the ISH11 Phase 2 Main Report, which also shows the 33 recommended locations, of which 25 are on the Mekong mainstream (including Bassac) and 8 are on the lower reaches of hydropower-affected tributaries. Full details of the FP's well-established monitoring network of 39 current monitoring sites are shown in Attachment 1. These include 24 of the locations recommended by ISH11 and 15 other locations. Most of the FP sites are spread along the mainstream, providing a good coverage of the all Mekong

hydro-ecological zones and most of the proposed or operational hydropower projects or groups. Currently, FP monitoring generally supports understanding of mainstream processes such as fish migration and larval drift, as well as changes in fisheries across national borders. From a hydropower perspective, of the 33 ISH11 locations, there are nine additional locations for monitoring by the FP that should be considered as shown in Table 7 of the Main Report. Given the large spatial scale of fish migrations and likely distribution of fish assemblages, fish sampling sites can be selected within a few kilometres of target locations, to avoid places of heavy traffic or fishing activity or local impacts such as pollution.

4.2.2 Parameters

Table 3 shows the main groups of parameters that should be monitored to meet the needs of hydropower-relevant fisheries information and these are discussed further below.

Table 3 – Parameter Needs for MRC Hydropower-Relevant Fisheries Information

MRC-Centralised Parameter Groups, Parameters	Hydropower Relevance	Example Basin-Scale Indicators
Abundance and diversity of fish in catches or samples: CPUE (numbers and biomass) by species can be used directly and to generate various indicators.	Fisheries are affected in many ways by hydropower development, which should be planned and managed and mitigate impacts.	✓ Current status and changes in fish stocks and species diversity ✓ Total biomass that may need to be passed through dams at locations and change over time ✓ Reliance of the riverine communities on fish resources ✓ Reservoir fisheries as proportion of total consumption ✓ Changes in extent of standing and running water ✓ Aquaculture as proportion of total
Participation in fisheries and fishing effort: Number of fishers full-time, part-time, occasional, fishing effort by fisher, time and gear type.	Participation in fisheries changes under hydropower development, which requires planning, management and mitigation. Commercial fisheries appear in reservoirs and downstream fisheries methods usually change with some species declining.	
Biological characteristics of fish: Fish health, diet, growth rate, reproduction, condition, mercury content and value as food, habitat preferences and swimming speeds.	Fish biology may change as a result of hydropower development; monitoring allows adjustments to mitigate and manage impacts. Habitat preferences and swimming speed information are needed for fishway design and other mitigation measures.	
Habitat: River width, depth, current speed, substrata, in-stream and riparian vegetation.	Hydropower development will change habitats, leading to a range of flow-on effects which require management and mitigation. WUA is a useful indicator.	
Aquaculture and Reservoir Fisheries: Species, production quantity and value, inputs and costs, profitability.	Aquaculture may be favoured in reservoirs as well as downstream of HP plants if flows are stabilized.	
Fish processing and marketing		

Fisheries monitoring typically reports **abundance** (numbers and biomass) of each species in catches or in samples, expressed as CPUE (catch per unit effort), which is assumed to be correlated with underlying changes in fish populations. Reporting of **diversity** usually includes estimates of the number of species present and some measure of evenness or dominance, i.e. the extent to which the assemblage is dominated by one or a few species. Basic data are often further analysed to provide indicators

FP is currently cleaning and analysing fisher catch monitoring data which have been collected since the reporting periods of the most recent data reviews (Halls et al., 2013a; 2013b) (i.e. since 2010 for the most recent data). Referring to Table 3, the FP review focuses on ***Abundance and diversity of fish in catches or samples.*** The current indicators that are being summarised for each FP database are as follows:

1. Abundance and diversity
    - 1.1. Fish family composition by numbers and biomass
    - 1.2. Number of fish species in each family
    - 1.3. Species composition total by numbers and biomass
    - 1.4. Species diversity indices by numbers and biomass
    - 1.5. Species richness estimation (species rarefaction/accretion curve)
2. Average daily catch (per fisher) versus average daily soak hour by habitat.
3. Average daily catch per fisher (kg and number of fish) versus time.
4. Indigenous and exotic species (kg and nos.) versus time.
5. Frequency distributions of daily catches per fisher.
6. Composition by maximum fish size (cm).
7. Composition by size category (small-med-large-giant).
8. Catch (kg) by ecological guilds.
9. Catch by trophic guilds.

CPUE by species is likely to change in response to many factors, but can also be used to derive indicators which are likely to be affected specifically by hydropower dams; such indicators could include proportion of large

These are appropriate best-practice ways of summarising and reporting such data and can be used directly or with some refinement as indicators of hydropower effects; e.g. proportions of highly migratory migratory fishes (likely decrease) and planktivorous species (likely increase). FP is also reviewing the classification of fish into guilds as a way to reduce the complexity of reporting where many species are present. Guilds are groupings of fish judged as ecologically similar, e.g. in terms of size, breeding characteristics, trophic level and migratory behaviour. Classification should take account of the review by Jutagate (2007) who addressed this issue under the WUP project for MRC. Given the large numbers of fishers operating throughout the LMB and the capacity and resources available, the overall approach to monitoring for fish abundance and diversity by FP is appropriate. The main gaps identified relate to standardisation of sampling and rationalisation of monitoring frequency (Section 5).

CPUE data on abundance and diversity need to be supplemented with information on ***participation in fisheries and fishing effort*** (Table 3), because changes in CPUE are often attributable to the effects of fishing pressure. In general, the number of fishers and total effort are thought to be increasing in most of the Mekong basin, so average CPUE is declining, which confounds interpretation of

development impacts. Participation in fisheries and fishing effort can be estimated by socioeconomic surveys such as the SIMVA study, and ISH11 recommendations in this regard are presented in the Phase 2 Main Report and Socioeconomics Annex.

As well as abundance-related indicators, the ***biological characteristics*** of fish may change as a result of hydropower dams as summarised in Table 3. While surveys in the LMB have collected data at various times and places, there is no routine large-scale collection of such data as needed for a best-practice understanding of hydropower impacts and mitigation. This is a significant gap which needs to be addressed with some urgency.

Hydropower development will also cause changes in ***habitat*** extent and quality (Table 3). Habitat assessments can be considered part of best-practice monitoring for river systems generally and particularly for hydropower development which may cause significant changes. Weighted useable area (WUA) is a common derived indicator reported downstream of hydropower dams, and identifies the hydraulic conditions most suited for the habitat of particular species. MRC has classified the mainstream into river reaches, a macro-habitat classification, but there is no available meso-habitat data (classification within reaches into riffles, runs, pools, backwaters etc.). Some data is being collected at MRC monitoring locations on micro-habitat characteristics (e.g. depth, velocity, substrate, cover, vegetation) through the EP Ecological Health Monitoring (see ISH11 Phase 2 Report Aquatic Ecology Annex, Section 3.4), but this could be better captured and shared for the benefit of fisheries as well as sediments, water quality and hydrology interests. There are no habitat monitoring systems in place for the Mekong mainstream and lower reaches of tributaries which constitutes a very significant gap for interpreting fisheries data as well as other monitoring data (Section 5).

Aquaculture is heavily promoted in LMB countries, where all national fisheries agencies collect detailed data on aquaculture, so there is not a significant gap that needs to be filled at present. FP is also currently implementing aquaculture monitoring in each country, but results are not available at present. **Reservoir fisheries** are also monitored by LMB fisheries agencies and hydropower developers generally monitor fisheries of the reservoirs formed by their dams, so there is not a priority gap in this area.

4.2.3 Timing

MRC information to support hydropower planning and management should take into account the following timing needs and considerations important to fisheries.

- Patterns of **fish migration and spawning** need to be taken into account when planning monitoring. While general patterns are known for the LMB, migration periods differ by species and also by season and location. It is not always possible to predict their timing, and accompanying data (e.g. lunar cycles, hydrology, water quality and biomonitoring) can improve understanding of cues for migration. Many studies in the LMB show migration peaks can be over very short periods, when daily monitoring may be necessary, with relatively low catches at other times, when sampling can be less frequent with little loss of information.
- Fisheries monitoring needs to take into account **fishing regulations and socio-economic factors** which may affecting fishing effort at certain times and thereby the results from catches or samples.
- **Multi-year intervals** are appropriate for monitoring trends in participation, fishing pressure and household catches and consumption over large scales. Supplementary information on collection methods is needed to document and record **event-based** information such as effects on fisheries of droughts and floods.
- Most FP monitoring data is now collected daily, which promotes consistency and continuity, but the frequency is well in excess of that typically found in other similar monitoring programs.

Daily monitoring as currently practised does not lead to "gaps" in information, but may be excessive for accurately describing catches, which leads to **gaps in meeting other needs for other monitoring** because limited resources are over-allocated to the current monitoring, particularly of fisher catches.

- Daily data collection also leads long delays in reporting, a significant gap relative to needs, so a review is needed to justify some reduction in frequency which will lead to **faster data processing and reporting** (see Section 4.2.4).

Currently, fisher catch monitoring is daily, which is considered excessive in terms of covering natural cycles, fish migrations and operational system changes, as well as being far more frequent than in typical monitoring programmes elsewhere, where data are collected at intervals varying from 5-6 times per month to annual, depending upon specific objectives and environmental characteristics. (FAO 1999). Or, where catches are high over relatively short periods (e.g. at the beginning and end of the wet season), sampling may be stratified, with data recorded more frequently in the high-catch period and less frequently at other times. Reducing the frequency of MRC fisheries monitoring would allow for faster data processing, analyses and reporting, and would also free-up capacity for standard sampling, biological analyses and habitat assessment. Any changes to monitoring frequency should however be justified fully based on statistical principles and after reviewing existing data and taking into account objectives and the particular features of the Mekong's fisheries. For example, where there are highly skewed catch distributions (as is typical in the Mekong), monitoring should be stratified between high-catch periods (short duration, high sampling frequency required) and low-catch periods (longer duration, much less frequent sampling) periods. It may also be desirable to collect field data daily (as at present) but process the data at a reduced frequency, which would significantly reduce cost and time delays as well as eliminating any risk of lost data.

Proposed standard sampling should be at the same frequency as fish catch assessment, but preceded by training, trials and calibration during intensive sampling exercises at key locations. Proposed biological analyses should be carried out at least monthly as is typical to cover the range of seasonal variation. Frequency of habitat assessments would vary depending upon scale – over large scales assessments could be made at intervals up to 5 years which would suit State of the Basin reporting. More frequent assessments – monthly or quarterly – are typical over smaller scales, such as for sampling locations or sites.

4.2.4 Information Management

MRC data need to be publically available and **up-to-date** to provide their full value to users.

Currently, fisheries monitoring data is analysed by FP and reported in Technical Papers and other documents which are available on the MRC website, but at present most monitoring data are not available more recently than 2010. FP is in the process of cleaning and documenting data, and plans to work with IKMP to institutionalise the process. The last 3 years have been spent in data cleaning and there is still another year's work to do to get current data up-to-date. Data management for the new methods that are proposed by ISH11 (see Section 5) would be developed from the outset in consultation with IKMP and the database specialist to ensure consistency with MRC QA/QC approaches and database structures.

There is a need to write SOPs to fully describe the process of data collection through cleaning, data storage and analyses; this issue is well-known to the FP. Any direct recording of data by the fishers themselves should involve periodic (monthly) audits and testing, as it is to be expected that a significant proportion of fishers will not provide good quality data. Moreover, any changes in gears or effort must be fully documented as these will cause changes in catches. The monitoring of larger fisheries also requires several improvements to meet minimum quality standards. Some improvements which are specific to this kind of data collection include:

- training and testing of logbook fishers for their ability to correctly identify, measure and record data;
- training, testing and certification of agency staff for their ability to correctly identify fish, to measure and record data, and to train fishers;
- auditing of logbook fishers several times during the year by independent observers;
- auditing of technical agency staff by supervisors;
- photo-documentation of every catch and sample to enable easy checking against databases;
- more timely entry of data, preferably on laptops in the field so that any anomalies can be checked directly with fishers.

4.2.5 Information Use

Two review reports have been recently published by the FP in 2013. Halls *et al.* (2013a) reviews all FP monitoring data from 1994 to 2010; within this period some datasets cover shorter time periods. Halls *et al.* (2013b) reviews in more detail monitoring of the Tonle Sap dai fishery from 1998 to 2008. Delays in publishing these reports reflect the large size of databases and consequent analytical demands, as well as internal delays in MRC (the reports were in final draft in 2011). Monitoring reports should be published faster for the results to be most useful for management. Reporting could be speeded up if field data collection is reduced and resources are increased for analyses and write-up of data.

The MRC FP reports produced to date show that flooding has a large beneficial effect on fish production in subsequent years, but other residual variation in the long-term datasets has not been adequately explained. In terms of informing hydropower development, despite several large tributary dams being recently constructed (e.g. Nam Theun 2 and several dams in the Nam Ngum basin), the FP reports do not identify any particular impacts from these dams at the monitored locations along the mainstream. The data are variable and the analyses to date have been quite broad-brush, so more detailed analyses are required. Small changes may not be distinguishable from natural variation or from variation introduced by measurement error, highlighting the need to standardise and document methods if the results are to be used to generate useable information.

For hydropower information at the basin-wide level, and in the long-term, MRC's monitoring data could be used to audit predictions of impact and the degree of mitigation as published in EIAs and other recent publications and thereby to improve EIA accuracy and mitigation outcomes for hydropower. MRC publications on fisheries are already widely cited, and their credibility will be further enhanced by systematic documentation of methods in SOPs. MRC fisheries monitoring data are likely to increase in importance for supporting regional dialogue on hydropower impacts, in assessing basin-wide and transboundary effects on fisheries, and as inputs for PNPCA assessments. Assessment and monitoring of dam impacts by developers will also benefit from the availability of suitable tested standard methods.

There are various other opportunities to use fisheries monitoring data to meet information needs (e.g. Section 4.1 above), and data currently collected by the FP and EP is already of great value in this regard. The FP has a laudable record of publishing over the last decade, but there have been significant delays in reporting, mainly because of the large amount of data collected. Any available resources, including support from ISH, could be put to good use in assisting with the task of cleaning and analysing data and publishing reports. More dialogue is also needed between MRC programs to work on connecting fisheries information to decision-support systems.

4.3 Opportunities for Improvement

There is considerable scope to improve the FP monitoring, and also the SIMVA monitoring as discussed separately in the ISH11 Phase 2 Report Socio-Economics Annex.

FP activities all developed from separate aid-funded activities, each with a capacity-building element, and each has continued based on available capacity and familiarity of counterpart staff. It is suggested that all need be re-focused based on the elements of the guiding framework: Locations, Parameters, Timing, Information Management and Information Use as discussed above. In general, information use and management should be the starting points which will guide changes to be considered for the other elements in the light of the discussion above (Sections 4.1-4.2).

The main opportunities for improvement follow from consideration of the guiding framework are to increase the sampling coverage to more sites and to follow the improvement proposals (Section 5) which provide opportunities as follows:

Fisheries indicators for hydropower information. The opportunities are to:

(1) improve the quality of data and provide justified approaches to sampling frequency (see Section 4.2.3), which will free-up resources for reporting and for development of standard methods; and

(2) develop examples of hydropower indicators from the data which will inform further improvements in sampling approaches (see Section 4.2.5).

Fish sampling standard methods. The opportunity is to improve the quality of the fish abundance and diversity parameters (Section 4.2.2) in two ways:

(1) For existing monitoring, to reduce variability in the data of the fishers who are routinely monitored, as well as the single gears that are monitored (dais in the Tonle Sap and the lee trap and gill net sampling at Ban Hat and Ban Hadsalao in Lao PDR). Current standard sampling for larvae can also be improved and documented.

(2) There is an opportunity to test and document new standard methods systematically, and to recommend long-term monitoring.

Habitat assessment standard methods. As there is no monitoring of habitat at present the proposed activities will provide an opportunity to test and document methods systematically, to build capacity, and to recommend long-term monitoring.

Biological analyses standard methods. Similarly, as there is no monitoring of the biological condition of fish at present, the proposed activities will provide an opportunity to test and document methods systematically, to build capacity, and to recommend long-term monitoring.

Figure **15 – IFReDI staff training and testing fishers at a workshop in Kratie, May 2010**

5 Improvement Proposals for Consideration

5.1 Approach and Rationale

There is a need for more quantitative and up-to-date information on fisheries status and trends and impacts of development, consistent with the the size, value and importance to livelihoods of the Mekong fisheries. The improvement proposals relating to fisheries information for hydropower planning and management strongly endorse activities identified and in progress to varying degrees within FP. The gap analysis for fisheries information shows that many Guiding Framework criteria are either fully met or in progress. The improvement proposals seek to further advance FP objectives and to reinforce efforts so that the outcomes can benefit hydropower information needs.

Proposal F1 'Fisheries Indicators for Hydropower Information' addresses a number of aspects of the Guiding Framework that are presently not fully met. The proposal would involve analysis of existing fisheries data which would identify potential costs savings and timing efficiencies, better understanding of stressors and potential to link with other forms of data, improvements to the way information is managed for faster outputs, and a better understanding of what tools are needed for hydropower decision-support and analysis.

Proposals F2, F3 and F4 are to develop standard methods for fish sampling, habitat assessment, and biological analysis respectively. From a hydropower-information perspective the most critical of these is standardised fish sampling methods; standard habitat assessment and fish biological analysis methods would be beneficial to add once standard fish sampling is developed, to increase the level of understanding of fisheries status, trends and influences. All standard methods need to be supported by SOPs and WIs to ensure data quality and consistency. These improvements would address aspects of the Guiding Framework relating to parameters and information management that are not presently fully met.

There are some gaps in monitoring locations shown in Tables 19 of the Main Report, that are not focussed on in these improvement proposals. Hydro-ecological zones and locations near hydropower projects and national boundaries are reasonably represented by the present FP sampling, but could be further strengthened in terms of value for hydropower planning and management by sampling at all the 33 locations identified by ISH11.

5.2 F1: Fisheries Indicators for Hydropower Information

Gaps Addressed in Guiding Framework: The following Guiding Framework criteria would be addressed or enhanced by this proposal.

- *2. Parameters Monitored; 2c) Able to be measured and analysed at a low cost.* There are potential efficiencies and cost-savings through less frequent sampling, but need to avoid loss of information or gaps in data.
- *2. Parameters Monitored; 2d) Able to help predict as well as explain cause and effect of changes.* Can be improved with better understanding of stressors and collection of biological and habitat parameters.
- *4. Information Management; 4b) Systems allow information to be centrally archived and shared.* Frequency is excessive – daily - for most monitoring and could be reduced.
- 5. *Information Use; 5b) Links to tools are available for decision-support and analysis.* Not presently clear what tools are needed for hydropower decision-support and analysis relating to fisheries.

Objective and Description: In the early phases of the Fisheries Programme (late 1990s up to 2010) the main purpose of field data collection was to document the size and value of the fishery, so that fisheries would receive appropriate consideration in development planning. FP reports documenting some of that data have been widely disseminated and cited, with the result that the profile of Mekong fisheries has risen significantly over the last 10 years. Now the importance of fisheries is generally agreed, while at the same time hydropower development is increasing, especially in Laos and Cambodia, with the aim of providing national income to support poverty reduction and/or meeting the demand for income and power. In the past, some FP data have taken several years to compile, analyse and report, and in some cases data remain unreported. There is a demand for fisheries information to inform hydropower development and management, so there is a need to speed-up the sampling, analysis and reporting time for fisheries data. Moreover, additional sampling work is planned, and additional analyses to generate hydropower indicators are required, which will require reducing the current workload. A further consideration is that in 2015 all data collection will be decentralised; i.e. fully outsourced to agencies, so any sampling should be the minimum possible that can achieve objectives. If sampling is reduced data quality can also be improved – less data means fewer errors in absolute terms and data checking and verification take less time. There will also be more time to develop and report fisheries indicators for hydropower impacts.

These considerations apply also to fisheries data collected by the SIMVA survey under EP. It is considered that there are currently too many questions and too many fields in the database; many have not been analysed or used in any way, and there are some errors or inconsistencies in the databases. These issues have already been communicated in a SIMVA workshop and formally through the ISH socio-economist, who will work with EP on improving the survey.

It should be noted that these issues are not unusual; in large programs it is common to initially over-sample and it is also usual to later reduce sampling effort based on clarification of objectives and considerations of workload and data quality.

It is proposed to review existing databases for two purposes: 1) to recommend where data collection effort can be reduced without compromising quality, and 2) to develop fisheries indicators for hydropower information. Procedures would also be reviewed in consultation with the programmes to develop SOPs to a standard format.

Linkage to Programme Activities: FP and EP are reviewing their monitoring activities and any additional review would need to be carried out working directly with FP and EP staff.

Relevant MRC Procedures or Guidelines: None identified.

Proposed Activities: The review would aim to analyse existing datasets to determine how to 1) optimise sampling from a statistical perspective and 2) how to produce useful fisheries indicators of hydropower information. It would be necessary to discuss and agree with ISH team and FP & EP on the approach. FP would be asked to provide up-to-date databases for assessment. EP SIMVA review would be via general advice to the ISH11 socio-economist.

Outputs: The review would produce report(s) which would include:

- recommended changes to sampling approach and frequency to achieve objectives without compromising quality;
- recommended fisheries indicators for hydropower information with examples based on current datasets;
- some additional examples of recommended fisheries indicators from proposed monitoring of habitat and biological analyses (see below); and
- draft SOPs for each monitoring activity.

The review would also include a presentation and workshop to explain results, and training in preparing SOPs and WIs if required.

Implementation Commitments: FP is currently cleaning and reviewing all databases and prepares various reports and summaries. FP data is to be transferred to IKMP in this phase of the programme (2011-15). FP is reporting a range of parameters or indicators (see 4.2.2).

Sustainability Considerations: Each LMB country now has fisheries and environmental legislation that includes provisions for monitoring which could cover continuation of the current FP monitoring, but it is not yet clear how handover of monitoring will be implemented. It is more likely to be successful if clear and documented methods are in place and data collection effort is the minimum required.

Outcomes and benefits:

- More timely availability of data and information and in the form of suitable indicators for hydropower development and management.
- Resources can be freed-up to support additional activities.
- Decentralisation in 2015 is more likely to succeed so that data will continue to be collected.
- In general, less data of better quality will be more credible for outsiders who need to use them.
- SOPs/WIs for current FP monitoring will be available for hydropower developers to apply in their monitoring, which will enhance communication and cooperation within the sector.
- Capacity-building opportunities include:
  - Improved ability to clean and manage databases
  - Learning about how to optimise sampling statistically.
  - Learning how to write SOPs and Work Instructions according to EMS guidelines.

5.3 F2: Fish Sampling Standard Methods

Gaps Addressed in Guiding Framework: The following Guiding Framework criteria would be addressed or enhanced by this proposal.

- 2. Parameters Monitored; 2b) Able to be replicated across the basin. Standard methods are being developed by FP.
- 2. Parameters Monitored; 2d) Able to help predict as well as explain cause and effect of changes. Can be improved with better understanding of stressors and collection of biological and habitat parameters.
- 4. Information Management; 4a) Quality management systems are in place to ensure consistency across countries. SOPs/WIs for fisheries monitoring are in development but not presently available.

Objective and Description: Current FP monitoring relies mainly upon monitoring fisher catches, for which gears and effort are not under the control of the FP. It is recommended to supplement the fisher catch sampling with standardised sampling; i.e. representative sampling under controlled conditions (standardised gears used in a standardised way with associated data fully recorded) so that changes in underlying fish populations will be evident and not confounded by variations in **methods and effort. This proposal aims to c**arry out field testing of methods of fish sampling that are usually applied elsewhere, also taking account of local methods and conditions, so that standard

methods can be used in long-term monitoring to objectively establish status and trends in fish populations over time. The intention is also to write **Standard Operating Procedures and** Work Instructions based on test results to be applied in future monitoring.

Linkage to Programme Activities: This work would be implemented by the FP working through line agencies. Standardised fish sampling of fish complements existing FP sampling of fishers or gears. EP should also be involved as the results of standardised fish sampling could be used for river health monitoring. Fish-based assessment of river health is standard practice elsewhere. Other programmes' data on hydrology and water quality is required for interpretation of fish sampling data and the activity thereby promotes integration of disciplines.

Relevant MRC Procedures or Guidelines: None identified.

Proposed Activities: It would be necessary to discuss and agree with ISH team and FP & EP on the approach. This could range from full involvement of ISH11 specialist consultant(s) to a more restricted alternative or supplementary approach of "train the trainer"; i.e. to provide detailed training and ongoing support to FP staff in approaches to standardised fish sampling as well as to carry out initial field testing in 2013 in-house. This approach would be consistent with MRC's policy of decentralisation and relatively manageable.

FP would be asked as a minimum to provide staff to assist in the activity and to be trained in sampling and reporting. FP has four well-qualified Programme Officers (one for each LMB country) as well as an experienced Capture Fisheries Expert. Once trained, they should be able to transfer the approach for standardised fish sampling to counterparts and include final methods in contracts with agencies.

In October 2013 a workshop was held on this subject in Vientiane, attended by FP and agency staff and NMCs. The workshop included background reviews and outline of methodologies, examples of field interview forms and SOPs. There is still a need to agree on FP and or agency staff for training and implementation schedule and to discuss about adding this work to FP agency contracts in 2014 as a training/field testing component. Other programmes should be informed of the proposed approach and invited to comment.

Trials should cover four seasons in 2014. It would be best to include this work where possible in the FP 2014 work-plan and agency contracts. Time is needed to purchase equipment in 2013.

Outputs:

- Reports on field activities in each country, assessing the practicality and suitability of the tested methods, and including information on standardisation, calibration and validation of each method.
- SOPs for each method.
- FP and agency staff trained in methods and reporting.

Implementation Commitments: FP is proposing to develop standard methods in 2014.

Sustainability Considerations: Handover to LMB countries in 2015 is likely to be successful if methods are properly documented and consistent with international practices.

Outcomes and Benefits:

- A standard approach for fish sampling at any site will improve consistency and quality of data collection and reduce variance caused by artefacts, including operator errors, which will provide better information for balanced discussion over impacts and management of hydropower and will lead to a better understanding of hydropower impacts and our ability to manage them.

- SOPs/WIs for fish sampling will be available for hydropower developers to apply in their monitoring, which will enhance communication and cooperation within the sector and to others.

5.4 F3: Habitat Assessment Standard Methods

Gaps Addressed in Guiding Framework: The following Guiding Framework criteria would be addressed or enhanced by this proposal.

- 2. Parameters Monitored; 2a) Provide inputs to indicators related to hydropower planning and management. Missing better habitat assessment data.
- 2. Parameters Monitored; 2b) Able to be replicated across the basin. Standard methods are being developed by FP.
- 2. Parameters Monitored; 2d) Able to help predict as well as explain cause and effect of changes. Can be improved with better understanding of stressors and collection of biological and habitat parameters.
- 4. Information Management; 4a) Quality management systems are in place to ensure consistency across countries. SOPs/WIs for fisheries monitoring are in development but not presently available.

Objective and Description: Local conditions at a sampling site (e.g. depth, current speed, substrate and vegetation) affect water quality and aquatic fauna, and can also influence sampling efficiency. Hydropower developments alter hydrology and transport of sediment and organic material, including large woody debris. Changes in habitat quantity and quality lead to changes in productivity and fish communities downstream. ISH11 proposes to trial methods of habitat assessment and provide a standard approach to be used by field staff so that long-term changes at each site can be systematically monitored. Habitat assessment is routinely applied elsewhere, and needs to be developed and tested for the Mekong.

At a broader scale (macro-habitat), river systems are classified across whole basins into segments or reaches from source to mouth. Aquatic organisms are distributed in predictable ways over large scales, so meso-classification is useful for selecting large blocks of habitat for analysis. The MRC has classified the Mekong into six main reaches using such an approach.

Linkage to Programme Activities:

- Standardised sampling of fish complements existing FP sampling of fishers or gears.
- This sampling also provides data which can be used to support EP bio-monitoring. Fish-based assessment of river health is standard practice elsewhere.
- Other programmes' data on hydrology and water quality is required for interpretation of fish sampling data.
- Promotes integration of disciplines.

Relevant MRC Procedures or Guidelines: None identified.

Proposed Activities: There are various approaches to habitat assessment and it is necessary to further scope this activity in consultation with MRC programmes and the ISH11 team and to agree on FP and or agency staff for training and implementation schedule, as well as adding this work to FP agency contracts in 2014 as a training/field testing component. It would also be necessary to inform other programmes and disciplines of the proposed approach and invite comment.

As a minimum, some basic measurements would be made as part of proposal F2 'Fish Sampling Standard Methods' to support SOP development and interpretation of data.

Fieldwork could range from full involvement of ISH11 specialist consultant(s) to a more restricted alternative or supplementary approach of "train the trainer"; i.e. to provide detailed training and ongoing support to FP staff in approaches to habitat assessment as well as to carry out initial field testing in 2013 in-house. This approach would be consistent with MRC's policy of riparianisation and relatively manageable.

It would be useful to support an internal practical workshop on this subject and to include a field visit. The workshop could include background review and methodology to be tested, (1 day), field work (1-2 days) and analysis and write-up of SOPs and WIs (2-3 days).

Outputs:

- Reports on field activities in each country, assessing the practicality and suitability of the tested methods, and including information on standardisation, calibration and validation of each method.
- SOPs for each method.
- FP and agency staff trained in methods and reporting.

Implementation Commitments: This activity is not currently covered by any programme's work plan, but it has some support in principle from FP and EP.

Sustainability Considerations: Unknown at this stage.

Outcomes and Benefits:

- A standard approach for assessing habitat at any site will improve consistency and quality of data collection and allow for better discrimination of hydropower-induced changes from any local impacts unrelated to hydropower.
- Habitat and flow data together with information on preferences of fish can be used to estimate weighted useable area (WUA) in reaches affected by hydropower as an aid to planning.
- Improving data quality and interpretation will lead to a better understanding of hydropower impacts and our ability to manage them.
- SOPs/WIs for habitat assessment will be available for hydropower developers to apply in their monitoring, which will enhance communication and cooperation within the sector and to others.
- Habitat description can complement all other MRC field sampling by providing information on local conditions that correlate with other variables and/or that may influence sampling results. Habitat assessment primarily supports existing and planned FP monitoring by providing information on those habitat variables that influence fish and OAA distribution and abundance.
- Supports interpretation of EP bio-monitoring data by providing information on those habitat variables that influence distribution and abundance of aquatic organisms.
- Provides information on variations in local conditions that might affect fisher catches or sampling efficiency or success of fisheries or EP bio-monitoring.
- Complements existing IKMP discharge & sediment monitoring program (DSMP), Water Quality Monitoring Network (WQMN), and HYCOS network by providing information about habitat changes near sampling sites that would lead to local inputs of sediment or organic material or other changes in conditions that might influence sampling conditions or results.

- Promotes integration of disciplines and a broader understanding of sampling artefacts and data interpretation.
- Additional information is also of relevance to CCAI, NP and FMMP.

5.5 F4: Biological Analyses Standard Methods

Gaps Addressed in Guiding Framework: The following Guiding Framework criteria would be addressed or enhanced by this proposal.

- 2. Parameters Monitored; 2a) Provide inputs to indicators related to hydropower planning and management. Missing biological parameters for targeted individual fish species.
- 2. Parameters Monitored; 2b) Able to be replicated across the basin. Standard methods are being developed by FP.
- 2. Parameters Monitored; 2d) Able to help predict as well as explain cause and effect of changes. Can be improved with better understanding of stressors and collection of biological and habitat parameters.
- 4. Information Management; 4a) Quality management systems are in place to ensure consistency across countries. SOPs/WIs for fisheries monitoring are in development but not presently available.

Objective and Description: This proposal aims to carry out laboratory testing of methods of biological analyses as usually applied elsewhere, so they can be used in long-term monitoring to objectively establish status and trends in fish condition, diet, reproductive output and other features such as contaminant content. These issues are highly relevant to hydropower-information needs, because as hydraulic, sediment and run-off conditions in the river change with hydropower and other developments the ecological processes adjust including food chains and balance of food sources for fish species. Biological analyses of fish help understand how the fish are adapting to changed circumstances and will assist in being able to predict their resilience to further changes. The intention is also to write SOPs and WIs based on test results to be applied in future monitoring.

- Biological analyses complement data on catches by fishers or standard gears.
- Using condition of fish to assess river health is quite standard elsewhere.
- Other programmes' data on hydrology and water quality is required for interpretation of fish data.
- Promotes integration of disciplines.

Linkage to Programme Activities: This work would be implemented by FP and Fisheries Line Agencies.

Relevant MRC Procedures or Guidelines: None identified.

Proposed Activities: Initially, we should discuss and agree with FP on the approach and and concepts of trialling biological analyses. Existing agency capacity and resources should be evaluated and then agency staff would be trained in methods and materials would be purchased as required for laboratories in each country. Training could be carried out on-the-job based on fish collected by standardised sampling (proposal F2) or from ongoing monitoring of fisher catches. For most parameters sampling should be at least monthly, so any trial would need to obtain material at this frequency.

Training/testing should cover all seasons through 2014. It would be best to include this work where possible in FP 2014 work-plan and agency contracts. We need to allow for time to purchase equipment.

It would be useful to hold a two-day workshop to discuss and agree on approaches, resources, agency staff and schedules for training and implementation schedule.

Outputs:

- Reports on results of laboratory analyses in each country, assessing the practicality and suitability of the tested methods, and including information on standardisation, calibration and validation of each method.
- SOPs for each methods.
- FP and agency staff trained in methods and reporting.

Implementation Commitments: FP is supportive of this activity, but concerned over variable agency capacity and experience.

Sustainability Considerations: Unknown at this stage.

Outcomes and Benefits:

- A standard approach for biological analyses of fish will improve consistency and quality of data collection and reduce variance caused by different methods being applied.
- Better information will be available for balanced discussion over impacts and management of hydropower on fish and fisheries, and will lead to a better understanding of hydropower impacts and approaches to manage them.
- SOPs/Work Instructions for biological analyses will be available for hydropower developers to apply in their monitoring, which will enhance communication and cooperation within the sector and to others.
- Capacity-building opportunities include:
    - Laboratory methods for biological analyses and recording input of data.
    - QA/QC of data and analysis and interpretation of data.
    - Comparison of methods and preparation of SOPs and work instructions for long-term monitoring.
    - Provision of laboratory instruments as required and training in their use.
    - Opportunity to interact effectively with hydropower developers to improve their EIA and monitoring.

6 Conclusion

This report reviews existing fisheries monitoring, and provides recommendations that are intended to assist Member Countries obtain a clear and scientifically-sound understanding of conditions, changes and trends in fisheries of the LMB to inform hydropower planning and management. The proposed actions also have direct benefits in terms of capacity-building, support the decentralisation process, and are consistent with the other recommended studies of ISH11.

The MRC has played a leading role in sponsoring fisheries research in the Mekong basin, has developed strong long-term collaboration with regional fisheries agencies, and continues to produce high-quality reports on fisheries which are widely read and cited. Most MRC fisheries data are collected under direction of the FP, while the EP also collects interview-based household survey data in the SIMVA surveys that are useful in defining participation, effort and consumption over large areas. The recommendations of this report cover current FP data collection, whereas the Socio-Economics Annex covers the ISH11 recommendations for the EP SIMVA survey. Ancillary data which are useful in interpreting fisheries data include hydrology, water quality and biomonitoring, and are reviewed and described in other ISH11 Phase 2 Report Annexes.

The status and gap analysis against the Guiding Framework in the ISH11 Phase 2 Main Report has identified opportunities for improvement. ISH11 recommends sampling at 33 locations. The FP's site coverage is adequate for a good coverage of the mainstream, but 9 additional sites should be considered, consistent with those recommended for all disciplines under ISH11.

Regarding additional monitoring activities, the ISH11 team has focussed on those it considers would add most value, and has formulated proposals for action for the consideration of MRC Programmes and Member Countries. Whilst several current gaps and opportunities for improvement are recognised by FP and built into their current work plan, from a hydropower information perspective the most critical of these is the absence of standardised fish sampling methods. FP is addressing this need; and given the importance of fisheries in the region this gap needs to be addressed immediately, as conclusions relating to hydropower developments cannot be confidently stated at present and decisions need to be made on mitigation and management measures. All standard methods should be supported by SOPs and WIs to ensure data quality and consistency.

Further areas of attention important from a hydropower-information perspective relate to timing; systems need to be improved to enable faster processing and reporting so that fisheries information is available in a timely manner to fully support hydropower information needs. This will require a review of current data collection frequency as well as consideration of reducing sampling frequency (usually daily at present), and/or staging of analyses so that initial reporting is based on a subset of data at reduced frequency.

As well as reviewing the sampling approach, a data review would be useful for generating indicators in formats most suitable for hydropower

Standard habitat assessment and fish biological analyses should also be developed to increase the level of understanding of fisheries status, trends and influences, as is usual in best practise elsewhere, but these new activities could be a second priority to be addressed after standard fish sampling is developed.

MRC FP provides a centralised approach to fisheries monitoring and information sharing. At present data are being cleaned and formatted into documented databases which will be quality assured and transferred to IKMP for general access, an activity that could also be supported by ISH11 in Phase 3.

The MRC ISH and the ISH11 team welcome the views and advice of MRC Member Countries and other stakeholders on the needs, gaps and improvement proposals presented in this report, and look forward to a constructive process of ISH11 study Phase 3 and 4 formulation that builds on and enhances the existing work in the LMB.

7 References

Adamson EAS, Hurwood DA, Baker AM and Mather PB (2009) Population subdivision in Siamese mud carp *Henicorhynchus siamensis* in the Mekong River basin: implications for management. *Journal of Fish Biology* 75: 1371-1392.

Allen D, Darwall W, Dubois M, Kong KS, Lopez A, McIvor A, Springate-Baginski O, Thuon T (2008) Integrating people in conservation planning. An integrated assessment of the biodiversity, livelihood and economic implications of the proposed special management zones in the Stung Treng Ramsar Site, Cambodia. Overseas Development Group, University of East Anglia, UK, and IUCN, Cambodia. 101 pages.

Anonymous (1992) Fisheries in the Lower Mekong Basin. Review of the Fishery Sector in the Lower Mekong Basin. Main Report. Interim Committee for Coordination of Investigations of the Lower Mekong Basin,, Bangkok, Thailand. 92 pages.

Arthur RI, Lorenzen K, Homekingkeo P, Sidavong K, Sengvilaikham B and Garaway CJ (2010) Assessing impacts of introduced aquaculture species on native fish communities: Nile tilapia and major carps in SE Asian freshwaters. *Aquaculture* 299: 81-88.

Backiel T and Welcomme RL (1980) Guidelines for sampling fish in inland waters. *EIFAC Technical Paper* 33: 1-176.

Bain MB and Stevenson NJ (Eds) (1999) Aquatic Habitat Asessment - Common Methods. American Fisheries Society, Bethesda, Maryland, USA. p. 136 pages.

Baird IG (2004) Strength in diversity: fish sanctuaries and deep-water Pools in the Lao PDR. *Fisheries Management and Ecology* 13: 1-8.

Baird IG, Flaherty MS and Phylavanh B (2003) Rhythms of the river: lunar phases and migrations of small carps (Cyprinidae) in the Mekong River. *Natural History Bulletin of the Siam Society* 51: 5-36.

Bao TQ, Bouakhamvongsa K, Chan S, Phommavong T, Poulsen AF, Rukawoma P, Suntornratana U, Tien DV, Tuan TT, Tung NT, Valbo-Jorgensen J, Viravong S and Yoorong N (2001) Local knowledge in the study of river fish biology. *Mekong Development Series* 1: 1-22.

Bonar SA, Hubert WA and Willis DW (2009) Standard Methods for Sampling North American Freshwater Fishes. American Fisheries Society, Bethesda, Maryland. 459 pages.

Bouapao L, Thim L, Bamrungrach P, Lo TD and Chamberlain JR (2012) Social Impact Monitoring and Vulnerability Assessment: Regional Report. Final Draft Dec 2012., Vientiane, Lao PDR.

Caddy JF (2004) Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. *Canadian Jorunal of Fisheries and Aquatic Sciences* 61: 1307-1324.

CEN (2005) *Water Quality - Sampling of Fish with Multi-mesh Gillnets. European Standard EN14757*. Comité Européen de Normalisation. 27 pages.

Coates D (2002) Inland capture fishery statistics of southeast Asia: current status and information needs. *RAP Publication* 2002/11: 1-114.

Cooke SJ, Dunlop WI, Macclennan D and Power G (2000) Applications and characteristics of angler diary programmes in Ontario, Canada. *Fisheries Management and Ecology* 7: 473-487.

Deap L, Degen P and van Zalinge NP (2003) Fishing gears of the Cambodian Mekong. . *Inland Fisheries Research and Development Institute of Cambodia (IFReDI), Technical Paper Series* 4: 1-269.

DEP (2006) Standardised Biological Field Collection and Laboratory Methods. Pennsylvania Dept of Environmental Protection, Bureau of Water Standards and Facility Regulation.

FAO (1999) Guidelines for the routine collection of capture fishery data. *FAO Fisheries Technical Paper* 382: 1-113.

Fiedler JL, Lividini K, Bermudez OI and Smitz M-F (2012) Household Consumption and Expenditures Surveys (HCES): a primer for food and nutrition analysts in low- and middle-income countries. *Food and Nutrition Bulletin* 33: 171-183.

Friend RM (2009) Fishing for influence: fisheries science and evidence in water resources development in the Mekong basin. *Water Alternatives* 2: 167-182.

Garaway CJ, Photitay C, Roger K, Khamsivilay L, Halwart M (2013) Biodiversity and Nutrition in Rice-Based Ecosystems; the Case of Lao PDR. *Human Ecology* 41: 547-562.

Growns IO, Pollard DA and Harris JH (1996) A comparison of electric fishing and gillnetting to examine the effects of anthropogenic disturbance on riverine fish communities. *Fisheries Management and Ecology* 3: 13-24.

Haggan N, Neis B and Baird IG (2007) Fishers' Knowledge in Fisheries Science and Management. UNESCO, Paris, France. 437 pages.

Halls AS, Paxton BR, Hall N, Hortle KG, So N *et al.* (2013a) Integrated analysis of data from the MRC fisheries monitoring programmes in the Lower Mekong Basin. *MRC Technical Paper* 33: 1-130.

Halls AS, Paxton BR, Hall N, Peng Bun N, Lieng S, Pengby N, So N (2013b) The stationary trawl (dai) fishery of the Tonle Sap-Great Lake, Cambodia. *MRC Technical Paper* 32: 1-142.

Hortle KG (2007) Consumption and the yield of fish and other aquatic animals from the lower Mekong basin. *MRC Technical Paper* 16: 1-88.

Hortle KG (2009a) Fisheries of the Mekong River basin. In 'The Mekong: Biophysical Environment of an International River Basin'. (Ed. IC Campbell) p. 432. Elsevier Publishers Amsterdam, the Netherlands.

Hortle KG (2009b) Fishes of the Mekong - how many species are there? *Catch and Culture* 15: 4-12.

Hortle KG (2010) Basin development plan and fisheries. *Catch and Culture* 16: 4-8.

Hortle KG and Bamrungrach P (2012) Fisheries habitats and yield in the lower Mekong Basin. *MRC Technical Paper* in press.

IFREDI (2012) Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia. Synthesis report of the FiA/Danida/WWF/Oxfam project "Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia". Inland Fisheries Research and Development Institute, Fisheries Administration. Phnom Penh, Cambodia. 41 pages.

Jensen SS (2001) Fisheries sector review. *Catch and Culture* 7: 6-9.

Jutagate T (2007) Integrated Basin Flow Management Specialist Report. Fisheries: Revision of Fish Guilds in the Lower Mekong Mainstream. Environment Program. Mekong River Commission, Vientiane, Lao PDR. 64 pages.

Kusek JZ and Rist RC (2004) Ten steps to a results-based monitoring and evaluation system : a handbook for development practitioners World Bank, Washington.

Lazarte CE, Encinas ME, Alegre C and Granfeldt Y (2012) Validation of digital photographs, as a tool in 24-h recall for the improvement of dietary assessment among rural populations in developing countries. *Nutrition Journal* 11: 1-14.

Le Gallic B (2002) Fisheries sustainability indicators: the OECD experience. In 'Tools for measuring (integrated) fisheries policy aiming at sustainable ecosystems.' OECD, Brussels, Belgium.

Lieng S (2003) Report on Monitoring of Ecological Health of the Mekong River. Inland Fisheries Research and Development Institute. Report to the MRC, Phnom Penh.

Lorenzen K, Garaway CJ, Chamsingh B and Warren TJ (1998) Effects of access restrictions and stocking on small water body fisheries in Laos. *Journal of Fish Biology* 53 345–357.

Mattson N, Jutagate T (2005) A Review of Fish and Fisheries of the Lower Mekong River, and an Analysis of Likely Impacts of Water Resources Development. Restricted Distribution Report. Water Utilization Program/Environment Program, Mekong River Commission, Vientiane, Lao PDR. 70 pages.

MDBC (2003) Fish Theme Pilot Audit Technical Report - Sustainable Rivers Audit. Murray-Darling Basin Commission, Canberra, ACT.

MRC (2010) State of the Basin Report 2010. Mekong River Commission, Vientiane, Lao PDR. 232 pages.

Neebling TE and Quist MC (2011) Comparison of boat electrofishing, trawling and seining for sampling fish assemblages in Iowa's non-wadeable rivers. *North American Journal of Fisheries Management* 31: 390-402.

Pantulu VR (1986) Fish of the Lower Mekong Basin. Ch. 14A in 'The Ecology of River Systems'. (Eds BR Davies, KF Walker) 793 pages. Dr W. Junk Publishers, Dordrecht, The Netherlands.

Poizat G and Baran E (1997) Fishermen's knowledge as background information in tropical fish ecology: a quantitative comparison with fish sampling results. *Environmental Biology of Fishes* 50: 435-449.

Potter ECE and Pawson MG (1991) *Gill netting. Laboratory Leaflet No. 69.* Ministry of Agriculture, Fisheries and Food, Lowestoft, UK. 34 pages.

Poulsen AF, Ouch P, Viravong S, Suntornratana U and Nguyen TT (2002) Fish migrations of the Lower Mekong River Basin: implications for development planning and environmental management. *MRC Technical Paper* 8: 1-62.

Schaeffer NC and Presser S (2003) The science of asking questions. *Annual Review of Sociology* 29: 65-88.

So N, Leng SV, Prum S, Le XS, Pomeroy R (Eds) (2010) 'Assessment of diversity and bioecological characteristics of low value/trash fish species. pp. 259-230.' (AquaFish CRSP Management Entity, Oregon State University, Corvallis, OR, USA). 510 pages.

So N, Pomeroy R (2011) Developing management recommendations for freshwater small-sized/low value fish in the lower Mekong region of Cambodia and Vietnam. Final Technical Report. . Inland Fisheries Research and Development Institute. Phnom Penh, Cambodia. 17 pages.

Sverdrup-Jensen S (2002) Fisheries in the lower Mekong Basin: status and perspectives. *MRC Technical Paper* 6: 1-95.

Tek V (2008) Building on Local Knowledge for Basin Development Plan. BDP Stakeholder Consultation, 12-13 March 2008, Powerpoint Presentation. 24 pages.

TVA (2010) *Standard Operating Procedure for: Fish Sampling with Gill Nets*. Tennessee Valley Authority. 17 pages.

USGS (2002) *Revised Protocols for Sampling Algal, Invertebrate and Fish Communities as Part of the National Water-Quality Assessment Program*. US Geological Survey. 75 pages.

van Zalinge NP, Degen P, Pongsri C, Nuov S, Jensen JG, Nguyen VH and Choulamany X (2004) The Mekong River system. *RAP Publication* 2004: 335-357.

Viravong S, Phounsavath S, Photitay C, Putrea S, Chan S, Kolding J, Valbo-Jorgensen J and Phoutavong K (2006) Hydro-acoustic surveys of deep pools in Southern Lao PDR and Northern Cambodia. *MRC Technical Paper* 11: 1-70.

Vo TTL, Bush S, Le XS, Hap N, Nguyen TK (2009) Value chains for sustainable Mekong fisheries: the case of *Pangasius hypophthalmus* and *Henicorhynchus*/*Labiobarbus* spp. in Vietnam and Cambodia. Draft Document, Please do Not Cite. Cantho University and An Giang University, Vietnam; Wageningen University, the Netherlands; Inland Fisheries Research and Development Institute (IFReDI), Cambodia. 58 pages.

WUP/EP (2006) Overview of Biotic Aspects and Impacts from Changes of Flow Regime to the Mekong Delta. Final Report October 2006. Water Utilization Program/Environment Program, Mekong River Commission, Vientiane, Lao PDR. 55 pages.

Zale AV, Parrish DL and Sutton TM (Eds) (2013) Fisheries Techniques. American Fisheries Society. 1009 pages.

Attachment 1 – MRC Fisheries Programme Sampling Sites as at November 2013

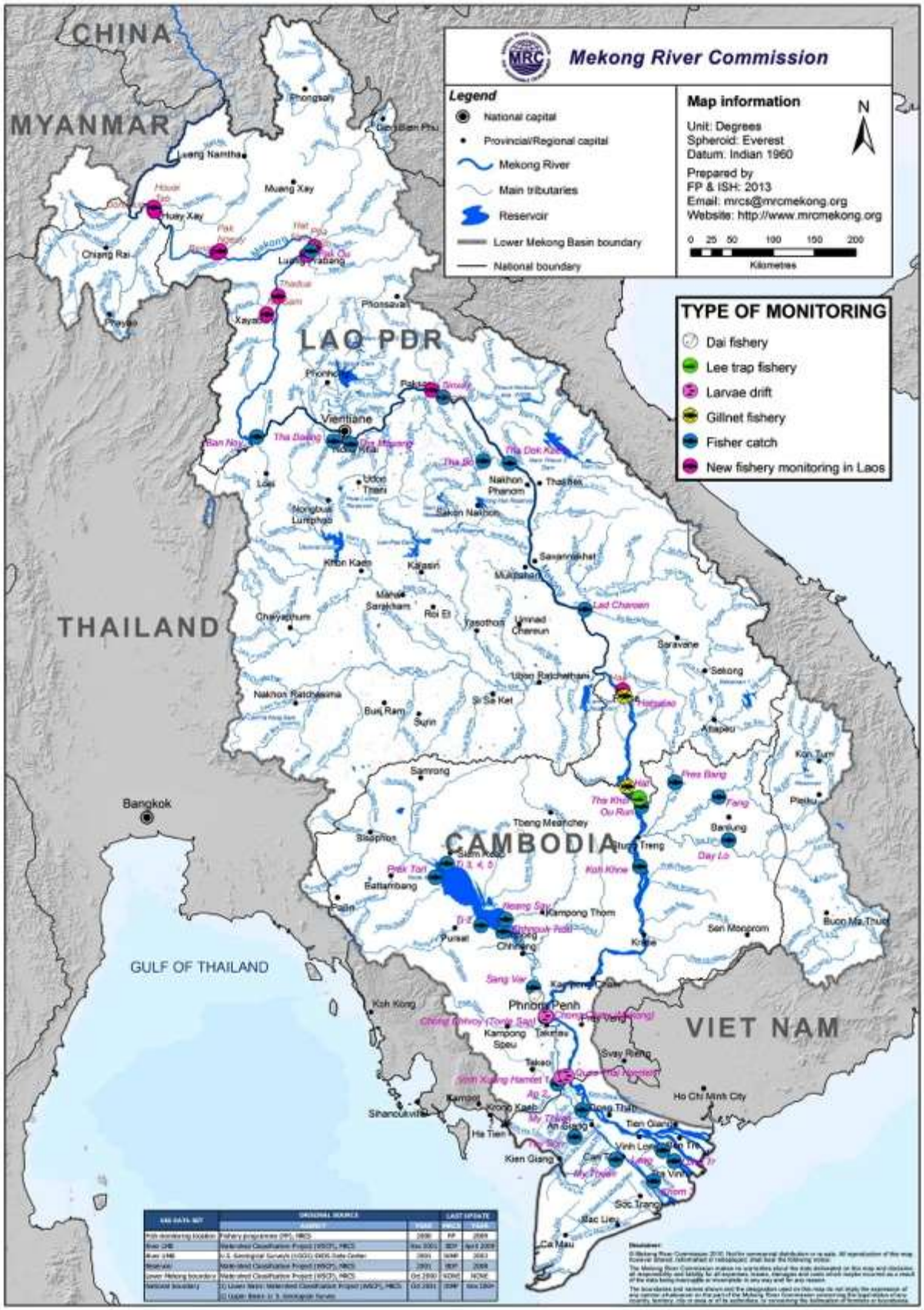
Highlighted sites are new and were advised during Phase 2

Type of monitoring	Country	Province/City	Village	Habitat	Latitude (N)	Longitude (E)	No. of fishers or samples	Agency
Fisher catch	Cambodia	Stung Treng	Pres Bang	Sekong R.	14°07'503"	106°23'981"	3	IFReDI
	Cambodia	Ratanakiri	Day Lo	Srepok R.	13°28'429"	107° 0'	3	IFReDI
	Cambodia	Ratanakiri	Fang	Sesan R.	13°57'808"	106°48'771"	3	IFReDI
	Cambodia	Stung Treng	Ou Run	Mekong R.	13°52'088"	106°00'244"	3	IFReDI
	Cambodia	Kratie	Koh Khne	Mekong R.	13°08'915"	106°04'175"	3	IFReDI
	Cambodia	Kandal	Sang Var	Tonle Sap R.	11°49'945"	104°48'148"	3	IFReDI
	Cambodia	Kampong Chhnang	Chhnouk Trou	Tonle Sap lake/stream	440780	1382000	3	TSA
	Cambodia	Pursat	Ti 2	Tonle Sap lake/stream	413925	1389594	3	TSA
	Cambodia	Battambong	Prek Torl	Tonle Sap lake/stream	358733	1447749	3	TSA
	Cambodia	Siem Reap	Ti 3,4,5	Tonle Sap lake/stream	372438	1464233	3	TSA
	Cambodia	Kampong Thom	Neang Sav	Tonle Sap lake/stream	443929	1396817	3	TSA
	Lao PDR	Bokeo	Donkoun	Nam Ngao R.	20°22'4.12"N	100°22'19.05"E	3	LARReC
	Lao PDR	Bokeo	Houai Tab	Mekong R.	20°19'40.36"N	100°23'2.72"E	3	LARReC
	Lao PDR	Luang Prabang	Hat Nga	Nam Ou R.	19°58'47.93"N	102°14'44.43"E	3	LARReC
	Lao PDR	Oudomxai	Beng	Nam Beng R.	19°54'33.77"N	101° 9'9.11"E	3	LARReC
	Lao PDR	Luang Prabang	Pha Nom	Nam Khan R.	19°53'9.14"N	102° 9'34.41"E	3	LARReC
	Lao PDR	Oudomxai	Pak Ngeuy	Mekong R.	19°53'26.94"N	101° 7'10.56"E	3	LARReC
	Lao PDR	Xayaburi	Thadeua	Mekong R.	19°25'44.52"N	101°50'12.16"E	3	LARReC
	Lao PDR	Xayaburi	Na Sam	Nam Heung R.	19°13'48.43"N	101°42'25.86"E	3	LARReC
	Lao PDR	Bolikhamxai	Phosy	Nam Ngiep R.	18°25'29.64"N	103°37'5.49"E	3	LARReC
	Lao PDR	Champasak	Hae	Nam Sedon R.	15° 8'34.40"N	105°48'7.43"E	3	LARReC
	Lao PDR	Luang Prabang	Pak Ou	Mekong R.	19° 55'52.03"	102° 12'9.19.94"	3	LARReC
	Lao PDR	Vientiane Capital	Tha Mouang	Mekong R.	17° 46'55.96"	102° 41'16.14"	3	LARReC
	Lao PDR	Bolikhamxai	Sinxay	Mekong R.	18° 20'51.4"	103° 45'09.42"	3	LARReC

	Thailand	Loei	Ban Noy	Mekong R.	17°54'26.35"	101°41'24.31"	3	IFRDB
	Thailand	Nong Khai	Tha Daeng	Huai Mong	17°51'21.49"	102°29'59.46"	3	IFRDB
	Thailand	Nakhon Phanom	Tha Dok Kaew	Mekong R.	17°37'12.96"	104°30'53.83"	3	IFRDB
	Thailand	Nakhon Phanom	Tha Bo	Songkhram R.	17°39'12.50"	104°12'55.47"	3	IFRDB
	Thailand	Ubon Ratchathani	Lad Charoen	Mekong R. (Deep Pools)	16° 1'10.36"	105°20'55.23"	3	IFRDB
	Viet Nam	Vinh Long	Lang	Mekong R.	10° 06′ 06.8	106° 13′ 36.1	3	RIA2
	Viet Nam	An Giang	Tay Son	Seasonally flooded area bw Mekong R. & Bassac R.	10° 15′ 09.2	105° 15′ 14.6	3	RIA2
	Viet Nam	An Giang	My Thuan	Bassac R.	10° 32′ 49.0	105° 20′ 05.1	3	RIA2
	Viet Nam	An Giang	Ap 2	Bassac R. and Tributary	10° 50′ 01.6	105° 03′ 47.0	3	RIA2
	Viet Nam	Tra Vinh	Khom 3	Bassac R. - Estuarine	09° 45′ 55.0	106° 07′ 28.5	3	RIA2
	Viet Nam	Can Tho	My Thuan	Seasonally flooded area west of Bassac R.	10° 00′ 14.1	105° 42′ 25.8	3	RIA2
	Viet Nam	Tra Vinh	Long Trị	Mekong R. - Estuarine	09° 59′ 00.5	106° 21′ 24.9	3	RIA2
Gillnet fishery	Lao PDR	Champasak	Hatsalao	Mekong R.	15° 04'28.10"	105° 49'19.76"	3	LARReC
	Lao PDR	Champasak	Hat	Mekong R.	14° 05'05.98"	105° 50'46.51"	3	LARReC
Larvae drift	Cambodia	Phnom Penh	Chong Chhroy Village	Mekong R.	11°34’19”	104°56’26”	1	IFReDI
	Cambodia	Phnom Penh	Chong Chhroy Village	Tonle Sap R.	11°34’38”	104°55’52”	1	IFReDI
	Viet Nam	An Giang	Vinh Xuong Hamlet 1	Bassac R.	10°54'11.9"	105° 6'	1	RIA2
	Viet Nam	An Giang	Quoc Thai Hamlet 1	Mekong R.	10°55'13.2"	105° 10'	1	RIA2
Lee trap fishery	Lao PDR	Champasak	Tha Khor (Hoo Som Yai)	Mekong R.	13° 57'29.85"	105° 58'55.34"	15-20?	LARReC
Dai Fishery	Cambodia	Kampong Cham/Kandal	Several	Tonle Sap R.	Pending			IFReDI

MRC FP fisheries sampling sites

Includes 10 new sites in Lao PDR advised during Phase 2



Attachment 2 – Response to Information or Comments During Consultation

---

1 Cambodia - Solieng Mak Working Notes 27 June 2013

Regarding Fisheries Information Needs

Institutional framework for monitoring fisheries in the Mekong basin, responsible agencies

Comment: Under coordination of the MRC-Fisheries Program for the Lower Mekong Basin, IFReDI is in charge of the monitoring at the national level, and the Tonle Sap Authority (TLSA) is responsible for the Tonle Sap Lake with five provinces. The monitoring work is participated by IFReDI staff, staff from provincial quarter and fisher folks.

Response: Much of this work is for the MRC FP as covered in Section 3 of this report. Other once-off studies are mentioned below.

Monitoring data which are routinely collected by these agencies on fisheries and aquaculture

Comment: In Cambodia, three main types of fisheries monitoring are taking place, including Dai, Fish Catch and Larvae Monitoring.
Response: This work is all covered in Section 3 of this report.
Dai monitoring started since 1995 by the Fisheries Department and at present by IFReDI. It is conducted on the Tonle Sap River annually between October and February or March of the year. The parameters measured include no. of Dai fishing operated, amount of fish caught per Dai per day and fish species.

Annual Fish catch started from 1994 *(2004 is correct)* (by 3 fishermen per location during their fishing hours) is conducted in six locations of the Mekong River System by IFReDI: two on the Mekong mainstream in O Run Village, Thalaborivath District of Stung Treng Province and in Koh Khne village in Kratie Province; three on the tributary rivers (one on the Sekong River in Thmar Baing Village, Siempang District of Stung Treng Province, one on Sesan river in Veunsai Village of Ratanakiri Province and one on Sre Pok River in Deylo Village, Lumphat District of Mondulkiri Province); and one location on Tonle Sap River in Sangvor Village, Phnea Leu District of Kandal Province. In addition to this, Fish Catch monitoring on the Tonle Sap Lake is conducted by TLSA in five provinces (Kampong Chhnang, Pursat, Battambang, Siem Reap and Kampong Thom). The parameters measured for fish catch monitoring include: fishing gears, fish abundance, and fish species with their length and weight. This record is for every time they go fishing during flood receding and rising periods.

Larvae monitoring started in 2001 under Assessment of Mekong Capture Fishery Project (AMCF) of the Department of Fisheries which is FiA at present. It is conducted every year on the Tonle Sap River and Mekong River in Phnom Penh around Chaktomuk area in Chruoy Changvar District, generally from the 1st of June to 30th September of the year. Samples by bongo-net every six hours for 30 minutes operation (at 6:00, 12:00, 18:00 and 24:00 hours) have been collected from the two locations. The parameters measured include density of larvae per 1,000 m3, number of larvae per sampling during 30 minutes and fish species.

Recent (last 5 years) surveys on fish/fisheries and aquaculture

Comment: Baseline poverty survey of fishers in Kratie, Ratanakiri, Mondulkiri, Kampong Speu, Kampot and Kep Province in 2012 (FiA and DANIDA, 2013)

Response: Cannot find it; not sure of its relevance.

Comment: Assessment of diversity and biological characteristics of low value/small-sized fish in the Lower Mekong River Basin of Cambodia and Vietnam (So *et al.* 2010).

Response: This is a review of previous information on small fish species in Cambodia and Viet Nam under a USAID-funded project: Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Markets". The context is feeding small fish to snakeheads and other carnivores, thereby raising the price and impacting poorer people who traditionally depended upon small fish species that have been very cheap compared to larger fish. New information was gained by interviews and field observations of fishers. For the ISH11 project some relevant new information includes observations on useful and common gears and the relative importance of small fish species and the increasing pressure they are under which is reflected in a relatively large recent increase in prices. The report also highlights the complex interactions between capture and culture fisheries and the difficulty of separating impacts from any one sector when many factors are in play. Continuing surveys of this type will provide important supplementary information for understanding the big picture of Mekong fisheries, and it is hoped that similar work will be implemented basinwide under the guidance of the FP. A related report by So and Pomeroy (2011) extends the desk-based review to develop management recommendations; it reviews more background information on fisheries status and trends, concludes that capture fisheries in Cambodia and Vietnam are overfished and affected by floodplain or wetland degradation and developments in other sectors, and provides 33 conclusions and/or recommendations, covering fisheries research, management and communication, emphasising a balanced and integrated approach between sectors. The recommendations are a useful summary, and support many of the activities of the FP in its 2010-15 Programme Document.

Comment: Value chains for sustainable Mekong fisheries: the case of *Pangasius hypophthalmus* and *Henicorhynchus*/*Labiobarbus* spp. in Vietnam and Cambodia. *(Vo et al. 2009).*

Response: This report deals with market chains for the main aquaculture species in Vietnam and for small cyprinid species from wild capture fisheries in Cambodia. While ISH11 supports expanded market monitoring of fisheries, this is being covered by FP and is not a primary focus of the recommendations for implementation in Phase 3 of ISH11.

Access to reports or data on monitoring

Comment: At the national level, as normally practiced by the government line ministries, to obtain survey reports or data on fish monitoring, the users can make official request to the Director of IFReDI or General Director of FiA. At the regional level, survey reports and data on monitoring can be obtained by making official request to the MRC-Fisheries Programme.

Response: Reports have been provided via the FP to date.

Other study relevant to ISH11 Project

Comment: Village data fisheries resources collection namely Sala Phoum Research started in 2005. This research is done with purpose to compile local knowledge on water and related resources, detect changes to the fisheries resources resulted from impact of upstream development and develop network for knowledge exchange within and between villages. The collection is conducted by four villagers located along the Mekong River in Stung Treng Province, including Koh Khondin, Koh Sneng, Koh Lngor and Vern Sien Villages under coordination of CEPA. The parameters measured

include fish species, fish habitats (particularly deep pools and aquatic plants), fish spawning grounds, migration routes, and fishing gears. The research approach consists of field research, household interview, network meetings to share and validate research findings and final consultation with diverse stakeholders. This research could be ended by end of 2013 due to fund ending.
Response: This type of research is very useful to complement conventional 'scientific' research and should be referred to in training for the planned village interviews. The research results are incompletely documented, but the basics of the approach are well-known and also from Tai Baan research (Allen et al. 2008; Friend 2009) (Tek 2008)

---

2 Working Notes by Lao National Consultant

June 29, 2013 in Vientiane

Lao expenditure consumption survey (LECS)

Comment: The first LECS was conducted in 1992/1993, LECS 2, 3, 4, and 5 was conducted in 1997/1998, 2002/2003, 2007/2008 and 2013, respectively. The initial 1992/1993 LECS survey focused on consumption and social indicators. The 1997/8 LECS expanded the coverage of economic issues. The latest LECS or LECS 4 has a sample size of The 8,304 household from 518 villages. The surveyed villages were the same village group of the LECS 3. In every village 16 sample households were selected. The LECS 3 and LECS 4 are broadly similar to each other and collect information not only to measure household income and consumption, but also to investigate a wide range of poverty-related issues.

Response: This is a very useful national study which demonstrates the importance of fisheries based on consumption values. In 2013 LECS has been expanded to include 5 extra fishing-related question – including fishing as primary and secondary occupations and also a question on fishing habitats and value of fish sold. Similar but more detailed questions are asked in the SIMVA study for which advice was provided to the ISH11 socio-economist.

Section 2 - Progress Regarding Fisheries Information Needs

Surveys conducted by LARReC and DLF

Comment: In recent year, LARReC and DLF mainly collaborated with FAO and IUCN to conduct a number of fisheries data. For instance, surveys on Rice Field Fish Consumption was conducted in 2003 and 2007 under the FAO support.

Response: This has been published by (Garaway et al. 2013), a study that shows the importance of seasonal ricefield habitats as the major source of aquatic animals in Lao PDR. This is the first survey to use 24-hour recall to accurately estimate consumption, an approach that should be considered for any future consumption monitoring.

In 2009, a JICA funded project cooperating with the LARReC conducted a survey on fish prices in Savannakhet, Oudomxay, Vientiane and Champasak province. Dr. Sinthavong is supposed to keep the survey data. This is not published yet, was requested from LARREC.

Based on meeting with Dr. Chanda, there was a IUCN joint research project on fish species study and Dr. Sinthavong is supposed to keep the data. The surveys carried out by the LARReC and DLF are largely limited by the fund availability. This is not published yet, was requested from LARREC.

Regarding the data availability, following shows a list of survey results on the data availability (based on the parameter/indicator stated in the inception report). The survey was conducted during the National Consultation on May 9-10. The survey respondent was Mr. Douangkham Singhanouvong from the LARReC. *These reports or data are mainly covered in the Section 3, but information about the last 3 is pending from LARREC.*

	Organization	**Person in charge**	**Location**	**Frequency**	**Year of data**	**Data management**
Species diversity	LARReC	Mr. Douangkham	Bokeo –Vientiane, Xiangkhuang, Savannakhet	Daily	from 2004-2013 depend on location	Data is kept in LARReC in the format of Access
Fish catch	LARReC	Mr. Douangkham	Bokeo, Oudomxay, Luangprabang, Xayaburi, Vientiane, Bolikhamxay, Champasak		2003 and 2007	Data is kept in LARReC in the format of Access
Lee trap and gill net	LARReC	Mr. Vannaxay Soukhaseum	Champasak	Once per week during May-September	1994-2013	Data is kept in LARReC in the format of Access
Larvae sampling	LARReC	Dr. Sinthavong Viravong	Luangprabang, Xayaburi, Vientiane, Champasak	Once per week during May-December	2008-2010	Data is kept in LARReC in the format of Access. The analysis program used is Primer and CONACO
Market monitoring	LARReC	Mr. Douangkham	Oudomxay, Luangprabang, Vientiane, Champasak	Once per week	2002-2004	Data is kept in LARReC in the format of Access. The analysis program used is Exel.
Number of fishers	LARReC		Luangprabang, Champasak		2000 and 2002	Data is kept in LARReC
Gear	LARReC		Luangprabang, Champasak		2011	Data is kept in LARReC
Catches as CPUE or consumption	LARReC	Mr. Douangkham	Luangprabang, Champasak	Two times	2000 and 2002	Data is kept in LARReC in the format of Access.

Mr. Douangkham informed that all the data mentioned above are sent to MRC , so that data should be able to obtain at the MRC.

In tracing the importance of fisheries and fish culture to people's livelihood, questions on household's fisheries activities and earning relating to fisheries are included in LECS4 and LECS 5. Appendix A shows the questions raised relating to household fisheries activities and earning relating to fish culture in LECS 5.

3 Working note on information of the River and data availability from Thailand For ISH 11 Project

The Fisheries statistic were collected by the Department of Fisheries for Inland Fisheries product which divided into 2 parts i.e. Aquaculture and capture fisheries. Marine Fisheries statistic is also one of the most important information for capture fisheries in Thailand.

Fish larvae study

Comment: Hydropower project had study the drifting fish larvae in Lower Mekong Basin in 2009.

Response: This is the RIS study report which is in draft with ISH and is a once-off study. These study comprise of fish larvae and juvenile at the difference area along the main steam of Mekong river from Laos PDR, Thailand, Cambodia to Vietnam. In Thailand the sampling stations were Nongkhai, Mukdahan, Nakorn Phanom and Ubon Rajathani.

---

4 ISH11 – Working Note by Vietnam National Consultant – Dr. Nguyen Van Tuan, 20 July 2013

General Statistics Office of Vietnam:

- Household Living Standard Survey 2010
- Rural, Agricultural and Fishery Census, 2011
- The 2009 Viet Nam Population and Housing Census.

Responses to questionnaire sent to consultant

Question: Could you please meet with Ministry of Fisheries and with those responsible for monitoring inland fisheries and aquaculture in the Mekong basin (delta and highlands); please meet with Can Tho university staff also.

Question: Please provide some information on the institutional framework now for monitoring fisheries in the Mekong highlands and the Mekong delta…which agencies are responsible and at what levels?

Response: Directorate of Fisheries - DoF (under MARD) is the major responsible agency on fisheries. DoF has its own organizational system down to provincial levels (Provincial Department of Fisheries).

Question: What monitoring data are routinely collected on fisheries and aquaculture?

Response: Production, productivity, areas, etc. For detailed monitoring data, need to meet with DOF (its functional department such as Department of Aquaculture, Fisheries Information Center).

Comment International Consultant: It is hoped that the national consultant can meet with the agencies and request their data.

Question: Can we get any reports or data on monitoring?

Response: Yes, but we need to meet with relevant department of DoF to see what kind of data available that DoF can share with us.

Comment International Consultant: It is hoped that the national consultant can meet with the agency and request their data.

Question: What are their recent (last 5 years) surveys on fish/fisheries and aquaculture?

Response: For detailed information, need to meet with DoF.

Comment International Consultant: It is hoped that the national consultant can meet with the agency and request their data.

Question: Can we get any survey reports or data on monitoring?

Response: Yes, but we need to meet them to see what kind of survey reports they can share with us.

Comment International Consultant: It is hoped that the national consultant can meet with the agencies and request their data.

Comment Consultant: For more information, in framework of the Fisheries Programme of MRCS, there are two relevant activities in the Work Plan 2013: 1) Activity on "National Census and Surveys in each Lower Mekong Basin Country" with one specific objective on "Review the national censuses and surveys that are carried out routinely and/or non-routinely in each LMB country'; and 2) Activity on "Review all national fisheries plans and strategies from the Mekong Basin Countries". Unfortunately, these activities are still at a phase of selection of national consultant (by FP) and not implemented yet. Therefore, if ISH wants to have this kind of information before FP can get and share it, relevant action should be considered.

Comment International Consultant: We have to work through FP and cannot duplicate their efforts.

5 Phase 2 compilation - Working notes comments and responses on report and from consultations 25 June 2013.

Parameters

Comment: A concern is detail under each fisheries parameter, due to different values and importance of indicators; it is suggested to evaluate carefully and apply some weighting of importance. Data is needed on suitability of hydropower developments for aquaculture.

Response: Details of parameters and indicators can be further developed in ISH11 Phase 3. The weightings depend largely upon the users needs, which should be further articulated. The primary data to be collected – species, numbers and biomass – according to standard sampling methods, do not change and the priority is to develop the sampling methods. Use of fish guilds as recommended by (Jutagate 2007) will aid in indicator development.

Methods

Comment: Some Member Countries might have good approaches/methods for monitoring fish with regard to barriers such as dams, that we could draw on to be used more consistently across the LMB; have we identified these?

Response: DoF in Thailand uses a standardised set of gill nets for sampling in reservoirs. The same mesh sizes were used for the draft design of panel nets for standard gill-netting. Information on gears as used in each country will be requested during the Standard Methods Workshop and ISH11 national consultants and FP Programme Officers could assist to get this information.

Comment: Cambodia requests including fisher-catch monitoring for standard method development.

Response: Yes fully agreed, current fisher catch monitoring should be improved and standardised as far as possible as discussed at the Standard Methods Workshop.

Equipment:

Comment: Improved equipment requests at existing monitoring stations include sensor technology to monitor fish movement.

Response: The technology is expensive and requires arrays every few metres in the river. It is only possible to operate at sites funded by hydro companies for very specific purposes, and could not practically be deployed at the sites proposed by ISH11 for routine long-term monitoring.

Parameters

Comment: CCAI asked whether offshore plankton monitoring was being considered. MRC FP was interested in why phytoplankton was not included in the aquatic ecology parameters, which they felt was an important area of knowledge need for fisheries. Thailand proposes additional parameter groups, e.g. fish, shellfish, and larvae which are on FP's future plans for data collection.

Response: Agreed that these are important but not the immediate focus or priority for this ISH11 study.

Attachment 3 – Annotated Bibliography

Is this an MRC report?	Is this a Mekong Basin report?	Year	Reference	Relevance to ISH11 study
MRC supported this study	MB	2009	Adamson EAS, Hurwood DA, Baker AM and Mather PB (2009) Population subdivision in Siamese mud carp *Henicorhynchus siamensis* in the Mekong River basin: implications for management. *Journal of Fish Biology* 75: 1371-1392.	Shows migration systems related to stocks an example of how to support the division of river into reaches.
	MB	2008	Allen D, Darwall W, Dubois M, Kong KS, Lopez A, McIvor A, Springate-Baginski O, Thuon T (2008) Integrating people in conservation planning. An integrated assessment of the biodiversity, livelihood and economic implications of the proposed special management zones in the Stung Treng Ramsar Site, Cambodia. Overseas Development Group, University of East Anglia, UK, and IUCN, Cambodia. 101 pages.	Comprehensive overview of a study using Sala Phoum (LEK) research approach known as Tai Baan in Thailand. Sala Phouom approach complements conventional 'scientific' research and should be referred to in training for the planned village interviews.
MRC (Interim Cttee) Report	MB	1992	Anonymous (1992) Fisheries in the Lower Mekong Basin. Review of the Fishery Sector in the Lower Mekong Basin. Main Report. Interim Committee for Coordination of Investigations of the Lower Mekong Basin, Bangkok, Thailand. 92 pages.	A very important sector review of fisheries prepared from country missions with key national staff. Includes 323 references. Covers all aspects of Mekong fisheries and provides many recommendations for studies which formed the basis for aid funding and later program formulation.
	MB	2010	Arthur RI, Lorenzen K, Homekingkeo P, Sidavong K, Sengvilaikham B and Garaway CJ (2010) Assessing impacts of introduced aquaculture species on native fish communities: Nile tilapia and major carps in SE Asian freshwaters. *Aquaculture* 299: 81-88.	One of the very few LMB documents which contains a peer-reviewed study using a robust statistical hypothesis-testing approach and use of standard methods. A useful reference for sampling design and standard methods.
		1980	Backiel T and Welcomme RL (1980) Guidelines for sampling fish in inland waters. *EIFAC Technical Paper* 33: 1-176.	A frequently cited early work for standard fisheries methods as used worldwide.
		1999	Bain MB and Stevenson NJ (Eds) (1999) Aquatic Habitat Assessment - Common	An overview of common standard methods for habitat

			Methods. American Fisheries Society, Bethesda, Maryland, USA. p. 136 pages.	assessment. None have yet been used in the LMB and this and similar works are a useful basis for developing methods.
	MB	2004	Baird IG (2004) Strength in diversity: fish sanctuaries and deep-water pools in the Lao PDR. *Fisheries Management and Ecology* 13: 1-8.	Example of use of fishers' knowledge methods applied in the LMB.
MRC Report	MB	2001	Bao TQ, Bouakhamvongsa K, Chan S, Phommavong T, Poulsen AF, Rukawoma P, Suntornratana U, Tien DV, Tuan TT, Tung NT, Valbo-Jorgensen J, Viravong S and Yoorong N (2001) Local knowledge in the study of river fish biology. *Mekong Development Series* 1: 1-22.	Example of use of fishers' knowledge methods applied in the LMB.
		2009	Bonar SA, Hubert WA and Willis DW (2009) Standard Methods for Sampling North American Freshwater Fishes. American Fisheries Society, Bethesda, Maryland. 459 pages.	Up-to-date review of all methods of sampling fish, including warm-water fish in large non-wadeable rivers as is most relevant to the LMB.
MRC Report	MB	2012	Bouapao L, Thim L, Bamrungrach P, Lo TD and Chamberlain JR (2012) Social Impact Monitoring and Vulnerability Assessment: Regional Report. Final Draft Dec 2012. Vientiane, Lao PDR.	Very useful survey along the Mekong-Tonle Sap corridor which provides a good coverage and includes many questions relevant to fisheries monitoring.
		2004	Caddy JF (2004) Current usage of fisheries indicators and reference points, and their potential application to management of fisheries for marine invertebrates. *Canadian Journal of Fisheries and Aquatic Sciences* 61: 1307-1324.	Useful discussion on fisheries indicators which has relevance to BDP approach and review of standard methods worldwide
		2005	CEN (2005) *Water Quality - Sampling of Fish with Multi-mesh Gillnets. European Standard EN14757*. Comité Européen de Normalisation. 27 pages.	Widely used reference for European Framework Directive sampling methods - standard monitoring using gill-nets.
MRC supported background works	MB	2002	Coates D (2002) Inland capture fishery statistics of southeast Asia: current status and information needs. *RAP Publication* 2002/11: 1-114.	Contains a thorough review of all official statistics collection in SE Asia, including LMB data situation, and explains why many official data are not reliable or useful for monitoring purposes.
		2000	Cooke SJ, Dunlop WI, Macclennan D and Power G (2000) Applications and characteristics of angler diary	Example of a review of a standard method based on fisher diaries with some of

			programmes in Ontario, Canada. *Fisheries Management and Ecology* 7: 473-487.	the advantages and disadvantages - essentially the same method as used by the FP for monitoring fishers through use of logbooks.
MRC Report	MB	2003	Deap L, Degen P and van Zalinge NP (2003) Fishing gears of the Cambodian Mekong. *Inland Fisheries Research and Development Institute of Cambodia (IFReDI), Technical Paper Series* 4: 1-269.	Compendium of gears and methods as used in the LMB. A very useful basis for adapting any standard methods from elsewhere to take account of local conditions.
		2006	DEP (2006) Standardised Biological Field Collection and Laboratory Methods. Pennsylvania Dept of Environmental Protection, Bureau of Water Standards and Facility Regulation.	An example of a State agency guide to standard methods including fisheries. Useful technical content and formatting.
		1999	FAO (1999) Guidelines for the routine collection of capture fishery data. *FAO Fisheries Technical Paper* 382: 1-113.	Probably the most widely cited guide to standard methods for fisheries assessment worldwide.
		2012	Fiedler JL, Lividini K, Bermudez OI and Smitz MF (2012) Household Consumption and Expenditures Surveys (HCES): a primer for food and nutrition analysts in low- and middle-income countries. *Food and Nutrition Bulletin* 33: 171-183.	Approaches for consumption surveys for standard methods worldwide.
	MB	2009	Friend RM (2009) Fishing for influence: fisheries science and evidence in water resources development in the Mekong basin. *Water Alternatives* 2: 167-182.	Detailed review of principles and methods of acquiring and intrepeting fisheries information based on the Mekong basin; emphasises the value of LEK research to complement more traditional 'scientific' approaches.
	MB	2013	Garaway CJ, Photitay C, Roger K, Khamsivilay L, Halwart M (2013) Biodiversity and Nutrition in Rice-Based Ecosystems; the Case of Lao PDR. *Human Ecology* 41: 547-562.	Survey of 240 HHs in Lao PDR using 24-hour recall consumption approach. Confirms high fish and OAA consumption as in the review by Hortle (2007) and the importance of ricefields.
		1996	Growns IO, Pollard DA and Harris JH (1996) A comparison of electric fishing and gillnetting to examine the effects of anthropogenic disturbance on riverine fish communities. *Fisheries Management and Ecology* 3: 13-24.	Example of approach for a study to compare two standardised fish sampling methods.

		2007	Haggan N, Neis B and Baird IG (2007) Fishers' Knowledge in Fisheries Science and Management. UNESCO, Paris, France. 437 pages.	Compendium of 22 studies on local ecological knowledge of fishers.
MRC Report	MB	2013	Halls AS, Paxton BR*, et al.* (2013a) Integrated analysis of data from the MRC fisheries monitoring programmes in the Lower Mekong Basin. *MRC Technical Paper* 33: 1-130.	
MRC Report	MB	2011	Halls AS, Paxton BR, Hall N, Hortle KG, So N, Chea T, P. C, S. P, Lieng S, Ngor P, Ngor P, Chan S, Vu VA, Nguyen N D, Doan VT*, et al.* (2011) Integrated analysis of data from MRC fisheries monitoring programmes in the Lower Mekong Basin. *MRC Technical Paper* in press.	Review of all MRC fisheries monitoring data including all key riparian staff as co-authors. Includes cross-references to 45 earlier documents.
MRC Report	MB	2013	Halls AS, Paxton BR, Hall N, Peng Bun N, Lieng S, Pengby N, So N (2013b) The stationary trawl (dai) fishery of the Tonle Sap-Great Lake, Cambodia. *MRC Technical Paper* 32: 1-142.	Most recent and comprehensive review of this important fishery. Shows that flooding is the main influence on production.
MRC Report	MB	2007	Hortle KG (2007) Consumption and the yield of fish and other aquatic animals from the lower Mekong basin. *MRC Technical Paper* 16: 1-88.	Review of all MRC and other fisheries household surveys, covers 20 interview-based or monitoring studies in the LMB countries and refers to 79 earlier studies.
MRC Report	MB	2009	Hortle KG (2009) Fisheries of the Mekong River basin. In 'The Mekong: Biophysical Environment of an International River Basin'. (Ed. IC Campbell) p. 432. Elsevier Publishers Amsterdam, the Netherlands.	Review of all data and reports on fisheries in the Mekong basin, synthesises information from 232 cited references.
MRC Report	MB	2009	Hortle KG (2009) Fishes of the Mekong - how many species are there? *Catch and Culture* 15: 4-12.	Review of previous estimates, showing there is no basis for some published high estimates which are a result of 'escalation bias'.
MRC BDP Report	MB	2010	Hortle KG (2010) Basin development plan and fisheries. *Catch and Culture* 16: 4-8.	Review and summary of BDP fisheries study, - BDP Technical Note 11 Impacts on Fisheries, based on national LMB data and 27 cited references. This approach was also used by the consultant for calculating fisheries impacts in the MRC SEA.

MRC Report	MB	2012	Hortle KG and Bamrungrach P (2012) Fisheries habitats and yield in the lower Mekong Basin. *MRC Technical Paper* in press.	Review of MRC GIS data and Mekong basin fisheries yield data. Examines all MRC GIS datasets and published studies on yield by habitat. Contains 70 references.
	MB	2012	IFREDI (2012) Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia. Synthesis report of the FiA/Danida/WWF/Oxfam project "Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia". Inland Fisheries Research and Development Institute, Fisheries Administration. Phnom Penh, Cambodia. 41 pages.	Important recent national survey which confirms high fish consumption estimates as in the review by Hortle (2007)
MRC Report	MB	2001	Jensen SS (2001) Fisheries sector review. *Catch and Culture* 7: 6-9.	Refers to status of fisheries sector reviews in LMB.
MRC-WUP Report	MB	2007	Jutagate T (2007) Integrated Basin Flow Management Specialist Report. Fisheries: Revision of Fish Guilds in the Lower Mekong Mainstream. Environment Program. Mekong River Commission, Vientiane, Lao PDR. 64 pages.	Outlines an approach to classify fish into 12 main guilds - groups based on similar behaviour, reproduction or habitat use. Fish within guilds likely to respond in similar ways to hydropower impacts, simplifying analyses, as there are typically 200-300 species recorded at any site and about 850 recorded from the Mekong Basin (Hortle 2009).
		2004	Kusek JZ and Rist RC (2004) Ten steps to a results-based monitoring and evaluation system: a handbook for development practitioners World Bank, Washington.	Background document for overall approach for monitoring.
		2012	Lazarte CE, Encinas ME, Alegre C and Granfeldt Y (2012) Validation of digital photographs, as a tool in 24-h recall for the improvement of dietary assessment among rural populations in developing countries. *Nutrition Journal* 11: 1-14.	Example of ways of using digital photography to improve quality of standard methods.
		2002	Le Gallic B (2002) Fisheries sustainability indicators: the OECD experience. In 'Tools for measuring (integrated) fisheries policy aiming at sustainable ecosystems.' OECD, Brussels, Belgium.	Experience with use of fisheries indicators in Europe.
MRC-EP	MB	2003	Lieng S (2003) Report on Monitoring of Ecological Health of the Mekong River.	The only MRC trial of standard methods for fish

Report			Inland Fisheries Research and Development Institute. Report to the MRC, Phnom Penh.	sampling in the LMB using gill-nets, carried out as part of the development of bio-monitoring but not continued.
		1998	Lorenzen K, Garaway CJ, Chamsingh B and Warren TJ (1998) Effects of access restrictions and stocking on small water body fisheries in Laos. *Journal of Fish Biology* 53 345–357.	One of the very few LMB documents which contains a peer-reviewed study using a robust statistical hypothesis-testing approach and use of standard methods. A useful reference for sampling design and standard methods.
MRC-WUP Report	MB	2005	Mattson N, Jutagate T (2005) A Review of Fish and Fisheries of the Lower Mekong River, and an Analysis of Likely Impacts of Water Resources Development. Restricted Distribution Report. Water Utilization Program/Environment Program, Mekong River Commission, Vientiane, Lao PDR. 70 pages.	Reviews many aspects of Mekong fisheries, particularly regarding effects of flow modifications and water utilisation, prepared under the MRC-WUP.
		2003	MDBC (2003) Fish Theme Pilot Audit Technical Report - Sustainable Rivers Audit. Murray-Darling Basin Commission, Canberra, ACT.	Use of standard electrofishing for monitoring of fish communities and development of indicators.
MRC Report	MB	2010	MRC (2010) State of the Basin Report 2010. Mekong River Commission, Vientiane, Lao PDR. 232 pages.	Fisheries section reviews and synthesises all national fisheries monitoring data supplied by countries and MRC studies on fisheries monitoring data.
		2011	Neebling TE and Quist MC (2011) Comparison of boat electrofishing, trawling and seining for sampling fish assemblages in Iowa's non-wadeable rivers. *North American Journal of Fisheries Management* 31: 390-402.	Report which shows how to study and statistically compare three standard methods in a large warm-water river. Highly relevant for the Mekong.
MRC (Interim Mekong Committee) Report	MB	1986	Pantulu VR (1986) Fish of the Lower Mekong Basin. Ch. 14A in 'The Ecology of River Systems'. (Eds BR Davies, KF Walker) 793 pages. Dr W. Junk Publishers, Dordrecht, The Netherlands.	Fisheries sector review of all data up to 1986, summarises 17 key references. The author worked with and reviewed the major Michigan University 1970s Mekong Basin Fisheries studies (17 volumes) on which much later work was based.
		1997	Poizat G and Baran E (1997) Fishermen's knowledge as background information in tropical fish ecology: a quantitative	Comparison of fisher's knowledge with standardised gill-netting.

			comparison with fish sampling results. *Environmental Biology of Fishes* 50: 435-449.	
		1991	Potter ECE and Pawson MG (1991) *Gill netting. Laboratory Leaflet No. 69.* Ministry of Agriculture, Fisheries and Food, Lowestoft, UK. 34 pages.	Early standard gill-netting method from the UK.
MRC Report	MB	2002	Poulsen AF, Ouch P, Viravong S, Suntornratana U and Nguyen TT (2002) Fish migrations of the Lower Mekong River Basin: implications for development planning and environmental management. *MRC Technical Paper* 8: 1-62.	Review of fisheries interview methods and migration systems, useful for devising sample frame for fisheries.
		2003	Schaeffer NC and Presser S (2003) The science of asking questions. *Annual Review of Sociology* 29: 65-88.	Introduction to asking interview questions and advantages and disadvantages.
	MB	2010	So N, Leng SV, Prum S, Le XS, Pomeroy R (Eds) (2010) 'Assessment of diversity and bioecological characteristics of low value/trash fish species. pp. 259-230.' (AquaFish CRSP Management Entity, Oregon State University, Corvallis, OR, USA). 510 pages.	This is a review of previous information on small fish species in Cambodia and Viet Nam under a USAID-funded project: Development of Alternatives to the Use of Freshwater Low Value Fish for Aquaculture in the Lower Mekong Basin of Cambodia and Vietnam: Implications for Livelihoods, Production and Markets".
	MB	2011	So N, Pomeroy R (2011) Developing management recommendations for freshwater small-sized/low value fish in the lower Mekong region of Cambodia and Vietnam. Final Technical Report. . Inland Fisheries Research and Development Institute. Phnom Penh, Cambodia. 17 pages.	extends the desk-based review to develop management recommendations; it reviews more background information on fisheries status and trends, concludes that capture fisheries in Cambodia and Vietnam are overfished and affected by floodplain or wetland degradation and developments in other sectors, and provides 33 conclusions and/or recommendations, covering fisheries research, management and communication
MRC-BDP Report	MB	2008	Tek V (2008) Building on Local Knowledge for Basin Development Plan. BDP	

			Stakeholder Consultation, 12-13 March 2008, Powerpoint Presentation. 24 pages.	
		2010	TVA (2010) *Standard Operating Procedure for: Fish Sampling with Gill Nets*. Tennessee Valley Authority. 17 pages.	Standard fisheries method as used by an agency that operates 29 hydropower dams.
		2002	USGS (2002) *Revised Protocols for Sampling Algal, Invertebrate and Fish Communities as Part of the National Water-Quality Assessment Program*. US Geological Survey. 75 pages.	Standard methods as recommended by the USGS including Fisheries Monitoring.
MRC Report	MB	2004	van Zalinge NP, Degen P, Pongsri C, Nuov S, Jensen JG, Nguyen VH and Choulamany X (2004) The Mekong River system. *RAP Publication* 2004: 335-357.	LMB fisheries sector review of all data up to 2004, includes 58 key references, co-authored by lead Fisheries Programme counterparts.
MRC Report	MB	2006	Viravong S, Phounsavath S, Photitay C, Putrea S, Chan S, Kolding J, Valbo-Jorgensen J and Phoutavong K (2006) Hydro-acoustic surveys of deep pools in Southern Lao PDR and Northern Cambodia. *MRC Technical Paper* 11: 1-70.	Example of a possible standard method applied in the LMB.
	MB	2009	Vo TTL, Bush S, Le XS, Hap N, Nguyen TK (2009) Value chains for sustainable Mekong fisheries: the case of *Pangasius hypophthalmus* and *Henicorhynchus*/*Labiobarbus* spp. in Vietnam and Cambodia. Draft Document, Please do Not Cite. Cantho University and An Giang University, Vietnam; Wageningen University, the Netherlands; Inland Fisheries Research and Development Institute (IFReDI), Cambodia. 58 pages.	Describes market chains for the main aquaculture species in Vietnam and for small cyprinid species from wild capture fisheries in Cambodia.
MRC-WUP Report	MB	2006	WUP/EP (2006) Overview of Biotic Aspects and Impacts from Changes of Flow Regime to the Mekong Delta. Final Report October 2006. Water Utilization Program/Environment Program, Mekong River Commission, Vientiane, Lao PDR. 55 pages.	Describes impacts of possible flow changes on the delta, including some reference to fisheries.
		2013	Zale AV, Parrish DL and Sutton TM (Eds) (2013) Fisheries Techniques. American Fisheries Society. 1009 pages.	Up-to-date comprehensive reference for all fisheries techniques, including standard methods for large non-wadeable warm-water rivers, highly relevant for the Mekong.