



Mekong River Commission

Fisheries in the Lower Mekong Basin: Status and Perspectives

MRC Technical Paper

No. 6

May 2002

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Maps 2-8, nor the graphics associated with the box story
on page 66

Report prepared by the MRC Fisheries Programme.

Published in Phnom Penh in May 2002 by
the Mekong River Commission

This document should be cited as:

Sverdrup-Jensen, S. 2002. Fisheries in the Lower Mekong Basin: Status and Perspectives. MRC
Technical Paper No. 6, Mekong River Commission, Phnom Penh. 103 pp. ISSN: 1683-1489

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Table of Contents

ACKNOWLEDGEMENTS.....	ii
EXECUTIVE SUMMARY.....	iii
CHAPTER 1 - STATUS OF THE FISHERIES SECTOR.....	1
1.1. Capture Fisheries.....	1
1.2. Aquaculture Production.....	24
1.3. Consumption, Processing and Marketing.....	33
1.4. Fisheries Information.....	38
CHAPTER 2 - SECTOR ANALYSIS	43
2.1. Demand.....	43
2.2. Capture Fisheries Management.....	47
2.3. Reservoir Fisheries.....	48
2.4. Ecological information needs.....	48
2.5. Aquaculture	55
2.6. An Approach for the Coming Decades.....	62
2.7. The need for Integrated Planning and Regulation.....	64
2.8. Catchment Planning.....	68
ANNEX 1 THE MEKONG RIVER BASIN - AN OVERVIEW	77
A.1. Agriculture.....	82
A.2. Fisheries.....	82
A.3. Forestry.....	84
A.4. Hydropower and Dams.....	84
A.5. Industry, Mining and Trade.....	84
A.6. People and Settlements	84
A.7. Food Security.....	84
REFERENCES AND FURTHER READING.....	89

Acknowledgements

I wish to acknowledge the financial support extended to me by my employer, the Danish Institute for Fisheries Management, while I was preparing this report. Similarly, financial and logistical support was provided by the MRC Fisheries Programme and its principal donor, Danida. I would particularly like to thank the two managers of the Fisheries Programme during the period the report was being prepared, namely Jorgen G. Jensen and Jeanineke Dahl Kristensen, for their considerable and constant assistance in ensuring the success of this undertaking.

Many people have contributed technical information, comments and ideas to various aspects of the report. In this regard, I specifically wish to thank the following: Eric Baran, Chris Barlow, Xaypladeth Choulamany, David Coates, Peter Degen, Poul Degnbol, Wolf Hartmann, Kent Hortle, Jorgen Jensen, Mercedes Logarta, Kathleen Matics, Niklas Mattson, Nao Thuok, Nguyen Van Hao, Sommano Phounsavath, Chumnarn Pongsri, Anders Poulsen, Jens Sjoerslev, John Sollows, John Valbo-Jorgensen, Nicolaas van Zalinge, Sinthavong Viravong and Terry Warren.

A special thank you goes to Mike Phillips, who together with Mekong aquaculture experts Simon Funge-Smith, Don Griffiths, Hans Guttmann and Graham Haylor, contributed the bulk of information on the status and perspectives for aquaculture in the Lower Mekong Basin.

Photographs were kindly supplied by Chris Barlow, Ngor Peng Bun, Zeb Hogan, Jorgen Jensen and Nicolaas van Zalinge. Maps were prepared by Penroong Bamrungrach and Jens Sjoerslev.

To all the others who helped in many different ways, I extend my sincere gratitude.



Executive Summary

STATUS OF THE MEKONG FISHERIES

The Ecological System

The Mekong River Basin hosts one of the most diverse freshwater faunas in the world. There are 1,200 recorded fish species and the number will increase as new species are discovered and classified. Diversity among other groups of freshwater animals (frogs, snakes, crustaceans, molluscs and insects) is also high. Diversity is based on a wide range of permanent and seasonal habitats, which are a result of the Mekong Basin's complex geological history.

The hydrological cycle is the main physical parameter influencing the river's ecology. The annual flood-pulse caused by the monsoon rains is responsible for the creation of vast floodplains in the Mekong Basin. These floodplains are highly productive for fish and other aquatic animals.

Most fish species depend on different habitats at different stages of their life and at different seasons of the year. During the flood season, most Mekong species take advantage of the floodplains for feeding, breeding and rearing their young. Outside the flood season, fish stay in dry-season refuge habitats, mainly in permanent lakes and pools or within river channels. Certain stretches of the Mekong and its major tributaries contain deep pools, which are particularly important as dry season refuges.

The separation of major fish habitats in time and space forces all Mekong fish to migrate. Some species migrate only short distances between permanent and seasonal water-bodies on the floodplain. Important examples are snakeheads, gouramis and *Clarias* spp. catfishes. Other species migrate long distances from dry-season pool habitats within river channels, to flood-season feeding habitats on the floodplains. Examples include most of the carps (cyprinids) and river catfishes (pangasiids).

The Lower Mekong Basin has three major migration systems that are interconnected. The Lower system extends downstream from the Khone Falls, and includes the Tonle Sap River and lake system in Cambodia and the Mekong Delta in Viet Nam. The Middle Migration system runs from above Khone Falls to the Loei River. Within this system, floodplain habitats are connected with the large tributaries on both sides of the Mekong. The Upper Migration system stretches upstream from the Loei River. This system is characterised by upstream migration to spawning habitats near or in the Upper Mekong Basin. The Mekong giant catfish is a well-known member of this migration system.

The Capture Fisheries

The capture fisheries of the Lower Mekong Basin have a centuries-long history of local resource knowledge, catch technology, fish processing, marketing and social organisation. The fishery is highly diversified and adapted to the variable and complex environments in the Basin. Floodplains,

swamps, rice-fields, canals, streams, tributaries, the main river, lakes, estuaries and large and small reservoirs are exploited.

A wide range of fishing methods is used and most of the fishing gear and boats are of traditional design and manufactured with extensive use of local material. Fish processing is for traditional products that are widely consumed in the region.

Socially, the Mekong fisheries range from individuals fishing part time for subsistence, to large-scale industrial operations with fishing labourers employed full time. Participation in capture fisheries is high throughout the Basin, especially at the small-scale and household level. Men, women and children of all ages are involved with roles influenced by gender, age and the type of fishing operation. Virtually all farming households fish part time on a seasonal basis, with captured fish making a significant contribution to food security, nutrition and income generation. The number of rural dwellers active in the fishery is estimated at 40 million.

An estimated 2 million tonnes of fish and other aquatic animals are consumed annually in the Lower Mekong Basin. Of this, 1.5 million originates from catches in natural water-bodies and 240,000 tonnes from catches in reservoirs. The total value of the catches is about US\$ 1,200 million.

The seasonal peaks in the Mekong catches have stimulated the development of a large industry which produces dried and fermented fish products, fish sauce and paste. This processing industry adds value to the catch, provides employment and spreads the economic and nutritional benefits of the catch over the full year.

Many Mekong fish species are trans-boundary during their life cycle. Despite the fact that several migratory stocks are shared, including the high profile and endangered Giant fish species, there are no institutional arrangements at the regional level for joint management of trans-boundary fish resources.

There are long standing traditions of fisheries management being undertaken by communities in many areas of the Lower Mekong Basin. Rules on fishing, often associated with spiritual beliefs, are established to sustain local resource levels and to ensure equitable distribution of benefits. Such local rules, whether documented or not, are often recognised *de facto* by provincial and national fisheries authorities, and their enforcement is supported. Growing political interest in the riparian countries in promoting user participation in natural resource management has recently led to legislation favouring co-management arrangements, whereby the fisheries are jointly managed by public authorities, resource users and other stakeholders at various administrative levels.

For more than five years, the MRC Fisheries Programme and other donor-supported and national research projects, have made substantial contributions to capacity building within the national fisheries research institutions. Staff of provincial and district fisheries authorities involved in field research activities have also benefited from capacity building. Through these initiatives, considerable information and knowledge on the aquatic ecosystems and the fisheries of the Mekong River have been gathered. This all provides a solid basis for informed management of the Mekong fisheries.

The relationships between fisheries and agriculture, hydropower, navigation, tourism and other economic sectors are complex. Generally, other sectors impact on fisheries more than fisheries impact on them. Usually the impacts are brought about through changes in the aquatic environment or socio-economic conditions. Impacts from other sectors are mostly negative, primarily because the fishery relies on aquatic ecosystem health and integrity to maintain the resource base. Water, which is by far the most important of all natural resources in the Mekong Basin, is not abundant as

previously believed, but finite and fragile. Its availability is increasingly influenced by development activities at all levels, and conflicts over the allocation of water between the various sectors are escalating.

Aquaculture

Aquaculture in the Lower Mekong Basin is a diverse activity encompassing the production and sale of fry and fingerlings and raising wild or artificially produced fingerlings in enclosed or semi-enclosed water bodies. Total production in the Basin is estimated at some 260,000 tonnes per year with a farm gate value of about US\$ 270,000 million. These figures do not include brackish water prawn culture.

There are relatively few examples of large-scale commercial farms in the Lower Mekong Basin. Examples would include cage farms producing catfish in the Bassac River and large integrated fish farms near towns and cities in Northeast Thailand. Most aquaculture production comes from small-scale operations run by rural households. At this level, aquaculture is becoming increasingly important throughout much of the Basin. Small-scale aquaculture contributes to food supply in areas where wild fish are deficient. It provides opportunities for supplementary income and helps families diversify.

Except for Cambodia, ponds and rice fields are the most common means of producing fish throughout the Basin. There are distinct differences between fish culture practices in peri-urban areas close to markets, and in rural areas remote from markets and support services such as feed supplies.

The Mekong Delta has the largest aquaculture area (330,000 ha) and freshwater production is above 170,000 tonnes. An estimated 80,000 ha are presently under rice-fish culture, with a mean annual production of 370 kg/ha. In ponds, polyculture combining fish, livestock and vegetables is the norm. Mean annual pond production is 4.8 tonnes/ha. There are more than 100 hatcheries in the area. The most commonly cultured species include catfish, barbs, carps, tilapia, gouramis and sand goby. There are about 5,000 fish cages in the Delta. The cages are mostly stocked with fry and juveniles from the wild. In Cambodia, most of the aquaculture production comes from cages and pens. River catfish and snakeheads are the dominant species.

Northeast Thailand is the second largest area in the Lower Mekong Basin for aquaculture production. Production has expanded significantly over the last decade and annual output is in the range of 65,000 tonnes. Pond culture of exotic and indigenous species makes the biggest contribution to production. Cage culture of tilapia has recently expanded significantly in reservoirs and in the Mekong River.

Governments are increasingly supportive of investments in aquaculture and fund research, infrastructure, education and extension. Although there is no separate legislation on aquaculture in any MRC-member country, it is under review in all of them.

Trans-boundary issues such as genetic quality of broodstock have yet to be addressed. Environmental concerns include the balance between exotic and indigenous species, culture of predator species, collection of juveniles from the wild, water pollution and the spread of fish disease.

Fish Consumption and Markets

Fish and other aquatic animals are the most important source of animal protein for the approximately 60 million inhabitants of the Mekong Basin. Average fish consumption ranges from about 30 kg per

capita in mountainous areas, to 70 kg in the Great Lake Tonle Sap area in Cambodia. In many parts of the Basin, fish is part of every meal. During lean seasons, fermented fish are used in place of fresh fish. Fish sauce is a staple used by most households all year round. Fish also have high levels of vitamin A and micronutrients essential to humans.

The bulk of Mekong fish is consumed locally or traded fresh at village, district or provincial markets. There is considerable trade in fish within the Mekong Basin and its neighbouring catchments. Exports out of the region are limited, but increasing.

SECTOR ANALYSIS

Capture Fisheries

Preliminary calculations suggest a 20 percent increase in fish demand in the Lower Mekong Basin over the next 10 years. Fishing in the Basin is likely to increase due to population growth and ease of access. This may result in an increase in overall catches, at least up to a certain point. The increase will be accompanied by a continued decrease in the prevalence of the larger slow-growing migratory species in the catches. From a food security point of view, this may be acceptable even if the overall value of the catches decrease. However, people throughout the Basin are partial to the larger species, which makes it desirable to mitigate the decline in biodiversity, where possible.

This will require coordination and integration of management interventions at all levels. For the non-migratory fish species, there is no indication at present that future increases in fishing effort will lead to decreased catches or reduced diversity. This assumes that the integrity and spatial extent of the habitats (mainly floodplains), are not compromised. Adopting co-management approaches may prove the most appropriate for management of these fisheries, as cause and effect may be observed within local community boundaries.

A major threat to sustaining capture fisheries is environmental degradation arising from the activities of other sectors. These include:

- ✂ Destruction of spawning grounds or dry season refuges by habitat alterations (e.g. stream bed blasting, dredging, removal of rapids or siltation from removal/alteration of vegetation).
- ✂ Local changes in the quantity and quality of water available for sensitive habitats and the timing of hydrological events, and pollution from agriculture and urban development.
- ✂ Construction of dams, weirs or diversions which act as physical barriers to fish migrations.
- ✂ Increased sediment load due to deforestation.

Two developments could reduce these constraints. Firstly, the true value of water should be reflected in costing development activities. This would force planners to factor in consideration of the impacts on other water users. Second, existing water resource users (including users of wetlands), should be given legal rights over their use. Better governance is the only solution, and has to include better approaches to integrated planning for natural resources management

Capture fisheries from reservoirs may increase with the construction of new reservoirs for hydropower, irrigation and flood control purposes in the Basin. Improved local level management will be crucial.

Aquaculture

The past 10 years has seen five-fold increase in aquaculture production. Continued expansion could contribute significantly to meet the need for fish products in the Lower Mekong Basin in the coming decade. However, the development of aquaculture is strongly influenced by market demand, particularly in the local market. The demand will, to a high degree, depend on the availability of consumers who can pay the price, often US\$ 1.00 or more per kg. Low per capita income in rural areas may limit the scope for aquaculture development in some areas, and tie it to development of infrastructure and urban expansion. However, an increasing number of small-scale farm households could be expected to make individually-small, but cumulatively-significant, contributions to aquaculture production throughout rural areas.

Aquaculture growth as a sector requires a significant expansion in hatcheries and nursing capacity. The centralised large government hatchery model has not been successful. Development of local small-scale hatcheries, hapa nursing and trading networks, and on-farm breeding will be more effective in supporting rural, small-scale aquaculture.

There are several constraints to the development of aquaculture. Many of these are institutional rather than technical. The existing capacity and resources of government institutions for participatory extension and research is limited. Therefore, capacity building is required to support this approach.

The development of aquaculture to date has been driven by a sectoral approach. A shift is now required; the promotion of aquaculture in the Mekong Basin should take food security and poverty alleviation as a starting point for interventions. It should identify and overcome constraints to entering aquaculture by building capacity in local institutions. Integrating aquaculture into fisheries projects and wider rural development strategies would produce a more balanced approach

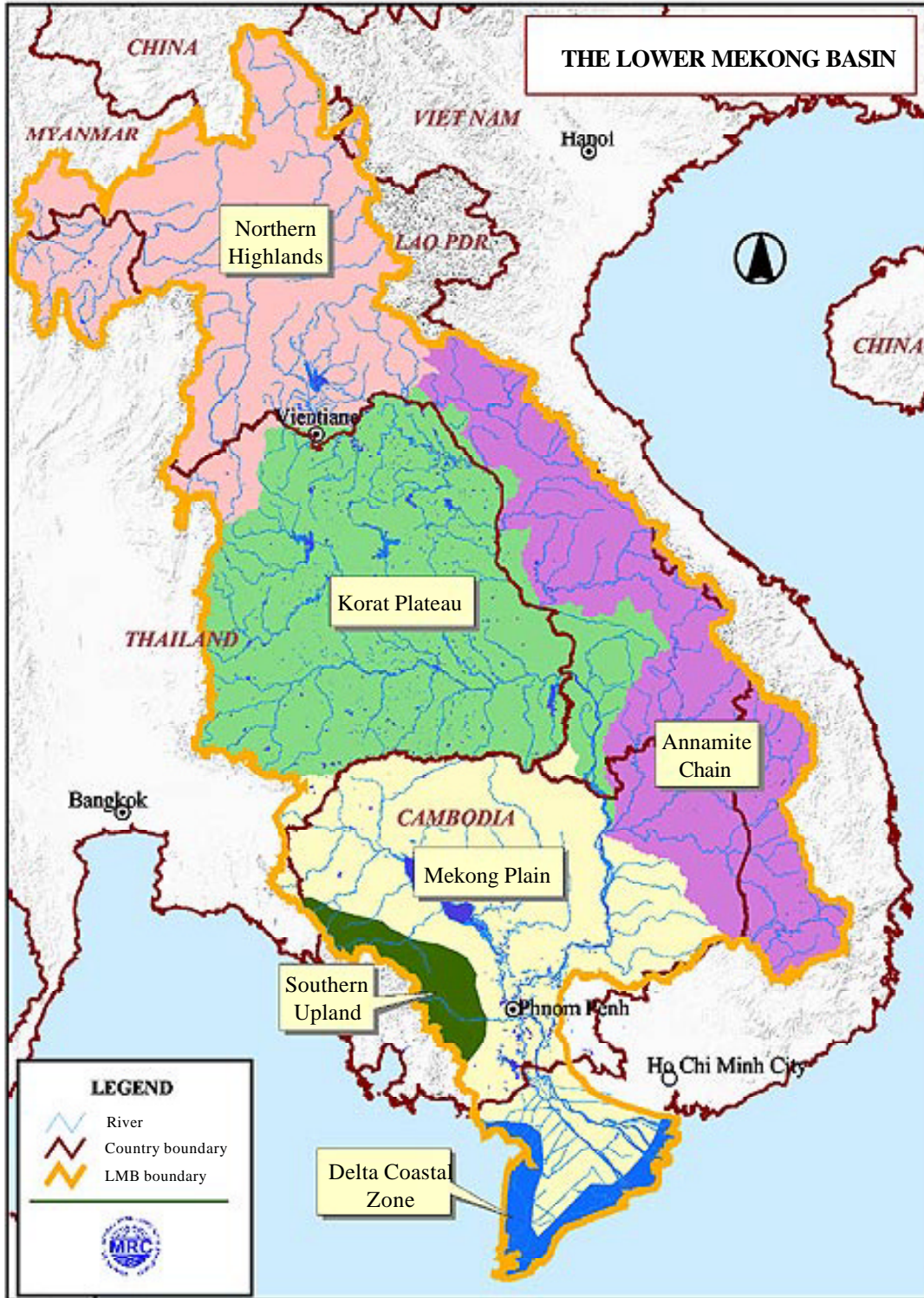
Aquaculture, capture fisheries and reservoir management should be considered as a holistic system. Concentrating policy and development efforts on aquaculture as “an easy option” for fish production, without taking proper care of the wild fisheries, could result in a dramatic loss of wild fisheries resources. This in turn could severely affect food security for the entire Lower Mekong Basin, particularly for poor people.

One promising approach for improving management of both capture fisheries and aquaculture is a focus on individual catchments. With this focus, the fisheries sector can present its potential and requirements to other sectors and respond to their plans for development. A key element in the catchments approach, which is being promoted by the MRC Water Utilisation Programme, is bottom-up planning and data gathering, with assistance from people whose livelihoods depend on the resources of the catchments.

The MRC Fisheries Program is moving from capacity building and knowledge generation, to resource management on a sustainable basis. Indicative of this is the establishment of the Technical Advisory Body on Mekong Fisheries (TAB). TAB is intended to take an increasingly active role in the introduction and coordination of regional fisheries management initiatives.

The MRC Fisheries Programme has made substantial contributions to promoting sustainable Mekong fisheries on many levels. The Programme has succeeded in raising awareness of the economic and social value of the fishery, and of the many threats it faces.

Map 1 - The Lower Mekong Basin



STATUS OF THE FISHERIES SECTOR

CHAPTER 1

1.1. CAPTURE FISHERIES

The Mekong River Basin hosts one of the most diverse freshwater faunas in the world. There are 1,200 recorded fish species. The number of recorded species may eventually reach 1,700 as new species are discovered and classified. Diversity among other groups of freshwater animals (frogs, snakes, crustaceans, molluscs and insects) is also high. This amazing diversity is based on a wide range of permanent and seasonal habitats, a result of the Basin's complex geological history. Diverse ecological strategies of the aquatic fauna and flora have evolved in response to the environmental opportunities provided by the river. In the Mekong, two main physical parameters influence river ecology: the physical nature of the river basin and the water regime or hydrological profile.

The Lower Mekong Basin can be divided into six distinct aqua-ecological zones (Map 1).

The Coastal Area, the marshy coastal areas adjacent to the South China Sea have intimate ecological links with the inner areas of the Delta.

The Korat Plateau, characterised by a low relief and drained by large tributary systems dominated by the Mun-Chi and the Songkhram Rivers.

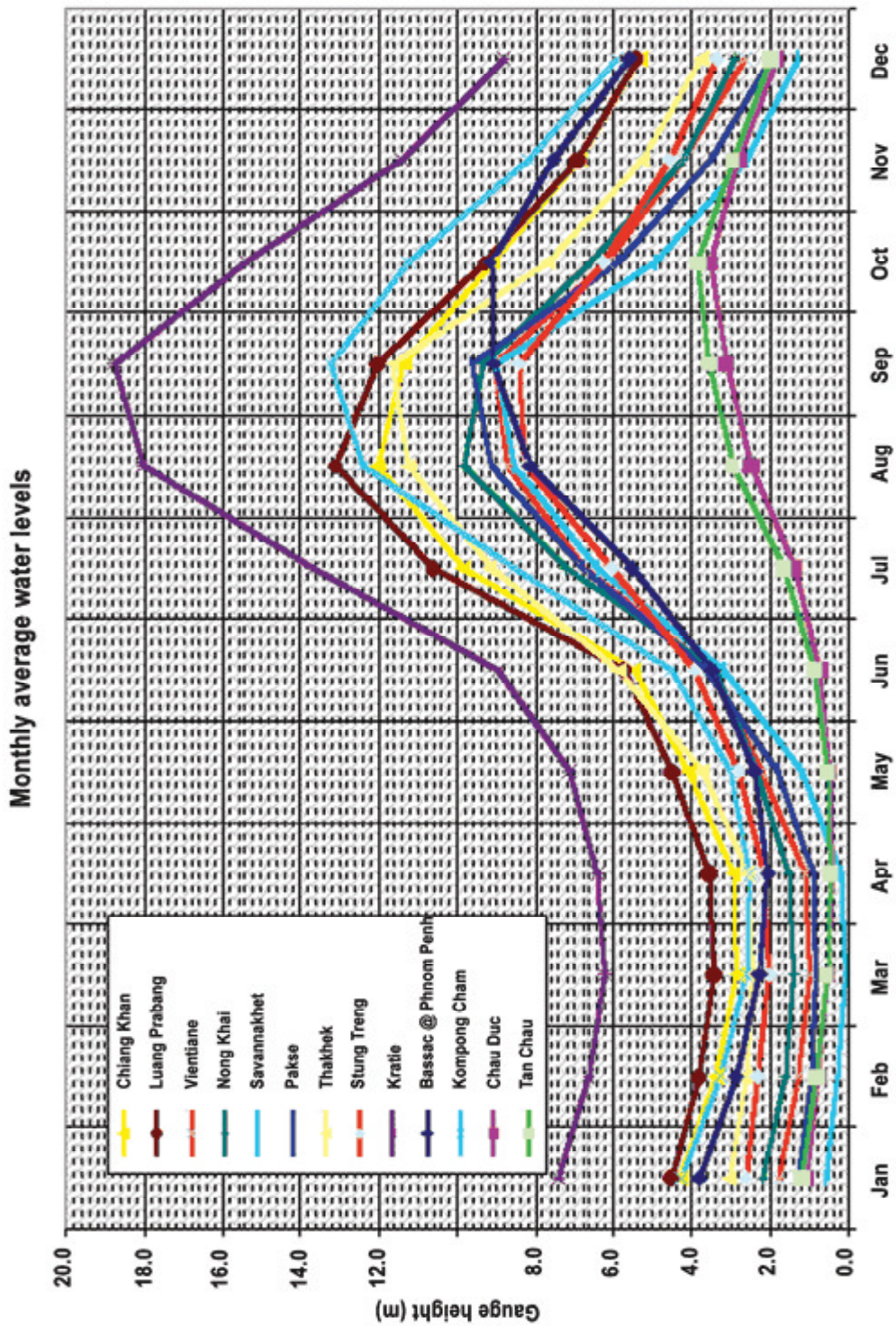
The Mekong Plain, the only true lowland area of the Basin, which covers most of Cambodia, the Mekong Delta in Viet Nam and small parts of adjacent Thailand and Lao PDR. The Tonle Sap and the Great Lake are included in this area.

The Annamite Chain in the north, characterised by a limestone cliff, which comes close to the Mekong River. In the south, the topography is dissected hills and rolling plateau. This area bears the full force of the monsoon rains and discharges into some of the major Mekong tributaries. Together they supply more than half the total water volume of the Mekong.

The Southern Uplands has thickly forested low hills but have been extensively cleared for orchards and field crops lower down. These uplands drain into the Great Lake and the Tonle Sap River.

The Northern Highland Steep is characterised by rugged topography, narrow river valleys and a few tributary systems joining the Mekong.

Figure 1 Hydrological cycle



Within this macro-classification, the Khone Falls area represents an important and unique ecological region consisting of a series of shallow braided channels that enter a 40 km wide stretch of waterfalls and cascades created by a geological fault line. Although the Khone Falls are a zoogeographic barrier for some fish species, in particular species of marine origin, several of the falls are passable for many species. Important fish migrations take place over the falls, both in the flood and dry seasons.

The hydrological cycle is the most important influence affecting fish ecology (Figure 1).

The annual flood-pulse is responsible for the creation of vast seasonal floodplain habitats. These areas are highly productive for fish and other aquatic animals and most Mekong species take advantage of this opportunity for feeding, breeding and rearing their young. Even fish species limited to the river mainstream are influenced by this seasonal cycle (Map 2).

The hydrological profile of the river environment also plays an important role in linking different ecological elements of the system. The same water flows between different river sections and habitats and is the integrating element of a large aquatic ecosystem. This holistic view is particularly important when considering fish migrations and water resources management.

Most fish species depend on different habitats at different stages of their life and at different seasons of the year. In general, seasonal floodplains are used as feeding and reproduction habitats by a large number of important Mekong fish. Outside the flood season, fish stay in dry-season refuge habitats, mainly in permanent lakes and pools or within the river channels. Certain stretches of the Mekong and its major tributaries contain deep pools, which are particularly important as dry-season refuges.

The separation of major fish habitats forces fish to migrate and is a conspicuous feature of the life cycle of most fishes. Some species migrate only short distances between permanent and seasonal water-bodies on the floodplain. These species are often referred to as 'blackfish'. Important examples of Mekong blackfish include snakeheads, gouramis and *Clarias* spp. catfishes, all of which breathe air and can survive in anoxic conditions as waters recede and stagnate.

Other species migrate long distances, often from dry-season pool habitats within river channels to flood-season feeding habitats on the floodplain. These species are often referred to as 'whitefish'. They tend to be more fragile and less tolerant of poor water conditions. Some whitefish migrate short distances within the river channels, whereas others migrate very long distances. Examples include most of the carps (cyprinids) and river catfishes (pangasiids).

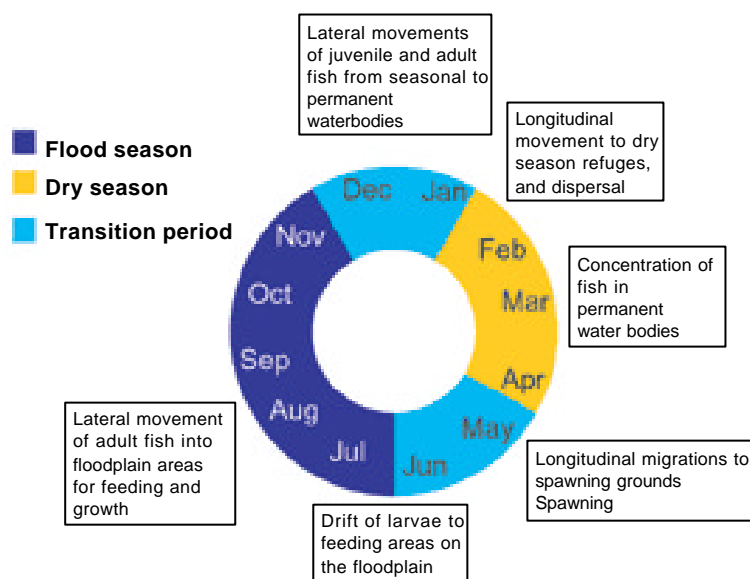
The division of Mekong fish species into 'blackfish' and 'whitefish' is simplistic but useful for describing two dominant life cycle strategies. It is also useful for categorising species according to their management requirements - blackfish require primarily local management, while whitefish are more trans-boundary in nature.

Fish production figures per unit area of habitat are now being generated, particularly for floodplains. Reliable estimates range from an average of about 205 kg per hectare per year for the Great Lake area to 375 kg per hectare per year for the floodplain near Phnom Penh. The differences in estimates mainly reflect differences in exploitation. The highest estimates are for areas where fish have the least chance of avoiding fishing gear. Similarly, production from rice fields varies between 25 to 300 kg per hectare per year depending on the level of exploitation and management systems used. These amounts are well in excess of earlier data but are in-line with recent data for comparable ecosystems.

1.1.1. Major Migration Patterns

Three major migration systems have been identified within the freshwater sections of the Lower Mekong River through Local Ecological Knowledge surveys (see box "Local Knowledge in Fisheries Research"). For convenience, these systems are referred to as the lower, middle and upper migration systems. These systems should not be viewed as closed systems, isolated from each other, but as convenient conceptual divisions of a complex whole system (Figure 2).

Figure 2: Generalised life cycles of Mekong fishes



The lower and middle migration systems are interconnected, as many species are known to migrate over the Khone Falls during both the flood and dry seasons. For some species (e.g. *Cirrhinus microlepis*) juveniles may be part of the lower migration system and the adults join the middle migration system.

The Lower Migration System extends downstream from the Khone Falls to southern Cambodia and includes the Tonle Sap system and the Mekong Delta in Viet Nam. The rise in water levels at the beginning of the flood season triggers migrating fish to move from the dry season habitats just below the Khone Falls (for example, the deep pools along the Stung Treng-Kratie stretch) towards the southern floodplain feeding habitats on the Mekong Plain. Some species spawn on or near the floodplain; others spawn far upstream and their larvae drift down with the current to the floodplains. One example of a group of species undertaking this type of migration is the *trey riel* (*Henicorhynchus* spp.). These fish are among the most important in terms of total fisheries production. In the *dai* fishery in the Tonle Sap River, they account for 43 percent of the total annual catch. Larger white-fish species, such as giant barb *Catlocarpio siamensis*, *Cirrhinus microlepis*, *Cyclocheilichthys enoplos*, seven-line barb *Probarbus jullieni*, as well as several river catfish species, including the Mekong giant catfish, *Pangasianodon gigas*, also follow this migration pattern.

The Middle Migration System runs from above the Khone Falls to the Loei River. Within this section, floodplain habitats are mainly connected with the large tributaries on both sides of the Mekong. Seasonal movements of migrating fish from mainstream dry-season habitats to floodplain

feeding/rearing habitats are via these tributaries. In general, at the onset of the flood season, fish move upstream within the Mekong mainstream until they reach the mouth of one of these major tributaries from which they eventually reach the floodplain habitats. At the end of the monsoon the migrations reverse from the floodplains through the tributary rivers and back to the Mekong mainstream where fish spend the dry season in deep pools. There are complex interconnections to the lower migration system with many of the same species following both patterns, either as different, genetically distinct populations, or at different stages in the life cycle of the same population.

The Sesan/Srepok/Sekong is one of the largest tributary systems in the Basin. Many species migrating north use this system rather than the Khone Falls. For example, large quantities of trey riel migrate into the Sesan from the Mekong during the dry season. Like most tributaries, this system also supports its own discrete fish migrations.

The Upper Migration System stretches upstream from the Loei River into the Upper Basin. This section of the Mekong River system is characterised by a smaller floodplain area and fewer major tributaries. This system is characterised by migrations to upstream spawning habitats at the onset of the flood season from dry season refuge habitats in the main river. The most-well known member of this migration system is the Mekong giant catfish, *Pangasianodon gigas*. This highly endangered species is caught in northern Thailand and Lao PDR in April and May during the upstream spawning migration.

The fourth system is the Lower Delta where fish, crabs and prawns migrate within and across the saline transition zone from fresh to salt-water. Studies of this ecology, with its complex environment and large fishery, have just begun.

Fish migrations tie together the Lower Mekong Basin via complex interconnected networks. Where the migrations cross international borders they become trans-boundary stocks requiring international co-operative management (see box "Importance of fish migrations in the Mekong River system").

1.1.2. The Mekong Fisheries

The capture fisheries of the Lower Mekong Basin have a centuries long history of catch technology, local resource knowledge, fish processing, marketing and social organisation. The fishery is highly diversified and adapted to its variable and complex environment.

Floodplains, swamps, rice fields, canals, streams, tributaries, main river, lakes, estuaries, and large and small reservoirs are exploited. A wide range of fishing methods are used to catch all types of fish and other aquatic animals. The methods include traps, hooks and lines, gill nets, drift nets, drift seines, drag seines, encircling seines, frame trawls, lift nets, cast nets, river barrages with associated trap systems and extended floodplain/lakeshore fences with trap systems. The methods have considerable design variations and size ranges. Much of the technology is indigenous to the Basin or has been extensively adapted to local conditions.

Most of the fishing gear and boats used are of traditional design and are manufactured with extensive use of local materials. The major items of recent origin are twine, netting material and engines. An important aspect of catch technology is the ecological knowledge applied by local people in their fishing activities. Most fisheries activities are based on an intimate knowledge of fish response to seasonal environmental changes.

Importance of Fish Migrations in the Mekong River System

Fish migration is an important and conspicuous feature of the fisheries of the Mekong River Basin. Most fish species carry out some form of migration at certain times during their life cycle. Some species move only a short distance, e.g. between permanent lakes and flooded areas adjacent to the lake, whereas others move many hundred kilometres from downstream feeding habitats to upstream refuge habitats or spawning areas.

Many fisheries activities in the Basin are based on the capture of migrating fishes. The most conspicuous examples are the *dai* fishery of the Tonle Sap River in Cambodia and the Khone Falls fishery on the border between Cambodia and Lao PDR. But in general, villages all along the Mekong and its tributaries have adjusted their daily lives to the coming and going of migratory fishes.

Seasonal events, particularly the flood–draught cycle, force most fishes to move to refuge habitats at certain times of the year. The annual flood pulse caused by



Only the strongest swimming fish can pass the Khone Falls on the Mekong River

the monsoon climate is a ‘driving force’ for fisheries ecology, creating vast areas of seasonal floodplain habitats, which are the main feeding habitats for most fishes. It is in these extremely productive habitats that the bulk of the fisheries yield is produced.

The onset of the floods also triggers many fishes to spawn. Eggs and larvae drift downstream with the

water current and are distributed throughout downstream floodplain areas, which provide optimal rearing conditions for the young and fragile fish larvae.

As water begins to recede at the end of the flood season, fishes young and old move out of the floodplains and back into river channels, where they start spectacular migrations towards their dry season refuges that are associated with deep pools within the river channel. Here, they spend the dry season waiting for the next monsoon to arrive, triggering the cycle to repeat itself.

Three different general migration patterns have been identified within the Lower Mekong Basin:

- 1) In the lower part of the Basin, large-scale migrations occur between downstream floodplain habitats (that is, the Mekong Delta in Vietnam and southern Cambodia, including the Tonle Sap/Great Lake system), and dry season refuge habitats further upstream near the border between Lao PDR and Cambodia (in particular, the stretch between Kratie and Khone Falls).

- 2) Upstream of the Khone Falls, many fishes move seasonally between dry season habitats within the Mekong mainstream and flood season feeding and rearing habitats on floodplains associated with major Mekong tributaries.
- 3) In the upper stretches of the Basin (that is, approximately from the mouth of Loei River and upstream), the Mekong becomes a typical mountain river with very little floodplain habitat. Here, fishes mainly migrate between deep pool habitats in the lower stretches, and spawning habitats in the upper stretches.

These three migration patterns represent a rather simplistic view of fish migration in the Mekong. There are numerous migratory species inhabiting the Mekong, each with its own particular life history. However, all species are faced with the same environmental and hydrological circumstances and, thus, the general patterns apply to most species.



Many migratory fishes of the Mekong carry out their migrations across international borders. They thus constitute shared or trans-boundary resources between two or more countries. Such resources require coordinated management strategies to ensure that they can successfully complete their life cycle. For example, for species which have their feeding habitat in one country and their spawning habitat in another, the two countries must work together to ensure that both habitats are maintained, including the maintenance of access to these habitats (that is, no barriers along migration corridors).

Many fish migrate long distances in the Mekong River system

Socially, the Mekong fisheries are as diverse as the ecological niches exploited. They range from individual seasonal fishers in the highlands of Lao PDR to fishing lot owners with large-scale operations in the Great Lake of Cambodia; from full-time specialised traditional fishers in the Khone Falls area to unemployed people returning from Bangkok to their native villages in Northeast Thailand who fish to support themselves in times of economic difficulties. Men, women and children of all ages are involved in the fisheries with roles influenced by both gender and age (see box "Women in Fisheries Network").

Participation in capture fisheries is high throughout the Basin, especially at the small-scale and household level. Virtually all farming households fish part time on a seasonal basis with captured fish making a significant contribution to food security. According to the Lao PDR 1998 agricultural census, 71 percent of all farm households were engaged in fishing. That equates to 2.9 million people dependent to varying degrees on fisheries as a livelihood strategy in Lao PDR alone. Northeast Thailand statistics show even higher levels of participation. Throughout the Lower Mainland Basin at least 40 million rural dwellers are active in the fishery. Surveys show that for most rural households captured fish is important for family nutrition and income generation.

Large-scale fishing operations are often based on exclusive access to sites obtained through purchase of government licenses. Capital expenses for fishing gear (barrages, fences, traps, nets, etc.) are relatively high and the individual operator is often dependent on a network that may also include sub-contractors for a part of the license fee. Large-scale fishing operations are generally based on hired labour.

In the Mekong sub-system fisheries, some households and communities have developed specialised fishing as a full-time livelihood. The highest degree of commercial specialisation is found in the large floodplains of central and southern Cambodia and the northern part of the Mekong Delta. Specialisation is closely related to access to productive fish habitats and is also highly related to ethnicity. In many resource rich areas households and entire villages do not fish at all.

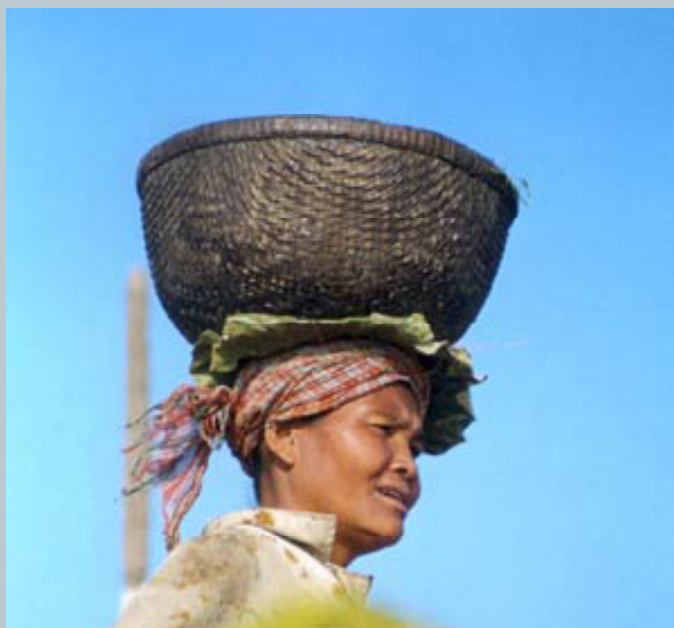
All Mekong fisheries are highly seasonal and determined by the river flood-pulse system. Seasonal peaks result in a glut of fresh fish far beyond what local demand can absorb. This has stimulated the development of highly effective, low technology fish processing and marketing systems based on the production of fermented fish products, pastes and sauces. This large, mainly domestic industry provides seasonal employment and spreads the nutrition and economic benefits of seasonal fish production over the full year.

The major capture fisheries systems in the Lower Mekong Basin can be described as follows:

In the Mekong River and major tributaries, catches comprise whitefish species during their migration when the water level rises following the onset of the monsoon rains. In the dry season, catches are mainly taken in or around deeper stretches of rivers where many sedentary and migratory fish species take shelter. Large set nets and other commercial gear are employed in this system, notably in Viet Nam and Cambodia. Above the Khone Falls, individual professional fishers operating medium-scale gear usually conduct mainstream fishing operations.

In the Great Lake and Tonle Sap River system fishers use nearly all gear types and sizes. The catches from the open waters of the lake and the Tonle Sap consist of highly migratory whitefish species. In the seasonally inundated lake areas, floodplains and streams surrounding Tonle Sap, the more sedentary blackfish predominate in catches. The catches in both systems teem with small, fast-growing opportunist species, which reproduce and grow prolifically during the flood period.

Women in Fisheries Network



Woman preparing to trade rice for fish

Women engaged in fisheries face a wide range of problems that were unrecognised a few years ago. Some of the difficulties, including lack of training opportunities and access to natural resources, were aired by women themselves during a benchmark seminar in March 1996 on Women in Fisheries in Indo-China organised by the Partnership for Development in Kampuchea (PADEK).

A year later, the MRC Round Table Discussion on Women in Fisheries in the Mekong Basin, held in Can Tho, Viet Nam, agreed upon setting up National Networks to address challenges at the national level. The MRC

Fisheries Programme facilitated the establishment of Women in Fisheries Networks in Cambodia (October 1997), the Lao PDR (October 1999), Thailand (February 2000) and Viet Nam (March 1999). The four National Networks are integral parts of the Regional Network launched in May 2000. Since then, the MRC Fisheries Programme has offered an annual venue for this regional forum to meet, exchange views and seek solutions. Thus, over the years, women involved in fisheries are becoming more visible to policy-makers and the general public alike.

But this state of affairs was not always the norm. In the past most people tended to overlook the fact that women are fully involved in fish processing, marketing and trading aquatic products. Only recently have decision-makers become aware that women actually play a crucial role in the nutrition, health and well being of rural families in the Mekong Basin. Greater recognition by the general public is also emerging.

The Networks call for equal access to training opportunities, including extension services, which formerly were accorded to their male partners or village heads. Some training organisers try to achieve a 50/50 percentage of male and female participants so that they learn to work together and become more sympathetic to the other's point of view. The trainers know that neglecting women could result in the loss of significant potential and dynamic energy.

The Regional Network, called the Network for Women and Gender in Fisheries Development in the Mekong Region, has pointed out the impact of women on the economy and social development in each of the riparian countries. National statistical data substantiate the significance of women in fisheries development. Women continue to improve the quality of life in rural communities and they want to participate fully in the planning of future development initiatives that will affect them and their families. They especially want to contribute in tandem with men to develop the fisheries of the region. By realising their potential, society as a whole will benefit.

The majority of large-scale operations in the Mekong system are found in this system (Map 3) and include barrages in the branches of the upper Tonle Sap, extended lake fences (60 km or more) around demarcated fishing lots in the lake and the largest set bag nets in the system, the dais in the lower stretches of the Tonle Sap. A '*dai*' is a stationary trawl gear fixed by stakes in the river. The mesh size is small (less than 25 mm) and a single gear can land up to 0.5 tonnes of fish per haul in 15 to 20 minutes during peak periods of the lunar cycle. There are presently 15 rows of *dais* (more in the past), with one to eight *dais* in each row.

In Cambodia, fishers on the floodplains from Phnom Penh down to the upper part of the Mekong Delta use extended fence systems on the plains and barrages at outlets of the main rivers. In Viet Nam, the floodplains become a vast lake where fish are caught in large seines and lift-nets under open access conditions. Whitefish are the target species during and after peak floods and blackfish when the water is receding. Catches in this system are also dominated by the 'opportunist' fast growing fish species.

1.1.3. Reservoir Fisheries

Most of the 25,000 reservoirs in the Lower Mekong Basin have been constructed for irrigation. The larger ones were built for flood control and electricity generation. Reservoirs are normally constructed by damming rivers or streams and they interfere with the natural migration of fish to the point where some species eventually disappear. The reservoir fish fauna then becomes less diverse. There are few fish species in the LMB well adapted to living in a lake environment. However, large reservoirs tend to be built on major tributaries and conditions upstream may provide riverine fish recruits. A good example is Nam Ngum reservoir in Lao PDR, where over 50 riverine fish species are thriving and where introduced exotics, including tilapia, have failed to proliferate. A few Mekong species are well adapted to the reservoir environment and can complete their whole life cycle within the reservoir.

Hatchery produced fish are stocked into many reservoirs in the Basin. The fish species most commonly used for reservoir stocking in Thailand are tilapia, bighead carp and rohu; these plus other Indian carps, common carp and grass carp are commonly used in Viet Nam.

In most small reservoirs, a variety of cyprinids and blackfish are exploited on a subsistence or semi-commercial basis using gill nets and traps. In larger reservoirs fishing operations include big lift nets. Small-scale operators living in communities surrounding reservoirs typically dominate reservoir fisheries. Frequently, the construction of a reservoir has given local people access to a new fish habitat and resources about which they have little knowledge. In Thailand, small reservoirs have been constructed and stocked with fish under community development projects by the Department of Fisheries. Fish are harvested on a specific fishing day, when tickets are sold to participants from inside and outside the village. Stocking of reservoirs by the Thai government is largely undertaken to serve social purposes rather than to optimise economic or biological yields.

1.1.4. Fish Catches

There is no system in the Lower Mekong Basin for effective collection of statistical data on inland capture fisheries. Existing official statistics on inland fisheries grossly under-report catches. No authority collects data on small-scale family fishing because these fisheries have always been considered of minor importance to the national economy. Most large-scale capture fisheries data are inaccurate. Nowhere in the world are fishers who pay license fees based on catch likely to report correctly. Mekong fishers are no exception.

During the last decade, however, household fish consumption surveys have been conducted in 15 of the 87 provinces in the Lower Basin. These surveys show that annual fish consumption ranges from 20 kg per person in mountainous areas with limited access to fish resources to 70 kg per person in floodplain areas of Cambodia and Viet Nam where fish is abundant most of the year (Map 4). In Northeast Thailand, home to about one third of the population in the Basin, annual fish consumption is about 36 kg per person. Most fish is supplied from local inland areas. Surplus fish is transported for sale in local and more distant markets.

The national statistical authorities in Lao PDR and Cambodia have recently undertaken national household consumption and expenditure surveys. These surveys are largely consistent with the household consumption figures mentioned above.

Extrapolation of household survey findings provides a conservative estimate for total fish consumption in the LMB of 2 million tonnes annually. Without reliable fish import and export data, it is assumed that fish import and export volumes are similar and that fish consumption is equal to the amount of fish caught and produced in culture. Since aquaculture and reservoir fisheries catches produce 260,000 and 240,000 tonnes of fish per year respectively (1999/2000 figures), the production from the freshwater natural water body fishery is approximately 1.5 million tonnes per year.

This catch figure is nearly 100 percent higher than the 1992 MRC review (Fisheries in the Lower Mekong Basin) estimate and is 50 percent higher than the MRC 1997 estimate. One and a half million tonnes per year corresponds to an average catch of 150 kg per hectare per year from the total 10 million ha of wetlands in the Basin, a number that can be considered fairly realistic.

1.1.5. Economic Value of Fish Production and Fish Habitats

Using an average farm-gate price of US\$1.05 per kg for cultured fish and an average initial sale price of US\$0.68 per kg for captured fish, the monetary value of the 2 million tonnes of fish caught and produced from the Lower Mekong Basin is estimated at US\$1,400 million (see box "Size and value of the fishery in the LMB").

It is difficult to estimate the true economic value of the natural aquatic resource system of the Mekong Basin, as costs of fishing need to be included in the analysis. In addition, economic values for food security and informal employment are difficult to assess. The aquatic resource system also produces significant levels of non-fish products including other food items, house building and tool making materials as well as herbs and medicines. These goods are mostly harvested with low capital investment by rural dwellers, whose livelihood options depend on their availability. The decrease or eventual disappearance of these goods would seriously undermine sustainable livelihoods. Another direct-use value relates to their diversity and seasonality. It is this combination that provides livelihood options and choices.

In addition to the direct use value related to harvest of fish and other marketable goods, the Mekong wetland system produces important indirect, non-marketable use values in the form of flood control and groundwater recharge. The rich biodiversity of the Mekong wetlands also has an economic value in the genetic material present in the system and economic non-use value related to the very existence of the biological richness of the system. As an example, the Irrawady dolphins living in the Mekong River below the Khone Falls have a high economic 'existence value' because of their rarity in addition to their considerable economic value for tourism.

It would make little sense to attempt a valuation of the entire Mekong wetland system using, for example, the Ramsar criteria. Wetland system valuation makes more sense when wetlands are at risk of being converted, totally or partly, to other uses either locally or cumulatively through basin-wide impacts. A case in point is the flooded forest around the Great Lake in Cambodia, which is at risk of being converted into rice fields. Based on simple calculations, conversion to rice fields might appear justified, though more holistic consideration suggests a need for greater caution with such development

Size and Value of the Fishery in the Lower Mekong Basin.

Estimating the yield from the fishery in the LMB is extremely difficult using traditional fisheries statistics collection methodologies. In the LMB, the fisheries are widely dispersed, effectively operating along the lengths of all the main rivers and most tributaries. There are no centralised landing ports where data can be comparatively easily collected. There are numerous species, the catch of which varies seasonally and with the many different types of gears. Most importantly, the fisheries operate at a commercial, semi-commercial and subsistence level. Statistics on family or subsistence level fisheries have not been collected in the past by fisheries authorities in the LMB, and this has led to serious underestimations of fisheries yields, and hence the economic and nutritional importance of the fisheries.



A busy market where many species of Mekong River fishes are traded

The dispersed and varied nature of the fisheries in the LMB applies to other major inland fisheries, for instance in China, India and Bangladesh. One promising, albeit indirect, approach to gathering fisheries data in such situations is via rural household food consumption surveys at national and local levels (Crispoldi 2001).

In the 1990s household surveys on the quantities of freshwater fish, fish products and aquatic animals eaten and their supply source were conducted by several different agencies in 15 of 87 provinces in the LMB. The surveys found that people in the region are consuming from less than 20 kg per person in mountainous areas with limited access to fish resources, to about 60 kg per person in floodplain areas of Cambodia and Viet Nam where fish is abundant most of the year. In Northeast Thailand, home to about one third of the population in the Basin, annual fish consumption is about 35 kg per person (Sjorslev in press). The overall average value for consumption of fish and other aquatic products in the LMB is 36 kg/person/year (Table 1).

The results of other household consumption and expenditure surveys conducted by the national statistical authorities in Lao PDR and Cambodia between 1998-2000 are largely consistent with the household consumption figures given above.

Sjorslev (in press) used these data and regional population figures to determine regional consumption of fish and other aquatic products. For the 15 surveyed provinces mean fish consumption figures and census population data were used to calculate total annual provincial fish consumption volumes. The 72 provinces that were not surveyed were classified according to area and type of water resources and fish habitats, before being assigned the mean consumption figure of the most similar surveyed province. Extrapolation of the household survey findings as above gives an annual total consumption of freshwater fish, fish products and other aquatic animal products in the LMB of about 2,033,000 tonnes (see Table 1).

Table 1. Estimated freshwater fish and aquatic product consumption in the Lower Mekong Basin (from Sjorslev, in press)

Country	Population in LMB 1999/2000	Assessed consumption in per capita per year of all fisheries products. Average (range), kgs	Assessed total consumption of freshwater fish, fish products and aquatic animals (tonnes) 1999/2000
Cambodia total	10,775,000	47 (10-89)	508,000
Lao total	5,087,000	26 (17-36)	133,000
N-E Thailand	22,439,000	35 (20-41)	795,000
Vietnam - Mekong delta	17,958,000	33 (15-60)	597,000
TOTAL	56,259,000	36	2,033,000

To use fish consumption data as an estimate of fisheries yield requires the assumption that the import and export of fisheries products from the region are similar in magnitude. Unfortunately, there are no reliable data on the import and export of fishery products in the LMB. However, export is considerable: for instance in Cambodia, at least 50,000 tonnes of freshwater fish are exported to Thailand annually (van Zalinge 2002). We do not know regional import levels. Nevertheless, one can reasonably assume for the present purposes that import into the LMB is approximately equal to export out of the LMB.

Given this assumption, it follows that fish consumption is approximately equal to the amount of fish caught plus that produced from fish farming. In 1999-2000, 260,000 tonnes of fish was produced by the aquaculture industry (Phillips *et al.* in press), and 240,000 tonnes of fish was taken from reservoirs (Virapat and Mattson 2001; Mattson 2002 pers. comm.) in the LMB. Therefore, the total yield from the freshwater *riverine and wetland capture* fishery is at present about 1,533,000 tonnes per year.

The validity of this estimate can be cross-checked using data from studies on fisheries yields from wetlands in the LMB. Estimates of mean fish yield range from about 205 kg per hectare per year for the Great Lake area to 375 kg per hectare per year for the floodplain near Phnom Penh, though these means are based upon small survey areas. Based on a much larger survey area, Baran *et al.* estimate the annual yield of the Tonle Sap Lake and floodplain to be 230 kg per hectare. An average yield of 230 kg per hectare from the 9.69 million hectares of wetlands in the basin (MRC 1997; MRCS 1997) extrapolates to a total yield of 2.23 million tonnes per year. Therefore, the estimate of 1.533 million tonnes (equivalent to 158 kg/ha of wetlands) of freshwater fish and aquatic products captured from the river and wetlands fishery in the LMB each year is considered realistic, and possibly conservative.



A river catfish, very important in the capture fishery and in aquaculture

The Mekong fishery is probably the largest river fishery in the world (Coates in press). In 1999 the total world capture fisheries (marine and freshwater) catch was 92.3 million tonnes (FAO 2000). Based on the figures presented here, the Lower Mekong Basin freshwater fishery is about 2 percent of the total world capture fisheries yield.

The value of the fishery in the LMB is very difficult to estimate, because the relative proportions of fish, processed fish products and other aquatic animals are not well described, and the average prices of these different products in different regions are not known.

Table 2. Production and value of fish, fish products and other aquatic animal in the LMB. Prices for capture fish are from Aeron-Thomas (in press), and for aquaculture fish are from Phillips (in press).

Fish, fish products and aquatic animal source	Quantity (tonnes)	Price (\$ per kg)	Value (\$ millions)
Riverine capture fisheries	1,533,000	0.68	1,042
Aquaculture	260,000	1.05	273
Reservoirs	240,000	0.68	163
TOTAL	2,033,000		1,478

Nevertheless, we can get an approximate idea of the value of the fishery if we apply fish prices to the total yield of fish, fish products and other aquatic animals. We can use an average farm gate price of US\$1.05 per kg for cultured fish (Phillips in press) and an average first hand sale price of US\$0.68 per kg for capture fish (Aeron-Thomas in press). For the reservoir fisheries, the conservative value of US\$0.68/kg is used, because although the fish are produced by both aquaculture and capture fisheries, the relative proportions cannot be estimated. This results in an estimate of US\$1,478 million for the value of the fishery. This is for first sale price only, and so does not include any estimate of the multiplier effects of the fish trade.

1.1.6. Fisheries Management

Regional level

Many Mekong fish species are trans-boundary during their life cycle. Although several species stocks are shared, including some rare high profile migratory species, there are few institutional arrangements at the regional level for the joint management of trans-boundary fish resources. The endangered giant fish species, about which there is both a growing knowledge base and motivation to improve management, present immediate opportunities to rectify this.

National level

At the national level, management of inland fisheries varies from country to country. In Cambodia, the 1987 Fiat Fisheries Law formalised fisheries practices established in 1908. A new Fishery Conservation, Management and Development Law was drafted in 1999 but has not yet been adopted. The spatial applicability of the Fiat Law includes the habitats that together constitute the fisheries domain: rivers, tributaries, streams, floodplains (including flooded forest), lakes, channels and other wetlands. The Law consists of detailed rules on who can access fish resources, when, where and on what conditions as well as rules on fishing operations, types of gear and enforcement and control. The management system serves the triple purpose of protecting the resources, providing access for poor people to fish for food and, foremost, to maximise the resource rent, which is collected through a licensing scheme on middle and large-scale fishing. The enforcement of the Law is the responsibility of the Department of Fisheries, which is "mandated to manage activities related to water, fisheries, flooded forests, mangroves, swamps and industrial fisheries". Law enforcement is far from effective and lack of compliance and conflicts over access are increasingly problematic (see box "The Cambodian fishing lots: a limited access system").

There is no specific fisheries law for the general regulation of capture fisheries in Lao PDR. However, both the 1996 Water Law and the recently adopted Environment Protection Law have clauses relating to wild fish resources management. The mandate of the Department of Livestock and Fisheries is determined in the Ministerial Decree on Fisheries. Apart from enforcing a set of rather detailed operational rules for fishing in the Nam Ngum reservoir, the DLF is mainly practising a hands-off policy on capture fisheries. This reflects the limited need for regulatory intervention at the national level (no major conflicts over access to fish resources, no report of overfishing etc.) and the lack of resources for such intervention.

In Thailand, inland capture fisheries have been regulated since the 1947 Fisheries Act. The law was last revised in 1984 and covers most aspects of inland fisheries management. Law enforcement is in the hands of the Department of Fisheries, which through the Wildlife Preservation and Protection Act is also mandated to protect endangered aquatic animals. Compliance with rules and regulations by fishers is low and DoF enforcement of fishing regulations is not very strict. Since the 1960s, the DoF has focused on reservoir fisheries management, which has increased in socio-economic importance with the construction of a growing number of multi-purpose reservoirs. Activities include the management of large fishery enhancement programmes through fish stocking.

In Viet Nam, the fresh water fisheries in the Mekong Delta and elsewhere are regulated through a Fisheries Law that focuses primarily on marine fisheries. The Ministry of Fisheries is the national authority responsible for fisheries management. However, at the operational level, provincial, district and commune level People's Committees make policy decisions. Management intervention with inland capture fisheries has traditionally been minimal.

The Cambodian Fishing Lots, a limited access system

Fishing lots (*loh nesaat*) are concessions auctioned off by the Cambodian government to the highest bidder for a two-year period of exclusive exploitation. The auction is one of the government's main instruments for extracting revenue from fisheries. In the Mekong region, the lot system is presently only found in Cambodia, but in the past it also operated in Thailand and Viet Nam. Lots are allowed to operate between October and June under the general fishery law and other specific regulations.

The lot system has been in use for over a century, but was gradually reduced in size (ca 70 percent) between 1919 and 2001 (Degen *et al.* 2000, 2001).

Area covered by Fishing Lots		
Year	Sq. Km.	% reduction
1919	14,347	-
1940	9,520	34
2000	9,335	2
2001	4,152	56



Arrow-shaped fish trap in the Great Lake



Fences, many kilometers long, in fishing lots in the Great Lake

Fences, many kilometers long, in fishing lots in the Great Lake (*Channa micropeltes* and others), followed by cyprinids and gouramis. The volume of the catch is very difficult to estimate, but probably exceeds 100,000 tonnes annually.

Fences

The fenced fishing lots in the Great Lake are very large (the largest is ca500 km²), encompassing vast tracks of floodplain. Fishing in the lots tends to start in January or February, when water levels have gone down to about four meters, and they continue until June. As water levels drop, fish move out of the flooded forests and they are channeled by kilometer-long fences into pens where they are caught and killed. The catch is dominated by snakeheads (*Channa*

Barrages

The barrages of Kampong Chhnang are a variation of the lots described above. They are built across branches of the Tonle Sap River delta – an extensive wetland that forms the transition of the Great Lake into the Tonle Sap River. The number of barrages is strictly regulated to allow an adequate number of fish to escape downstream to the Mekong. They catch numerous white fish, but also substantial catches of black fish.

Dais

Number of <i>Dai</i> lots		
Season	Number	% reduction
1938-1939	128	-
1983-1988	86	33
1995-2000	63	27
2001-2002	60	5

A *dai* is a kind of bagnet or stationary trawl positioned in the Tonle Sap River to capture migratory fish. The legal mechanism is similar to that for fishing lots, but instead of auctioning off a piece of land and water, the Cambodian government auctions an anchoring location in the river. *Dai* lots tend to be much cheaper on average than the other types of fishing lots. The number of *dai* lots decreased by 53 percent between 1938 and 2002 (Lieng *et al.* 1995, MRC data).

The *dai* fishery operates from the end of October until around the middle of March. As the floods recede, fish move out of the submerged land around the Great Lake into the lake itself. They then migrate via the Tonle Sap River to the Mekong. More than half of the season's catch is taken in January, with the peak migration occurring one to six days before the full moon. The bulk of the catch consists of small "white" fish species, especially *trey riel* (*Henicorhynchus* spp.). These are used for making fish paste (*prahoc*), fish sauce and fish oil, and they are also salted and dried. Catch estimates are



A barrage fishery on the Tonle Sap River

quite accurate, ranging from ca7,000 to ca18,000 tonnes annually. There is a close relationship between the maximum flood level of the season and the fish catch. The greater the area of flood plain inundated, and the longer the duration of flooding, the greater the volume of fish.



Mekong giant catfish about to be released. This fish was 2.35 m long and weighed 260 kg.

One of the most famous species caught in the *dai* fishery is the Mekong giant catfish. It is endemic to the Mekong and close to extinction. In the year 2000, only 11 giant catfish were caught, and in 2001, only eight. Their sizes ranged from 20 kg to 270 kg. In 2000 and 2001, to preserve the species, most of the giant fish caught were bought with funds from WWF and MRC, tagged and released alive (Hogan *et al.* in press). Another famous fish is the giant barb (*Catlocarpio*

siamensis), which is also found in the Chao Phraya River system in Thailand. It is regularly taken in very small numbers in the *dai* fishery at sizes that rarely exceed 100 kg.

There are also a number of fishing lots in the floodplains south of Phnom Penh and in Kampong Cham. These generally use some barrages to block canals or small rivers. Use of seine nets, brush park (*samrah*) fishing and pumping out of small lakes are common. Many of these lots no longer have natural habitats because those who hold the leases have converted the wetlands to rice fields and now rent them out for farming. As a consequence, fish productivity has declined considerably.

Provincial level

In all four MRC member countries, provincial government offices have a high degree of autonomy. This affects how national legislation is interpreted at the operational level and the level of enforcement. On policy matters, provincial fisheries authorities normally report to the Provincial Government (in Viet Nam the Provincial People's Committee), whereas on technical matters reporting is to national line agencies.

Village and community level

Over the last decade, MRC member governments and line agencies responsible for the management of natural resources have increasingly involved end users in resource management. Users represent a significant resource for enforcement and regulation and defining operational rules. Their understanding and acceptance of rules ensures a high degree of compliance. There are long-standing traditions of fisheries management being undertaken by communities in many areas of the Lower Mekong Basin. Rules on fishing, often associated with spiritual beliefs, are established to sustain local resource levels and to ensure the equitable distribution of benefits. The rules established for traditional, community based fisheries management, whether documented or not, are often *de facto* recognised by provincial and national authorities and their enforcement is supported.

The growing political interest in promoting user participation in resource management has recently led to legislation favouring co-management arrangements whereby local fisheries are jointly managed by public authorities at various administrative levels, local fishers and other stakeholders. New legislative initiatives in Cambodia promote the establishment of community fisheries groups that will take part in the management, conservation, development and sustainable use of fisheries resources. The 1997 revision of the Constitution of the Kingdom of Thailand includes the provision that the "traditional community shall have the right to conserve and restore their custom, local intellect, art and good culture of their community and the nation and participate in the management, maintenance, preservation and exploitation of natural resources and the environment in a balanced fashion and persistently as approved by law."

In Lao PDR there is constitutional support for local management and customary law. A new decentralisation policy launched in 2000 represents a conscious effort to empower provincial and district authorities to actively manage local financial and natural resources to optimise the local development process. The province is the strategic unit, the district is the planning and budgeting unit and the village is the implementing unit. This decentralisation process gives formal recognition and status to a process that has been underway for a number of years.

Similar to Lao PDR, Viet Nam's current policies give communities an active role in fisheries management, an equitable share in resource property rights and shared responsibilities for conservation and management. However, these policies are vague, as they do not state how this sharing of management is to take place.

Compliance

Lack of compliance with national and provincial fisheries regulations has been a longstanding problem in Cambodia. This includes fishers at all levels and has increasingly been a source of conflict among stakeholder groups. Violations include preventing access of small-scale fishers to fishing areas during open seasons, illegal expansion of fishing lot boundaries, illegal fishing for juveniles and destructive fishing practises. In Thailand, the compliance of small-scale operators with gear regulations and closed seasons is very low.

In contrast, in the Siphandone area of southern Lao PDR, local fishers are complying extremely well with fishing regulations, despite a significant increase in demand for fish. Another example of high compliance is the controlled fishing in the back swamps of southern Lao PDR after fish stocking under co-management arrangements.

Fisheries research

For over five years the MRC Fisheries Programme and other donor supported and national research projects have made substantial contributions to capacity building within the national research institutions. Staff of provincial and district fisheries authorities involved in field research activities have also benefited from capacity building. Through these programmes, considerable information and knowledge on aquatic ecosystems and the fisheries of the Mekong River and related topics have been gathered. The MRC Fisheries Programme and other fisheries databases have been compiled. Processes have begun to archive data held by national institutions and provide better access for interested users.

Fisheries training

Whereas Thailand and Viet Nam both have universities that offer fisheries and related programmes from diploma to Ph.D., Cambodia and Lao PDR are less advanced. The national universities in these two countries offer only a few fishery courses within their agricultural programmes.

Links have been established and strengthened between the fisheries research institutes and universities. Support is being provided for curriculum development and student thesis work. At the regional level, AIT has expanded its Master and Doctoral Programmes to provide wider coverage of fishery and fishery related subjects. A significant number of scholarships are available to students from the MRC member countries.

1.1.7. Fisheries and Other Sectors

The relationships between fisheries and agriculture, hydropower, navigation, tourism and other sectors are complex. Generally, other sectors impact on fisheries more than fisheries impact on other sectors. Usually the impacts are brought about through changes in the aquatic environment or socio-economic conditions amongst the population living in the Basin. Impacts from other sectors are generally negative, primarily because fisheries rely so heavily on aquatic ecosystem health and integrity to maintain the resource base.

Water is by far the most important of all the natural resources in the Mekong Basin. Mistakenly regarded as abundant, water resources are both finite and fragile. Water availability varies considerably by region, season and year. Ominously, water availability is increasingly influenced by major local, regional and global human activities. There are escalating conflicts over the allocation of water between the various sectors. Development pressures place rapidly increasing demands on water resources and poor planning only exacerbates an already critical problem. In addition, as water flows down through the Basin, it easily carries accumulated pollutants from unsustainable development activities upstream.

Unsustainable slash and burn agriculture in upland areas causes increased soil erosion and affects water balance. This has major impacts through local destruction of fish habitats and other local and downstream alterations in the natural ecology of the river ecosystem.

The carrying capacity of lowland farm areas has almost reached its limits. In the Mekong delta in Viet Nam, for example, the population per unit area of farmland is amongst the highest in the world. As cash cropping expands and the population increases, countries will turn to agricultural intensification to increase production. Improperly managed, this will have greater impacts on fisheries through increased water extraction and the local and downstream effects of agro-chemicals, particularly pesticides.

For centuries, water-intensive rice production has been the staple food provider in the region. More recently, it has been an important export industry. Expanding rice production for food security is one of the top priorities on the political agendas of MRC member countries. Increased production has been achieved through a policy of irrigation expansion. Storage reservoirs are essential for increasing dry season cropping. Like traditional rice agriculture, irrigated rice fields can in theory produce a significant by-crop of aquatic animals through natural recruitment, stocking or both. The potential is often undermined through poor engineering design and management, including excessive agrochemical use. Unfortunately, many areas targeted for irrigation development are also seasonal wetlands that are lost as productive habitats for fisheries.

Mineral exploration and mining has not been a major factor in the Mekong Basin although there are areas with high potential, particularly in Lao PDR. However, interest has recently increased and a number of schemes are at the feasibility or implementation stages. Mining can have very significant negative downstream impacts on fisheries, mainly through alterations of water quality.

The Mekong River has more hydropower potential than any other river system in East Asia. The high relief in the Lancang River Basin, Northern Highlands, the northern half of the Eastern Highlands, and some areas of the Southern Uplands, make it well suited for hydropower development. Less than 9 percent of the potential has been realised. By changing the water flow, sediment, nutrients, energy and biota, dams interrupt and alter important ecological and physical processes in a river. Consequently, dams have local, upstream, downstream and cumulative impacts on fisheries. The effects of dams and reservoir projects on fisheries fall into four general categories:

- ✧ Effects on water level fluctuations, especially reductions in the duration and extent of flooding downstream
- ✧ In-stream flow changes which impact on mainstream ecology
- ✧ Physical blocking of fish migration routes
- ✧ Water quality alterations

Uninterrupted navigation from China to the Delta is not currently feasible due to the rapids, shoals and sharp bends on the Myanmar border and the Khone Falls between Pakse and Phnom Penh. Decreased water discharges in the dry season through upstream storage or extraction, riverbank erosion and sedimentation of waterways reduce navigability. The response of the navigation and transport sector is to undertake both local and regional engineering works to clear suitable waterways for ever larger vessel sizes. These efforts focus on modifying natural stream morphology. This can seriously impact fisheries, especially where important main channel fish habitats, such as rapids and deep pools, are significantly modified.

Contrary to past forecasts, industrial development has yet to take off on a substantial scale in the Mekong Basin. Two main industrial regions are likely to develop in the foreseeable future: one for light manufacturing in Northeast Thailand and the other for agro-industries in the Mekong Delta.

Industrialisation has potential impacts on fisheries in three major ways: increased water extraction by specific types of industry, increased production of wastes and effluents discharged into

waterways and increasing urbanisation. Presently, only about 16 percent of the inhabitants of the LMB live in urban areas, but this proportion is expected to increase to about 30 percent by 2010. Many of the main Basin cities are characterised by poor infrastructure. Urbanisation will lead to changes in water quality and the environment that will undermine fisheries. Urbanisation will also influence shifts in demand for fisheries products. The extent and nature of these changes will depend largely on whether or not urbanisation is accompanied by a general reduction in poverty levels.

Tourism in many forms is developing rapidly, much of it unregulated. Tourism development may have long-term positive implications for fisheries by focusing more attention on environmental protection and possibly by increasing demand for quality fisheries products. A number of key vulnerable habitat areas for fish (e.g., Khone Falls, Stung Treng, Tonle Sap) are coincidentally important sites for tourism. Recreational fishing has yet to take off generally in the Mekong but it is becoming a widespread and high profile pastime in Thailand.

1.2. AQUACULTURE PRODUCTION

Aquaculture production is highest in the Mekong Delta of Viet Nam and the Korat Plateau in Northeast Thailand, with steady growth in production throughout the Lower Basin over the past 10 years, from around 60,000 tonnes in 1990 to around 250,000 tonnes in 2000. It is a diverse activity encompassing production and sale of fry and fingerlings and raising wild or artificially produced fry and fingerlings in enclosed or semi-enclosed water bodies for sale and home consumption. Supplies of inputs for aquaculture, handling, processing, marketing and consumption of aquaculture products are the basis of rural livelihoods in many remote parts of the Basin. There is a close link between aquaculture and capture fisheries (see box "Interaction between capture fisheries and aquaculture in the Mekong Delta").

Based on an estimate obtained from official government statistics and household consumption surveys, the farm-gate value of these aquaculture products in 2000 was around US\$260 million¹. There is a widespread belief that small-scale aquaculture production is widely practiced among rural households but under-reported.

There are relatively few large-scale commercial fish farms in the Lower Mekong Basin. Two examples would include cage farms producing river catfish in the Bassac River and large integrated peri-urban fish farms near urban centres in Northeast Thailand. Most aquaculture production comes from small-scale operations run by rural households. At this level, aquaculture is becoming increasingly important throughout much of the Basin. In Northeast Thailand, for example, more than 6 percent of the 2.6 million rural households are involved in small-scale aquaculture. Small-scale aquaculture contributes to food supply in wild fish deficit areas and in seasons when wild fish are not readily available. It provides opportunities for flexible supplementary income and helps families diversify out of the wild fishery and rice farming.

¹ Includes additional estimated value from Northeast Thailand from unreported small-scale aquaculture farms.

Interaction between Capture Fisheries and Aquaculture in the Mekong Delta

The interaction between capture fisheries and aquaculture can be found in every kind of culture system in the Mekong Delta. The capture fishery supplies wild seed and trash fish as inputs to aquaculture. Aquaculture helps to increase the effectiveness of the capture fishery when capture production cannot keep up with the consumer demands of an increasing population.



River fish are sometimes on-grown in cages

In cage culture, the capture fishery provides fingerlings and trash fish as feed for cultured fish. Fish are kept in cages and grown to a larger size, and low-quality trash fish is converted to high-quality, marketable fish. With species that can be bred in captivity, this interface is limited to providing feed for aquaculture from the capture fishery.



Feeding fish in aquaculture cages

Snakehead culture in ponds follows this pattern. In the breeding season, fingerlings are collected from the wild and stocked in ponds and fed trash fish which are captured from the wild.

In some *Melaleuca* forests during the fish capture season (dry season), indigenous species (snakehead, climbing perch, catfish, snakeskin gourami) are taken from the channels surrounding the forests. The larger fish are released back to the channels so they can breed during the rainy season and their offspring can then be captured the next season.



Fish cages come in many shapes and sizes

For shrimp culture in mangrove forests, wild seed is collected through a sluice gate system, kept in ponds for a short period of time, fed on natural food and harvested periodically by the same sluice gate system.



Fingerling fish ready for stocking

In rice-fish culture, rice fields are modified with a system of dikes and trenches surrounding a large area of hundreds of hectares. When the floods come, rice is harvested and the bunds are opened to allow wild fish into the fields. When the floods recede, the fish live in the trenches around the edges of the field. In an alternative method, fish traps are set up in the major irrigation canals to capture all the fish moving from the rice fields back to the river when the floodwater recedes.

In deep-flooded areas, fish can be kept in a system of fences designed to make use of the natural food available during the flood season, to maintain the same hydraulic regime outside and inside the boundary, and to prevent fish from escaping. Fingerlings caught in the wild can be also stocked within the fences.

A wide cross-section of socio-economic groups are involved in aquaculture production, from low income and poor people to the better off with more capital to invest. For the better off, aquaculture can offer a lucrative return on investment. Even though start-up capital is required for aquaculture, there are examples of the poorest landless people involved in and benefiting from aquaculture. To date, aquaculture development has emphasised increasing productivity through technology, an approach that has not always been focused on the poor. Experiences in Lao PDR and Cambodia demonstrate how aquaculture can make a significant contribution to improving livelihoods and alleviating poverty if the poor are targeted as a group.

Women, men, children, the disabled and the elderly are all involved in small-scale aquaculture. Each group has different roles at different stages of the production cycle. There are few cultural constraints to women's participation in most aquaculture activities although the distance of the operation from the house may limit their involvement. Experience from Viet Nam suggests that the role of women is greater for poorer households where the men have to work away from home on a daily or seasonal basis.

1.2.1. Aquaculture Systems and Species

In all MRC member countries except Cambodia, ponds and rice fields are the most common means of producing fish (see box "Fish in Mekong basin rice fields - catch or culture"). There are distinct differences between fish culture practices in peri-urban and rural areas. Peri-urban areas are closer to markets and have better access to agricultural inputs and more intensive livestock production, particularly pigs and chickens, that provides useable wastes. Access to technical information and fish seed is also considerably easier due to the proximity of government stations and fish seed suppliers. In Thailand and the Mekong Delta of Viet Nam, better infrastructure allows easier access to inputs and markets than in the more remote rural areas of Cambodia and Lao PDR.

The number of aquaculture farms and land allocated to aquaculture has increased throughout the Basin over the past 10 years. In Northeast Thailand, there has been substantial construction of fish

ponds since 1997, influenced in part by the economic crisis and the self-sufficiency and food security principles and projects promoted by His Majesty the King. In Cambodia, large numbers of household ponds have been dug by donor agencies, although only some of these multiple-purpose ponds are used for aquaculture. Available statistics under-estimate the area devoted to small-scale aquaculture scattered throughout rural areas of the Basin.

Mekong Delta in Viet Nam

The Mekong Delta has the largest aquaculture area in the Basin, covering 330,000 hectares. Freshwater aquaculture production in 1999 was 171,570 tonnes. Production is high, with the mean annual pond production of 4.8 tonnes per ha. Over 100 hatcheries in the Delta produced an estimated 1,615 million fry and 595 million fingerlings in 1999. The most commonly cultured fish species are river catfish, silver barb, common carp, tilapia, giant gourami, sand goby, hybrid catfish, silver carp, Indian carps and snakehead. Polyculture is the norm and pond production is generally integrated under the 'VAC' system, an acronym from the Vietnamese words for 'livestock', 'pond' and 'vegetables'.

Eighty thousand hectares is presently under rice-fish culture. Silver barb, common carp, silver carp, tilapia, Indian carps, climbing perch, and snakeskin gourami are most frequently stocked in rice-fish systems. The mean annual production is 0.37 tonnes per ha. Fish are often held in the rice fields for two or three successive rice crops.

There are nearly 5,000 fish cages in the Delta ranging from 50 to 400 m² in size. Each cage consists of accommodation on top and the submerged cage portion below. River catfish, snakehead, red-tail tin foil barb, silver barb and common carp are the common species reared in these cages. Cages are most often stocked with wild captured fry or juveniles. Fish are fed wet sticky balls of mixed rice bran, broken rice, trash fish and vegetables. Fish are cultured for 10 to 14 months and yields range from 80 to 120 kg/m³. Cage culture of high value species requires investment levels beyond the reach of poor and marginal farmers.

The government of Viet Nam has recently begun promoting giant freshwater prawn culture in the Mekong Delta and it is expanding rapidly. There are more than 30 fish and prawn species cultured in the Lower Basin including exotics and indigenous species.

Korat Plateau

The Korat Plateau is the second largest area for aquaculture in the Basin after the Delta. Aquaculture production has expanded significantly over the past ten years. Fish culture in ponds, rice fields, ditches and cages contributes over 33,500 tonnes per year according to official Department of Fisheries statistics. These statistics underestimate total production since small-scale producers are not included. With production from small-scale operations estimated to be in excess of 30,000 tonnes per year, a conservative estimate for the total annual aquaculture production is 65,000 tonnes.

Pond culture makes the biggest contribution to total production and both exotic and indigenous species are produced. Species include a mixture of indigenous catfish, snakeheads and silver barb and exotic species including tilapias, Chinese and Indian carps. Pond culture is based largely on the use of agricultural by-products, such as manures and vegetable matter, inorganic fertilisers and the increasing use of pelleted diets. Larger integrated farms are found around urban centres where organic matter from pigs and chickens is readily available.

Fish in Mekong Basin Rice Fields – Catch or Culture

The lowland rice fields and associated canals and nearby swamps in the Mekong Basin provide an important source of fish and aquatic animals, which are used for consumption and sale by around 80 percent of rural households. It is an important factor in household food security and in the income generating strategies of rural people.

The quantity of aquatic animals caught in and around rice fields is surprisingly high. Studies in the Basin indicate an annual catch of between 100-680 kg per family per year. At a consumption rate of between 20-40 kg per person per year, some 100-200 kg per year is sufficient for household consumption. The surplus can be sold or given away (e.g. as merit making at festivals).



Rice fields are important for aquatic animal production

In irrigated areas, aquatic animals are available in the fields during cropping seasons, provided that not too much pesticide is used. In rain fed areas, where snails, crabs, frogs, toads and some fish species dig into the fields to survive the dry season, these animals form an important part of the dry season diet in many areas, and are a final line of defence against famine in drought years. At the beginning of the rainy season, many water insects and fish fry migrating out from dry season refuges are part of the rural diet before larger fish and frogs start appearing. The rice field environment is diverse, with some 20-30 species of fish in any particular rice field.

Studies in Cambodia have shown that the market value of the fish and other aquatic animals caught from rice fields are worth 40-80 percent of the rice value (not taking into account the cost of growing rice) (Gregory and Guttman 2002).

Fish in rice fields is a resource of major economic and nutritional importance, and needs to be managed in a sustainable way. Development of active management strategies needs to be initiated to protect, for example, dry season refuges for fish and other aquatic animals.

Another management option is to enhance the supply of aquatic animals by actually stocking the rice fields with fish fry. This is termed rice-fish culture. It is particularly common in northeast Thailand. The pros and cons of rice fish culture are presented in the table below.

The Pros and Cons of Rice-Fish Culture

Pros

It poses few risks to the farmer. Costs, and therefore potential losses, are low. It requires relatively few changes to existing practices, and competes minimally with other farming practices.

The technical details of the practice can be easily adapted to the circumstances of most farming families.

It provides a convenient, continuous, predictable source of income and protein to farming families.

It is not very vulnerable to market price fluctuations,

Rice yields usually increase after fish culture is integrated with rice farming.

It can support other on-farm activities, chiefly through conservation of water.

Cons

Production cannot be guaranteed. The final yield depends on many factors, not all of which can be controlled. These include water quality and quantity, stocking mortalities, theft and predation.

Occasionally rice yields are affected; this usually happens if large fingerlings are stocked in newly planted fields.

Some farmers report that wild fish yields are affected if domesticated species are stocked.

Rice-fish culture is also practiced. Cage culture of tilapia, supported by larger agro-industrial concerns, has expanded in the past three years in reservoirs and the Mekong mainstream. Cage culture of river catfish using wild seed is also present in the Mekong River and its expansion can be anticipated if the breeding technologies become more widely adopted. Northeast Thailand is also an important supplier of seed and feed to areas in Lao PDR bordering the Mekong River.

Aquaculture appears to have particularly good potential where there is food insecurity and in areas where wild fish stocks are insufficient to meet demand. There are a number of important factors influencing development, as the potential for aquaculture is not evenly distributed. These factors include infrastructure, access to markets, supply of inputs, access to extension and other support services and fish seed. In Lao PDR, for example, economic factors are a major constraint and include a poorly developed market economy outside major towns and limited access to long-term credit.

Mekong Delta and Tonle Sap system in Cambodia

In Cambodia, over 80 percent of production comes from cages and pens in the Great Lake and the Tonle Sap, Mekong and Bassac Rivers. The major species are river catfish and snakeheads. Juvenile river catfish and snakeheads are collected from the wild fishery. Pond culture and farming fish in rice fields is less developed in Cambodia, although its importance has been increasing in recent years as a result of NGO and international donor assisted projects.

There are two basic pond systems used in Cambodia. Intensive catfish culture is common in and around Phnom Penh and Kandal Province near urban markets. Fish fingerlings are collected from the wild, held in small ponds, and intensively fed rice bran or wild fish when these are abundant.

The second type is low-input pond culture, rice-fish and other integrated fish/livestock/vegetable culture techniques using various exotic and indigenous species. Although pond and rice-fish culture makes a limited contribution to total production, small-scale farming provides an important opportunity for poor households to improve nutrition and to generate cash income in fish deficient areas farther from the Tonle Sap and other major rivers.

Lao PDR

Rural areas in Lao PDR are typified by their self-reliant subsistence agriculture operations. Agricultural surplus is minimal and livestock production is still at a relatively undeveloped stage. Fish culture is constrained by the lack of seed, supplemental feed and manures. Technical information and extension services are hard to obtain, due partly to the low population density and poor communication between villages.

Fish culture in ponds and rice fields is widely practised and a variety of systems are used depending on the agro-climatic characteristics of the area. The attraction of aquaculture to rural farmers is most obvious in locations where capture fisheries are inaccessible or require excessive effort for a limited catch. There is a small amount of cage culture in reservoirs and rivers but this system presently makes only a small contribution to national production. Most ponds are hand constructed and shallow, with water depths less than 50 cm. Low productivity figures for aquaculture ponds reflect the limited amount of inputs applied, limited stocking of fish seed and a short grow-out season. A diverse number of species is cultured, including exotic carps and indigenous fish.

Upland rain fed and irrigated rice fields with terracing are common in Lao PDR. This limits the size of individual paddy fields and farmers are reluctant to further reduce rice production area by cutting channels or constructing refuges for fish. In some areas water is supplied to the paddies from small diversion irrigation systems. Where these are present, the requirement for deep-water refuges is reduced as water is continually replenished in the paddy. Upland areas are also cooler so high water temperatures are less problematic. Where irrigation is used (usually from stream diversion), rice-fish culture is more successful. Typically, common carp and crucian carp are produced and spawn naturally in rice fields and adjoining ponds. This activity is extremely popular since farmers can produce fish seed themselves and no cash is required for stocking.

1.2.2. Policy and Institutional Support

Government policy in MRC member countries has been supportive of aquaculture and most governments have production and earning targets for future development. These pro-aquaculture policies have supported investments in research, infrastructure, education and extension that have contributed significantly to the growth in aquaculture over the past ten years.

Recently, governments have been emphasising aquaculture development as part of their rural development and poverty alleviation policies. The rural development focus and the emphasis on democratisation in some countries will have a major impact on the management and development of aquaculture and capture fisheries in the coming years.

The policy environment outside the fisheries sector, particularly policy for water and land use, has also had a major influence on aquaculture development. In Viet Nam and Lao PDR, the conversion of rice fields to aquaculture ponds has only recently been allowed under changes in land use policy as part of a government concern to alleviate poverty in rural areas through rice farm diversification.

Tenure and land use issues play an important role in how village fish ponds are owned and managed in Northeast Thailand. Similarly, government policies supporting international and regional trade and infrastructure development are leading to greater movement of fingerlings, input supplies and fish to markets.

However, most line agencies involved with aquaculture tend to be driven by a sectoral perspective and have yet to evolve new governance strategies to deal with the new emphasis on rural development and decentralisation. This is recognised in Thailand, for example, where the Department of Fisheries is considering new legislation and institutional strategies to cope with these changing circumstances and associated shifts in government funding.

Laws and regulations have been developed at various levels, but there is no separate legislation on aquaculture in any MRC member country. Aquaculture is generally considered part of national fisheries legislation. Apart from Lao PDR, fisheries legislation is now undergoing revision in all member countries to reflect changing circumstances.

There are trans-boundary policy issues relevant to aquaculture but governments have generally not yet addressed them. High demand is driving a significant movement of fry, and to a lesser extent fingerlings, but governments have yet to address the trans-boundary genetic and health issues. Co-operation on this issue may become important in the future. Similarly, genetic strategies and national broodstock management plans are still to be developed—a significant issue for aquaculture, wild fisheries and the future management of genetic resources within the Basin.

Policy promoting aquaculture is implemented within each country by government institutions that support extension, research, education, and training. Thailand and Viet Nam have invested considerably more resources in aquaculture, but Viet Nam has an ambitious plan to support capacity building and extension for aquaculture. Research support has traditionally focused on technical issues and less on formulating and implementing farmer-driven research agendas, while extension has largely been prescriptive rather than farmer-needs based. Awareness of the need for more participatory approaches is growing. The shift from technology transfer to supporting and empowering farmers and rural households will take time.

Extension support is critical to the success of aquaculture and there are a considerable number of institutions providing such support, including government and non-government agencies. A feature of extension in the Basin is the relatively small population compared to the number of farmers. Without access to appropriate extension and inputs, aquaculture will continue to suffer setbacks (see box "Targeting women in aquaculture extension").

1.2.3. Aquaculture and the Environment

Aquaculture development interacts closely with the environment and success depends heavily on environmental goods and services. Small-scale ponds throughout the region are an example of the aquaculture contribution to environmental improvement. They store water during the dry season which can be used for livestock, watering vegetables or as a domestic water supply. They also provide a means of recycling nutrients and organic matter. As part of a small household livelihood strategy, the pond is an important asset.

Environmental conditions, mainly due to natural climate changes, have significant effects on aquaculture. In Lao PDR, most fish ponds are seasonal as a result of a six-month dry season. As the

ponds dry up, water temperature becomes a factor in production. At the other extreme, monsoon rains can cause rapid flooding and serious losses of fish. Recent floods in the Delta caused extensive damage to aquaculture operations, although household losses were offset by a corresponding increase in wild catch.

Human environmental changes also affect aquaculture. Disposal of toxic waste into shared river and canal systems by upstream users can have devastating effects on household ponds downstream. This is of particular concern in the highly populous Delta and in parts of the Korat Plateau. Potentially damaging wastes for aquaculture include pesticides, tannery and sugar processing effluent.

Exotic and indigenous fish species

Aquaculture in the Basin relies heavily on introduced species (carps and tilapias). Consumers, however, often prefer indigenous species and government policy is now promoting aquaculture of more local species. One argument for using indigenous species over exotics is to reduce potential risk to basin biodiversity from alien species that escape into the wild during floods. Another concern is the creation of indigenous/exotic species hybrids. While favouring indigenous species is a positive move, the initiative needs to be accompanied by an effective broodstock management strategy incorporating genetic concerns.

Culture of predatory fish species

There is some concern over the culture of predatory fish, particularly snakehead and catfish cage culture in Cambodia and Viet Nam. Estimates suggest that up to 300,000 tonnes of trash fish are used to feed catfish. Implications of the use of such large quantities need further investigation.

Collection of fish juveniles from the wild

The majority of fish seed comes from hatcheries, although some species, such as catfish and snakeheads in Cambodia, giant prawn in Viet Nam and a few other species such as sand goby are collected from the wild. In Viet Nam, recent successes in catfish breeding have led to more farmers stocking hatchery reared catfish seed. In the Delta, prawn post-larvae are increasingly supplied by hatcheries as demand rises. Wild capture of juveniles has been banned in both Viet Nam and Cambodia but the ban has had limited impact. From the information available, there is no evidence that juvenile collection is a wasteful use of the resource.

Water pollution from feed

In semi-intensive farming, the water and sediments from fertilised ponds can be recycled efficiently for use on agricultural crops with limited environmental impact. Water pollution can occur where there are dense concentrations of intensive farms. Large-scale cage culture where wastes are discharged directly into natural water bodies without treatment can cause localised water pollution. Cumulatively, this could lead to a general deterioration of water quality and more frequent outbreaks of fish disease.

Fish disease

There have been a number of disease outbreaks in the Basin and it is likely that such problems will increase with more intensive aquaculture. While the occurrence of large-scale outbreaks has been rare, there are occasional serious outbreaks and low level health problems are a constraint in small-scale pond culture. These problems represent a threat to future expansion but can be mitigated by improved diagnostic and extension services.

CONSUMPTION, PROCESSING AND MARKETING

1.3.1. Consumers and Markets

Inland capture fisheries and rice are the basis of food security for the rural population. Fish is the single most important source of animal protein and rice, in the form of carbohydrates, the most important source of energy. With a total inland fisheries production from wild capture fisheries, reservoir and aquaculture of approximately two million tonnes (and given approximately 60 million inhabitants), the average per capita fish consumption surpasses 30 kg per year. Exports and import of marine fish into the Basin add to the ambiguity of this figure but hardly change its magnitude.

This average figure is supported by detailed field surveys indicating a consumption of around 30 kg per capita per year in the mountainous areas of Luang Prabang, an area where fish consumption would be expected to be low, and consumption of around 71 kg per capita per year in the Great Lake Tonle Sap area, where high consumption would be expected. A consumption rate of 70 kg per year is among the highest in the world and is found in only a few countries like Japan, Norway and some island communities in the Pacific Ocean. In contrast, the average annual consumption of fish in the United States is 15 kg per year.

In many parts of the Basin, fish is a part of any meal if a household has the means to acquire it. During lean seasons, dried or fermented fish products are used in place of fresh fish. Fish sauce is a staple used by most households all year round. A meal may at times consist only of steamed rice with a little fish sauce or fermented fish and some vegetables.

The consumption of traditional dried and fermented products in Lao PDR and Cambodia, amounts to 10-14 kg per capita per year, a figure from surveys carried out by the MRC Fisheries Programme. This is nearly one-third of total fish consumption. With a consumption of approximately 14 kg (fresh fish weight) around the Great Lake Tonle Sap, dried and fermented products seem to complement fresh fish consumption rather than compete with it.

Aquaculture products are becoming more common in local fish markets, particularly in Viet Nam and Thailand. Markets determine the success of aquaculture, and products from capture fisheries have a strong influence on local markets. Cultured fish have two major advantages: they can be marketed live which provides a fresher product, and they can be marketed when there is insufficient wild fish supply and market prices are favourable.

Most of the products produced from aquaculture are consumed in the Basin or nearby markets. There are some exports, the most notable being river catfish from Viet Nam. This species has a growing market in the United States and Europe as fillets. Attempts to develop the tilapia market for export have generally not been successful. So far, value-added to cultured fish is limited. Wild fish tend to be dried, smoked or fermented. By contrast, aquaculture is more focused on growing a premium fresh product and harvesting when needed.

1.3.2. Fish Products, Their Use and Nutritional Values

From late November when the major fish migrations out of the floodplains begin, until late March-beginning of April, fish is abundant and the fresh fish price is low. When the rains start in May or the beginning of June, fish become scarce in most places and prices at urban markets increase steeply. Traditionally, this has led to an increased production of dried, salted and fermented fish. These products, with a storage life of six to nine months at the high ambient temperature of the region, represent for many families the most important protein supplement to their rice-based diet

Targeting Women in Aquaculture Extension



Women are involved in all aspects of fisheries in the Mekong

Women actively participate in many routine aquaculture activities, including daily pond fertilisation, fish feeding and selling. However targeting women in aquaculture extension is problematic because training activities and meetings often take place at times when women are busy with household activities. Women may not be able to travel easily between villages and do not have long periods of time available to attend training. Importantly, men in poor rural households are more likely to work away from home. Recognising these factors, The Rural Extension for Aquaculture Development (READ) component of the MRC Fisheries Programme arranged training at times and locations that encouraged the involvement of women and children in all fish culture activities, including record keeping, training, fertilising, feeding and farmer

progress meetings. We considered the active involvement of women essential to ensure sustainability of the results of the project.

Women's Associations in Viet Nam were extremely keen to be trained in fish culture activities. 3,477 women (34 percent of the total) were trained by READ in appropriate fish spawning, nursing and grow-out systems from 1998-2001. From August 2001 onwards, READ adopted a policy of training one woman for every man. Fish seed production, both breeding and spawning, are activities that are highly suited to women's involvement, especially if the production site is located near the homestead.

In addition, 215 key staff (21 percent women) from various formal and informal extension agencies at the community level were given two days instruction on basic small-scale integrated aquaculture systems, including livestock-crops-fish and rice-fish. These key staff, with some support from the Provincial Fisheries Extension Centre of Tien Giang Province, have since trained 225 rural people (33 percent women) on integrated pond culture. At one Women's Association meeting, integrated fish culture followed a presentation on HIV-AIDS prevention.

The women trained under the informal small-scale integrated aquaculture project are continuing to train other rural people even though READ has ended. The use of women farmers as trainers is a good example of women's ability to successfully engage in aquaculture.



A young woman on the family fish farm

during the rainy season (see box "Traditional fish products: the milk of southeast Asia"). These strong tasting products have gained a place in national cuisines as a much-appreciated ingredient all year round.

The variety of traditional fish products is enormous. Although there are several main groups of products, production varies from province to province and often from village to village. The most important products comprise the following groups:

Dried fish: Surplus catches of fresh fish are sun-dried after some pre-treatment. The smallest species may be dried whole with larger species being first eviscerated, headed, split or filleted according to size to ensure the fish dry before spoiling. Salt may be added before drying but rarely to any appreciable extent. Sugar is added to some fairly high-value products, for instance, dried, salted and smoked snakehead fillets. In some places, fish are dried over an open fire, adding a smoky taste. Smoked fish familiar in many temperate countries is not well known. The product may not stand up against heat, bacteria and insects for a long time.

Fermented fish: *pra hok* in Cambodia, *pla ra* in Thailand and *pa daed* in Lao PDR are salted and fermented products that have become symbols of their national cuisine. When bumper catches of small to medium-sized fish are taken during the main fishing season, considerable quantities are used in this production. The production methods vary according to locality and tradition. The fish is dressed, often headed and partly or wholly eviscerated and mixed with salt. After some days, it may be further treated, for instance, filleted or cleaned and packed in airtight containers. Salt and carbohydrate is usually added to lower the pH and thereby increase the storage life and add to the taste. The carbohydrate may be in the form of cooked rice or other grains or fruit. The taste is strong but very much appreciated in the local cuisine. Among the widely famed areas of production are the banks of the Tonle Sap River in Cambodia and the Songkhram River Basin in Thailand.

Fish Sauce: Fish sauce is the traditional form of adding salt to food. Salt as used in western cuisine is not normally offered at a meal. Fish sauce forms part of almost any dish in the Lower Mekong Basin. For the production of *nam pla* in Thai, *teuk Trey* in Khmer, *nam pa* in Lao, and *nuoc mam* in Vietnamese, small fish are salted and kept in closed containers for months. From inland waters, this is often some anchovy or freshwater sardine species. In some production methods, cooked rice is added to feed the fermentation. After three to six months, a clear brown liquid forms which is then saturated in salt and filtered off as the first grade. More water is added to the residue for production of a second or third grade product. Fish sauce is also produced from marine species and Thailand has developed a considerable export trade in fish sauce to the other countries in the region. Traditionally, production is in inland areas where small fish species are available.

The role of fish as the most important source of animal protein in Southeast Asia goes undisputed. Many species have a high content of vitamin A. This is needed to prevent and treat a widespread deficiency causing eye infections and blindness among a high number of people in the region. Particularly, the eyes and entrails of certain species are high in vitamin A. Identification of species most suited as sources of vitamin A is still ongoing. Fish are also an important source of iron and zinc. Other wetland species including frogs, crabs and edible insects are less well known as a source of nutrition.

1.3.3. Marketing

The bulk of fish catches taken by small-scale farmers and fishers are consumed locally or traded fresh at village, district or provincial markets. Storage time from catch to consumption is short and usually little or no ice is used or needed. Some of the more robust species are marketed live. Ice is in widespread use in Thailand and southern Viet Nam for storage and for transport to large cities. With the growth of towns and the development of transport infrastructure, the use of ice is expected to expand.

Domestic markets are the most important. Fish species in the Mekong, as in other parts of the world, are often particular to a river basin and little known elsewhere. This limits their export potential. Other species, the sand goby for example, are widely known and highly priced in Asia and have a huge export market in Singapore and Hong Kong. Tilapia may, as an internationally known species, have market potential outside the region, but as it is not a highly priced species, the transport costs may be a limiting factor. River catfishes (*Pangasius* spp) from Viet Nam are one of the few local species groups to find an export market, mainly in countries where Vietnamese immigrants have settled. Recently, a considerable export market has developed in the USA where the marketing of catfish from the Mekong seems to have benefited from the already established market for the American catfish of the Ictaluridae family.

There is considerable trade in fish within the Mekong Basin and its neighbouring catchments. Fresh fish from the Great Lake Tonle Sap in Cambodia is exported to Thailand in large quantities. River fish, including river catfish juveniles for cultured grow-out, are finding their way from Cambodia southwards into Viet Nam. A lively trade is taking place between Thailand and Lao PDR, with Lao traders sending high valued species over the river to Thailand, receiving in exchange tilapia and other species. *Pra hok*, the fermented fish product from Cambodia, is highly valued in large parts of Thailand and is exported together with some high quality dried fish products. The quantities traded across regional borders are not included in national statistics.

1.3.4. Human Health Aspects

The important role of fresh fish and traditional fish products is accompanied by a number of health hazards. Puffer fish (family Tetraodontidae) provide a dramatic example as they are highly poisonous. They are, however, easy to identify and generally well known by professional fishers. Still, fatal poisonings occur from time to time. Far more significant and less visible is the high frequency of parasites in freshwater fish that can be transferred to humans during part of their life cycle. One of these is the widespread liver fluke (*Opisthorchis viverrini*). The adult liver fluke is an 8-10 mm long trematode. The eggs are passed in human faeces. When ingested by a particular snail, the eggs hatch and the second stage of the parasite is born in the snail. The parasites later develop free-swimming cercariae, tiny organisms which leave the snail and enter freshwater fish beneath their scales. They encapsulate themselves in the muscle tissue of the fish as metacercarial cysts less than one tenth of a millimetre in diameter. If the fish is eaten raw or not sufficiently cooked, the cysts develop in the body of the human host and the cycle is completed. The liver fluke causes very serious illnesses that can be fatal. Fresh fish, when well cooked, present little danger.

Many fish species can carry the liver fluke, among these several from the family of Cyprinidae. Fish from still water in reservoirs, swamps and fish ponds are in particular prone to parasite infections and the people living around these water bodies are the most exposed. The liver fluke is only one of the dangerous parasites found in fish. The extent of the problem is not fully known, but a recent study carried out by FAO in collaboration with the Lao Department of Livestock and Fisheries and the Centre for Malariology, Parasitology and Entomology (CMPE) in Vientiane indicates the order

Traditional Fish Products: The 'Milk' of Southeast Asia



Small fish are nutritionally important

calcium content in the raw foods used in Southeast Asian cooking, and on new studies of the absorption of calcium from small fish that are consumed whole. Contrary to what was once believed, calcium from the bones of small fish is easily absorbed by the human body. Small fish and traditional products from fish and other aquatic animals are the common food items with by far the highest calcium content. A few examples will illustrate:

Calcium content in mg per 100 g:

Polished rice: 0-14	Shrimp paste: 1,564
Tamarind: 148	Frogs: 2,164
Small eggplant: 158	Fermented fish powder: 2,392
Soybeans: 245	Dried small fish: 4,960
Small fish: 813	

WHO and FAO recommend a minimum daily intake of 400-500 mg calcium for adults, and 500-700 mg for adolescents. A modest daily intake of fresh or dried fish easily supplies these amounts.

Increased milk consumption is often recommended for optimum growth



Processed fish products

Fish means more than animal protein in a diet. It also means calcium, which is important in human nutrition and needed in substantial quantities for skeletal growth of young children. It is also necessary for the growth of the foetus, for lactation and for prevention of brittle bones (osteoporosis) in the elderly.

In Western countries, milk is the most important source of calcium. Milk is not part of the traditional diet in the Mekong or in most Southeast Asian countries, so where do Asian people get their calcium? The answer is mainly from small fresh fish and traditional products made from small fish. This conclusion is drawn from a study of the



Part of the catch in a fine-mesh gill net

in children. While there is no reason to doubt that this will work for many children, there may be easier ways to achieve the same result. As milk is not a part of the traditional diet in rural areas in Southeast Asia, it may be difficult to incorporate into the local cuisine. It is relatively expensive and many young people and adults who have not consumed milk since early childhood, have lost the ability to digest the lactose (milk sugar). Consumption of traditional dried and fermented fish products can supply similar amounts of calcium at a substantially lower cost, and has done so for centuries. It may be worth promoting the consumption of these traditional products rather than replacing them with western-style foods.

of magnitude. Seventy four per cent of people living around a large reservoir in the Lao PDR were found infected with parasites, and of these 52 percent with liver fluke (*Opisthorchis viverrini*). Several other species of fish-borne parasites were identified through faecal analyses.

The spread of parasites is closely related to the traditional consumption of raw fish, which has increased in recent times as a result of the number of reservoirs and other permanent still water bodies. Combating this problem will require further studies of the extent of this problem and information campaigns to change food habits and improve hygiene. Some parasites can survive the processing methods used in traditional fermented or dried products. A study of traditional processing methods is therefore warranted.

Insects easily attack dried fish products. Fly maggots may develop in fish during lengthy drying periods in days or weeks with high humidity. Some insects seem to thrive on all kinds of dried fish, although fewer on slightly salted or smoked products. Although insect infestations may not be hazardous to health, they can produce considerable losses for the producers or to households storing these products for later consumption. An effective but hazardous method of preventing insect infestations is to spray the fish with insecticides. It is obvious to many market goers that this practice exists, but to what degree, is not well known. Once the importance of fresh and traditionally processed fish products is realised, the need to address health hazards becomes apparent.

1.4. FISHERIES INFORMATION

1.4.1. The Role of Fisheries Statistics

From a medium-term perspective, fisheries are irreplaceable for food security and income creation in the region. The capture fisheries and their extraordinarily high productivity represent a huge opportunity for livelihoods in the region. This opportunity may be lost if development impacts on the ecological system (floods, habitat availability and inundation, migration) driving the fisheries production. Lack of knowledge of aquatic resources and their importance combined with negligence has, within a few decades, wiped out unmeasured riches for people living in other river basins and transformed rivers into little more than open waste water channels or dried out river beds.

Perhaps the first problem to address is the lack of information about the Mekong river system and the ecology that sustains its productivity. Reliable sector information is needed to preserve the fisheries sector and highlight its role in food security and income creation. The type of information needed depends on the stakeholders.

While not downgrading the importance of technical reports produced by fisheries scientists, in reality they reach only a narrow group of like-minded colleagues and lead to few changes. To be effective, the information generated from research must be understood by the stakeholder in relation to their needs and concerns. Information has to be presented in formats suitable for each stakeholder group. Four main stakeholder groups include:

- ✦ Politicians, professionals in national planning agencies and the National Mekong Committees are not necessarily acquainted with the characteristics of the Fisheries Sector but are setting priorities in national and regional planning. People in this group need to understand the importance of the fisheries sector in the national economy and to have access to information on how it is influenced by developments in other sectors. Reliable fisheries statistics are an important part of this information.

- ⚡ National Fisheries Agencies are the traditional counterparts of the MRC Fisheries Programme. These are the people who implement the Programme through their institutions and staff. These people need the information created by the Programme in a timely and well-presented manner—and more of it in their national languages.
- ⚡ Sectors dependent on water resources need data on fisheries to evaluate the possible effects of their activities on the fisheries, to assess the overall cost-benefit of their activities and to plan their future activities.
- ⚡ The general public is a critical constituency. Unless the public understand the value of fisheries resources, management systems will not be viable. Government priorities reflect public interests.

Biological and socio-economic surveys are the basis for the production of various kinds of information. These surveys are the basic material for development of local and regional fisheries management systems; impact assessments of water management projects; development of extension systems; and inputs to the creation of popular knowledge.

Fisheries statistics are the basis for any assessment of the economic importance and overall impact of major policy decisions on the sector. Generation of these data requires a specially designed system involving routine collection of selected data and processing for specific aims and target groups. It is widely recognised that most of the current techniques for fisheries statistical data collection and processing do not provide accurate information.

Inland fish production is included in national statistics of the four MRC member countries. In 1991, official statistics registered an annual fish production of 356,000 tonnes, including 8-10 percent coming from aquaculture. With a population then estimated at 50 million, this translated into an average per capita fish consumption of 7.2 kg per year. The most recent estimate of total fish production is close to two million tonnes with an average per capita consumption around 30 kg per year.

The main reason for the difference between these figures is that new data collection methods have been used to include small-scale fisheries. A distinction between farmers and fishers is very difficult in the Mekong Basin. There are very few full-time fishers and very few farmers who do not fish in rice fields or in nearby wetlands and streams. A huge variety of traditional large and small-scale gear exists, which is well adapted to the different species, habitats and seasons. In Cambodia alone, the MRC Fisheries Programme has catalogued more than 170 different types of fishing gear. Small-scale production figures, the biggest part of the total catch, are not reflected in the national statistics because this production is not registered by traditional data collection methods.

It is obvious that the traditional marine fisheries method of quantifying fish production through collection and analysis of catch and effort data is not applicable to a seasonal small-scale fishery in floodplains and rice fields with hundreds of different gear types. It is also clear that exclusive registration of more visible large-scale fisheries will only target a fraction of the real production. This is a dilemma for countries with large inland fisheries. Under traditional data collection methods only large-scale fisheries in major reservoirs and rivers and outputs from large aquaculture programmes have been registered as these are the fisheries which contribute to government revenues through taxes and license fees. More accurate data are crucial for the purposes of shifting the focus to food security for the rural poor and getting the sector included in the national and regional economic planning.

The MRC member countries, in cooperation with the MRC Fisheries Programme, have produced estimates using a number of data collection methods. While large-scale fisheries may be registered directly, consumption surveys have proven more efficient in recording the total production in small and family-scale fisheries. This method includes recording of traditional salted, dried and fermented products. These surveys are accompanied by biological surveys, which reveal information on individual fish species, their habitats and migration routes—vital information for the development of fisheries management systems.

Though the new estimates have been generally accepted by national fisheries agencies, the much larger figures have yet to enter the official statistics. The old low figures continue to be disseminated for official purposes because the new estimates are not compatible with the existing methods of collecting information. Fisheries production data are usually collected monthly or quarterly and always province-wide. They are sent to the national statistical bureaus where they are processed and disseminated together with statistics from other sectors. There are no channels for submission of overall national annual production figures and no way of breaking down the new overall figures in a way that can substitute or even complement the existing data on a monthly and province-wide basis. There is little possibility of introducing consumption surveys as the routine official methods of collecting production data through provincial and district fisheries and agriculture officers. National and regional institutions recognise the dilemma. A request to the MRC Fisheries Programme for assistance in establishing a better statistical system has been ongoing since the start of the Programme.

The main problem is that a new method has to cope with representative data sampling in a floodplain area and in small-scale and family-scale fisheries. The consumption surveys used for creation of the new data require considerable effort and expense. The approach may serve well as a survey carried out every five or ten years but it is not suitable for routine data collection.

A second issue is to define in greater detail the objectives, target groups and scope of an inland fisheries statistics system. A minimum 'need-to-know' approach may help ensure that the most important information is collected with a sufficient degree of accuracy and at the lowest possible cost. This alone would be a huge step forward in available fisheries information at a macro-level. Once established, such a system could be expanded to include more detail on species, value, product, operator and other parameters.

A third issue concerns enabling national statistical agencies to operate such a system in a sustainable manner on a basin-wide scale in cooperation with other national fisheries and non-fisheries systems and with the international organisations involved.

The underlying assumption is that a suitable data sampling system, tailor-made for the administrative area under consideration, can be developed over a reasonably short period and can be expanded to cover the entire Lower Mekong Basin.

Local Ecological Knowledge in Fisheries Research

Mekong communities have always depended on the fisheries resources in the river. As a result, they have accumulated a large body of ecological and biological knowledge about these resources. In many places along the Mekong, communities have established management practices, including limitations on fishing gear types, seasonal limitations and conservation zones in order to ensure that fish are harvested sustainably.

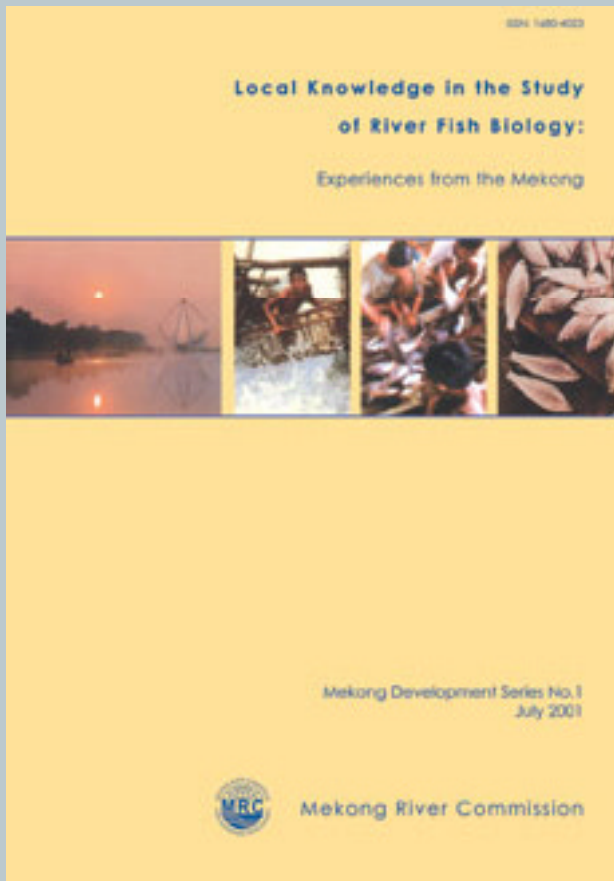
Since 1997, the Fisheries Programme of the Mekong River Commission has been accessing local knowledge in some of its basin-wide ecological research activities. The objective of this research was to obtain life-cycle information about important Mekong fish species, particularly in relation to migration and spawning. Local 'expert' fishers were interviewed and have provided a large amount of information on the nature, location and timing of fish migrations and spawning behaviour. By merging information from different areas along the river, migration routes and essential habitats have been identified.



Expert fishers sharing their ecological knowledge



Using photo flip-charts to identify fish in local ecological knowledge surveys



This research demonstrated that by accessing local knowledge it is possible to obtain vital information that could not be obtained using conventional biological research techniques. Although local knowledge on its own cannot provide all the answers about the functioning of a large and complex ecological system such as the Mekong, it can provide a solid foundation for basin-wide planning and decision-making. Furthermore, information obtained through local knowledge can help focus future research, management and monitoring activities.

Future development and resource management in the Mekong River basin will be successful only if local communities are involved in the planning and management process. As part of this process, the knowledge that exists within these communities must be taken into account.

SECTOR ANALYSIS

CHAPTER 2

2.1. DEMAND

Preliminary calculations suggest a demand of around 2,440,000 tonnes of fish and other aquatic animals in the Lower Mekong Basin in ten years. Thus, an additional 440,000 tonnes of aquatic animal products will be required just to maintain consumption at the present level. These estimates need verification through more detailed analysis but they provide an indication of the magnitude of this issue.

The demand for aquatic products can be met in several ways. Capture fisheries may still increase—although there is emerging consensus that there is a limit to expansion of yields. Stocking and harvesting fish from reservoirs and aquaculture will contribute to the supply and more fish will be imported into the region as infrastructure improves.

In practice, the fisheries target almost all species in the Mekong River and its tributaries. Stocks are extensively exploited except in areas with low population densities. Reliable fishery statistics for gross production are generally unavailable as well as data for individual species. Limited time series data for better-documented parts of the fishery do not extend beyond the longer-term natural cycles. Establishing trends in the species population is therefore rather speculative.

The limited data available suggest that the overall catch level has been maintained and is quite possibly increasing. Historical data from various sources show an increase in catches in line with the population growth. This is supported by recent catch estimates based on per capita fish consumption. Catch data collected over a six-year period from indicative Mekong fisheries show no evidence of a general decline. The data do show correlations between catches and variations in water levels with greater total catches in years with higher water levels and heavy flooding.

Preliminary data analyses suggest that catches per capita from floodplains in central Cambodia are close to those obtained in the same resource system in the more densely populated adjacent Delta. This does not indicate a fishery in decline but rather that there may be potential for increased catches in more lightly fished areas. In Northeast Thailand the fishing pressure has increased substantially over the last five years as a consequence of the reverse urban drift caused by the economic crisis of 1997 but no subsequent decline in total catches has been reported.

The available figures refer only to gross production. Catch per unit effort is declining and it is likely that there have been serious declines in the stocks of some larger, slower reproducing migratory species. Populations of the non-migratory and the smaller migratory species are still being sustained.

Are the fish resources of the Cambodian Mekong overfished? Yes and No!



Fishing barrage on the Tonle Sap River in Cambodia

The high intensity of fishing operations in many parts of the Mekong River Basin has supported a general impression that the system is overfished. This impression is strengthened by anecdotal evidence from many fishers who claim that their catches have been decreasing over time. Fishers perceive the decrease in catch-rate as “overfishing”.

In fisheries management, the term “overfishing” refers to a situation where the same amount or more fish could be taken with less fishing effort. Usually we speak of overfishing when dealing with a single species fishery. In the Mekong, we have more than 120 species traded, and virtually every type of fishing gear catches many different commercial species.

In reality, the overall catches in the Mekong are higher now than in the past, although individual catch rates have declined, because the increase in population and the number of fishers has outstripped the increase in catch.

The 1940 and 1995/96 data for the Tonle Sap Great Lake region illustrate this. The fish catch refers to all species caught. Overall, there is no “overfishing” and if fishing pressure would increase further, we would expect the catch still to increase a little bit. However, at a species level, the situation is more complicated, as is discussed below.

Tonle Sap Great Lake region.

Changes in population size and fish catch between 1940 (Chevey and Le Poulain, 1940) and 1995-96 (MRC data).

Period	Cambodian population	Fishing commune inhabitants (11.2 % of total pop.)	Increase in population	Great Lake fish catch (tonne)	Increase in fish catch	Fish catch per fishing commune inhabitant per year	Decline in catch per fishing commune inhabitant
1940	3.2 million	0.36 million		125,000 t		347 kg	
1995-96	10.7 million	1.20 million	3.3 x	235,000 t	1.9 x	196 kg	44%

1. “White” fish (about 60 percent of total catch)

These are long-distance migratory species. Annually, migrations take place between the spawning areas in the Mekong in southern Lao PDR and northeastern Cambodia, and the feeding/nursery grounds in the floodplains around the Tonle Sap, south of Phnom Penh and in the Vietnamese Mekong Delta and back.



Sorting the catch

- ⌘ **Large and medium sized fish species** tend to spawn later in life. Many species have significantly declined, some nearly to extinction. Examples are the famous giant Mekong catfish. This catfish is reported to spawn only after reaching a weight of at least 160 kg (Mengumpan *et al.* 2001), which is perhaps at an age of six years or older (Rainboth 1996). Clearly, very few individuals survive the heavy fishing pressure long enough to reach sexual maturity. Thus, the later in its life that a species first spawns, the more vulnerable it is to overfishing.
- ⌘ **Smaller fish species** usually are early spawners. Most stocks have not declined and they dominate present catches. A good example is the cyprinid, *trey riel*. It spawns for the first time when about one year old. It could be fished more intensively and still not be overfished.

2. “Black” fish (about 40 percent of total catch)

These are the short distance migratory species. Movements of members of this group are much more limited, e.g. from flooded forest to lake/river and back. Stocks have probably not declined, as these fish do not run the same gauntlet of fishing gears as do the long-distance migratory species. Snakeheads are the most important species group. They spawn in the flooded forests and are the most valuable part of the catch of the Great Lake fishing lots.



Hauling in a catch of fish from a dai fishery unit

Conclusion:

The overall tonnage of fish caught in the Mekong system is still increasing. A number of larger species are overfished, but most smaller species are not overfished at all. However, due to the reduction of larger fish species in the catch, and the shift to smaller sizes, the average value per kg has decreased. Thus, not only has the catch rate per fisher dropped, the value of the catch has decreased as well.

Multispecies river systems cannot be intensively exploited without loss of the larger elements of the fish population, which are less abundant and reproduce slowly. When fishing effort increases, the pressure on the large and medium-sized fish species may be above what provides the maximum

sustainable yield of these species, but the yield from other species and the total fisheries may be still increasing. Species usually do not become extinct from excessive fishing pressure and the potential for fish productivity does not diminish as long as the natural habitats remain intact and the average level of flooding remains stable.

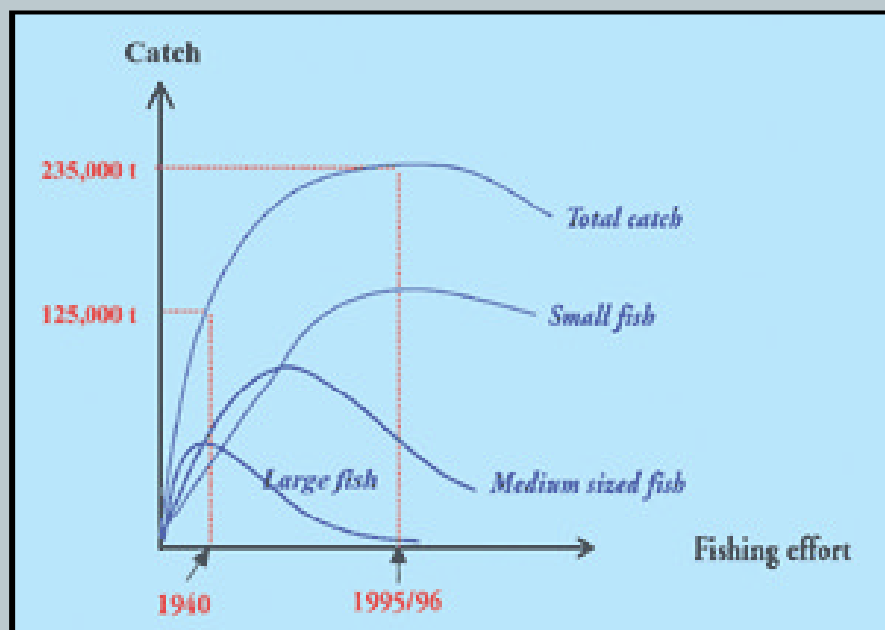


Illustration of the fishing-down process : in 1940 the Tonle Sap Great Lake region catch of 125,000 tonnes consisted mainly of large and medium sized fish, while the 1995-96 catch of 235,000 tonnes contained hardly any large fish and was strongly dominated by small fish.

2.2. CAPTURE FISHERIES MANAGEMENT

Fishing in the Lower Mekong Basin is likely to increase due to population growth and ease of access. This may result in an increase in the overall catches, at least up to a certain point. This increase will be accompanied by a continued decrease in the prevalence of the larger slow-growing migratory whitefish species in the catches. Some species may already be depleted, at least locally, to the point of effectively disappearing from the catches (see box "Are the fish resources of the Cambodian Mekong overfished? Yes and No!").

From a food security point of view this development may be acceptable even if the value of the catch decreases because large species fetch a better price per kilogram. However, the partiality that people throughout the Basin have for the larger fish species, not to mention the almost cult-like status of the giant Mekong species, would make it desirable to most stakeholders to mitigate the decline in biodiversity where possible.

To reverse or even slow this decline will be difficult and will require coordinated management interventions at many levels. The migration pattern of these fish suggests a spatial separation of the various stages in the life cycle often over great distances. Communities which control the breeding and nursing habitats may not benefit from catching the adult fish and may not be inclined to protect the habitats. Under such circumstances, management interventions at the provincial or national level may be required. If protection of feeding or refuge habitats in the local area would lead to an increase in catches of the species in question in the same area, management interventions may be left with the local community. Where migration routes cross national borders, stock management becomes a trans-boundary issue and requires international collaboration.

With the adoption of policies on decentralisation of fisheries management, MRC member countries have taken important steps towards vertical integration of management interventions—a prerequisite for efficient management of migrating stocks. However, for interventions to be successful it is important that all involved parties share a common understanding of the issues regarding conservation and development of fish resources and of cause and effect relationships involved. This may be a less daunting task than it first appears. Recent experience has shown a high level of agreement between local ecological knowledge and fisheries science.

Another positive development is that all member countries have taken a co-management approach to decentralisation of fisheries management. Mechanisms are now being established throughout the Basin for dialogue between local resource users, government authorities, scientists and other stakeholders on management needs and methods. Legal bodies are also being established which allow resource users and government authorities to share management responsibility for fish resources and habitats.

At the regional level, the 1995 Mekong River Commission Agreement states that the signatories shall: "co-operate in all fields of sustainable development, utilisation, management and conservation of the water and related resources". At the activity level, the Agreement refers, amongst other issues, to the development of rules for water use and a Basin Development Plan to categorise and prioritise projects. Both programmes should incorporate management considerations for the Basin's trans-boundary fish stocks. In the short term, the emphasis might be on developing appropriate procedures for co-operation at the international level in harmony with national and local management initiatives. The best opportunities are with the high profile migratory fish species such as the giant Mekong fishes and the vulnerable habitats such as the flooded forests and the deep pools where a consensus already exists on the need for action.

For the non-migratory blackfish species there is no indication at present that future increases in fishing effort will lead to decreased catches or reduced catch diversity. This assumes that the integrity and spatial extent of the habitats in question are not compromised. The decentralisation of management responsibility to the community and adopting co-management approaches may prove the most appropriate for management of these fisheries, as cause and effect may be observed and controlled within the local community boundaries.

2.3. RESERVOIR FISHERIES

Construction of reservoirs in Thailand has declined because of low economic returns on irrigation schemes in recent years. However, the number of small village ponds has increased. It is expected that fish production from small reservoirs will increase with improved local level management. In Lao PDR a major hydropower reservoir is planned on the Nam Theun River, Nakai Plateau in Khamuane Province. No other reservoir construction is planned in the near future. The output from existing small reservoirs is also expected to increase with improved local level management.

In Viet Nam, reservoir construction in the Central Highlands is expected to continue to serve agriculture and flood control needs for a growing population. Reservoirs are also needed to provide a reliable supply of fish. The policy target is to double fish production from reservoirs by 2010. This goal will be partly achieved by improved management of existing reservoirs (see box "It's co-management or no management").

2.4. ECOLOGICAL INFORMATION NEEDS

In general, researchers now have a reasonable understanding of the Mekong Basin ecology. However, there are certain gaps in our knowledge that remain to be filled.

- ✧ Understanding the sub-populations and to what degree they overlap is crucial for the delineation of management units (stocks). For many of the species studied it has been possible to hypothesise the existence of sub-populations at least on a basin-scale. One method that could be used to clarify this issue is population genetics research. This should be considered a priority.
- ✧ For certain species (e.g. the river catfishes) little is known about spawning sites or spawning behaviour. Some are believed to spawn in deep sections of river channels. One conspicuous example for both population genetics and spawning biology is the giant catfish. In terms of population genetics the main question is whether this species encompasses two sub-populations—one in the lower Mekong (south of the Khone Falls) and one in the upper reaches (i.e. up stream from Vientiane) or whether it consists of one single population distributed throughout the whole Mekong Basin. Spawning is believed to occur somewhere upstream from Chiang Khong/Bokeo but the exact location, the spawning behaviour and habitat requirements of this species are unknown.
- ✧ Inter-connectivity of essential habitats is not well known especially for the long-distance migrants where spawning areas can be very distant from nursery areas. Knowledge of adult migrations is increasing, but larval and fry migration studies have begun only recently.

It's Co-Management or No Management!



Effective management arrangements are needed to ensure the survival of species such as the giant barb. This fish was released alive. It was 1.62 m long and weight 86 kg.

Co-management has been a common feature in fisheries development in the Mekong Basin for more than thirty years. A survey carried out by members of the MRC Fisheries Programme (Phounsavath *et al.* 1999) revealed that co-management initiatives have been very practical in their approach, and the outcomes are positive. The cases analysed show that co-management does most of what is normally done in any other type of fisheries management. Problems addressed are similar, as are measures proposed and activities carried out. However, *how* this management is done is different: With co-management, user community members are increasingly accepted as equal partners in the decision-making process.

Co-Management is not a new concept in the LMB

Though not necessarily known under the name of "co-management" the concept of user involvement in management is quite common in the LMB and, in some cases, goes back many decades. National governments in all the four riparian countries of the LMB have policies and legislation that aim at strengthening

shared decision-making of natural resources - and thus "co-management"!

Are all fisheries co-managed?

Fisheries co-management in the LMB has many forms and characteristics. It may even seem that all fisheries are co-managed in one way or another, as no resource management system is isolated from the users. Knowingly or unknowingly, fishers operate within a framework of national legislation and policies; similarly, while the legal and policy framework is formulated at the top, rules and regulations are ultimately implemented (or not!) by resource users on the ground. However, for analysis and planning purposes, a more specific description of the concept is needed.



Natural resource management involves all user groups

The MRC Fisheries Programme has suggested the following "working definition" of co-management: *A formalised process of sharing of authority and responsibility by government and organised user groups in decentralised decision-making aiming at improved - since participatory and democratic - resource management.*

It should be kept in mind, though, that the degree of formalisation and sharing varies from case to case. Thus, co-management covers a wide spectrum of management forms and styles between the two extremes of totally government-based and totally community-based management. These forms of

management include: *instructive co-management* with minimal information exchange between the partners; *consultative co-management* where users are consulted prior to implementing management measures; *co-operative management* where government and users work together as equal partners; *advisory co-management* where users recommend management measures to the government agencies concerned; and, finally, *informative co-management* where overall management authority is delegated to resource users.

Co-management outcomes are generally positive

Out of thirty co-management initiatives surveyed, nine cases were analysed in more detail. The analysis revealed the following.

- ✦ The main problems addressed through co-management are: declining fish abundance and over-fishing, under-employment, destructive practices in key habitats; and resource conservation.
- ✦ Important co-management measures focus on: habitat and resource protection and enhancement; resource and management system research; and resource use co-ordination between competing users.
- ✦ Co-management activities undertaken to obtain the desired results are: stock and habitat enhancement; resource and management system research; fishery regulation; technology development and credit; licensing and access restriction; and awareness creation. Typically, co-management initiatives combine two or more of these activities.
- ✦ While all examples report positive outcomes, the following results are most frequently mentioned: increased fish production and enhanced stocks; improved information on the state of the resource and its management; improved awareness, stewardship and management capabilities of users; and increased income, particularly village income for investment in community utilities.
- ✦ Thus, co-management does most of what other fisheries management mechanisms aim for, but with a difference: government staff and fishers work together! Expected effects are legitimacy of rules, regulation compliance, efficient management, lower implementation costs of management systems, increased popular participation and democracy.

Co-management initiatives need support



Managing fisheries can be complex

Important elements for an enabling fisheries co-management framework are in place in the four riparian countries. Foremost among them is the intention of all governments in the LMB, as expressed in legislation and policies, to decentralise decision-making to administrative levels closer to where natural resource management takes place, and to devolve some of it to local user communities.

Organisational and legal multiplicity and competition between participating government agencies, and unclear definition of community rights and duties, is a common feature in all the countries in the Basin. Similarly, there is a general lack of security of property rights in natural resources. This leaves many co-management initiatives characterised as "ad hoc approaches" rather than sustained and widespread strategies, and dependent on a situation of "legal and administrative tolerance". The result can be a downgrading of the legitimacy of user-based solutions in the eyes of decision-makers at various government levels.

Technical assistance projects can make a number of direct and indirect contributions to co-management development and implementation. Pilot projects can be undertaken in different areas to test and further refine concepts of participatory management of allocated resources under different ecological and socio-economic conditions. Communities face material, technical and institutional limits in developing new management and production systems. Thus, natural resource co-management needs livelihood development and improvement, in order to stimulate the self-help capacities of local users. In particular, the provision of credit through small revolving funds has been a catalysing factor for participatory resource use planning based on locally identified needs, as well as for leadership formation. And finally the provision of training of villagers and government staff alike at various stages and levels of the partnership, is important in ensuring the successful implementation of co-management initiatives.

- ✂ Quantitative data on fisheries yield by species and by habitat is required. Although more and better information now exists on the total fisheries yield of the Mekong system, there are very few quantitative data by species and by habitat.
- ✂ Economic valuation is still limited. There is little reliable information on the size and value of exports, in particular the relationship between fish yields (by species) and habitat types. Better understanding of such relationships will be crucial in implementing measures for habitat protection.
- ✂ Macro-habitat requirements are known for a few species in broad categories such as floodplain habitats and deep pools. However, micro-habitat requirements are unknown for most species. For example, even if it is known that a certain species lives in deep pool habitats during the dry season, the habitat features that the species require within the deep pool (type of substrate, vegetation, depth, slopes, current etc.) are unknown. Such micro-habitat requirements determine types of pools certain fishes prefer and indirectly determine other ecological characteristics including migration patterns.
- ✂ Feeding biology for most species is related to the micro-habitat issue since availability of food (for example on the floodplain) determines the preferred floodplain micro-habitat.
- ✂ There is a need for detailed socio-economic studies on the functioning and resilience of traditional fisheries management systems, as well as the functioning of co-management fishery systems recently established by local initiatives.
- ✂ More information is needed on the trade of fish and fish products within the Basin and exports and imports to and from the Basin.
- ✂ More information on species interactions and inter-relationships is needed.

There may be an opportunity for improved integrated planning between capture fisheries and other sectors, especially aquaculture. As natural resources come under stricter management control, the borders between culture and capture fisheries become blurred or non-existent. This is especially so as capture fisheries become enhanced through culture-based activities (stocking). It would be

unproductive to sustain a continued and artificial division between these two sectors when joint planning could improve the circumstances under which various forms of aquaculture might be promoted in a region where capture based activities will remain dominant for the foreseeable future.

One of the major threats to sustaining capture fisheries is environmental degradation arising from the activities of other sectors. Better governance is the only solution and has to include better approaches to integrated planning for natural resources management. Achieving this goal will not be easy. Worldwide, those sectors (or indeed countries) have tended to separate resources in river basins, particularly water, through unilateral planning. This has generally left downstream users to deal with problems caused upstream, with fisheries being at the bottom of the hierarchy of influence. Until recently this has been the trend in the Mekong region but there are encouraging signs that things are changing and real opportunities are emerging.

An example is the Mekong Agreement of 1995 including subsequent strategic plans whereby four countries of the Lower Basin pledge to develop the Basin with sustainable livelihoods, poverty reduction and maintaining ecosystem integrity as cornerstones of development. Recent recommendations by the World Commission on Dams promote similar principles for dam planning. Notably, this was prompted largely by documented impacts of dams on fisheries (see box "Some impacts of a dam on the Mekong fisheries"). However, there remains much to be done at the technical level in terms of implementing these and related principles.

The developed world has few examples of how to sustain river ecosystems. However, much attention has recently been given to river ecosystem restoration, which, in essence, is natural resources planning in reverse. Working technologies are now emerging including integrated aquatic resources management planning, which may have significant potential use in the Mekong.

Two developments could significantly reduce or even eliminate the constraints. First, the true value of water should be reflected in costing development activities. This would force development planners to factor into project design consideration of the impacts of their activities on other water users. Second, existing water resources users (including users of wetlands) should be given legal rights over their use. These changes would significantly improve the rational economic base for decision making in natural resource allocation. For political reasons, neither is likely to occur in the near future. However, legal rights for users is well established for river fisheries in developed countries (mainly for recreational uses which have very high economic value) and has been responsible for halting, in some cases reversing, the harmful impacts of other resource users.

The fishing lot system in Cambodia is not far removed from this concept. It requires only clarifying the legal status, long-term ownership and establishing an effective legal infrastructure under which those who cause damage can be sued. The basis for legal instruments enabling users to seek compensation from other countries for trans-boundary impacts already exist under the 1995 Mekong Agreement.

A more attainable short-term goal is to promote changes to land classification systems, which are the basis for both natural resources planning and asset allocation. The current system suffers from a bias toward dry-season agricultural uses of land. It appears that legal systems are ill equipped to deal with assets undergoing dynamic changes especially for seasonal wetlands. Wetlands rarely have any legal status and are usually regarded as open access areas during the flood season. Converting these areas to agricultural use would not necessarily be more efficient biologically but it would enhance people's security of access and ownership. The legal status of wetlands and related institutional limitations are already recognised as constraints in achieving sustainability of natural resources.

Some Impacts of a Dam on the Mekong Fisheries

Dams cause major changes to rivers and their ecology, and have been the most significant cause of declines in many wild fisheries on all continents.

A dam's most obvious effect on fish is interference with fish movements. Many river fishes migrate upstream to breed, so a dam may form an insurmountable barrier to adult fish. For species that migrate several times in their life, the adult's return migration is also hazardous, over a spillway, or through turbines, or into diversion channels. Similarly larvae and juveniles, which would normally drift downstream to disperse and grow on floodplains, may be trapped in a reservoir, diverted, or injured or killed in transit through turbines or spillways.



Dams can alter downstream water quality

Fishways have a generally poor record in mitigating such impacts, as they are often poorly designed, and do not mitigate the impact of the barrier on returning adults, larvae and juveniles. In addition, it is impossible to design one fish ladder that can cater for the different biology (e.g., swimming speeds, endurance, urge to move upstream) of the multitude of fishes in a species-rich river such as the Mekong. A range of other mitigation measures, in addition to fishways, may also be applied, but it is always preferable to avoid building dams on any main fish migration routes.

A second major issue is the impact of dams on water quality. Most dams that are more than about 10 metres deep stratify, that is, a layer or stratum of warm water, which is less dense, overlies a layer of colder denser water for much of the year. The oxygen in the trapped bottom layer is consumed by the decomposition of organic material, which then decays anaerobically and produces toxic substances, including methane and hydrogen sulphide. Under such conditions bottom sediments may also become sources of metals, including iron and manganese. The bottom layers of the reservoir may be toxic to aquatic organisms, and if the water is released, it may kill fish and other organisms for many kilometres downstream.

Moreover, when surface waters cool in winter (November–December in the Mekong Basin), the colder water sinks; the bottom water is then displaced to the surface, a phenomenon known as overturn, during which fish kills may also occur. Fish kills downstream of dams, and in reservoirs due to winter overturn, have been reported from several large dams in the Mekong Basin. Mitigation includes destratification within the dam, aeration measures downstream, multi-level offtakes, and vegetation clearance prior to dam construction. However, to date there has been little mitigation of such water quality impacts for Mekong Basin dams, with ongoing negative impacts on fisheries.

Dam projects usually aim to modify hydrology. Abstraction of water for other uses competes with its use for fisheries. Often wet-season water is stored for use or release in the dry season. As fish production in the Mekong depends almost entirely on inundation of the floodplain (which fish must access for several months of the year), any reduction in the extent of flooding will directly affect fish production.



Nam Ngum hydropower dam, in the Lao PDR

Water releases from hydropower dams are often for short periods to provide peak power. The downstream environment is subjected to daily flushing, a situation which cannot be tolerated by most aquatic species, and which can also be extremely disruptive for riverside communities using the river for fishing, transport, irrigation, washing and so on. But, pulsed releases from hydropower dams can be mitigated by, for example, a suitably large regulating pond downstream of the main dam.

Dams have many other impacts on fish and fisheries, including changes in habitat, changes in the aquatic food chain, increases in the prevalence of exotic species and diseases, increased salinity from evaporation and abstraction, trapping of sediments needed on the downstream floodplain and delta, and effects on the fishers and their communities.

These impacts and the costs of their mitigations and management should all be properly assessed in environmental assessments if the Mekong is to continue providing its benefits to dependent communities. We need to learn the lessons from other large rivers, where in general, the value of fisheries to downstream communities has been underestimated. There has been inadequate planning of dam projects to reduce impacts, and little attention given to monitoring, managing and mitigating impacts once dams are built.

The technical details of integrated natural resources planning can be complex. In the short-term, the level of detail required should not be overstated. The aquatic resources sector is well placed in that impacts of activities occurring via water can be expressed and tracked spatially (e.g. mapped in relation to river flows and wetlands). The Geographic Information Systems (GIS) technology offers a very powerful tool for resources management planning, especially on a basin-wide level. Much progress has been made in recent years in GIS applications to natural resources management and there are significant opportunities in applying the technology further in fisheries planning.

Planning considerations are mostly the same at the local and basin-wide level. Differences centre largely on the stakeholders involved and the scale of the planning. Perhaps the most significant progress recently has been made at the Basin-wide level. All three MRC core programmes (the Water Utilisation Programme, Basin Development Plan and Environment Programme) focus on improving capacity for integrated resources planning with the objective of generating technically based policy advice. These three programmes are central to the prospects for sustaining the Mekong River fisheries.

The fisheries sector should not be entirely defensive in response to the impacts of other resource users. There is much scope for enhancing the positive impacts of other sectors on fisheries through proactive involvement in planning. Traditionally, the fisheries sector has been a rather passive exploiter of the aquatic environment. However, water management opportunities are changing. Elsewhere, inland fisheries are becoming increasingly dominated by enhancement activities, in particular environmental modification to boost fisheries production or facilitate access or exploitation. In many tropical rivers, although in more complex management systems than the Mekong, water is actively managed to improve fisheries output. Mekong River fisheries managers have yet to begin to exploit such opportunities.

2.5. AQUACULTURE

2.5.1. Recent Developments

The past ten years has seen an almost 5-fold increase in aquaculture production from around 60,000 tonnes in 1990, to 250,000 tonnes in 2000. Continued expansion of aquaculture will contribute significantly to meeting the anticipated demand for fish products in the coming decades, although the difficulties in meeting anticipated demand are considerable.

Aquaculture, capture fisheries and reservoir management should be considered as a holistic system. Concentrating policy and development efforts towards aquaculture, as an 'easy option' for fish production, without taking proper care of the wild fisheries could result in a dramatic loss of wild fisheries resources, with food security implications for the entire Lower Mekong Basin, particularly for poor people. Similarly, aquaculture and fisheries are strongly influenced by the development of other sectors. A balanced approach to fisheries development is required.

Aquaculture can have the greatest impact on rural households in areas with food insecurity and limited wild fish supplies. The approach to supporting food security and livelihoods should be based on identifying these areas and supporting local area development, which may be aquaculture or wild fisheries activities or a combination of both (see boxes "Fisheries production and a growing population" and "The Mekong prawn: a new indigenous resource?").

2.5.2. Future Development

Farmers involved in aquaculture will market some of their product; more commercial aquaculture farms will sell their entire product. The development of aquaculture is strongly influenced by market demand, particularly in local markets. The market demand will, to some extent, depend on the availability of consumers who can pay the price, often US\$0.75 to US\$1.00 per kg or more. Rural per capita income in some areas is commonly in the range of US\$120 to US\$150 per year. This may limit the scope for aquaculture development in some areas, and closely tie it to development of infrastructure and urban expansion.

Small-scale farm households make individually small but cumulatively important contributions to aquaculture production throughout the rural areas of the Basin. Aquaculture contributes to income through the sale of fish while ponds provide food. The recommended approach is to emphasise small-scale aquaculture for rural households, promoting equitable participation in aquaculture production within the Basin. This approach can contribute to food security for poor households, poverty alleviation and rural development. Emphasising large-scale commercial export-oriented aquaculture without attention to the small-scale sector may lead to inequity in rural development and environmental problems.

Technologies

The technologies for small-scale freshwater aquaculture have been largely put in place over the past 10 years—a major achievement in itself. The technologies that work best for poor rural households can be characterised as low investment and low risk. They provide a quick return, are simple and easy to copy, contribute to local fish seed supply and are easily extended. These technologies may include ponds, nursing fish in hapas in common water bodies, fish grown in rice fields and even simple cage culture. These technologies should be integrated into the existing rice-based farming systems predominant in the Basin.

Inputs

Aquaculture requires a number of important inputs, in particular, sufficient fish seed, fertilisers, feed, land area and water of suitable quality. Institutional support and services such as credit and extension are also required.

The availability of good quality seed has increased substantially in the past ten years, especially in Thailand and Viet Nam where there has been significant hatchery and nursery development in both the public and private sectors. In Cambodia and Lao PDR many ponds remain un-stocked, often because local fish seed is unavailable.

Aquaculture growth as a sector requires a significant expansion in hatchery and nursing capacity. The centralised large government hatchery model has not been successful. Development of local small-scale hatcheries, hapa nursing, nursing and trading networks and on-farm breeding will be more effective in supporting rural, small-scale aquaculture development.

Species to be cultured

Culturing fish that eat low in the food chain allows farmers to use locally available feed inputs and is ecologically more efficient. The bulk of existing aquaculture production is from fish that eat all feed types (omnivores) and from plant eating indigenous and exotic species. Stocking a variety of fish species (polyculture) fully uses different available natural feeds. There is a preference in many rural areas for indigenous species and development of indigenous species for aquaculture should be continued. Culture of fish eating species, such as snakeheads, should focus on improving the efficiency of feeding systems, ensuring that fish diets do not contain wild fish that are consumed by poor people, making efficient use of fish protein and reducing pollution loads to the environment (see box "Indigenous species for use in aquaculture").

Feed and fertilisers

Feeds and fertiliser inputs will initially come from on-farm sources, although as many rice-based farms are constrained by lack of inputs for aquaculture ponds, intensification will require off-farm inputs. Rice bran and animal manures will be major pond inputs but other inputs are available depending on local resources and use of inorganic fertilisers. Inputs are likely to be diversified and the situation will change with time as some farmers will specialise depending on resource limitations. Geographically, inputs are more easily available in Viet Nam and Thailand. A more detailed analysis of future trends and needs for different feeds would be useful for planning.

Fisheries Production and a Growing Population



Children hoping for a bountiful harvest in the future

Recent studies of the capture fisheries in the Lower Mekong Basin indicate landings of 1.5 million tonnes of fish annually (including other aquatic animals, such as shrimp, frogs and mussels). This makes the Mekong one of the most productive inland fisheries in the world. Aquaculture and reservoir fisheries are estimated to contribute additional 260,000 and 240,000 tonnes, respectively. With a population of some 56 million, the total fisheries and aquaculture yield corresponds to an estimated per capita fish consumption of 36 kg per year (assuming that exports equal imports).

The annual population growth rate of the region varies from less than one percent in Northeast Thailand and Vietnam to 2.9 percent in Lao PDR, for an overall weighted average of 1.45 percent. Assuming a constant growth rate, this translates to a population increase of about 33 percent over the next 20 years (about 75 million people by 2020). Traditionally, most of the animal protein consumed is from fish, and it seems likely

that fish will preferentially fill the future food requirements. To maintain the present consumption pattern it will be necessary to increase fish production at the same rate as the population growth, or to fill the gap with imported fish products. The latter is unlikely given that imported fish products will be too expensive for the bulk of the population.

The capture fishery of the LMB is likely to be close to being fully exploited. Its importance now and in the future cannot be overemphasised. The fishery is spatially dispersed, and a large segment of the riparian population rely on capture fishery for their livelihood. Fishing requires relatively little investment and it provides quick returns. Moreover, the fishery is accessible to large parts of the rural population, and thus serves as a fallback when other occupations fail. The cost of replacing this essentially-free resource with another source of food, income and employment would be prohibitive. With this perspective, it is clear that the conservation of capture fisheries is crucial to maintaining food security and social stability. There are some opportunities for increasing the efficiency of the utilisation of products from the capture fishery, but these will not keep up with the rate of population growth.

Aquaculture production is growing in the Basin, and it has been suggested that it will cover the increasing demand for fish. Assuming that the capture fishery and/or import of fish do not increase substantially, an increase in aquaculture production of more than 600,000 tonnes would be required in



A young fisherman learning the trade

2020 to sustain the present rate of fish consumption. Population growth and general development is expected to bring increasing demands on land and water resources. Therefore, an increase in aquaculture production will probably only be possible through intensification of the culture systems. Intensive culture systems require diets with high protein and fat content, which may come from marine fish or more likely from Mekong "trash" fish. Feeding cultured fish with "trash" fish (traditionally processed and consumed by humans) from the capture fishery, will lead to a net decrease in fisheries production, since losses will occur in the energy transfer. Fish produced in such intensive systems will be relatively expensive, and unless the wealth in the Basin increases sufficiently, a large portion of the cultured fish may be exported for luxury consumption elsewhere.

So-called low-input aquaculture will be able to fill some of the increased demand in the near future, particularly since many parts of the Basin do not yet have access to the inputs, infrastructure and marketing systems required for intensive aquaculture, and because there is a general lack of know-how. Low-input aquaculture requires relatively more land and water resources, which in the longer term is likely to become a constraint. The profits from such systems are relatively low, which in a developing economy may make them less attractive in comparison with alternative systems. The main argument for low-input aquaculture is increased ecological efficiency since the inputs are usually from low levels in the food chain, using for example farm by-products. Development of aquaculture feeds based on protein and oil from plants could eventually lead to low-input aquaculture systems transforming into culture systems with production and profitability similar to the present intensive culture systems.

The required increase in fish production needed over the next generation to maintain the present rate of fish consumption in the Mekong Basin appears unlikely to be provided by aquaculture systems in their present forms. The capture fishery has some potential for increased landings, provided that the environment is not overly degraded by development activities, and that smaller species are used for human consumption.



Fish for the future

Water and land

Water of sufficient quality and quantity is a must for aquaculture. Most small-scale aquaculture ponds in the Basin are rain fed and aquaculture success can vary from year to year depending on rainfall patterns. Use of water is not likely to be a constraint with rain fed ponds, but in irrigated farming areas or areas with multiple use of water, other considerations may arise. Water quality is a concern for future aquaculture development. Ponds in several parts of the Basin have turbidity and productivity problems due to poor soils and inappropriate management practices. These problems can be addressed through adoption of better water quality management practices. In more open farming systems, such as cages or culture of fish in rice fields, water pollution can also be a concern. Integrated pest management (IPM) offers considerable scope for improving rice and fish yields while reducing pesticide use and should be explored more aggressively. In cage and pen culture located in open access waters, more attention is needed on environmental management and planning as well as potential conflict with other water resource users.

Land availability in some parts of the Basin may be a constraint. Rice land in many areas can be used for pond construction. However, pond construction in some areas such as the upland areas in Lao PDR will be an issue since flat land is scarce and is used mainly for rice cultivation. The approach should be to ensure that aquaculture adds value and promotes diversity and more efficient economic use of land.

2.5.3. Constraints

There are several constraints to the development of aquaculture that will have to be addressed. Many of these are institutional rather than technical. The existing capacity and resources of government institutions for participatory extension and research is relatively weak and manpower is limited. Therefore, capacity building is required to support this approach. New partnerships going beyond traditional fisheries or aquaculture extension are needed. The policies to support an integrated approach to aquaculture and fisheries are not yet in place. There is a need to develop enabling policies to support the approach, but this will take time.

Environmental risks and degradation of the natural resource base are a major threat to aquaculture development and fisheries. Aquaculture is affected by natural disasters, aquatic animal diseases, possibly by introduction of exotic species, loss of genetic diversity through poor genetic resource management strategies and water pollution. Management strategies need to be put in place to deal with these issues, including joint approaches among MRC member countries to address common problems.

Cross-sectoral coordination and cooperation has always been difficult. Cooperation may be easier to achieve in cases where agencies are already working together at the local level.

Research

As the technologies for small-scale aquaculture are readily available there is less need to generate information on technologies. The emphasis should be on extension of existing knowledge. Capacity building will be essential to implement new integrated development approaches and support local institutions to manage and provide aquaculture development services, particularly in addressing farmers' needs. New research agendas will evolve through more farmer-driven approaches. Regional research issues include the following:

- ✦ Diversification of rice farming systems and integrated pest management including economics and livelihood impacts of farming options and practices

Indigenous species for use in Aquaculture



Harvesting a village pond

Relatively confined water bodies, such as small to medium sized reservoirs, and swamps and backwaters, may be stocked to enhance fisheries production. This is particularly applicable in productive fisheries with high, but controlled, fishing pressures. The main constraint may be availability of suitable stocking material. However, stocking should only be done with progeny of parental fish that have not been genetically selected for aquaculture purposes. Stocking of domesticated strains

The supply of fingerling fish is a constraint for aquaculture development in many parts of the basin, both for high-value and low-value species. For several indigenous species (which generally speaking are the high-value fishes), domesticated strains are not available, and aquaculture relies completely on wild caught seed. Thus there is a need for work towards domestication of indigenous species for aquaculture purposes.

The present widespread use of exotic species for aquaculture presents a risk to biodiversity and capture fisheries when cultured fish escape to the wild, which is virtually unavoidable. The risk is particularly high in conjunction with general environmental degradation due to dams, habitat loss and so on. The use of exotic species in aquaculture should, over time, be discontinued and instead suitable indigenous species should be farmed.



Snakehead fishes, prized in aquaculture



A family pond is an important source of income

of indigenous species should be avoided, as the domesticated strains may affect genetic variation in wild populations and biodiversity. In some areas, there is a high dependence on stocking with exotic species. As with aquaculture, stocking with suitable, indigenous species should be encouraged and over time, stocking with exotics reduced, and preferably, discontinued.

- ⚡ Development of indigenous fish aquaculture including information on genetic issues that will influence policy development
- ⚡ Efficient use of feed and fertiliser resources including bio-economics research on the use of wild fish to feed predatory fishes
- ⚡ Poverty-focused aquaculture systems including micro cage culture systems and prawn culture
- ⚡ Environmental management of intensive aquaculture systems such as cage culture
- ⚡ Reducing risks to rural livelihoods from aquatic animal diseases

Extension

A major constraint to improved extension is the lack of extension workers. This means that alternative options for support will have to be used. In Lao PDR, partnerships between local government and farmer groups, fry traders and nursing networks are effectively used for extension. Farmer extension groups show considerable promise for self-help. Use of non-traditional means of extension will be necessary including the use of mass media.

The emphasis for aquaculture sector management should be on extension of knowledge and building of institutional support for rural households where there is potential for aquaculture. There is evidence that the major impediment to poor people's entry into aquaculture is lack of effective targeting based on assessment of poor people's needs and understanding of their constraints to entry. Involving poor people requires a shift in extension services away from technology towards a more flexible people-centred participatory approach to extension and research supported by favourable policies, institutions and processes that make aquaculture an attractive option for poor people.

Reorganisation will likely involve different partnerships (e.g. private sector-NGO-Government), increased use of mass media and experiments with new approaches. Human resources at the local level can be more actively engaged.

Government agencies tend to focus on aquaculture activities located near urban centres due to accessibility, private entrepreneur involvement, higher input availability and access to markets. In the future, emphasis should be on farmers. Focusing support on small-scale aquaculture and poorer rural households will provide the necessary balance to more commercially oriented aquaculture. Extension workers will also need to develop participatory people-centred approaches rather than purely technical aquaculture skills.

An important constraint for poor people is access to capital inputs such as credit. In Lao PDR and Cambodia the credit systems in rural areas are undeveloped and difficult to access. They are better developed in Thailand and Viet Nam. Credit should be analysed as part of the process to support farm households entering aquaculture. The special difficulties faced by poor households should be recognised and addressed.

National issues

Supporting local capacity and adopting new approaches will require policy change. Aquaculture and capture fisheries policies are different. Aquaculture policy is more about extending information and is easily defined. Capture fisheries policy is likely to be more focused on co-management. Policy development at the national level is needed to support local institutions, processes and general governance that support farmers. There is certainly room for further development of policy and management of aquaculture as experience with new approaches is gained. There are also considerable opportunities to share experiences in policy development within the Basin as all MRC countries are working within this changing environment.

2.6. AN APPROACH FOR THE COMING DECADES

The development of aquaculture to date has been driven by a sectoral approach. A shift in approach is now required. The promotion of aquaculture should take food security and poverty alleviation as a starting point for interventions. It should identify and overcome constraints to entering aquaculture by building capacity in local institutions. Integrating aquaculture into fisheries projects and wider rural development strategies would produce a more balanced approach. The catchment approach provides an opportunity to apply an integrated holistic planning process.

2.6.1. Marketing, Processing and Consumption

The Mekong Basin fisheries sector has enormous economic and nutritional potential. No alternative source of animal protein is as readily available as fish. The development of aquaculture will contribute substantially to the increased demand for fish. Qualifying assumptions are that capture fisheries production is kept at a continued high output and that aquaculture techniques and species selection will not have adverse effects on the wild fishery.

The other important opportunity within the fisheries sector lies with its potential role as an economic accelerator. Fish is traded across borders in unknown and unregistered volumes. Expanding this trade (and making it taxable) seems to present an opportunity for economic development. Most locally abundant Mekong fish species are well known and are potential products for inter-basin trade. Trade will require development of infrastructure including cross-border road connections (a process already well underway at the initiative of other sectors), increased use of ice in long-distance fish transport (to limit presently assumed high fish losses), and the revision of laws and regulations on border trade to ensure quick passage.

China, Indonesia and Malaysia represent potential markets. Malaysia and Indonesia once formed part of a continent where the Mekong River ended its flow and many Mekong River fish species are familiar in these two countries. During colonial times a large export of inland fish and fish products reportedly took place from Cambodia to Indonesia. This may have been a continuation of a dried fish export trade dating back to the times of the Khmer Empire of Angkor Wat. This market potential may still exist.

Overseas markets exist for a number of species that are widely known outside the Mekong sub-region. The sand goby, *Oxyeleotris marmorata*, has a large and lucrative market among Chinese consumers in Singapore and Hong Kong. This species is indigenous to the Mekong but its capture fisheries production is limited. It is, however, an obvious candidate for aquaculture. Intensive research is being carried out in the Mekong countries to solve problems encountered in the survival of the fish larvae at the early stages of the production process and to start commercial production. Other indigenous aquatic Mekong species may have important export potentials. Some of the indigenous Mekong freshwater shrimps, not yet cultured, may be among them. The river catfishes, *Pangasius* spp., which are now increasingly cultured from hatchery-produced seeds, may find a large market in the region in line with the growing market for this species group in the USA. Some gourami species may present similar opportunities. Other scenarios could be tested for developing aquaculture production of suitable indigenous aquatic species for export.

Value-added products such as frozen fish or retail packed fish fillets or fish portions may also have potential. Markets for these products will normally follow the restructuring of trade towards urban

supermarkets and the growth of a large consumer group in the urban middle classes. It will be some time before such scenarios will be a factor in the Mekong sub-region. Until then, the demand for frozen and partly prepared fish products can be expected to come from developments in the hotel industry and export to industrialised countries. The lucrative markets in Europe and USA may look very attractive to regional fish exporters, and for good reason. However, the requirements for food hygiene are very strict in these markets and this presents a major obstacle at present.

While export and high-value markets have a certain glamour, governments must not overlook more traditional fish products (crabs, frogs and water insects) and their role in nutrition. The conservation of important production areas like the Songkhram River Basin, the Tonle Sap River area and upstream areas, and other less well-known production centres is equally important. A policy to gather and disseminate information on the value of these areas and their products is also necessary. Threats to wetlands will rarely come from within the fisheries sector itself but may come from other sectors competing for the use of these highly productive water resources.

Cross-border trade will increase through the construction or improvement of strategic roads and the revision, amendment or enforcement of rules and regulations on regional and international fish trade. The development and extension of fish culture of Mekong species with a potential for export will need support from governments and international donors.

Expanded markets will have an impact on aquatic resources. Improved roads and increased trade will create additional demand and rising prices which will increase the pressure on fish resources. It is critical, therefore, that the establishment or strengthening of fisheries management systems goes hand-in-hand with market development. Without this tandem development there will likely be a short-term monetary gain followed by a collapse of the fishery. In many countries, exaggerated investments in infrastructure like harbours, cold storage and ice production facilities have led to over-fishing in an attempt to justify the economics of large production facilities. These industrial installations and human settlements around them pollute the resources on which they depend. The long-term effects of such development have almost always been negative.

Support to aquaculture for export will also have an impact on the resources needed for production of fish feed. In a sub-region like the Mekong Basin where small fish play an important role in human consumption there is hardly any surplus; the use of small fish for feed and production of fishmeal should be avoided. This means that aquaculture development should concentrate on species which are omnivorous or herbivorous and consequently do not need fish as part of their diet.

Information on a number of issues and a policy for national or sub-regional nutrition and health management is required to formulate a strategy for marketing and export of fish products. The role of fish in nutrition beyond that of supplying animal protein needs to be further clarified, and the importance of fish as a major source of calcium and vitamin A and other micro-nutrients further explored. A well-planned food and nutrition policy would help to improve the people's health through the maintenance and promotion of consumption of traditional fish products. A precondition to the success of such a policy is that the quality of traditional products is improved and that hazards from harmful parasites and chemicals are eliminated. This is not an impossible task but it requires a well-planned effort with basin-wide cooperation to determine the extent of the problems, to address them in an effective manner and to protect and promote the production of traditional fish products. This offers a low-cost approach to improved health and nutrition that does not exclude the low-income strata of the population.

Nutrition and food safety

- ✎ Understanding the extent of health problems related to fish-borne parasites and how they infect humans along with a strategy to address their spread
- ✎ Further clarification of the nutritional role played by fish and other aquatic products and their contribution to essential micro-nutrients in the human diet
- ✎ Understanding the nutritional and economic value of wetland products including crabs, frogs, water insects and plant products before they are altered or destroyed

Traditional fish products

- ✎ Data on the production of traditional fish products and information on the main processing methods and marketing channels
- ✎ Understanding the requirements for traditional processing methods to ensure the final products are free of live fish-borne parasites at any stage of their life cycle
- ✎ Understanding the impact of insecticides and other chemicals in the processing and marketing of dried fish and related products and a strategy on eliminating possible problems

Export and trade potentials

- ✎ More detailed surveys on how indigenous species may find overseas markets if cultured in sufficient quantity and quality
- ✎ Information on the present level of cross-border trade in inland fish and fish products between the MRC member countries and outside the region
- ✎ Determination of fish species with possible export potential which are free of parasites or which may be produced in a way that the risk of parasites has been eliminated
- ✎ A study of the potential impact of road improvement and other infrastructure on the cross-border fish trade along with an assessment of the resulting market development on the resource and needs for related resource management

2.7. THE NEED FOR INTEGRATED PLANNING AND REGULATION

The Mekong fishery is in reasonably good shape, unlike the situation in many other large river systems elsewhere. Slow-growing migratory fish species (with a few exceptions) are still being harvested in substantial quantities. Important fish habitats are still in good condition and exist on a large-scale. There is no indication that this fishery has reached its maximum annual yield. Indeed, there may still be potential to increase the total market value of the fishery. However, this will require management at regional, national and local levels.

Policy makers in the Lower Mekong Basin are increasingly recognising the economic value of the Mekong River fishery and its importance to rural livelihoods. This recognition provides a strong incentive for central and provincial level management to support and promote initiatives aimed at sustaining or increasing fish production. Water planners and managers understand the importance of maintaining fish habitats and water management regimes that are supportive of natural fish production.

Over the last decade, considerable information has been collected on aquatic ecology, socio-economics and the aquatic resources livelihood strategies of rural households in the Mekong Basin. Much of this information can be found in existing databases. Other data can be found in a number of recent publications on Mekong ecology, biodiversity and fisheries. Supplemented by updated Basin water hydrology information and local ecological and social knowledge of resource users, these data provide a firm basis for informed decisions on the management of the Mekong fisheries (see box "Why is the fishery in Cambodia so productive?").

The last decade has also seen establishment of more enabling institutional environments for sustainable fisheries management. Most notably the Mekong Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin (5 April 1995) established an institutional framework for initiating joint management of trans-boundary fish resources. At the national level, new constitutional legislation in all four countries has paved the way for widespread user participation in natural resources management through co-management arrangements. These initiatives have made the Mekong fishery a leading example of sustainable natural resource management and have drawn the attention of international donor agencies keen to provide support to national, regional and local organisations and NGOs.

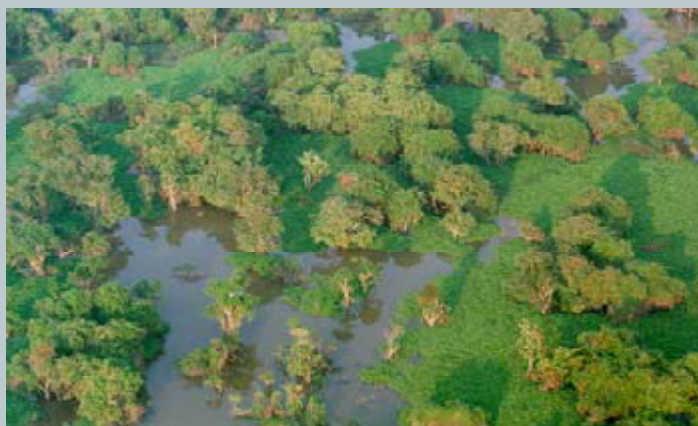
Reservoir fisheries can make a significant contribution to fish production. Stocking costs are generally low and returns on investment can be high. However, the environment in a reservoir is not particularly controllable. Weather and the demands of other water users (mainly agriculture and power generation) will influence success of these fisheries. The existing fish fauna and local livelihood strategies will have to be thoroughly examined. Stocking may be less rewarding in reservoirs with a diverse productive wild fish population.

There are serious threats to the development of Mekong fisheries from within and arising outside the sector. Threats include the use of destructive fishing methods and other unsustainable fishing activities including fishing in sensitive areas (e.g. spawning grounds) or at sensitive times (e.g. spawning periods). Destructive fishing methods such as use of poison and explosives are banned throughout the Basin as they are unselective and most often harmful to habitats and fauna.

Mass movement within a short period of time characterises the highly migratory stocks of whitefish. This makes them vulnerable to specialised and seasonally intensive fishing operations and promotes industrialised capital-intensive fisheries such as the barrage and bagnet (*dai*) fisheries in Cambodia. Requirements for returns on capital can exacerbate the problem of over-exploitation. The dry season migrations tend to be associated with breeding. Concentration of breeding populations at localised spawning sites increases the vulnerability of stocks to over-fishing. Observations from catch compositions show that catches of the larger species are diminishing and their average size is decreasing. This implies that the number of spawners is being reduced. It is unknown whether there has been an impact on recruitment in recent years. Fish larvae and fry studies have just been initiated.

Introduction of new species into the Mekong system through aquaculture poses a threat to existing stocks as escape of new species into the wild cannot be avoided. The increasing awareness of policy makers, aquaculture extension services workers and producers would help to reduce this threat. The same holds for the risk that diseases may spread to wild fish stocks from intensified aquaculture production.

Why is the fishery in Cambodia so productive?



Flooded forest habitat is important for fishery production

The primary reason for the enormous fish wealth in Cambodia is the annual monsoon rains and the associated inundation of vast areas of highly productive flood plain. The flood plains, in particular the flooded forest habitats, provide enormous quantities of food to support the huge

production of fish. Without the floods and the floodplains, the fish catch would be only a small fraction of what it is now.

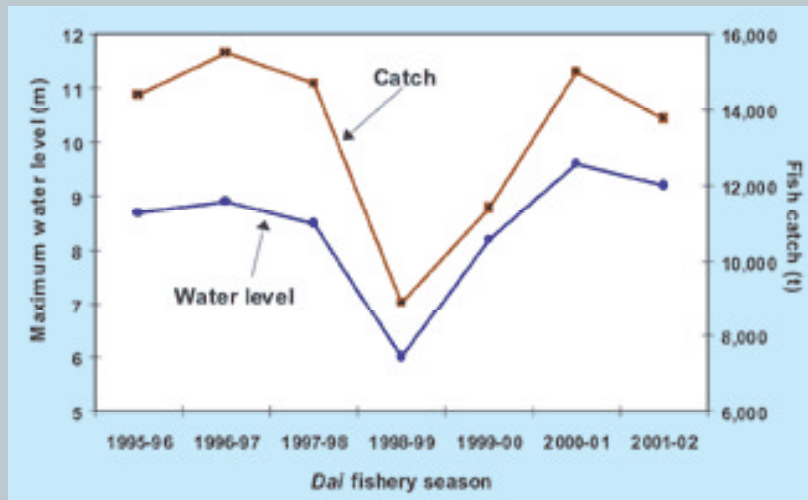


Six dai fishery units on the Tonle Sap River

Each year, the size of the Tonle Sap floodplain varies tremendously from the dry to the wet season. In the dry season, the Great Lake is only ca2,700 km², while in the wet season the lake grows to between 10,000-15,000 km². Thus, in a dry year (e.g. 1998/99), fish production is much less than in a wet year (e.g. 2000/01) since much less land is

inundated. This variation for the *dai* fishery is illustrated in the graph below. The relationship between the maximum flood level of the year and the fish catch shows that a permanent lowering of average peak flood levels due to flood control or other development, would result in a considerably lower fish catch.

Because fish productivity is related to the extent of flood plain inundation, any developments which may lower peak flood levels will be detrimental to the fishery. These include dams, irrigation, river canalization and water diversion for irrigation purposes. Similarly, the loss of natural floodplain habitats is detrimental. Hence, cutting or conversion of flooded forest to create agricultural land has a negative effect on fishery production.



Relationship between the maximum flood level of the season and the fish catch of the *Dai* or *Bagnet* fishery in the Tonle Sap river. This is a small fishery of 63 bagnet units (60 in 2001-02) targeting “white” fish migrating out of the floodplains around the Great Lake to the Mekong river.

The large-scale fisheries in the Tonle Sap Great Lake and River are truly magnificent. In the Great Lake, fences as long as a kilometre and arrow-shaped enclosures direct fish into traps. In the Tonle Sap River delta, in Kampong Chhnang, fish are caught by extensive barrages. In the lower part of the Tonle Sap River, just before it joins the Mekong near Phnom Penh, fisherman use enormous bagnets to trap



Living with the annual flood

fish. These large-scale fisheries take place in the fishing lots that have been leased to entrepreneurs by the Cambodian Government (see box on Fishing Lots). However, most of the 1.2 million fishers in the Tonle Sap Great Lake area are engaged in middle-and small-scale, or family, fisheries. A wide variety of gears are used in these sectors. Most fishers are living at the edges of the floodplain, but quite a number live on the Great Lake itself, in floating villages, or in houses located high above the flood waters on stilts.

Changes in the river environment and habitat have significant impacts on the fishery. Some of these include:

- ✧ Destruction of local spawning grounds or dry season refuges by habitat alterations (e.g. stream bed blasting, dredging, removal of rapids or siltation from removal or alteration of vegetation)
- ✧ Local changes in the quality and quantity of water available in sensitive habitats and the timing of hydrological events through local water management regimes and pollution
- ✧ Construction of dams, weirs or diversions which can act as physical barriers to fish migrations
- ✧ Increased sediment load due to deforestation is a water quality concern, particularly in the upper part of the Basin. In the Lower Basin, the high population density is a source of urban pollution.

Since the fisheries exploit most of the available aquatic biodiversity, threats to fisheries and biodiversity are inseparable. Changes in the biodiversity of fisheries resources are occurring or imminent but the underlying causes are not clear. Fishing pressure is increasing but environmental changes are occurring even more rapidly. Even where the effects of fishing are obvious it is not known if the situation is critical due to fishing effort alone or because other factors have exacerbated the effects of fishing. However, it is obvious that the resource cannot withstand the current exploitation levels combined with environmental degradation.

2.8. CATCHMENT PLANNING

The catchments approach has recently come into vogue as a management tool. A catchment or river basin bio-physical system can be defined as a topographically delineated area from which rainwater drains as surface runoff via a river or stream system and discharges into a large river, lake or reservoir. The catchment is the upstream land area segment of the entire river basin land area.

The Mekong Basin is one large catchment but each tributary also has its own sub-catchment. A tributary catchment can be further subdivided to the level of micro-catchment. This is shown in Table 1, which also identifies the corresponding management levels. Within a catchment, the complement of natural resources (water, land, fauna and flora) can be used for economic activities (agriculture, fishery, forestry, mining, hydro power, irrigation, tourism, infrastructure etc.) and social services (recreation, cultural activities, health etc.). The catchment is also an appropriate biophysical unit for environmental management (biodiversity conservation, soil erosion control, water conservation, pollution control, flood mitigation etc.).

Table 1. Level of management activities and their relationships with the scale of the catchment.

Management Level	Catchment Scale
Community and village	Micro catchment level
Sub-district	Small catchment level
District	Large catchment level
Provincial	Tributary river basin
National and International	Mekong River Basin

A catchment system as defined above consists of closely interrelated relationships of cause and effect. Effective catchment management, therefore, needs to be holistic in its coverage and interdisciplinary in its scope. Integrated catchment management is a participatory process that involves

both technical and policy initiatives to enable the catchment's natural and human resources to contribute to the following objectives:

- ✧ Increasing the marginal productivity values of natural resources
- ✧ Poverty alleviation and improvements of living standards
- ✧ Improved conservation of natural resources
- ✧ Improved water resources management

2.8.1. Integrating Fisheries

The Mekong River is the highway connecting the tributary basins and their habitats. It provides shelter and survival opportunities for a large number of fish species during the dry season when many wetlands dry out and fish migrate to deeper waters. Viewing the Mekong Basin this way makes it easier to understand the complexity of the resource system and to structure management and research initiatives. To manage the fisheries, fish species and their habitats must be identified along with migrations in and out of these areas. With knowledge of where the fish go and when, it becomes possible to coordinate management efforts between basins and across borders. The people in the catchment who earn a living from the fishery and other important stakeholders must be identified and their uses of natural resources understood. At the moment, we know this for only a few major Mekong River tributaries.

With this knowledge it will be easier to predict the effect of interventions from other sectors in the catchment on fisheries. The integrated catchment approach allows coordination with other sectors and implementation of fisheries management strategies, which aim to avoid or mitigate potentially damaging effects of developments in other sectors (see box "Modelling the Mekong fisheries: what can be done?"). Aquatic environmental impact assessments (EIAs) may be carried out in the early planning stage of water management projects and may include thorough assessments of the potential effects on local biodiversity. However, this is possible only if the species composition, habitats and migration patterns are well known in advance.

With important wild fish habitats mapped out, impacts from aquaculture escapees can be mitigated. A species policy can be developed for one or more catchments defining which fish species may be used for aquaculture in that area and which species should be avoided to minimise potential damage to the ecosystem. This might, for example, make it possible to prevent the spread of tilapia to parts of the Mekong Basin where it is still not present and to avoid it spreading to the Great Lake.

An efficient low-cost contingency plan for fish health management may also be established on a catchment basis. Plans should be prepared for the containment and treatment of fish disease including the prevention of trade in live fish and movement of fry and fingerlings from a catchment area where an outbreak has been detected.

When planning the construction of dams and reservoirs, the hydrological characteristics of the upstream catchment area should be examined. In a fisheries context, the reservoir also forms part of the catchment. Indigenous fish species may establish new migration routes upstream from the reservoirs and fish stocked in the reservoir to enhance production may easily spread downstream as the reservoir is an open water body. This makes it even more important to formulate a species policy for the catchment area and set up rules for potential mass releases of indigenous or exotic fish species that may have considerable effect downstream.

Modelling the Mekong Fisheries: What Can Be Done?

Modelling the fish resource and its exploitation in a system as complex as the Mekong River is a challenging exercise. First there are annual variations in the timing, duration and extent of flooding that strongly influence the natural fish production targeted by fishermen. Second, the fishing methods are very diverse (more than 150 types of gears), fishing is seasonal, fishing is distributed over an area of floodplains as vast as Ireland, and is therefore difficult to monitor. Third, data are scant and there are no long time-series. These constraints call for an innovative approach to fisheries modelling.

Modelling: what tools, what for?

Modelling, whatever the method, comprises several steps: definition of the modelling objective; definition of the system studied; formulation of a conceptual model; formulation of the mathematical and computer model; validation and application.

In the case of the Mekong fish and fisheries, we are presented with a complex case where the object of interest is poorly understood, requires research, and urgently needs sound management tools. Thus all the usually distinct aims of modelling are here simultaneously required: identification of critical questions; building of a conceptual framework synthesising the different perceptions of the various stakeholders; synthesis of existing knowledge and identification of knowledge gaps; production of simulation scenarios and provision of advice to managers.

Assuming that modelling fisheries is aimed at i) understanding the functioning of the system; ii) predicting the future of the fishery (fish and fishers) under different scenarios, and iii) providing sound advice to decision-makers, we briefly review here four categories of modelling: classical fishery modelling, ecological, Bayesian and multi-agent modelling.

Classical modelling approaches

Traditional fishery modelling

Common global and analytical models require data on harvested biomass (catch statistics), virgin biomass, catchability, fishing effort, growth, stock-recruitment relationships, etc. Such data are not available even for dominant commercial Mekong fish species, not to mention the hundreds of rarer species. These models also require long time series of data to encompass biological variability. Furthermore these classical fishery models have been heavily criticised for their simplistic initial assumptions, ignorance of social and economic factors, and general failure (Caddy & Mahon 1995, Beverton 1998, Holt 1998, Pitcher *et al.* 1998). For these different reasons a comprehensive and reliable model of the Mekong fisheries based on classical fishery models may be difficult to achieve in the near future.

Ecological modelling

Existing ecosystem models such as Ecopath or Ecosim (Christensen & Pauly 1992, 1993, Walters *et al.* 1997) require data on biomass of certain groups (e.g. phytoplankton, zooplankton, benthos, etc) and on related trophic flows that are simply non-existent for the Mekong system.

Similarly, individual-based ecological modelling has recently been subject to severe criticisms, mostly due to its extreme complexity and multiple underlying assumptions (Grimm 1999, Grimm *et al.* 1999).

Alternative modelling approaches

In a complex environment with multiple interacting factors (such as fish groups, fishers, farmers, dams, etc) equation-based approaches have limitations. Chief amongst them are feedback loops between factors and the lack of data for many interactions. Similarly, purely statistical approaches are also limited, as the number of variables and their interactions would require, for proper testing, an unrealistically large number of test sites.

Models based on computer simulations provide an alternative and recent solution to this problem. We present here two approaches, based either on Bayesian networks (Jensen 1996) or on multi-agents (Ferber 1999, Bousquet *et al.* 1999). In both these approaches, i) major interacting compartments of the system are identified; ii) a synthetic representation of the system is built; iii) interactions between compartments are characterised; iv) the consequences of a given management decision, based on the sum of interactions, is predicted.

Bayesian modelling

This modelling is based on variables representing the modelled environment. Variables can be quantitative (e.g. "Flood level") or qualitative (e.g. "Migrating species", "Subsistence fishers", etc). A variable is defined by classes (e.g. variable "Flood level" can be Low/Medium/High, or actual values can be entered when available).

These variables are connected together by links expressed in terms of probabilities (e.g. if variable "Flood level" is High, there is an 80% chance that variable "Fish production" is Good). These probabilities are defined in consultation with experts in the specific area (in our example, fisheries biologists and local fishermen), or from the scientific literature whenever possible.

The interactions between multiple variables consist in conditional probabilities, and the model calculates the trend resulting from the sum of interactions within the system. Different scenarios can be considered by modifying the variables, and sensitivity analysis can point out variables that are critically important.

Bayesian networks have been developed in the mid-90's to build Decision Support Systems. They are intuitive and easy to compute, making excellent tools for communication between stakeholders. They have been developed in particular for Integrated Natural Resources Management (Cain 2001), and are being applied to Mekong fish resources (Baran and Cain 2001, Baran and Baird 2001).

Multi-agent modelling

This modelling is based on "agents", or elements of the system, that interact together (e.g., rice field fishes, flooded forest fishes, professional fishers, farmers, etc). The action of one agent on another is transmitted to other connected agents depending upon their respective interactions. This includes diverse degrees of action and feedback loops.

Multi-agent frameworks have already been developed for different biological and management systems (Sichman *et al.* 1998, Moss & Davidsson 2000) and are being developed in Europe for freshwater integrated resource management (FIRMA 2000). Tropical river fisheries have already been addressed this way in the Niger inner delta (Bousquet 1994).

2.8.2. Integrated Planning

Integrated catchment planning is not reserved for fisheries. Hydrological models are always based on catchment considerations. More importantly, the Basin Development Plan under preparation by the Mekong River Commission will be based on catchments with scenarios for economic development. By applying the catchment approach to development and research the fisheries sector can communicate more easily with planners in other sectors and can present its values and potentials including how it may react to the plans of other sectors. The MRC Water Utilisation Programme will provide an important interface with the Fisheries Programme in this context. The prediction of fish yield will be connected to the extent of flooding and to the general development in the hydrology of the catchment. This adds a new dimension to the equation of effects of water management projects.

The MRC's Agriculture, Irrigation and Forestry Programme will be implemented through a catchment planning and development approach. By coordinating with the Fisheries Programme and the MRC Environment Programme, a true livelihoods focus can be pursued.

2.8.3. The Planning Process

The Mekong catchments vary considerably in terms of their natural resource base and their human resources. Local communities, districts, provinces and national government agencies may assign different priorities to different catchment basins according to their potential. Thus, catchment interventions should consider the different stakeholders' interests and aspirations and include mechanisms for preventing and resolving conflicts. There should be a bottom-up planning process that will include:

- ✧ Partnerships: People and organisations most affected by management decisions should be involved throughout the process and shape key decisions. This process ensures that environmental objectives are well integrated with economic development, stability and other social and cultural goals. The process also provides a mechanism for informing and incorporating the participation of all stakeholders in planning and implementation activities.
- ✧ Geographic focus: Activities are directed within specific catchments, typically the areas that drain into surface water bodies or that recharge or overlay ground waters, or a combination of both.
- ✧ Planning techniques based on science and data: Collectively, catchment stakeholders employ scientific data, tools and techniques in an iterative decision-making process including the valuation and characterisation of the natural resources and the communities that depend on them; goal setting and identification of environmental objectives based on the condition or vulnerability of those resources and the needs of aquatic ecosystems and the people within the local communities; identification of priority problems; development of specific management options and action plans; implementation; and evaluation of effectiveness and revision of plans as needed.

The challenge of integrated catchment basin management is to find ways to meet multi-criteria objectives. Variations among individual catchments in the Mekong Basin are numerous and complex. Some areas call for total protection for biodiversity preservation, wildlife or headwater protection. For most catchments, the ultimate goal should be the sustainable and equitable use of natural resources for economically productive purposes in ways that meet the requirements of those downstream for water and flood protection. This will require mechanisms based on assigned land-use and water rights and for allocating and enforcing these rights among competing sectors. This will in turn require the development and adoption of improved forest, crop, fisheries and livestock management practices that are both productive and sustainable.

THE LOWER MEKONG RIVER BASIN - AN OVERVIEW

The Mekong is a highly seasonal river with extensive floodplain areas. Floodplains cover approximately 70,000 km² (about 11 percent of the total area). The water level begins to rise in May-June following the onset of the southwest monsoon and attains its maximum height from August to October. The water level decreases rapidly until December and then recedes slowly until late April when the minimum level is reached.

The largest single water body is the Tonle Sap Great Lake in Cambodia. Its surface area expands from 3,000 km² in the dry season to more than 10,000 km² in the flood season. A unique feature of the Great Lake is the reverse flow. In the rainy season, the rising water level in the Mekong River forces the flow of the Tonle Sap River to reverse. Water flows into the Great Lake causing it to increase dramatically in area. As the Mekong recedes at the onset of the dry season, the Tonle Sap again reverses its flow, so draining the water from the Great Lake to the Mekong. The Great Lake is the major natural reservoir regulating the floods in central and southern Cambodia and the Mekong Delta in Viet Nam (see box "The Tonle Sap Great Lake fisheries").

There are large wetland areas in the North and Northeast of Thailand and Lao PDR adjacent to the main channels of the Mekong and its tributaries (Map 6). The Mekong Delta is a vast wetland consisting of freshwater floodplains, tidal marshes, melaleuca and mangrove forests and brackish water estuaries.

The Lower Mekong Basin has more than 25,000 constructed reservoirs, most with less than one km² of surface area and used mainly for irrigation or flood control. The larger reservoirs shown on Map 6 were purpose-built for hydropower generation. There are no dams on the mainstream in the Lower Basin.

The Tonle Sap Great Lake fisheries



Giant lift nets in action

Since the Tonle Sap Great Lake in Cambodia was formed some 5,000-6,000 years ago (Carbonnel 1963, in Rainboth 1996), it has teemed with fish. Indeed, some attribute the rise of the Khmer Angkor Empire to both the abundance of fish and of the rice that grows in the rich, well-watered flood plains around the Tonle Sap. The profusion of fish and rice pictured in the reliefs on the walls of the Bayon and Angkor Wat temples are testimony to their importance, and they are still staple foods for the majority of Cambodians.

Until recently, Khmer-speaking rice farmers in northeast Thailand (Buriram), trekked to the Great Lake during the fishing season to trade rice for fish. They processed their fish on the spot to make fish paste (*prahoc*) and similar products.

The French colonisers, recognising Cambodia's wealth in fishery resources, modelled their taxation system on the traditional royal practice of raising funds by leasing fishing lots. The French also introduced Cambodia's first fishery laws (Petillot 1911 in Van Zalinge *et al.* 2000).

Petillot reported that in 1910, about 50,000 tonnes of fish were exported in the form of dried, salted, and live fish. They were also processed as fish oil and paste. In the 1920s and 1930s, exporting dried fish to Java was a big business. Chevey and Le Poulain (1940) reported that annually, Chinese traders from Singapore shipped an average 25,000 tonnes of Cambodian fish. Given a ratio three fresh fish to one dried fish (Chhouk 1996), this volume suggests an annual catch of about 75,000 tonnes of fresh fish. Chevey and Le Poulain (1940) estimated the total fish yield of the Tonle Sap to be 125,000 tonnes per year. This trade no longer continues, although similar quantities are being exported to Thailand and Viet Nam, mostly in fresh and dried/smoked form or as fish paste/sauce.

In the Mekong River, wild fish production takes place in a wetland ecosystem that is the result of annual flooding during the southwest monsoon (June – October). In Cambodia, the Tonle Sap River, which flows out of the Great Lake into the Mekong River at Phnom Penh, is forced to flow backwards due to the greater height of water in the Mekong. As a result, water levels in the Great Lake rise by



Barrage fishing lot in the Tonle Sap River

6–9 metres and thousands of square kilometres of land around the lake are temporarily submerged. The flooding makes abundant food resources accessible, and provides breeding places and shelter for numerous species of fish. The principle habitats are riverine forest along the lakeshore and waterways (?20 percent) and short tree/shrub land vegetation (?30 percent). Both of these are able to withstand long periods of inundation as well long dry spells in intense heat. Grasslands,

which constitute ?10 percent, lie further away from the lake as do deepwater rice fields that constitute another ?20 percent. The remaining area (?20 percent) is open water at all times, although this is



Tonle Sap River delta floodplain

sometimes covered by aquatic vegetation. The main threat to these habitats and the fish they sustain, is the conversion of wetlands to agricultural use.



Great Lake floodplain habitat

When the floods recede and the height of the water in the Mekong drops (October-November), the flow of the Tonle Sap River changes again. Water levels in the lake start dropping, signalling to most fish species that it is time to migrate to deeper water in the lake and

river (lateral or short distance migration). A number of species called “black” fish do not migrate further. Others, the so-called “white” fish, undertake longer (longitudinal) migrations from the Great Lake to the

Mekong River, where most of them continue moving upstream. The large and middle-scale fisheries are geared to intercept these migrations. Long distance migrants constitute about 63 percent of the total catch taken by fisheries in the Tonle Sap area.



Conversion of natural habitats into agricultural land is a threat to fish production

Many “white” fish species begin to spawn in the Mekong River at the beginning of the rainy season (May-July), when the first floodwaters are coming in and water levels start rising again. Large numbers of fish eggs and fry are carried by the current and swept into the floodplains as they are being inundated. Important spawning areas are located in the Mekong in Kratie and Stung Treng Provinces, and are linked with the Tonle Sap and other floodplains by the Mekong.

When the flood waters rise, the “black” fish species migrate back from the rivers and lakes to the floodplains for spawning.

A.1. AGRICULTURE

Thirty-six per cent of the Lower Mekong Basin is currently under permanent or seasonal agriculture (Map 7), which is the cornerstone of the Basin economy. Three quarters of the 56 million people living in the Lower Mekong Basin earn their living from combining agriculture and fisheries. The agricultural economy has developed differently in the four LMB countries. Many communities in Cambodia and Lao PDR are fully dependent on subsistence agriculture and fisheries. In Thailand and Viet Nam, agriculture is more intensified with significant commercial production

Lao PDR has large tracts of unused arable land resources mainly in the South. In the north, more than 400,000 hectares are farmed on steep slopes prone to soil erosion. The Mekong Delta may have reached its carrying capacity for farming due to the application of intensive techniques and the use of high yield crop varieties. Expansion of agricultural area in Northeast Thailand is constrained by low water supply in the dry season.

Rice is the predominant crop throughout the Lower Mekong Basin covering 60-90 percent of the cultivated land area. Upland rice is grown as a dry season crop on sloping land, mainly under slash-and-burn systems. This type of cultivation is restricted to the Northern Highlands and the Annamite Chain. Rain fed lowland paddy rice is the dominant crop on the Korat Plateau in Northeast Thailand and the Mekong Plains of Cambodia and Viet Nam. Paddy rice is grown in most major floodplain areas. Irrigated rice dominates production in the Mekong Delta and is of some importance on the Korat Plateau.

Crop diversification in the Mekong Delta has been a prominent trend in recent years, especially bean crops and sugar. The Korat Plateau sustains the most diversified agricultural economy in the Basin where field crops cover more than 20 percent of the agricultural area, mainly cassava and maize.

A.2. FISHERIES

Capture fisheries and aquaculture are significant economic activities. Small-scale fishing and fish production for household consumption are common part-time activities. Current estimates indicate a total production, including other aquatic animals such as turtles, frogs, snails and crustaceans, of more than 2 million tons per year. Of this, 1.5 million tons comes from capture fisheries in natural water bodies, 240,000 tons from reservoir fisheries and 260,000 tons from aquaculture.

There are no indications that wild fish resources, in general, are over-exploited. However, changes in the species composition, and especially a decline in the abundance of larger slower growing species, indicates the present exploitation rate is high and that the scope for future increases in overall annual catches from heavily exploited areas may be limited. In less heavily exploited areas, some scope for modest increases may exist.

There is potential for expanded fish production from aquaculture both in peri-urban and rural areas. There is some potential for increased production from stocking small reservoirs provided supporting management systems are in place.

The Mekong Prawn – a New Indigenous Resource?

In 2000, a survey was conducted by the Living Aquatic Resources Research Center, LARReC, on a freshwater prawn fishery in Mekong tributaries near Luang Prabang in northern Lao PDR. The first objective of this survey was to collect local knowledge regarding the biology and ecology of indigenous prawns. The second objective was to establish if these prawns might be suitable for aquaculture. This survey, and all subsequent research, has been carried out in cooperation with the Na Luang Fishery Station at Luang Prabang.



Macrobrachium sp. prawns from the Mekong River

Of particular importance is a species of *Macrobrachium* known locally as the “Mekong prawn”. It is found in the

Mekong mainstream near Luang Prabang, but apparently it is not found in tributaries of the Mekong. If the Mekong prawn is migratory, its pattern is unknown. Only a few Mekong prawns are caught during any particular week of fishing during the dry-season, and usually only by local fishers using cast nets. However, it appears to have some potential for aquaculture, and may be of some value to resource-poor villagers in Lao PDR (particularly as a by-catch). The Mekong prawn appears to survive in “buffalo” ponds and does not have a high dissolved oxygen requirement. It scavenges on all types of animal and plant detritus. It breeds from February to October. It is a hardy species, and can be handled relatively easily. The Na Luang Fishery Station at Luang Prabang has successfully raised the Mekong prawn for a number of years now. Evidence suggests that once a certain number of individuals have been released into a pond, population expansion takes place on its own. The presence of fish does not appear to affect this.

A feeding trial with the Mekong prawn is currently being undertaken at LARReC. Results are expected in August or September 2002. The results will be used to plan further research at Na Luang Fishery Station in purpose-built net cages held in ponds.

LARReC is also investigating the breeding habits of the Mekong prawn. To date, the Mekong prawn has been successfully spawned in aquaria in the laboratory. However, first feeding of the newly hatched prawns remains a research challenge at present.

The survey also identified a number of other indigenous prawns in the fishery. All species encountered belong to the *Macrobrachium* genus. Fishers target migrating prawns moving up and out of the turbid waters of the mainstreams during the wet-season into clear, cool, streams issuing from the bases of limestone hills in the area. The Nam Ou and Nam Xuang are two tributaries where such fisheries exist.

Of particular importance are the “red head” and the “green head” prawns. These are very likely to be the different sexes of the same species. Very little indigenous knowledge regarding their life cycle was available from local sources, apart from information about their nightly migratory patterns during the wet-season.

Unfortunately, attempts at raising both red head and green head prawns in net cages, ponds and aquaria have so far not been successful. The animals either die within a week or so of being stocked, or in the case of ponds during the wet-season, simply walk out of the pond at night when it is raining. No further research is planned for these prawns, and LARReC has determined that they are not suitable for aquaculture in the Lao PDR.

A.3 FORESTRY

The forests of the Lower Mekong Basin have decreased significantly in terms of both area and quality over the last decades. Present forest cover is about 40 percent of the total Lower Mekong Basin (Map 7). This is a major reduction from about 56 percent in 1970. The causes of forest degradation include commercial logging, slash and burn cultivation, land encroachment for human settlements, farming and infrastructure development and cutting wood for fuel. The loss in forest quality is significantly higher than the loss in forest area, as logging has concentrated on commercially valuable species and larger-size logs. Only about 10 percent of the remaining forest is of commercially high value. Large-scale clearing of timber has serious environmental effects on other economic sectors.

Fuel wood accounts for more than 80 percent of the wood volume felled annually. As most fuel wood is obtained from scattered trees and locally managed forests, the environmental impact is much less than felling figures would indicate. About 90 percent of the total energy used for cooking and heating in the Basin is based on fuel wood.

A.4. HYDROPOWER AND DAMS

The hydropower potential of the Lower Mekong Basin outside the main river is estimated at about 17,000 MW, although not all of this may be economically viable. Eleven hydropower projects have been completed totaling some 1,600 MW or 9 percent of the potential. Hydropower generated in the Basin is often an export commodity generating income for governments. The projected electricity demand within the Lower Mekong Basin itself is minimal compared to the potential.

The impacts of dams on water flow, volume, quality, and fish migration have serious implications for rural livelihoods (see box "Fish passage and fishways"). Impacts include resettlement, loss of land, and access to natural resources. Downstream impacts include cumulative loss of fisheries through environmental changes. Positive impacts include potential for dry season irrigation and fish production in reservoirs.

A.5. INDUSTRY, MINING AND TRADE

Despite the wealth in minerals and recently discovered hydrocarbons, mining remains relatively undeveloped. Available data on trade among the four countries are weak. Considerable informal and illegal cross border trade occurs.

A.6. PEOPLE AND SETTLEMENTS

Approximately 56 million live in the Lower Mekong Basin (2000). The population density varies significantly (Map 8). Population growth is estimated at 1.45 percent (weighted average for four countries), but growth rates are uneven and strongly affected by migration in some areas. The population is demographically young, with 50 percent less than 15 years of age. Under-employment, low productivity and low-income levels are a common feature of rural life throughout the Basin.

A.7. FOOD SECURITY

Rice and fish are the basis of food security. Rice production in the lowlands has increased in the last decade, and export of surplus rice generates much needed foreign exchange earnings.

Annual consumption of fish and other aquatic animals is over 30 kg per person per year (Map 4). Fish and aquatic animals are the single most important source of animal protein, nutrients and minerals. Fish consumption per person has remained stable during the last decade, indicating that the natural resource base has been strong enough to sustain the needs of the growing population. It is expected that demand for fish products will increase with population growth. Food security has already become a critical issue in upland areas where there is insufficient arable land to meet population growth.

Fish Passage and Fishways

All fish must move during their lives, particularly those that inhabit rivers, where habitats for feeding, spawning and resting may be widely separated. Movements may be over short or long distances, and of different durations or timing. Movements may be active, for example, as with adults migrating to spawn, or passive, as with the drift downstream of larvae and juveniles.

Sometimes the movement of fish can be blocked, for instance when fish encounter a man-made barrier such as a weir or dam. When the movement of fish past such barriers is facilitated by some engineered structure, we term that movement *fish passage*.



Fishways allow some fish species to swim past constructed barriers

In the Mekong System, the most crucial movements are along the main rivers, and onto the floodplain. Thus, the most obvious impacts on fish migration are caused by large dams. But even barriers on small tributary streams, such as weirs for irrigation or flood control, or road culverts, can isolate floodplain habitat. They may, in fact, have a greater incremental impact, because fish production in floodplain rivers is proportional to the area of floodplain habitat.

Mitigation of the effects of barriers on rivers has often been by stocking of hatchery-reared fish, but maintenance of breeding populations of wild fish is far preferable for many reasons. Under natural conditions, recruitment of wild fish far exceeds any possible hatchery production, and the resulting fish will be healthier, more genetically diverse, and better adapted to the wild environment.

The first and preferred option for mitigating barrier effects is by designing barriers and managing their operation so that fish can pass at critical times. For example, a watergate or other low barrier, may be designed to open if it is known that upstream migration of adult fish, or downstream drift of larvae, occurs for only short periods of time.

Physical mitigation of barriers is by *fishways*, structures that provide a water passage for fish around an obstruction. *Fish ladder* is an older term for one type of simple fishway. Although the first fishways were built over 300 years ago in Europe, it is only in the last two decades that significant numbers of effective structures that allow large numbers of fish to pass have been built. Effective fishways must be hydraulically sound, suitable for site conditions, and based on an understanding of the movement needs and swimming ability of fishes.

There are three general types of fishway (Thorncraft and Harris 2000). The most familiar are channel fishways, usually used for fish passage where barriers are less than 7 m in height. Among these, the most well-developed and successful type of channel is the vertical-slot fishway. For higher barriers, vertical-lift fishways are used; these either trap and transport the fish or use locks to lift the fish. For very low barriers of 1-2 m, nature-like fishways may be used. These are generally simple rock ramps or bypasses that resemble natural channels.



Poor design and placement of fishways can render them useless

In general, larger fishways allow larger numbers of fish to pass, but are more expensive, so fishway design seeks to balance costs against the target capacity for passage of fish through the fishway. The potential value of fishways is evident from some data on fish movement through fishways.

- ✂ The recorded maximum passage for temperate fish is 20,000 salmon per hour, or two million fish in six days, through a vertical-slot fishway (Mallen-Cooper 1996).
- ✂ The recorded maximum for tropical river fishes is 4,800-6,000 fish per hour through a fishway in Brazil (Mallen-Cooper 1996).
- ✂ Unpublished data from a small “Pool and Weir” fishway (3 m x 30 m x 1 m; slope = 1:5) at Nam Kum, Sakolnakhon in Thailand in 1981, showed some 25 species successfully passing through the ladder. The appropriate flow velocity was between 0.46-0.67 m/s. Average passage was 10,400 fish per hour (250,000 fish/day), with most fish moving in the late afternoon (15:00-18:00 hrs).

Although these figures are impressive, they are small compared to the numbers of fish migrating in the Mekong system. For instance, the number of fish passing a given point in the Tonle Sap River at peak migration times is approximately 50,000 fish per minute (Baran *et al.* 2001). The Tonle Sap River fish migrations are conservative estimates based on *dai* fishery catches. It is impossible for this quantity of fish to pass unaffected through any sort of fishway. Consequently, there is no existing fishway technology able to overcome the obstacle created by a dam or weir on the Mekong mainstream or on the lower reaches of its major tributaries. On the mainstream, the choice therefore remains: fish or dams.

Fishways may, however, be workable on minor streams in the upper catchments, but only where peak migrations are less than a few thousand fish per hour.

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