THE MEKONG RIVER SYSTEM

ABSTRACT

The Mekong is the longest river in Southeast Asia. From its source on the Tibetan plateau it runs for 4800 km through China, Myanmar, Lao PDR, Thailand, Cambodia and Viet Nam to the South China Sea, where it discharges on average 475 000 million m$^3$ per year. The total Mekong Basin (MB) catchment area covers 795 000 km$^2$ and has 73 million inhabitants. The Lower Mekong Basin (LMB) comprises four countries, i.e. Cambodia, Lao PDR, Thailand and Viet Nam, which signed the 1995 river development agreement and cover 77 percent of the total basin with 55 million people. The degree of inundation of the 70 000 km$^2$ flood-
plains depends on the strength of the monsoon, as 85-90 percent of the discharge is generated during the wet season from May to October. Although far from pristine, the river still is in a relatively good condition. Only two mainstream dams have been built (in China), but there are many more on the tributaries. The number of fish species that has been found in the MB exceeds 2,000. Many migrate across international borders, thus constituting trans-boundary resources. The largest fisheries are found in the extensive floodplains in central Cambodia and the delta. A huge variety of fishing gear is used, from the most simple traps to kilometres-long fence systems. Catch levels of the capture fisheries in the LMB are estimated to top 2.6 million tonnes annually with a value exceeding US$1.7 billion. In Cambodia fisheries contribute 16 percent to the GDP. Strong increases in human population are matched by equal increases in fishing effort resulting in catch levels that are probably higher than ever. Major declines in stock sizes of the larger later-in-life spawning species have been witnessed. Catches are now dominated by smaller rapidly reproducing species.

Aquaculture is widespread in the Thai and Vietnamese parts of the LMB; production is estimated at 260,000 tonnes. In addition, 240,000 tonnes are captured in reservoirs. In rural areas most people engage in fishing to generate part of their income and food supply. The basin-wide consumption of fish and other aquatic animals ranges from 42 to 66 kg caput\(^{-1}\) year\(^{-1}\). The Mekong River Commission came into being with the signing of the 1995 agreement by Cambodia, Lao PDR, Thailand and Viet Nam. It focuses on the need for cooperation in the sustainable development of the LMB. China and Myanmar have not joined yet. The member nations have agreed to prior consultation on proposed river water usage. The most important interventions required to sustain the fisheries are: (1) strengthening of the capacity of riparian governments in coordination and balanced decision-making on water resources development; (2) setting up of consultation procedures on water resources and fisheries management with resource users, decision makers, researchers and donors; (3) collection of data clarifying the contribution of fisheries to the national economy, food security and livelihoods; (4) participation of resource users in fisheries management; (5) protection of floodplain habitats; (6) maintenance of highest possible flood levels and a free flowing mainstream with as many free tributaries as possible.

**DESCRIPTION OF THE RIVER SYSTEM**

The Mekong River Basin has a very diverse fish fauna that provides the basis for a large variety of fisheries, some with very impressive yields, especially in the lowlands of Cambodia and Viet Nam.
**Geography**

With a total length of about 4,800 km the Mekong is one of the longer rivers in this world (Figure 1). Its source is on the north-eastern rim of the Tibetan plateau (Qinghai Province) at an elevation of more than 5,000 m from where it flows through six countries: People’s Republic of China, Myanmar, the Lao PDR, Thailand, Cambodia and the southern end of Viet Nam before it reaches the South China Sea, where it discharges on average 475,000 million m$^3$ per year (15,062 m$^3$ per second). The contribution of each country to the average river flow is as follows: China 16 percent, Myanmar 2 percent, Lao PDR 35 percent, Thailand 17 percent, Cambodia 19 percent and Viet Nam 11 percent (MRC 1998). The Mekong has 249 major tributaries.

The upper part of the river is called Lancang Jiang (in China) for about 2,400 km and is characterized by deep gorges and steep declines. Having fallen to about 360 m, it passes the Golden Triangle, where the borders of Lao PDR, Myanmar and Thailand meet. This is where the Lower Mekong Basin (LMB) starts and the river runs for another 2,400 km to the sea. For a stretch of about 900 km it forms the common border of the Lao PDR and Thailand. There is an inland delta at the geological fault line forming also the 21 m high Khone Falls on the Lao-Cambodian border. At Kratie about 545 km from the sea it becomes a lowland river. Then at Phnom Penh some 330 km from the sea, it is joined by the Tonle Sap River, which connects the Great Lake of Cambodia with the Mekong. There, the river splits into the Mekong proper and the much smaller Bassac to form a large estuarine delta, called the Nine Dragons in Viet Nam, before it empties in the South China Sea.

**Basin Size and Population**

The total Mekong Basin catchment area covers some 795,000 km$^2$ and has over 60 million inhabitants (Kristensen and Lien 2000). The Lower Mekong Basin comprises the four countries, Cambodia, Lao PDR, Thailand and Viet Nam that signed the 1995 river development agreement, which established the Mekong River Commission (MRC). The LMB covers 609,000 km$^2$ (77 percent of the total) and harbours 55.3 million people, of which ca. 50 percent is below 15 years of age. Population densities are lowest in the Lao PDR and Myanmar followed by Cambodia and Yunnan (China). Densities are much higher in north-east Thailand and highest in the delta of Viet Nam. Average population growth is 2 percent. The LMB countries are classified as low-income nations with GDPS of less than US$300 per capita per year, except for Thailand, which is a middle-income country. With growing populations, urbanization and industrialization, water demands will increase.

**Flood Regime**

The river has one flood pulse a year. During the wet season (May-November) the discharge is 30 times greater than in the dry season (December-April) at Pakse (southern Lao PDR) and 53 times at Kratie (Cambodia). Floodplains cover some 70,000 km$^2$. The degree of inundation depends on the strength of the monsoon, as 85-90 percent of the discharge is generated during wet season. The Tonle Sap Great Lake floodplains in the heart of Cambodia contain the largest continuous areas of natural wetland habitats remaining in the Mekong system. One of the striking characteristics of the Mekong’s hydrologic regime is the flow regulation by the Great Lake in Cambodia, the largest permanent freshwater body in Southeast Asia. The Tonle Sap River at Phnom Penh connects the lake to the Mekong. During most of the wet season the Mekong pushes the Tonle Sap River flow toward the lake. This expands it 3 to 6 times from 2,700 km$^2$ to 9,000-16,000 km$^2$. In the dry season the flow direction is reversed. Then the lake supplies water to the Mekong and thereby raises the dry season water levels in the delta for some 5-6 months.

The hydrological cycle is shown in Figure 2. The recording stations shown are all in the LMB with
Luang Prabang being the farthest upstream and Chau Doc in the delta in Viet Nam. Prek Kdam is on the Tonle Sap River. Flood levels peak at Luang Prabang in August, but at Prek Kdam and Chau Doc in October.

Hydrographic data are available from Pakse and a few other places along the Mekong River since 1924. They show a considerable inter-annual variation in wet season river discharge (by a factor of two), which affects the extent of floodplain inundation. Weather patterns associated with the El-Niño phenomenon are thought to be partly causing these variations. However, the average wet season discharge in the last twenty years (1979-98) appears to be at least 10 percent lower than in 1924-56 (34 years), while the inter-annual variations have become more extreme. The downward trend seems to be independent of fluctuations in rainfall and has been linked to building of weirs and dams that started in the late 1950s (Nam Sokleang 2000).

**FLOOD CONTROLS AND MITIGATION**

Flood controls (dykes) are widely applied in the Vietnamese part of the delta for irrigated rice growing. In the dry season saltwater intrusion in the Vietnamese delta can occur as far inland as 40 km from the sea (ESCAP 1998) posing a major problem for irrigation practices at this time of the year.

The Mekong River Commission Secretariat operates a flood forecasting system (www.mrcmekong.org). It is presently being expanded in Cambodia to help vulnerable communities to cope with the floods.

**HYDROPOWER**

Demand for energy comes mainly from Thailand and increasingly Viet Nam, whereas the Chinese province of Yunnan and the Lao PDR have the greatest hydropower potential. Hydropower development in the LMB has so far only taken place in the tributaries (11 dams, totalling 1600 MW or 9 percent of the estimated potential), mainly in Thailand, but also in the Lao PDR, resulting in several large reservoirs. However, in Yunnan one mainstream dam has been completed, a second one is under construction and three more are planned by 2020 (Lukang 2001). By that time there will be a decrease in wet season flows and increase in dry season flows. There are also undeveloped plans for several mainstream dams in the Lao PDR and one in Cambodia (at Sambor), but greater public scrutiny and increasing regulatory procedures,
including requirements for detailed Environmental Impact Assessments and resettlement plans, are likely to influence their future unfavourably (Hill and Hill 1994; Gleick 1998; Ringler 2000) and financing is likely to be difficult.

IRRIGATION

There are thousands of reservoirs in the LMB largely concentrated in northeast Thailand, which are mainly used for irrigation and most are less than 100 ha in size (Virapat, Phimonbutra and Chantarawaratid 1999). They significantly contribute to the breaking up of the river system and hamper fish migrations. In the LMB a total of over 2 million ha was irrigated in the late nineties (Ringler 2000). Expansion plans include Mekong water diversion projects to alleviate dry season water shortages in Thailand. Northeast Thailand and the Vietnamese delta are largely deforested and are major rice producing areas with the largest water consumption. Dry season flow levels are of extreme importance to the delta. Water needs in irrigation and hydropower usage clash strongly with the water needs in fisheries and other wetland resource usage. The poor, who comprise the great majority of the Mekong basin’s people, disproportionately rely on the latter resources (Ringler 2000; Sverdrup-Jensen 2002).

FOREST COVER AND SEDIMENTATION

Forest cover is still about 36 percent of LMB and mostly found in Cambodia and the Lao PDR. Deforestation is rampant: in Cambodia 1.4 percent is lost every year, in the Lao PDR 0.9 percent and in Viet Nam 0.8 percent (MRC/GTZ 1999).

Natural floodplain habitats consist of forests with plant species that can withstand seasonal inundation, as well as lakes and extensive grasslands, where deep-water rice farming takes place. Riverine forest is found along the lake and stream borders. It acts as an important trap of the sediments brought in with the Mekong water during the rising flood phase (van Zalinge et al. 2003). The average rate of sedimentation in the Great Lake itself is estimated to be 0.08 mm per year since the lake was formed 5 000-5 600 years ago (Tsukawaki 1997). The lake is on average a little over 1 m deep in the dry season and will eventually silt up, but the process is expected to take thousands of years, except if rampant deforestation and erosion in the Tonle Sap watershed would speed it up. The mainstream dams already built or planned in Yunnan, China, will trap the sediments brought down by the river from the Tibetan plateau. After the Manwan dam was closed in 1993, the average level of downstream total suspended solids in the river water nearly halved at Chiang Saen (north Thailand) compared to the average level before the closure, thereby lowering the fertility of the Mekong water (MRC 2002). The effect was still noticeable at Pakse in the southern Lao PDR, but had disappeared in Cambodia.

The natural floodplain habitats are in a much better condition around the Great Lake than in the floodplains south of Phnom Penh, which have largely been turned into rice fields by removing the flooded forest vegetation.

NAVIGATION

Only limited parts of the river are navigable for small ships all year round: mainly from Yunnan to Luang Prabang and from Phnom Penh to the sea. The main obstacles are the extreme difference in wet and dry season flow, as well as the rapids of the upper Mekong, the Khone Falls and the Stung Treng-Kratie river stretch.

Channel modifications for navigation of ships up to 200 tons have taken place in Yunnan, China. Proposals have been made by China for blasting of the rapids in the part of the Mekong from the Yunnan border to Luang Prabang in the Lao PDR, which is now suitable for vessels up to 80 tons. China is likely to push for further channelization of the river.
WATER LAWS AND POLLUTION

Water laws are quite new to countries of the region. Lao PDR and Viet Nam had framework laws coming into effect respectively in 1997 and 1999. Cambodia and Thailand still have draft laws only. Thailand and Viet Nam have the “polluter-pays” principle incorporated in their legislation, although little monitoring and enforcement take place (Ringler 2000).

In Yunnan a major source of pollution are the paper mills. Domestic wastewater is the major source of river pollution in northeast Thailand, as it is generally discharged without treatment (ESCAP 1998). Industrial pollution and agricultural run-off are also major problems, in particular for the Mun River. Phnom Penh city mostly discharges its raw sewage into the nearby rivers. Agro-pollutants have been found in fish, but dietary intake of PCBs and DDT from fish was lower in Cambodia than in other Asian countries (JSRC 1996; In Nakata, Tanabe et al. 1999).

FISH DIVERSITY AND MIGRATIONS IN THE MEKONG BASIN

FISH DIVERSITY

According to Rainboth (pers. comm.) the number of species occurring in the Mekong Basin may exceed 1 100. This includes nearly 900 freshwater species and some 200 estuarine species. In addition, there is likely also a high degree of genetic variation within species. Endemicity is fairly high, especially in the upper catchments and will probably grow in line with in-depth taxonomic studies. The high species diversity is a product of the geological history of the area, whereby different drainage systems each with their own set of species have joined to form the modern Mekong (Rainboth 1996). It also reflects a great diversity in habitat types. In fact, per unit area the Mekong basin has more species than the Amazon basin.

Coates (2001) has argued that human interferences (dams, habitat destruction, pollution) work to undermine ecosystem integrity and this may be a greater threat to diversity than over-exploitation by fisheries. Currently the state of the environment is still in reasonably good shape, especially in Cambodia and the Lao PDR, mainly because of slow development due to the regional conflicts in the recent past. Rainboth (pers. comm.) believes that there may have been a few extinctions, i.e. of Puntioplites bulu and others, but is not certain, as detailed surveys have not taken place.

MAIN GROUPS OF FISH

Following Welcomme (1985) the river fish species are broadly classified by life cycle strategy into black fishes and white fishes. Black fish species like the snakeheads (Channa spp), gouramis (Trichogaster spp) and the catfishes (Clariidae) undertake relatively short migrations between the flooded areas in the rainy season and permanent waterbodies in or close to the floodplain in the dry season. They are adapted to withstand adverse environmental conditions (e.g. low dissolved oxygen) often prevailing on the floodplains. During the wet season the fish go back to the floodplains for feeding and spawning. In particular, the Channidae support large fisheries and are regarded as a valuable food resource fetching high prices.

The large group of “white fish species” carries out considerably longer migrations. At the beginning of the dry season most species move from the floodplains via the tributaries to the Mekong main stream. Their migrations may extend to several hundred kilometres. In the main stream they use the deeper parts of the river as refuges for the rest of the dry season. At the onset of the rains spawning takes place near these areas before the adult fish move back again for feeding to the floodplains again for feeding. In Cambodia the fish larvae drift downstream with the river current to the floodplains.

Well known white fish species are the river catfish, Pangasianodon hypophthalmus and two giant
fishes: the giant Mekong catfish, *Pangasianodon gigas* a Mekong endemic of truly gigantic proportions (individuals exceeding 300 kg have been caught) and the beautiful giant carp, *Catlocarpio siamensis*, which can exceed 100 kg. The giant catfish is very rare nowadays. In Cambodia known catches were in the order of 6–11 fish annually in 2000-2002 (Hogan, Ngor and van Zalinge 2001; Mattson *et al.* 2002).

Among the white fish species group, there are a number of species with a short life span and a fast rate of reproduction. They mature and reproduce within the first year of their life. They are sometimes called “opportunists”, because each year their abundance in the catch appears to follow the level of the floods. The dominant species is the cyprinid, *Henicorhynchus siamensis*, which is an important food fish, as it forms the basis for a large production of traditional fermented fish products. Throughout the LMB these migrations support large fisheries, such as the *Dai* (bagnet) fishery in Cambodia. In Cambodia the fish and the national currency bear the same name: riel.

The bulk of the migrating riel (*Henicorhynchus* spp) tends to move out of the floodplains in January and in smaller quantities in February and March. Curiously they migrate en mass in a time window of 6-1 days before the full moon. More than half of the season’s catch is taken in the January peak period, when close to 1.5 million riel are taken per hour in the *Dai* fishery (that is ca. 36 percent of the catch). The catch estimates for this particular fishery are quite accurate and range from 9 000 - 16 000 tonnes annually.

**FISH MIGRATIONS**

Much of what is known about the fish migrations in the Mekong River basin has been gained by tapping the local knowledge that is held by the fisher communities along the rivers (Bao *et al.* 2001; Poulsen *et al.* 2002) and through monitoring of selected landing sites in Cambodia (Srun and Ngor 2000; Kong, Ngor and Deap 2001).

Typically, most migrations in the Mekong River take place during the rising flood and the drawdown period. Based on different migration patterns Poulsen *et al.* (2002) distinguish three major systems in the lower Mekong in which white fish species participate. The systems are interconnected to some extent and have many species in common. The migration patterns are shown in Figure 3.

**The lower Mekong migration system (altitudinal range 0 - 150 m)**

This system covers the migrations taking place in Cambodia and Viet Nam. The upstream limit is the Khone Falls, although Baird *et al.* (2000a, 2000b) report that many species are able to cross this barrier, but possibly in small numbers only. The migrations are basically movements out of the floodplains and tributaries, including the Tonle Sap, to and up the Mekong at drawdown, where a number of species spawn around their dry season refuges usually at the onset of the monsoon. The return migration is made to the floodplains with the rising flood. The fish larvae generally drift downstream during the rising flood and pangasiid larvae are fished for stocking fish forms (van Zalinge, Lieng, Ngor *et al.* 2002). However, the large seasonal fisheries target only the drawdown migrations.

In the dry season the Sekong, Srepok and Sesan tributaries act as an extension of the Mekong for some species, such as *Henicorhynchus* spp and *Probarbus jullieni*, a large cyprinid (Poulsen *et al.* 2002), while other species, such as *Mekongina erythrospila* and *Bangana behri*, visit these tributaries mainly during the wet season.

**The middle Mekong migration system (altitudinal range 150-200 m)**

The system covers migrations from the Khone Falls upstream to approximately the level of Vientiane. Contrary to the lower system, in the middle system the fish move upstream in the Mekong during the wet sea-
son and enter the tributaries and their associated flood-
ed areas for feeding. Some species spawn in the flood-
plains, while others spawn around the dry season
refuges. During drawdown they leave the tributaries
and return to dry season refuges downstream in the
Mekong (Figure 3). These migrations tend to be short-
er than in the lower system. Both systems have many
of the species in common that may or may not form
genetically distinct populations.

Interestingly Poulsen et al. (2002) report that
some species, such as *Cyclocheilichthys enoplos* and
*Cirrhinus microlepis* are mainly caught as juveniles
and sub-adults in the lower system and as adults in the
middle system. They speculate that this may be also
true for other species, such as giant Mekong catfish
(*Pangasianodon gigas*).
The upper Mekong migration system (altitudinal range 200 - 500 m)

This system is relatively isolated from the middle system possibly by a lack of dry season refuges in the section between the two. It stretches from the mouth of the Loei River in north Thailand (ca. 150 km upstream of Vientiane) to Chiang Rai and probably beyond into China. This section of the river has relatively few floodplains and major tributaries. In the wet season fish migrate upstream to spawning habitats in the Mekong to return later to their dry season habitats also in the main river. Spawning habitats are to be found in river stretches with alternating rapids and deeper channels.

Again this system has some species in common with the downstream systems, such as the giant Mekong catfish. In addition, there is also a *Henicorhynchus* species, which is also important for the fisheries here. It may be genetically distinct from the stock(s) downstream.

**MANAGEMENT OF MIGRATORY FISH STOCKS**

Poulsen *et al*. (2002) have pointed out that all six Mekong riparian states are signatories to the Convention on Biological Diversity, which commits these states to the conservation of biodiversity, their sustainable use, etc. In addition, the nations sharing the LMB signed the 1995 Agreement establishing the Mekong River Commission, which provides the framework for management of transboundary fish resources. This would involve the maintenance of habitats critical to the survival of migratory stocks and includes maintenance of connectivity (i.e. migration corridors) between these habitats (Poulsen *et al*. 2002). The types of habitats that are of critical importance have been mentioned briefly in the section above.

**THE STATE OF FISHERIES**

The size of the fisheries in the LMB appears to be related to the extent and inundation of the floodplains. Thus, the largest fisheries are found in the lowest parts of the river system in central Cambodia and the delta. More upstream floodplains are less extensive, the major ones being associated with the Songkram, the only un-dammed Thai tributary. As the floodplains are only temporarily covered with water, fish are forced to migrate to and from them. This necessity makes the fish vulnerable to interception by a large variety of fishing gears. “Black” fish species tend to move short distances from the nearest permanent water to the floodplain and back. “White” fish species cover much longer distances, as has been described above. The sum of these movements can result in an almost complete seasonal species turnover at a specific location. Hence, most fisheries are strongly seasonal.

**TYPES OF FISHERY**

A huge variety of fishing gear is found in the LMB reflecting the diversity of the fish stocks and the complexity of their relationship to the different habitats at different stages of their life cycles and different times of the season.

Around 200 fishing gears and methods have been recorded in the extensive Cambodian floodplains and river systems, ranging from the mere use of the hands for collecting living aquatic products, simple basket traps and hook and lines to larger seines, trawl nets and lift nets to yet larger fishing operations like barrages, bag nets (*Dais*) and fishing weirs with kilometre long lead fences and intricate labyrinth constructions guiding the fish into big traps or even pens. The large-scale fishing activities commonly combine a series of successive fishing strategies, which complement each other into a highly efficient operation. Most of the gears and in particular the large-scale gears operate during the drawdown phase of the flooding season working on the principle that fish will have to move to deeper water when water levels are falling.

Large-scale inland fisheries are now limited to Cambodia, where they are managed as government
concessions, the fishing lots. Their main purpose is to raise a rent on these rich resources. The system pre-dates the French colonial occupation of Cambodia. Since 1919 the area covered by the lots has been reduced by ca. 70 percent. The largest reduction took place in 2001 apparently as a reaction to the mounting conflicts over access to fishing grounds between lot managers and fisher communities. The “freed” areas were placed under community fisheries management. The results so far are not encouraging, as the communities are not experienced in handling management and moreover appropriate laws have not been adopted yet. Detailed descriptions can be found in Lieng, Yim and van Zalinge (1995); van Zalinge et al. 2000; Degen et al. (2000); Degen et al. (2000, 2002); and Sverdrup-Jensen (2002).

Horizontal and vertical basket traps made of widely available natural raw materials, such as bamboo, rattan and vines reveal the biggest variety. Basket traps are passive fishing gears and as such well adapted to the needs of fishing/farming households. In all four countries of the LMB monofilament gillnets with their different ways of operation (floating, set, bottom, surface or mid-water) is the most popular gear. Descriptions of the gears found in Lao PDR and Cambodia are given in Claridge, Thanongsri Sorangkhoun and Baird (1997) and Deap et al. (2003), respectively.

In floodplain environments in Cambodia, the Mekong Delta of Viet Nam, the Khone Falls and the Songkram River the variety of gears seems to be bigger than in upland areas where fishing is carried out mainly during the rainy season.

In the floodplains fishing intensity is the highest during the recession period (October to April). In the uplands of the Lao PDR, northern Thailand, northeastern Cambodia and the central highlands in Viet Nam mainly small-scale fishing gear including fishing by hand is used to retrieve aquatic animals from the wetlands, including rice fields. In addition, there are important fisheries for freshwater shrimps (Caridea, in particular Macrobrachium spp) and mollusks. The fishing principles are the same, the shape of the traps may vary considerably and mark local traditions and customs, including beliefs.

Though legally forbidden everywhere destructive fishing practices such as the use of explosives, electric shock, as well as chemical and natural fish poisons still constitute a threat to fish stocks, habitats and to consumers (in the case of poisons).

**Exploitation Levels**

Estimates of the total catch made by the fisheries in the LMB have increased dramatically in recent years and are presently topping 2.6 million tonnes annually (see Table 1) with a value exceeding US$1.7 billion (Jensen 1996; Sjorslev 2001; Sverdrup-Jensen 2002; Hortle and Bush 2003). These figures are based on per capita consumption of all freshwater fish and other aquatic animal products and exclude the fish produced in aquaculture and in reservoirs, respectively 260 000 and 240 000 tonnes. In northeastern Thailand aquaculture and reservoir fisheries are relatively important, as is aquaculture in the Vietnamese Mekong Delta. Estuarine fish production in Viet Nam is excluded from these figures.

The capture fisheries estimates are nearly nine times higher than the figures routinely used in FAO world fisheries statistics in the past. Closer examination of other tropical river systems is likely to lead to similar increases in the estimation of fish catches. Data collection by standard statistical methods is often greatly hampered by the dispersed small-scale nature of fresh water fisheries and therefore an approach using fish consumption information, as applied in the LMB, can be revealing.

The levels of the exploitation of the resources in the LMB are likely to be high to very high every-
where and related to the presence of a large low-income rural population. However, despite a much higher population in the Mekong Delta of Viet Nam compared to Cambodia per capita consumption does not differ much (Table 1). Coates (2001) has suggested that this could mean there still is potential for increases in fish production in more lightly populated areas. As the flooding regime and the state of the natural environment are the most critical factors in the survival of the fish resources of the LMB, the situation in some countries may be deteriorating. In Thailand, large-scale alterations of the river system have taken place. Also in the Mekong Delta in Viet Nam widespread irrigation works are preventing fish to access large areas of floodplain, while in the central Vietnamese highlands reservoirs are being established on most rivers. To a lesser degree this is also the case in the Lao PDR. Only in Cambodia are the river systems still largely free flowing and fish are able to utilize the floodplains.

### Table 1: Estimated annual consumption of freshwater fish products, including other aquatic animals in the lower Mekong basin by country and by source, in 2000, expressed in whole fresh weight equivalents (as recalculated by Hortle & Bush 2003)

<table>
<thead>
<tr>
<th>Country</th>
<th>Population (million)</th>
<th>Average per capita consumption (kg)</th>
<th>Total(^1) fish consumption (tonnes)</th>
<th>Capture(^2) fisheries fish catch (tonnes)</th>
<th>Reservoirs(^3) fish catch (tonnes)</th>
<th>Aquaculture(^4) production (tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>11.0</td>
<td>65.5</td>
<td>719 000</td>
<td>682 150</td>
<td>22 750</td>
<td>14 100</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>4.9</td>
<td>42.2</td>
<td>204 800</td>
<td>182 700</td>
<td>16 700</td>
<td>5 400</td>
</tr>
<tr>
<td>Thailand</td>
<td>22.5</td>
<td>52.7</td>
<td>1 187 900</td>
<td>932 300(^i)</td>
<td>187 500</td>
<td>68 100</td>
</tr>
<tr>
<td>Viet Nam</td>
<td>17.0</td>
<td>60.2</td>
<td>1 021 700</td>
<td>844 850</td>
<td>5 250</td>
<td>171 600</td>
</tr>
<tr>
<td><strong>Total LMB</strong></td>
<td>55.3</td>
<td>56.6</td>
<td>3 133 400</td>
<td>2 642 000</td>
<td>232 200</td>
<td>259 200</td>
</tr>
</tbody>
</table>

\(^2\) Total consumption minus Reservoir catch and Aquaculture production  
\(^3\) MRC Management of Reservoir Fisheries data  
\(^4\) Phillips (2002)  
\(^5\) Includes a large part of the probably more than 50,000 tons of freshwater fish products exported from Cambodia to Thailand (van Zalinge et al. 2001)

#### Cambodia

Within the MB fisheries are economically most significant in Cambodia, where they presently contribute 16 percent to the GDP (Zia Abbasi, pers. comm.; van Zalinge 2003). As in the Angkorian period (802-1432 A.D.), today fish and rice production are the basis of the food security in the country. Export of fish and fish products to the neighbouring countries is important, especially to Thailand. The seasonal inundation of the extensive floodplains, such as around the Tonle Sap Great Lake, is the reason for the wealth of fish. Fish yields in the Tonle Sap floodplain area range from 139-190 kg/ha per year (Lieng and van Zalinge 2002). Overall about 700 000 tonnes are caught in the country annually (van Zalinge et al. 2000; Sjorslev 2001; Hortle and Bush 2003). Limited historic information on catches is available; see e.g. Chevey and Le Poulain (1940), Fily and d’Aubenton (1965). However, because the human population in Cambodia has increased considerably (3-fold since 1940) and lives mainly (85 percent) in rural areas, full and part-time employment in fishing is very high (ca. 6 million or over 50 percent of the population), fishing effort
must have increased equally strongly, probably resulting in catch levels that are higher than ever. Catch rates of individual fishers must have gone down a lot. Strong declines in stock sizes have been witnessed in the larger, later-in-life spawning, species. Catches are now dominated by smaller short-lived and rapidly reproducing species, the so-called opportunists, whose abundance seems to be directly related to the maximum flood level attained by the Mekong River during the wet season. This shift to smaller and cheaper species has reduced the average per-kg value of the catch.

It was found that the higher the Mekong flood and its sediment load are, the higher the catch of opportunist species in the Dai (bagnet) fishery (van Zalinge et al. 2003). The Dai fishery targets fish migrating out of the Great Lake area to the Mekong River during the drawdown of the floods. Among the ca. 100 fish species caught the genus *Henicorhynchus*, small cyprinids, is by far the most prominent (van Zalinge et al. 2003). Higher floods also favor better growth of these species.

The effect on the catch of longer-lived species is probably delayed, as for snakehead species (*Channa* spp) the best correlation was found with the catch in the following year. Degradation of the natural habitats in the floodplains, such as conversion of flooded forest to rice fields, leads to a significant decline in the value of the fish yield per ha of inundated area mainly as a result of changes in the species composition of the catch. For instance, the share of the valuable snakehead species decreases proportionally when rice fields replace flooded forest habitats (Troeng et al. 2002). On the other hand it is likely that the value of the rice crop compensates for this loss.

The flood-yield relationship (Figure 4) also implies that fish catches will be lower if upstream river interventions result in lower average flood levels and sediment loads, as seems to have happened already in the past 30-40 years (Nam Sokleang 2000; MRC 2002). This will be particularly harmful to Cambodia, where so many people depend on fish and fisheries for food and employment. Cambodia would be well advised to continue assessing its fisheries output and to monitor upstream developments carefully.

**Lao PDR**

Fish consumption is estimated to be 204 800 tonnes (Sjorslev 2001; Hortle and Bush 2003), mainly from small-scale river fisheries, but also from reservoirs and aquaculture. Although fish is a significant part of the animal protein intake, it is not as important as in Cambodia, because Laotians rely also on hunting and trapping of forest animals to make up for the shortfall in their diet. Nevertheless, a fishery survey carried out in Luang Prabang found that 83 percent of households reported to fish and collect aquatic animals (Sjorslev 2000). Total production was estimated at 10 000-15 000 tons per year. A large variety of mainly small gears were used.

Fairly large fisheries exist in the Khone Falls area, where migratory fish are intercepted in the falls with many special gears (Roberts and Baird 1995). Baird et al. (1998) infer that annually some 4 000 tonnes are caught in the Khong district alone.
As the Lao PDR has adopted a policy favoring the use of hydropower, the number of reservoirs and related fisheries will increase. Mainstream dams have so far not been constructed in the Lao PDR still leaving the Mekong open to fish migrations. Fisheries for native species in the Nam Ngum hydropower reservoir have developed well since its closure in 1972 yielding 173 kg ha\(^{-1}\) year\(^{-1}\) in 1998. The catch is dominated by *Clupeichthys aesarndensis*, a small pelagic clupeid, which contributed 24 percent (Mattson *et al.* 2000). However, the importance of the Nam Ngum catchment for fisheries was not assessed before the closure of the dam and at least ten migratory species are not found anymore upstream of the dam (Schouten 1998).

**Viet Nam**

The parts of Viet Nam that are in the LMB are a section of the central highlands and the Mekong Delta. Fishing activities are largely small-scale. Fishery surveys carried out in the delta provinces of An Giang and Tra Vinh show that 66 percent and 58 percent of households were part-time and 7 percent and 4 percent full-time involved in fishing in 1999 and 2000 (Sjorslev 2001a; AMF 2002). Most of the catch is for home consumption. Overall fish consumption in the Vietnamese parts of the LMB was estimated to be 1 021 700 tonnes annually (Sjorslev 2001; Hortle and Bush 2003). This figure includes fish and aquatic animals from inland fisheries, aquaculture and reservoir fisheries, as well as imports from Cambodia.

**FISHERIES AND AQUACULTURE**

Fish fry are caught for stocking purposes in all four countries of the LMB. The main species are snakehead (*Channa*) and pangasiid catfish. Cheap fish are often used as fish feed. It is argued that aquaculture production based on wild resources should also be included in capture fisheries.

Among the riparian countries there are no agreed policies for regulations on introductions of exotic species into the basin, nor on movements of genetic strains within the basin. According to Welcomme and Chavalit (2003), 17 species have been introduced successfully into the LMB, but their impact appears to be relatively minor so far. The lack of impact is thought to be due to the relatively good condition of the environment and this supports the native species.

**Cambodia**

Due to the large output of the capture fisheries and the low price levels, aquaculture development has been very slow. Hatchery production is low, as most culture establishments stock wild caught fry, mainly snakeheads (*Channa spp*) and pangasiid catfishes.
Cheap fish is generally used as feed. Mainly due to flooding of aquaculture ponds escapes of tilapias and carps have occurred and very small quantities are regularly caught in the wild. There is a large clandestine fishery for pangasiid fry (Pangasianodon hypophthalmus and Pangasius bocourti) in the Cambodian Mekong in the rising flood period. The fry is mainly exported to Viet Nam for culture (van Zalinge et al. 2002).

**Lao PDR**

Due to a large increase in irrigation schemes during the past few years, the potential for aquaculture, including rice-fish culture, has grown. However, fish seed production still does not meet the demand. Quite a few exotic species have been introduced, mainly tilapias and carps. The Lao government has made a policy towards banning the practice of stocking of certain exotic fish species in natural bodies. Cage culture of snakehead (Channa spp), such as practiced in the Nam Ngum reservoir, depends on fry and feed collected in the wild.

**Thailand**

Freshwater aquaculture has been developed mainly for domestic consumption and fish seed is commonly supplied by hatcheries. Higher-priced indigenous species, such as catfish, snakehead and freshwater prawn, are raised in commercial freshwater ponds. About 62 percent of farms are integrated, primarily with chicken farming and tree crops. More than 115 freshwater species have been introduced in Thailand, most of them through the ornamental fish trade. To enhance fish production the Department of Fisheries has long been stocking exotic species, such as tilapias, Chinese carps, major Indian carps and common carp, in public water bodies all over the country, but only tilapias, in particular Oreochromis niloticus, are commonly found in major reservoirs and lakes. The African catfish, Clarias gariepinus, was introduced by the private sector some 20 years ago. Although the Department of Fisheries has tried to minimise the possible impact of this species by hybridisation, this aggressive species has been able to spread and is found in open waters occasionally. The Department of Fisheries has developed regulations regarding introductions of exotic species into the country, but is not monitoring the level of infiltration.

**Viet Nam**

The Mekong Delta has the largest aquaculture output in the basin: 171 600 tonnes in 1999. Integrated cultures are quite common, as is rice-fish farming. In these farming systems are stocked both indigenous and exotic fish seeds mainly from hatcheries.

Snakehead is grown in cages, but pond culture is now also developing. Both completely depend on seed collected in the wild. Cage and pond culture of pangasiid catfish has relied heavily on stocking with wild caught fry in the past, most of which was coming from Cambodia, even though the fishery was declared illegal in 1994. In recent years hatchery output of fry has increased and is overtaking wild fry in importance. Most catfish is exported to overseas markets (van Zalinge et al. 2002).

Stock enhancement with exotic fish is mainly taking place in reservoirs and lakes. Tilapias have been used a lot with the result that populations have established themselves in brackish water bodies. Traditional extensive shrimp farming in the brackish waters of the Mekong Delta completely depends on wild seed, while in intensive farming only hatchery seed is used. In mud crab and bivalve farming mainly wild seed is stocked.
IMPORTANCE OF FISHERIES FOR LIVELIHOOD, EMPLOYMENT, FOOD SECURITY AND RECREATION

LIVELIHOOD AND EMPLOYMENT

The large majority of rural dwellers in the LMB are engaged in a wide range of production and income generating activities. These activities are integrated with all aspects of people’s livelihood strategies and many of them exploit common property resources such as fish, aquatic products and water. Since products obtained for household consumption do not go through market chains and the cash economy, these activities have largely remained unnoticed or undervalued by policy planners. Farming, especially of rice and other related land based activities, is generally the most important source of employment. Depending on the proximity and the duration of access to water bodies, fishing is the second or third most important activity.

With the absence of comprehensive data and of total figures for the riparian countries, some targeted case studies may give indications of the importance of fishing activities for livelihoods and employment. In the provinces around the Great Lake Tonle Sap in Cambodia more than a million people generate income from fisheries (Ahmed et al. 1998). In Luang Prabang province in Lao PDR 83 percent of all the households in all surveyed villages are engaged in fishing and collection of aquatic animals, which is the third most important economic activity (after rice farming and livestock rearing) (Sjorslev 2000). Access to fish and aquatic resources is crucial for the most vulnerable strata of the rural populations. Their ability to access fish and collect other kinds of common property resources from their immediate natural surroundings serves them as an important sometimes last resort safety net of subsistence. It allows them to produce valuable proteins and nutrients for their household consumption and to market the surplus in order to cover the expenses of other basic needs of living. Results from a fishery survey in Luang Prabang show that 91 percent of people catch for home consumption, although 79 percent of the total catch was sold to middlemen (Sjorslev 2000). A recent survey of fisheries communities in a limited area in the Tonle Sap flood plains in Cambodia reveals that 31 percent of the households derive their main income from fishing, however 98 percent of all households report being involved in some kind of fishing activity throughout the year (Degen et al. in preparation).

In mountainous areas in the northern Lao PDR an important fishery for tadpoles in rice fields was observed at the beginning of the rainy season. There, tadpoles are collected mainly for income generation through export to lucrative Thai markets.

FOOD SECURITY

Although overlooked in the past, it does not come as a surprise that fish and other aquatic animals are the most important sources of animal protein and thus, a major support to food security, in particular of the rural population in the LMB. Apart from fish, frogs, tadpoles, snails, mollusks, shrimps, crabs, snakes and other reptiles and water birds from wetland habitats are considered “aquatic animals”. Average basin-wide consumption of fish and other aquatic animals is estimated at 56 kg capita\(^{-1}\) year\(^{-1}\) (Hortle and Bush 2003). In high-yielding fishing areas such as in rural communities of the floodplains around the Great Lake Tonle Sap in Cambodia fish consumption is as high as 71 kg capita\(^{-1}\) year\(^{-1}\) (Ahmed et al. 1998). Even in mountainous regions like Luang Prabang in the Lao PDR, which present similar physical-geographic conditions as the central highlands in Viet Nam or northern Thailand or north-eastern Cambodia, fish and other aquatic animals account for 55 percent (29 kg capita\(^{-1}\) year\(^{-1}\)) of the total animal protein intake of the human population in rural areas (Sjorslev 2000). In An Giang province in the Vietnamese Mekong Delta consumption of fish, aquatic animals and processed products is reported as high as 58 kg capita\(^{-1}\) year\(^{-1}\) (Sjorslev 2001).
RECREATION AND ECO-TOURISM

Compared to other inland fisheries in the world, sport fishing for recreation occurs on a very limited scale in the LMB. In Thailand, weekend tourism for fishing in the reservoirs enjoys a certain popularity.

Eco-tourism is starting in such obvious areas as the inundated forests around the Great Lake in Cambodia with its unique and rare bird colonies. Likewise the Khone Falls in the southern Lao PDR and more recently the undisturbed tributaries like the Srepok River in Ratanakiri and Mondulkiri provinces in Cambodia are attracting eco-tourists.

FISHERIES MANAGEMENT

EXISTING MANAGEMENT AND THE WAY FORWARD

Management measures and the registration of fish production have traditionally concentrated on the larger water bodies. All the four countries conduct management in relation to larger reservoirs, either through exclusive fishing rights, as in many Vietnamese reservoirs, or closed seasons and gear regulations as in many Thai reservoirs. A complex system for the management of the large scale fishery is in operation only in Cambodia, where it is based on licences to fish sections of the floodplains (the so-called fishing lots) and for major gears, like arrow-shaped traps, seines, trawls, barrages and bagnets (Dais). However, this system is not based on integrated plans for managing the fishery in a sustainable way, but rather on maximizing profits or, at best, maintaining catch levels in certain water bodies by habitat protection (Degen et al. 2000). Because it is very effective in controlling “open access”, the fishing lot system would have been termed “best management practice” by Coates (2001), if the social problems caused by it could be addressed. Management experiments involving communities in operating fishing lots have not been tried so far.

Recent research (see above) has demonstrated how most fish species in the Mekong depend on annually repeated migrations for their survival. These migrations will often cross borders and may in all cases depend on the water quality and quantity in the mainstream and the tributaries. Dams and weirs may directly obstruct the migrations. Pollution may affect the stocks and reduce the survival and growth of larvae and fry, while alternative land use, alterations of wetlands and rock clearing for navigation may destroy the crucially important habitats, just to mention a few dangers emanating from other sectors. Present national laws are generally too limited to deal with these situations (Sverdrup-Jensen 2002).

It is therefore obvious that cooperation among several countries will be needed in order to manage these resources and secure their sustainability. And it is necessary to realize that fisheries management is not confined to the fisheries agencies and the fishers, but fisheries management includes habitat management and thereby the effects caused by other sectors. The Mekong River Commission seems at the moment to offer the best framework for such cooperation. Considerable information on the fish resources has been created in a close cooperation among the line agencies for fisheries of the four MRC countries and the corresponding National Mekong Committees. A Technical Advisory Body has been established with members from the top of the four national line agencies for fisheries, where issues of joint interest regarding regional fisheries management are being discussed and advice is being given to the National Mekong Committees and the national agencies responsible for fisheries management.

Hand in hand with the strengthened cooperation a viable strategy must be established to manage the resources jointly. And it will not be sufficient to do this country by country. Fish do not respect national borders, but do respect catchment (watershed) borders. For this reason, a “catchment approach” to fisheries management will be the most natural strategy to apply. Fish migrations can be seen as species migrating from...
The Mekong river system

one tributary catchment area where it spawns, entering the mainstream and exiting it into another tributary catchment area where it feeds, etc. The mainstream becomes the “highway” connecting tributary catchment areas. Everything, which goes in or out passes the “gate”, where the tributary meets the mainstream.

The model is simple and functional. Water management measures, e.g. dam projects, may be examined through their potential effect at the building site, on the particular tributary catchment area and on distant tributary catchment areas sharing the same fish resources. Effects of aquaculture on the wild fish resources may be evaluated in the same way and catchment-specific regulations made for introduction of exotic species. A fish health management system, comprising temporary closure of trade in live fish and disease treatment, may be based on tributary catchments or clusters of catchments as well.

This will to some extent require working across the administrative borders and give rise to some headaches for a few administrators, but fortunately the administrative borders follow to a large extent the watersheds in the Mekong basin. To coordinate basin-wide management exchanges of research information, regular meetings among the fisheries managers of the participating countries are needed.

CO-MANAGEMENT

De facto co-management arrangements have been in use for a long time in the LMB. In all four riparian countries basic legal conditions (an enabling framework) for involving communities in natural resource management are in place (Hartmann et al. 1999). However, in practice the implementation of this enabling framework differs from country to country and from case to case and comprises a continuum of forms that range from more government-directed approaches at one extreme to community-based initiatives at the other. Rights and obligations of state and community differ accordingly. Since in all riparian countries stewardship of natural resources is vested in the state, governments have established more or less detailed legislations on fisheries management. Thus, consciously or unconsciously, resource users are ultimately implementing (or not!) these rules and regulations (Sverdrup-Jensen 2002).

In legislating fisheries, governments face the difficulty of addressing the specific requirements of a multitude of fisheries situations and conditions. In order to solve this problem and in line with the overall tendency of strengthening democratic governance structures, all governments in the LMB are decentralizing fisheries management decision-making to administrative levels closer to the fishers. The degree of decentralization differs in the four countries.

The dispersed settlement structure and remoteness of villages in some areas of the Lao PDR (Claridge et al. 1997; Sjorslev 2000) and north-eastern Cambodia has given rise to localized fisheries management regulations including permanently or seasonally closed fishing grounds, restrictions on specific fishing methods and protection of particular fish species or groups. These management initiatives, many of them focusing on migratory fish species, have evolved empirically and are embedded in local cultural institutions and reflect a deep knowledge of environmental conditions held by resource users. Frequently, such community-based management systems focus mainly on conflict management through managing fishing effort, including gear use regulations, conservation zones, seasonal fishing restrictions and procedures for handling cases of contention (Baird 2001). The dispersed nature of rural communities, their fragmented organization and the difficulties of communication have prevented effective socio-political representation of fishing communities.

In Thailand the existence of traditional forms of user organizations at village level is in decline and NGOs addressing issues of fisheries and natural
resource use management have emerged more prominently than in other riparian countries. In Viet Nam co-management initiatives are embedded into the established politico-administrative system. Local authorities, in principle, follow the regulations on management and protection of natural fish resources stipulated by the Ministry of Fisheries. The degree of compliance, however, is reported to be less than satisfactory.

In Cambodia, the Government has drafted a special legal instrument (a decree) for the development of “community fisheries”, through which small-scale fishers obtain the right to use and manage fishing grounds that were formerly exploited by private large-scale fishing concessionaires. The implementation of this important change in the management regime, though, is hampered by still weak organizational capacities at village levels and the traditional focus on production with a view to maximize income for the privileged rather than protection of stocks and habitats and equitable sharing of the benefits from the fisheries resources. However, the reform process towards community fisheries has initiated a potentially powerful platform for creating transparency and awareness on the need for responsible participation of resource users at community level (Degen et al. 2002).

In Cambodia, attempts are undertaken to anchor local fisheries management efforts within the context of an integrated natural resource management approach at community level. A broader scope of management tries to “internalize” the effects of agricultural practices, forest use and other forms of exploitation of locally available natural resources. This for example includes linkages to water use for irrigation, the use of flooded forest for fish habitat, firewood and the forest soil for agricultural land. However, it is difficult for local communities to influence development measures, such as agro-business developments, deforestation and dam building, which may occur outside their limited boundaries, but have a large impact on local fisheries.

Unless community-based fisheries management initiatives are integrated into a functioning co-management set-up that involves, in addition to the local level, also national and regional levels, through which their members can exert influence on constraining external factors such as environmental degradation or decrease in water quality and quantity, decentralized management approaches will fail to achieve sustainability in fisheries resource management.

**HOW TO SUSTAIN THE FISHERIES OF THE MEKONG BASIN?**

Due to the inherent incompatibility of the various sectors with interests in water resources management and development, it will ultimately be necessary to make hard choices on how to develop the Mekong basin. To assist in the decision-making process and have proper representation of fisheries interests, it is felt that the most important interventions required to sustain the fisheries are:

1) Strengthening of the capacity of riparian governments in coordinating decision-making on water resources development plans that have been based on objective research;

2) Setting up of consultation procedures on water resource usage and fisheries management with resource users, decision makers, researchers and donors;

3) Collection of data clarifying the contribution of fisheries to the national economy, food security and livelihoods;

4) Participation of resource users in fisheries management; and

5) Clarifying the basic principles of fish productivity and lifecycles, such as the need for the protection of floodplain habitats, for maintaining high flood levels with a sufficient sediment load and minimally a free flowing mainstream.
REFERENCES


Jensen J.G. 1996. 1,000,000 tons of fish from the Mekong? Mekong Fish Catch and Culture, 21.


