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MEKONG RIVER COMMISSION
FOR SUSTAINABLE DEVELOPMENT

Mekong River Commission

State of the Basin Report 2010

STATE OF THE BASIN REPORT 2010

Mekong River Commission

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PREFACE

About 60 million people live in the Lower Mekong Basin (LMB) and while continued economic growth has led to a significant improvement in living standards in recent years, many of the basin's population still live in poverty. The livelihoods and food security of most people in the basin are closely linked to the Mekong and the resources it supports.

The Mekong River Commission (MRC) has been in existence since 1995 and its role is to help the governments of the Lower Mekong Basin (Cambodia, Lao PDR, Thailand and Viet Nam) sustainably manage the basin's water and related resources and help use these resources to lift the population out of poverty. It is important that decision-makers have timely and accurate information on water-related sectors and an understanding of the impact that developing these sectors is having on the economy, environment and people. In support of these objectives the MRC presents the *State of the Basin Report 2010*.

This report builds on the first *State of the Basin Report*, which was published in 2003. It describes the status of fisheries, forestry, agriculture, hydropower, water quality, wetlands, navigation and trade, climate change and flood management in the LMB and the interactions between them. The report provides readers with information about the ecological health of the Mekong river system, highlighting its resilience to current human induced pressures and also the threats it faces. It outlines some of the development challenges facing water resources in the basin – including hydropower development, land use change and climate change. These will be monitored and revisited in subsequent *State of the Basin* reports.

An understanding of the status of water resources in the basin provides a broader perspective on the potential vulnerability of its inhabitants and informs the poverty alleviation objectives of the governments of the MRC Member Countries, all of which have indicated a desire to supplement the already considerable natural resource benefits that the river provides by including the Mekong Basin in their economic development strategies.

As with other basins, informed choices need to be made and some of the proposed developments, especially proposed hydropower schemes on the mainstream Mekong, are contentious. This report provides an important contribution to the ongoing debate that is taking place among stakeholders in Mekong countries and supplements other analysis being carried out by MRC on the opportunities and risks associated with various future development scenarios. In this respect the *State of the Basin Report 2010* will be an important reference tool for stakeholder engagement for both the MRC and the governments and national agencies of the Member Countries.

This document outlines some important challenges that will require further cooperation in monitoring, research and management over the next few years. Many of these already form the core of MRC's work and I trust that highlighting them in this report helps move these issues further into the public domain. These challenges include:

- In general, water quality in the Mekong Basin remains good, however, trends indicate that in areas of high human habitation or intensive agriculture, water quality is declining.

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The Mekong River – the livelihoods of millions depend on careful management of the river basin and its resources.

- Biodiversity, water quality, flood protection, fisheries, and a range of livelihoods in the basin are at risk from endangered wetlands and increasing deforestation.
- Given the importance of fish to food security in the basin, it is a concern that fishers are reporting declining catches and falling average sizes.
- With increasing development and growing population, there is a need for more effective flood forecasting and preparedness systems.
- The growth in intensive agriculture will result in increased demand for water resources while also endangering water quality and biodiversity through increased use of pesticides.
- Climate change will dramatically increase people's vulnerability to poverty and food insecurity in the basin by increasing the risk of extreme weather events such as drought and flooding.

These challenges are just some of the considerations Mekong governments need to take into account as they plan for the future use of the basin's resources. MRC is working with them to develop an Integrated Water Resources Management (IWRM) Basin Development Strategy as part of the response, which is scheduled for completion by the end of 2010.

The livelihoods of millions depend on the careful management of the basin in a climate of openness and transparency. To this end, I am confident that the *State of the Basin Report 2010* will be a valuable reference for strategic planning in the Mekong region for several years to come, and will contribute to the foundation for knowledge-based environmental policy.

The MRC has compiled and edited the *State of the Basin Report 2010* on the basis of contributions from a large number of sources both within and outside the organisation. I would like to take this opportunity to thank all those who have contributed to the report and look forward to their continued cooperation.

Further, if you would like to contribute to the debate over use of water resources in the Mekong Basin, or have any comments or feedback on this report, please submit your ideas through the MRC website <www.mrc-mekong.org>.

Jeremy Bird
Chief Executive Officer
MRC Secretariat

INTRODUCTION

In 2003, the Mekong River Commission (MRC) published the first State of the Basin Report. It was a step in the process of reviewing the condition of the basin and changes that had been taking place. The report formed part of the commitment by Cambodia, Lao PDR, Thailand and Viet Nam to collaborate for the sustainable use, management and conservation of water and related resources in the Mekong Basin. This second report continues the process. It is hoped that the information presented here gives readers a better understanding of:

- the important role that the Mekong system plays in the lives of the people who live in the basin and depend on its water and related resources
- the up-to-date status of and trends in water and related resources in the basin
- the need to develop water and related resources in ways that are equitable and sustainable from an economic, social and environmental point of view
- the importance of planning and monitoring development on a basinwide scale – an integrated water resources management (IWRM) approach.

With these objectives, the State of the Basin Report 2010 provides an introduction to the geography, hydrology, plant and animal life of the Lower Mekong Basin (LMB), as well as the social and economic circumstances of its peoples. It also reviews key economic, environmental and social issues.

The report is published in two parts: the main technical report (this volume) and a summary booklet which presents the key findings and is translated into the four riparian languages.

As well as providing an up-to-date status of water and water-related resources in the basin, the report also considers the rapid and planned development in the region, along with new global and regional emerging issues, such as climate change, to help readers keep abreast with the latest information on 'meeting the needs, keeping the balance'.

The report is arranged in five chapters: Chapter 1 describes the key features of the LMB, as a prelude to the assessments in the following chapters. The MRC Member Country vision: *an economically prosperous, socially just and environmentally sound Mekong River Basin* shapes the following three chapters which provide an assessment of status and trends of social, environmental and economic issues, underlying pressures and future threats and challenges. Chapter 5 is an assessment of emerging trends affecting the basin's development, related governance issues and the status of cooperation between the Mekong countries.

The target audience for this report includes policy makers in the Mekong countries, their line agencies, MRC development partners and other stakeholders such as civil society, regional organisations, academics and researchers.

The report is based on the wealth of information available at MRC, including monitoring data, reports and studies. The MRC monitoring data in general show data to the end of 2008, whereas other statistical data can be less recent due to time delays caused by the rigorous quality assurance of national statistical offices. Information from relevant studies is also included and literature on relevant aspects of the LMB and its Member Countries has been reviewed to provide supporting information. In general, the data cover the LMB but in some cases information was only available on a whole country basis (i.e. including areas outside the basin). This is clearly indicated in the presentation of the information.

I
SETTING AND CONTEXT

Allan Michaud

1.1 GEOLOGY AND GEOMORPHOLOGY

The Mekong is one of the world's great rivers (Table 1.1.1). Together with its sister rivers, the Salween and the Yangtze, it drains the eastern watershed of the Tibetan plateau (Figure 1.1.1). These rivers fall off the eastern rim of the plateau in a narrow geographic zone characterised by deep gorges and high ridges known as the 'Three Rivers Area'. In this narrow zone the three great rivers flow parallel to one another in a strip of terrain some 100 km wide by 500 km long. Downstream of the Three Rivers Area, the courses of Salween, Mekong, and Yangtze diverge, so that the rivers eventually discharge into the Andaman Sea, South China Sea, and East China Sea respectively.

Table 1.1.1 The 10 largest rivers of the world ranked by length

Rank	River	Landmass	River length (km)	Outflow
1	Nile	Africa	7088	Mediterranean Sea
2	Amazon	South America	6575	Atlantic Ocean
3	Yangtze	Eurasia	6236	East China Sea
4	Mississippi	North America	6084	Gulf of Mexico
5	Yenisei	Eurasia	5816	Arctic Ocean
6	Yellow River	Eurasia	5778	Yellow Sea
7	Ob'	Eurasia	5525	Gulf of Ob'
8	Amur	Eurasia	5498	Tatar Strait
9	Congo (Zaire)	Africa	5118	Atlantic Ocean
10	Mekong	Eurasia	4909	South China Sea

Source: Liu et al. (2009)

The internal drainage patterns within these three basins are unusual when compared to those of other large rivers. Most large-river systems that drain the interiors of continents, such as the Amazon, Congo, and Mississippi, have relatively simple dendritic tributary networks that resemble a branching tree (Clark et al. 2004). Typically, such patterns develop in basins with gentle slopes where the underlying geological structure is fairly homogenous and stable, exerting little or no control on river morphology (Twidale 2004). In marked contrast, the tributary networks of the Salween, Yangtze, and particularly the Mekong, are complex with different sub-basins often exhibiting different, and distinct, drainage patterns. These complex drainage systems have developed in a setting where the underlying geological structure is heterogeneous and active, and is the major factor controlling the course of rivers and the landscapes they carve out (Twidale 2004; Tandon & Sinha 2007).

PRECEDING PAGE

The Tonle Sap River departs its normal course to spread far and wide in the wet season. *Photo by Joe Garrison.*

FACING PAGE

Tatai Waterfalls in the Cardamom Mountains in SW Cambodia.

Figure 1.1.1 Major drainage basins of Southeast Asia.

Origin of sediments in the Mekong Basin

The elevation of the Tibetan Plateau during the Tertiary period was one of the important factors in the genesis of the south-west monsoon (Clift & Plumb 2008), which is the dominant climatic control influencing the hydrology of the Mekong Basin (see sections 1.2 and 1.3). Understanding the nature and timing of the elevation of Tibet (and the Central Highlands of Viet Nam) therefore helps explain the provenance of sediment reaching the delta and the Tonle Sap Great Lake today.

Studies of the provenance of sediments in the Mekong Delta reveal a major switch in the source of sediments about eight million years ago (Ma) (Clift et al. 2004; Clift et al. 2006). From 36 to 8 Ma the bulk (76 per cent) of the sediments deposited in the delta came from erosion of the bedrock in the Three Rivers Area (Figure 1.1.2, Table 1.1.2). However, from 8 Ma to the present the contribution from the Three Rivers Area fell to 40 per cent, while that from the Central Highlands rose from 11 to 51 per cent.

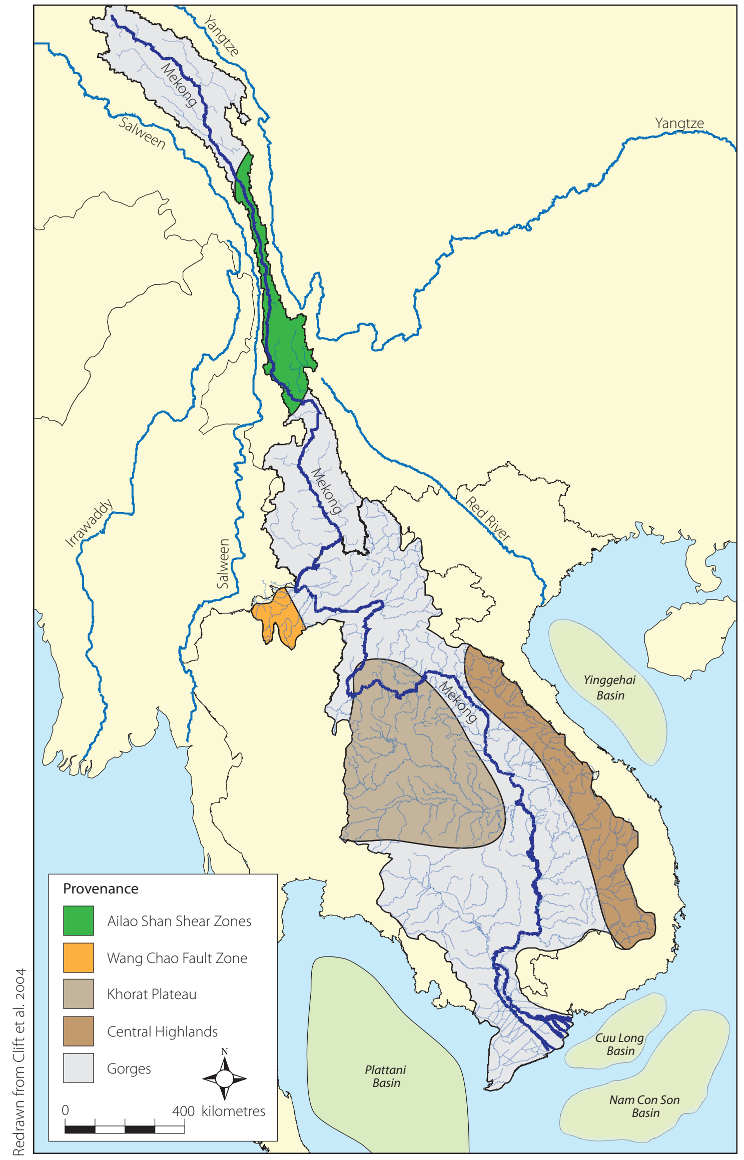


Figure 1.1.2 Major provenance of sediments in the Mekong Delta.

One of the most striking conclusions of provenance studies is the small contribution of sediment from the other parts of the Mekong Basin, notably the Khorat Plateau, the uplands of northern Lao PDR and northern Thailand, and the mountain ranges south of the Three Rivers Area.

Table 1.1.2 Estimated volume of erosion in provenance areas of sediments deposited in the Mekong Basin

Source Area	Volume of eroded rock (km³)			Proportion of 36–8 Ma (%)	Proportion of 8–0 Ma (%)	Proportion of Total (%)
	36–24 Ma	24–8 Ma	8–0 Ma			
Central Highlands Viet Nam	33,750	33,750	90,000	11%	52%	20%
Tibetan Gorges	0	1600	4800	0%	3%	1%
Ailao Shan Shear Zone	175,000	280,000	70,000	76%	40%	68%
Wang Chao Fault Zone	18,500	55,500	9250	12%	5%	11%

Source: Clift et al. 2004

The evolution of the Mekong Delta and the Tonle Sap

The last glacial period came to an abrupt end about 19,000 years ago (ka) when sea levels rose rapidly, reaching a maximum of about 4.5 m above present levels in the early Holocene at about 8 ka (Tamura et al. 2009). At this time the shoreline of the South China Sea almost reached Phnom Penh and cores recovered from near Angkor Borei contained sediments deposited under the influence of tides, and salt marsh and mangrove swamp deposits (Tamura et al. 2009). Sediments deposited in the Tonle Sap Great Lake about this time (7.9–7.3 ka) also show indications of marine influence, suggesting a connection to the South China Sea (Penny 2006). Although the hydraulic relationships between the Mekong and the Tonle Sap Great Lake systems during the Holocene are not well understood it is clear that between 9000 and 7500 years ago the confluence of the Tonle Sap and the Mekong was in close proximity to the South China Sea.

The present morphology of the Mekong Delta developed over the last 6000 years (Figure 1.1.3). During this period the delta advanced 200 km over the continental shelf of the South China Sea, covering an area of more than 62,500 km^2 (Nguyen et al. 2000). From 5.3 to 3.5 ka the delta advanced across a broad embayment formed between higher ground near the Cambodian border and uplands north of Ho Chi Minh City. During this phase of its development the delta was sheltered from the wave action of longshore currents and was constructed largely through fluvial and tidal processes (Ta et al. 2002b). At this time the delta was advancing at a rate of 17–18 m per year. However after 3.5 ka the delta had built out beyond the embayment and became subject to wave action and marine currents. These deflected deposition south-eastwards in the direction of the Camau Peninsula (Figure 1.1.3), which is one of the most recent features of the delta.

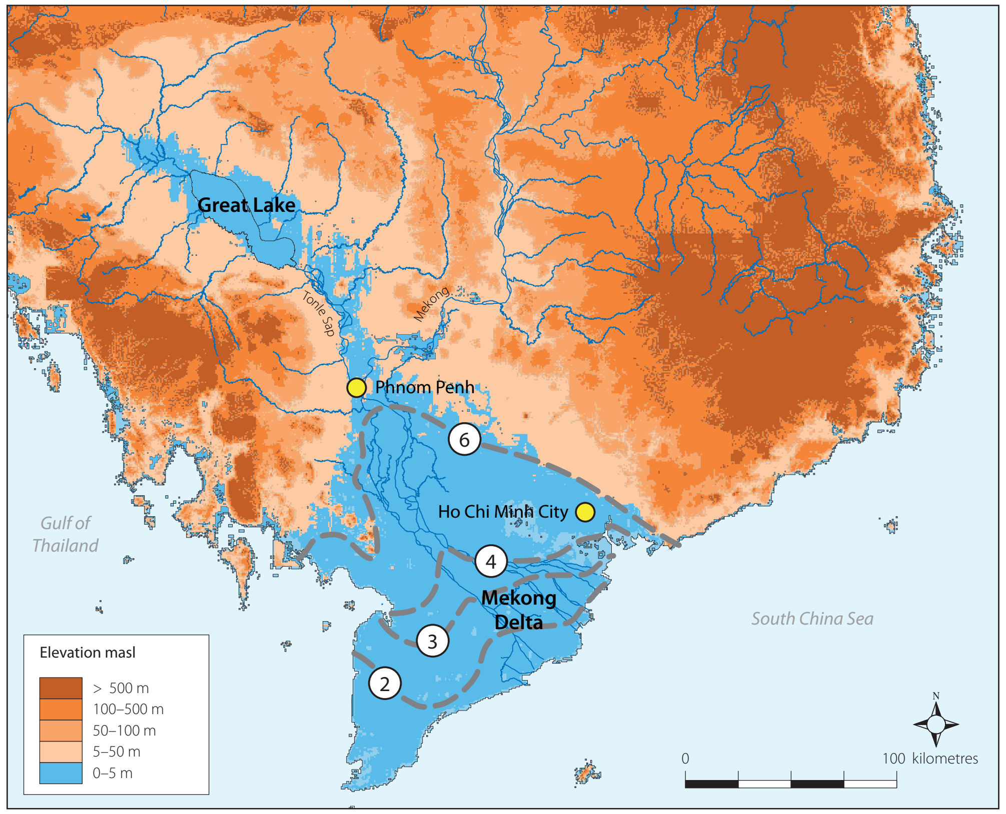


Figure 1.1.3 Development of the Mekong Delta over the last 6000 years.
The progression of the coastline is indicated in dashed lines (numbers in the circles indicate the location in ka).

Geomorphological zones

For much of its length the Mekong flows through bedrock channels, i.e. channels that are confined or constrained by bedrock or old alluvium in the bed and riverbanks (Figure 1.1.4). Geomorphologic features normally associated with the alluvial stretches of mature rivers, such as meanders, ox-bow lakes, cut-offs, and extensive floodplains are restricted to a short stretch of the mainstream around Vientiane and downstream of Kratie where the river develops alluvial channels that are free of control exerted by the underlying bedrock.

Recent seismic activity

The Mekong Basin is not normally considered a seismically active area as much of the basin is underlain by the relatively stable continental block. Nonetheless, the parts of the basin in northern Lao PDR, northern Thailand, Myanmar and China do experience frequent earthquakes and tremors. The magnitude of these earthquakes rarely exceeds 6.5 on the Richter scale and is unlikely to cause material damage (Fenton et al. 2003).

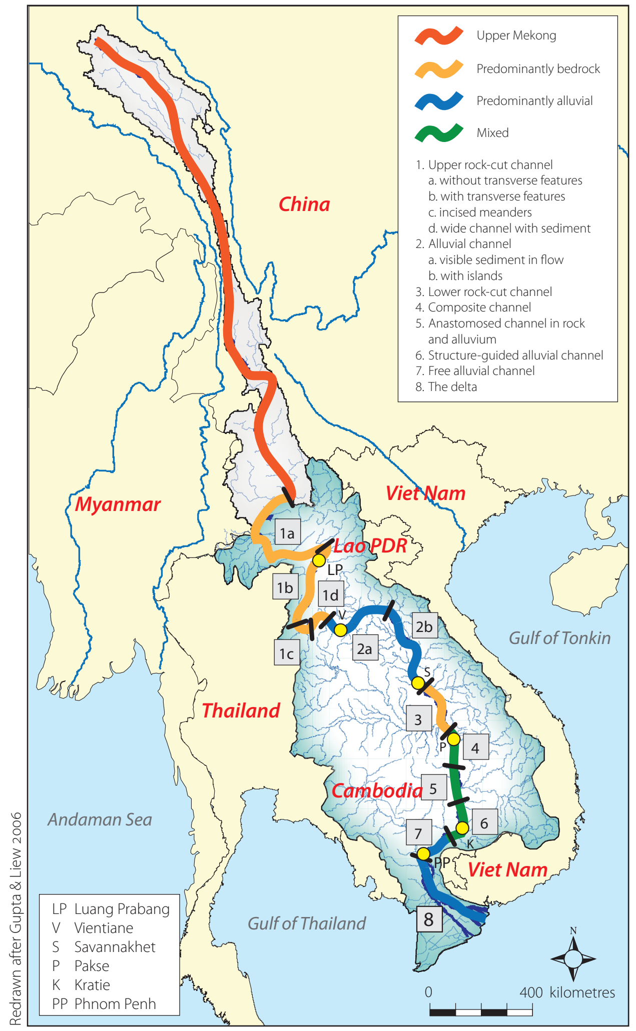


Figure 1.1.4 Geomorphologic zones of the Mekong.

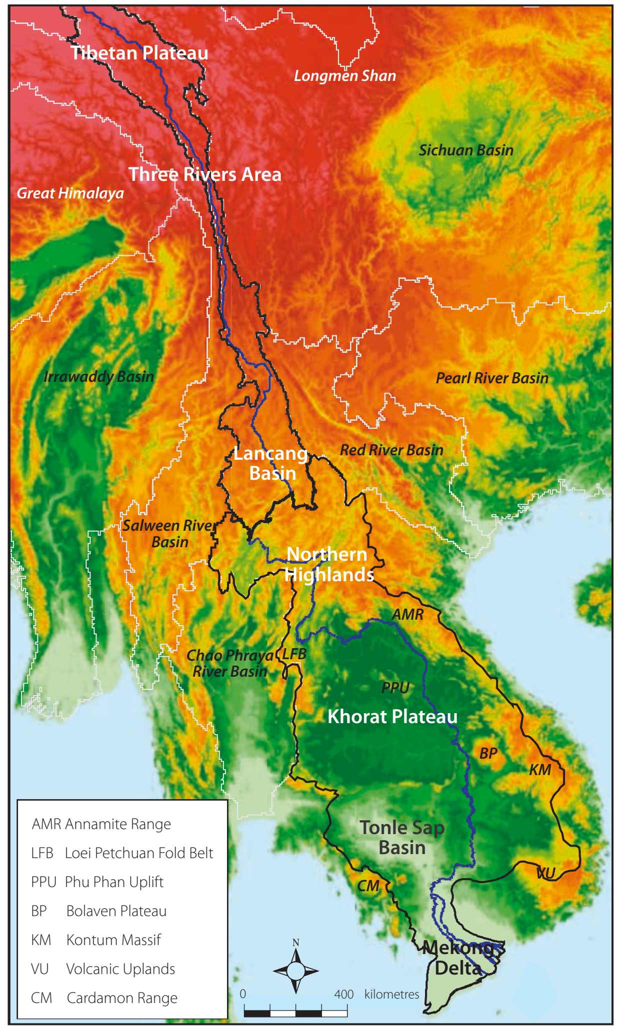


Figure 1.1.5. Topography and physiographic zones of the Mekong Basin.

The physiography of the Mekong Basin

The Mekong Basin can be subdivided into seven broad physiographic regions described by topography, drainage patterns, and the geomorphology of river channels (Figure 1.1.5). The upper three regions (Tibetan Plateau, Three Rivers, and Lancang Basin) make up the Upper Mekong Basin. The Lower Mekong Basin contains four physiographic regions – Northern Highlands, Khorat Plateau, Tonle Sap Basin and the Mekong Delta.

Physiographic regions

TIBETAN PLATEAU

The Guyong-Pudigao creek at 5160 masl near the foot of Mt Jifu on the Tibetan Plateau is designated as the source of the Mekong (Liu et al. 2007). The plateau is the most densely glaciated region on Earth and while nearly half the glaciated area (49,873 km^2) is within China (WWF 2005), only 316 km^2 of this area is attributed to the Mekong Basin (Eastham et al. 2008). The eastern third of the plateau drains into the basins of the Salween, Mekong and Yangtze rivers. On the high plateau the course of the Mekong and its tributary network is influenced strongly by the tectonic fabric of the Tibetan Plateau. Here the mainstream and the major tributaries run more-or-less parallel in a NNW to SSE direction (Figure 1.1.5). Short river segments, which cut across the tectonic grain at right angles, connect the larger tributaries to one another and to the mainstream.

THE THREE RIVERS AREA

In this area, the Mekong sweeps through a broad north–south trending arc as it flows for more than 500 km through a deep ravine that is incised more than 2500 m in some places (Figure 1.1.5). In this stretch of the Mekong, where the river has no significant tributaries, the basin is very constricted and at its narrowest is only 20 km wide.

LANCANG BASIN

To the south of the Three Rivers Area the Upper Mekong Basin broadens as the Salween and Yangtze diverge to the west and east respectively (Figure 1.1.5). This area, known as the Lancang Basin, is still at a high elevation (between 2000 and 3000 masl) compared to the LMB, and the river continues to flow down a steep gradient. However, small tributary catchments are now developed on both the right and left banks of the mainstream. Channel morphology is largely bedrock constrained.

NORTHERN HIGHLANDS

The Northern Highlands forms the upland region of northeast Myanmar, northern Thailand and northern Lao PDR (Figure 1.1.5). In this region the Mekong is constrained in steep-sided bedrock cut channels.

The tributary network in this area has large tributaries entering the Mekong's left (Nam Ta, Nam Ou, Nam Soung and Nam Khan) and right (Nam Mae Kok and Nam Mae Ing) banks. These tributary networks mostly flow through steep-sided rock-cut valleys. However, in places the tributaries broaden and develop floodplains.

KHORAT PLATEAU

The Khorat Plateau is a saucer-shaped basin perched at an elevation of about 300 masl. The rim of the basin is defined by a sharp cuesta formed by the highly resistant sandstones of the Khorat Group. The plateau is bound to the west and northwest by the Loei – Petchabun foldbelt, and by the Annamite Mountains to the east and northeast (Figure 1.1.5). To the south the cuesta forms a low ridge that sits above the Tonle Sap Basin.

The only significant internal topographic feature is a low range of hills (Phu Phan uplift) that cut across the basin trending from the NNW to SSE. This low range divides the Khorat Plateau into two sub-basins, the Sakhon Nakhon/Savannakhet Basin to the north, and the Mun/Chi Basin to the south.

The tributaries on the right bank of the Mekong (Songkhram and Mun), which flow across the low-gradient and low-relief central region of the Khorat Plateau, have well developed dendritic architecture. In contrast, the tributaries on the left bank of the river (Nam Ca Dinh, Se Bang Fai and Se Bang Hiang) fall steeply from sources high in the Annamites.

TONLE SAP BASIN

The Tonle Sap Basin is a large dome like structure that has been 'unroofed' through erosion, leaving a rim of hills standing above the alluvial plains that fill the centre of the basin. The Mekong enters the basin just north of Pakse and flows through a broad valley flanked by the southern rim of the Khorat escarpment to the west and the Boloven Plateau to the east. At the southern end of this stretch the mainstream breaks up into a complex network of branching and reconnecting channels – typified by the islands and channels forming the Siphandone (4000 islands) area in southern Lao PDR (Gupta and Liew 2006).

The Mekong drops into the alluvial plain of Cambodia through a series of cataracts at Khone Falls. The river then flows southwards along the eastern margin of the basin in a section of branching channels until Kratie. Here, the course of the mainstream takes a right-angled turn westwards as the river is deflected by extensive basaltic lava flows that form the upland area north of Ho Chi Minh City.

The tributary network entering the left bank of the Mekong in this stretch of the river is dominated by the catchments of the Se Song, Se San, and Sre Pok (3S basin). These fast flowing rivers drain a chain of mountainous terrain that extends in a broad arc from the Boloven Plateau of Lao PDR, though the Kontum Massif, to the volcanic uplands of southern Viet Nam.

Downstream of Kratie the mainstream develops a broad alluvial floodplain with associated shifting channel morphologies including meanders, scroll-marks, and ox bow lakes (Gupta and Liew 2006).

The western and central part of the Tonle Sap Basin forms a low-gradient and low-relief landscape in which sits the Great Lake, its extensive floodplain and the network of tributaries that feed into the lake. The Tonle Sap River, which links the Mekong and the Great Lake, has hydraulic characteristics rarely found elsewhere in the world. During the dry season, the river behaves as a normal tributary draining water off the Cambodian floodplain and its surrounding catchment into the mainstream of the Mekong. However, during the wet season the dramatic increase in the discharge of the mainstream cannot be accommodated by the distributary network of the Mekong Delta, and the level of the Mekong rises higher than the Tonle Sap River. When this happens the flow of the Tonle Sap River reverses direction as water from the Mekong flows 'upstream' overfilling the Great Lake and flooding the surrounding forested lowlands. During this part of the annual flood-cycle, the area of the Great Lake increases six-fold from 2500 km^2 to 15,000 km^2 and its volume from 1.5 km^3 to between 60 and 70 km^3. At the end of the wet season the discharge of the Mekong falls, and the flow of the Tonle Sap River reverts to the normal downstream direction, draining excess water off the inundated floodplain surrounding the Great Lake.

THE MEKONG DELTA

The top of the Mekong Delta is defined near Phnom Penh where the largest distributary river channel, the Bassac River, splits from the mainstream. South of Phnom Penh, the delta rapidly expands to form a wedge shaped delta plain that covers an area of 62,520 km^2 (Nguyen et al. 2000). The modern delta has two major distributary channels, the Mekong and Bassac Rivers, which split into a number of smaller channels to form the Nine Dragons, as the mouths of the Mekong are collectively known.

The sub-aerial region of the delta plain can be divided into two parts: an inner delta plain that is dominated by fluvial process, and an outer delta plain that is dominated by marine processes (Ta et al. 2002a). The inner delta plain is low-lying and close to sea level while the outer delta-plain, which is built of coastal plain deposits, is fringed seawards by mangrove swamps, beach ridges, sand dunes, spits and tidal flats (Ta et al. 2002a).

Groundwater and aquifers in the Mekong

Aquifers in the LMB can be subdivided into four categories based on lithology and connectivity:

- *A suite of basement rocks* (granites, basalts, and high-grade metamorphic rocks) which do not support a coherent subsurface flow regime, but which support groundwater storage in weathered and fractured zones.
- *Late Palaeozoic strata* which, being sedimentary rocks (sandstones and limestones), possess the primary and secondary rock properties of porosity, permeability and connectivity.
- *Mesozoic strata* comprised predominantly of massively bedded sandstones. These provide regional aquifers which, with intrinsic permeability, porosity and regional hydraulic heads, will host the main groundwater flow regime in the basin.
- *Holocene alluvial/fluvial deposits in upstream areas of the basin and the alluvial/deltaic/ marine sediments of the Mekong Delta*. These are intrinsically porous and permeable aquifers. However, the alluvial aquifers are continually reworked by present day river processes and their lateral continuity will be defined by bed-form geometries. The deltaic sediments, which comprise a complex body of inter-fingering marine and freshwater depositional bodies, are considered to be a major resource, but some local water-quality concerns, such as saline intrusion, may occur in the marine and brackish deposits.

The aquifers developed in the Mesozoic strata are likely to be the most regionally extensive. The most significant of these will be in the region of the Khorat Plateau of northeast Thailand, central Lao PDR and northern Cambodia. Flow within the aquifer will be controlled by the structural geometry of the carrier beds and the relationships between them and the impervious layer, particularly the salt.

The alluvial aquifers may also be extensive and continuous within the confines of the meander belts, floodplain and delta plain. This aquifer may extend across country borders along both the mainstream and larger tributaries, but the internal architecture of the carrier beds is likely to be complex, and this will also complicate flow within the aquifer.

Because they are inherently fragmented, both the basement and Paleozoic aquifers are likely to be more geographically restricted. However, this does not mean they may not have important, if local, transboundary effects in the border areas between Lao PDR and northern Thailand, and between Cambodia, Lao PDR, and Viet Nam in the area of the Annamite Chain and the Central Highlands. This latter area may include trans-boundary effects on water quality arising from the exploitation of mineral resources. Understanding these issues will require fairly detailed geological and hydrogeological mapping.

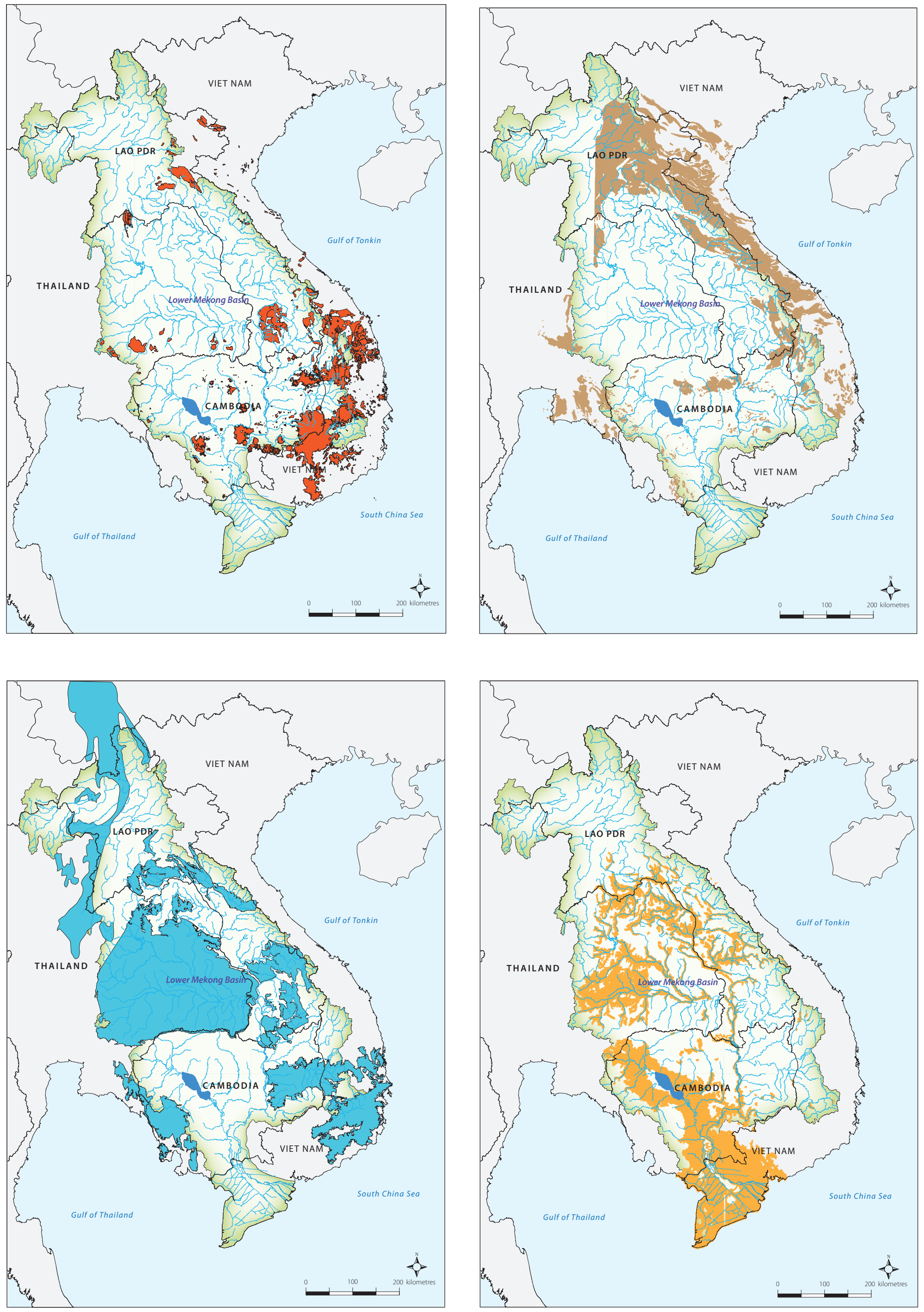


Figure 1.1.6 Types of aquifers in the Lower Mekong Basin:

Top left: Basement rocks (granites and high-grade metamorphic rocks), groundwater storage in weathered and fractured zones. ***Top right***: Late Paleozoic strata (sandstones and limestones), fragmented aquifers discharging to the Mekong mainstream and tributaries. ***Bottom left***: Mesozoic strata (sandstones), regional aquifers, hosting the important groundwater flow regime in the Khorat Plateau. ***Bottom right***: Alluvial/fluvial deposits in upstream areas and alluvial/deltaic/marine sediments of the Mekong Delta, important aquifers.

1.2
CLIMATE

The tropical monsoonal climate

The climate of the Lower Mekong Basin is classified as tropical monsoonal, almost always hot and seasonally excessively moist, with a minimum average monthly temperature never lower than 20°C. However, the tropical monsoonal regime is distinguished by a highly seasonal rainfall pattern due to a winter/summer reversal of airflow. As warm, moisture-laden air flows from the Indian Ocean in summer, a wet season develops. In winter, a high pressure system develops over the Asian continent and becomes the source of very dry air masses.

The south-west monsoon between mid May and October, which is the dominant climatic feature, generates a distinctly bi-seasonal pattern of wet and dry periods of more or less equal length (Figure 1.2.1). The winter north-east monsoon brings lower temperatures but little rainfall, its impacts being confined to Viet Nam to the east of the Central Highlands which provide a rain shadow effect over the Mekong Basin.

Tropical climates with a distinct dry season form a bioclimatic zone in which the forest becomes less dense, with individual trees more widely spaced. Groundcover is therefore better developed since more light penetrates through the canopy. The dominant vegetation type is known as deciduous dipterocarp forest or Central Indo China dry forest. Reflecting the climate, it defines the natural vegetation of most of the LMB in Thailand, within the Mekong tributaries of central and southern Lao PDR, on the plains of northern, eastern and south central Cambodia and in the upper Se San and Sre Pok Basins in Viet Nam.

Figure 1.2.1 Generalised features of the seasonal climate of the Lower Mekong Basin

Cooler	Hot / Dry				Wet				Hot / Dry		
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE monsoon		Transition		SW monsoon						NE monsoon	

The rainfall climate

The distribution of mean annual rainfall over the basin shows a distinct east to west gradient (Figure 1.2.2). The highest rainfalls of more than 2500 mm/year occur in the western montane regions of Lao PDR and the lowest, less than 1000 mm/year, in the central regions of Thailand within the Mun–Chi Basin. This geographical pattern determines that by far the greatest contributions to mainstream flows during the summer monsoon season originate within the large left bank tributaries in Lao PDR.

Although monsoonal rainfall climates are by definition highly seasonal, the variance of annual total rainfall from year to year is modest and typically of the order of +/- 15 per cent as illustrated at three sites (Figure 1.2.3), of which Chiang Rai represents the northern

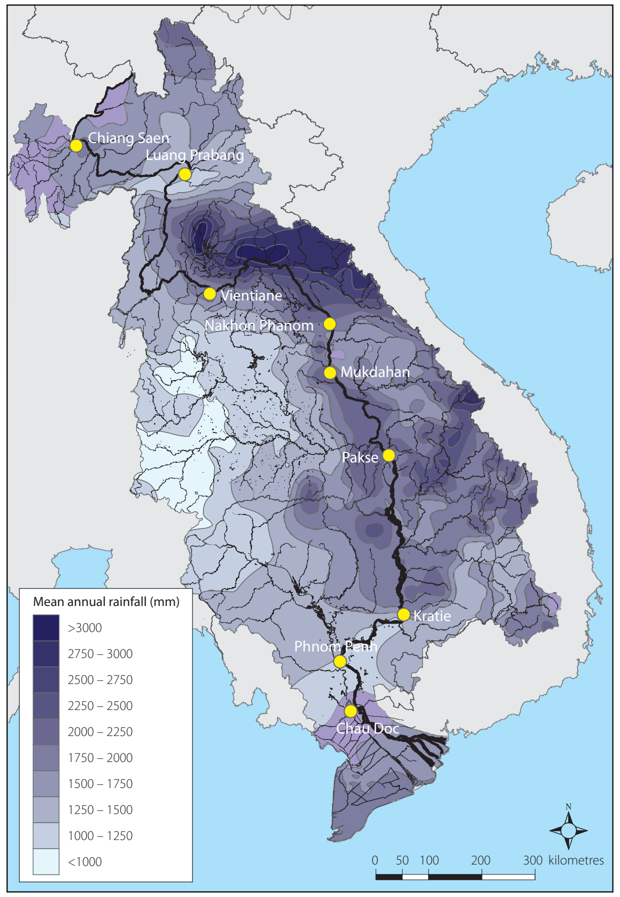


Figure 1.2.2 Lower Mekong Basin – mean annual rainfall.

Storm episodes provide most of the LMB's annual rainfall.

regions of the basin, Khon Kaen the drier eastern parts, and Pleiku the Central Highlands. With the exception of Chiang Rai in the north, the seasonal distribution of rainfall is distinctly bimodal. This is explained by two factors, the first being what are known as monsoonal 'breaks' when the synoptic conditions linked to rainfall generation weaken and become less active. This typically occurs during July and August and is linked to the reduced formation of tropical monsoonal low pressure systems. The second peak in September and October is partly related to the impact of tropical storms and typhoons moving across the LMB from the Gulf of Tonkin and the South China Sea. Their peak incidence occurs from September to November, although their average track tends to move from north to south as the season progresses.

In most years, the geographic variability of total rainfall over the basin is high since the synoptic conditions that cause major storm rainfall events do not extend to the basin scale. Intense tropical depressions tracking from east to west typically affect only part of the region while distribution of rainfall associated with these depressions also depends on how rapidly they weaken as they move towards the west. Convective cells typical of the monsoon are even more localised in their impacts. Such storm episodes provide most of the annual rainfall and their local frequency in any given year determines whether the year is particularly wet.

Despite the high spatial variability of tropical monsoon rainfall, it is possible to obtain a general regional overview of the conditions over recent years by pooling the annual time series expressed as deviations above and below the mean annual rainfall for the 25 years from 1980 to 2004 (Figure 1.2.4).

The period began with average to drier conditions which intensified post 1985 and then became much more severe during the early 1990s when almost all sites recorded a run of several years of much reduced rainfall. After 1995, general regional rainfall moved back to normal levels and then into a distinctly wetter phase between 1999 and 2002, after which it decreased to average and below.

The regional onset and end of the south-west monsoon in terms of rainfall are remarkably consistent, as illustrated for four selected sites (Table 1.2.1), which is however not the case for the average date of monsoon end. The average end date of monsoon rainfall towards the north in Chiang Rai and south at Kratie is several weeks later than within the central areas of the basin. This might be because the incidence of tropical storms that move into the basin from the South China Sea is highest in October and November. Over the last 50+ years there appears to be no evidence to suggest that the regional timing and duration of the south-west monsoon has undergone any modification to indicate climate change.

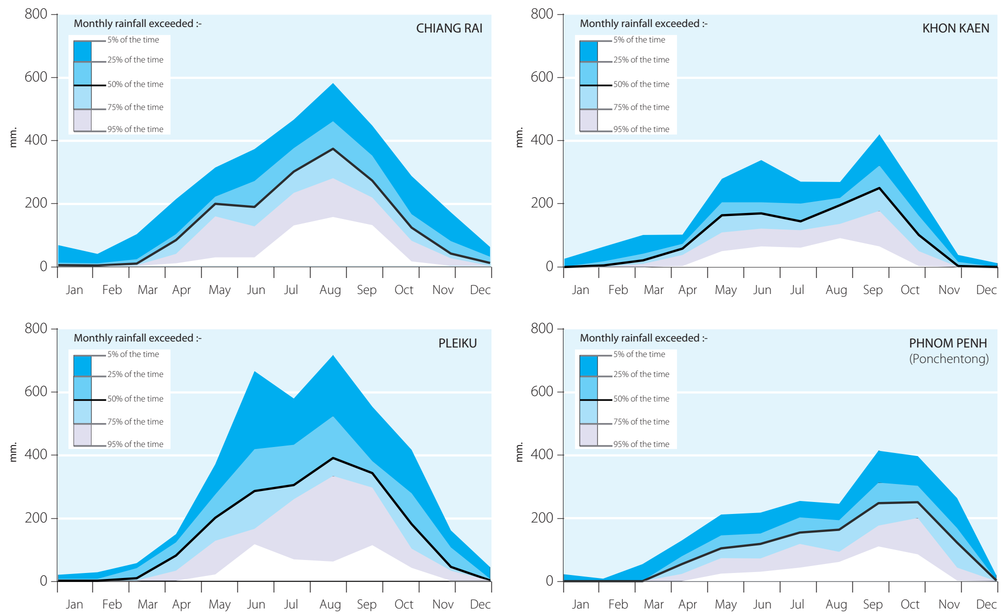


Figure 1.2.3 Lower Mekong Basin – distribution and range of monthly and annual rainfall at selected locations.

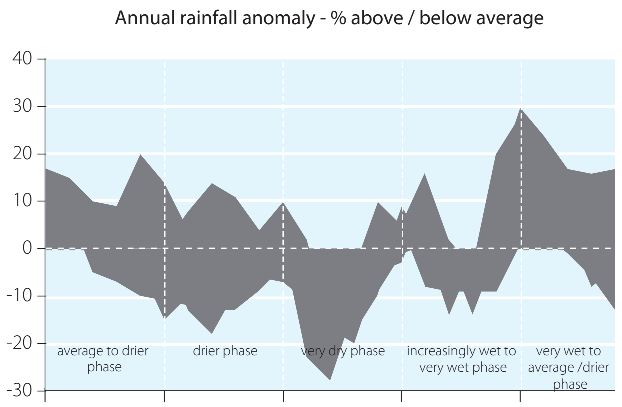


Figure 1.2.4 Deviations of regional rainfall above and below average over the 25 years between 1980 and 2004, based on pooled data.

Table 1.2.1 Historical (1950–2006) mean date and standard deviation of the onset and withdrawal of the south-west monsoon at selected locations in the Lower Mekong Basin

Site	Monsoon onset		Monsoon end	
	average date	standard deviation	average date	standard deviation
Chiang Rai	8 May	9 days	6 Nov	27 days
Khon Khaen	9 May	9 days	16 Oct	18 days
Vientiane	5 May	7 days	11 Oct	16 days
Kratie	9 May	5 days	7 Nov	17 days

Moisture budgets

Regional mean annual rates of evaporation vary between 1000 and 2000 mm, with little variability from year to year due to the high relative humidity. The highest figures occur over the Khorat Plateau of northeast Thailand, one of the driest parts of Southeast Asia. Over the region as a whole the average figure is 1500 mm but falling to as little as 1000 mm in the Central Highlands.

Over the major part of the basin, annual evaporation and rainfall are roughly equal, as indicated by the results for Vientiane and the delta (Figure 1.2.5). Towards the north (Chiang Saen) a considerable moisture surplus develops as a result of higher rainfall and lower evaporation. The major regional feature, however, is the very high moisture deficits that characterise the Khorat Plateau, represented by the result for Khon Kaen, where evaporation exceeds rainfall by almost 700 mm in an average year. Here only two summer months have a surplus of any significance, compared to five and six months elsewhere. This means that the area is particularly vulnerable to critically low levels of soil moisture during winter, has a high incidence of agricultural drought conditions and the highest regional crop water requirements.

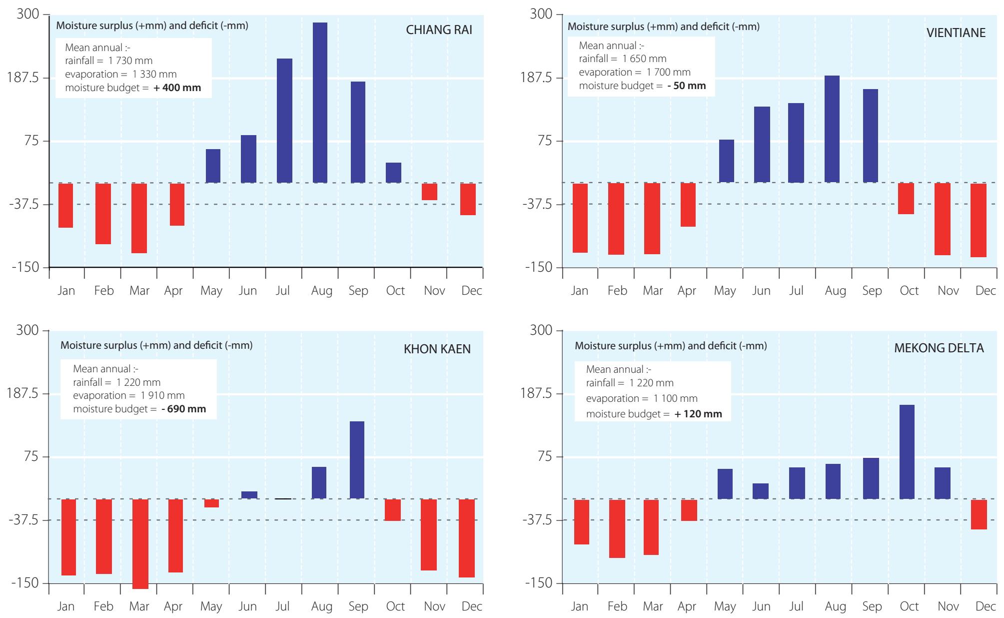


Figure 1.2.5 Average seasonal and annual moisture budgets at selected locations.

Temperature

The principal regional temperature gradient is latitudinal with other variations that are a function of altitude so that average temperatures towards the eastern margins of the basin and the Central Highlands are lower than elsewhere.

The annual range of mean temperature between the hottest and coldest months throughout the region is just five degrees. A definitive feature of tropical climates is that the diurnal range is higher, typically of the order of 8–10 degrees in summer and more in winter. Maximum summer temperatures at altitudes of less than 500 masl typically reach 35 degrees, while minimum winter figures can fall as low as 15 degrees and below during December and January (Table 1.2.2). At higher altitudes, local ground frost is not uncommon.

Table 1.2.2 Indicative mean monthly temperatures in the Lower Mekong Basin

Month	Pleiku	Chiang Rai	Vientiane	Khon Khaen	Phnom Penh
	Central Highlands	Northern basin	Central basin	Khorat Plateau	Cambodian floodplain
	2460 masl	380 masl	160 masl	165 masl	10 masl
January	18	21	24	24	27
February	20	22	25	25	28
March	23	26	28	28	30
April	24	30	29	29	31
May	24	29	29	28	30
June	23	27	29	28	29
July	22	28	28	27	28
August	22	27	28	27	28
September	22	27	28	26	28
October	22	27	28	26	28
November	21	23	25	25	27
December	19	21	23	23	26
Year	22	26	27	26	28

1.3 HYDROLOGY

The Mekong hydrological regime

The annual hydrological regime of the Mekong (Figure 1.3.1) is determined by two major influences. The first and obvious one is climate and the response to the south-west monsoon between June and October. This results in an annual flood pulse and therefore a distinct seasonality in the annual hydrological cycle between a flood season and a low-flow season.

The second, and perhaps less obvious, factor is scale. On the mainstream and within its larger tributaries the vast areas of drainage systems result in runoff responses to individual storm events caused by monsoonal depressions that tend to coalesce and therefore accumulate into a single seasonal flood flow regime. This means it is not generally possible to distinguish the runoff response to individual events unless the cyclonic storm system is very intense and regional in scale. Tropical typhoon incursions into the basin from the South China Sea are the weather systems most responsible for generating distinct individual peaks to the monsoonal flow. These generally occur during September and October when the seasonal discharge is already high and tend to generate a second significant peak to the annual flow. Historically these events have been responsible for many of the most extreme flood discharges and water levels that have been observed.

The convergence and accumulation of monsoonal flood runoff into a single seasonal flow makes the Mekong floods amongst the largest in the world (O'Connor and Costa 2004).

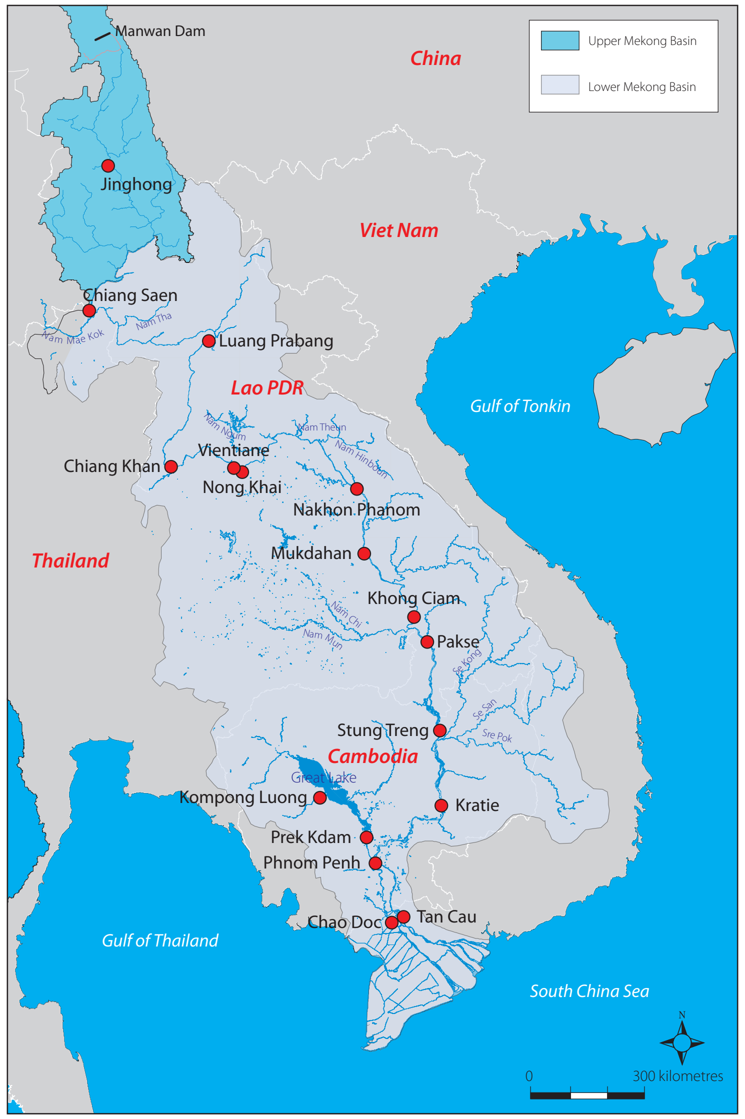


Figure 1.3.1 Major Mekong mainstream gauging stations.

Regional runoff and stream flows

The hydrological geography of the lower Mekong is to some extent affected by upstream conditions but most water is contributed from within the LMB (Table 1.3.1). The upper Mekong in China contributes 16 per cent of the total flow in an average year, while 55 per cent comes from the large left bank tributaries in Lao PDR along with the Se Kong, Se San and Sre Pok (3S) river system. This is reflected in regional distribution of annual runoff (Figure 1.3.2). Although the Mun/Chi tributary complex drains 20 per cent of the lower basin area, average annual runoff is only 250 mm, which is considerably less than half of the regional average figure of 600 mm, with the result that this vast area of northeast Thailand contributes less than six per cent to the mean annual Mekong flow.

Table 1.3.1 Proportional contributions to total Mekong mean annual flow by river reach, distinguishing those made by the left and right bank tributary systems

River reach	Left bank (%)	Right bank (%)	Total (%)
China	16*		16
China – Chiang Saen	1	3	4
Chiang Saen – Luang Prabang	6	2	8
Luang Prabang – Vientiane	1	2	3
Vientiane – Nakhon Phanom	18	4	22
Nakhon Phanom – Mukdahan	3	1	4
Mukdahan – Pakse	4	6	10
Pakse – Kratie	22	2	24
Tonle Sap	9		9
Total	55	20	100

* This figure is based on data at Chiang Saen. China quotes 13.5% as its overall contribution of flow to the basin, based on data at Jinghong. The 2.5% difference is explained by the contribution to the mainstream between the two stream gauges, from the left bank in China and from the right bank in Myanmar.

The estimated mean annual flow of the basin as a whole is almost 460 km³ (Table 1.3.2). Of the total annual flow, in an average year about 75 per cent occurs within just four months between July and October (Table 1.3.3). The distribution of annual flow volumes based on adjusted data at Kratie for the 85 years between 1924 and 2008 (Figure 1.3.2) shows the range of flow volumes observed during this period. The minimum flow occurred in 1992 and the maximum of almost 630 km³ was associated with the disastrous flooding in Cambodia and Viet Nam in 2000.

Table 1.3.2 Distribution of annual flow volumes

Mainstream site	Catchment area km²	Mean annual flow as			as % total Mekong
		Discharge m³/sec	Volume km³	Runoff mm	
Chiang Saen	189,000	2700	85	450	19
Vientiane	299,000	4400	139	460	30
Pakse	545,000	9700	306	560	67
Kratie	646,000	13,200	416	640	91
Total	760,000	14,500	457	600	100

Table 1.3.3 Mekong at Kratie: monthly proportions of mean annual flow

Monthly proportion of mean annual flow (%)											
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2	2	1	1	2	7	14	23	23	14	7	4

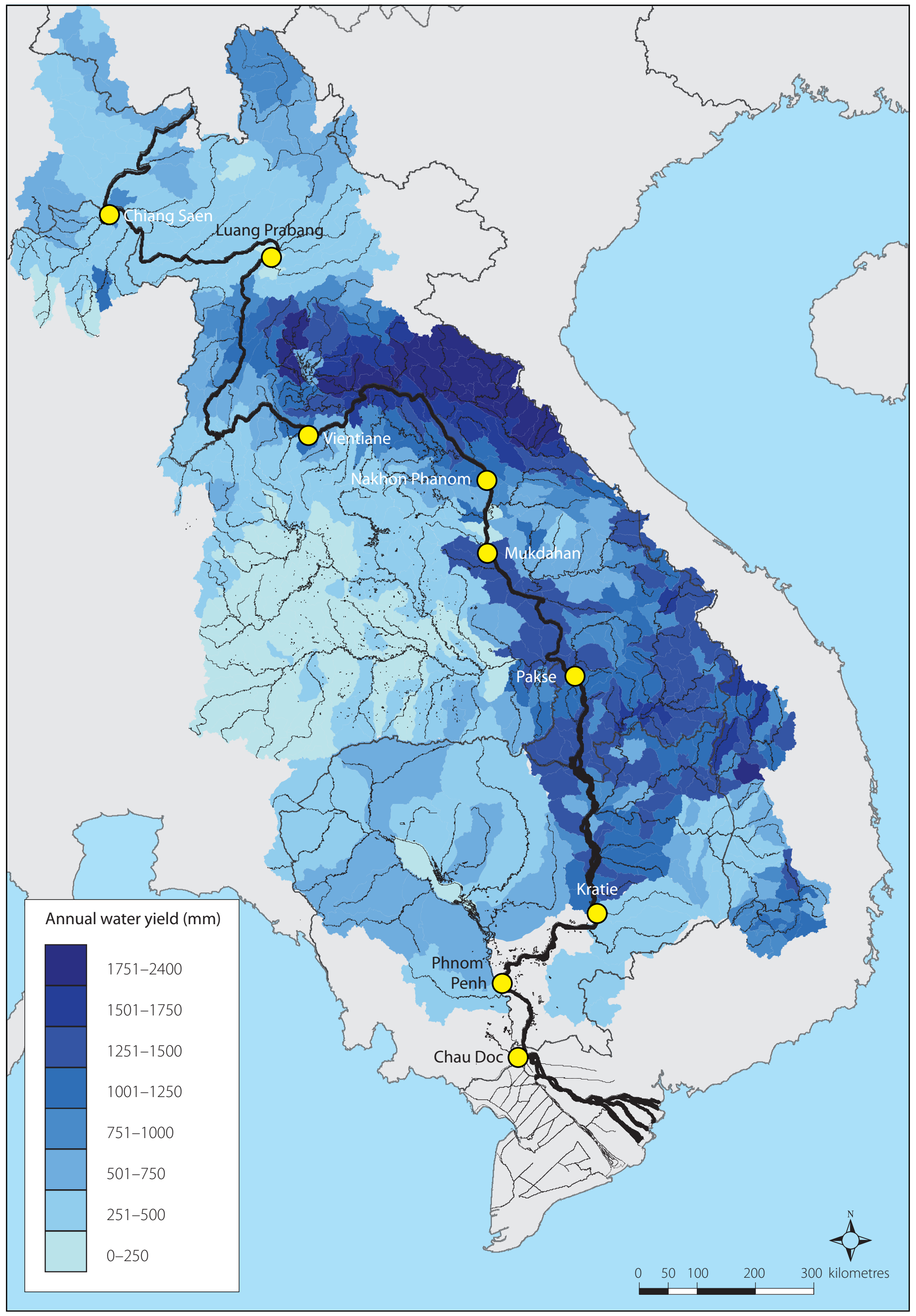


Figure 1.3.2 Mean annual runoff (mm) in the Lower Mekong Basin.

Flood and drought years

Tropical monsoonal regions are generally associated with a water surplus and a highly reliable flow regime. Nevertheless, the flow still varies significantly from year to year. The magnitude of the flood is defined by both the seasonal volume of flow and the maximum discharge or water level. The latter indicates the potential depth of inundation over the floodplain while the volume provides an indication of its duration.

The definition of the flood season in each year is the period that discharges are above their long-term average. For example, the mean annual flow at Vientiane is 4400 m³/sec, a figure that is usually exceeded from July to October. The relationship between the flow volume and discharge can illustrate significant and severe flood and drought years (Figure 1.3.3). The data for the Mekong at Vientiane and Kratie indicate that regionally the most severe drought year was 1992 when the peak and volume of the flood were 40 per cent and more below the average figures. At Vientiane, the most extreme flood conditions occurred in 1966 and at Kratie in 1978, in terms of flood peak and in 2000, in terms of flood volume. A feature of the flood regime that is illustrated in Figure 1.3.4 is that, except for the basin-wide drought of 1992, there is little connection in the severity of the annual flood or drought between the northern and southern parts of the LMB. This is because the weather generating mechanisms which cause extreme conditions, such as tropical storms and cyclones, track across just part of the basin and are not large enough to affect the region as a whole. An example is the flood of 2008, which was extreme at Vientiane but below average at Kratie.

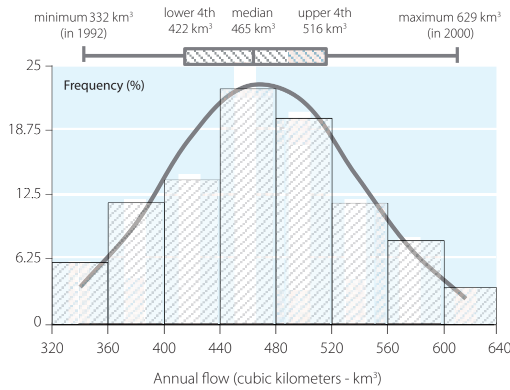


Figure 1.3.3 The frequency distribution of annual Mekong flow volumes based on the adjusted data at Kratie for the period 1924 to 2008. The sample flows are approximately normally distributed as shown.

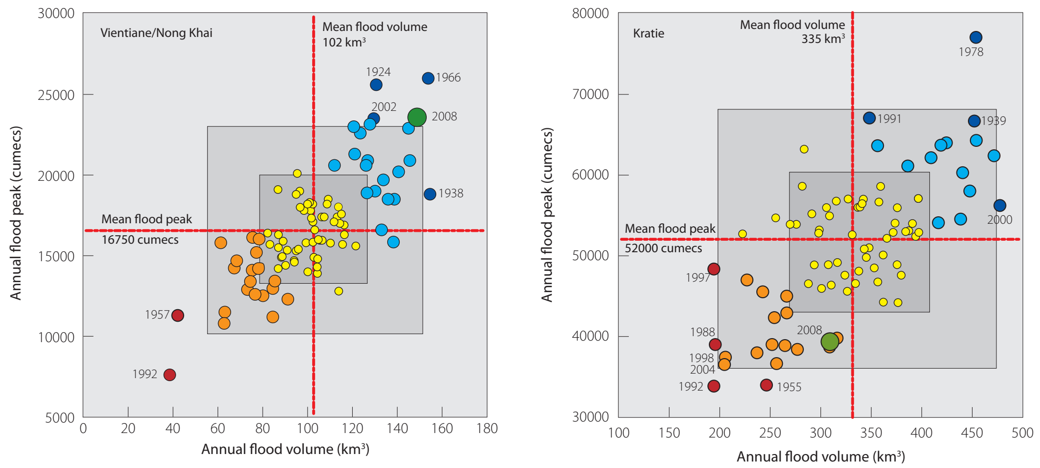


Figure 1.3.4 Scatter plots of the joint distribution of the annual maximum flood discharge (m³/sec) and the volume of the annual flood hydrograph (km³) at Vientiane and Kratie. The squares indicate one (1δ) and two (2δ) standard deviations for each variable above and below their respective means. Events outside the 1δ box might be defined as 'significant' flood years and those outside the 2δ box as historically 'extreme' flood years.

1.4
BIODIVERSITY, ENVIRONMENT AND LIVELIHOODS

The Mekong Basin, with its range of geographic and climatic zones, is one of the richest areas of biodiversity in the world. Local climate, geology, terrain and riparian conditions shape riverine ecosystems into an almost unquantifiable variety of types. The Mekong River region contains 16 WWF Global 200 ecoregions, which are critical landscapes of international biological importance. This represents the greatest concentration of ecoregions in mainland Asia (Thompson 2008).

Recent estimates of the biota of the greater Mekong region include 20,000 plant species, 430 mammal, 1200 bird, 800 reptile and amphibian (Thompson 2008), and 850 fish species (Hortle 2009). New species continue to be described, even today. Between 1997 and 2007, at least 1068 new species were discovered in the Mekong Basin. This figure does not include invertebrates, which could possibly add thousands more new species to the list (Thompson 2008). Thus, despite the wealth of recent discoveries, the biological diversity of the region has not yet been completely documented.

The monsoon climate, with its tremendous seasonal changes, also drastically contributes to the range and nature of habitats available, especially for riparian organisms influenced by the annual fluctuations in river flow. The natural variation in river hydrology, both within and between years, is a key driving force in sustaining ecosystem diversity (Coates et al. 2003). The significance of the 'flood pulse' for river fisheries ecology is reasonably well documented but the importance of hydrological cycles for sustaining biodiversity is still not widely appreciated. It is not enough simply to maintain a flood regime, the timing, duration and extent of flooding must be considered, along with the discrete natural hydrological variations that exist within and between years.

Deep pools are relatively deep areas in the river channel found along the entire river at irregular but frequent intervals. Pools with depths of more than 90 metres have been identified and the longest pools found are almost 10 km in length. The median pool depth is about 22 m for bedrock-alluvial reaches and 7.5 m in alluvial reaches. The median pool length is 1.4 km for bedrock-alluvial reaches and 3.7 km for alluvial reaches (Conlan et al. 2008). About 500 deep pools have been identified in the Lower Mekong River mainstream. These pools are believed to provide critical refuge habitat during the dry season and possibly also critical spawning and/or nursery habitat during the wet (flood) season for many species belonging to the migratory 'whitefish' and for the endangered Mekong population of Irrawaddy dolphin (*Orcaella brevirostris*) (MRC 2008 and see box on p. 66).

The water quality of the Mekong is generally good and there are no direct water quality threats to the river's aquatic biodiversity. Nutrient levels are similar to or slightly lower

Rice fields, flooded forests and shrub lands in Kompong Cham, Cambodia.

than many other large rivers in the world and, overall, there are no signs of eutrophication. Information on toxic pollutants, such as heavy metals and persistent organic pollutants, is scarce in the basin but available data suggest that there are no pollutants of basinwide concern. Still, some areas with high population densities and intensive agriculture and aquaculture do show signs of increased pollution. For example, levels of nutrients in the Mekong Delta are comparatively high, indicating increased eutrophication in some areas. Elevated levels of mercury, DDT and PCB in Irrawaddy dolphins confirm the global experience that these substances accumulate in top predators and may also pose a threat in the Mekong River if pollution increases. Thus, caution is needed as future development of the basin may increase the pollution load with possible impacts on aquatic health.

The Mekong's vast ecosystem diversity underpins a wide variety of livelihoods and food security for most of the rural population in the basin. It has been argued that the Mekong, while by no means the largest, is perhaps the greatest, tropical river of the world because of the extremely rich biodiversity it supports and, even more importantly, because of the inter-relationships between the people of the basin and the river resources. Studies of the livelihoods of rural people in wetlands of the region clearly show the close relationship between the hydrological cycle of the Mekong River, the rich biodiversity of floodplain habitats, and the way of life of rural communities and their dependence on fish and other aquatic organisms that these habitats support (Mollot et al. 2003; Meusch et al. 2003; Balzer et al. 2005; Hortle 2007; Halwart 2008). For example, in southern Lao PDR, aquatic animals (fish, frogs, snails and insects) and plants have been important ingredients in diets of local people for generations, providing a food source that is high in protein and rich in fat (Mollot et al. 2003; Meusch et al. 2003). As a result, rural livelihoods depend on the broad diversity of aquatic plants and animals and are closely entwined with the seasonal rhythm of the river.

The importance of hydrological cycles for sustaining biodiversity is not widely appreciated…the timing, duration and extent of flooding must be considered…

The inhabitants' broad knowledge of the ecology of their local environment means they are adept at using the natural resources of the dynamic ecosystems associated with the Mekong River. Men, women and children are all active in fishing and collecting non-timber forest products, but the age, gender and wealth of an individual will determine the habitat they use, the type of gear they employ and fish species they target (Mollot et al. 2003). To fish in the main rivers often requires a considerable investment in boats, motors and nets, while in habitats like flooded forests, wetlands and streams poorer people can use simple gear to collect fish and other aquatic organisms such as frogs, snails and insects. This diversity of habitat ensures a range of households have access to aquatic resources on a regular basis. Women and children may forage the wetland habitat near the village to collect plants, snails and fish for their families to eat while men often fish the mainstream channels of the river where they can catch larger fish that they normally sell to traders to provide household income (Mollot et al. 2003).

Recent studies on the availability and use of aquatic biodiversity from rice-based ecosystems in Cambodia, China, Lao PDR and Viet Nam recorded a large number of species, including 145 fish, 11 crustacean, 15 mollusc, 13 reptile, 11 amphibian, 11 insect and 37 plant species directly caught or collected from wetlands and used by rural people during one season (Halwart 2008). These species are collected from a wide variety of both permanent and seasonally flooded habitat, including perennial rivers, ponds, marshes and flooded forests, which all depend on the seasonal fluctuations of the Mekong River.

Although overexploitation may pose a threat to some of the natural resources and endangered species in the basin, most reviews conclude that the major threat to sustaining biodiversity and river fisheries is environmental degradation (Coates et al. 2003).

1.5 ENERGY DEMANDS AND RESOURCES

Energy demand

Over the past few decades, the Mekong region has experienced high rates of economic growth (see section 1.6) accompanied by large increases in energy demand. From 1993 to 2005, economic growth and energy demand both increased at an average annual rate of about eight per cent, which is one of the highest growth rates in the world over a sustained period.

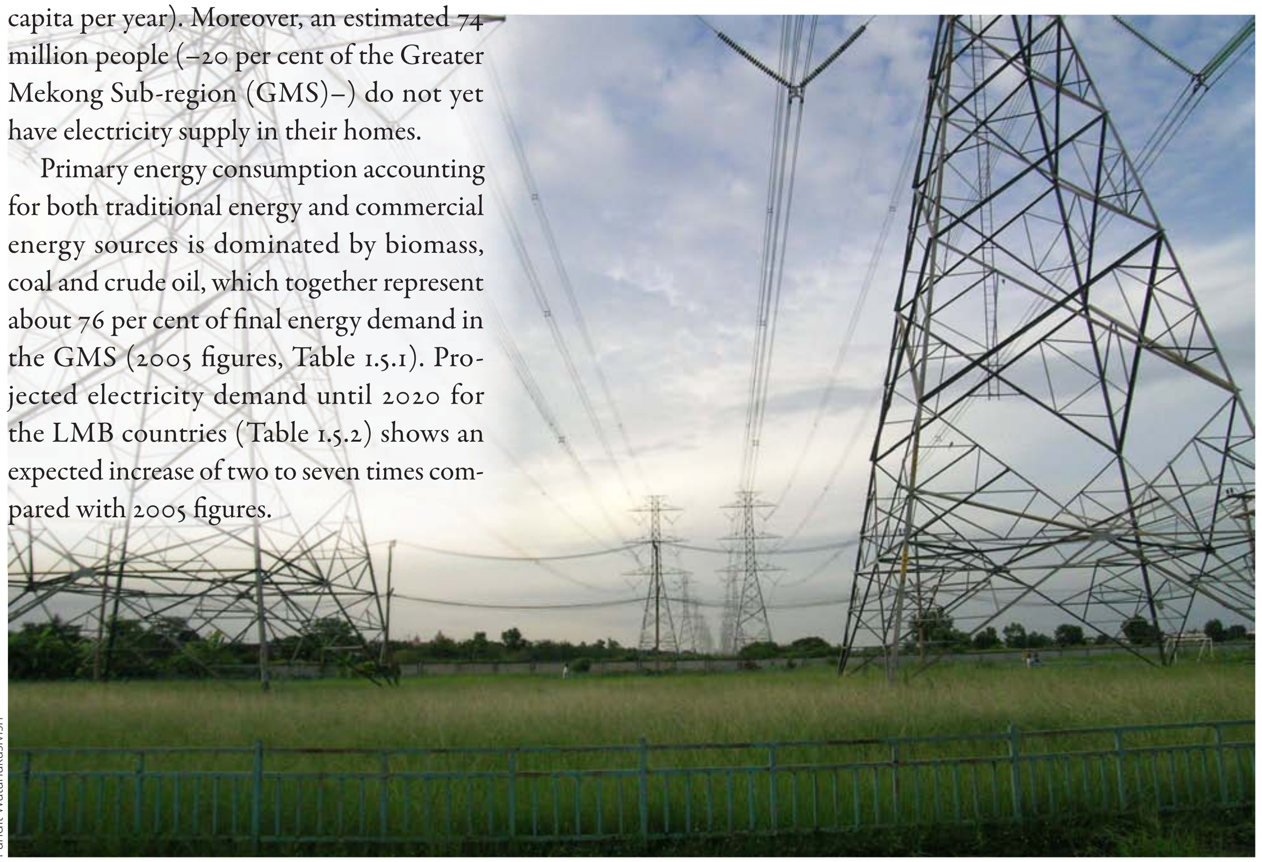
While the rate of energy demand growth in the region is high, average per capita electricity consumption in the greater Mekong region still remains only two-thirds the average of all developing countries (920 kWh per capita per year). Moreover, an estimated 74 million people (~20 per cent of the Greater Mekong Sub-region (GMS)~) do not yet have electricity supply in their homes.

Primary energy consumption accounting for both traditional energy and commercial energy sources is dominated by biomass, coal and crude oil, which together represent about 76 per cent of final energy demand in the GMS (2005 figures, Table 1.5.1). Projected electricity demand until 2020 for the LMB countries (Table 1.5.2) shows an expected increase of two to seven times compared with 2005 figures.

Table 1.5.1 Primary energy consumption in the GMS – all sectors (2005)

Energy	Petajoule	Per cent
Biomass	2772	27.9
Coal	2625	26.5
Crude oil	2162	21.8
Natural gas	1233	12.4
Oil products	877	8.8
Hydro	203	2.0
Electricity	26	0.3
Other renewable	22	0.2
Total	9920	100

Source: ADB 2009a



Pandit Watanakasivish

Thailand and Viet Nam have achieved more than 70 per cent rural electrification based on power line extensions.

Table 1.5.2 Regional power demand forecasts (MW)

Year	2005	2010	2015	2020	2025
MRC Member Countries					
Cambodia[1]	302	407	699		
Lao PDR[2]	291	648	1216	1487	
Thailand[3]	20,538	25,612	33,897	44,695	
Viet Nam[4]	9255	20,000	31,495	50,000	68,440
MRC Dialogue Partners					
China (Southern Power Grid)[5]	69,590	114,300			
Myanmar[6]	966	1593			

Sources: [1] Cambodia: World Bank (2006); [2] Lao PDR: Electricité du Laos (2008); [3] Thailand: EPPO, Ministry of Energy and EGAT (2008); [4] Viet Nam: Institute of Energy (2007), Viet Nam Ministry of Industry and Trade (2008); [5] China: China Southern Power Grid Co. Ltd (2008); [6] Myanmar: PEMRG (2004).

'Energy poverty' is widespread in the region. Access to modern energy is uneven across economies and between urban and rural areas. Many people in rural and peri-urban areas still depend heavily on traditional biomass energy sources, such as wood and agricultural waste, for household or on-farm needs. The region as a whole is increasingly reliant on fossil fuel imports as e.g. 80 per cent of total electricity generation is based on fossil fuels (oil, gas, coal) and, thus, increasingly vulnerable to volatile international energy prices that increase national debt burdens. Energy imports to the region account for more than 21 per cent of final energy consumption (2005 figures). Thailand imports more than 50 per cent of its domestic energy requirements, while Cambodia and Lao PDR import all their commercial fuels. Oil dependency in the GMS is projected to increase dramatically in the coming decades, especially with the growth of the transport sector (ADB 2009a).

Energy resources in the Mekong Basin

Overall, the Mekong Basin is well endowed with energy resources, including those to support electricity generation at different scales. However, these resources are not uniformly distributed among countries in the basin. Lao PDR and Viet Nam, for example, have significant hydropower potential at all scales. Hydrocarbon exploration continues in Cambodia and Viet Nam, while Thailand has the largest proven gas reserves and Viet Nam has the largest proven coal deposits.

Hydropower is regarded as an indigenous renewable energy source with limited carbon emissions. Increasing its use could boost the region's contribution to climate change mitigation, through reducing dependence on fossil fuels (coal, gas and oil) that today account for up to 80 per cent of total electricity generation.

The Mekong Basin also has renewable energy resources, such as biomass, wind, solar and small-scale hydropower to support decentralised off-grid electrical generation and to feed the electrical grid. Such technologies have a significant potential role in rural electricity supply and to help meet ambitious rural electrification targets of basin countries. The governments have policies to develop rural electricity generation options in parallel with conventional grid-based generation that serve major population centres and industrial loads, as well as grid extension to rural areas (e.g. Thailand and Viet Nam have achieved more than 90 per cent rural electrification based on power line extensions). Lao PDR and Cambodia have set policy targets of 100 per cent rural electrification by 2020. This is to be achieved through a mix of conventional grid extension and development of decentralised systems based on local renewable sources including micro-hydropower, as well as diesel.

Hydropower potential of the Lower Mekong Basin

The estimated hydropower potential of the LMB is 30,000 MW. More than 3235 MW of hydropower capacity has been installed on tributary systems, mostly in the past two decades (MRCS Hydropower database). A further 3209 MW are currently under construction. Adding the planned hydropower projects (Figure 1.5.1) exhausts the potential at 30,000 MW (134 projects in total, see section 4.4).

Thailand has developed most of its potential tributary sites and Viet Nam is already well advanced in developing the potential of its tributaries. Lao PDR has developed only a few of many potential sites while Cambodia has yet to construct its first major hydropower project within the basin.

A new, and controversial, development is the recent shift to consider mainstream hydropower on Lao, Lao–Thai and Cambodian reaches of the mainstream. At least 11 sites are at various stages of feasibility study under agreement with governments. In the Upper Mekong Basin, China has an ambitious development plan for mainstream projects. Three large run-of-river projects have already been completed. Altogether, up to eight are in operation, under construction and planned, with a total capacity of 15,800 MW (see section 4.4).

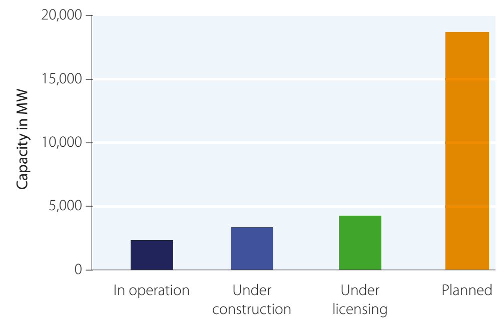


Figure 1.5.1 Hydropower development in the Lower Mekong Basin.

Energy policies

Energy policies and strategies in the region are targeted to close the energy poverty gap and build a sustainable energy future linked to the region's energy resources. In the power sector, for example, beyond meeting the projected power demand with indigenous energy sources, a common interest of the GMS governments is to promote cross-border power trade within the wider framework of regional energy trade and economic integration. For Mekong countries with large potential energy resources compared to their national needs (in particular hydropower resources in Lao PDR and Cambodia) there is also strong interest in generating national income from power exports.

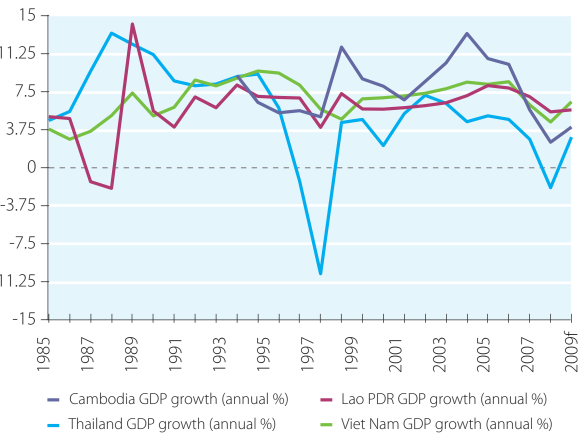
As a result of all these factors, the Mekong has become one of the most active regions for hydropower development in the world. At the same time, concerns are being expressed about the impacts of proposed new developments and existing hydropower on the environment, fisheries and people's livelihoods. The need to develop coordinated and integrated impact assessments for sustainable forms of hydropower, consistent and fair mitigation measures and to take account of issues such as trans-boundary fisheries and biodiversity impacts is becoming increasingly apparent to all stakeholders in the LMB.

1.6 THE ECONOMY OF THE LOWER MEKONG BASIN

Growth of GDP, trade and inflation

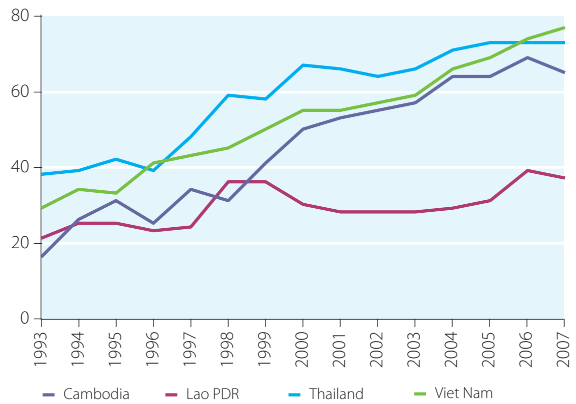
During the early 1990s, the LMB countries made significant advances to move towards market-driven economies. The onset of the Asian financial crisis from mid-1997 to 1998 slowed economic growth and caused a sharp contraction of growth in Thailand, from which it recovered fast in early 1999. On average, the LMB countries experienced a high rate of GDP growth of about 7.2 per cent from 2000 to 2007 (Figure 1.6.1).

Export volume as a percentage of shared GDP increased steadily, which has been significant for poverty alleviation as employment and production have increased in the region (Figure 1.6.2). The export sector has performed very well in the LMB since the early 2000s, reflecting an increase in trade openness.



Source: World Bank Database 2009 and Asian Development Bank 2009; e, expected; f, forecast; No data available for Cambodia before 1994.

Figure 1.6.1 Trends in economic growth and decline in LMB countries.

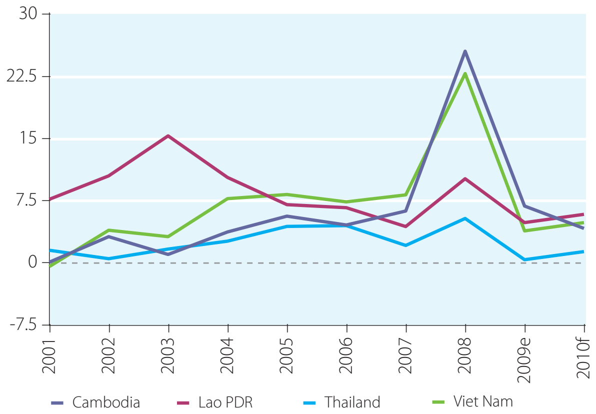


Source: World Bank Database, 2009.

Figure 1.6.2 Export of goods and services (per cent of GDP).

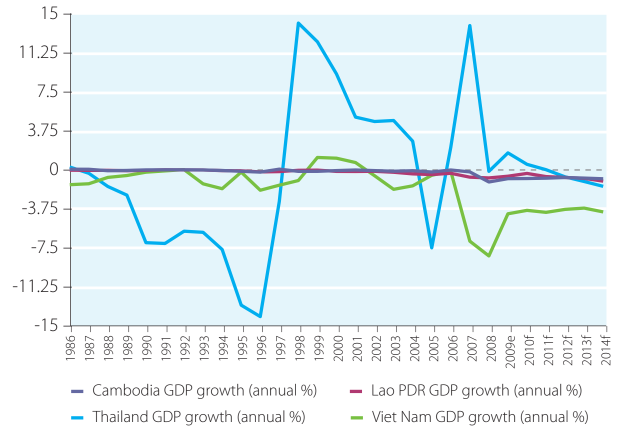
The global financial crisis in 2008 has seen a sharp downturn in global demand, affecting LMB countries through high inflation and economic contraction (Figure 1.6.3). Cambodia and Thailand experienced the greatest fall in GDP growth rate in 2009. A surge in the commodity price, especially for imported oil, has led to high inflation in Cambodia and Viet Nam, but inflation is expected to return to normal in 2010 and beyond. Thailand and Lao PDR are able to manage inflation through monetary policy. It is worth noting that this steep fall in GDP growth has occurred despite policy easing and other measures taken by governments in the LMB and around the world.

The countries' balance of payment figures (Figure 1.6.4) show that Thailand recovered fast from the Asian financial crisis through its effective firm revenue measures and reduced government expenditure. Cambodia, Lao PDR and Viet Nam also experienced negative balance of payments as they invested heavily in infrastructure and social development. Economic growth is expected to resume in the LMB as governments inject investment into infrastructure development, irrigation and a range of small-scale development projects.



Source: Calculated from Inflation Index of the average consumer prices of the IMF Database, April, 2009 and the Asian Development Bank Database, 2009.

Figure 1.6.3 Inflation rate year on year in the LMB (2000=100).



Source: IFM Database, 2009, No data available for Cambodia before 1996 (Lao PDR and Cambodia have almost the same BoP from 1996 to 2003).

Figure 1.6.4 Balance of payment figures (billion US$).

Regional economic cooperation

Through the Greater Mekong Sub-region (GMS) program, the connectivity of road infrastructure and power have been improved with great benefits for the LMB countries and the region through savings in travel time, lower travel costs for passengers, lower maintenance costs for vehicles, an increase in value of trade and other spillover benefits such as an increase in tourism and business opportunities (ADB 2009b). Since 1992, the leaders of the GMS countries have taken the initiative for regional economic cooperation, leading to substantial progress in connectivity being included in highway projects, cross-border transportation, power grid and other trade facilities. Between 1992 and 2008, more than US$3 billion was invested in the region (ABD 2009c). Major projects related to trade include the following:

- The Phnom Penh-Ho Chi Minh City project, which was completed in 2005 and increased the estimated volume of trade through the Moc Bai-Bavet border by about 40 per cent per annum from 2003 to 2006.
- The east-west corridor project, which included the rehabilitation of Route 9 in Lao PDR, completed in 2004 and Route 9 in Viet Nam completed in 2006. The travel time from the Lao–Viet Nam border to Savannakhet in Lao PDR by bus has been reduced from about 12 hours in 2001 to about three hours; similarly, the travel time between Tien Sa–Da Nang Port and the Viet Nam–Lao border has been reduced from six to four hours.
- The GMS cross-border transport agreement (CBTA) has played a significant role in facilitating trade in the region by addressing non-physical barriers to the free movement of vehicles, goods, and people across international borders. The CBTA is a comprehensive multilateral instrument that includes single-stop/single-window customs inspections, the cross-border movement of people, transit traffic regimes, requirements and standards for road vehicles, exchanges of commercial

traffic rights, and infrastructure standards. The pilot tested at the Lao–Viet Nam border (Dansavanh–Lao Bao) since 2005 showed a reduction in the processing time for cargo trucks from three hours to 70–80 minutes and for passenger cars, from two hours to 30 minutes. The CBTA has not been fully implemented, partly due to the absence of an agreement to facilitate cross-border movement of vehicles.

- The development of the power market in the GMS and the evolution of an integrated sub-regional power grid are very important for economic development in the region as economic growth brings with it increased energy demands (ADB 2009d). In 2002 at the first GMS summit, the countries signed the Intergovernmental Agreement on Regional Power Trade (IGA) that was later ratified in 2005 at the second GMS summit. To implement the IGA, the Regional Power Trade Coordination Committee was established to oversee the formulation and adoption of a regulatory, institutional, and commercial framework for power trading. The Theun Hinboun Hydropower is a cross-boundary project, which started commercial operations in March 1998. Its main economic benefits are the export revenues for Lao PDR from the sale of hydropower to Thailand.

The Mekong River provides an important transport link between countries, e.g.ferry crossings carry trucks and tankers across the river between Lao PDR and Thailand.

1.7 POPULATION, ECONOMIC AND SOCIAL INDICATORS

About 60 million people live in the Lower Mekong Basin, according to national population statistics of the four LMB countries. The figures indicate that the overall population has increased by about 12 per cent since the figures reported in 2003 (55 million) although the trends vary between countries. The LMB population has increased by 25 per cent in Cambodia, by about six per cent in Lao PDR, has remained the same in Thailand and increased by about 10 per cent in Viet Nam. The percentage of population and territory within the basin varies between countries. Cambodia and Lao PDR lie largely within the basin but together comprise only 30 per cent of the basin population. The basin territory in Thailand is only 37 per cent of the country and comprises about 39 per cent of the basin's population. In Viet Nam, the Mekong Delta and Central Highlands comprise only 20 per cent of the country but contain 31 per cent of the basin's population (Table 1.7.1).

About 75 per cent of the basin's population live in rural areas. Overall, population density is low at about 124 people per km² although this masks large differences between the countries. If the limits of arable land are considered, net densities are significantly higher, especially in Lao PDR and Viet Nam (Table 1.7.1). More than 70 ethnic groups live in the Mekong region, most of them practising subsistence agriculture in upland regions.

The population of the LMB is young, especially in Lao PDR and Cambodia where 37 per cent and 39 per cent of the population, respectively are under the age of 15. In Thailand and Viet Nam, the figures are 21 and 29 per cent (Figure 1.7.1).

Since the first *State of the Basin Report* in 2003, Lao PDR and Cambodia have moved out of the UNDP's low income classification and all four LMB countries are now classified as middle-income countries.

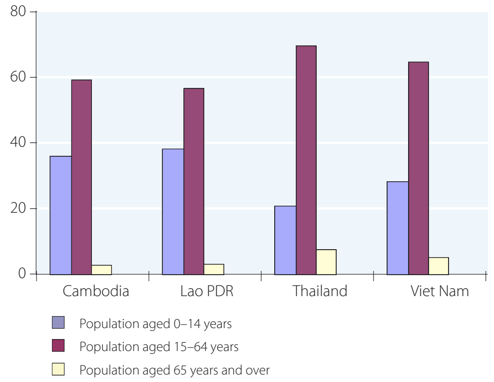


Figure 1.7.1 Population age structure in the LMB (% 2006).

Life expectancy is lowest in Cambodia (Table 1.7.1) although in all countries it has increased in recent years. Infant mortality rates have improved although are still high in Cambodia and Lao PDR.

Thailand and Viet Nam continue to have a high rate of adult literacy and rates are improving in Lao PDR and Cambodia but remain below the the regional developing country level of 85 per cent. Women, rural people and ethnic minorities have the lowest literacy levels. Primary school enrolment rates have increased in Cambodia and Lao PDR and Viet Nam continues to have a nearly universal primary school enrolment rate.

Access to improved water supply and sanitation varies across the LMB. These services are almost universally available in Thailand and the vast majority of people in Viet Nam have access to clean drinking water (Table 1.7.1) but in Cambodia and Lao PDR the situation is much worse (see also section 4.5).

Table 1.7.1 Socioeconomic indicators in the LMB countries.

Indicators	Cambodia	Lao PDR	Thailand	Viet Nam
Total area (km^2)	181,035	236,800	513,120	332,000
Total LMB area (km^2)[1]	156,435	206,620	203,060	34,373 (Mekong Delta) 32,400 (Central Highlands)
Population 2007 (million)[2]	14.4	5.9	63.9	87.4
LMB population 2007 (million)[1]	13.0	5.2	23.1	18.7
Number of provinces	25	17	75	58
Number of provinces in LMB	23	17	25	20
Composition of ethnic groups (% of total)[3, 4]	Khmer (90) Vietnamese (5) Chinese (1) Mon-Khmer (2) others (2)	Lao (55) Khmu (11) Hmong (8) others (26)	Thai (75), Chinese (14) others (11)	Kinh (Viet) (86.2), Tay (1.9), Tai (1.7), Muong (1.5), Khmer (1.4), Hoa (1.1), Nun (1.1), Hmong (1), others (4.1)
Languages	Khmer	Lao	Thai	Vietnamese
Religions	Buddhism	Buddhism	Buddhism	Buddhism
Average annual population growth rate (%, 2007)[6]	1.9	2.1	0.8	1.2
Population density (people per km^2, 2007)[2]	80	25	125	265
Rural population (% of total population, 2007)[8]	78	69	68*[7]	72*
Rural population density (people per km^2 of arable land, 2005)[7, 5]	303	450	323 (1999)	930
Access to clean drinking water (% of population, 2006)[9]	65	60	98	92
Improved sanitation (% of population with access to, 2006)[2]	28	56[15]	96	65
GDP per capita (US$, 2006)[14]	648	674	3000	900
Proportion of population below national poverty line (%)[2]	35 (2004)	33 (2003)	10 (2006)[16]	16 (2006)
Life expectancy at birth (years, 2007)[2]	59	64	71	74
Infant mortality (rate per 1000 live birth, 2006)[2]	65	59	7	15
Malnutrition rate (%, 2007)[10]	28	36 (2000)	7	20
Global hunger index level (2009)[11]	Alarming/high vulnerability	Serious/high vulnerability	-	Serious/high vulnerability
Net primary school enrolment rate (%, 2007)[9]	89	86	94	98
Adult literacy rate (%, 2007)[2, 13]	76	73	94	90
Freshwater withdrawal for agriculture (%, 2002)[2]	98	90	95	68.1
World corruption ranking (2007)[12,**]	134	140	67	98

* data are for the whole country; ** lower rankings are preferable;

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Joe Garrison

Setting a gillnet at the base of a 100-metre limestone cliff, the site of a deep pool where the Nam Ou meets the Mekong in Lao PDR.

2
PEOPLE AND LIVELIHOODS STATUS AND TRENDS

2.1 INDICES OF HUMAN DEVELOPMENT

Human development is about expanding choices for people to live the lives they value. The Human Development Index (HDI) is a composite index developed by the UNDP to provide a way of viewing human progress and the complex relationship between income and wellbeing, using indicators such as longevity, knowledge and standard of living. This index is not a comprehensive measure of human development as it does not, for example, include important indicators such as gender or income inequality and more difficult to measure indicators like respect for human rights and political freedom (UNDP 2009a).

The HDI measures a country's average progress towards human development, while another index, the Human Poverty Index (HI-1) focuses on the proportion of people below certain threshold levels in each of the dimensions of the HDI.

While HDI measures average achievements, the Gender-related Development Index (GDI) adjusts the average achievements to reflect the inequalities in achievements between women and men. The greater the gender disparity in basic human development, the lower is a country's GDI relative to its HDI.

A new Gender Empowerment Measure (GEM) was introduced recently to focus on inequalities in opportunities for women and men in three areas: participation and decision-making power in political and economic life and power over economic resources.

Development indices of LMB countries and trends

All countries in the LMB are classified as 'medium human development' countries, with HDI values between 0.500 and 0.799 and showing steady improvement over the past few decades (Table 2.1.1). However, the HDI of Lao PDR and Cambodia in 2007 was still lower than that of Thailand in the 1990s. The HDI of Thailand is slightly above the average for East Asia and the Pacific (0.770) and for Asia (0.724). Viet Nam's HDI is close to the average for Asia, while those of Lao PDR and Cambodia are lower.

Looking beyond the average HDI, disparities exist across the LMB countries. The HPI-1 value for Cambodia is 27.7 per cent with 18.5 per cent of people unlikely to survive past the age of 40 years, 35 per cent don't have access to an improved water source and 36 per cent of children aged 0–5 years old are underweight. In Lao PDR, the human poverty index is 30.7 per cent, the under-40 mortality rate is 13.1 per cent and 40 per cent of the population lack access to clean drinking water (the figure is better for urban areas). Forty per cent of children under 5 years old are underweight. In Thailand and Viet Nam, on average, these indicators are less than 10 per cent, but the human poverty index for Viet Nam is 12.4 and 25 per cent of children under 5 years old are underweight.

Viet Nam and Thailand are more advanced in gender equality in basic human development with a ratio of GDI to HDI of 99.8 per cent compared with 99.3 per cent and 98.8 cent for Cambodia and Lao PDR respectively. In terms of GEM, Viet Nam is ranked 62 out of 108 countries, with quite a

PRECEDING PAGE

For this Cambodian family and millions like them, the river provides a major source of food and income.

FACING PAGE

Most of the LMB population live near rivers, lakes and wetlands.

high percentage of seats in the parliament held by women (25.8 per cent compared to 8.7 per cent in Thailand and an average of about 20 per cent among countries with a high HDI). This ranking is 78 for Thailand and 93 for Cambodia respectively. No GEM ranking is available for Lao PDR due to lack of data.

Table 2.1.1 Human development indices in the LMB (1990–2007)

	1990	1995	2000		2007	
	HDI	HDI	HDI	GDI	HDI	GDI
Cambodia	–	0.540	0.547		0.593	0.588
Urban				0.601		
Rural				0.496		
Lao PDR	0.478	0.524	0.563	–	0.619	0.614
Vientiane			0.665*	0.650*		
Northern			0.531*	0.490*		
Central			0.539*	0.550*		
Southern			0.519*	0.520*		
Thailand	0.712	0.745	0.761	0.755*	0.783	0.782
Northeast						
Viet Nam	0.590	0.672	0.711	0.687	0.725	0.717
Central Highlands			0.669	0.668		
Mekong Delta			0.604	0.599		

Sources: UNDP 2009, UNDP Cambodia 2007, UNDP Laos 2008, UNDP Thailand 2008, UNDP Viet Nam 2008.
(Note that the * represents the HDI from 1999 to 2001) the rest of HDI and GDI broken down by regions are still to be calculated.

Countries in the LMB have been measuring national human development progress over the last decade. Thailand has developed human achievement indicators (HAI) to measure comparative human achievement progress across its provinces. The HAI index comprises a larger range of indicators than the HDI to measure quality of life, including measures such as percentage of population with physical and mental illness, HIV AIDS incidence, and percentage of households with housing security or in debt. Across Thailand, the provinces in the LMB, mostly in the northeast, are amongst the bottom HAI ranking. Nine out of the 10 bottom HAI provinces in 2003 were from the northeast region. Half of them graduated from this list in 2006.

In Cambodia, the urban areas (Phnom Penh, southern provinces and new urban centres) enjoy the highest levels of human development. The provinces in the northeast that are part of the LMB have the lowest HDI values (0.30–0.36). The provinces on the Tonle Sap Great Lake fall in the middle range. However, human poverty is the highest in this region, which coincides with the high rate of consumption-based poverty levels.

In Lao PDR, on the other hand, apart from Vientiane, the differences among regions are not very large (Table 2.1.1). As of 2006, 7 out of 18 provinces in the three regions of the country were in the low human development category with HDI values ranging from 0.458 to 0.496, which was not much lower than the middle human development range and the regional average for the country.

Viet Nam is preparing its 2010 National Human Development Report, which will provide the updated HDI broken down to regions and provinces.

2.2
PROGRESS TOWARDS THE MILLENNIUM DEVELOPMENT GOALS

All LMB countries are making progress towards achieving the Millennium Development Goals (MDGs), although at different pace (Table 2.2.1).

Table 2.2.1 Progress towards the MDGs in LMB countries

MDG	Cambodia	Lao PDR	Thailand	Viet Nam
1. Eradicate extreme poverty and hunger	Possible to achieve if changes made	Insufficient information	Achieved	Achieved
2. Achieve universal primary education	On track	On track	Achieved	On track
3. Promote gender equality and empower women	On track	Insufficient information	Achieved	On track
4. reduce child mortality	On track	On track	Achieved	On track
5. Improve maternal health	Possible to achieve if some changes	On track	Achieved	On track
6. Combat HIV/AIDS, malaria and other diseases	Possible to achieve if some changes	Insufficient information	Achieved	Possible to achieve if some changes
7. Ensure environmental sustainability	Insufficient information	Insufficient information	Insufficient information	Insufficient information

Source: UNDP 2009. (http://www.mdgmonitor.org)

Cambodia localised the MGD targets in 2003 to develop the Cambodia Millennium Development Goals (CMDGs). Although Cambodia is on track to achieve several global MDG and CMDG targets, it is not on track in many critical areas related to food security, poverty reduction, education and sustainable social and economic development as well as de-mining, unexploded ordanance and victim assistance, which have been identified as part of the CMDGs. Cambodia's progress toward the CMDGs is constrained by a chronic shortage of investment and by poor access to international markets, especially in developed countries. Cambodia will not be able to achieve the CMDGs by 2015 unless its efforts are reinforced by global support (RGC 2005).

Data constraint is an important issue for Lao PDR to report on its progress in achieving the MDGs. Because of this, the baseline year and targets for some indicators have been changed. Lao PDR is on course to attain the first MDG goal by halving poverty by 2015 (Govt of Lao PDR-UN 2009). However, malnutrition, especially chronic malnutrition and stunting among children under five, is still a major concern. Disparity between ethnic groups, regions and provinces is common across other MDGs in Lao PDR. For example, there are considerable differences in enrolment rates between Lao native-speaking and ethnic dialect speaking groups, and between girls and boys at all levels of education. On the other hand, the proportion of women members of the national legislature tripled between 1990 and

2003 and is among the highest in the region. Significant progress has been made on expanding access to safe water and sanitation over the last decade although performance across provinces is varied and access is limited during the dry season because of the lack of rainwater; the percentage of poor households without access is about 10–15 per cent greater than for non-poor households.

In Thailand, the targets for poverty, hunger, gender, HIV/AIDS, malaria and access to water have already been achieved, more than 10 years ahead of schedule and it is likely that the educational goal will be achieved soon. The other targets including reversing the spread of tuberculosis, improving the lives of slum dwellers, integrating principles of sustainable development into national policies and reversing the loss of environmental resources are likely or have the potential to be reached (NESDB & UNCT Thailand). Thailand has also set its MDG Plus targets, which are more ambitious than the international MDG targets. Examples of the Thai MDG Plus indicators include the reduction of poverty rate to less than four per cent by 2009, achieve the universal upper secondary education by 2015 and specific targets for the least developed provinces in the country such as reduce by half, between 2005 and 2015, the Under-Five Mortality Rate and the maternal mortality ratio in highland areas, selected northern and three southernmost provinces.

Viet Nam continues to make good progress in integrating the MDGs into its socio-economic development strategies. The country has made significant progress to achieve the Viet Nam Development Goals and is on track to achieve most of the MDGs (Ministry of Planning and Investment 2008). Nevertheless, disparities exist between population groups and regions. While the poverty rate fell from 54 per cent in 1993 to 10 per cent among the Kinh and Chinese in 2006, among other ethnic groups the change over the same period was from 86 to 52 per cent. The poverty rate in the Central Highlands remains high (29 per cent) compared with the national average of 16 per cent.

Roengchai Kongmuang@SEI

There are considerable differences in enrolment rates between girls and boys at all levels of education.

2.3 CHARACTERISTICS OF POVERTY

Millions of people living in different geographical areas of the LMB depend on the river system for their livelihoods. Many of them live in poor conditions with limited access to clean water and sanitation, employment or even sufficient food. As well, many of the population face uncertainties, such as flooding and other disasters, lack of land ownership and consequences from global economic failure.

In many cases, people lack the opportunity to exercise their civil rights or access information. The mechanisms do not exist that allow them to take part in decisions on issues concerning water resource management, impacts of development or access to common goods such as lands and flooded forests. National economic development, supporting infrastructure and welfare are still sparse. Such factors aggravate the conditions of poverty and vulnerability.

The water and aquatic resources of the Mekong Basin, such as fish, other aquatic animals and plants, are virtually free and play a vital role in ensuring food, income and livelihood security for many people across the LMB. In rural areas, particularly, poverty and food security are strongly linked. Although there is no precise estimate of the number of people in the LMB who depend on the basin's aquatic resources, national surveys and qualitative case studies provide some indication. A social impact monitoring and vulnerability assessment carried out by the MRC (see section 2.4) provides some estimates of the proportion of the population that depend on aquatic resources and the extent of that dependency.

Cambodia

Despite rapid economic growth over the past two decades, Cambodia is still one of the world's poorest countries, with 35 per cent of the population living below the national poverty line and 15–20 per cent living in conditions of extreme poverty (WFP 2009). In many areas, almost 80 per cent of the population is below the national poverty line (WHO 2009). Although 79 per cent of the population live in rural areas, there has been a significant urban drift among the young.

In 2003–05, Cambodia's economic growth increased by at least 10 per cent, with increasing demand for labour in the industrial sector, mainly the clothing, tourism and construction industries. However, the agricultural sector, especially rice farming, still dominates the workforce, employing 70 per cent of the working population.

Most of Cambodia's rural population belong to the subsistence economy. Rice production, wild fisheries, livestock and wildlife are the main food sources. The high rate of poverty, together with limited local opportunities for earning income and the extremely low labour wage mean that household purchasing power and new options for food security are extremely low. Many areas lack sufficient rice for household consumption for several months of the year due to droughts and floods. The shortage of land for crop production exacerbates the problem. The occasional drastic decline in wild fish yields has also increased food insecurity.

The World Food Programme (2009) noted that national food supplies are barely adequate, for reasons ranging from natural disasters to a lack of agricultural policies. As a result, there are huge problems in distribution and access for a significant and growing portion of the population. Food security and nutrition are the main areas of focus for poverty reduction among decision makers and international aid agencies. Malnutrition is prevalent across the country, with 33 per cent of the population undernourished (WFP 2009). The child mortality rate is 91 per 1000 population (year 2007) (UNICEF 2009).

From MRC's fish consumption study of 10 provinces around the Tonle Sap area (Hortle 2007) and the WFP (2009) figure for child stunting, there appears to be a connection between protein intake and health condition. Fish consumption in the eight provinces nearest to Tonle Sap Great Lake ranged from 43–105 kg/head/year; higher than in inland provinces, which consumed only 27–34.5 kg/head/year (Hortle 2007). The child stunting rate in the provinces nearer to Tonle Sap is 10–20 per cent less than in the provinces that consumed less fish (WFP 2009).

The vast area of wetlands and flood plains and the country's tropical climate make Cambodia prone to transmission of vector-borne diseases such as malaria and dengue fever, as well as cholera from unsafe drinking water and food poisoning. Industrial pollution and urbanisation accelerate the spread of these diseases.

Lao PDR

Despite an annual 5–7 per cent increase in GDP since 2000, the incidence of poverty in terms of income, malnutrition and lack of supporting infrastructure and services remains widespread throughout the country. In terms of purchasing power parity (PPP), 71 per cent of the population lives on less than US$2 per day and 23 per cent live on less than US$1 per day (WHO 2009).

Lao PDR has the most diverse population in the LMB with 79 per cent of the population living in rural areas and more than 30 per cent of people below the national poverty line. The large majority of people depend on natural resource subsistence and agriculture. Two-thirds of households have no access to electricity, 40 per cent have no safe water supply and half of all villages are unreachable by all-weather roads during the rainy season (World Bank 2009).

Agriculture continues to increase, partly due to a national promotion policy and the desire to promote intensive rural labour but irrigation is still a major challenge as the most intensive agricultural areas are not located in the lowlands or next to major water sources. Land ownership is a key issue as there has been no formal change in the land-use policy and farmers still do not own their own land (Messerli et al. 2008).

The highest concentrations of poverty (percentage of population) are found in the southern highlands along the border with Viet Nam, in east Savannakhet, Saravane, Sekong and Attapeu provinces (Messerli et al. 2008). Lower rates are found in the mountainous villages in the north and the least poverty occurs in urbanised areas in and around the largest towns. However, large numbers of people living below the national poverty line are still found in the lowlands and around big cities. Many also live along the Mekong River and its tributaries in west Savannakhet, Pakse and Vientiane provinces (Messerli et al. 2008).

Health, nutrition and literacy indictors of people living in remote areas of the country are significantly lower than the national averages, particularly for women. Food insecurity is widespread throughout the country and alarmingly high in rural areas. Two-thirds of the population in Lao PDR are food insecure or at risk of food insecurity, in the case of a 'livelihood shock' (WFP 2009). In some areas, such as Attapeu province, villagers have insufficient food for four to eight months of the year (Health Unlimited 2009). Nineteen per cent of the population are undernourished and the Lao global hunger index is classified as 'serious' (IFAD 2009).

Even though, the child mortality rate in Lao PDR has improved significantly, from 170/1000 in 1995 to 98/1000 in 2005, the rate is still the highest among the ASEAN countries after Myanmar. A large proportion of these deaths are reportedly due to malnutrition (WHO 2009).

Wild fisheries have played an important role in securing food for the poor. According to the Lao Expenditure and Consumption Study in 2002–03, average fish consumption was more than 25 kg/head/year. This was more than average meat consumption by almost 3 kg/head/year (Hortle 2007) and does not include other aquatic animals, such as frogs, molluscs, field crabs etc, which provide a significant source of protein (see p. 50). Due to the greater abundance and diversity of aquatic products in central and southern Lao PDR, the average fish consumption of the populations in those areas is much higher than in the north. While aquaculture is still not extensive in the country, this figure reinforces the high dependency of Lao people on the natural wetland and aquatic resources of the Mekong Basin (Hortle 2007).

Thailand

Although Thailand reduced poverty from 27 per cent in 1990 to 10 per cent in 2006 (NSO 2006), social gaps and inequality are still widespread. The income of the poorest 20 per cent is eight times less than that of the highest income group and 60 per cent of the population shares less than 15 per cent of the national income (World Bank 2003). Thailand's overall malnutrition rate is seven per cent (2006). Northeast Thailand, which accounts for 85 per cent of the Mekong Basin in Thailand, is the poorest and most densely populated region. Although, in terms of average household income, most of the provinces in the northeast are almost 10 times above the national poverty line, on the other hand, expenditure and debt are at least as high as income. Evidence from a number of qualitative case studies indicates that many of the communities in the Thai Mekong Basin rely on river dependent resources like capture fisheries, non-timber forest products and collection of aquatic animals as sources of income and food.

Viet Nam

Reflecting the country's rapidly growing economy, the rate of poverty in Viet Nam declined from 75 per cent in 1990 to 15.9 per cent in 2006 (UN 2009).

Although living conditions, nutrition and economic benefits have improved for many Vietnamese, inequality and social differences are higher than ever. This difference exists between rural (73 per cent) and urban population groups, where the respective poverty rates are 44.9 and 18.3 per cent (UNICEF 2009). Ethnic minorities have not shared many of the benefits of the past decade's developments. This is especially true in rural areas where living standards have improved at a much lower rate and where cash is still scarce. Gender discrimination also continues to undermine the wellbeing of women and children (UNICEF 2009). In 2006, 92 per cent of the population had access to an improved water source and 65 per cent to improved sanitation (WHO 2009).

About 43 million people were employed in the industrial sector in 2005, representing 53 per cent of the population (WHO 2009). It is planned that, by 2010, eight million workers will be employed, reducing unemployment to five per cent, and that farming will only involve 50 per cent of the labour force (WHO 2009). Pollution from industry, agriculture and solid waste is a major issue that creates severe health problems.

The Mekong Delta, the most densely populated agricultural region, has a population of more than 17 million (21 per cent of Viet Nam's population). The delta has fast become the most important agricultural region in the country, producing more than 50 per cent of staple food crops and 60 per cent of fish production. It contributes 27 per cent of Viet Nam's GDP (SUMMERNET-Tran et al. 2007).

In response to economic growth and improved sanitation and living conditions, the child mortality rate (under five years old) has fallen from 55.4 per 1000 in 1990 to 25.9 per 1000 in 2007. Nevertheless, in order to achieve the MDG of 18.4 per 1000 by 2015, progress must be accelerated (WHO 2009). The Mekong Delta population is estimated to consume about 56 kg/head of fish and other aquatic animals (Hortle 2007), which represents the highest figure among the LMB countries.

Many LMB households depend on a combination of water-related occupations, such as farming and fishing, and other occupations.

2.4 WATER RESOURCES RELATED LIVELIHOODS AND FOOD SECURITY

The livelihoods and food security of most people in many parts of the LMB are highly water resources related. This is reflected by where they live, their occupations, sources of income, food and other livelihood aspects. Information in this section is derived from a social impact monitoring and vulnerability assessment (SIMVA) study undertaken by MRCS in 2008–09 involving a survey of 1364 households living in 68 villages within 15 km of the upper flood limit of the Mekong mainstream, including Tonle Sap Great Lake and other dependent wetlands. The report is still in draft form and results should be treated as preliminary.

Population distribution

About 85 per cent of the LMB population live in rural areas (Landscan data 2007). Most live near rivers, lakes, and wetlands, with 25 million living within a 15 km corridor either side of the Mekong mainstream (Landscan data 2007). However, the distribution of population within this corridor varies considerably across national boundaries. Cambodia has the highest proportion of its national population living in this corridor (70 per cent), followed by Lao PDR (53 per cent), Viet Nam (16 per cent) and Thailand (4 per cent).

More than three quarters (79 per cent) of the 15 km corridor population live within 5 km of the mainstream; another 11 per cent live between 5 and 10 km away and 10 per cent live between 10 and 15 km from the mainstream. By country, Viet Nam accounts for 51 per cent of the 5 km corridor, Cambodia, 34 per cent, Lao PDR, 9 per cent and Thailand, 4 per cent.

Studies suggest that rural residents who live closer to water resources are more dependent on the resources than those who live further away. However, exceptions occur. In Cambodia, for example, people travel long distances to become seasonal fishers. On average, people make use of ecosystems within 15 minutes distance in the dry season and within 20 minutes in the wet season. Only 10 per cent of people use ecosystems for fishing that are more than 30 minutes away and only two per cent use ecosystems that are more than one hour away (MRC 2010).

Water and non-water related livelihoods

Livelihood activities and sources of food and income of most of the rural population who live near rivers, lakes and wetlands are highly water resources related. These include farming, fishing and collection of other aquatic animals and plants.

The SIMVA data (MRC 2010) indicate that 63 per cent of the economically active population, (EAP) of 10 years and older, have a water resources related occupation as their main occupation and 38 per cent as their secondary occupation

(Table 2.4.1). Water resources related occupations include farming, fishing, collection of other aquatic animals, or edible plants, aquaculture, use of mini-hydro, fish processing, fish marketing, marketing of other water-dependent products, net making/repairing, boat making and/or repairing and farm labour. By study site, Tonle Sap Great Lake in Cambodia has 67 per cent water resources-related main occupations, Siphandone in Lao PDR has 66 per cent and the Mekong Delta in Viet Nam has 53 per cent. Equity exists between EAP males and females participating in water-related sectors as their main occupation (50.2 per cent and 49.8 per cent respectively). However, when it comes to secondary occupation, more male than female EAP are participating in water related occupations (58 per cent and 42 per cent respectively). More than half (54 per cent) of the total EAP responding that their main occupations are non-water resources related have a secondary occupation related to water resources.

Table 2.4.1 Economically active population participating in water and non-water related occupations in five social ecological zones in the LMB

	Economically active population		Economically non-active population
	Water related occupations (%)	Non-water related occupations (%)	
Main occupation	62.6	12.7	24.7
Secondary occupation	38.3	7.5	54.2

Source: MRC 2010

Although the study confirms that many rural households in the LMB study sites depend on a combination of water and non-water, farm and non-farm related activities, reflected by multiple occupations expressed by the sample households, the data show that a substantial proportion of the sample households have no second occupation. This indicates their vulnerability to a decline in the resources on which their main occupation depends. Altogether, 21 per cent of the total sample households claimed to have no second occupation. By site, the numbers are: 33 per cent in the Tonle Sap Great Lake, Cambodia; 30 per cent in Chiang Saen and Udon Thani, Thailand; 11 per cent in the Mekong Delta, Viet Nam; and 10 per cent in Siphandone, Lao PDR. Further, SIMVA data for the Tonle Sap Great Lake sites reveal that nearly half (48 per cent) of those saying fishing was their main occupation had no second occupation in their household.

Farming

By sector, farming is one of the largest water users in terms of water abstraction. Famers in the LMB have been irrigating farmlands for centuries. Thousands of farmers produce two (and sometimes three) rice crops per year using water from more than 12,500 irrigation schemes (MRC 2010, see section 4.3). Agricultural labour in Cambodia, Lao PDR and Viet Nam ranges from 65 to 85 per cent of the total workforce. Even in Thailand, where agriculture accounts for less than 10 per cent of GDP, 70 per cent of the workforce in the northeast region works in the agricultural sector (MRC 2003).

The SIMVA study shows that almost half (49 per cent) of the EAP claimed farming as their main occupation in 2008. By study site, the proportion of the EAP engaged in farming as their main occupation ranges from 38 per cent in Viet Nam to 44 per cent in Cambodia (Tonle Sap Great Lake) and just under 63 per cent in Lao PDR (Siphandone). However, even more people (73 per cent of the total sample households) said that farming was the most important occupation in their household. These perceptions vary according to age group. In the 20–41 year old sample population, 52 per cent of people said farming was their main occupation and for the 41–60 year old age group, the proportion was 70 per cent. Even among the very young population (11–14 and 15–19 age groups) nine and 33 per cent respectively reported their main occupation as farming, indicating a high school drop out rate.

Fishing

Fish provide an important contribution to regional food security, in the form of consumption of fish bought or caught and cash income from fish related activities, ranging from making nets to fish sales. A large proportion of this is from the Mekong and other ecosystems connected to the mainstream. In 2003, it was reported that some 40 million people or about two-thirds of the LMB population were involved in the Mekong's fishery at least part-time or seasonally. In Lao PDR, more than 70 per cent of rural households depend on fishing to varying degrees for subsistence livelihoods and additional cash income. In Cambodia, 40 per cent of the total population is dependent on the Tonle Sap Great Lake and its flood plains for their livelihoods. Over 1.2 million people residing in fishing communes around Tonle Sap Great Lake are reliant almost entirely on fishing as their main livelihood (MRC 2003).

The SIMVA data show that, in 2008, although relatively few household members (six per cent of the total sample population, all age groups) reported fishing or related activities (fish processing, marketing, etc) as their main occupation, 12 per cent of the EAP is engaged in fishing as a secondary occupation. However, in the case of Siphandone, 64 per cent of respondents reported fishing as the second most important occupation in their households. Combined, EAP involved in fishing either as main or secondary occupation, accounts for 18 per cent of the total EAP, with 50 per cent of all households saying they had fished at some point in the year before the survey.

Other aquatic animals and useful plants

Other aquatic animals (OAA) and useful plants are part of the livelihoods of people in the LMB. For example, people in three study villages in Attapeu in southern Lao PDR commonly accessed and used about 200 species of aquatic plants and animals. Together with fish, these OAAs contribute the main animal source of dietary protein (Eckman 2005).

OAA and useful plants are usually collected by women and children and this activity is not considered as an occupation. Moreover, if fish are available to catch; the OAA and useful plants are hardly touched. At the same time, more than 10 per cent of the EAP refer to this activity as their secondary occupation. This ranges from five per cent in Siphandone to 28 per cent in the Mekong Delta.

Sources of food and income

Food

Aquatic resources, including fish, OAAs and plants provide both a source of income and an important food source. In the lowland areas of the LMB, protein from aquatic animals comprises 40–80 per cent of animal intake. In Cambodia, fish and aquatic animals provide more than 75 per cent of animal intake in rural areas (MRC 2003). While the Mekong River is central to sustaining diverse water resources, other aquatic ecosystems and rice fields are very important for food security because they are the most readily available, reliable and cheapest sources of animal protein (Eckman 2005). Wild meat together with aquatic resources, particularly wild fish, contribute the largest source of animal protein in rural Lao PDR (WFP 2007). For most rural households in the LMB, although fish, OAA, and useful plants are primarily collected for household consumption, some surpluses are sold for cash.

Most of the sample households in the SIMVA study ate fish and aquatic plants (93 and 95 per cent respectively) in the week preceding the survey. The most diverse consumption pattern occurred in Siphandone, Lao PDR (Table 2.4.2), with the highest proportion of households that had eaten some frog, shrimp, snail/shell, crab and/or turtle in the week before the survey. This is followed by the study sites in Thailand and Viet Nam. Residents in the Tonle Sap Great Lake sites have the least diverse consumption pattern, although they have the most fish dependent diet.

Table 2.4.2 Households consuming fish and OAA in the 7 days preceding the SIMVA survey (%)

	Tonle Sap Great Lake, Cambodia	Siphandone, Lao PDR	Udon Thani and Chiang Saen, Thailand	Mekong Delta, Viet Nam	Total
Fish	91.9	95.0	90.1	96.2	**93.3**
Frog	8.4	50.0	15.4	5.0	**19.7**
Shrimp	4.5	32.9	25.0	9.4	**18.0**
Snail/shell	11.4	36.5	27.9	14.7	**22.7**
Crab	10.8	20.9	11.3	14.7	**14.4**
Turtle	0.6	3.5	0.3	0.6	**1.3**

Source: MRC 2010

The average calorific intake was 2407 calories per day, which compares to a food poverty line of 2100 calories. Of this figure, 76 per cent came from rice, which is eaten at all meals. Aquatic resources contributed 13 per cent of total calories. The Mekong Delta, which had the highest food diversity, had the lowest calorific intake (1864 calories), due to the lower calorific values of non-rice foods. By contrast, Siphandone, the study site with the least diversity (i.e. most heavily dependent on rice), had the highest calorie intake (3171 calories). In terms of the proportion obtained from aquatic foods, the Tonle Sap Great Lake, which has the highest proportion of full-time fishermen came first (335 calories).

The calorific intake from fish at all four sites is significant and well above international averages. Fish provide essential micro-nutrients that are not found in other staple foods, as well as fatty acids important for brain development. Corridor households (those within 15 km of the mainstream) consume more fish and less OAA than the LMB average.

People who caught their own fish tended to consume more than those who bought it (54 vs 49 kg/head/year) and also were much more likely to consume more OAAs (5.1 kg vs 2.1 kg/head/year). This indicates that fishers use their time while fishing to also catch OAAs. It also suggests a form of double vulnerability: should fishing no longer be worth the effort, it is highly likely that OAA catch and consumption will also decline.

Overall, 30 per cent of the sample households consumed food that they had grown or caught themselves, while the remainder purchased food. However, there was a large difference between sites. The vast majority of households in Siphandone, Lao PDR (97 per cent) consume their own food derived from natural resources, whereas at the other study sites, this was only 10–30 per cent.

In Viet Nam, respondents listed many food items that they had eaten the previous day, indicating a wide diversity and choice of food. Most of the food (90 per cent) served at these meals had been purchased. By contrast, in Lao PDR, the variety of food was much less and only 2.8 per cent of food items were purchased. In Cambodia and Thailand the per cent of purchased items is also high (77 per cent and 69 per cent respectively).

Fishing households at all the study sites were much less likely to eat purchased food (23 per cent of food items for fishing households vs. 48 per cent for non-fishing households).

Income

Agriculture is the single most important economic activity in the LMB (see section 4.3). Overall, the study results point to the extent to which rural households are highly dependent on water resources for income. By far the most common source of income for the rural residents of the Mekong corridor is the sale of rice (50 per cent of households). This is followed by sale of own fish catch (25 per cent); sale of OAAs (six per cent); aquaculture (four per cent); and sale of others' fish catch (three per cent). Other non-water resources sources of income are remittances from family members (31 per cent); local irregular/seasonal employment (30 per cent); full-time employment (25 per cent); sale of livestock (25 per cent); business profit (19 per cent); credit (14 per cent); savings (13 per cent); and other miscellaneous sources (less than one per cent each). At Tonle Sap Great Lake, for example, households are highly dependent on water resources for income; fish sales are a source of income for more than 40 per cent of the Tonle Sap households; at Siphandone, on the Lao mainstream, just under 40 per cent of households get some income from fish, far more than in Thailand or Viet Nam, where less than 10 per cent of households obtain income from this source.

Fishing households at the Tonle Sap Great Lake sites obtained over half their household income from fishing, far more than households at other SIMVA study sites which have more alternatives. For those using the mainstream as their preferred fishing site, about one fifth of their total income was derived from fish sales.

A wide range of factors are involved in the variations in the income derived from fish. For example, it is reported that people residing in the Lao uplands are less likely to sell fish because they have limited market access (e.g. lack of roads and transport), hence they consume less fish as well (Meynell 2003). By contrast, fishers in Thailand are well linked to the world market, exporting more than US$3.7 billion worth of fish annually (Sugiyama et al. 2004).

Impacts of water resource changes

Over the past five years, changes have taken place in water related resources. Almost one in six households have members who have changed occupation because of declining productivity and services of the aquatic ecosystems. The data suggest that the impacts of changes in resources (caused by a wide variety of factors) are already being felt at all study sites.

The high degree of dependence of the population on water resources for livelihoods and food security implies a high vulnerability to declining availability, quality, and diversity of the resources. The uneven distribution of the population and varied degree of dependence suggest disparity in distribution of impacts of changes in the resources across national, social, and ecological boundaries and social groups.

2.5
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Allan Michaud

Many rural people in the LMB lack access to safe drinking water. For this Cambodian girl, fetching water involves a 5 km walk each way.

3
ENVIRONMENT STATUS AND TRENDS

3.1
WATER RESOURCES

Flow regimes

The hydrology of the Mekong shows no evidence to date of significant impacts from human induced land use changes that can be detected against the natural background variability, both long and short-term, of its flow regime (Figure 3.1.1). When considering the impacts of land-use change on the hydrological environment, scale is an important issue. As the area increases so does the physical and biological complexity of the catchment landscape.

Benchmark hydrological indices are needed, against which any anticipated changes can be measured, the consequent ecological, environmental and socio-economic impacts assessed and practical management and mitigation measures developed. A number of flow indices have been developed which summarise the structure and function of the flow regime in terms of both its quantitative and temporal characteristics (Adamson and King 2009). The selection of these indices takes account of issues relating to the geographic scale of the basin, the nature of the hydrological regime and the types of planned resource development.

Four flow seasons were identified – the flood and low-flow seasons and two transition periods in between. Discharge thresholds define the onset and end of each one. Two flow indices were selected for each season. The objectives were to employ only a small number of parameters and to identify those with a wide environmental relevance, which define as completely as possible the overall structure and pattern of the flow regime, particularly the distribution and volume of seasonal flows. The onset and end dates of the four prescribed seasons at Vientiane and Kratie over the past 80–90 years (Figure 3.1.2) show that not only are they unchanged but also that they show a relatively narrow range from year to year. In view of this, any small change in these temporal variables would not only be statistically significant but may potentially have ecological and environmental consequences that are disproportionate to the size of the temporal shift. The refilling of reservoir storages, for example, could result in a delay of two weeks or more to the onset of the flood season which would be easily detectable given the consistent historical natural pattern.

Benchmark hydrological indices are needed in order to measure changes, assess impacts and develop practical management and mitigation measures

From 1960 onwards, large-scale commercial logging has been carried out in the LMB and the area classified as undisturbed forest has fallen by 20 per cent (MRC 2003). The conventional view is that deforestation results in a decrease in the natural water storage capacity of a river basin which, in turn, leads to an increase in water yield, the magnitude of which varies with the local rainfall climate, the topography and the proportion, type and density of the removed forest cover (Newson 1997). In principle therefore, two potential hydrological impacts are possible – total water yield is increased as annual water loss through forests decreases and the seasonal distribution of flows is modified as flood run-off increases and dry season flows decrease.

In the Mekong region clear felling has not been a significant factor in forest removal as it has been elsewhere in Southeast Asia.

PRECEDING PAGE

The Mekong Basin, with its range of geographic and climatic zones, is one of the richest areas of biodiversity in the world.

FACING PAGE

Pollution is a major issue that creates severe health problems.

Rather, upland forests, where they have been removed or degraded, have been replaced by fragmented landscapes consisting of remnant forest patches and various types of humanly disturbed land cover. Such fragmentation results from a number of activities, including timber extraction, shifting agriculture, permanent cultivation, forest gathering, dwelling construction, road building and, in some cases, revegetation (Ziegler et al. 2004). The hydrology of these fragmented landscapes is only distinguishable from that of the natural forests they have replaced at the local scale. So, claims that land-use changes have historically had a detectable influence on the flow regime of the Mekong mainstream cannot be substantiated by data analyses (Adamson 2006a).

Even at the scale of regional tributaries, where historical rates of deforestation and shifting cultivation have been particularly widespread, there are no general systematic trends that can be accredited to human activity such as deforestation. Where some systematic drift in the data is statistically evident it is either relatively weak or not in the direction expected (Adamson 2006a).

However, there is little doubt that this situation will change in the near future in the face of the accelerating rate of regional hydropower expansion. Among the perceived adverse impacts of reservoir development is the regulation of the downstream flow regime. This may be defined in simple terms as some degree of modification of the seasonal flow pattern by the reallocation of water from the wet to the dry season. At the end of the dry season the reservoirs are drawn down and begin to refill over the first weeks and months of the flood season. Downstream flows at this time therefore decrease and the natural timing of the onset of the flood season is delayed. Since the annual flood season flow volumes are usually very large compared with storage volumes, dams will often spill but there will still be a detectable decrease in flows at this time of the year as the duration of the flood season is decreased and peak discharges reduced. The major anticipated consequence of hydropower regulation is an increase in regional dry season flows as water stored in the flood season is used for power generation in later months.

Hydrological impacts of hydropower dams in Yunnan Province, China

Particular attention has been paid to the potential hydrological impacts of the cascade of hydropower dams being developed on the mainstream in China, which, when fully developed in 2020, will have a total active storage of 23 km^3, equivalent to 30 per cent of the mean annual flow volume that enters the LMB from Yunnan. This means that the degree of regulation (the proportion of flood season flows transferred to the low-flow season) could be as high as 20 per cent.

The downstream consequences for the mainstream low-flow regime are amplified because a disproportionate volume of regional dry-season flows are generated in Yunnan. As far downstream as Kratie it constitutes as much as 40 per cent of the flow in April (Figure 3.1.3). Conversely, in the wet season the proportion falls to 15 per cent. The clear implication is that large-scale river regulation in Yunnan will have a significant impact on the low-flow regime throughout the lower system.

Hydrological modelling of impacts of hydropower dams in Yunnan Province (15,800MW, see section 4.4) has confirmed a significant increase in average discharge during the low-flow season, of about 40 per cent in the upper reaches and about 20 per cent as far downstream as Kratie (Figure 3.1.3). The decrease in flood season flows is proportionally far smaller (about 15 per cent in the upper reaches and less than five per cent at Kratie (MRC 2009a). These hydrological changes shift the timing of the four flow seasons, including timing of the reverse flow to Tonle Sap Great Lake, and affect the flooded area as well as the dry season area, which are key parameters for the Great Lake's productivity, including fishery production.

To date there is no convincing statistical evidence that the existing tributary dams in Lao PDR, Thailand and Viet Nam have modified the mainstream flow regime. However, even when the much larger projects in China are commissioned, the natural seasonal and inter-annual variance of the flows could make it difficult to isolate potential long-term changes that are likely to be permanent.

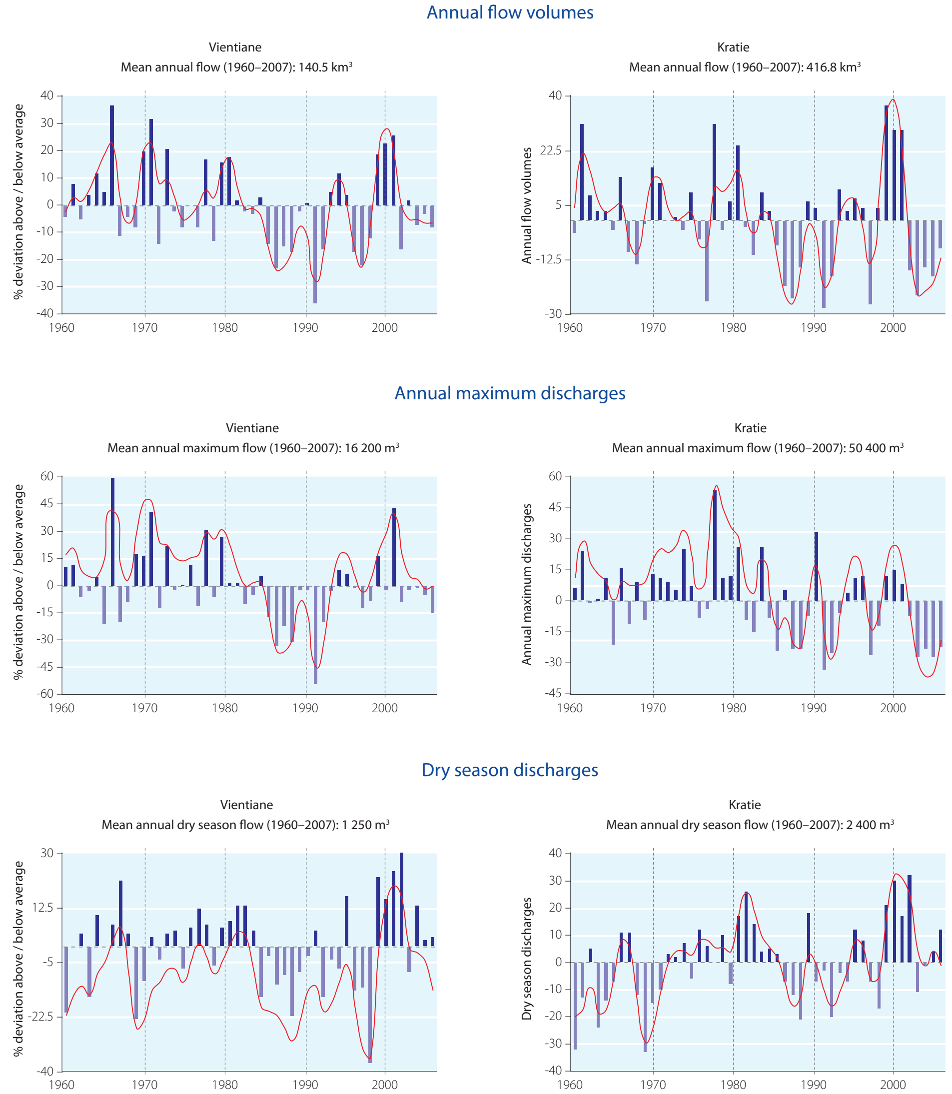


Figure 3.1.1 Mekong at Vientiane and Kratie – percentage deviations of the annual flow volumes, annual maximum discharge and average dry season discharge above and below their long term mean values over the period 1960 to 2007. The smooth functions are the 5-year running means.

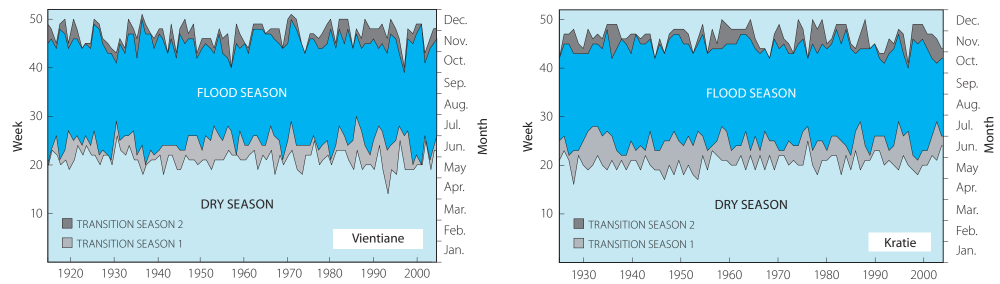


Figure 3.1.2 Historical onset and duration of the four Mekong flow seasons at Vientiane (1913–2005) and Kratie (1924–2005).

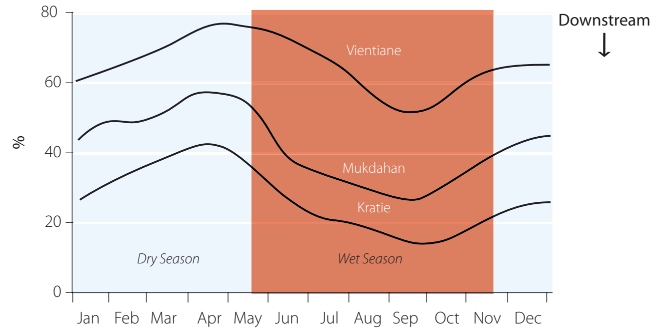


Figure 3.1.3 Mekong at Vientiane, Mukdahan and Kratie – the percentage contribution of the outflows from China to long-term mean monthly flows.

Water quality

The Mekong River is still regarded as a fairly unpolluted river with generally good water quality, although some areas near urban centres, or with intensive agriculture and aquaculture, can experience elevated levels of nutrients and organic matter. Data on toxic micro-pollutants, such as organo-chlorines and heavy metals, are scarce but available data do not raise any specific concerns.

Water quality monitoring in the Lower Mekong Basin

The Interim Mekong Committee (forerunner to the MRC) established a water quality monitoring network in 1985 to help the countries in the region detect changes in the environment and take preventive and remedial action if water quality deteriorated. The network provides an ongoing record of water quality in the Mekong, its major tributaries and the Mekong Delta by measuring a number of different parameters (Table 3.1.1). The number of stations sampled has varied over the years. Before 2009, 87 stations were monitored but the number was reduced to 55 in 2009 (Figure 3.1.4). These 55 are designated 'primary stations' as they have basinwide, or trans-boundary, significance. The remaining 32 are designated 'secondary stations'. Of the primary stations, 23 are located on the mainstream (17 on the Mekong, and six on the Bassac), 23 on tributaries and nine are in the delta.

Based on a review of the scientific literature and statistical characteristics of available data in the MRCS database, the following six parameters and their guideline values were selected to assess the suitability of water quality for protection of aquatic life (WQI^{ai}) in the Mekong River: pH, conductivity, ammonia, dissolved oxygen, nitrite and nitrate, and total phosphorus.

Table 3.1.1 Parameters measured in MRC's water quality monitoring programme

temperature	calcium	total nitrite and nitrate
conductivity	magnesium	total phosphorus
total suspended solids	chloride	chemical oxygen demand
pH	sulfate	faecal coliform
dissolved oxygen	alkalinity	chlorophyll-a
sodium	total nitrogen	
potassium	ammonium	

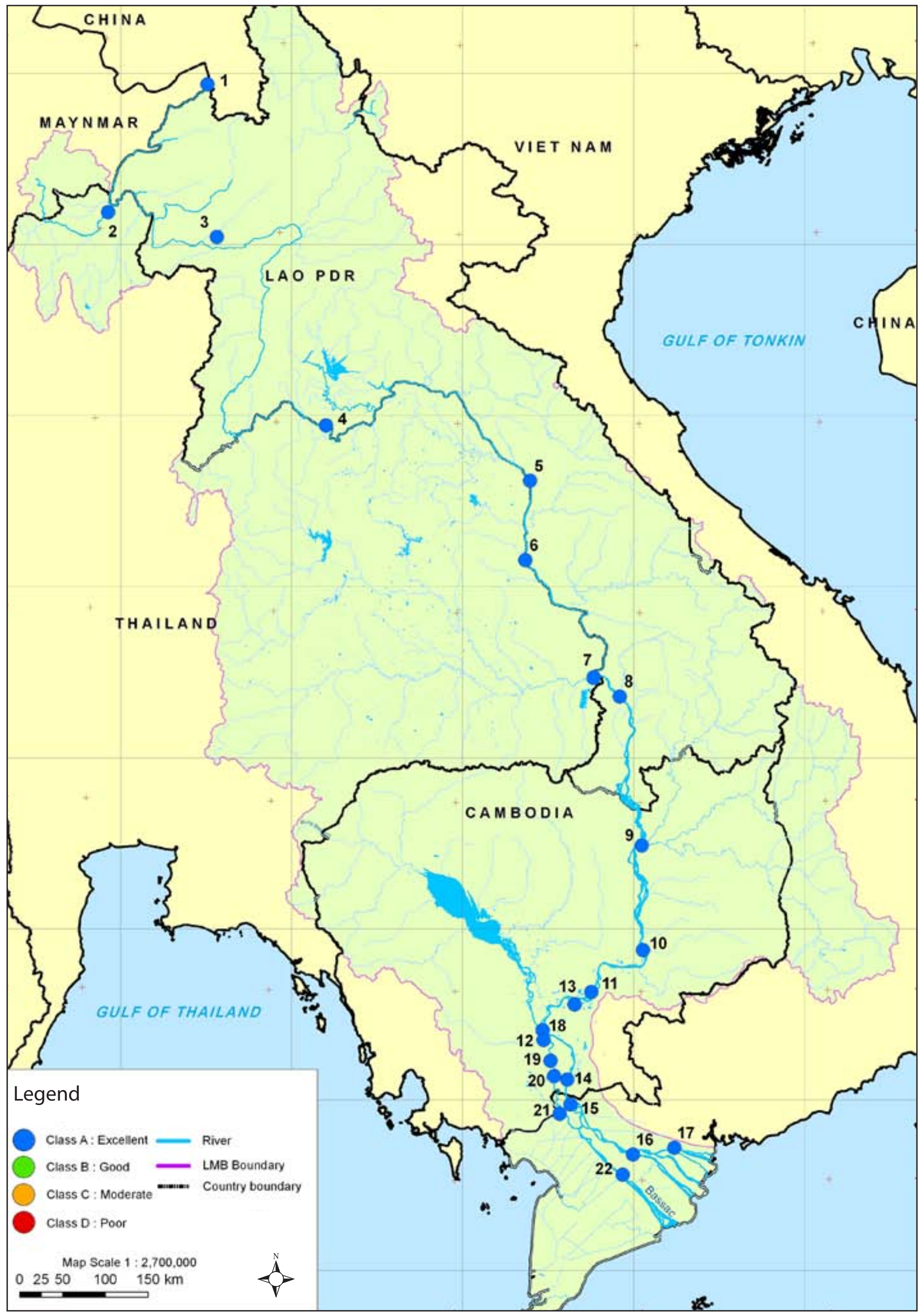


Figure 3.1.4. Some of the stations monitored for water quality. The station numbers are referred to in Figures 3.1.6–3.1.12. Stations 15, 16, 17 and 21 are located in the Mekong Delta.

Water quality trends

Overall, the concentrations of nutrients at all mainstream stations in the Mekong River are low compared with values known to cause eutrophication and algal blooms (Voss et al. 2006; MRC 2008a). Between 2000 and 2008, total phosphorus concentrations increased significantly at the mainstream stations (Figure 3.1.5), but no such trend is found for the tributaries (MRC 2008a). The highest total phosphorus concentrations are found at the stations in the Mekong Delta (Figure 3.1.6). The nitrate and nitrite concentrations did not change significantly between 2000 and 2008. Like phosphorus, nitrogen levels are slightly elevated in the delta (MRC 2008a). Elevated levels are also found in the upper part of the Mekong River and close to Vientiane (Figure 3.1.7, MRC 2008a).

Ammonium concentrations increased significantly between 2000 and 2008 (Figure 3.1.8). Elevated concentrations are found in the upper parts of the basin close to confluences with tributaries, Vientiane and on the Cambodian side of the Bassac River (Figure 3.1.9). However, the measured values are well below the national standards for ammonium in ambient water (0.5 mg/L).

Some 'nutrient hot spots' in the Mekong Delta include, for example, the Tien and Hau rivers, which show signs of large amounts of organic matter and microorganisms, due to untreated industrial, aquacultural and agricultural waste. At Chau Doc in Viet Nam, levels of total phosphorus are now approaching those associated with algal blooms in stagnant water. Flushing by the river may be sufficient to reduce the likelihood of severe algal blooms at mainstream sites, but if water flows are reduced, e.g. by upstream dams or irrigation projects, the problems could become far more severe (MRC 2008a). The tributaries in Thailand show elevated nutrient levels, although with a declining trend.

The chemical oxygen demand (COD) (an indirect measure of organic matter) increases along the river, showing lower values upstream and higher values at downstream stations (Figure 3.1.10), similar to the trend in total phosphorus, indicating an increased production of organic matter with increased phosphorus levels. The COD concentrations have increased slightly over the past five years (Figure 3.1.11) but levels are still below the national standards for COD in ambient water (10 mg/L).

A high concentration of organic matter is accompanied by low concentrations of dissolved oxygen (DO) as bacteria oxidise organic matter while consuming oxygen. The variation in DO along the river indicates a higher pressure on water quality downstream of Pakse (Figure 3.1.12). The lowest concentrations in dissolved oxygen are found at Ta Khmau and Koh Khel stations, which are both on the Cambodian side of the Bassac River and downstream from Phnom Penh. It is worth noting that almost all the measured values are higher than (i.e. better than) the national standards for dissolved oxygen in ambient water (5–6 mg/L).

Water quality for protection of aquatic life

A healthy aquatic life in the Mekong Basin depends on water quality, especially an acceptable concentration of dissolved oxygen and low concentration of toxic ammonia. Low pH values can be a limiting factor

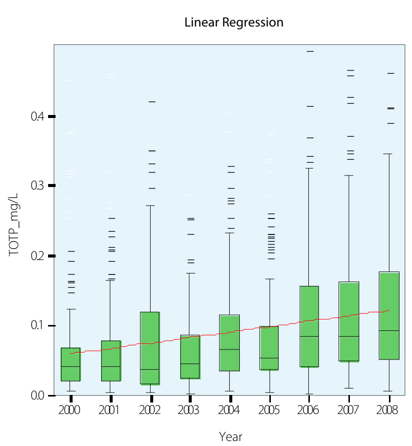


Figure 3.1.5 Variation in total phosphorus (mg/L) in the Mekong River 2000–2008.

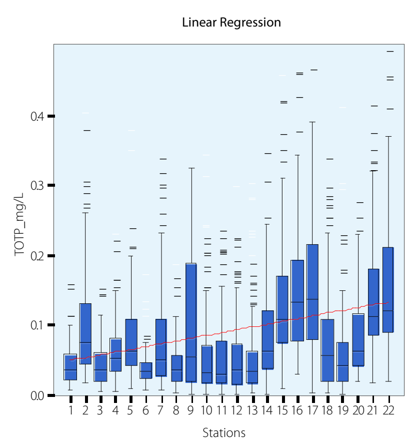


Figure 3.1.6 Variation in total phosphorus (mg/L) at 22 stations along the Mekong (1–17) and Bassac Rivers (18–22) 2000–2008.

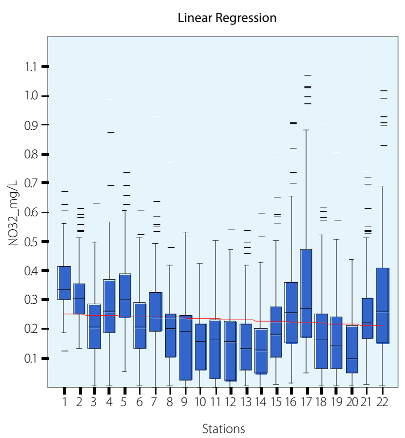


Figure 3.1.7 Variation in nitrite and nitrate (mg/L) at 22 stations along the Mekong (1–17) and Bassac (18–22) rivers 2000–2008.

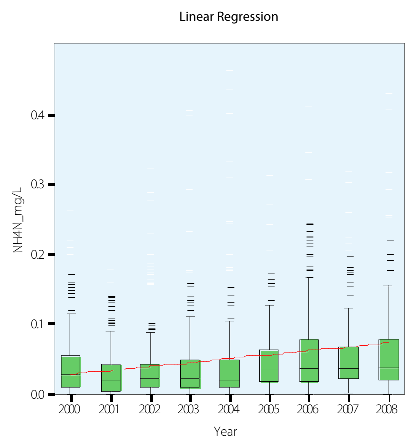


Figure 3.1.8 Ammonium concentration (mg/L) in the Mekong River 2000–2008.

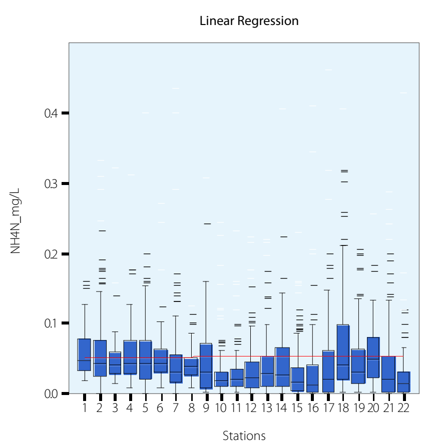


Figure 3.1.9 Variation in ammonium concentration (mg/L) between 22 stations along the Mekong (1–17) and Bassac (18–22) Rivers (2000–2008).

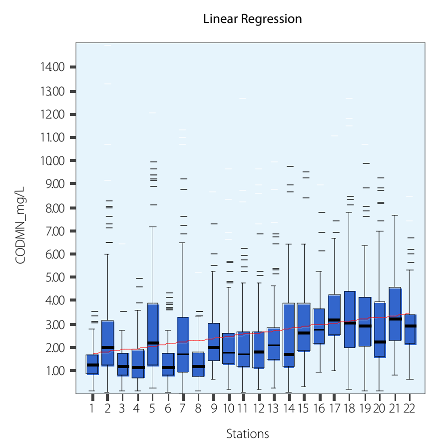


Figure 3.1.10 The variation of COD (mg/L) at 22 stations along the Mekong (1–17) and Bassac River (18–22), 2000–2008.

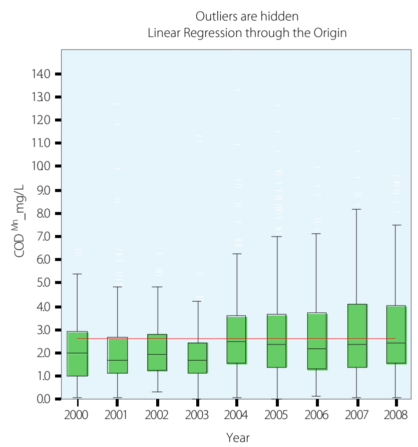


Figure 3.1.11 The variation of COD (mg/L) in the Mekong River 2000–2008.

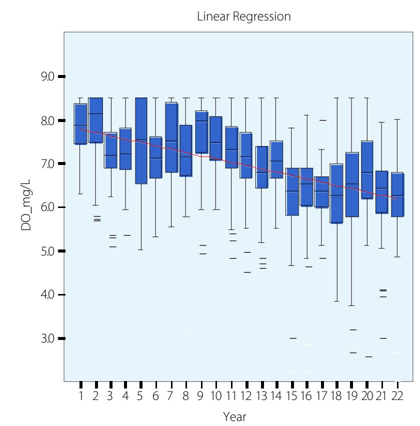


Figure 3.1.12 Variation in dissolved oxygen (DO) (mg/L) at 22 stations along the Mekong (1–17) and Bassac (18–22) Rivers, 2000–2008.

and balanced concentrations of nutrients are also needed to support aquatic primary production.

The water quality of almost all the mainstream stations is rated as 'excellent' for the protection of aquatic life for the period 2000–2008 (MRC 2008a). The few exceptions are in Viet Nam at My Tho station in 2002 and 2005, My Thuan station in 2006 and Chau Doc station in 2002. At these stations the water quality was rated as good/acceptable quality for the protection of aquatic life with only minor downgrading caused by natural salinity intrusion or elevated nutrient concentrations.

The water quality for protection of aquatic life of stations on tributaries differs significantly from those on the mainstream. While the water quality for protection of aquatic life index at most stations is classed as 'excellent', the stations on the Tonle Sap River, Great Lake and the delta at Ca Mau and Long Xuyen are classed as only 'moderate' quality, which means that most aquatic life is protected but some species may be threatened or impaired.

Trans-boundary water pollution

There is no strong evidence for trans-boundary pollution within the Mekong Basin (i.e. between Lao PDR and Thailand, Lao PDR and Cambodia, and Cambodia and Viet Nam) (MRC 2008a), although elevated nitrogen levels in the upper part of the river indicate some trans-boundary transmission of pollutants from the Upper Mekong Basin into the LMB (MRC 2008a). The rapid development of the Lancang Basin in China and increasing pollution in Chinese rivers may raise some concerns in future about the quality of incoming water from the Lancang Basin (MRC 2007a).

The Mekong River transports large amounts of sediment, much of which originates in the upper part of the basin (see p. 72) This process helps to redistribute nutrients within the basin and is very important for areas of high productivity, such as the Tonle Sap Great Lake (Kummu et al. 2008). In this sense, trans-boundary transportation of nutrients along the river has, so far, been regarded as a benefit rather than a cause of pollution.

Persistent organic pollutants

Large gaps exist in the scientific data about levels of persistent organic pollutants (POPs) in the environment of the Mekong River Basin (MRC 2007a). Most of the available data are restricted to investigating levels of a few organochlorines, such as DDT and PCB.

Recent studies conducted in the Mekong Delta reveal the presence of POPs in sediment and biota (Minh et al. 2006; Minh et al. 2007; Carvalho et al. 2008; Ikemoto et al. 2008b). Most of the organisms investigated (phytoplankton, crustaceans and fish) contained levels of POPs, with DDT being the main contaminant (Table 3.1.2). A similar contamination pattern was found for POPs in sediment, with DDT most abundant. The concentrations of DDT and PCBs were higher in sediment next to urban areas than in sediments from rural and agricultural sites, suggesting that urban areas were important point sources of DDTs and PCBs in the river (Minh et al. 2007).

Table 3.1.2 Average concentrations of persistent organic pollutants (POPs) in the Mekong Delta

Species	Number of samples	Lipid (%)	Moisture (%)	PCB[3]	DDT[3]	CHL[3]	HCH[3]	HCB
Phytoplankton[1]	1	0.07	96.20	0.02	0.06	0.00	0.00	0.00
Crustaceans[1]	33	2.97	72.62	2.12	5.32	0.16	0.01	0.04
Fish[1]	18	2.02	77.43	4.25	8.00	0.27	0.03	0.03
Sediments[2]	24			0.98	5.50	0.77	0.12	0.02

[1]ng/g wet weight in whole organisms from Mekong River mainstream, Can Tho 2004 (modified from Ikemoto et al. 2008b); [2]ng/g dry weight from Mekong River (Hau River) 2003–2004 (Minh et al. 2006); [3]Figures represent the sum of all components found.

Although the proportion of undegraded DDT is generally less than its breakdown products (DDE and DDD), some samples have a high proportion of undegraded DDT, indicating recent inputs of DDT into the aquatic environment. This result indicates that although the magnitude of contamination has probably decreased over time, inputs of DDT are still occurring. Some sediment samples from the Mekong Delta had concentrations of DDT compounds higher than Canadian environmental quality guidelines, suggesting continuous monitoring for POP contamination in the Mekong River is necessary (Minh et al. 2007).

In Cambodia, DDT and its derivatives had the highest concentrations and were the most commonly detected POPs in both marine and freshwater fish (Monrith et al. 1999). PCB was the second highest followed by HCH, CHL and HCB. Freshwater fish contained higher concentrations of DDT than marine fish, implying that the sources of DDT are inland watersheds such as the Mekong River, Bassac River, Tonle Sap River and Tonle Sap Great Lake. Many studies confirm that environmental levels of persistent organic pollutants are higher in Southeast Asia than in many temperate areas, while levels of PCBs are comparatively low because of lower industrialisation in Southeast Asia (Allsopp and Johnston 2000; Monrith et al. 2003; Tatsuya et al. 2004; Carvalho et al. 2008).

Concentrations of DDT in human breast milk from Cambodia and Viet Nam were notably higher than for developed countries and comparable to levels from other developing countries where DDT is still being used for agriculture and public health, thus indicating recent use of DDT in Cambodia and Viet Nam (Tatsuya et al. 2004; Viet et al. 2004). Concentrations of other organochlorines in human breast milk from Cambodia, on the other hand, were one to two orders of magnitude less than those from other countries, indicating that Cambodia is one of the less contaminated countries for PCBs (Tatsuya et al. 2004). The high levels in breast milk are due to the fact that many persistent organic pollutants are biomagnified (increased) along the food chain, where fish consumption may be one important route for uptake of these compounds (Minh et al. 2007; Ikemoto et al. 2008b). This also explains the high levels of DDT recently found in Mekong Irrawaddy dolphins in Cambodia (Dove 2009, see box on p. 66).

Ed Polderman

Transportation of nutrients along the river has, so far, been regarded as a benefit rather than a cause of pollution.

A flagship species of the Mekong under threat

The Irrawaddy dolphin (*Orcaella brevirostris*) is found in a few locations in South and Southeast Asia. One of three exclusively freshwater populations inhabits a 190 km stretch of the Mekong River between northern Cambodia and southern Lao PDR. The upstream limits of dolphin distribution are the Khone Falls In Lao PDR. Globally IUCN lists this species as vulnerable, but the small population in the Mekong River has been listed as critically endangered because it is isolated and declining in number. The Mekong population is thought to contain 66–86 individuals (Dove 2009).

Both the Khmer and Lao people regard dolphins as a sacred animal and they are rarely hunted. They are, however, a valuable resource, generating tourism dollars for many communities. Dolphins and the Khone Falls are the main attractions for tourists visiting the Siphandone region in southern Lao PDR. In 2005, at least 9000 people visited the dolphin pool there, and 52,000 tourists visited the Siphandone region, generating an estimated revenue of US$8.2 million. In 2015, the number of tourists visiting the region is expected to increase to more than 100,000 per year (Bezuijen et al. 2007). However, concerns have been raised that the number of dolphins is critically low and very vulnerable to any additional external stress (Lopez 2005; Dove 2009).

Since 2003, 88 dolphin deaths have been recorded. It is likely that this population of Irrawaddy dolphins is the most threatened of all the existing populations in Southeast Asia (Dove 2009). The principal cause of adult mortality has been drowning in fishnets, which from 2001 to 2005 accounted for almost one-third of documented deaths in Cambodia and Lao PDR (Bezuijen et al. 2007). Causes of high juvenile and calf mortality are largely unknown but a recent report suggests that pollutants, such as mercury, DDT and PCB, may have weakened the animals' immune systems – especially in young individuals – making them more susceptible to disease (Dove 2009). This and other stresses, in combination with limited genetic diversity due to inbreeding, may have made otherwise manageable bacterial diseases become deadly.

Another threat to the dolphin population is mainstream hydropower dams, which may lead to a reduced abundance and diversity of fish prey species and alter conditions in deep pools, a primary dolphin habitat during dry seasons. Dams could also divide dolphins into smaller groups, which would become more genetically isolated and therefore more vulnerable to extinction (Bezuijen et al. 2007).

Management actions to preserve the remaining population of Irrawaddy dolphins could include:

- Maintenance of sufficient natural flow regime so dolphin behaviour is not restricted and dolphins have full access to fish prey, hunting, feeding and other critical activities
- Joint actions to address illegal fishing and demarcation and zoning of dolphin pools
- Enhancing genetic variation within the dolphin population
- Establishing an endangered species recovery plan
- Supporting long-term abundance, mortality, and pollution monitoring
- Assessment of current and future stresses and their cumulative effects on dolphins.

Richard Zanre

Mekong dolphin in Kratie, Cambodia.

Heavy metals and other trace elements

Like persistent organic pollutants, the data about heavy metals and other trace elements is scarce and scattered for the Mekong River. Somewhat elevated levels have been found in areas with significant boat traffic and/or with high population densities, mainly in downstream areas of Phnom Penh and in the Mekong Delta, but also in border areas between China and Lao PDR (MRC 2007a).

Studies on trace elements in the aquatic food web in the Mekong Delta report that concentrations in bodies of fish and crustaceans sampled from the delta were comparable with, or lower than, the values reported for fish and crustaceans around the world (Ikemoto et al. 2008a). The same study also reports relatively low concentration levels in water for toxic elements such as silver, cadmium, mercury, thallium and lead (<1.0 µg/L), while higher levels were found for arsenic and some other elements.

Arsenic has been reported as one of the more significant toxic elements in the region. In 2003 and 2004 somewhat elevated levels were found in downstream areas of Phnom Penh and in border areas between China and Lao PDR (MRC 2007a). Natural arsenic is widespread in soils at typical concentrations between 8 and 16 ppm (dry weight) (Stanger et al. 2005). Industrial and agricultural arsenic is localised and relatively unimportant compared to natural alluvial arsenic. Groundwater arsenic pollution seems to be of natural origin and caused by reductive dissolution of arsenic-bearing iron phases buried in aquifers (Stanger et al. 2005; Berg et al. 2007). Aquifers most typically contain arsenic concentrations of no more than 10 µg/L, although scattered anomalous areas of 10–30 µg/L are also quite common (Stanger et al. 2005). Arsenic concentrations in groundwater from the Mekong Delta ranging from 1 to 1610 µg/L in Cambodia (average 217 µg/L) and from 1 to 845 µg/L in southern Viet Nam (average 39 µg/L) have been reported (Berg et al. 2007).

There is no evidence of widespread arsenicosis, but there are serious localised health hazards, and some risk of low-level arsenic ingestion through contaminated food and water (Stanger et al. 2005). In recent surveys of groundwater in the Mekong Delta floodplain, 27–37 per cent of the studied wells exceeded WHO guidelines of 10 µg/L arsenic (Shinkai et al. 2007; Buschmann et al. 2008). A subset of hair samples collected in Viet Nam and Cambodia from residents drinking groundwater with arsenic levels >50 µg/L was shown to have a significantly higher arsenic content than control groups (Berg et al. 2007).

Mercury levels have also caused some concerns in the region. In a basinwide survey during 2003 and 2004, high mercury levels in sediments were primarily found at stations in Cambodia (Prek Kdam, Neak Leang and Kratie) (MRC 2007a). High levels of mercury have also been reported in fish and dolphins in the area between Kratie and Stung Treng in Cambodia. The use of mercury in local gold mining could be one of the sources of elevated environmental levels in certain areas (Murphy et al. 2007, 2009; UNIDO 2007; Dove 2009) (see p. 198). People located in areas with gold mines, on average, had more mercury in their hair (4.4 µg/g) than those living in areas with no gold mines (3.4 µg/g) (Murphy et al. 2009). In the same way as persistent organic pollutants, but unlike most heavy metals, mercury can be biomagnified along the food chain, with increasing levels at higher trophic levels (e.g. predator species) (Ikemoto et al. 2008a). This could explain the high levels found in Irrawaddy dolphins. Fish is probably a main route for uptake of mercury, not only for dolphins but also for the human population (Agusa et al. 2005; Agusa et al. 2007; Murphy et al. 2009).

Water quality: pressures and threats

The elevated concentrations of phosphorus, nitrogen and COD, and the lower dissolved oxygen in the Mekong Delta compared with upstream stations are most likely due to high population densities and intensive agriculture (Campbell 2007; MRC 2008a). Estimates based on available data suggest that about 225,000 tonnes of nitrogen and 37,000 tonnes of phosphorus per year are washed into the Mekong River. More than 40 per cent of this nitrogen and phosphorus is likely to be lost from agriculture in northeast Thailand and the Mekong Delta (MRC 2008a).

Thus, despite fairly low nutrient levels in the Mekong River in general, there may be local risks of elevated levels potentially leading to algal blooms due to excessive use of agricultural fertilisers, particularly those with a high phosphate content, and the discharge of untreated or inadequately treated domestic and industrial wastes from urban centres (Snidvongs and Teng 2006) (see p. 201).

The use of mercury and cyanide in local gold mining and release of acidic tail water has caused incidents of local pollution with fish kills and elevated environmental levels in certain areas (see section 4.7).

Aquatic ecological health

The livelihoods of millions of people in the Lower Mekong Basin depend on the Mekong River. From this perspective as well as from an environmental one, the ecological well-being of the river, its major tributaries, and their associated floodplains, lakes and wetland habitats is of vital importance.

Biomonitoring in the Lower Mekong River

Water quality monitoring (see p. 61) gives an indication of the status of the environment in which aquatic organisms live, but it does not directly assess the health status of these organisms. The most relevant way to assess aquatic ecological health is to monitor the health of key functional groups of organisms in the Mekong River – biomonitoring. Relevant indicator organisms are, for example, primary producers, such as phytoplankton and 'consumers', such as zooplankton and other invertebrates, which are commonly found and easily collected. An indication of a negative health impact could be a reduced number of individuals or species when compared with undisturbed reference sites (MRC 2008b).

The assessment of aquatic ecological health compared with reference sites showed that of the 109 sampling events conducted over five years, 37 were classified as 'excellent', 44 as 'good', 27 as 'moderate'; and one was classified as poor (Figure 3.1.13). This rating suggests that the water quality of the principal rivers of the LMB is not yet showing severe harm from the development of water resources or waste disposal. However, some rivers are showing signs of stress (MRC 2008b).

As for water quality monitoring, the results indicate that the Mekong Delta is slightly more affected than other parts of the river. Also, in accordance with reported elevated levels of nitrogen in water (MRC 2008a) and heavy metals and arsenic in sediments in the northern parts of Lao PDR, the biomonitoring programme indicates some impacts from human activities in the stations between Myanmar and Lao PDR (MRC 2007a, 2008a).

The possible impacts on aquatic organisms in these areas were further confirmed in bioassays conducted on the small crustacean *Hyallella azteca* in 2003 and 2004, which showed a higher mortality when exposed to sediments from these areas compared with uncontaminated sediments (MRC 2007a).

Biomonitoring in the Lower Mekong River

The health of species that live in the river is a good indicator of water quality over time. Aquatic plants and animals are affected by episodic or intermittent pollution that may not be present when physical and chemical water sampling takes place. Indicator species sensitive to pollution will be affected by, and may take a long time to recover from, even a short decline in water quality. Biomonitoring can detect negative impacts of factors that are not practical to measure routinely by physical and chemical monitoring and therefore provides an indication of environmental problems that are not detected by standard water quality monitoring.

The MRC biomonitoring programme was initiated in 2003. The indictor species cover four groups: (i) benthic diatoms (microscopic algae attached to a substrate), (ii) zooplankton (microscopic animals that float or drift in river water), (iii) benthic macroinvertebrates (animals such as insects, snails and worms that live on, or in, the river bed), and littoral macroinvertebrates (animals such as insects, snails and worms that live in shallow water at the shoreline of rivers and lakes). These groups of animals and plants respond to a range of stresses caused by human activity, are identified easily and quickly and can be collected and analysed easily at low cost.

A total of 60 sites were sampled up to 2008. The sites cover a wide range of river settings and environments, including rock-cut channels in northern Lao PDR and northeast Thailand, alluvial channels and floodplains of southern Lao PDR and Cambodia, and the distributary system of the Mekong Delta in Cambodia and Viet Nam. The sites also exhibit varying levels of disturbance from human activities. Some are located in, or near, villages or towns, some are next to fields where crops are grown and livestock graze, some are upstream or downstream of dams and weirs, and at some there is moderate to heavy river traffic.

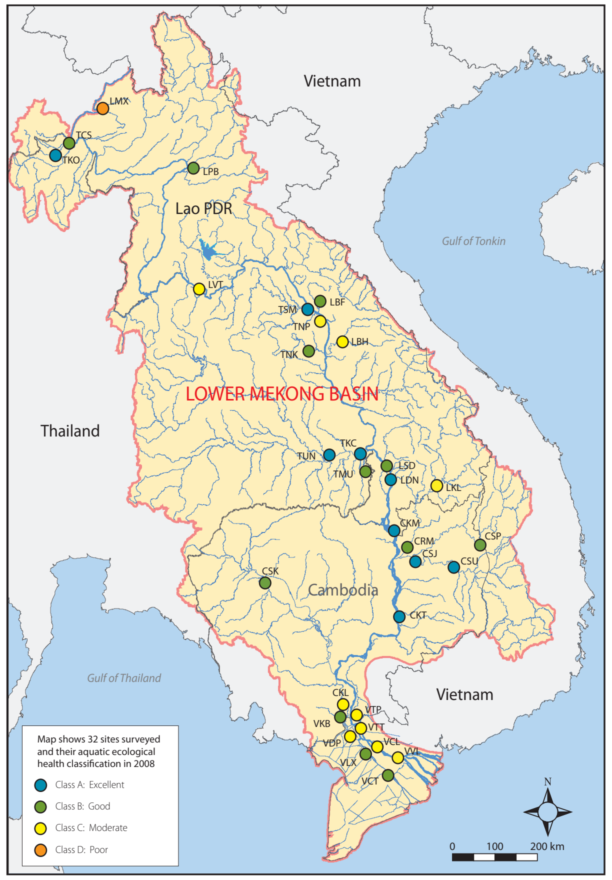
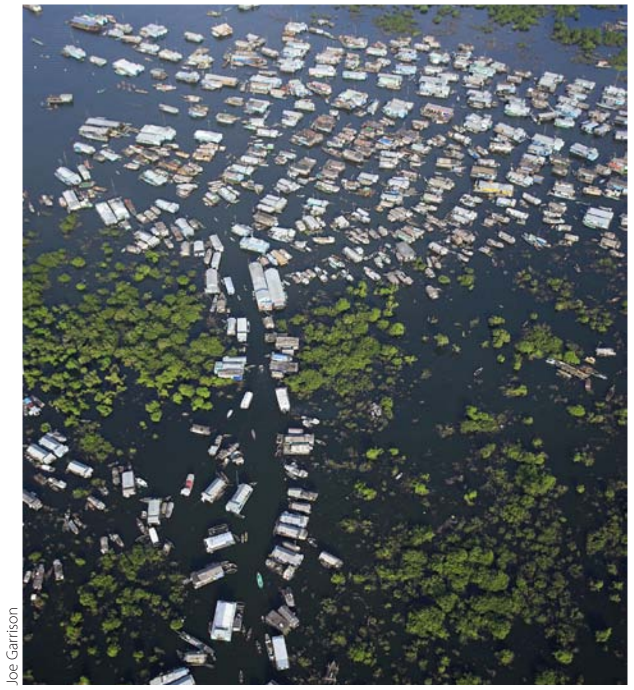


Figure 3.1.13 Sites sampled for aquatic ecological health (2004–2008) and their classification.



A large floating village on the Tonle Sap Great Lake.

Aquatic health – pressures and threats

Although the biomonitoring programme indicates that the water quality of the Mekong River and its tributaries is good compared to many large rivers in other parts of the world, in areas with high population densities and intensive human activities, such as agriculture, aquaculture and mining, impacts are evident.

The use of agrochemicals, especially pesticides, poses a threat to aquatic organisms. Agrochemicals are most intensively used in the Mekong Delta, where farmers may have as many as three crops of rice per year. Also, the use of pesticides in orchards and on vegetables is high, where large quantities are suspected to end up in the aquatic environment. Many pesticides, especially insecticides, with high toxicity to aquatic organisms and humans are still being used (see p. 64)

Chemicals used in livestock farming and aquaculture, such as antibiotics for catfish (*Pangasius*) and shrimp farming may pose a threat to aquatic organisms (Gräslund 2004; Sarter et al. 2007; see box opposite). Little is known about the effects of these chemicals in the environment but caution is needed as they can result in antibiotic resistant bacteria and may accumulate in species used for human consumption (Sarter et al. 2007).

The use of pesticides and herbicides in agriculture poses a threat to aquatic organisms.

Another threat to aquatic health and biodiversity of the Mekong River is the introduction of alien species. In the Mekong Basin, species have been introduced for four major purposes: aquaculture, stocking of lakes and reservoirs, pest control (e.g. mosquitoes) and the aquarium trade. One study identified 17 species introduced into the Mekong Basin that have either established a population or have a strong chance of doing so (Welcomme and Vidthayanom 2003). So far though, the impacts of introduced fish species appear to be relatively minor and their benefits have far outweighed any negative effects. However, some impacts on the environment have been reported. For instance, the hybrid African catfish (*Clarias gariepinus*) may be contributing to a decline in native catfish (*Clarias batrachus*) and established populations of Rohu carp (*Labeo rohita*) may damage native species of the same genus (Welcomme and Vidthayanom 2003). Other introduced species which are affecting the ecology of the Mekong Basin wetlands are the giant mimosa (*Mimosa pigra*) and the golden apple snail (*Pomacea* sp.).

Other important impacts on aquatic health and biodiversity are overexploitation of species and habitat degradation. The latter is probably the largest threat and includes, for example, stream-bed dredging, removal or alteration of vegetation, and bank modification; changes in the seasonal variation and quantity of water available as a result of storage in dams and abstraction for irrigation; and construction of barriers (dams, weirs, diversions). These physical impacts may significantly reduce aquatic productivity and biodiversity. An example of this was found during the 2008 biomonitoring survey where the decline in water quality seen at some sites has probably been caused by bank erosion during the rainy season. Other sites have changed in terms of water flows, water levels and amounts of sand and clay accumulation. These factors could have affected the organisms living in the area and caused the recorded changes. (MRC 2010).

Catfish farming in the Mekong Delta

Pangasius (catfish) aquaculture occurs in Viet Nam, mainly based on two species – tra (*Pangasianodon hypophthalmus*) and basa (*Pangasius bocourti*). In 2008, Viet Nam produced about one million tonnes of catfish, a staggering increase considering that in 2000 the industry was only producing 100,000 tonnes (Wilkinson 2008; Phan et al. 2009). By 2009, the country was on target to produce between 1.3 and 1.5 million tonnes of catfish with an export value of US$1.5 billion (Phan et al. 2009).

It takes about six months to grow a market-sized pangasius – which means it is often possible to grow two crops a year. The fish grow to full size in ponds, pens and cages. Stocking density is very high with 40–50 fish/m^2, which can result in yields as high as 500–600 tonnes per ha per crop (Poulsen et al. 2008; Phan et al. 2009). Even though the profit margin is small (about US$ 0.1–0.15 per kg) the total return to the farmer (US$60,000–90,000 per hectare) is vastly superior to any other crop (Wilkinson 2008). Questions are being raised about how long such production can be sustained without a severe impact on the environment, with concerns being raised on a number of issues.

These aquaculture operations discharge large amounts of waste to the aquatic environment and indications are that the scale of production is already approaching the environmental carrying capacity, resulting in blooms of toxic algae and anoxic conditions in bottom waters (Poulsen et al. 2008). A typical feed conversion ratio of two (2 kg of feed produces 1 kg of fish) (cf. Phan et al. 2009) and a production of one million tonnes of fish means that about one million tonnes of waste is discharged to the environment annually. With some 70–80 per cent of Viet Nam's catfish production in provinces close to the Mekong River, this means that 700,000 to 800,000 tonnes of organic waste potentially enters the river each year.

With increasing stocking density, disease is a major problem, which can spread to wild stock. Fish that escape from farms may also compete with wild fish and affect ecosystem diversity. The use of antibiotics and potential for them to leak into the environment is also of concern. Little is known about the amounts of antibiotics used, their fate and impacts on the Mekong River ecosystem. Antibiotics may also accumulate in the fish, which can result in export bans (Poulsen et al. 2008).

The use of land and water by catfish operations is also a concern as sensitive habitats can be destroyed and water is often diverted, which can affect other water users and the environment (WWF 2009).

NGOs, such as Eurepgap, GTZ, WWF and Naturland have established, or are attempting to establish, certification standards for catfish aquaculture. Farmers are keen to improve the performance of their farms and the quality of their products to meet market demands and requirements of importing nations (Wilkinson 2008).

Catfish farming is an important industry for the region that hopefully can be further developed by implementing sustainable farming practices that maximise long-term production while avoiding negative impacts from overexploitation of natural resources, environmental pollution and reduced biodiversity.

Geoff Morris

Feeding catfish at a farm near Can Tho, Viet Nam.

Sediment characteristics and trends

The relationship between sediment concentration and water discharge is complex and varies seasonally (Figure 3.1.14). As expected, concentrations are at their lowest during the dry season but then rise fairly dramatically during the first months of the flood season, after which they decline, even though water discharge remains high. This is due to weathering during the dry season producing loose material which is then flushed from the surface by the first seasonal storms. Other contributory factors are agricultural land preparation, such as ploughing before planting of rain-fed crops and the fact that ground cover is less well developed than later in the season, so there is more potential for erosion during storms.

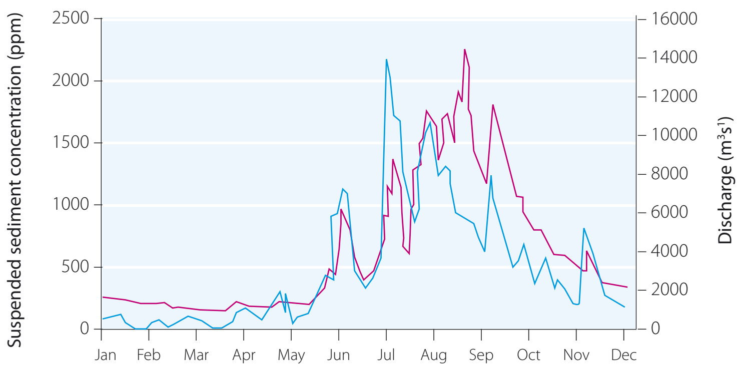


Figure 3.1.14 Mekong at Luang Prabang: An example of the characteristic seasonal relationship between water and sediment discharge on the mainstream, indicating that the linkage between the two has a significant systematic seasonal variability (*Source*: Walling 2005).

A mean annual suspended sediment load of 160 x 10^6 tons is frequently cited for the Mekong in global data compilations (Milliman and Meade 1983; Milliman and Syvitski 1992), the figure relating to the total basin area of 760,000 km². More recent results suggest that this figure could be rather high (Kummu and Varis 2007). There are two major sources of regional sediment production, which between them produce 90 per cent of the total (Clift et al. 2004). The first is the upper basin in China with an estimated production of 60 x 10^6 tons per year (based on the post 1993 data sampled at Chiang Saen), which is about half of the regional total and sourced from less than 20 per cent of the overall basin area. The second major source terrain is the Central Highlands, with the Se Kong, Se San and Sre Prok tributaries delivering considerable loads to the Mekong mainstream (Clift et al. 2004). Elsewhere, tributary sediment contributions are relatively low with erosion rates just 5–10 per cent of those in the two principal source areas (Harden and Sundborg 1992).

Sediment issues have received considerable attention in recent years, reflecting a growing realisation of the potential consequences of reduced sediment transport due to trapping behind dams. Given the scale of the potential expansion of dams, the reduction in mainstream sediment budgets is widely regarded as a serious concern. Already there is evidence to suggest that the sediment flux, as it is known, that enters the LMB from China has declined since the construction of Manwan dam in 1993 (Figure 3.1.15).

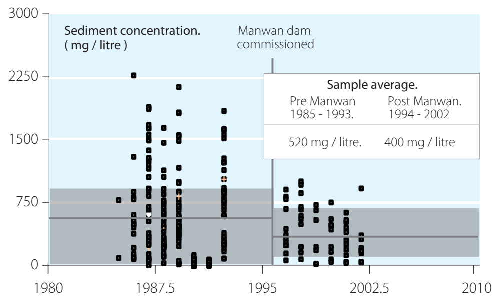


Figure 3.1.15 Mekong at Luang Prabang – reduced suspended sediment concentrations in samples taken before and after the construction of Manwan dam in China in 1993.

With perhaps 50–60 per cent of the regional sediment load originating in China, sediment budgets are a potential major trans-boundary issue. A number of studies suggest that sediment delivery from the upper Mekong has decreased, though they differ about the extent of this change, some suggesting the figure could be as high as 50 per cent since 1993 and the closure of the Manwan dam (Lu and Siew 2006; Fu and He 2007; Kummu and Varis 2007). The efficiency of the mainstream dams in removing sediment from the system is indicated by the fact that Manwan lost 20 per cent of its storage capacity to sediment deposition during the first 10 years of operation, equivalent to a mean annual rate of mainstream sediment loss of 20 x $10^6 m^3$. It is estimated that the completed Yunnan cascade will trap some 90 per cent of the upper Mekong sediment contribution to the lower basin (Kummu and Varis 2007).

The series of five dams proposed on the mainstream in Lao PDR between Pak Beng and just upstream of Vientiane, although much smaller, will further contribute to a reduction in the fluvial sediment flux. An exploratory assessment of the combined sediment trapping efficiency of these schemes reveals that there is a potential to retain more than half the material that enters the cascade at Pak Beng (Adamson 2009).

The major fluvial system response to sediment removal is increased erosion downstream since the hydraulic transport capacity exceeds the available supply of material. This leads to downstream impacts such as channel bed degradation, textural changes involving coarsening of surface grain-size distribution, lateral channel expansion and bank erosion. Incision can cause river channels to deepen by 2 or 3 m and a reduction in the over bank flooding, which supplies water, sediment and nutrients to the flood plain and wetlands. Channel incision also causes an adjustment to the hydraulic river slope, which instigates a complex series of geomorphic responses. These may include changes to channel widths and alterations to lateral migration patterns. Consequently, roads, bridges and streamside settlements are vulnerable to damage from these changes in stream behaviour.

The effects in the Mekong are therefore likely to be evident far downstream of the mainstream dams in China and northern Lao PDR, given that the tributary sediment contributions are modest until northern Cambodia and the entry of the Se Kong, Se San and Sre Pok – a drainage complex which is also a major focus for hydropower and reservoir development.

Reduced sediment supply to the delta in Viet Nam is likely to have serious consequences, particularly with regard to increased coastal erosion, a situation which is aggravated by possible sea level rise due to climate change. The sensitivity of the area to the available sediment budget is illustrated by increased bank erosion downstream of areas associated with sand mining from the river bed. The impacts of upstream sediment trapping are likely to be long term, however, since the supply from bank erosion downstream of the reservoirs will only compensate in part.

The Intergovernmental Panel on Climate Change (IPCC) has declared that the Mekong Delta is one of the three deltas most at risk globally from increased sea levels (see section 3.5). But equally, and just as serious, are the potential impacts of a reduced sediment supply. There are many examples in the world of the consequences of fluvial sediment removal by reservoirs. Erosion and the loss of agricultural land in the Nile Delta because of the Aswan dam and the Volta Delta in West Africa because of the Akosombo dam are well documented.

The major response to sediment removal is increased erosion downstream.

3.2
WETLANDS

The Mekong River Basin contains a great diversity of wetlands that provide a wide range of functions and support important social, economic and cultural values. Wetlands include a wide variety of aquatic habitats lying at the border between land and water, such as rivers, lakes, ponds, swamps, streams, rice fields, mangroves, mudflats, and coral reefs. They are among the most complex and diverse ecosystems in the world, highly biodiverse as well as highly productive. Wetlands of the region are associated with the Mekong mainstream itself, as well as its tributaries from the mountains of southern China, Lao PDR and the Central Highlands of Viet Nam, the broad pleateau of northeast Thailand; and the great floodplains of Cambodia and the Mekong Delta in Viet Nam (Figure 3.2.1).

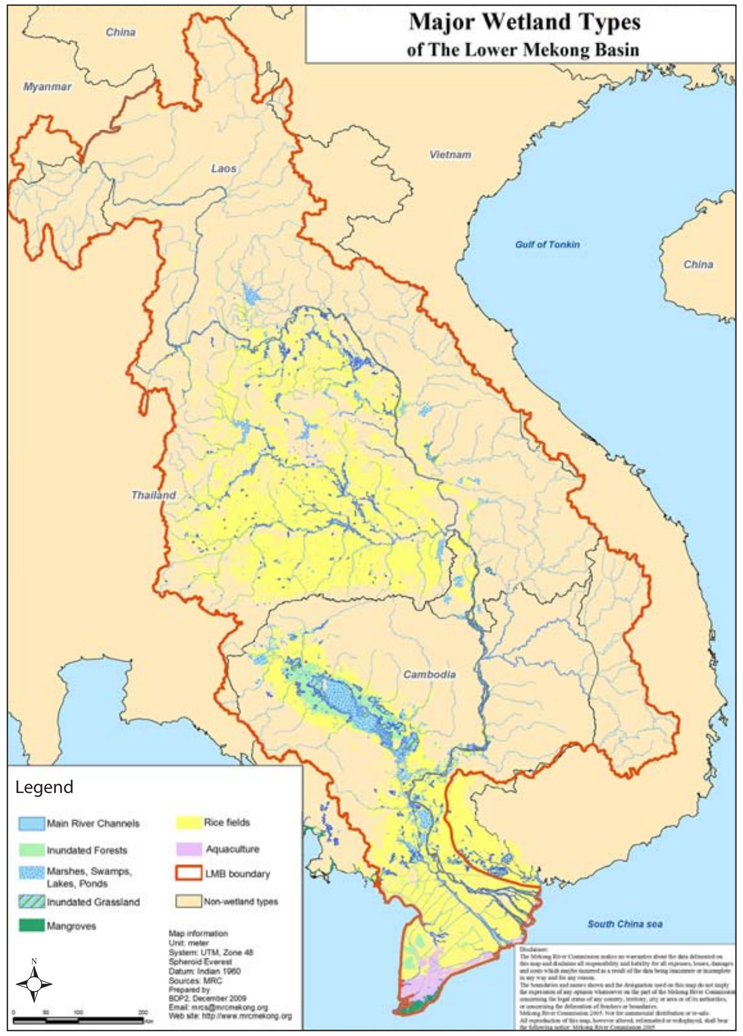


Figure 3.2.1 Extent of wetlands in the Lower Mekong Basin.

What is a wetland?

According to the Ramsar Convention (one of the broadest and most widely used definitions) wetlands are: "*Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six metres*".

Wetlands play a vital role in the livelihoods of local people and the socio-economic development of the region. Their use for rice cultivation and freshwater capture fisheries provides the staples of people's diets throughout the region, as well as a major source of export revenue. Among other direct uses, wetlands provide grazing lands for animals, a source of wood and fibrous plants for building materials, medicinal plants and foods gathered to supplement the diets of rural people, as well as water for household use (Ratner et al. 2004).

The indirect uses of wetlands are sometimes less obvious but no less important. Natural wetlands absorb floodwaters that could otherwise be disastrous during the wet season. Cambodia's Tonle Sap, for example, expands in surface area as much as four to five times during the wet season. Without this natural absorption, Phnom Penh would be completely flooded every year (Ratner et al. 2004). Mangroves in the coastal areas of the delta and *Melaleuca* forests in floodplains help to protect against erosion and trap nutrients that contribute to the high agricultural and fisheries productivity of the LMB.

Urban and peri-urban wetlands, such as That Luang Marsh in Vientiane (see box on p. 91), provide natural purification functions by removing excessive nutrients and toxins from agricultural, industrial and municipal waste water before it enters the Mekong mainstream (Gerrard 2004). Urban and rural wetlands also provide recreational areas and support cultural functions. An increasing number of wetlands in the region, such as the Siphandone in Lao PDR, are becoming major tourist destinations, bringing important economic revenue to the region (see section 4.8).

Because of the high diversity of wetland functions and services supporting livelihoods and economic development in the region, it is no surprise that the region's population is concentrated around wetlands. Yet, accelerating economic development, population growth and changed consumption patterns of the basin's population are placing the health of wetland ecosystems and their ability to sustain the livelihoods of a growing population at risk.

Accelerating economic development, population growth and changed consumption patterns of the basin's population are placing the health of wetland ecosystems and their ability to sustain the livelihoods of a growing population at risk.

Ramsar in the Mekong Basin

The Mekong is second only to the Amazon in terms of biodiversity importance, and is the most productive inland fishery in the world. Wetland goods and services have supported Mekong peoples for thousands of years and wetlands throughout the Mekong basin today are subject to significant human use. It may be surprising then that designation of Ramsar sites with the clear aim of supporting 'wise use' of internationally important wetlands has not been more widespread in the Mekong Basin.

To date Thailand has designated 10 Ramsar sites, two of which are within the Mekong Basin; Cambodia has designated three sites, two of which are in the Mekong Basin; Viet Nam has designated two sites (neither in the basin) and Lao PDR is yet to designate any. In total there are just four Ramsar sites in the LMB - yet studies have identified the clear potential for at least 40 Mekong wetlands that would meet Ramsar criteria.

Dao Huy Giap

Fish and other aquatic animals from wetlands provide a source of income for many Mekong residents.

Wetland types and distributions

The LMB contains rich and extensive areas of wetlands, estimated to cover 6–12 million hectares of the entire lower basin (Ringler 2001). The river and its numerous tributaries, backwaters, lakes, and swamps support many unique ecosystems, such as deep river pools, plains of reeds and mangrove forests. A number of important wetland types have been identified in the LMB (Figure 3.2.1 and Table 3.2.1).

Table 3.2.1 Important wetland types in the Lower Mekong Basin by country

Wetland types	Cambodia	Lao PDR	Thailand	Viet Nam
Flooded forest	X	X	X	X
Rivers/streams	X	X	X	X
Marshes/swamps	X	X	X	X
Floodplain marshes/swamps	X	X	X	X
Peatlands	X	X		X
Lakes/ponds	X	X	X	
Rice fields	X		X	X
Reservoirs		X	X	
Rivers/streams with pools/rapids	X	X	X	
Floodplain lakes/ponds	X	X	X	
Floodplain grasslands	X		X	X
Saline lakes/ponds/marshes/swamps			X	
Fish ponds & aquaculture			X	X
Mangrove forest				X

Source: Vathana 2003; Phittayaphone 2003; Choowaew 2003; Thinh 2003.

Cambodia

About 90 per cent of the land area of Cambodia lies within the Mekong Basin. Most of the central and southern areas are part of the Mekong floodplain system, while the northeastern and eastern plains are covered by a habitat mosaic of dry deciduous and semi-evergreen forests with seasonally wet meadows and other wetlands. The Sekong, Sesan and Srepok (3S) tributaries and parts of the mainstream between the Lao border and Kratie town support some of the fullest riverine bird communities remaining anywhere in Southeast Asia. The Tonle Sap Great Lake is the largest freshwater lake in Southeast Asia and the largest floodplain lake in the world. It is surrounded by important areas of seasonally inundated swamp forest, grassland and scrubland.

Cambodia may have up to 20 separate wetland sites of regional and/or international significance – five examples are listed below (Table 3.2.2). Two are internationally significant Ramsar sites and one is the core zone of a Biosphere Reserve. The others have high biodiversity and other values and both would meet the criteria for Ramsar status.

Table 3.2.2 Examples of important wetland sites in Cambodia

Name of site	Importance	Area (ha)	Province	Types	Key biodiversity information
Middle stretches of the Mekong north of Stung Treng	Ramsar site Refuge for rare fish, dolphins and birds	14,600	Stung Treng	Flooded forest	Important breeding and feeding habitat for rare species of fish and globally threatened wetland dependent birds, including the critically endangered white-shouldered ibis (*Pseudibis davisoni*) (Timmins 2006)
Middle stretches of the Mekong between Kratie and Stung Treng towns	Rich biodiversity	33,808	Stung Treng, Kratie	Braided channels, islands and sandbars, flooded forest and grasslands, gallery forest and channel woodland; deep pools, rocky rapids and turbulent stretches	Variety of habitats supporting a wide range of aquatic species as well as water birds and mammals (Bezuijen et al. 2008); most of the Mekong population of Irrawaddy dolphins are found here
Prek Toal	Core Zone of Tonle Sap Biosphere Reserve	39,873	Battambang	Flooded forest – savanna forest with an almost complete groundcover of *Sesbania javanica* with groups and isolated trees of mainly *Barringtonia* (freshwater mangrove	Supports internationally important colonies of a number of globally threatened water birds, including breeding colonies of spot-billed pelicans (*Pelecanus philippensis*), greater adjutant (*Leptoptilos dubius*) and white-winged duck (*Cairina scutulata*)
Boeng Chhma, associated river and floodplains	Ramsar site High biodiversity	28,000	Kampong Thom	Seasonally flooded forest and swamp	Supports a large assemblage of plant, fish and water bird species, many of which are listed as rare, vulnerable or endangered
Bassac Marshes	Potential Ramsar site (criteria 2, 4, 6)	52,316	Kandal	Seasonally inundated herbaceous, shrub and savanna vegetation.	Of great importance to water birds, important site for the spot-billed pelican

Source: Adapted from Vathana 2003

Lao PDR

A total of 30 regionally/internationally important wetland sites have been identified in Lao PDR (Calridge 1996), mainly in the central and southern parts of the country. Although Lao PDR is not a contracting Party to the Ramsar Convention, considerations to join are ongoing. Examples of four important wetlands are given below (Table 3.2.3). Other important wetlands not discussed include parts of the upper Xe Khaman in southern Lao PDR, the wetlands of the Nakai Plateau in central Lao PDR and parts of the Nam Ou in the north of the country. As well as Siphandone, three other sections of the Mekong mainstream in Lao PDR have been recognised as priority areas for fish and birds within the Indo-Burma Biodiversity Hotspot. These are: the Mekong from Siphandone to Phou Xiang Thong, the Mekong upstream of Vientiane and the upper Mekong in northern Lao PDR. However, very little survey work has so far been conducted to document the real values and importance of these stretches of river.

Allan Michaud

The largest known colony of oriental darter (*Anhinga melanogaster*) in Southeast Asia is found in the flooded forest of Prek Toal.

Table 3.2.3 Examples of important wetland sites in Lao PDR

Name	Importance	Area (ha)	Province	Types	Key biodiversity information
Siphandone Wetland	High biodiversity	6000	Champasak	Perennial wetlands, seasonal river channels, rapids and waterfalls and seasonal flooded forest	At least 205 species of fish recorded at Siphandone; critical to the life-cycle of many migratory fish species and home to the most northerly group of Mekong Irrawaddy dolphins
Xepian-Xe Khampho Wetland	High biodiversity	2000	Attapeu and Champasak	Freshwater lakes and ponds, freshwater marsh, seasonally flooded grassland	Critically important fish breeding and spawning grounds; endangered Siamese crocodiles (*Crocodylus siamensis*) confirmed (Bezuijen et al. 2006)
Bung Nong Ngom	High biodiversity Potential Ramsar site	1000	Champasak	Freshwater marshes and seasonally flooded forest	Rich fish fauna; important for a wide variety of resident and migratory waterfowl; Siamese crocodile thought to inhabit (Phittayaphone 2003)
That Luang Marsh	Natural urban waste water purification	2000	Vientiane municipality	Seasonal freshwater marsh, aquaculture ponds, seasonal flooded grassland/shrubland, irrigated floodplain-wet rice	See box on p. 91

Source: Adapted from Phittayaphone 2003

Table 3.2.4 Examples of important wetland sites in the Lower Mekong Basin in Thailand

Name of site	Importance	Area (ha)	Province	Types	Key biodiversity information
Nong Bong Khai non-hunting area	Ramsar site	434	Chiang Rai	Riverine plain, seasonal and intermittent marsh	Includes 121 species of birds (57 residents) including 53 water birds and 13 species of fish including threatened Siamese fighting fish *Betta splendens* (OEPP 2002)
Bung Khong Long non-hunting area	Ramsar site	2214	Nong Khai	Permanent natural water reservoir	Includes 64 fish species (31 of economic importance) and five species of threatened birds (OEPP 2002)
Lower Songkhram River floodplains	Potential Ramsar site	96,000	Nong Khai, Udon Thani, Sakhon Nakhon, Nakhon Phanom	Free flowing river and seasonally inundated floodplain	Supports 183 species of fish including 19 Mekong endemics and 18 species threatened in the wild (OEPP 2002)
Goot Ting marshes	Proposed Ramsar site	2600	Nong Khai	Marshes, streams, evergreen forest, flooded grassland	Supports at least 123 species of fish (56 of economic importance) including Thai endemic *Boraros micros*, one of the smallest fish in the world and the globally threatened *Probarbus jullieni* 100 species of birds (60 wetlands dependent); a large number of wigeon, highest number of falcated teal from a single site in Thailand; endangered Baer's Pochard (*Aythya baeri*) (WWF Thailand unpubl.)

Source: Adapted from Choowaew 2003

Thailand

Altogether, a total of 39 important wetland sites cover an area of 1,601,082 ha in the Mekong River Basin of Thailand (Scott 1989; Wolstencroft et al. 1993; OEPP 2002). At least 15 of these wetlands are of international importance and 15 are of priority national importance, according to criteria of high fish and bird diversity (OEPP 2002). Examples of four of these sites are shown in Table 3.2.4.

Viet Nam

The Mekong River Delta stretches from Kampong Cham in Cambodia through Viet Nam to its discharge in the South China Sea. About 70 per cent of the Mekong Delta formed by sediment deposition in the last 6000 years lies within Viet Nam and is home to 17 million people, who depend upon it for their livelihoods. Each year flood waters inundate 3.9 million hectares. Lower reaches of the mainstreams; estuaries and floodplains (including seasonally inundated grasslands); as well as mangrove and *Melaleuca* forest and mudflats are the most important wetland ecosystems. The fauna of the delta include 23 species of mammals, 386 species and subspecies of birds, 35 species of reptiles and six species of amphibians (Thinh 2003). At least 460 species of fish are known from the delta (Vidthayanon 2008).

The Mekong Delta contains about 20 important wetlands, four of which are shown below (Table 3.2.5).

Another four or five important wetland sites are found in the headwaters of the Sekong, Sesan and Srepok rivers in Viet Nam.

Table 3.2.5 Examples of important wetland sites in Viet Nam

Name of site	Importance	Area (ha)	Province	Types	Key biodiversity information
Tram Chim National Park	National park	7588	Dong Thap	*Melaleuca* swamp, seasonally inundated grassland, lotus swamp	Created in 1998 to protect several rare birds, especially the sarus crane (*Grus antigone*) and typical ecosystems found in the Plain of Reeds; important site for conservation of wild rice (*Oryza rufipogon*)
U Minh Thuong National Park	National park	8154	Kien Giang	Peat land, *Melaleuca* forest, swamp, grassland and open water, waterways	Supports one of the largest breeding colonies of water birds in the Mekong Delta; confirmed 187 bird species including the globally threatened spot-billed pelican and lesser adjutant; harbours a diversity of flora, including 226 rare species of wild vascular plants
U Minh Ha National Park	National park	8286	Ca Mau	Peat land, *Melaleuca* forest, swamp, grassland and open water, water ways	High abundance and species richness of water birds, including small bitterns (*Ixobrychus* and *Dupetor*), bronze-winged jacana (*Metopidius indicus*) and purple swamp hen (*Porphyrio porphyrio*); habitat for endangered mammals such as the hairy-nosed otter (*Lutra sumatrana*) and the Asian small-clawed otter (*Aonyx cinerea*)
Mui Ca Mau National Park	National park UNESCO-Biosphere Reserve	41,862	Ca Mau	Sub-tidal and tidal coastal wetlands: mud flat, mangrove swamp, shrimp ponds	Excellent habitat for migrating shore birds, 93 species of birds from 38 families listed, including seven species listed in the IUCN Red Book

Source: Thinh 2003

Wetland and national park

Mui Ca Mau National Park in Ca Mau has a total area of about 41,862 ha, including 15,262 ha inland and 26,600 ha on the coast. It was established in 2003 and recognised as a UNESCO Biosphere Reserve in May 2009.

The wetland types in the national park include sub-tidal and tidal mangrove and mud flats. The mangrove vegetation is dominated by *Avicennia alba* near the sea and *Rhizophora apiculata* further inland. Extensive mudflats are also being colonised naturally by mangrove. Each year, the submerged flora on the western beach of the park extends nearly 100 metres into the sea, creating an ideal environment for the reproduction and development of shrimp, fish and molluscs.

Dao Huy Giap

Long-tailed macaque (*Macaca fascicularis*) in Mui Ca Mau National Park - human activities are placing pressure on mammal populations in the park.

Many faunal species have disappeared or their numbers have been greatly reduced. Wild pig, otter, fishing cat, monkey, deer, and other species have occurred in the area but, with high pressure from human activities, it is unlikely that viable populations of these species still survive (Giap et al. 2007). The park still has a rich fauna, with 26 species of animals belonging to 11 families recorded there. However, abundance of mammals is low.

The complex of mudflats and area of open generating mangrove provides excellent habitat for migrating shorebirds, herons, egrets, gulls and terns, with 93 species of birds from 38 families listed, including seven species listed in the IUCN Red Book. The mangroves at Mui Ca Mau perform an important role in coastal protection. The park also has high potential for recreation, ecotourism, conservation education and scientific research (Giap et al. 2007)

Wetland resources and biodiversity

The Mekong River wetlands provide unique habitats for both aquatic and terrestrial plants and animals. Some wetland species, such as mammals and birds, may spend only part of their lives in wetland habitats whereas others, such as amphibians and fish, may depend entirely on wetlands for their survival. Important species associated with wetlands are those that are seen as a resource, either because they are rare and therefore have a special conservation value (Table 3.2.6) or because they are seen as an important resource for people's livelihoods.

Table 3.2.6 List of threatened Mekong wetland fauna

No.	Scientific name	Common name	Global threat status						
			Critically Endangered	Endangered	Vulnerable	Cambodia	Lao P.D.R.	Thailand	Viet Nam
	MAMMALS		1	4	2	7	7	6	6
1	*Lutrogale perspicillata*	Smooth-coated otter			VU	x	x	x	x
2	*Lutra sumatrana*	Hairy-nosed otter		EN		x	x	x	x
3	*Aonyx cinerea*	Small-clawed otter			VU	x	x	x	x
4	*Prionailurus viverrinus*	Fishing cat		EN		x	x	x	x
5	*Orcaella brevirostris*	Irrawaddy dolphin (Mekong population)	CR			x	x		
6	*Axis porcinus*	Hog deer		EN		x	x	x	x
7	*Rucervus eldii*	Eld's deer		EN		x	x	x	x
	BIRDS		3	6	10	13	9	16	16
8	*Acrocephalus tangorum*	Manchurian reed-warbler			VU	x	x	x	x
9	*Anas formosa*	Baikal teal			VU			x	
10	*Aythya baeri*	Baer's pochard		EN				x	x
11	*Cairina scutulata*	White-winged duck		EN		x	x	x	x
12	*Egretta eulophotes*	Chinese egret			VU			x	x
13	*Grus antigone*	Sarus crane			VU	x	x		x
14	*Grus nigricollis*	Black-necked crane			VU				
15	*Haliaeetus leucoryphus*	Pallas's fish-eagle			VU	x		x	
16	*Heliopais personata*	Masked finfoot			VU	x	x	x	x
17	*Houbaropsis bengalensis*	Bengal florican	CR			x			x
18	*Leptoptilos dubius*	Greater adjutant		EN		x	x	x	x
19	*Leptoptilos javanicus*	Lesser adjutant			VU	x	x	x	x
20	*Mergus squamatus*	Scaly-sided merganser		EN				x	x
21	*Mycteria cinerea*	Milky stork			VU	x		x	x
22	*Platalea minor*	Black-faced spoonbill		EN				x	x
23	*Pseudibis davisoni*	White-shouldered ibis	CR			x	x	x	x
24	*Rynchops albicollis*	Indian skimmer			VU	x	x	x	x
25	*Pseudibis gigantea*	Giant ibis	CR			x	x	x	x
26	*Tringa guttifer*	Spotted greenshank		EN		x		x	x
	REPTILES		5	4	5	10	10	11	13
27	*Amyda cartilaginea*	Asiatic softshell turtle			VU	x	x	x	x
28	*Batagur baska*	Mangrove terrapin	CR			x		x	x
29	*Chitra chitra*	Southeast Asian striped softshell turtle	CR					x	
30	*Crocodylus siamensis*	Siamese crocodile	CR			x	x	x	x
31	*Cuora amboinensis*	Asian box turtle			VU	x		x	x
32	*Cuora trifasciata*	Chinese three-striped box turtle	CR				x		x
33	*Cuora galbinifrons*	Indochinese box turtle	CR			x	x		x
34	*Heosemys grandis*	Giant Asian pond turtle			VU	x	x	x	x
35	*Hieremys annandalii*	Yellow-headed temple turtle		EN		x	x	x	x
36	*Malayemys subtrijuga*	Malayan snail-eating turtle			VU	x	x	x	x
37	*Pelochelys cantorii*	Giant softshell turtle		EN		x	x	x	x
38	*Platysternon megacephalum*	Big-headed turtle		EN			x	x	x
39	*Sacalia quadriocellata*	Four-eyed turtle		EN			x		x
40	*Siebenrockiella crassicollis*	Black marsh turtle			VU	x		x	x
	AMPHIBIANS		0	1	10	3	6	0	9
41	*Bombina microdeladigitora*	Small-webbed bell toad			VU				x
42	*Leptobrachium banae*	Red-legged leaflitter toad			VU	x	x		x
43	*Limnonectes toumanoffi*	Toumanoff's wart frog			VU	x			x
44	*Nanorana liui*				VU				
45	*IngeranaLiui*				VU				
46	*Quasipaa spinosa*	Giant spiny frog			VU		x		x
47	*Nanorana yunnanensis*	Yunnan spiny frog		EN			x		x
48	*Odorrana jingdongensis*				VU		x		x
49	*Rhacophorus annamensis*	Annam flying frog			VU	x			x
50	*Kurixalus baliogaster*				VU		x		x
51	*Rhacophorus exechopygus*				VU		x		x
	FISH		5	6	2	9	8	13	6
52	*Yasuhikotakia sidthimunki*	Dwarf botia	CR				x	x	
53	*Chela caeruleostigmata*	Leaping barb	CR			x		x	
54	*Dasyatis laosensis*	Mekong freshwater stingray		EN		x	x	x	x
55	*Himantura chaophraya*	Giant freshwater stingray			VU			x	
56	*Himantura oxyrhynchus*	Marbled freshwater stingray		EN		x	x	x	
57	*Himantura signifer*	White-edged freshwater whipray		EN			x	x	
58	*Pangasianodon gigas*	Mekong giant catfish	CR			x	x	x	x
59	*Pristis microdon*	Freshwater sawfish	CR			x		x	
60	*Pristis zijsron*	Narrowsnout sawfish	CR			x		x	x
61	*Probarbus jullieni*	Jullien's golden carp		EN		x	x	x	x
62	*Puntius speleops*				VU			x	
63	*Scleropages formosus*	Asian arowana		EN		x	x	x	x
64	*Tenualosa thibaudeaui*	Laotian shad		EN		x	x	x	x
	Total		14	21	29	42	40	46	50

Source: modified from WWF and IUCN Red Book.

Mammals

There is little information about the mammals associated with wetlands in the LMB although it is known that populations are kept low by heavy hunting pressure (Bezuijen et al. 2008). Wildlife is seen as a culinary delicacy as well as a source of income and populations of all large species of open habitats have declined as a result (Birdlife International 2003). As many as 70 mammal species are endemic to the Mekong Basin (Thompson 2008). In many of the remote habitats of the basin, pockets of unique biodiversity have evolved and survived in total isolation, reliant on the continued existence of their local habitat.

As a result of extensive habitat degradation and high exploitation, a number of mammal species within the basin are considered rare (Table 3.2.6). One terrestrial mammal closely associated with the river, the fishing cat (*Prionailurus viverrinus*), is considered globally endangered due to its dependence on wetlands, which are increasingly being settled and converted for agriculture, and also due to human overexploitation of local fish stocks.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The fishing cat (*Prionailurus viverrinus*), is considered globally endangered due to its dependence on wetlands and also due to human overexploitation of local fish stocks.

The basin is home to three species of otter of special interest – the hairy-nosed otter (*Lutra sumatrana*), the smooth-coated otter (*Lutrogale perspicillata*) and the oriental small-clawed otter (*Aonyx cinerea*), of which the first species is considered as endangered to extinction and the latter two species as vulnerable. The first two species have been found in the Tonle Sap Great Lake, which may represent their major global stronghold. All otter species are under heavy threat by the local demand for skins and for use in traditional medicine (Campbell et al. 2006). Other mammals reported in flooded forests near Tonle Sap include flying-foxes (*Pteropus* sp.) and three species of primate; the slow loris (*Nycticebus coucang*), the long-tailed macaque (*Macaca fascicularis*) and the silvered leaf monkey (*Semnopithecus cristatus*) (Campbell et al. 2006). The Mekong stretches in northern Cambodia may be globally significant for the conservation of at least three mammal species; hog deer (*Axis porcinus*), silvered leaf monkey and otters (Bezuijen et al. 2008). The most important habitat for large mammals is the mosaic of tall grass formations on floodplains (Bezuijen et al. 2008).


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The smooth-coated otter (*Lutrogale perspicillata*) is under heavy threat due to local demand for skins and use in traditional medicine.

The deep pools of the Mekong River on the border between Cambodia and Lao PDR shelter a small population of Mekong Irrawaddy dolphins (see box on p.66). Globally, IUCN lists this species as vulnerable, but reports have assessed the population in the Mekong River as critically endangered because of its small population size (Dove 2009).

Birds

Despite the high appreciation of birds in many Asian cultures, the natural environments in which birds live tend to be accorded far less value, and many important bird habitats have been degraded, followed by a reduction in the bird population and even extinction of some species from the region.

Lao PDR has a rich and diverse avifauna. Most of the bird species whose numbers have declined seriously in Lao PDR over the past 50 years are wetland birds (MRC 2003). The decline has been particularly noticeable in species that rely on sandbars and large rivers as breeding or feeding habitat (Birdlife International 2003). For example, the plain martin (*Riparia paludicola*), which has declined significantly in Lao PDR and Thailand, nests in burrows on sandbars, a habit probably shared with the now extinct white-eyed river martin (*Pseudochelidon sirintarae*) (MRC 2003). As well as degradation and fragmentation of habitats, birds in Lao PDR are threatened by subsistence egg collection, hunting and trade. Guns, slingshots and a wide array of ground snares and nets are used to hunt most birds, which are sold for food, pets and medicine (Birdlife International 2003).

The plains of the lower Mekong, including southern Lao PDR, still retain some areas of near primary habitats for water birds, with mosaics of open deciduous dipterocarp forests, seasonally inundated wetlands and grasslands and riverine habitats. Most notably, the plains of northern and eastern Cambodia are the last stronghold for giant ibis and breeding grounds for white-shouldered ibis and sarus crane (BirdLife International 2003; Bezuijen et. al. 2008; Wright et al. 2009). The area along the Mekong River is probably also critical for the conservation of the Mekong wagtail (*Motacilla samveasnae*) and may support the largest Indochinese populations of river tern (*Sterna aurantia*), woolly-necked stork (*Ciconia episcopus*) and pied kingfisher (*Ceryle rudis*), as well as the only known breeding colonies of plain martin in Cambodia. The most important habitats for birds are the well-vegetated areas of the Mekong channel, particularly those areas forming a mosaic of seasonally exposed sand, grass, shrub and tree patches (Bezuijen et al. 2008).


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The Mekong plains in Cambodia are the last stronghold for critically endangered giant ibis (*Pseudibis gigantea*).

Further south, the Tonle Sap Great Lake is one of the most important areas for bird conservation in the region and has long been understood to be extremely important for gregarious large water birds, particularly storks, pelicans, ibises and cormorants. Seventeen globally threatened or near threatened species occur regularly around the Tonle Sap Great Lake (Campbell et al. 2006). The swamp forests around the lake support globally significant breeding populations of spot-billed pelican, lesser adjutant and greater adjutant. The seasonally inundated grasslands around the lake are probably also the global stronghold for Bengal florican (*Houbaropsis bengalensis*). In 2006, the Government of Cambodia set aside more than 258 km^2 of grassland to protect this habitat from being converted to rice farms (BirdLife International 2003; ScienceDaily 2006). About 10–20 pairs of milky storks (*Mycteria cinerea*) are also thought to inhabit the lake.

Grasslands in the Mekong floodplain and delta support several hundred pairs of sarus crane. Several threatened bird species are also found in forests and associated


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The seasonally inundated grasslands around the Tonle Sap Great Lake is an important area for the critically endangered Bengal florican (*Houbaropsis bengalensis*).

wetlands, such as white-winged duck, masked finfoot (*Heliopais personata*), green peafowl (*Pavo muticus*), and Manchurian reed-warbler (*Acrocephalus tangorum*) (BirdLife International 2003). These ecosystems also harbour important populations of white-rumped (*Gyps bengalensis*) and slender-billed vultures (*Gyps indicus*), both critically endangered species. One of the only known slender-billed vulture nesting areas in the world was found in 2006 just east of the Mekong River in Cambodia's Stung Treng province (ScienceDaily 2007).

Although the Mekong and its tributaries still support some of the few remaining examples of near-intact riverine habitats and bird communities in Southeast Asia, wetland bird habitats are being increasingly used for human settlements which bring with them regular motorised boat traffic. Proposed hydropower schemes in the Mekong catchment threaten river flow rates and seasonal water levels, which may also affect the distribution of water birds. The seasonally inundated grasslands in the Mekong Delta regions of Cambodia and Viet Nam, for example, are extremely important habitats for sarus crane, Bengal florican and many other water birds. Wetlands and grasslands in this region are also threatened by the large-scale intensification of agriculture. In many places, temporary farming is practised in the dry season along margins of rivers and wetlands, reducing habitat for large waterbirds (BirdLife International 2003).

Hunting and egg collection are widespread in the Mekong region, where water birds are poisoned, shot, or caught on hooked lines. Until the recent establishment of a conservation area, the sarus cranes at Ang Tropeang Thmor were hunted for food, or captured for trade to Thailand (BirdLife International 2003). In the dry season, the problem intensifies as permanent wetlands attract concentrations of water birds that are especially susceptible to intense hunting pressure.


Joe Garrison

These snakes are raised in concrete pens by the Mekong near Vinh Long on the delta.

Reptiles

The Mekong Basin is home to some of the world's most spectacular and threatened amphibians and reptiles. Sophisticated hunting and trading practices have destroyed local populations and removed species from large areas of the Mekong Basin (Bezuijen et. al. 2008). Reptiles comprise the largest portion of all animals found in trade in Viet Nam and the regional trade in turtles has reached alarming rates (Stuart 2004; Stuart and Platt 2004).

The largest of the reptiles in the basin are two species of crocodile, the Siamese crocodile (*Crocodylus siamensis*), which is listed as critically endangered, and the estuarine crocodile (*Crocodylus porosus*). Wild crocodiles are now restricted to inaccessible swamps and river stretches in remoter parts of the basin. Large wild populations of the Siamese crocodile have a stronghold in the rivers of the Cardamom Mountains to the south of the Tonle Sap Great Lake (Platt et al. 2006). The species still occur in the lake, particularly in the Prek Toal Core area but their numbers are greatly reduced through capture for farming and trade (Campbell et al. 2006). Remnant populations of questionable viability have also been reported to persist at some places in Thailand, Viet Nam and Lao PDR (Bezuijen et al. 2006; Platt el al. 2006). Although their population is almost depleted in the wild, Siamese crocodiles are farmed extensively in Thailand and Cambodia. A few estuarine crocodiles may still live in the Mekong Delta, where a maximum of 100 were estimated in 1994, however more recent reports from U Minh Thuong Nature Reserve in the delta suggest it is unlikely that any wild estuarine crocodiles remain due to heavy hunting pressure (Stuart et al. 2002).

A number of aquatic or semi-aquatic turtles, snakes and lizards occur in the basin, many of which are hunted for subsistence or sold for food or medicine in local markets (Bezuijen et al. 2008). In 2005 *Enhydris chanardi* was added to the list of the 22 other Oriental-Australasian species of aquatic snakes in the region (Murphy and Voris 2005). The white-lipped keelback (*Amphiesma leucomystax*) was found in several locations in 2007 (David et al. 2007) including Viet Nam's green corridor, an area renowned for its high biodiversity. The species tends to live by streams where it catches frogs and other small animals.

Seven species of Homalopsine water snakes have been documented in the Tonle Sap Great Lake based on observations of catches and trade (Stuart et al. 2000). Market data gathered at the peak of the wet season during 1999 and 2000 estimated that more than 8500 water snakes were harvested and sold per day, primarily for crocodile and human food. In U Minh Thuong National Park in the Viet Nam delta, a total of 21 reptile species (about 1900 reptiles) were found in reptile trade shops, of which 16 species were seen harvested by local people. The harvesting practices in and around U Minh Thuong are seen as unsustainable and as a threat to the survival of some species (Stuart 2004).

Other reptiles commonly hunted and consumed in the region include the water monitor (*Varanus salvator*), Bengal monitor (*V. bengalensis*), water dragon (*Physignathis* spp), reticulated python (*Python reticulatus*) and the Tonle Sap water snake (*Enhydris longicauda*) (MRC 2003). At least 46 lizards join the ranks of the Greater Mekong's known reptile species. In 2007, four new gekko species were recorded in forests in southern Viet Nam (Grismer and Van 2007).

Four new turtle species have been recorded from the Greater Mekong in the last 10 years (Thompson 2008). Stuart and Platt (2004) recorded 19 species of freshwater turtles, tortoises, and marine turtles collected in Lao PDR, Cambodia, and Viet Nam. Five species of turtle have been confirmed to occur in and around the Tonle Sap Great Lake (Stuart and Platt 2004). The Mekong River in northern Cambodia is seen as globally significant for the Cantor´s giant softshell turtle (*Pelochelys cantorii*) and may support the largest remaining breeding populations in the Mekong Basin (Bezuijen et al. 2008).

Exploitation of chelonians for food and medicinal markets is widespread in Cambodia, Lao PDR and Viet Nam (Stuart and Platt 2004). The average quantity of turtles collected in a village in southern Lao PDR was equivalent to 21 kg per household per year (Mollot et al. 2003). Although turtles and tortoises are locally consumed and domestically traded in Lao PDR, Cambodia, and Viet Nam, most are exported to markets in southern China. The volume of this trade is believed to pose a serious threat to the continued viability of wild chelonian populations throughout Southeast Asia (Stuart and Platt 2004).

Amphibians

An astonishing 91 new species of amphibian have been described within the Greater Mekong region since 1997 (Thompson 2008). In Cambodia 30 species of frogs were documented (Stuart et al. 2006) including two new species and 11 species reported for the first time in the country. The frog fauna of Lao PDR is poorly known relative to that of neighbouring China, Thailand, and Viet Nam, but scientists have still been able to identify at least 46 species (Stuart 2005).

Frogs and other invertebrates, such as snails and crabs, are key sources of protein for rural families during the peak of the dry season when fish and other aquatic animals are scarce (Meusch et al. 2003; Mollot et al. 2003, Table 3.27). Large frogs, such as *Hoplobatrachus rugulosa*, are hunted for domestic consumption and local trade (Calridge 1996).

Contribution of other aquatic animals to people's livelihoods

Frogs are most abundant and easily caught in large quantities at the beginning of the rainy season in May and June. In southern Lao PDR the average catch has been reported to be 3–5 kg per night (MRC 2003). The average rainy season catch around Beoung Thom Lake in Cambodia is 20–30 kg per family per year or 3.6 tonnes from four villages surveyed. Similar figures (27 kg per family per year) were found for a village in southern Lao PDR (Mollot et al. 2003).

Tadpoles are usually caught in the middle of the rainy season (July and August). They are widely consumed in northeast Thailand and are considered a delicacy in the cities. One kilogram sells for two to three times the price of fish. The increased use of pesticides and fertiliser threatens the viability of frogs and other amphibians. However, until comprehensive studies are undertaken, threats and their effects will not be completely understood.

Table 3.2.7 Inland consumption of fish and other aquatic animals (OAA)

Country	Cambodia	Lao PDR	Lao PDR	Thailand	Viet Nam
Location	Svay Rieng	North	Champasak	NE Thailand	Tra Vinh
Fresh inland fish consumption	25.7	8.9	25.6	21.3	22.7
Reported OAA consumption	5.17	4.93	10.29	7.80	7.61
Corrected OAA consumption	8.67	4.93	10.29	8.49	7.61
Ratio of corrected OAA/ fresh fish consumption	0.34	0.55	0.40	0.40	0.36
Frogs and tadpoles	2.74		5.57	4.80	
Crabs	0.13		0.23	0.23*	
Shrimps	1.09		0.46	0.46*	4.72
Molluscs	3.50*		4.01	3.00	
Insects	0.01				
Birds	0.89				
Snakes	0.19				
Other not specified	0.13				

All values are in kg/head/year (Hortle 2007); * values were completed based on other studies, corrected OAA consumption includes these values.

Fish

The Mekong Basin has a diverse fish fauna, with about 850 fish species recorded from the entire basin in fresh and estuarine waters, although more coastal species might at times enter the river system, and new species are still being discovered (Hortle 2009a). Although all fish are caught at times, only 50–100 species are common in the fishery, which is predominantly based along fertile lowland floodplains where most people live.

Each new scientific survey of the river and its tributaries identifies new, often endemic, fish species. The striking feature of the Mekong's fish fauna is the great diversity of fish families; 65 families have been listed for the Cambodian section of the Mekong (Rainboth 1996) and 50 for Lao PDR (Kottelat 2001). The fish fauna of the Mekong is dominated by the family Cyprinidae, with 54 cyprinid genera from the Cambodian Mekong (Rainboth 1996) and 75 cyprinid genera and 193 species for Lao PDR (Kottelat 2001).

The role of flooding as a trigger for spawning, the importance of access to flooded areas and the need for fish to migrate between widely separated habitats indicates the importance of preserving the natural variations in river hydrology, both within and between years, for sustaining the high fish diversity (Poulsen 2004).

Two obvious changes have occurred in the fish fauna of the basin over recent times. One has been the introduction of a number of species either from other river basins in the region or from other regions. More than 20 introduced species are now established in the Mekong. Several of the species from outside the region are ones that are known to have become pest species when introduced elsewhere. These include Nile tilapia (*Oreochromis niloticus*) and mosquito fish (*Gambusia affinis*).

Secondly, and of greater concern, has been the apparent decline in large fish in the basin. A number of giant fish species, including the Mekong giant catfish (*Pangasianodon gigas*), the giant catfish (*Pangasius sanitwongsei*), the thicklip barb (*Probarbus labeamajor*) and the giant barb (*Catlocarpio siamensis*), are now all rare and some are considered endangered (Poulsen et al. 2004) (see section 3.3).

The Mekong giant catfish, which is endemic to the Mekong River, is only found in the mainstream of the LMB. It migrates huge distances to spawn and used to be relatively common along the northern Thai–Lao PDR border, but is now extremely rare in this area. The giant catfish occurs throughout the LMB, possibly extending into China and Myanmar. It is becoming increasingly rare and is listed on the IUCN list of endangered species as 'data deficient'. The thicklip barb and. Julien's golden carp (*Probarbus julieni*) occur throughout the LMB and may also be found in Myanmar and China. The former is endemic to the Mekong. The two species tend to disappear from areas affected by impoundments as they are generally intolerant of habitat alterations. Both species are included on the IUCN list of endangered species, *P. jullieni* as endangered, and *P. labeamajor* as 'data deficient' (Poulsen et al. 2004).

Fishing has contributed greatly to the decline of several large species through unsustainable practices and there is a need for improved regulations and enforcement (Poulsen et al. 2004). Threats to many of the giant migratory fish species in the Mekong include infrastructure development, such as dams that alter the natural flow of the river and block migration routes (see box on p. 97). Without the ability to move up and down rivers, the fish have fewer opportunities to breed. Critical habitats during the dry season are deep river pools, which may be affected by changes in river flow.

Invertebrates

Over the past decade thousands of new invertebrate species have been discovered, representing the largest group of new species finds in the basin (Thompson 2008).

Some groups of aquatic invertebrates show high levels of species richness within the basin. For example, within the molluscs (snails and mussels), the stenothyrid and pomatiopsid snails (gastropods) include more than 120 species, with at least 111 endemic to the river. This is the greatest known biodiversity of snails in any freshwater system in the world (MRC 2003).

People in the basin rely on aquatic invertebrates for food security and livelihoods, particularly during dry seasons and drought years, when fish may be less available (Meusch et al. 2003; Mollot et al. 2003; Balzer et al. 2005; Halwart 2008, Table 3.2.7).

At least six types of molluscs are commonly consumed in Lao PDR and other riparian countries (Calridge 1996). In southern Lao PDR, Cambodia and northeast Thailand the annual consumption of molluscs has been estimated at 3.5, 4 and 3 kg per head per year, respectively, comprising (next to frogs) the second largest proportion of non-fish aquatic animals consumed by people in the region.

Snails are abundant in the dry season in shallow water around the edges of lakes or rice fields, and at the beginning of the rainy season when the fields are filled with new water. Households in southern Lao PDR collected, on average, 49 kg of snails a year (Mollot et al. 2003) and households around That Luang Marsh near Vientiane, 175 kg of snails per household per year (Gerrard 2004). The excess catch is sold in local markets, where smaller snails (*hoi jeub*) are commonly seen. Larger snails (*hoi pang* and *hoi kong*), which are more valuable, are sold to middle men or in the district market. In Cambodia, the harvest of *leah* (Bivalvia) from natural lakes is very important for consumption and the local economy. The catch takes place when the water recedes (from November to April). Small freshwater shrimps and crabs are another food source (Meusch et al. 2003; Mollot et al. 2003; Hortle 2007), the shrimps also caught in receding waters and crabs, belonging to the genus *Somanniathelphusa*, dug out of rice fields at the end of the dry season. However, the crabs are not a popular food and are only eaten when other food is scarce (Balzer et al. 2005).

Insects are an important source of supplementary protein throughout the year, especially in the early dry season (Mollot et al. 2003; Balzer et al. 2005; Halwart 2008). An annual catch per household of 62 kg of aquatic insects and 32 kg of grasshoppers has been reported for Vientiane's That Luang Marsh (Gerrard 2004). At least 14 types of water insects are consumed in northeast Thailand and other parts of the LMB (Calridge 1996). The most common are giant water bugs (*Belostomatidae*) (known as *mangda* in Lao), beetles (Dystiscidae), dragonfly larvae (*mang nio*, or *mang rangum*) and black flies (*Diptera limuliidae*). In Thailand and Viet Nam the essence of giant water bugs is extracted and used to flavour other dishes. The giant water bug is also used as traditional medicine; mixed with alcohol it is given to women after birth (Balzer et al. 2005). Due to high levels of pesticides and fertilisers used in agriculture in Thailand giant water bug catches have greatly declined and so they are imported from Cambodia, where they are still common (Balzer et al. 2005).

Plant diversity

Plant diversity in the Mekong Basin has not been accurately assessed, however total vascular plant diversity may be as high as 20,000 species, with conservative estimates suggesting that about 50 per cent of flowering and seed-bearing plants are endemic to the region.

Over the past 10 years, 519 plants have been discovered in the Mekong Basin and more are likely to be found in coming years. Some scientists consider that Lao PDR, with as many as 11,000 flowering plant species, is still one of the most botanically unexplored countries in Asia (Thompson 2008).

Wetland plants play an important role in people's livelihoods with a wide variety of uses, including as food, medicine, firewood, construction material, tools and handicrafts.

FOOD

Studies on the availability and use of aquatic plants in Cambodia, China, Lao PDR and Viet Nam documented 37 species harvested by local residents for food and to sell at local markets (Halwart 2008). Each year, families living near That Luang Marsh collect an average 300 kg of aquatic vegetation per household, with a total value of US$87 (Gerrard 2004). These plants give fishers and farmers an almost year-round supply of fresh vegetables.

Popular vegetables are the lotus – tuber, stem, and seeds, water hyacinth flowers, riang leaves, and morning glory – the most frequently consumed aquatic vegetable. Fruits of native trees such as *Hymenocallis wallichii, Popowia diospyrifolia*, a 'soursop' and persimmon (*Diospyros mollis*) also supplement the diet and some introduced trees, such as Schleichera, the jujube plant (Zizyphus) and tamarind (Tamarindus) provide marketable fruits (McDonald 2005).

In seasonally flooded areas along the Songkhram River (a tributary of the Mekong in northeast Thailand) and its tributaries, tonnes of fresh and canned bamboo are sold in both local and regional markets each year. Bamboo shoots are also commonly collected in southern Lao PDR, with an average harvest of 240 kg per household per year. As well, each year families collect an average of 100 kg mushrooms, 160 kg *Yang* oil and 460 kg *Yang Bong* (*Nothaphoebe umbellif-lora*) (Mollot et al. 2003)

Mekong seaweed or *kai* which grows on exposed rock faces in the oxygenated waters of the Mekong River in northern Lao PDR, is considered a delicacy by local people who cultivate and harvest it by the tonne. The sale of this produce is often the primary source of income for many local families (McDonald 2005).

The Mekong Delta contains large stands of the mangrove or nipha palm (*Nypa fruticans*), which can be tapped to collect a sweet sap. In Thailand the sap is used to produce alcohol for sweet desserts. Young nipah palm shoots can also be eaten and the petals of the flower are brewed to make an aromatic tea. Another palm tree associated with wetlands is the freshwater sago palm, which can be used to produce starch from the trunk.

MEDICINE

Medicinal plants are important in the LMB, both for trade and local consumption. Local people of the region rely on medicinal plants for many of their ailments. Medicinal plants are not only popular in rural areas, where medical services are lacking, but also in major cities. A total of 61 medicinal plants were reported being sold at the Talat Sao 'Morning market' in Vientiane (Delang 2007). They are mostly used to cure fever or pain in different parts of the body, but some can have more specific uses. In 2009, 55 plant species, commonly used during pregnancy, childbirth and postpartum healthcare were identified among the Saek, Brou and Kry ethnic groups inhabiting the upper Nam Theun, Nam Noi and Nam Pheo in Lao PDR (De Boer and Lamxay 2009).

Thirty-five species of wetland plants used for medicinal purposes were recorded in the community of Prek Sramaoch on Tonle Sap Great Lake (Mcdonald and Veasna 1997). Some of the medicines include: *Diospryos* spp., which is taken to eliminate parasites; *Heliotropium indicum, Ludwigia dscendens, Quisqualia indica*, used to reduce fevers; the anti-inflammatory agents *Stenocaulon kleninii* and *euphoorb; Gmelina asuatica* and *Dasymaschalon lomentaceum*, which are used for various pregnancy and post-partum conditions; and *Bridelia cambodiana* and *Combretum trifoliatum*, which are given to newborn infants. *Porping gny* and *Porping chmol* (Khmer names) are reported to be used in Beoung Thom communities to treat pesticide poisoning. Oils from *Melaleuca* leaves and stems can be used for medicine, insect repellent and soap.

The wetland shrubs and trees including various mangrove species and *Melaleuca* provide firewood and building material (see section 4.2).

Wetland functions and values

The wetlands of the Mekong Basin provide a vast array of goods and services to people in the region. Isolated communities with limited access to markets and roads depend on locally available flora and fauna as their primary source of meat, fruits, vegetables, fodder for livestock, medicines, and construction materials. The services provided by wetlands include, for example, habitats for fish and wildlife, protection against erosion, storms and flooding, retention of nutrients and sediments, and purification and replenishment of groundwater. In both Vientiane and Phnom Penh, for example, urban wetlands play a central role in purifying waste water from domestic and industrial use.

Tourist operators in the LMB are increasingly recognising the importance of the unique biodiversity and cultural values of wetlands (see section 4.8). Both goods and services ultimately depend on a healthy and high diversity of wetland types and species.

Ecosystem services can be expressed in monetary terms as values to people. For example, a value can be determined by the revenue generated from the sale of fish that depends on the wetland, by the tourist dollars associated with wetland bird-watching, or the cost of building and running a waste-water treatment plant. However, determining the value of individual wetlands is difficult as each one is different and delivers functions of different value to different groups of people. Impacts on wetland functions can eliminate or diminish their value. Policy and decision-making processes should try to account for wetland values in development planning.

Total economic value of wetlands

Wetland values fall into the following categories:

1. Direct use values (DUV) are benefits derived from direct use or interaction with environmental resources and services. They involve commercial, subsistence, leisure, or other activities associated with a resource and may include:
   - agricultural production
   - non-fish aquatic goods such as plants, insects, and frogs
   - fish through capture fisheries and aquaculture within a wetland system
   - tourism revenue generated from visitors to the wetland area
2. Indirect use values (IUV) relate to the indirect support and protection provided to economic activity and property by the ecosystem's natural functions or regulatory 'environmental' services and may include:
   - flood mitigation
   - waste-water treatment
   - water storage
   - disaster protection
   - climate regulation
3. Option values (OV) are the premiums placed on possible future uses and applications of the environment and may include:
   - future patents
   - future leisure and tourism
4. Non-use values (NUV) or existence values are the intrinsic significance of resources and ecosystems that are derived neither from current direct or indirect use of the environment and may include:
   - cultural significance
   - biodiversity value
   - aesthetic value
5. Total economic value (TEV) is the sum of all of the above listed values and can be expressed as: TEV = DUV+IUV+OV+NUV

One of the most important direct uses of wetlands is agricultural production, especially rice, cultivated in irrigated and seasonally flooded areas. Fisheries is another direct use of significant importance throughout the region, most notably in Cambodia, where as much as 75 per cent of animal protein in a typical diet comes from fish. Non-timber forest products and non-fish aquatic products are other important direct uses, which although low in terms of net values per ha compared to commercial crops, are a critical component of rural livelihoods. As well as supplementing their food supply, the wetland harvest ensures food security in years when the rice crop fails (Meusch et al. 2003; Mollot et al. 2003). Fish and other aquatic animals, which are considered a common property resource, provide most of the protein in people's diets (Hortle 2007). However, many of these resources are never sent to the market so estimated net values may not adequately reflect their importance to the rural poor.

That Luang Marsh – an urban wetland in Vientiane

The That Luang Marsh is the largest remaining wetland area in Vientiane. It covers 2000 ha and provides aquatic resources to more than 3000 households, as well as valuable ecosystem services to Vientiane, such as waste water purification and flood protection. The marsh has been valued at about US$5 million annually, for both direct and indirect uses (Gerrard 2004). The wetland system consists of freshwater marshes, seasonally flooded grasslands and shrublands. It collects water that drains from Vientiane and surrounding areas, including the Hong Ke stream (which is fed by the city's drainage canals). Water flows out of the wetland via the Houay Mak Hiao River into the Mekong River, about 64 km south east of the city (IUCN 2003).

The marsh, which was mainly forested in the 1970s, is going through major changes because of expansion of agriculture and urban areas (Gerrard 2004). However, despite its altered state, it continues to provide a number of economically important goods and services to Vientiane's urban dwellers. Almost half the population living near the marsh depend on wetland resources in some way for their livelihoods. Rice is cultivated on up to 1000 hectares of the wetland, while vegetable gardens and a number of small, medium and large fish farms are located along its edges.

Fish is the most significant wetland resource contributing to local livelihoods, with other aquatic animals comprising a much smaller portion of household income. The average household collects 175 kg of snails, 17 kg of frogs and 62 kg of aquatic invertebrates per year. Many people also collect aquatic vegetation, such as morning glory (*Impomoea aquatica*), water hyacinth (*Eichhornia* sp.), yellow velvetleaf (*Limnocharis flava*) and lotus (*Nelumbo nucifera*). The total direct benefits of wetland goods from That Luang Marsh comprises 40 per cent of the total economic value of the wetland (Table 3.2.8).

That Luang Marsh also provides a range of indirect ecosystem services that are critical for the functioning of the city and the basic standard of living of the people who live there. Urban flood control, waste-water treatment and sanitation processes rely heavily on the presence of the wetland and its services (JICA 2002). Domestic sewage from a large proportion of Vientiane city is discharged to the marsh by way of several canals. By 2020, Vientiane's population is expected to reach 1,158,000 people, with waste water from 250,000 people expected to enter the marsh along with waste from an anticipated 700 factories.

The value of That Luang Marsh's flood protection and waste-water purification services represents 60 per cent of the total value of the marsh, indicating that the value of the marsh services is probably much larger than the direct value of the goods it provides.

Dao Huy Gap

That Luang market - fish is the most significant wetland resource contributing to local livelihoods..

Table 3.2.8 Annual value of wetland economic benefits from That Luang Marsh

Wetland goods — direct use values	(US$)
Rice cultivation	349,681
Garden cultivation	55,017
Aquaculture production	179,671
Capture fisheries (fish, frogs, snails and aquatic invertebrates)	1,092,095
Other wetland products (wild plants etc)	354,106
Sub total	2,030,570
Wetland services — indirect use values	
Flood protection	2,842,000
Waste-water purification	70,088
Sub total	2,871,000
Total	4,901,570

Source: Gerrard (2004)

MANGROVES

The value of mangroves was brought to the global public's attention following the 2004 Asian tsunami, where they played a vital role in coastal protection. Mangroves are also critical to people's everyday livelihoods by providing habitat for fish and shrimp and resources such as firewood, medicinal plants and construction materials. In a number of studies attempting to estimate the direct values of mangroves (Table 3.2.9), aquaculture provides the greatest value. Other important services include water transport, support to near-shore fisheries, tourism and recreation, sedimentation, water quality maintenance, cultural and biodiversity values (Ha et al. 2003). Overall, the indirect use value of service was found to be slightly larger than the direct use value of goods, but different stakeholder groups appreciated the value of these goods and services differently. Farmers within the protected forest placed more value on direct uses such as aquatic products whereas people outside the area valued protection against storms, floods and erosion the most and shrimp farmers put a high value on water quality maintenance. Provincial officials and urban people put a high value on tourism, recreation and biodiversity.

Table 3.2.9 Economic values of different wetlands in Southeast Asia

Author	Wetland classification	Goods/ services valued	Net value/ha/year (US$)*
Sathirathai 1998	Marine intertidal mangrove	Total economic value	3206–4116
Ha et al. 2003	Marine intertidal mangrove	Total economic value	1790–2340
		Direct use values	820–1070
		Indirect use value	970–1270
Do & Bennett 2005	Marine and estuarine mangroves	Direct use values	375
Emerton et al. 2002	Estuarine intertidal mangroves	Direct use values	344
McKenny et al. 2001	Flooded forest (Kandal province, Cambodia)	Direct use value	162
Gerrard 2004	Freshwater marsh (That Luang Marsh, Vientiane, Lao PDR)	Direct use value	1015
		Indirect use value	1435
		Total economic value	2450
Nhuan et al. 2003	Salt/brackish marsh (Giang-Cau Hai Lagoon, Thua Thien, Hue province, Viet Nam)	Total economic value	2034–2301

Source: MRC (in press) *No currency adjustments have been made for different years

FLOODED FORESTS

Despite their high value to local people and the large extent of flooded forests in the region, few studies have been carried out on the goods and services they provide. The direct use value of flooded forests in Kandal province, Cambodia (Table 3.2.9) is lower than the direct use value found for mangroves, probably due to the lack of high-value aquaculture in these ecosystems.

Many indirect values of flooded forests have not been accounted for adequately. The *Melaleuca* forests of the Mekong Delta, for example, provide flood protection by offsetting the increased volume of flow in the Mekong River during the wet season, help to catch nutrient-rich sediments and decrease the risk of erosion. Like mangroves, they provide rich habitats for fish and other animals for feeding and breeding. These forests also play an important role in maintaining soil and water quality by preventing acidification of topsoil and surface water, filtering groundwater and storing fresh water during the dry season (Day et al. 2005).

FRESH-WATER MARSHES

These important sources of fish, other aquatic species, birds, rats, and vegetation collected for food and handicrafts. They also provide free fodder for grazing animals. Depending on their location they can also provide valuable ecosystem services, including flood control, water purification and water storage. Freshwater marshes in the Mekong Basin have not been a significant focus of study and very little is known about local values.

Like That Luang Marsh, three urban wetlands in Phnom Penh – Boeng Trabek, Koeng Tumpun and Boeng Cheung Ek – absorb large quantities of household waste water, storm water, and industrial effluents each day (Muong 2004). These marshes are used for vegetable production. Most growers produce 5–10 tonnes of water spinach a year, earning US$350–700 per household per year (Khov et al. 2007). This compares favourably with average rural and urban (Phnom Penh) household incomes. However, pollutants in the waste water are cause for concern (Khov et al. 2007).

SALTWATER MARSHES

Very little is known about the value of saltwater marshes in the Mekong Basin. However, one extensive study on selected wetlands in Viet Nam provides an interesting overview of potential coastal wetland values (Nhuan et al. 2003). As with freshwater marshes and mangroves, the high values quoted from this study indicate the importance of saltwater marshes to the region (Table 3.2.9).

Although wetland services, such as flood control and storm buffering, amenity and aesthetics, and biodiversity are very important to people in the region, they are rarely taken into account. For example, a fundamental service that has never been valued is the transfer of nutrients and water by the Mekong River and its tributaries from upland areas. The role of Tonle Sap Great Lake in flood mitigation has never been valued but its loss would affect millions of people.

Tourism is another service which is becoming increasingly important for the region (see section 4.8). In some areas, local people and tourist operators are beginning to realise the benefits of wetlands as tourist destinations. At Thailand's Kuan Khee Sian Ramsar site, for example, tourist services such as restaurants and souvenir shops have surpassed direct extraction of fish and aquatic plants in terms of their importance to poor people's livelihoods (Ratner et al.2004). An increasing number of ecotourism operators are already capitalising on the significant value of the high diversity and culture related to many of the region's wetlands and many countries see wetland areas as prime tourist destinations. Popular wetland sites along the Mekong River include: the 'Ream' National Park and Tonle Sap Biosphere Reserve in Cambodia; Xepian national protected area, Nam Ha protected area and Khone Falls in Lao PDR; and U Minh Ha National Park and Tram Chim National Park in Viet Nam.

A final example of a significant service provided by rivers, lakes and canals in the basin is as a route for water transport which, in some areas, is the only, or at least the most efficient, means of transport available for much of the year (see section 4.6).

Pressures on wetlands in the Lower Mekong Basin

The loss of wetlands in the LMB has been widespread. In the Mekong Delta for example, less than two per cent of the area's original inland wetlands remain. Many of the pressures on wetlands in the delta – population growth, poverty and agriculture and upstream infrastructure development are common threats to wetlands throughout the Mekong Basin.

In the delta vast areas of natural wetlands have been converted to other uses. In recent decades, land development in Thailand for example has accelerated with the construction of many reservoirs for irrigation, flood control and hydropower. The area of wetlands reclaimed for cultivation has increased greatly, combined with intensive, often unsustainable, human use of those small wetlands which remain (Parr et al. 2009).

Deforestation, agriculture, mining, and road construction all increase the amount of silt and sediment in rivers and wetlands. Too much silt can clog up the gills of fish, suffocate freshly laid eggs, affect nursery grounds of juvenile fish and reduce the amount of light penetrating the water – reducing plant survival. Degradation of seasonally inundated forests along the banks, channels and islands of the Mekong mainstream and its tributaries has significant impacts– not least because forest fruits, flowers, leaves, bark and roots are important food items for various species of fish of economic importance that feed in the flooded areas in the rainy season (Baird 2007).

Of all planned developments, Mekong mainstream dams, represent the single largest threat to the wetlands, fisheries and local livelihoods of the Lower Mekong. Dams and reservoirs may block natural fish migration routes; alter the hydrology and the rivers' natural patterns of erosion and silt deposition; as well as water temperature and water quality – all of which have massive impacts on aquatic life (see box on p. 99). The wetland ecosystems exist in a transition zone between aquatic and terrestrial environments and can be dramatically affected by even slight alterations to hydrology. Reduced 'flood pulse' transport of sediment into the floodplains reduces the nutrients available for aquatic plant growth – the primary engine driving much of the fishery's productivity. At the same time, smaller floods of shorter duration reduce the available habitat for fish, and reduce the survival rates of eggs and juveniles (Barlow 2008). Changes in dry season flows and changes in the timing of the start of the floods, can disrupt the spawning and migration cues that trigger the changes in fish behaviour needed for migration, reproduction and ultimately the survival of the species (Baran 2006).

Governance of wetlands in the Lower Mekong Basin

Wetlands in the LMB are often subject to aspects of many different laws, policies and regulations with possible overlap and inconsistency between different sectors. Weak or totally lacking horizontal coordination and collaboration between sectors and stakeholders is also common. Decentralisation has been promoted in all the LMB countries but there, are for the most part, no clear indicators of effectiveness or efficiency.

Wetlands in the LMB (where they are managed at all) are generally being managed in isolation and as closed systems, with no consideration of links with outside processes and ecosystems, in a broader landscape context. The vast majority of wetlands have no special status and are extremely vulnerable to development.

A major problem with regard to wetland management in the Mekong countries is that the local users of wetlands resources often do not have their traditional rights to these ecosystems recognised, and therefore are not properly involved in management and control of these resources. Consequently, these important habitats are liable to suffer degradation at the hands of other, wealthier and more powerful sectors of society, altering land use, without benefiting the poorer parts of the population.

In many countries, establishment of community forests is a well regarded and clearly understood natural resources management strategy. Unfortunately, the same cannot be said for community-managed wetlands. In Viet Nam, for example, wetlands are regarded as 'special use forests' managed under policies and laws designed for forests with an overriding priority to prevent forest fires as the highest level management objective. In the Mekong Delta this has led to a situation where national parks management authorities dig additional canals and maintain artificially high water levels throughout the year rather than allowing the natural processes of seasonally flooded grassland wetlands systems to run their natural course.

All the LMB countries lack clear national policy statements on key wetland issues. Similarly, they do not have specific legislation for the community-based management and protection of freshwater wetlands.

Nevertheless, there have been some recent developments in this direction which could be spread more widely. One example is the creation of a wetlands technical advisory group in Dong Thap province, Viet Nam. The approval of a separate Wetlands Management Statute for Tram Chim wetlands is a key achievement of this initiative. This statute allows the hydrological and fire regime of Tram Chim to be managed in line with its priority wetland values. As another example, in Nong Khai province of northeast Thailand, a provincial wetlands committee and district wetlands working groups have been established, supporting and endorsing the community-led boundary demarcation, zoning, and natural resource use rules development in Kut Ting and Beung Kong Long wetlands (Parr et.al., 2009). Again, this approach could be spread more widely.

3.3
FISH AND FISHERIES

Mekong fish and their habitats

About 850 species of fish have been recorded in the Mekong River Basin (Hortle 2009). These can be grouped according to their ecology and migration patterns. The main groups in lowland fisheries are as follows:

- 'Black fish' are those species with limited lateral migrations from the river onto the floodplains and no longitudinal migrations upstream or downstream. They do not leave the floodplains and wetlands, and spend the dry season in pools in the rivers or floodplains. This group includes Channidae (snakeheads), Clariidae and some Bagridae (catfishes) and Anabantidae (climbing perch).
- 'White fish' undertake long-distance migrations, in particular between lower floodplains and the Mekong mainstream. This group includes many cyprinids (e.g. *Henicorhynchus* spp. and *Cirrhinus* spp.) and also most Pangasiidae catfishes.
- 'Grey fish' do not spend the dry season in floodplain pools but nor do they undertake long distance migrations. When the flood recedes they leave the floodplain and tend to spend the dry season in local tributaries. This group includes, for instance, *Mystus* catfishes.

As well as these groups, some freshwater fishes remain within the main river channels and many species are confined to tributaries and hill streams. In the lower reaches of the river system many salt-tolerant coastal and estuarine fishes are also caught. A large proportion of the total fish catch in the Mekong Basin is dependent on highly migratory fish (the white fish).

Fisheries depend on the availability of water and habitat and often compete for these resources with other sectors. The annual 'flood pulse' through a diverse range of natural habitats as well as the artificial habitats of rice fields and reservoirs favours natural fisheries production. The flood pulse inundates terrestrial foods and liberates nutrients from sediment, supporting high primary productivity, and in turn the food chains that fish depend upon. Most fish and other aquatic species migrate between feeding, spawning and resting habitats. Capture fisheries can be conserved and enhanced by maintaining the annual flood pulse, by conserving key habitats (such as spawning grounds, deep pools and floodplains) and by maintaining connectivity along key migration routes.

About 20 million hectares of wetlands (200,000 sq km) occurs in the LMB (including all seasonally inundated land and rice fields), 30 per cent within the zone that is inundated by major floods (Hortle and Bamrungrach in press). In Cambodia and the Viet Nam delta, most of the wetland area is within the productive major flood zone, whereas in Thailand and Lao PDR most of the wetland area is classed as rainfed. The total LMB catch comes mainly from the major flood zone and rainfed habitats (primarily rice fields) in about equal quantities. Large waterbodies contribute a smaller but significant proportion of the total yield.

Fisheries and hydropower dams

Dams are a barrier to fish migrations up and down rivers and mainstream dams in the middle and lower reaches of the Mekong could affect more than 70 per cent of the basin's catch (Dugan 2008).

Mekong fish migrate mainly for breeding and feeding. They migrate upstream to breed, after which their eggs and larvae are carried downstream to the floodplains where the fry feed and grow. Fish also migrate to feed, moving from the main course of the river onto highly productive floodplains at the beginning of the rainy season.

In the Mekong, upstream migrations are dominated by the breeding migrations of larger adult fish while downstream migrations are mainly feeding migrations undertaken by young fish and adults returning from the breeding areas.

A major impact of the proposed mainstream dams will be on the long-distance migrants that move upstream to breed, some as far as China. Dams can potentially cut off long distance migration routes of species such as the endangered giant catfish, affect critical habitats such as spawning areas and divide the existing wild population into separate groups above and below each dam. A series of dams would further isolate populations.

The effect of dams on fisheries production is highly dependent on the location, design and operation of the dams. Most production originates from floodplains in the middle and lower parts of the basin. So, dams built on the mainstream will have a much greater impact than dams built on tributaries, and those located in the middle and lower parts of the Mekong Basin will have a greater impact on fish production than dams located in the upper part of the basin.

Fish ladders or other types of fish passages are sometimes proposed as a solution to allow migrating fish to pass dam walls. However, there is no evidence that fish-passage methods can cope with the massive fish migrations and high species biodiversity in the Mekong, which has at least 50 important migrant species. Fish passes are usually not very efficient for passage over high barriers. Even if migrating fish manage to cross the wall of a large dam, they find themselves in a large reservoir which is totally different to the spawning habitat they seek in the flowing waters of a river. It is unlikely that tropical river fish will spawn in this situation and even more unlikely that their tiny fry (adapted to drift downstream in rising floodwaters) will survive in the alien reservoir environment.

A large part of the benefit of the Mekong fishery depends on mainstream fish migration and mainstream dams will effectively stop much of this migration, leading to reduced production, substantial economic cost and social deprivation.

Source: MRC 2008c

Capture and culture

Capture fisheries contribute most to total catches in the LMB but their importance is under-recognised due to a lack of statistics on most elements of the fishery. In particular, no statistics are regularly collected to quantify catches from small-scale family fishing (part-time or seasonal) which produces most of the total catch. LMB governments generally promote aquaculture to compensate for a perceived decline in capture fisheries, as well as to stabilise production and income and to increase export revenue. Aquaculture is well developed in Thailand and Viet Nam, where it may be contributing about half of the total yield from the fishery, whereas the capture fishery is much more important in Cambodia and Lao PDR. A regular and accessible supply of good quality water and the availability of flat land are features that favour aquaculture so many areas of the LMB appear to offer opportunities. However, development is constrained by a number of factors including the availability of fry and feed, security of tenure of land and water, capital and technical know-how. Capture fisheries can generally offer a much higher return than aquaculture for the millions of individuals who make relatively small investments in equipment to fish for subsistence or supplementary income.

Capture fisheries can generally offer a much higher return than aquaculture for the millions of individuals who make relatively small investments in equipment to fish for subsistence or supplementary income.

Size and value

The LMB inland fisheries yield was estimated at 2.6 million tonnes (Mt) per year in the year 2000 (Hortle 2007). Assuming constant per capita consumption, fish consumption in the LMB in 2008 was about 2.8 Mt (Table 3.3.1). Aquaculture contributed about 0.9 Mt and about one million tonnes of aquaculture products were exported from the basin, so the total yield in 2008 was about 3.9 Mt. This estimate is conservative as it does not take into account wastage and use in fish and animal feed. Capture fisheries contributed about 1.9 Mt/year. At current first-sale prices (US$1–1.80/kg) the total value of the fishery is about US$3.9–7 billion per year but its value could also be judged by its replacement cost, profitability, contribution to food security and nutrition. The nutrients and organic material in the Mekong's plume support a significant coastal fishery.

Table 3.3.1 Estimated consumption of fisheries products in the LMB (2008)

Country	Inland			Marine Products*	Total Aquatic
	Fish	OAAs	Fish plus OAAs		
Cambodia	555	121	676	13	689
Lao PDR	185	45	230	3	232
Thailand	740	196	937	134	1070
Viet Nam	746	173	920	140	1059
Total	**2217**	**535**	**2752**	**294**	**3045**

*fish and other marine species imported into the LMB and sold in markets. Values are fresh weight (000 tonnes (kt) per year) (Hortle 2007). Note that actual consumption is less due to losses in processing. OAAs – other aquatic animals

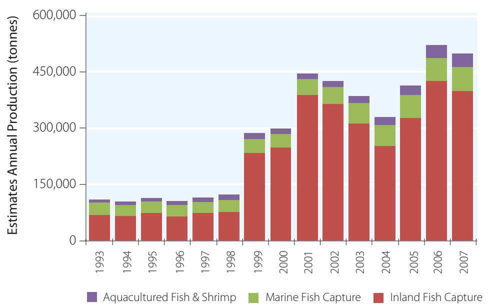

Figure 3.3.1 Estimates of fisheries production in Cambodia. The large increase in capture fisheries production reflects adjustments to estimates rather than an actual increase.

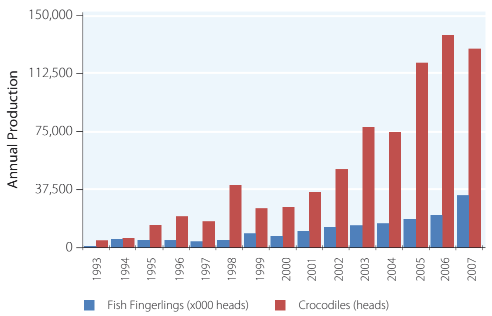

Figure 3.3.2 Production of fish fingerlings and crocodiles in Cambodia.

Cambodia

Cambodia has very large and productive fisheries around the lower Mekong and Tonle Sap Great Lake floodplains. The total inland fish catch was estimated at 395,000 tonnes in 2007 (Figure 3.3.1). Aquaculture is a relatively minor component of total production, but is increasing in importance and was officially estimated as 35,000 tonnes in 2007. Field surveys found production in 2004 was about 60–80,000 tonnes, about twice as much as official estimates (So and Haing 2007). The estimate for total national production now is becoming more closely aligned to the estimates from consumption (Table 3.3.1) but may still be an underestimate.

As well as fish and shrimps, crocodiles (*Crocodylus siamensis*) are being farmed in increasing numbers (Figure 3.3.2). They depend on the wild fishery as they are fed mainly on small low-value fish (trash fish) as well as snakes and other semi-aquatic animals. The aquaculture industry in Cambodia is also producing an increasing number of fingerlings of various species, which are used both for aquaculture and to stock reservoirs.

The Cambodian *dai* fishery

The *dai* or bagnet fishery along the lower 30 km of the Tonle Sap River in Cambodia has been in operation since the late 19th century. Large nets strung across the river filter the flow to catch fish migrating downstream during the flood recession. Most of the catch comprises small cyprinids, especially trey riel (*Henicorhynchus* spp.), herbivorous fish and other small herbivores or omnivores. The Cambodian Fisheries Administration (FiA) has systematically monitored this fishery since 1997–98 as an indicator of trends in catches.

Over the 12 seasons, total catches have varied from 8000 to 33,000 tonnes (Figure 3.3.3). While the number of dai units operating varied, fluctuations in catch per unit effort were similar to those of catches. In 10 of the 12 seasons, catches were well-correlated with an index combining flood extent and duration. In large-flood years more fish survive and grow to a larger size on inundated areas, resulting in more fish of a higher mean weight in the catches.

Within the entire 12-year data set fish biomass varies significantly with the flood index after accounting for the effects of changes in fishing effort (dai units), sampling location and time (month and lunar phase). The unusually high catches in 2004–05 and 2005–06 seasons are likely to reflect above average levels of recruitment to the fishery because mean fish weights for these two seasons were consistent with predictions based on the flood index (Halls and Paxton 2010; Halls et al. 2008). Factors responsible for these high levels of recruitment remain uncertain but a campaign by the FiA to confiscate illegal gears, particularly during 2003 and 2004, may have been influential (Hortle et al. 2005).

There is no trend over time in the 12-year dataset, and the total catch of the dai fishery appears to have changed little over many decades, based on comparisons with earlier crude estimates. These include 13,600 tonnes for the 1938–39 season (Chevey and Le Poulain 1940) and 5–18,000 tonnes per season over the period 1981–1993 based on Department of Fisheries statistics and Nguyen and Nguyen (1991). However, comparisons with earlier data do suggest a reduced proportion of larger species in recent catches (Halls and Paxton 2010). Therefore, a degree of 'fishing down' has taken place since the 1930s, as would be expected given an increasing population and availability of gears, which have led to increasing pressure on the same fish assemblage that is fished by the *dais*.

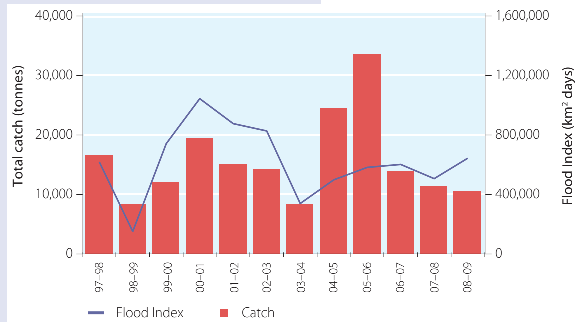

Figure 3.3.3 Trends in the Tonle Sap dai fishery The flood index combines extent and duration (Halls et al. 2008).

Lao PDR

The most reliable statistics indicating the size of fisheries are the household consumption statistics collected during the comprehensive Lao Expenditure and Consumption Survey (NSC 2004), which was carried out in 2003, covered 8100 households and was used as the main basis for the estimate of national consumption in Table 3.3.1. Lao people fish and collect aquatic animals throughout the country but there are no accurate catch statistics collected to quantify national production. Aquaculture production is also increasing and utilises the same main species as in Thailand (see below). FAO statistics indicate a steady increase in total national aquaculture production from 12,900 tonnes in 1995 to 78,000 tonnes in 2005 (www.faostat.org).

Fisheries of southern Lao PDR

The *li* fishery

Fish migrate in large numbers along the Mekong River in southern Lao PDR each year. At the start of the wet season many species migrate upstream from Cambodia seeking suitable spawning habitat; the dominant fish in this migration are pangasiid catfish. At the same time, other species, such as the cyprinid *Henicorhynchus lobatus* migrate downstream (Baird et al. 2004). The wet-season migration through the Khone Falls is heavily targeted by local fishers using *li* (wing) traps set in the many channels of the falls (Soukhaseum et al. 2007). The *li* trap catches in the main wet-season migration channel, Hoo Som Yai have been monitored since 1994 (Figure 3.3.4). Catches are very diverse, including more than 100 species. Up to seven tonnes are caught over a two-week monitoring period from just one type of gear in this single channel, which represents a small fraction of the total catch from the many channels of the falls. No long-term trend is evident in the catch per unit effort (CPUE) data, despite the general opinion expressed by many fishers that catches are declining. Large peaks in 2003 and 2005 may relate to some species experiencing good recruitment and growth during above-average flows and flooding between 2000 and 2002, but there is no simple relationship between flows and total CPUE. Large catches may be made in the same year as a large flood, or in subsequent years as many of the fish caught are between one and three years old.

The gill net fishery

Fishers in this area also target a dry-season migration of fish which move along the Mekong River searching for food, many of them originating in the Sesan–Sekong–Srepok (3S) system in Cambodia (Baird and Flaherty 2004). These fish are caught both above and below the Khone Falls using many kinds of gear, among which gill nets are the most productive. Gill net catches have been monitored upstream of Khone Falls at Hat Village (about 15 km upstream) and Hadsalao Village (about 120 km upstream). Catch per unit effort is highly variable from year-to-year (Figures 3.3.5 and 3.3.6), but shows no evident trend over the period of record. Several more years of record may be required to discern trends and a more detailed analysis by species will be required to understand the relationship between CPUE and flows.

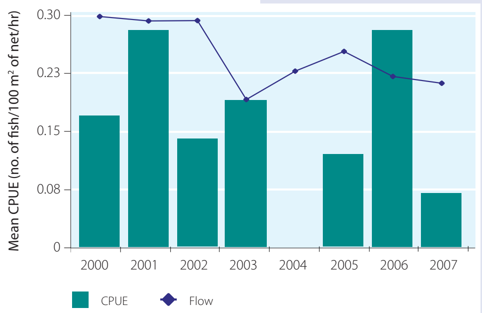

Figure 3.3.4 Mean catch per unit effort for fishers using 5-7 cm gill nets during the main dry-season migration in the Mekong River at Hat Village, Lao PDR, and mean annual flow. CPUE data were collected over 19 days in Jan-Feb. each year.

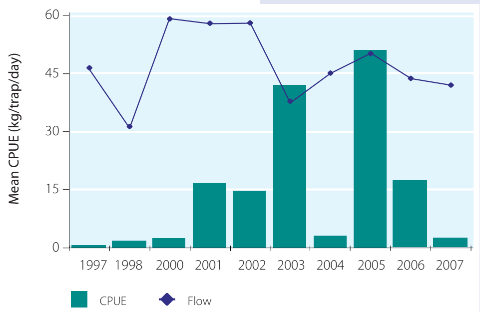

Figure 3.3.5 Catch per unit effort for fish caught in the early wet season li trap fishery at Hoo Som Yai, Khone Falls and estimated annual mean flows at Pakse. CPUE is based on 15-days sampling during May-June each year.

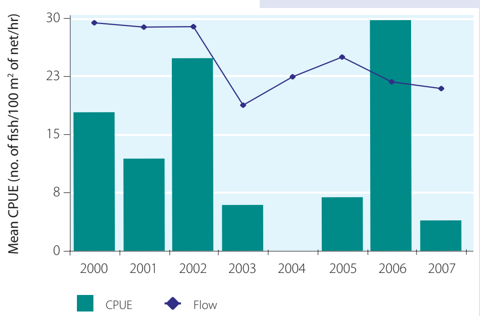

Figure 3.3.6 Mean catch per unit effort for fishers using 5-7 cm gill nets during the main dry-season migration in the Mekong River at Hadsalao Village, Lao PDR, and mean annual flow. CPUE data were collected over 19 days in Jan-Feb. each year.

Thailand

The area devoted to aquaculture has increased more than three-fold since 1995, while production quantity and value increased about six-fold (Figure 3.3.7). The most important aquaculture species by quantity are tilapia (*Oreochromis* spp.), African walking catfish (*Clarias gariepinus*) hybrids, Thai barbs (*Barbonymus* and *Puntius* spp.) and snakeskin gouramis (*Trichogaster pectoralis*) (Figure 3.3.8). Giant prawns are relatively unimportant in terms of weight, but are four times as valuable as tilapia (US$3.95 cf. US$0.96/kg) so form a relatively large proportion of the total value. Most of the cultured tilapia are Nile tilapia (*Oreochromis niloticus*) or red hybrid tilapia (*O. niloticus x O. mossambicus*), hardy omnivorous fish that suit hatchery production and grow out under a range of conditions. Indigenous fish which are beginning to contribute significantly to production include Thai barbs, snakeskin gourami and snakeheads.

Figures for capture fisheries are based on surveys of catches at landing sites in large permanent waterbodies including reservoirs and do not include many habitats such as rice fields, smaller swamps and waterbodies (Figure 3.3.9). Comparison of some official figures at certain reservoirs with those from household surveys (which should cover all fishers) show that official statistics may only record 10–50 per cent of total catches, the remainder being taken by small-scale fishers (Hortle and Bamrungrach in press). Nevertheless, the statistics do indicate trends in the fishery as well as the important species. Catches show an increase of about 45 per cent over the period 1995–2007 (Figure 3.3.9), which may be a result of an increasing number of large waterbodies, increasing fishing pressure and improvements in data collection. The total quantity recorded (122 kt in 2007) is similar to the total recorded from aquaculture (127 kt).

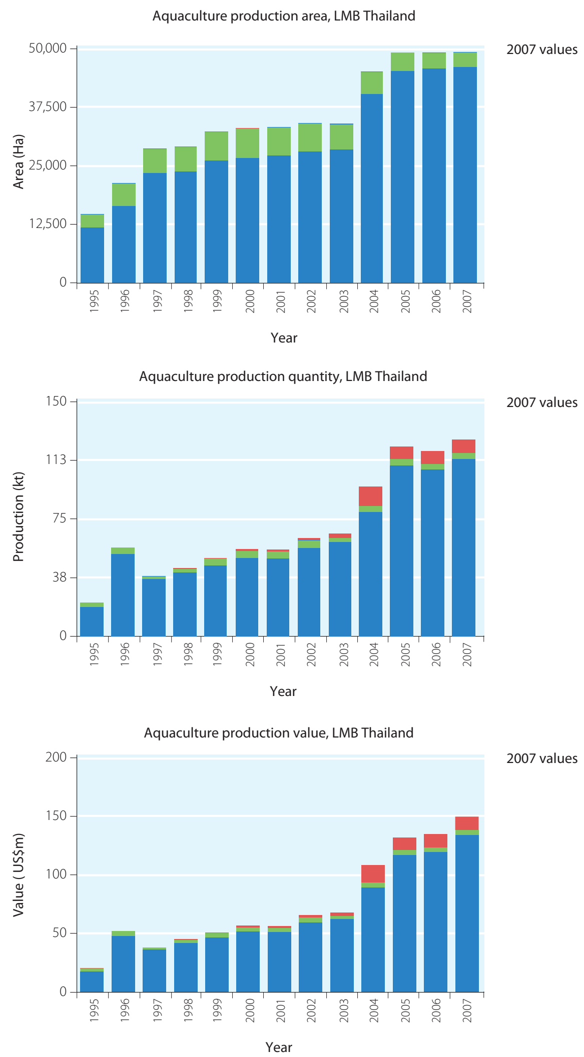

Figure 3.3.7 Summary of aquaculture trends in the LMB in Thailand. Note: includes all provinces in the LMB in north and northeast Thailand; units of production are 000 tonnes (kt) per year and value is expressed as US$m/year, estimated approximately as US$1=THB33. Culture in ditches is about 40 tonnes/year valued at US$40,000, not visible at this scale. Estimates are based on large-scale, randomised household surveys.

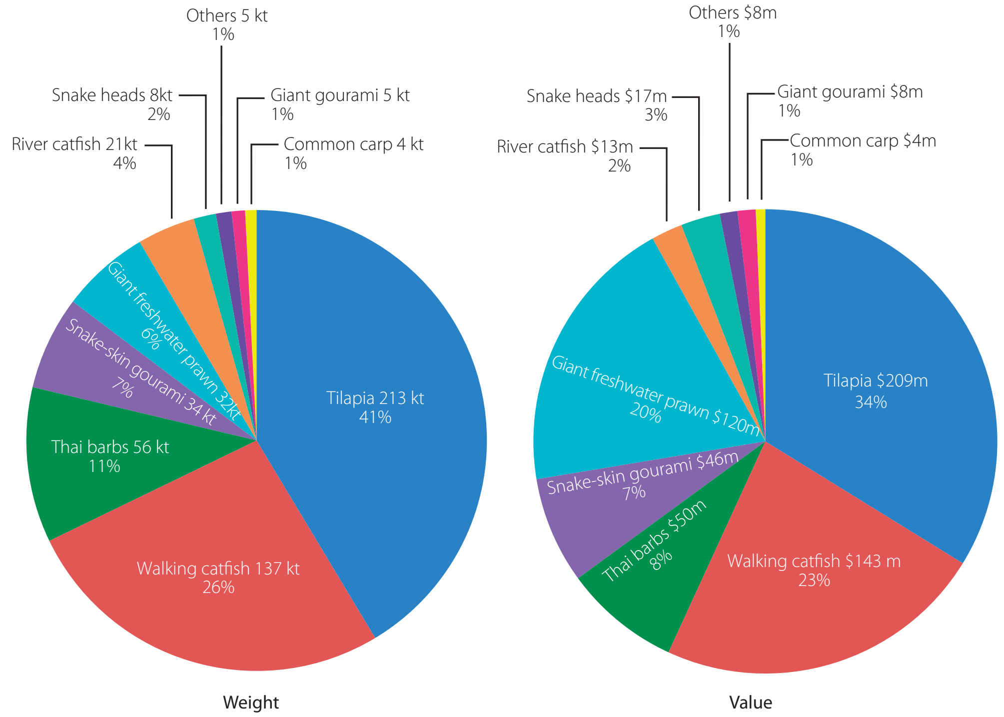

Figure 3.3.8 Composition by weight and value of aquaculture production in the Thai part of the LMB in 2007. Units are 000 tonnes (kt) per year and and value is expressed as US$M/year, estimated approximately as US$1=THB33.

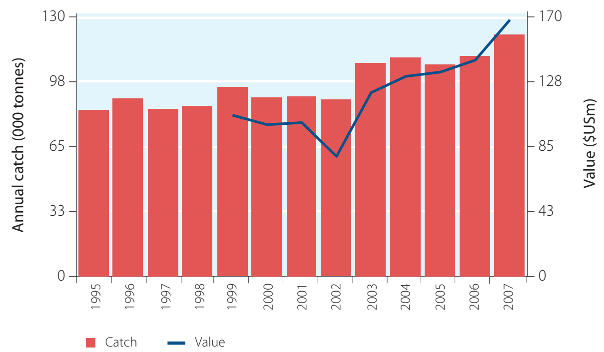

Figure 3.3.9 Trends in commercial catches in Thailand. Note: does not include small-scale catches; value data not available before1999.

Viet Nam

The Viet Nam delta is highly productive for both capture and culture fisheries (Truong et al. 2008). Estimates for capture fisheries cover only the commercial sector, whereas for aquaculture the estimates include both commercial and small-scale aquaculture production, although the small-scale figures may be underestimates. The information presented here is from a survey carried out by the Research Institute for Aquaculture No. 2, Ho Chi Minh City.

The recent growth in aquaculture production has been phenomenal (Figure 3.3.10), with total production in 2008 estimated at about 1.9 million tonnes, more than five times the level in 2000. Of this, about 1.6 Mt originates from within the LMB portion of the Mekong Delta. Most is thought to be exported from the basin and much of that from Viet Nam, but precise estimates of the proportions are not available. It is assumed for balancing consumption figures that about 0.6 Mt of the LMB Mekong Delta production is consumed within the LMB and the other one million tonnes is exported. Aquaculture production has been increased by expanding the area used, from about 417 km² in 2000 to about 726 km² or about 18 per cent of the delta's area by 2006, as well as by increasingly intensive and efficient production and processing.

About 82 per cent of the aquaculture area is brackish water, which produces about 36 per cent of the total quantity of products by weight, but which accounts for about 72 per cent of the total value. The brackish zone is mainly used to produce shrimp (mainly black tiger shrimp, *Penaeus monodon*), which accounts for most of the value of aquaculture production from the delta (Figure 3.3.11). Freshwater catfish (mainly *Pangasianodon hypophthalmus* or *ca tra*) are the largest component of production by weight but comprise a relatively small proportion of total value. Most of the production recorded in statistics is exported. Domestic consumption is supplied mainly from small-scale capture and culture fisheries.

Data on commercial catches are less reliable than those for aquaculture but, as shown in Figure 3.3.10, suggest a decline, which may be a result of the impacts of the increasing use of pesticides, other environmental pollution, increasing obstruction of fish passage or loss of habitat to aquaculture. An alternative explanation of the apparent decline is that subsistence catches are continuing to increase at the expense of commercial catches, with total catches stable or even increasing. In the absence of data for small-scale catches it is not possible to interpret the decline with any confidence.

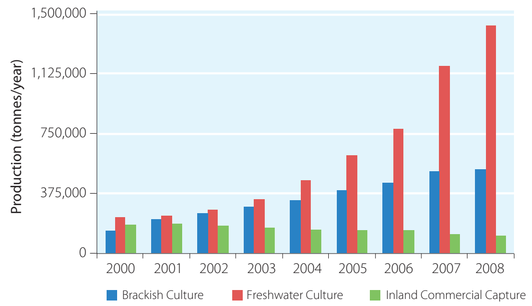

Figure 3.3.10 Production from the Viet Nam delta. *Note*: all provinces included, about 15 per cent of the area is east of the LMB catchment as usually defined.

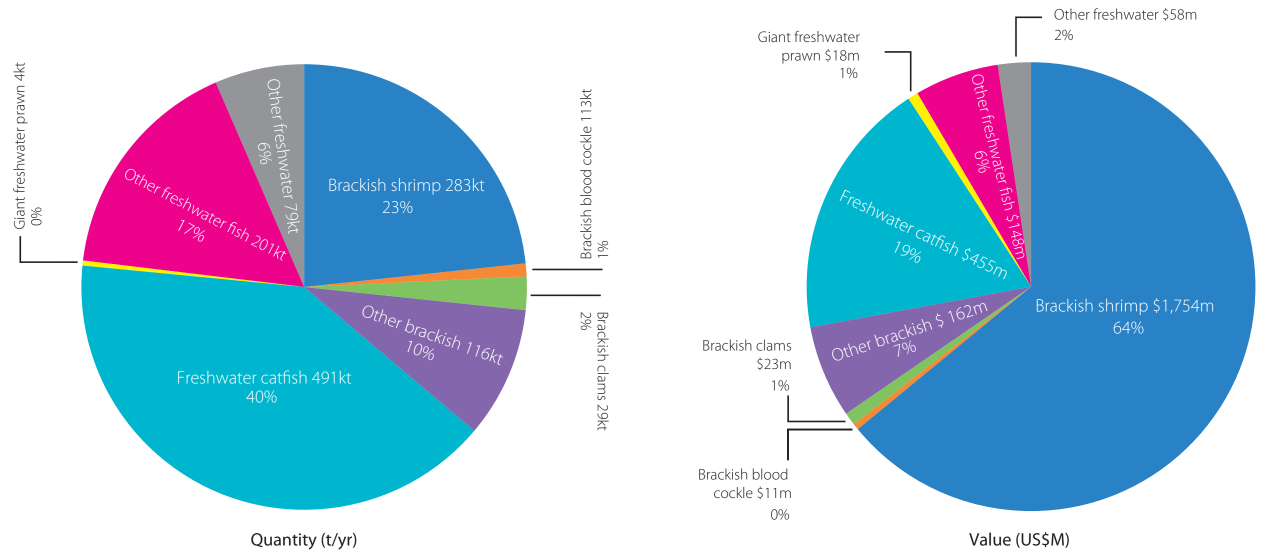

Figure 3.3.11 Composition by weight and value of aquaculture production in the Viet Nam delta in 2006, excluding small-scale aquaculture. Units are 000s tonnes (kt) per year and US$m/year, estimated approximately as US$1=VND15,000.

'Fishing down'

Fishers throughout the LMB generally report declining catches, falling average sizes and a declining proportion of large predatory species, although there is a lack of fisheries data to support such reports. Declining catches per fisher may be attributable to increasing numbers of fishers rather than to a decline in the total catch. In general, tropical flood-pulse environments are extremely resilient to fishing pressure because of the huge numbers of fish produced on the vast areas of seasonally flooded land each year. On the other hand, the negative impacts of habitat changes and water management are fairly well-documented in some parts of the basin. Construction of dams, weirs and other infrastructure, abstraction of water for other uses, clearing of flooded forest, deforestation of catchments and local pollution impacts are all likely to be causing reduced fisheries production which would contribute to declining catches. The fishing industry itself also has an impact through introduction of exotic species, possible incidental introduction of pests and diseases, pollution from large-scale aquaculture, and the use of destructive methods such as electro-fishing, explosives and fine-mesh barrier nets, all of which, although illegal, are widespread.

Status and trends in the river fishery

A study of the daily catches of typical commercial fishers along the Mekong mainstream from 2003 to 2005 has provided some information about status and trends in the river fishery. More than 100 fishers were monitored each day for up to one year and 31 of these fishers who produced high-quality data were monitored for an extended period (Table 3.3.2). The main gears used by fishers upstream of the delta included gill nets, which delivered most of the catch in Lao PDR, Thailand and Cambodia whereas in the Viet Nam delta active gears operated from boats were most important. More than eight million individual fish in 277 nominal species were recorded. The total catch of 204 tonnes among the 31 fishers indicates the viability and value of the river fishery, when it is considered that there are many thousands of similar commercial fishers operating in each country. The differences between countries reflect underlying differences in the quantity and composition of the fish assemblage at each location, as well as variation in specific types of gear used, the skill of each fisher and differences in fishing effort.

The following discussion draws some general inferences from this dataset, but it should be noted that it is not representative of the entire river fishery, which is dominated by small-scale fishers using smaller gears with generally finer meshes, nor does it represent the fishery in ricefields, the many tributaries or reservoirs

Table 3.3.2 Summary details of MRC fisher catch monitoring study (2003–05)

Country	Period	Months	No. of localities	No. of fishers	Main gears	Species	No. of fish (thousands)	Total catch (tonnes)
Lao PDR	Nov 03–Dec 06	38	5	6	gill net, cast net	153	1348	34.8
Thailand*	Apr 03–Dec 05	32	6	9	gill net, cast net, seine net, hook and line	137	148	4.1
Cambodia	Oct 03–Dec 06	39	4	9	gill net, seine net, lift net, cast net	172	1223	43.6
Viet Nam	Jun 03–Dec 05	31	6	7	push-net, trap-net, trawl-net, dai	252	5928	121.7
Total	**Oct 03–Dec 06**	**39**	**21**	**31**		**277**	**8647**	**204.3**

*Fishers were changed halfway through the study

Catch composition

Not surprisingly, most of the catches comprised river fish, as well as a significant proportion of estuarine and black (anoxia-tolerant) fish in the Viet Nam delta (Table 3.3.3). Exotic fish formed a low proportion of catches in all countries and made up less than one per cent of the total number of fish caught. Of the 13 exotic species reported, 11 were derived from aquaculture, one was an aquarium escapee and one a result of stocking for mosquito control. The most abundant exotic species included tilapia, common carp, Chinese and Indian carp and African catfish and its hybrids. In comparison to many other river systems the Mekong's fish fauna is relatively free of exotic species despite their widespread use in aquaculture and stocking of reservoirs.

The composition is typical of fish fauna in the region in terms of the dominant families and the relatively high species diversity. The most abundant families in terms of weight were carps, barbs or minnows (Cyprinidae), catfish (Siluridae, Bagridae, Pangasiidae and Sisoridae) and loaches (Cobitidae) (Figure 3.3.12). With the exception of Viet Nam, the catches in each country included approximately equal proportions of carnivorous, omnivorous and herbivorous species. In Viet Nam a high proportion of carnivores (54 per cent) was due to one fisher catching large fast-swimming species using a boat-mounted push-net. The high proportion of carnivores suggests that the fauna is not highly fished-down and that the fish assemblage, despite being heavily fished, is extremely resilient.

A further indicator of the condition of the fishery is provided by the contribution made by species of different sizes (Figure 3.3.13). Very large species (those which grow to one metre or more in length) and large species both made up a significant proportion of catches in all countries, a finding that is not consistent with a highly fished-down population, which would comprise mainly small or medium-sized species. Nevertheless, some degree of fishing down has probably occurred in parts of the basin and declines in catches are well documented for some large species, such as the giant catfish (*Pangasianodon gigas*).

It should be noted that much of the catch of large species comprises fish that are juveniles, for example most of the catch of the giant barb (*Catlocarpio siamensis*). Nevertheless many large fish were recorded, particularly in Lao PDR, including a giant catfish (*Pangasianodon gigas*) of 200 kg. The most abundant large species, making up about half of the catch weight was *Wallago attu*, with many large individuals recorded (Table 3.3.4). Other large catfish included *Bagarius yarrelli* up to 34 kg, *Pangasius mekongensis* up to 28 kg and *Hemibagrus wyckioides* up to 17 kg in weight. There is a general trend within many species for smaller fish to be caught towards the delta, which is an important nursery ground for river fish and for some large coastal species such as sea bass (*Lates calcarifer*), threadfin salmon (*Polynemidae*), sea catfish (*Netuma thalassina*), mackerels (*Scombridae*) and hammerhead sharks (*Sphyrna lewini*).

Table 3.3.3 Proportion of the main groups of fish in catches by weight

Category (%)	Lao PDR	Thailand	Cambodia	Viet Nam	Total
Exotic fish	1.1	5.7	0.5	1.4	1.2
River fish	98.4	94.1	97.4	86.9	91.2
Black fish	0.4	0.1	2.1	7.0	4.7
Estuarine/marine fish	0.01	0.00	0.02	4.7	2.8

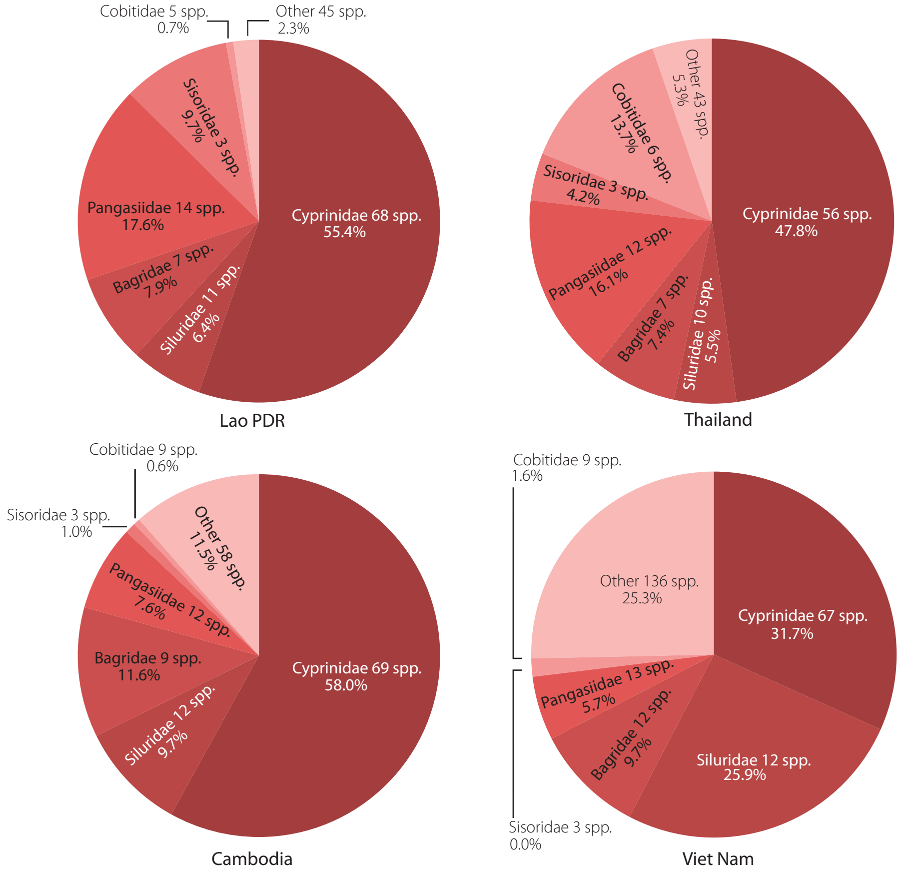

Figure 3.3.12 Composition of fish catches by family.

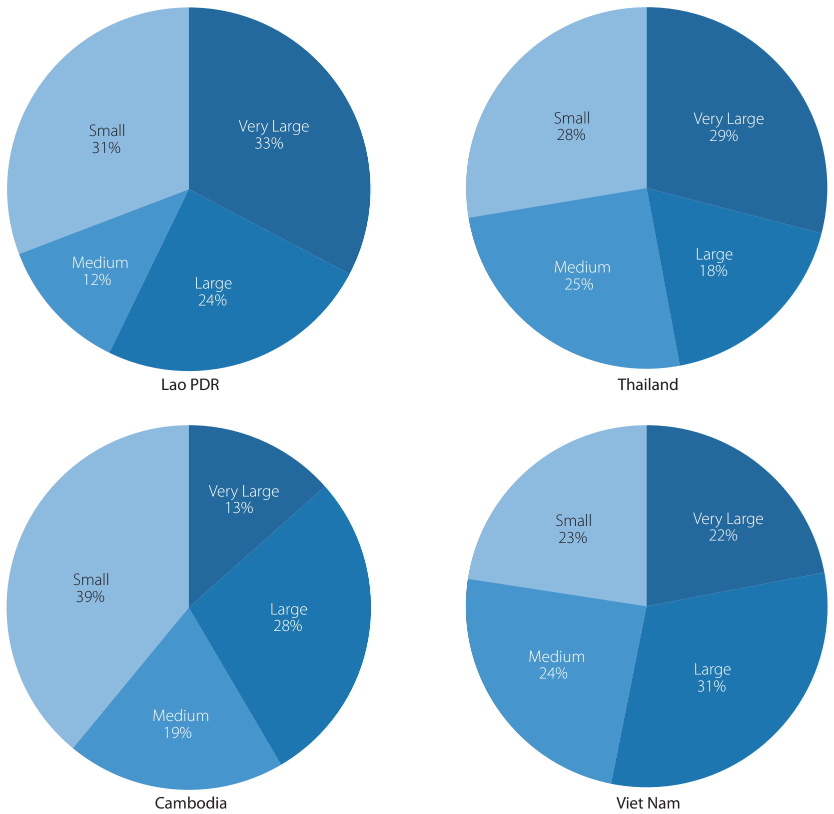

Figure 3.3.13 Composition of fish catches by size category based on maximum published total length; small 0–25 cm, medium 26–59 cm, large 60–99 cm, very large >99 cm.

Table 3.3.4 Summary of the most abundant 'very large' species in catches

Species	English name	Total individuals	Total weight (t)	Max. Length (cm)	Max. Weight (kg)	Max. length recorded in literature (cm)	Very large species (% of catch)
Wallago attu	Great white sheatfish	32,082	20.18	135	35.0	200	41.8
Cosmochilus harmandi	Blue barb	7210	4.15	88	11.7	100	8.6
Pangasius conchophilus	Snail-eating catfish	71,371	3.91	84	8.8	120	8.1
Bagarius yarrelli	Goonch	2197	3.65	134	34.2	200	7.6
Pangasius larnaudii	Spot pangasius	25,917	2.02	65	6.0	150	4.2
Boesemania microlepis	Boeseman's croaker	35,906	1.91	86	6.0	100	3.9
Netuma thalassina	Giant sea-catfish	137,278	1.18	50	1.0	185	2.4
Hemibagrus wyckioides	Red-finned catfish	2757	1.06	120	17.0	138	2.2
Pangasianodon hypophthalmus	Sutchi catfish	5648	1.04	95	8.0	150	2.2
Pangasius bocourti	Bocourt's catfish	12,895	0.91	82	9.0	100	1.9
Pangasius elongatus	Slender catfish	63,558	0.72	66	4.0	100	1.5
*Cyprinus carpio**	Common carp	504	0.54	85	7.0	120	1.1
Probarbus jullieni	Isok barb	2229	0.46	100	15.0	165	1.0
Probarbus labeamajor	Thicklip barb	1446	0.44	107	23.0	150	0.9
Other (32 species)		**57,956**	**3.06**				**6.3**

*exotic species

Endangered fish species

The catches provide some indication of the status of endangered species (Table 3.3.5). Two endangered species were not reported, suggesting that they are rare along the Mekong mainstream. While the marbled stingray may have never been common, the freshwater sawfish is well-known but is particularly susceptible to capture by gill nets which are now very commonly used and may be a significant cause of its rarity. Laotian shad used to be common, but as fast-swimming surface fish they are also particularly susceptible to gill nets. Despite the selective impacts of fishing on some species, catches of other endangered species indicate there are still large and viable populations, when it is considered that the monitored catches are a very small proportion of total catches from the river system.

Table 3.3.5 Summary of catches of Mekong mainstream fishes listed as endangered

Species	English name	Redlist Status	Total individuals reported	Total weight (kg)	Max. Length (cm)	Max. Weight (kg)	Max. length recorded in literature (cm)	Main occurrences
Dasyatis laosensis	Mekong stingray	Endangered	36	41.9	130	11.7	62	All countries
Pangasianodon gigas	Giant catfish	Critically endangered	3	201	210	200	300	Lao PDR, Viet Nam
Probarbus jullieni	Julien's golden carp	Endangered	2229	464.1	100	15.0	165	Cambodia, Lao PDR, Thailand
Tenualosa thibaudeaui	Laotian shad	Endangered	5927	152.0	26	0.2	30	Lao PDR, Cambodia, Thailand
Himantura oxyrhynchus	Marbled stingray	Endangered	0				36	presumed rare
Pristis microdon	Freshwater sawfish	Critically endangered	0				600	presumed rare

Source: IUCN Red List (www.iucnredlist.org)

Trends in catches

Catches tend to show seasonal patterns related to water level and flow, which directly affect fishing activities, but which are also correlated with fish migrations (Figure 3.3.14). Typically, high catches are made at the beginning of the wet season (June–July) when many fish are migrating to breeding grounds and also at the end of the wet season (November–December) when fish are migrating off flooded areas and swimming towards dry-season refuges. In addition, catches reflect fish recruitment and growth, which are strongly related to the strength of flooding in the same or earlier years. As well as these seasonal cycles, fish catches may exhibit longer trends over time, as shown by the fitted trend lines in Figure 3.3.14. Over all 15 stations, seven showed a declining trend, six an increasing trend, and two were stable. However, the declining trend in Cambodia and Viet Nam is likely an artefact of the lack of data for the early months of the study, when catches are typically low. Hence the data do not support the view that there is a general decline in catches, but for any definitive conclusion on trends a much longer period of record is required. Major changes in catches are likely to be largely a result of variation in the available biomass of fish, which is heavily influenced by the extent of annual flooding and by the condition of the environment. Some pronounced changes in catches include the following:

- Houay Xai, Bokeo, northern Lao PDR, a major decline in catches may be a result of the effects of new dams in Yunnan on flow patterns and stream temperature which adversely affect fish migrations and feeding. Although the Chinese dams have had little effect on total flows (see p. 60) daily fluctuations as water is released to meet peak loads may cause severe impacts.
- Hatxayfong, Vientiane and Thakek, Khammouane, Lao PDR, a large increase in catches comprised mainly large or very large species 3–5 years of age, which were probably recruited during prior high-flood years.
- Kampong Cham, Cambodia, large catches in 2005 coincided with large catches in the dai fishery, and comprised mainly small cyprinids, including trey riel *Henicorhyncus lobatus* and *H. siamensis*.
- Tien Giang, Viet Nam, a large decline in catches was associated with construction of a dike to cut off saltwater flow into mangrove habitat so it could be used for rice farming. Estuarine fish and other animals rely on these intertidal habitats for feeding so impacts on fisheries are to be expected and are widely reported.

Catfish farming is an important industry in the Viet Nam delta.

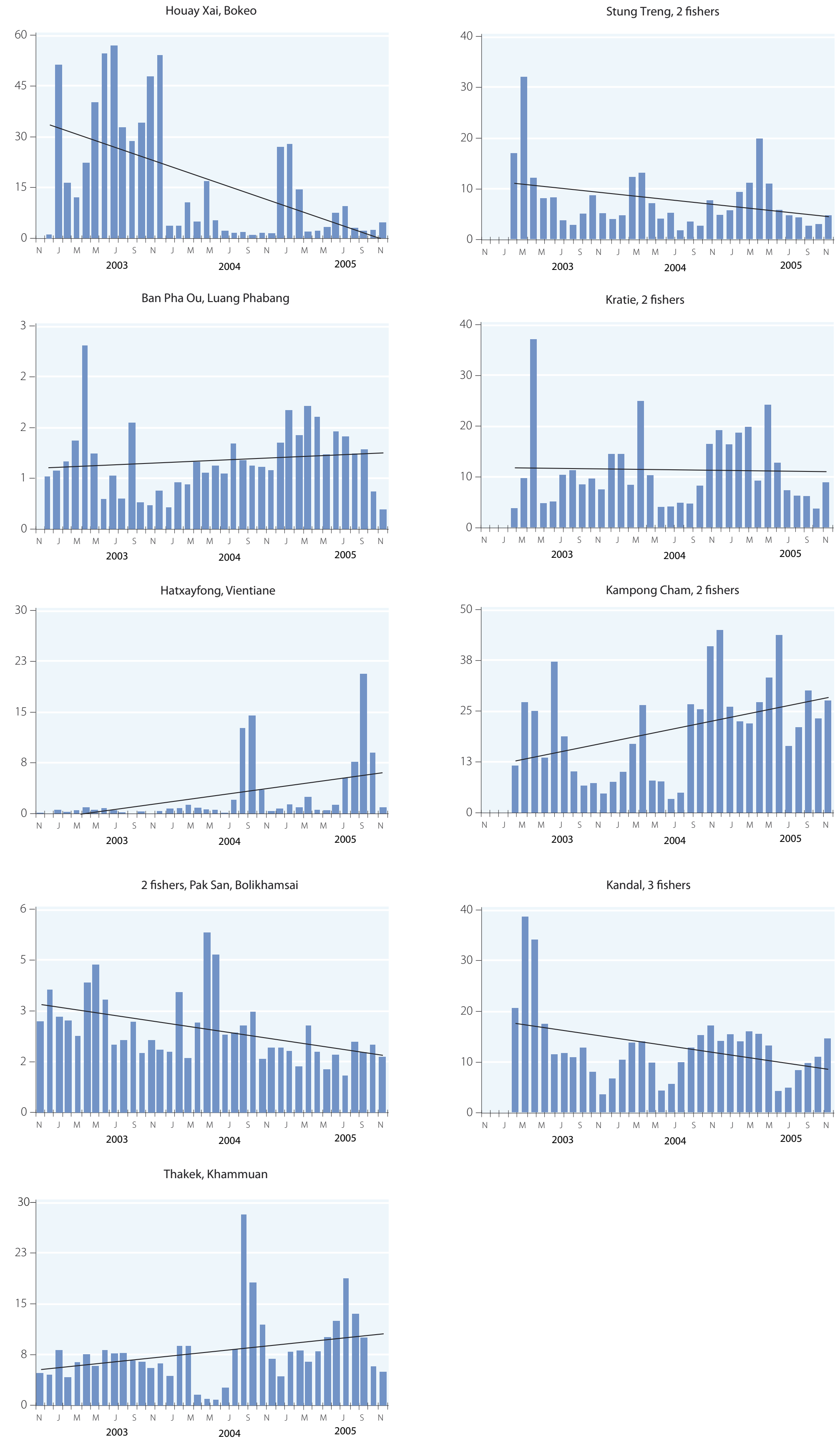

Figure 3.3.14a Trends in fisher catches, Lao PDR (left) and Cambodia (right). Locations are arranged from north to south in each country. Units are mean daily catches per fisher averaged each month (kg/fisher/day). Data for Thailand were not continuous so are not plotted.

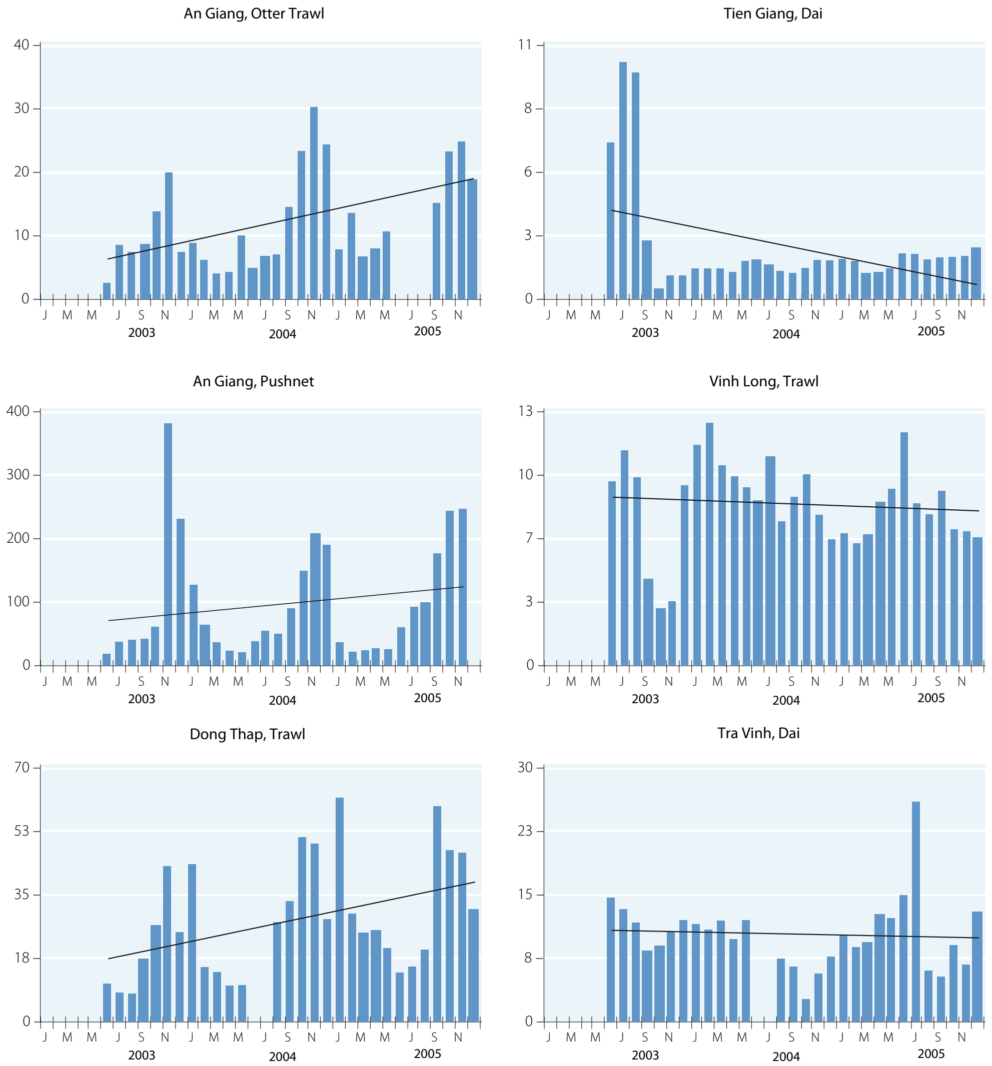

Figure 3.3.14b Trends in fisher catches, Viet Nam delta, Mekong mainstream and large canals. Upper delta sites are on the left; and sites from the middle and lower delta are on the right Units are mean daily catches per fisher averaged each month (kg/fisher/day).

Markets

Most fishery products that are consumed within the LMB are not marketed through formal channels because subsistence fisheries account for most catches as well as most production from aquaculture. However, trading of fishery products through markets is increasing in importance, particularly in Thailand and the Viet Nam delta. Markets operate at three main levels: large provincial or city markets, medium to small district level markets and small village markets, with about 5000–6000 markets in the LMB (Hortle 2009b). Markets provide important livelihood opportunities, particularly for women who make up 80–90 per cent of traders. Results from an MRC-sponsored survey of key city markets from late 2003 to late 2004 (Table 3.3.6) showed that capture fisheries were the dominant source of fresh inland fish in Phnom Penh but were less important in other city markets and contributed less than half of the weight of products overall. Capture fish were however generally more expensive than culture fish, with a mean price of US$1.95 per kg compared with only US$1.24 per kg for culture fish.

The higher value of capture fish is partly a consequence of the presence of large valuable fishes in catches, but wild fish generally command a higher price than cultured fish of the same species, because they are generally in better condition and many consumers think they taste better. Product quality is clearly a major issue to be addressed in aquaculture, for example by improving feeds and water quality near commercial aquaculture operations. The market data show that inland capture fish are cheapest in Cambodia, where extensive flooding supports a large yield and aquaculture fish are also cheapest in Cambodia and the Viet Nam delta, where fish culture is favoured by availability of flat land, water and access to fry and sources of feed.

The most expensive fish were all very large species, including giant catfish (mean price US$5.05/kg), goonch (mean price US$5.01/kg) and giant sheatfish (mean price US$4.55/kg).

The weighted mean price of city-retailed fish in 2003–04 was US$1.66 per kg, but the cost of other fishery products has increased since this survey in line with inflation and depreciation of the US$. It should also be noted that wild capture fish form a higher proportion of total production in the LMB, due to their greater importance in the dominant rural subsistence fisheries. Taking into account relative quantities of culture and capture fish, the mean retail market price of inland fish in the LMB was estimated at about US$2–3.60 per kg, with a first-sale price of US$1–1.80 per kg (Hortle 2009b).

As well as inland fish, other aquatic animals and various marine products are widely marketed throughout the LMB. The most expensive fishery products recorded in the MRC surveys were the giant freshwater prawn (*Macrobrachium rosenbergii*) which retailed for up to US$17.50/kg, and shrimps (Penaeidae) which retailed for up to US$8.67 per kg.

Table 3.3.6 Summary of data from markets based on interviews of all inland fresh fish sellers over a one-year period.

Location	Markets	Source	Total sales (tonnes/ year)	Annual Value (US$)	% of wt	% of value	Mean price ($/ kg)
Vientiane, Lao PDR	2 city markets	Capture	162.4	$449,720	32.0	49.3	$2.77
		Culture	295.3	$402,929	68.0	50.7	$1.36
		Total	457.7	$852,649			$1.86
Northeast Thailand	3 city markets	Capture	194.3	$455,989	39.8	50.7	$2.35
		Culture	294.3	$442,541	60.2	49.3	$1.50
		Total	488.6	$898,531			$1.84
Phnom Penh, Cambodia	1 city market	Capture	673.6	$795,398	70.5	73.5	$1.18
		Culture	282.3	$286,070	29.5	26.5	$1.01
		Total	955.9	$1,081,468			$1.13
Viet Nam delta	5 city markets	Capture	1046.9	$1,563,134	56.3	64.1	$1.49
		Culture	812.9	$874,693	43.7	35.9	$1.08
		Total	1859.8	$2,437,826			$1.31

Monitoring period 20 days, except Phnom Penh 15 days. Values are based on approximate conversions. US$1 = Kip10,000, Riel4000, THBt33, VND15,000.

3.4
FLOOD AND DROUGHT MANAGEMENT

Floods and droughts can occur anywhere in the LMB. Both impose large economic and social costs on the people of the basin but the economic benefits of floods far outweigh their costs. The average annual cost of flooding in the LMB is US$60–70 million a year, while the average annual value of flood benefits is US$8–10 billion a year, i.e. some 100 times greater. The challenge for better flood risk management is to reduce the costs and impact of flooding while preserving the benefits. The average annual cost of drought in the LMB is at least as large as the flood cost and possibly considerably greater.

Floods in the Lower Mekong Basin

The annual flood in the Mekong River is the most pervasive physical event in the lower basin. It has shaped the basin's environment and ecology, especially across the Cambodian lowlands and the Mekong Delta, including the nature, culture, welfare and economy of riparian societies and the vegetation, animals and land use of flood-prone areas. Between July and October, a massive flood wave moves down the Mekong River past Lao PDR and Thailand, growing in volume on its downstream journey. At Kratie in north-eastern Cambodia, with a volume of some 300 km^3 (average conditions), the floodwave moves out onto the Cambodian lowlands, where some 30 km^3 flows upstream along the Tonle Sap River into the Great Lake, and the remainder flows down the Mekong and Bassac Rivers and into the Viet Nam delta before entering the South China Sea. From October onwards, the Great Lake drains back into the Mekong and Bassac Rivers, sustaining the recession limb of the flood at downstream locations. In total, an average of some 460 km^3 of water flows out into the South China Sea each year.

Mainstream flooding across the Cambodian lowlands and Viet Nam delta persists for some two to four months each year, affecting several million people. Flooding also occurs in the various tributaries of the Mekong River, but is of a more sporadic nature and with a typical duration of several days to one week.

Building sandbanks to avert rising floodwaters in Vientiane, 2008.

Types of floods

The LMB is exposed to eight different types of floods (Joy 2007, Table 3.4.1), each with its own characteristic nature, risk and hazard. Typically the mainstream flood season is from June to November, with flood levels peaking in August–September (Adamson 2006b). Significant floodplains around the confluence of the Mekong and its tributaries are subject to backwater flooding from mainstream floods and to combined flooding from coinciding mainstream and tributary floods (Figure 3.4.1).

Table 3.4.1 Floods in the LMB

Flood		Cause	Characteristics	Risk and hazard ranking
Category	Name			
Rainfall	Mainstream	Excessive rainfall over basin catchment	Generally slow onset and slow moving, especially in lower reaches where flooding can last for 2-4 months.	*Rank 1*. Mainstream flooding in Cambodia and the Viet Nam delta clearly has the highest risk and hazard. Risk and hazard of mainstream flooding in Lao PDR and Thailand are an order of magnitude less.
	Tributary	Excessive rainfall over tributary catchments	Rapid onset and fast moving because of small, steep catchments. Duration typically several days to 1 week.	*Rank 2*. Tributary flooding in Lao PDR, Thailand and Cambodia, especially flash floods and landslips, are hazardous, but risk and hazard are an order of magnitude less than mainstream flooding in Cambodia and the Viet Nam delta.
	Local	Excessive rainfall over small local catchments	Rapid onset, 'nuisance' flooding. Duration typically hours to 1 day	*Rank 4*. Risk and hazard of local flooding are low; at least an order of magnitude less than tributary flooding.
Man-made	Dam release	Excessive release of water from dams	Onset can be rapid and unexpected, especially for emergency releases	*Rank 3*. Likelihood of dam release flooding is small, but potentially hazardous and destructive.
	Dam break	Structural failure of dams	Immediate onset with rapid increase in water levels and destructive velocities.	*Rank 3*. Likelihood of dam break flooding is very small, but potentially extremely hazardous and destructive.
	Dike breach	Structural failure or overtopping of dikes	Unexpected flooding of 'protected' areas.	*Rank 3*. Likelihood of dike breach flooding is small to moderate. Water levels and hazard are significantly lower than for dam break flooding.
Maritime	Storm surge	Tropical cyclones, depressions and storms	Slow onset, high water levels. Flood, wind and saltwater damage can occur.	*Rank 5*. Likelihood of significant storm surge flooding is low, but potentially hazardous and destructive. Limited to coastal areas of Viet Nam delta.
	Tsunami	Undersea earthquakes	Immediate onset. Extreme and immediate increase in water levels, very destructive.	*Rank 5*. Likelihood of significant tsunami flooding is small, but potentially hazardous. Limited to coastal areas of the Viet Nam delta, but orientation of coast provides some sheltering.

Mainstream flooding across the Cambodian lowlands and the Viet Nam delta persists for 2–4 months each year.

Flood severity

The severity of mainstream floods in the Mekong Basin can be depicted in several ways; e.g. by determining the frequency distribution of peak annual discharge and annual flood volume at various gauging stations along the Mekong River (see Figure 1.3.1 on p. 21), or in terms of the frequency distribution of peak annual flood levels. Alternatively, the number of days spent above nominated water levels (stage-duration curves) can be used to depict flood severity (Figure 3.4.2). The diagrams show that over the period 2000–2008, the year 2008 flood was the worst flood at Vientiane (flood levels peaked at about 1 m above flood stage and remained above flood stage for 6 days), whereas at Kratie, Prek Kdam and Tan Chau, the year 2000, 2001 and 2002 floods were much worse. Conversely, it is easy to see when floods did not cause problems at the various sites (e.g. the year 2003 and 2007 floods were minor floods of little significance at all four sites).

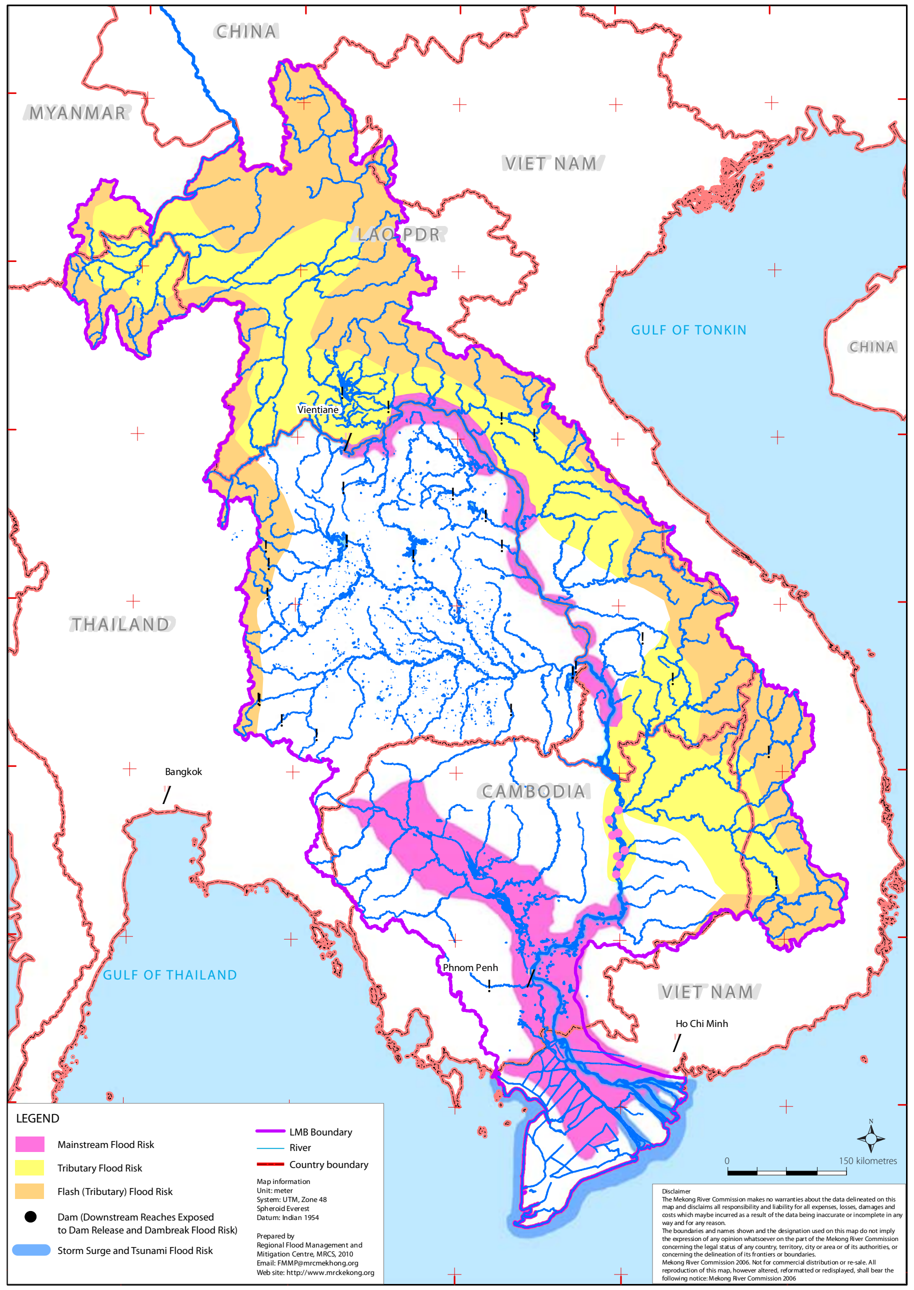

Figure 3.4.1 Indicative areas subject to significant flood risk in the LMB. Note that tributary flooding can occur in all areas across the basin.

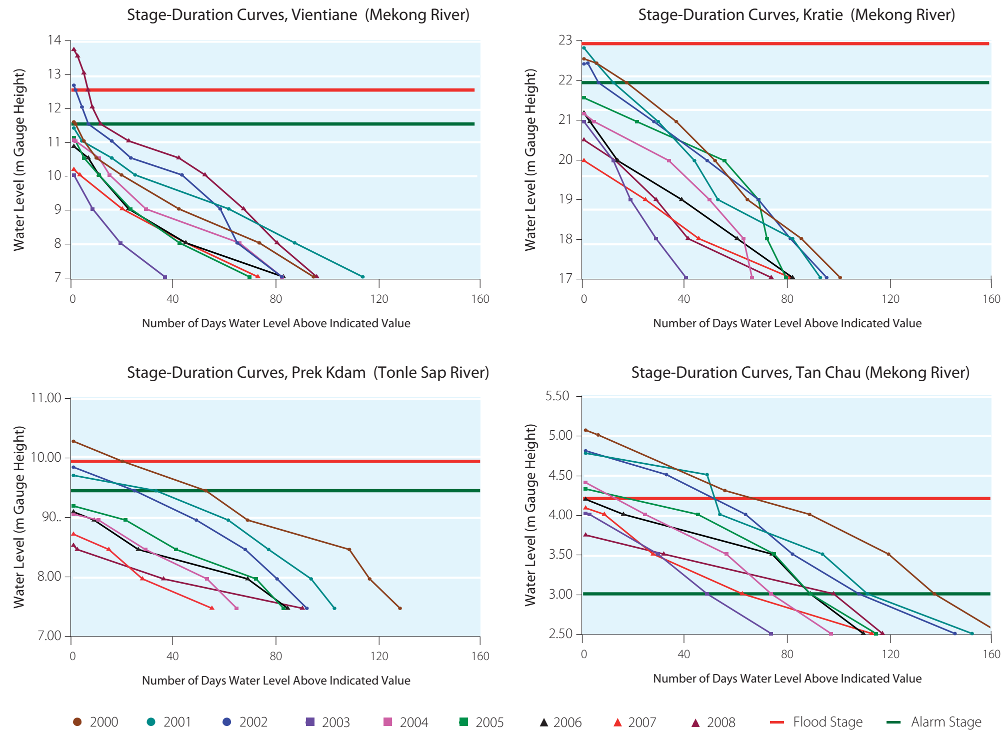

Figure 3.4.2 Stage duration curves (LMB 2000–2008) can be used to depict flood severity.

Flood behaviour

Each year, the nature, location and severity of flooding differs across the basin, depending on the underlying characteristics of flood producing rainfalls and other causative factors. The differences are highlighted in the examples of 2000, 2006 and 2008.

In 2000, severe mainstream flooding of extended duration occurred across the Cambodian lowlands and the Viet Nam delta, coupled with widespread flash flooding across the LMB and minor mainstream flooding in the upper, middle and lower river reaches (MRC 2006). The peak discharge and annual flood volume at Vientiane and Kratie were close to the median annual values; the average recurrence interval of peak flood levels at Prek Kdam and Tan Chau were 100 years and 40 years respectively ('extreme' events). Flood levels at Prek Kdam and Tan Chau remained above flood stage for 20 days and 65 days respectively.

The 2006 flood (MRC 2007b) was characterised by the absence of mainstream flooding of significance throughout the LMB; at Vientiane, Kratie, Prek Kdam and Tan Chau, peak discharges, peak flood levels and annual flood volumes were all around 'normal' levels. Modest flash flooding caused by tropical weather systems occurred in certain tributaries draining the Northern Highlands, Eastern Highlands and the Khorat Plateau.

The 2008 flood was different again, with severe tropical storm-induced mainstream and tributary backwater flooding along the upper river reaches of the Mekong River in Lao PDR and Thailand (MRC 2008d, 2009b). Flooding along the reach of river between Luang Prabang and Vientiane was 'extreme' and rapid. The peak discharges had an average recurrence interval of 30–40 years. The severity of mainstream flooding progressively declined downstream of Vientiane (middle river reach), falling to 'normal' at Khong Chiam and to significantly less than normal downstream of Stung Treng. Flooding was 'normal' across the Cambodian lowlands and the Mekong Delta. Limited flash flooding occurred in Cambodia and Viet Nam.

The cost of floods

The behaviour and socio-economic costs of floods in the LMB are similar to those experienced in other great, heavily settled river basins used principally for agricultural purposes, such as the Indus, the Ganges and the Brahmaputra Basins of the Indian Subcontinent. In all four basins, flooding is driven by the south-west monsoon, coupled with tropical weather systems.

The people of the LMB recognise both 'good' and 'bad' mainstream floods (there is no good side to flash floods). A 'bad' mainstream flood is one that reduces rice production. Such a flood is characterised by one or more of the following: early onset, high water levels, or delayed recession, which reduce the yield of rice crops before, during and following the wet season. Conversely, the enhanced rice production and other benefits of a 'good' (or normal) mainstream flood are considered to outweigh any residual adverse effects. The 'bad' floods of 2000, 2001 and 2002 depressed the annual value of agricultural production in the Viet Nam delta by US$200–300 million (MRC 2009b, Figure 3.4.3).

The average annual flood damage for the LMB is estimated to be US$60–70 million per year and is concentrated in Viet Nam and Cambodia, which between them account for about two-thirds of the total (MRC 2009b, Table 3.4.2). These costs include direct costs to agriculture, infrastructure and buildings but not indirect costs.

Apart from economic costs and the physical danger of floods, outbreaks of waterborne diseases, such as leptospirosis, diarrhoea, gastrointestinal diseases and conjunctivitis, often associated with stagnant floodwaters and unsafe drinking water, are health threats to flood affected people (MRC 2007b). The regular annual mainstream flooding of the Cambodian lowlands and the Viet Nam delta disrupts the schooling of many children. In Cambodia, schools across the lowlands can be closed for up to two months each year (Helmers et al. 2004).

Flooding causes great damage in urban centres as well as rural areas.

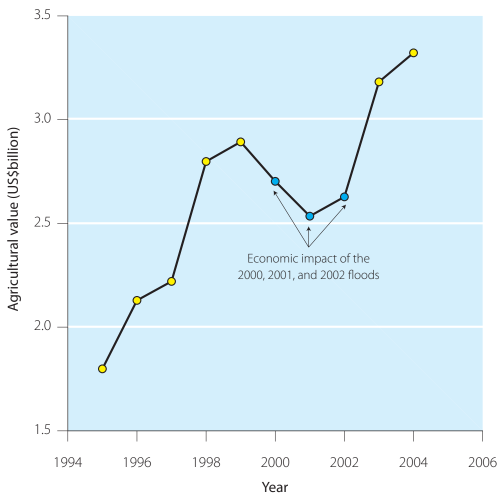

Figure 3.4.3 Impact of recent floods on agricultural production in the Mekong Delta.

Table 3.4.2 Annual flood impacts in the Lower Mekong Basin (2000–2008)

Cambodia

Year	Cost (US$ M)	People killed	People affected	Damaged crops (ha)
1996	86.5	169	-	250,200
2000	161.0	347	3.4 M	421,600
2001	36.0	62	0.6 M	164,200
2002	12.5	-	1.5 M	45,000
2003	-	-	-	-
2004	55.0	-	-	247,400
2005	3.8	4	-	55,000
2006	11.8	11	-	14,500
2007[a]	9.0	10	147,200	9500
2008[a]	5.8	-		18,900

[a] Damage in 2007 and 2008 in Cambodia was almost solely related to flash flooding.

Mekong Delta of Viet Nam

Year	Cost (US$ M)	People killed	People affected	Damaged crops (ha)
1996	113.0	-	-	-
2000	250.0	453	10 M	2.0 M
2001	99.0	393	1.0 M	-
2002	0.3	71	0.3 M	-
2003	15.0	23	-	-
2004	3.0	38	-	-
2005	3.5	44	-	-
2006	15.0	55	77,700	14,700
2007[a]	1.5	30	67,500	46,400
2008[a]	-	7	-	28,500

[a] Minimal damage in 2007, 2008.

Lao PDR

Year	Cost (US$ M)	People killed	People affected	Damaged crops (ha)
1996	10.4	-	-	67,500
2000	30.0	-	-	42,900
2001	56.0	-	-	42,200
2002	61.0	3	249,800	33,700
2003	18.3	-	-	800
2004	4.1	-	-	14,400
2005	18.3	5	480,900	56,000
2006	3.1	5	89,800	6900
2007	18.0	2	118,100	7500
2008	56.0[a]	7[b]	95,200	28,500

[a] Vientiane accounted for 45% of of the total damage.
[b] Flash floods caused 4 deaths, mainstream floods 3 deaths.

Eastern Highlands of Viet Nam

Year	Cost (US$ M)	People killed	People affected	Damaged crops (ha)
1996	-	4	-	-
2000	-	>20	-	
2001	-	-	-	-
2002	3.0	2	-	9000
2003	0.5	6	-	1000
2004	-	-	-	-
2005	-	-	-	-
2006	-	0	-	130
2007[a]	50.8	29	-	20,300
2008	1.0	7	-	80

[a] Flood damage in LMB of Viet Nam in 2007 was predominately due to flash flooding in the 3S catchments.

Northeast Thailand (LMB)

Year	Cost (US$ M)	People killed	People affected	Damaged crops (ha)
1996				
2000	21.0	25	-	-
2001	23.9	34	660,000	-
2002				
2003				
2004				
2005	2.8	0	305,000	39,500
2006	6.8	-	-	-
2007				
2008				

Flood benefits

The environmental, social and economic benefits of flooding in the LMB are unparalleled in any other river basin in the world. The annual pulse of mainstream flooding drives and sustains the basin's prolific fishery. Of seven environmental parameters identified as influencing the annual fish catch, four relate directly to flooding, namely flood level, duration, timing and regularity (Sverdrup-Jensen 2002). The relationship between the fish take in the Tonle Sap dai fishery and a flood index measuring the area–duration of flooding is discussed in section 3.3 (see p. 99).

Water supply is an obvious but often overlooked benefit of flooding; as floodwaters recede, channels, canals and depressions across the floodplain store water for use in the following dry season, especially for irrigation. Sluice gates that can be closed to exclude saltwater enable many channels of the lower Viet Nam delta to be used to store mainstream floodwaters during flood recession. Many irrigation storages in the Khorat Basin of Thailand, the driest area of the LMB, are recharged by tributary floods. Many farmers practise flood recession agriculture, planting rice, vegetables and other crops as floodwaters recede.

Flood-deposited sediments improve and sustain soil fertility across the floodplains of the LMB. It has been estimated that each year, mainstream flooding delivers 79 million tonnes of nutrient-rich sediments to the Viet Nam delta, of which some 9–13 million tonnes are deposited on floodplains, the remainder enlarging the delta (the Ca Mau peninsula of the Viet Nam delta is growing seawards by 150 m annually) and fertilising and sustaining coastal fisheries (Fox and Sneddon 2005; Huang and Tamai 1999). The economic benefit of seasonal soil rejuvenation must be substantial, given that 25,000 to 45,000 km^2 of the Cambodian lowlands and the Viet Nam delta are flooded each year.

Finally, floods serve a number of useful mechanical purposes: they flush stagnant waters and pollutants downstream; recharge groundwater tables; scour and cleanse gravel and rock bed sections of the river; maintain river morphology; and reset vegetation on islands, sandbars and riverbanks (MRC 2003).

Based on the above figures, the annual flood benefit to the LMB lies between US$7.8 billion and US$10.0 billion per year (MRC 2009b). Even though these benefits strongly outweigh the costs of floods, the costs are still very real to people affected and act to perpetuate ongoing poverty. The objective of better flood management is to reduce flood costs and impacts whilst preserving the benefits of flooding to the greatest extent possible.

Droughts in the Lower Mekong Basin

Droughts in the basin can occur at any time of the year. Through their impacts on agriculture and fisheries, droughts impose significant costs on people of the basin but, unlike floods, they provide no apparent benefits. Just as there are different types of floods, so there are different types of drought (Table 3.4.3).

Meteorological droughts, defined by low rainfalls over the wet season (May to November), reduce yields of rainfed rice and other crops. Hydrological drought is defined by a reduction in surface and groundwater resources. The agricultural impact of a hydrological drought is most severe during the dry season, when less than normal streamflows reduce irrigation opportunity and the yield of dry season crops. Hydrological droughts also occur during the wet season, when less than normal streamflows reduce the volume and extent of floodwaters stored in the Tonle Sap Great Lake and the yield of its fishery.

All droughts are meteorological in the first instance, the deficit in rainfall leading to a deficit in soil moisture and possibly to an agricultural drought in rainfed areas. If the meteorological drought persists for long enough, it will lead to a deficit in available water resources and possibly to a hydrological drought, which, in turn, may lead to reduced crop yields in irrigated areas or to decreased livestock and fishery yields. Meteorological droughts of even short duration (weeks) and critical timing can have a great impact on rice yields and national rice production.

The two dry areas that are highly susceptible to meteorological drought are south-east Cambodia, influenced by the rain shadow effect of the Cardamon and Elephant Mountains and the Thai Khorat Plateau including northeast Cambodia, which is similarly affected by a rain shadow cast by the Phang Hoei Range. The average annual rainfall in these two areas is less than 1250 mm, which is the lowest in the LMB (see section 1.2 for more details).

Table 3.4.3 Types of drought

Category	Cause	Effects
Meteorological	Less than normal rainfall over some prescribed period	Short-term droughts of only several weeks duration can reduce the yield of rainfed rice and, if of sufficient duration, reduce fodder available for livestock
Hydrological	Less than normal water availability over some prescribed period	Droughts of several months duration or longer reduce streamflows and the associated supply of water for irrigation and other purposes, and foster salinity intrusion into the waterways of the Mekong Delta
Agricultural	Impact of meteorological and hydrological droughts on crop, livestock and fishery yields	The reduced rainfall and irrigation supply associated with meteorological and hydrological droughts (i) reduce soil moisture, curtail yield and even kill both annual and perennial crops and (ii) reduce livestock and fishery production

Drought occurrence and severity

The likelihood of a 'drought year' is highest in Lao PDR and Thailand (two years in five) and declines as one moves down the basin through Cambodia and Viet Nam (one year in three) (Table 3.4.4, IRRI 2007).

The severity of a drought depends upon its intensity (i.e. water deficit, water use deficit or yield deficit), its timing and duration, and its socio-economic impact (e.g. effects on land use, infrastructure and society). For example, a three-week meteorological drought may be of great significance to rainfed agriculture, especially if it occurs at a critical crop stage, but may have little effect on stream flows or groundwater inflows.

Meteorological drought years are defined as those where the average annual rainfall deficit is more than 20 per cent of the average annual rainfall. Another aspect is the importance of the duration and timing of a drought event. The most recent regional drought event occurred in 2004. Some areas of the basin experienced only a minor annual rainfall deficit but some places experienced slightly above average rainfalls during the first nine months of the year, followed by the almost complete absence of rainfall over the last three months (Adamson 2006a). While the annual rainfall deficit for 2004 was close to zero, the deficit over the last quarter was close to 100 per cent. Rainfall over this last quarter is essential for late summer plantings of rainfed rice. The complete failure of these rains defined an extreme agricultural drought that resulted in complete and widespread regional crop failure, coupled with associated economic loss and social hardship (see the box on p. 120). Thus, the timing and duration of a drought are equally important in determining socio-economic effects (severity) as the level of water deficit.

Drought in the LMB

Drought events in the Mekong region have occurred several times over the past 20 years, including 1992, 1993, 1998 and 1999 (Adamson 2005). In 1993 and 1999 drought conditions extended across every region of Thailand, causing water shortages to all major water users. In 1998, the drought was equally profound in the Mekong Delta in both Viet Nam and Cambodia, and the Tonle Sap did not expand as usual, with an estimated flooded area of 7000 km^2 compared to a typical season maximum of 15,000 km^2 (Te 2007).

The most recent regional drought episode highlights the fact that drought is not just about total accumulated rainfall, the pattern of precipitation throughout the year is of critical importance (Adamson 2005; Te 2007). In fact, total rainfall in 2004 was largely average throughout the basin. However, rainfall distribution in the monsoon season was unusual, with most rainfall in the early parts of the wet season and an early finish to the rainy season. In northeast Thailand, for example, no rain fell in the final three months of the year, the only time this has happened in the 55 years of rainfall records at Khon Kaen (Adamson 2005). On average, some 130 mm of rain still falls during this final quarter, importantly contributing to the accumulation of soil moisture, which can subsequently be used for agricultural production. The complete failure of the rains in 2004 caused regional crop failure, social hardship and economic losses (Adamson 2005). The drought caused Thailand's agricultural sector to contract as rice production was hit hard and the production of other agricultural commodities was severely affected.

As well as the agricultural losses which occurred in northeast Thailand, the most recent drought has had a considerable impact throughout the LMB, highlighting the vulnerability of both the production system and related livelihoods. In Viet Nam, more than 10,000 ha of the winter–spring rice crop were adversely affected by saltwater intrusion in the delta because of lower than normal flows in the Mekong mainstream. In Cambodia, not only did the 2004 wet season end early, but the 2005 wet season did not commence as usual in May, delaying the planting of the rainfed rice crop, affecting an estimated 30 per cent of the country's farmland (including 500,000 ha of paddy rice). However, the below average flows over this period were not unprecedented or even that exceptional, and were regarded as entirely due to the natural drought process (Adamson 2005).

Although the 2004–2005 drought can be associated with atypical meteorological circumstances, there is a need to both analyse and communicate the causes and effects of particular drought events, and to distinguish between natural and man-made phenomena (Adamson 2005). Shortfalls of water supply in irrigated agriculture, for example, can be triggered by two important man-made processes: (i) the establishment of water storage infrastructure and irrigation systems in river systems that have already been developed close to their potential, thereby creating water demand that cannot be met, and (ii) by a shortage of water experienced by farmers who increasingly need to grow a second crop on an area that tends to be reduced from one generation to the next (Molle and Floch 2008). Invariably, both natural causes and man-made dimensions of shortfalls in water supply need to be understood if effective coping strategies are to be designed to decrease the vulnerability of mostly rural communities engaged in agricultural production.

The complete failure of rains in 2004 caused regional crop failure, social hardship and economic loss.

Table 3.4.4 Annual drought frequency, Lower Mekong Basin, 1950–2004

Country	Annual drought frequency
Lao PDR	0.42
Thailand	0.45
Cambodia	0.34
Viet Nam	0.30

Figures represent the ratio of the number of severe drought years (one or more droughts anywhere in the country) to the total number of years in the period 1950–2004 (IRRI 2007).

The costs of drought

The principal costs of drought in the LMB relate to the impact of agricultural drought: reduced yields or total loss of crops, especially rice, together with reduced livestock and fishery yields. In the Cambodian dai fishery, for example, the average annual take over the period 1998–99 to 2007–08 was 22,900 tonnes per year. However, in the drought years of 1998–99, 2003–04 and 2007–08 the annual fish take fell to about 10,400 tonnes per year, a loss of some US$14.5 million (MRC 2009b). The significance of hydrological drought on the yields of other fisheries has not been assessed. Drought adversely affects livestock, leading to shortages of fodder and water, which in turn lead to stressed animals that lose weight and are more prone to disease and possible death. The cost of droughts to animal husbandry has not been estimated.

Droughts also impose a variety of social costs, including loss of income, food and water shortages, increased susceptibility to disease, and additional hardships (Helmers and Jegellos 2004).

The average annual cost of drought in northeast Thailand was estimated at US$10 million per year. However, this is likely to be an underestimate, as the defined 'drought event' is based on monsoonal rainfalls over a seven-month period. An analysis based on one, two or three-month drought events, especially at critical crop stages, would be expected to identify a greater number of 'drought years' and hence a higher drought cost.

During the period 1998–2005, Viet Nam experienced eight droughts, three in the wet season and five during the dry season (Table 3.4.5). Of these, four affected the Mekong Delta.

The first drought of 2002 was a dry season drought that occurred from February to April. Some 70,300 ha of the delta were affected, with crops lost from 17,800 ha (25 per cent of the affected area). Crop losses in the Mekong Delta accounted for about one-quarter of the national crop loss and, based on these figures, the cost of this drought to the delta can be estimated as US$24 million (US$1350 per ha of crop loss). The 2004–05 drought was severe in all four riparian countries. The 2004 wet season finished early, causing widespread failure of the autumn rice crop, especially in the Mekong Delta, where low stream flows allowed ocean salinity to penetrate further upstream than normal, significantly reducing dry season irrigation supplies. More than 104,000 ha of rice was damaged in the delta. Ben Tre was the worst affected province, where 7000 ha of rice and 15,000 ha of fruit orchards worth US$33 million were destroyed. As well, more than 82,000 families were forced to buy water. The total drought damage bill to the delta was US$42 million (MARD 2005).

In Cambodia, the 2004–05 drought was the worst in recent times, with 14 out of 24 provinces affected; rice production fell in all provinces and half a million people were reportedly facing food shortages. The situation in Cambodia was exacerbated by the late start to the 2005 wet season (FAO 2005).

The drought was especially severe in Thailand, where 63 of the nation's 76 provinces were affected. Countrywide, some nine million people suffered and irrigation use was restricted (and even prohibited) to conserve water for domestic consumption. The estimated cost to the nation was US$193 million (FAO 2005). No specific figures were available for the Khorat Basin.

In Lao PDR, the drought was less severe than in the other countries. The 2004 wet season crop was larger than in 2003, providing a buffer for the dry season drought. Reduced rainfall and low stream flows led to a 25 per cent reduction in dry season plantings. (FAO 2005). The annual stream flow deficit at Vientiane and Kratie was about 15 per cent.

Assessing the cost of drought

The effects and cost of drought on rice production in northeast Thailand have been comprehensively assessed by IRRI (2007). The northeast region was divided into three zones based on rainfall and drought risk, the highest rainfall (and lowest drought risk) zone being in the east along the Mekong River and the lowest rainfall (and highest drought risk) zone being in the west in the rain shadow of the Phang Hoei Range. (In statistical terms, the 'drought years' of the IRRI study correspond to 'severe' or even 'extreme' rainfall deficit events). Drought is more likely to occur in the late monsoon season (rainfalls are more variable), when it interferes with the 'setting' of rice. The longer the drought period and the greater the area being considered, the less likely a drought is to be registered because of the averaging of rainfall over time and area. The study found that drought in the northeast region could be quite local at times, affecting only one or two provinces. In overall terms, the effect of drought was found to reduce average annual rice production in the northeast region by some 78,000 tonnes per year or 1.2 per cent of average annual total production (6.77 Mt). The associated average annual cost of this loss of production was US$10 million per year.

In the second part of the study, a detailed survey was undertaken of farmers' response to drought and the effect of drought on household income. Some 300 farming households from 15 villages across the three zones were surveyed. It was found that during drought years, farmers reduced the planted area of rice by 21 per cent compared to 'normal' years (these and following figures relate to the northeast region as a whole). When coupled with the reduction in yield caused by the drought (45 per cent), this resulted in a 56 per cent loss in rice production in a typical drought year, which translated to 12 per cent of total household income based on average income. However, for the lowest income quartile, a drought year results in the loss of 31 per cent of average household income.

Although information about the cost of droughts is incomplete and may underestimate total costs, the estimated costs are still significant. In terms of drought impact on rice production, the average annual cost to northeast Thailand has been estimated at US$10 million per year. This figure is comparable with the average annual cost of flood damage in northeast Thailand. Given the relatively high frequency of severe drought in the LMB, it is expected that the average annual cost of drought will be greater than the average annual cost of flooding, perhaps significantly so.

Table 3.4.5 Details of droughts in Viet Nam, 1998–2005

Year	Drought details			Extent of drought	National cost (US$ M)
	No.	Duration (months)	period		
1998	1.	5	Dec[a]-Apr	whole country	385
	2.	4	May–Aug	central areas	-
1999	1.	4	Dec[b]–Apr	Red River & Mekong Deltas	-
2002	1.	3	Feb–Apr	central & southern areas	91.2
	2.	3	May–Aug	central areas	50.0
2004	1.	3.5	Jan–Apr	northern areas	-
	2.	5	Jul–Nov	central & southern areas	-
2005	1.	6	Nov[c]–Apr	central & southern areas	110

Flood and drought risk

The risk of flood can be reduced (managed) by reducing the probability or hazard of flooding, by making land use, infrastructure and assets less damage-prone and by reducing community vulnerability (i.e. increasing community resilience).

Flood risk depends on the severity of a flood and the characteristics of flood behaviour. Deep, fast flowing floodwaters are more hazardous than shallow, slowly moving ones; the greater the area of flooding, the more people affected, and the greater the damage. Flood risk is also highly dependent on land use. In the LMB, major land uses adversely affected by flooding include agriculture, animal husbandry and urban settlements (typically villages).

In the case of drought, 'severity' depends on a number of factors including the timing, duration and spatial extent of the drought, as well as the severity of the various drought markers (rainfall deficit, streamflow deficit and soil moisture deficit). Again, drought risk is highly dependent on the land use and number of people affected. In the LMB, major land uses adversely affected by drought include agriculture (especially rainfed rice), animal husbandry, fishing and urban settlements.

Most communities in the LMB are exposed to the risk of drought but unlike floods, droughts do not physically damage community infrastructure and assets. Whilst a range of structural measures are available to reduce flood risk, the provision of irrigation supplies is the only day-to-day structural measure available to reduce drought risk in the LMB.

Flood risk management

The management of flood risk in the LMB is the statutory responsibility of the four riparian governments, each of which has different priorities and different capabilities regarding provision of flood risk management services. The broad categories of management measures used to reduce flood risk are: land-use control, development and building controls, regional flood emergency planning (collectively known as 'non-structural measures') and structural works.

There is no single solution to the future management of flood risk in the LMB. Flood risk cannot be eliminated and management requires local initiatives to increase the resilience of flood-prone communities and so enable them to better live with floods. Importantly, any proposed risk management scheme must be able to preserve the beneficial effects of flooding.

Improved land-use zoning is important but of limited effectiveness as population pressure and the fertility of the floodplains ensures that there will always be a large population exposed to flood risk, especially in Cambodia and the Viet Nam delta. Nonetheless, land-use zoning can reduce local flood risks and assist in the preservation of wetlands while the flood hazard maps used for zoning are essential for planning flood emergency management measures.

Flood-proofing (building and development controls) can reduce, but not eliminate, the impact of floods on buildings and infrastructure. Village-raising, which is occurring in the Viet Nam delta, is a relatively cost-effective local flood risk management measure with minimal environmental impacts. It has considerable potential as a low-key future risk management strategy.

Although, superficially, structural risk management measures that 'control' floodwaters appear attractive, even the construction of very large reservoirs in the upstream parts of the Mekong Basin has little effect on the risk associated with major floods, especially in Cambodia and the Viet Nam delta. The reduction in flood levels progressively declines along the river as upstream mitigation effects dissipate and additional tributary inflows enter the river (Hoanh et al. 2010).

Flood protection embankments can be very effective on a local scale but regional schemes hundreds of kilometres long may have unacceptable impacts because they raise flood levels elsewhere (MRC 2007b).

There is some prospect for reducing flood levels by enlarging waterway openings through road and rail embankments. Inadequately sized waterway openings can cause a significant increase in flood levels upstream (MRC 2007b).

Regional and community-based flood emergency planning centred on prevention, response, relief and recovery activities will remain an essential element of future flood risk management endeavours in the LMB. Poverty reduction, livelihoods enhancement and education programs will all help alleviate flood risk by making flood-prone communities less financially vulnerable and by providing children with the opportunity to live and work elsewhere. Thus, future flood risk management in the LMB is expected to comprise a variety of small-scale local initiatives to increase community flood resilience rather than grand one-off schemes.

Drought risk management

A limited range of options is available to reduce future drought risk in the LMB and will probably include a combination of small and large-scale measures. Small-scale measures include a change to drought resistant strains of rice and, possibly, the construction of small local water storages to tide farmers over the dry season. It is unlikely that any large-scale water storages will be constructed solely for irrigation in the LMB. However, major storages, both on the mainstream of the Mekong and across tributaries, proposed for hydropower generation will increase dry-season flows and thus provide a more reliable source of potential dry-season irrigation water to be tapped by small and possibly large-scale pumping stations. Despite this, many areas of the LMB, possibly large areas, will remain drought-prone in the future and regional and community-based drought risk management planning activities are expected to continue to play a major role. Drought forecasting is also expected to play an increasing role in future drought risk management in the LMB.

3.5 CLIMATE CHANGE IN THE LOWER MEKONG BASIN

The main issues related to climate change in the LMB are the possible impacts and adaptation to the changes that may occur.

The fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2007) and the IPCC Technical Paper on Climate and Water (Bates et al. 2008) outline current understanding of the climate change impacts on water resources. These include changes in weather patterns affecting temperature, rainfall and wind in terms of intensity, duration and frequency. The mega-deltas of the big river basins in Asia are considered particularly vulnerable because of the combination of increased fresh water flow, sea level rise and large populations. The time horizon of the expected changes implies that climate change may be fully felt 20–30 years from now.

Many of the impacts envisaged by the IPCC can be expected to affect the Mekong Basin. The projected weather pattern changes point to increasing variability, e.g. less rain during the dry season and more rain during the wet season and more frequent extreme weather events, although with regional differences within the basin (Eastham et al. 2008). Seasonal water shortages and floods may become worse, as may saltwater intrusion into the Mekong Delta due to storm surges and sea level rise (Carew-Reid 2007; SIWRP 2008). Impacts of such changes are expected to affect natural ecosystems and agriculture, and exacerbate the challenges of satisfying increasing food demands from growing populations (Hoanh et al. 2003).

Planned developments in the LMB over the next 20 years in combination with climate change will affect the hydrology, the environment and people's livelihoods. In some areas this will exacerbate the challenges of dealing with climate change and in other areas developments can counteract climate change impacts. Climate change adaptation has to be seen in this context, ensuring cost-efficient solutions.

Greenhouse gas emissions from the LMB

Until recently, the global discussion on climate change focused mainly on the causes of climate change: increasing anthropogenic emissions of greenhouse gases and negotiations over mitigation measures and emissions ceilings. The total emissions from the four LMB countries, excluding contributions from land use and land use change, comprise about 1.5 per cent of total world emissions and about 35 per cent of emissions from the ASEAN countries (Table 3.5.1, WRI 2009). The majority of emissions from Thailand and Viet Nam result from activities outside the LMB, e.g. in the major cities and industrial areas. Even though greenhouse gas emissions are increasing in the LMB countries along with economic development, per capita emissions are low compared with other parts of the world.

Cambodia has the lowest per capita emissions while Thailand has the highest. Greenhouse gas emissions relative to GDP (greenhouse gas emission intensity) are higher for Lao PDR than Cambodia, Thailand or Viet Nam. The greenhouse gas emission intensity varies greatly between countries because it expresses a complex mixture of a country's share of energy intensive industries e.g. mining, the proportion of energy derived from coal, oil and gas and its economic structure. The greenhouse gas emission intensity can be a valuable indicator to assess a country's direction and rate of change. A decline can demonstrate that even if a country is increasing greenhouse gas emissions in absolute terms, it is reducing emissions relative to economic growth (WRI 2005). The greenhouse gas emission intensity decreased for all four LMB countries from 2000 to 2005 (latest data) (WRI 2009).

Table 3.5.1 Greenhouse gas (GHG) emissions, per capita and relative to GDP

Country/region	GHG emissions (tonnes CO_2 eqv.)	GHG emissions/ capita (tonnes CO_2 eqv./person)	GHG emission intensity (tonnes CO_2 eqv./year 2000 international US$ million)
Cambodia	22.7	1.6	1131.6
Lao PDR	17.4	3.1	1691.1
Thailand	351.3	5.6	788.7
Viet Nam	176.9	2.1	993.2
ASEAN	1609.4	2.9	747.0
China	7219.2	5.5	1353.6
Europe	5047.7	10.3	387.4
USA	6963.8	23.5	561.7
Russia	1960.0	13.7	1151.4
World	37766.8	5.8	672.3

Data representing 2005 excluding contribution from land use change (WRI 2009). The majority of emissions from Thailand and Viet Nam result from activities outside of the Lower Mekong Basin, e.g. in the major cities and industrial areas.

Climate change projections

Climate change projections are derived from results of global models – the so-called general circulation models (GCMs, see the box opposite). A recent study predicted climate change parameters for 2030 based on the IPCC's Scenario A1B using the GCMs that best simulated past climate conditions in the Mekong Basin (11 out of 24 available model simulations were selected). The study predicted the following average future climate effects for the Mekong Basin:

- a basin wide temperature increase of 0.79˚C, with greater increases for colder catchments in the north of the basin (ranges from 0.68 to 0.81˚C)
- an annual precipitation increase of 200 mm, equivalent to 13.5 per cent, predominantly from increased wet season precipitation, with ranges from -3 to 360 mm
- an increase in dry season precipitation in northern catchments and a decrease in southern catchments, including most of the LMB
- an increase in total annual runoff of 21 per cent, which will maintain or improve annual water availability in all catchments, however with pockets of high levels of water stress remaining during the dry season in some areas, such as northeast Thailand and Tonle Sap Great Lake
- an increase in flooding in all parts of the basin, with the greatest impact in downstream catchments on the mainstream of the Mekong River.

A summary of the estimated potential impacts across the basin, reflecting the commonalities and differences, shows that temperature, annual precipitation and runoff increase across the basin, whereas dry season precipitation and runoff together with associated impacts on agricultural productivity and food availability, vary across the basin (MRC 2009c).

Climate change scenarios and projections

The global climate change projections are based on emission scenarios reflecting different development paths for the world. Four storylines were developed to describe the relationships between emissions driving forces, their evolution and scenario quantification. Each storyline represents different demographic, social, economic, technological, and environmental developments, which may be viewed positively by some people and negatively by others (IPCC 2000).

A1: Low population growth, very rapid economic growth

- A1FI: fossil intensive
- A1T: non-fossil energy resources
- A1B: balance across all sources

A2: high population growth, slower economic growth

B1: low population growth, introduction of clean, resource-efficient technologies

B2: moderate population growth and economic development

The scenarios can be grouped according to greenhouse gas emissions:

- low emission scenarios: B1, A1T
- medium emission scenarios: B2, A1B
- high emission scenarios: A2, A1FI

Climate change projections at the regional scale, e.g. the Mekong Basin, are associated with a range of uncertainties related to the underlying assumptions of the global climate change drivers (expressed in the global IPCC scenarios mentioned above), the selection of scenario for the projection, the uncertainties of the GCMs and uncertainties of regional downscaling of the global modelling results.

Several GCMs exist and the uncertainties related to these simulations are dealt with by considering the range of results from many models and deducing common trends rather than relying on one particular model (Richardson et al. 2009; Eastham et al. 2008). The spatial grids are, however, very large for the global models (grid cells typically 300 km in each direction) and the model cannot reflect regional physical variability.

To consider this and to provide results that are at a sufficient scale for hydrological modelling, various methodologies for downscaling of the global results are used e.g. statistical downscaling or dynamical downscaling (Hoanh et al. 2010) providing data at a scale of typically 20–50 km. This type of downscaling enables more accurate representation of different surfaces such as mountain topography, coastlines, islands and peninsulas. To reduce uncertainty, the downscaling models are adjusted by comparison with historic data (TKK & SeaSTART RC 2009). The trade-off of this type of downscaling is that it is based on results from only one GCM.

The detailed results presented in this section use the ECHAM4 GCM results and the downscaling model PRECIS developed by the Hadley Centre for Climate Prediction and Research. This GCM was one of the 11 GCMs that best simulated the past climatic conditions in the Mekong Basin in the study mentioned above (Eastham et al. 2008). The downscaling and hydrological studies used the IPCC emission scenarios A2 and B2 (TKK & SeaSTART RC 2009; Hoanh et al. 2010). Results for scenario A2 are presented here to illustrate the predicted changes. Results for IPCC emission scenario B2 are referred to in the study reports mentioned.

The effects of climate change on the hydrology of the Mekong River were investigated by downscaling global model results to the regional level of the Mekong Basin, providing more detailed hydrological information based on hydrological modelling (TKK & SeaSTART RC 2009; Hoanh et al. 2010).

A mean annual temperature increase was found across the basin, ranging from 0.4 to 1.2°C, by comparing the average over the period 1985–2000 (representing the current climate) with the average over the period 2026–2041 for IPCC emission scenario A2 (Hoanh et al. 2010). The increased temperature can also be illustrated by the changes in number of annual hot days (maximum temperature above 33°C), which is predicted to increase and the number of annual cool days (minimum temperature below average daily minimum temperature under current climate) which is predicted to decrease (Table 3.5.2). The most pronounced effects are seen in the southern part of the LMB.

An annual mean precipitation increase of 80 mm was found for scenario A2, equivalent to an increase of about five per cent of the annual precipitation for the whole of the LMB. However, large differences are predicted to occur occur across the basin (Figure 3.5.1). The change in wet season precipitation ranges from +133 mm to -35 mm and the changes in dry season precipitation from +54 to -29 mm. An increase in precipitation is predicted, particularly in the northern and western parts of the basin, and a decrease in the southern parts including the delta region and the central parts of Lao PDR from Vientiane and southwest towards the border with Viet Nam.

Table 3.5.2 Changes in number of hot days[1] and cool days[2] comparing the current situation (1985–2000) with future climate predictions (2026–2041) for IPCC emission scenario A2

Location	Number of hot days (1985–2000)	Changes in number of hot days	Number of cool days (1985–2000)	Changes in number of cool days
China–Lao border to Chiang Saen	148	19	167	-3
Chiang Saen to Luang Prabang	116	26	164	-4
Luang Prabang to Vientiane	114	29	219	-16
Vientiane to Mukdahan	117	31	155	-1
Mukdahan to Pakse	154	40	151	-6
Kompong Cham	125	65	174	-31

[1]maximum temperature above 33°C; [2]minimum temperature below average daily minimum temperature under current climate (1985–2000)

Climate change could have both positive and negative impacts on agriculture in the Mekong Basin.

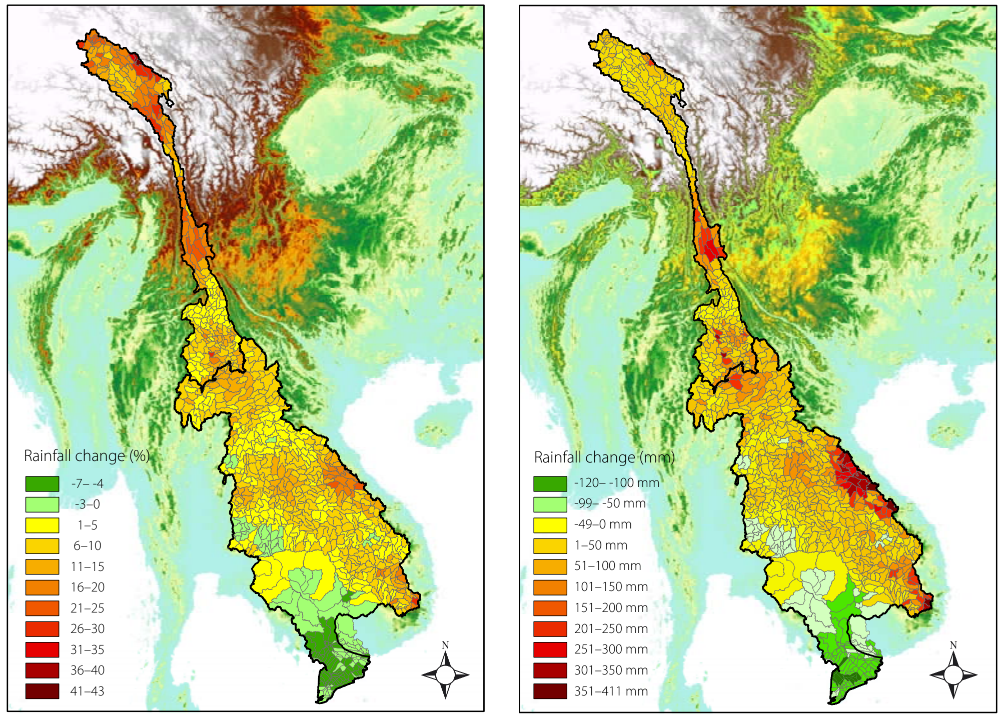

Figure 3.5.1 Change in mean annual precipitation totals comparing the existing situation (1985–2000) with the future (2026–2041) for IPCC emission scenario A2 showing left: mm change and right: per cent change.

Local perceptions of climate change

The GTZ–MRC Watershed Management Project carried out a study to identify the climate change threats, local vulnerabilities and adaptation capacities in two pilot watersheds of the Mekong Basin (Nam Ton, Lao PDR and Stueng Siem Reap, Cambodia). Villagers in 28 villages and more than 10 district officials were interviewed. Watersheds drain areas of 1000 to 10,000 km² and the relationship between natural resources, climate change and livelihoods is more evident here than at the river basin level. It is here that strategic decisions have to be translated into actions on the ground.

Villagers in both the Nam Ton and Stueng Siem Reap watersheds said that they already feel the climate is changing, e.g. an increase in temperature over the past few years. Nam Ton residents also reported an overall increase in precipitation with less rain in the dry season. The villagers in Stueng Siem Reap specifically reported the increasing irregularity of rainfall and its uneven geographical distribution, with a longer monsoon season in the mountainous upstream regions. In both watersheds, mid- season dry spells appear to last longer now than in the past (more than 20 days), which increases the risk of drought. At the same time, high floods have been reported as more frequent. Farmers reported that the start and end of the rainy season has already changed, a shift that affects their rice-farming practices. These observations are not backed up by scientific evidence but illustrate the perceptions and concerns of local people.

The predicted changes in precipitation and temperature would affect Mekong River flow. Mean monthly flow would increase in both the wet and dry seasons (Figure 3.5.2) with most pronounced effects for the dry season in the upper parts of the basin (Chiang Saen) and most pronounced for the wet season in the middle reaches (Kratie and Phnom Penh).

Due to the complex hydrology, areas where precipitation is predicted to decrease may nevertheless experience higher river flows in the future due to the increase in precipitation and flow from upstream. This is particularly clear for the downstream delta parts of the Mekong River. The wet season flow is predicted to increase about 15 per cent in the upstream sections down to Phnom Penh after which the increase is smaller due to the lower increase in precipitation (Figure 3.5.3). The percentage increase in flow for the dry season is about 30 in the upper parts of the river. The predicted lower increase in precipitation in central Lao PDR and in the southern parts of the basin reduces the increase in dry season flows from Vientiane and downstream to about 15 per cent in the delta region.

The increased flow in the Mekong River will increase water availability in the dry season and increase the risk of flooding in the wet season. The low-lying areas downstream of Kratie to the Mekong Delta, including the Tonle Sap Great Lake area, are particularly at risk of flooding. The areas affected by increased flooding due to rainfall and upstream freshwater flow, without considering sea level rise, are shown in Figure 3.5.4 for the extreme wet year of 2000 and a future extreme wet year (2048) for the IPCC emission scenario A2. The area affected by flooding in the future wet year (2048) compared with the extreme wet year experienced in 2000 is estimated to increase by about nine per cent, and the area where the flooding depth is high (more than 2 m) is estimated to increase by almost 40 per cent, meaning that flooding intensity is expected to increase.

In the Mekong Delta the most important factor related to flooding is expected to be the sea level rise. About 30 per cent of Viet Nam's Mekong Delta region would be inundated assuming a 1 m sea level rise, which is expected to occur in 2100 (Carew-Reid 2007). Other attempts to estimate the impacts on the delta region (TKK & Sea START RC 2009) found that the increase in flooding in the Viet Nam delta in an average year for IPCC emission scenario A2 was caused about equally by the increased flow from upstream and sea level rise. During dry years the sea level rise caused most of the changes. Another important factor for the coastal and tidally influenced areas of the delta is changes in the monsoon weather systems affecting the oceanic currents and storms from the sea. It has not been possible to quantify the effects yet.

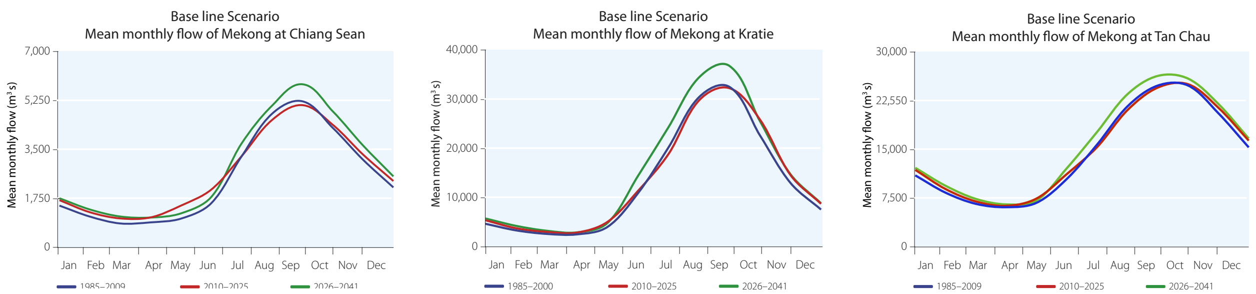

Figure 3.5.2 Mean monthly flow of the Mekong at Chiang Saen, Kratie and Than Cau under current climatic conditions (1985–2000) and future predictions for IPCC emission scenario A2 for the periods 2010–2025 and 2026–2041.

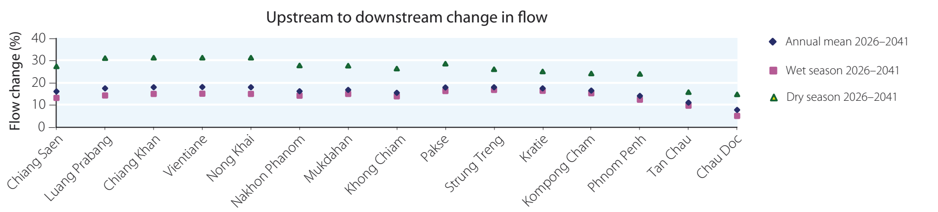

Figure 3.5.3 Change in flow (%) from the upstream part of the LMB to the delta region for IPCC emission scenario A2, comparing the current climatic conditions (1985–2000) and the future climate (2026–2041) for mean annual flow and wet and dry season flow.

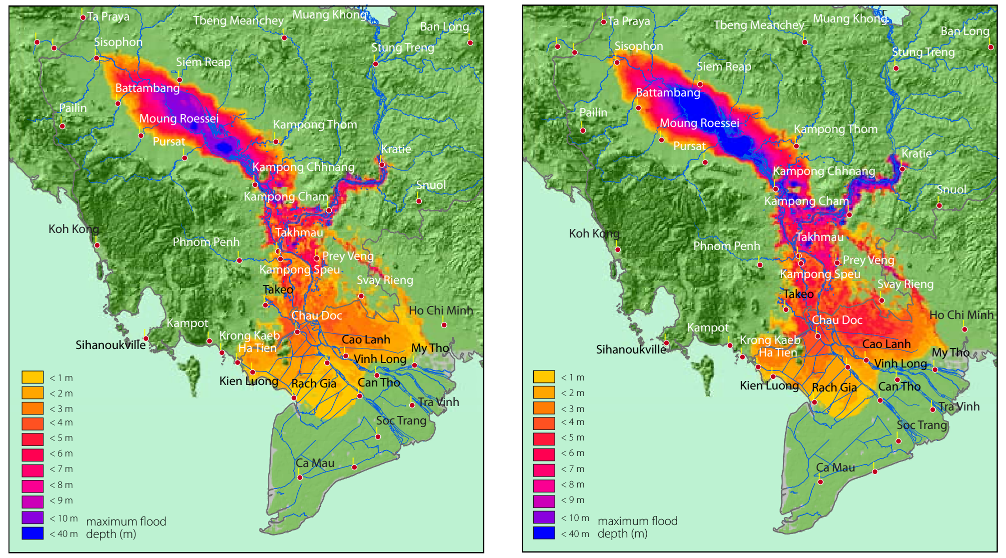

Figure 3.5.4 Flood areas derived from the maximum flood depths for the extreme year 2000 (left) and the future extreme year 2048 under IPCC emission scenario A2 (right) reflecting the effects of increased flow of the Mekong River but not including the effects of sea level rise (Hoanh et al. 2010).

Integrating development and climate change

Climate change is only one of many drivers of change for the LMB. Considerations about adaptation to climate change therefore need to take into account other future changes. Basin development scenarios have been constructed for the LMB based on the development plans of the four riparian countries. A development plan including hydropower and irrigation development looking 20 years ahead, combined with the IPCC emission scenario A2 demonstrates that some of the climate change effects on flow can be offset by development (Figure 3.5.5). The dry season flow will is predicted to increase and the wet season flow to only be slightly higher for the period 2026–2041 compared with the current situation (1985–2000). The main reason is the storage capacity in hydropower and irrigation dams. The results include the existing upstream dams and the dams under construction in the Upper Mekong Basin in China.

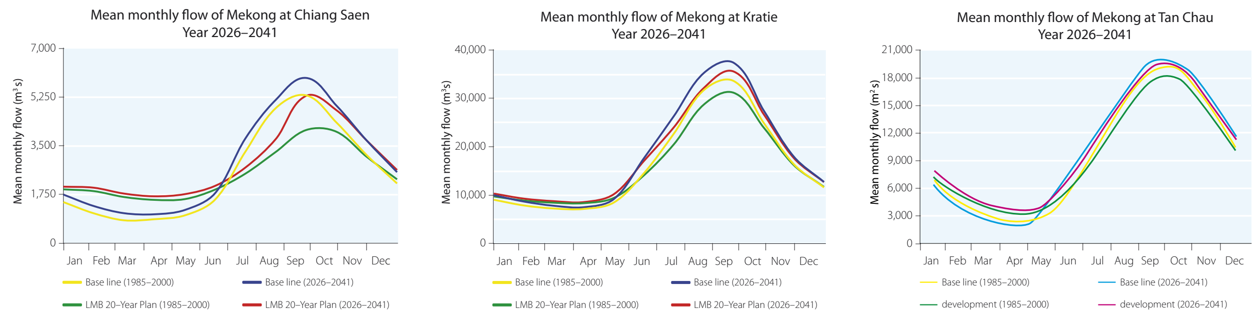

Figure 3.5.5 Mean monthly flow of the Mekong at Chiang Saen, Kratie and Than Cau comparing the current climatic conditions (1985–2000), future predictions for IPCC emission scenario A2 (2026–2041) and the effects of the 20-year development plan under current climatic conditions (1985–2000) and a future climate (2026–2041).

Impacts on ecosystems

The ecological consequences of climate change in the Mekong Basin will largely depend on the rate and magnitude of change in three critical environmental drivers: i) temperature; ii) water availability from precipitation and runoff; and iii) sea level rise. These factors regulate many ecological processes, both directly and indirectly.

Temperature increase

Temperature directly controls many vital life processes and a change in the thermal regime (e.g. extreme temperatures, their duration and seasonal rates of temperature change) can directly regulate rates of growth and reproduction for individual species. It can also change species distribution and important ecosystem processes like primary production, circulation of nutrients and degradation of organic matter (Kiem et al. 2008). Increase in temperature may, for example, enhance eutrophic conditions in aquatic ecosystems by stimulating increased production of e.g. macrophytes, such as *Eichornia* and also result in toxic algal blooms. The increased primary production would change the availability of nutrients and increase the oxygen consumption in bottom water as dead plants are being degraded. Increased temperature also leads to reduced oxygen holding capacity of water, which, together with increased rates of microbial degradation, increases the likelihood of anoxic conditions in bottom waters. Depressed oxygen levels can increase the likelihood of anoxic related kills or chronically stressful hypoxic conditions for aquatic organisms. Since individual species are adapted to a specific range of temperatures, global warming will shift the potential geographic ranges of species to the north or to higher elevations in mountainous regions. Species with low tolerance to warming and limited ability to disperse or acclimate, such as insects, amphibians and reptiles, are the most vulnerable to temperature changes (Deutsch et al. 2008). The synergistic effects of a high rate of endemism and habitat fragmentation may lead to the extinction of some species in the region because dispersal will become extremely difficult (Blate 2009).

Changes in hydrology

A modified seasonal flow pattern in response to climate change will have a strong influence on the future species composition and ecosystem productivity of the Mekong Basin. Species are closely entwined with the seasonal fluctuations of the river. The impacts of climate change in the region are thus transferred to ecosystems and species by alterations to the hydrological cycle (Falkenmark 2007). The lower Mekong floodplains receive more than 93 per cent of the available water resources and 95 per cent of the total suspended sediment flux from upstream and are therefore directly influenced by changes in hydrology upstream (TKK & SEA START RC 2009). In ecological terms, this 'pulse' of the Mekong River and its tributaries is a critical event that drives the high productivity of aquatic and wetland communities. It also helps to sustain a multitude of different habitats whose distribution varies over time. Wetlands have been considered to be among the most vulnerable ecosystems to changes in the hydrological cycle and climate change, partly because of their limited capacity for adaptation (Bates et al. 2008). These ecosystems exist in the transition zone between aquatic and terrestrial environments and can be dramatically affected by slight alterations in hydrology. A combination of increased temperature and decreased precipitation in some areas of the basin may result in decreased runoff and lowered groundwater levels, causing the drying of some wetlands. In other parts of the basin receiving more precipitation a change to more open wetland types may take place. Some plants are obligate wetland plants and will disappear if the wetland is not flooded for at least part of the year. Other facultative wetland plants may not persist without dry periods. Animals associated with wetlands will also be affected if the distribution and characteristics of wetland ecosystems change as a consequence of climate change.

Sea level rise

The third major impact of climate change on ecosystems in the Mekong Basin will be sea level rise. Although this effect is limited to the Mekong Delta, it is still of significant importance to the region, because of the delta's large area and high population density (500 people per km^2). The high population of the delta is supported by highly productive ecosystems such as coastal wetlands and estuaries. This high productivity is related to inputs of fresh water and fluctuating water levels caused by the oceanic tides. The mixing of fresh water and seawater creates water circulation patterns that help to retain nutrients and thus enhance productivity. The movements of many migratory aquatic animals to deeper seawater are regulated by estuarine salinity, which changes as fresh-water inflows mix with tidal salt water. A change in the balance between the fresh-water outflow from the Mekong River and salt-water inflow from the sea, induced by climate change, would thus probably have a major impact on both species distribution and ecosystem productivity of the delta. Fresh-water inputs from upstream areas deliver nutrients that support high production and also large quantities of suspended sediments, which are critical for the accumulation of wetland soils that allow plants to avoid permanent inundation by the sea. Coastal wetland plants thrive in a relatively harsh intertidal environment characterised by alternate flooding and draining of salt marshes with associated waterlogging of soils and depletion of oxygen. Plants have a number of adaptations to cope with these harsh conditions, including aerial roots and submerged tissues that allow them to capture oxygen. But these adaptations work only as long as the average water level remains relatively constant. Accordingly, coastal wetlands exist within a fixed elevation range, where the frequency and duration of inundation by seawater are relatively stable. These plants become progressively more stressed, and ultimately die, if they are inundated for too long (Mendelssohn and McKee 1988) and an increase in water levels due to sea-level rise can severely stress the integrity of coastal wetland ecosystems.

It has been estimated that a one metre increase in seawater levels would lead to inundation of several areas of key importance for biodiversity in the delta (Carew-Reid 2007). U Minh Thuong National Park and Bac Lieu Nature Reserve, for example, would be completely inundated. U Minh Thuong supports one of the last significant areas of peat swamp forest remaining in Viet Nam and is one of the three highest priority sites for wetland conservation in the Mekong Delta. It conserves many rare and endangered species including nine globally threatened or near-threatened bird species (see section 3.2 p. 81).

The predicted increased flow in the Mekong River due to climate change will increase water availability in the dry season and increase the risk of flooding in the wet season.

Climate change impacts on the Tonle Sap Great Lake

The Tonle Sap Great Lake is expected to be particularly sensitive to climate change impacts on river flow, which could alter the area's unique flood pulse system and thus also influence the high aquatic productivity of the lake and the associated floodplains (TKK & SEA START RC 2009). The future flood pulse in the Tonle Sap and the Cambodian floodplains is likely to be wetter with a more extensive flooded area, with longer flood duration and a higher water level during the dry season. Minimum water levels are projected to increase by an average of 0.1 m and maximum levels by an average of 2.3 m (Eastham et al. 2008). The net impact is likely to be complex, with potential for both positive and negative effects. These effects will be superimposed with the effects of developments on the Mekong River, which may counteract some of the expected impacts of climate change.

Because of the likely increase in the lake's minimum area, some of the flooded forest within this area will become permanently submerged and may be destroyed. The forest acts as a buffer protecting the floodplain against erosion under stormy conditions and provides important habitat for fish breeding, feeding and shelter (Baran et al. 2007).

Larger flood volumes have so far been associated with an increase in capture fisheries from Tonle Sap Great Lake. Increased runoff is likely to increase input of sediments, influencing nutrient cycling in the lake and the fertility of cropping enterprises on the floodplain (Eastham et al. 2008). An increased input of nutrient rich sediments combined with a higher water temperature could potentially increase growth rates and stimulate ecosystem production in the lake. For example, aquatic invertebrates at the base of the food web (e.g. aquatic insects) may mature more rapidly, and reproduce more frequently. This could potentially yield more food for fish.

Warmer water and an increased degradation of organic matter in bottom water could, on the other hand, lead to increased areas near the seabed with low oxygen levels. Such negative impacts on suitable habitats for aquatic organisms would have a negative impact on fisheries resources. Increased nutrient inputs may also stimulate growth of aquatic weeds and blooms of toxic blue green algae with, potentially, a negative effect on fisheries production.

Changes in aquatic productivity of the lake would most directly affect the fishing villages, where almost all villagers rely on fishing for livelihoods and food. Fish provide the main source of protein for a large part of the Cambodian population and the Tonle Sap system provides a huge part of the country's fish catch, so the impacts of a potential reduction in aquatic production would likely be felt much further (TKK & SEA START RC 2009).

Clearly, the potential impacts of climate change on the complex ecology of the Tonle Sap Great Lake and its associated floodplains are diverse and interrelated, and require further investigation to elucidate and determine the effects on the ecosystems, people's livelihoods and the economy of the region.

Impacts on livelihoods

People will be directly affected by climate change, experiencing higher temperatures and more flooding as well as indirectly through impacts on their livelihoods, such as agriculture, fisheries and forestry. People are also likely to be affected by more intense storms which are accompanied by strong winds, heavy rain, and high waves (TKK & SEA START RC 2009). These well known weather phenomena are expected to be more frequent and more intense as a result of climate change.

Agriculture

About 80 per cent of the agricultural area of the Mekong Basin is used for growing rainfed rice during the wet season (June/July–Oct/Nov). The remaining area is used for irrigated rice (during the dry season) and other crops (e.g. maize, sugarcane, soybean, cassava)

mainly under rainfed conditions with supplementary irrigation (Eastham et al. 2008).

Climate change can affect agricultural productivity through changes in temperature, CO_2 concentration, rainfall, and rainfall patterns. The increased temperature, CO_2 concentration and wet season rainfall predicted for the Mekong Basin would increase productivity of rainfed rice, while the decrease in dry season rainfall would potentially lead to a fall in irrigated rice production (Eastham et al. 2008). However, as water availability, in general, is predicted to increase, increased water requirements for irrigated rice could mostly be met thus compensating for the decreased rainfall. However, changes in rainfall patterns, such as more dry spells that could affect growth just after planting or heavy rains leading to flooding of paddy fields, would potentially damage rice production. The changes for other crop types are expected to be minimal (Eastham et al. 2008).

Basinwide agricultural production could potentially increase as a result of climate change, based on the predicted changes in rainfall and temperature, but not taking into account the effects of flood damage or dry spells (Eastham et al. 2008).

Fisheries

Warming in the basin could affect fisheries yields either positively or negatively depending on how dissolved oxygen concentrations and aquatic productivity (food availability) respond. The inextricable link between local water temperature and the life history, physiology and behaviour of most freshwater organisms makes most aquatic organisms, especially fish, very susceptible to even small-scale changes in environmental thermal regimes (WWF 2005). For example, a small increase (1–2°C) in temperature may have sub-lethal effects on tropical fish physiology, particularly reproduction.

Higher flows during the wet season are predicted to benefit fisheries. Changes to river flow in response to changing spatial and temporal patterns of precipitation in the basin are likely to have the most profound impact on the basin's fisheries resources. The growth of fish in the LMB is strongly linked to flood extent and duration (Halls et al. 2008). Increasing flows during the flood season will translate to more extensive and prolonged floodplain inundation, potentially increasing overall system productivity including the fish component (Welcomme 1985; Junk et al. 1989). Improved growth can favour survival and reproductive potential. Potential impacts on fisheries are related to spawning and migration. Spawning of many tropical fish species is triggered by rising water levels. Fish that spawn in seasonally flooded areas, for example, experience loss of juveniles entrained in off-channel areas and desiccation of eggs exposed by receding water levels. Changes in river flow could increase the magnitude of juvenile deaths by exposing more eggs to desiccation or, if flow increases, immersing eggs in sediment loaded water too turbid or deep for survival of eggs and juveniles (WWF 2005; Eastham et al. 2008). The most critical impact of a changed flow in the Mekong River is probably the potential effect on migratory fish species. Changes in water flow may disrupt the movements of migrating fish that use water conditions to control their development, time their migration, and orient themselves to navigate effectively. In the Mekong River, a number of factors trigger fish migration that may be sensitive to climate change. These include: i) variation in river discharges; ii) variation in water levels; iii) first rainfalls after the dry season; iv) change in water turbidity or colour; and v) presence of insects (Baran 2006).

Climate change and livelihood strategies in the Mekong Delta

In the Viet Nam delta, the impacts of climate change will be partly felt through changes in the Mekong River Basin and also through an increase in seawater level (TKK & SEA START RC 2009). It has been estimated that by 2050, more than one million people will be directly affected in the Mekong Delta through coastal erosion and land loss, primarily as a result of decreased sediment delivery by the Mekong River, but also through the accentuated rates of sea level rise (IPCC 2007). The Mekong Delta is considered one of the three most vulnerable deltas in the world (Dasgupta et al. 2007) because of the many people who will be affected by these impacts and because of its importance for food production. The delta is known for the vast rice fields that, together with other agricultural and aquacultural products, make up the core of this region's economy. Half of Viet Nam's national production and 70 per cent of its rice exports come from the Mekong Delta (TKK & SEA START RC 2009). Recent climate scenario simulations indicate that the changing climate will pose a risk to the delta's rice production, both through changed rainfall patterns, increased river flow from upstream and increased intrusions of saline water (Dasgupta et al. 2007; TKK & SEA START RC 2009).

Although rice is an aquatic plant which grows well under submerged conditions, deep and prolonged submersion of paddy rice adversely affects plant growth. High yielding varieties are more susceptible to flood damage than the more traditional ones. Thus, the predicted increase in frequency of extreme flood events in the Mekong Delta could have a negative impact on rice productivity (Eastham et al. 2008; TKK & SEA START RC 2009). These adverse impacts could affect all three cropping seasons; main rainfed crop, winter–spring crop and summer–autumn crop unless preventive measures are taken (Eastham et. al. 2008). The extended flooded areas may also affect aquaculture – particularly the shrimp ponds located in the coastal areas of the delta (TKK & SEA START RC 2009).

Both rice fields and natural wetlands are expected to be heavily influenced by changed saltwater intrusions. Currently the dry season tidal conditions in the South China Sea influence the water levels in the Mekong River system to just upstream of Phnom Penh. The extent of the future intrusion of saline water into the Mekong Delta depends on the magnitude of dry-season flows. The hydrological simulations suggest that minimum flows from upstream will increase under the likely impacts of climate change, to some extent potentially counteracting the effects of sea-level rise (Estham et al. 2008; Hoanh et al. 2010).

With more widespread permanent inundation, saltwater intrusion into fresh-water aquifers would significantly increase, threatening much of the water used for irrigation and drinking purposes (Carew-Reid 2007). It would also affect submerged aquatic vegetation, coastal marshes, flooded forests and other wetland types in the delta.

Another consequence of changed river flow and sea level rise is a change in the transportation and deposition of sediments in the delta, which affects how it copes with the physical impacts of sea level rise. In the Mekong River, where human activities have led to increased sediment loads in the past, the future construction of upstream dams may now result in a decreased supply of sediments to the delta. This, together with the sea level rise, may lead to more widespread coastal erosion. Coastal and estuarine wetland habitats may be destroyed if sea-level rise exceeds the rate of vertical sediment accretion. In many parts of the delta, inland migration of coastal ecosystems, in response to increased sea-level rise, may not be possible, because of human structures such as roads, dikes and drainage systems (WWF 2008).

Coastal erosion will also be a major consequence from more frequent storms. Globally, tropical cyclone intensity is predicted to increase as the oceans continue to warm (Solomon et al. 2007). In general, long-term changes in the frequency, intensity, timing and distribution of strong storms would most likely alter the species composition of coastal marshes, as well as the rates of important ecosystem processes such as nutrient cycling and primary and secondary productivity. There could be both positive and negative effects. For example, storms greatly increase the rate of soil accretion in marshes, thereby helping to offset accelerated sea-level rise. Runoff generated by storms introduces fresh water and nutrients that can enhance coastal wetland productivity. On the negative side, storms can reduce the structural complexity of coastal forested wetlands such as mangroves and tidal freshwater forested wetlands. In Ca Mau this problem is exacerbated by the cutting of mangrove forests to make way for shrimp farms (SIWRP 2008). Fresh water forested wetlands of the Mekong Delta are also slowly being degraded and disappearing because of human activity. Efforts are being made to re-establish stands of *Melaleuca* forests, however the successful establishment and growth of new trees could be affected by increased flooding and rising seawater levels.

Source: GTZ-MRC Watershed Management Project

Adaptation to climate change

The following sections provide an overview of the major adaptation activities being carried out by each of the LMB countries. The information is not exhaustive and focuses on those activities whose main theme or objective is climate change adaptation. Numerous other activities in LMB countries are contributing to climate change adaptation through other objectives such as reforestation or poverty reduction.

Cambodia

With support from various donors, Cambodia has implemented a number of projects to address climate hazards through natural disaster management response projects. During the period 1995 to 2003, Cambodia implemented 98 such projects to address institutional strengthening, infrastructure development and human resource development. However, surveys carried out during preparation of the Cambodian National Adaptation Programme of Action to climate change (NAPA) indicate that, overall, the preparedness to respond to extreme climate events is low, as is adaptation capacity to climate change (MOE, 2005a, b). There are cases where local communities are resourceful when dealing with climate hazards, but these are exceptions and usually coincide with settlements with higher socioeconomic standing and stronger local institutions. The Cambodian NAPA outlines 39 adaptation activities to be carried out within the following areas: coastal zone, health (malaria), water resources/agriculture, cross-sectoral and multiple hazards (MOE 2006). Of these proposed activities, 20 have been identified as high priority. Two years after the completion of the NAPA and its approval by the Royal Government of Cambodia, only one project – on water resources management – has been approved for funding by the Least Developed Countries Fund. The government has been unable to attract donor interest in financing the implementation of other high priority adaptation activities. The NAPA identified a number of barriers to the implementation of climate change adaptation projects in Cambodia. These include:

- inadequate technical, financial and institutional capacity of local communities in dealing with climate hazards, and limited coordination among them
- limited integration of climate-change issues into national policies and programmes
- limited awareness of climate-change issues.

Lao PDR

The NAPA for Lao PDR, which was launched in 2009, was prepared with support from UNDP (WREA 2009). It identifies 45 priority projects across the four sectors of agriculture, forestry, water and health. The process of developing the NAPA in Lao PDR not only identified a number of projects but also stressed the way forward for the Lao Government to continue to:

- strengthen the capacity of the National Disaster Management Committee to deal with likely future adverse impacts
- strengthen the Climate Change Office
- install a flood early warning system
- initiate in-depth studies of the impacts of climate change, especially concerning droughts and floods
- formulate a strategy on climate change
- mobilise increased reforestation

The government is implementing a number of adaptation activities through the frameworks of water resources, forestry, infrastructure development and disaster preparedness policies. These projects include embankments for flood protection, water drainage systems and irrigation systems to respond to potential impacts of floods and drought.

Adaptation needs suggested by farmers in pilot watersheds in Cambodia and Lao PDR

In Nam Ton watershed in Lao PDR, people emphasised the need for reforestation, development of agriculture and improvement and extension of water infrastructure (for irrigation and households). They also pointed out the need for better roads to access markets and for support in animal rearing. Specific requests in Nam Ton, Lao PDR:

- water infrastructure (domestic and irrigation)
- agricultural extension for animal rearing
- reforestation
- income diversification (weaving)
- road maintenance
- fish ponds

In Stueng Siem Reap, Cambodia, suggestions to increase the adaptive capacity to climate change refer to improvements in the health sector and veterinary system and to more agricultural extension to help reduce use of pesticides in rice and vegetables, and for forest and wetland protection. In the area of health care, people suggested that there should be more health centres and that health staff should be better trained. Fishing communities suggest an early flood warning system. Improvement of water infrastructure (drinking water and irrigation) and sanitation was also suggested, as well as a clearer demarcation of forest land to prevent further land encroachment. Specific requests were:

- health care
- agricultural extension
- support for animal husbandry
- forest, wetland and biodiversity protection
- demarcation of forest land
- water infrastructure
- early warning systems for fisheries communities

Thailand

Thailand has a long history of implementing adaptation and mitigation measures. Past efforts have dealt with promoting better management and conservation of natural resources in various sectors and promoting energy security, both with and without linking them directly to climate pressure and greenhouse gas emission reduction within various areas:

- water resource management and the agricultural sector
- natural disaster management
- restoration and conservation of biological diversity and forest resources
- management of carbon sources
- promotion of carbon sinks
- clean development mechanism (CDM) projects

Within different sectors, a range of approaches, particularly structural interventions like large-scale irrigation for agriculture and flood protection and warning systems, have been researched and developed. Traditionally, farmers have implemented a number of practices to adapt to climate variability, such as inter-cropping, mixed cropping, agroforestry and animal husbandry. Over the years Thailand has also implemented both surface water and groundwater irrigation and diversification in agriculture to deal with drought as well as structural and non-structural measures to cope with flood and drought. Several community-based adaptation measures to climate change, variability and extreme events have been or are being implemented in Thailand. Most of these are small-scale activities which concentrate on agriculture, water and natural disaster amelioration. Most of the community-based adaptation projects have an emphasis on livelihood of the affected community, diversification of agriculture, conservation of water and awareness raising to change practices.

Viet Nam

To date, national adaptation strategies in Viet Nam have focused on reducing the risk of disasters. They include a series of measures such as the establishment of disaster forecast centres across the country and awareness raising activities. However, these strategies focus on emergency responses to short-term climate extremes and reconstruction afterwards, rather than long-term adaptation to future climate change. They are also not integrated into wider policies for sustainable rural development and poverty reduction.

As part of Viet Nam's National Target Program to Respond to Climate Change (Government of Viet Nam 2008), a detailed program of adaptation activities for various sectors and regions is proposed. An 'Action Plan Framework for Adaptation to Climate Change in the Agriculture and Rural Development Sector Period 2008–2011' has been prepared, which demonstrates clear efforts to link disaster management with climate change adaptation activities (MARD 2008a). The objectives of the plan are to enhance the government's capabilities of adaptation and mitigation to climate change in order to minimise adverse impacts and to ensure sustainable development of the agriculture and rural development sector. The plan focuses on:

- ensuring the stability and safety of residents in cities and different zones and regions, especially the Mekong and Red River Deltas and central and mountainous areas
- ensuring stable agricultural production and food security in an agricultural area of 3.8 million ha with two seasonal rice crops
- ensuring the maintenance of dike and infrastructure systems to meet disaster prevention and mitigation requirements.

National and local authorities in the Mekong Delta are beginning to integrate climate resilient policies into wider programs of coastal zone management. In some areas of the delta, dikes are being strengthened or heightened, mangroves are being planted to improve protection from storm surges and houses are being built on bamboo stilts. Already, major investments have been committed to upgrading national and provincial dike systems. The Ministry of Agriculture and Rural Development is carrying out a national plan worth US$109 million to restore mangroves along Viet Nam's coastline. Other adaptation activities are being implemented as part of the National Strategy for Disaster Prevention, Response and Mitigation 2020 (MARD 2008b). This includes various mandatory requirements for flood safety and security in residential areas, including to raise house foundations and make them more flood secure.

Policy and institutional responses to climate change

All LMB countries have ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Each country has a primary policy document which outlines its strategy and responses to climate change. In Cambodia and Lao PDR, this takes the form of a National Adaptation Program of Action to Climate Change (NAPA). Thailand has prepared the 'Strategic Plan on Climate Change (2008–2012) and National Master Plan on Climate Change (2010–2019)' and Viet Nam has prepared the 'National Target Program to Respond to Climate Change'. In general, climate change issues are not well integrated into the broader policy frameworks of national governments (MRC 2009c)

Each of the LMB countries has nominated a national focal point for climate change issues. Within Cambodia, it is the Ministry of Environment, in Lao PDR, the Water Resources and Environment Administration and, in Thailand and Viet Nam, the respective Ministries of Natural Resources and Environment. All countries have established a high level governmental body with responsibility for the development of climate change policy and strategies. Cambodia has established the National Climate Change Committee, Lao PDR has established the National Steering Committee on Climate Change, Thailand has established the National Board on Climate Change Policy and Viet Nam has established the National Climate Change Committee.

The Mekong River Commission in 2009 launched a regional initiative on climate change and adaptation designed to address the shared climate change and adaptation challenges of the Lower Mekong Basin (MRC 2009d).

Projected weather pattern changes point to increasing variability, including more rain during the wet season and more frequent extreme weather events.

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4
ECONOMIC STATUS AND TRENDS

4.1 THE MACROECONOMY OF THE LOWER MEKONG BASIN

Among the LMB countries, Cambodia, Lao PDR and Viet Nam have made significant progress since launching their economic reform programs in the late 1980s and early 1990s; while Thailand has experienced steady growth since the 1960s. The LMB has a relatively stable macroeconomic environment with a fast growing economy since the early 2000s. LMB countries have made rapid strides towards regional market cooperation and integration into global markets. Their growth and export performance over the past decade and a half have been particularly impressive. However, there is still a significant development gap between countries in the LMB. Thailand is the largest economy, while Viet Nam has become the fastest growing and is expected to rank second after China in terms of growth prospects in the Mekong region. The incidence of poverty has fallen rapidly over the whole LMB; yet income inequality between urban and rural areas remains a major issue and challenge for governments (RIS 2007).

Despite the positive outlook for the LMB economies, a number of challenges remain if they are to fulfil their development potential and overcome the impact of the global financial crisis – even though this impact has been much less than in western economies. These challenges include to diversify the economies, improve efficiency and legal structures that have hindered business development, and to continue investment in infrastructure and expansion of human resource development, especially the skilled labour force, particularly in Cambodia and Lao PDR. Expanding public expenditure while balancing growth and inflation is relevant for Viet Nam. Restoring investor confidence through political stability and bolstering expenditure with expansionary policies are important challenges for Thailand.

With improved cooperation in the Mekong Basin, trade and investment should increase as these countries are rich in natural resources, especially in the potential for using Mekong water to enhance economic growth and development. The following sections describe the macroeconomy of the LMB countries.

Pace of economic development in Cambodia

Cambodia's economy grew rapidly from the early 2000s with a growth rate of 11.1 per cent from 2004 to 2007 (Figure 4.1.1). This strong growth was supported by increases in clothing exports, tourism, real estate development and agricultural production. Growth continued into the first half of 2008 before the economy suffered under the combined effect of political instability in Thailand and the global financial crisis. These factors contributed to slow growth and double digit inflation in late 2008 to early 2009, due to a surge in the price of imported commodities, especially oil and food items.

Cambodia's economy is heavily 'dollarised', i.e. foreign currency is freely used in the market to supplement the country's own currency. Because the country shares an open border with Viet Nam and Thailand, price developments in Cambodia would be expected to be heavily influenced by those countries – its two most important trading

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The Mekong Basin is rich in natural resources, especially in the potential for using Mekong water to enhance economic growth and development.

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Future cross-border power trade depends on what the Mekong countries specify in their individual power development plans.

partners. International food inflation for example, is passed on completely to Cambodia by its main trading partners (Ginting and Bird 2009). The underpinning situation of rising commodity prices was fuelled by an increase in commercial bank lending and wealth effects from earlier rises in real estate prices, stimulated by increased levels of consumer imports and contributing to inflation pressures (ADB 2009a). Inflation rose from more than six per cent in September 2007 to a peak of 25 per cent in May 2008, driven largely by a global surge in oil and food prices. Linked to the dollarised economy, a depreciation of the riel and the US dollar against trading partner currencies contributed to imported inflation, while rising domestic demand contributed to domestically generated pressures (ADB 2009a).

Cambodia is moving towards an open market economy and market integration within the region, reflected by its membership of organisations such as ASEAN, AFTA and the WTO.

The current GDP per capita has increased from US$260 in 1993 to US$648 in 2007 (Figure 4.1.2). At the same time, the poverty rate fell by 1.2 per cent annually from 1994 to 2004. With a high annual population growth rate of 2.5 per cent, the country faces many challenges to reduce poverty (RIS 2007).

Although about 70 per cent of the labour force is engaged in farming, Cambodia is moving gradually from agricultural based-production to mixed small industries and service sectors. The shared percentage of GDP by sector (Figure 4.1.3) indicates that the service sector contributed the greatest share (>40 per cent) to GDP in 2007 while industry and agriculture each contributed almost 30 per cent to GDP. This has changed since 1993 when agriculture was the dominant sector contributing almost 50 per cent to the GDP, while the industry and service sectors contributed a relatively small share.

Despite all the positive signs of economic development in Cambodia, the country still faces great challenges to diversify the economy and reduce poverty. As income becomes skewed toward the urban population, it creates income inequality between urban and rural populations. The economic downturn has made the government's efforts to reduce poverty more difficult. Reducing inflation in the short term and introducing policies and reforms to sustain strong growth in the medium and long term will be important to address the problem. The most effective way to reduce poverty is to focus on rural areas where 80 per cent of the poor population live, working in farming or fishing. Policies to help the poor should emphasise agriculture and rural development (ADB 2009b).

The Royal Government of Cambodia is taking steps to tackle the global financial crisis, for example, US$1 billion will be invested in the transportation, infrastructure and irrigation projects in 2009 and about US$2.8 billion will be spent in 2010–2012 to create jobs, especially in labour-intensive industries (Chhun 2009a; Chhun 2009b).

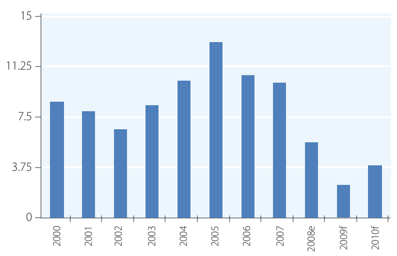


Figure 4.1.1 Cambodia's GDP growth rate (% annual). *Source*: World Bank Database 2009 and Asian Development Bank 2009; e, expected; f, forecast.

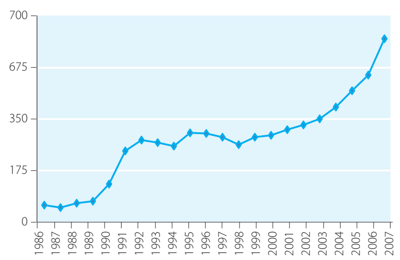


Figure 4.1.2 Cambodia's GDP per capita at current price (US$). *Source*: IMF Database, April 2009.

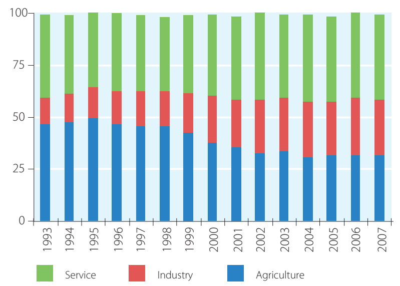


Figure 4.1.3 Cambodia's percentage of GDP by sector. *Source*: World Bank Database, 2009.

Pace of economic development in Lao PDR

Economic reforms since the early 1980s have contributed to positive GDP growth. Trade reform has been underway since 2008 as the Government of Lao PDR prepares to join the World Trade Organization (WTO) in 2010 with the formation of a new body to coordinate the effort and to oversee associated trade-related reforms. The government has made substantial progress in terms of economic performance. A GDP growth rate of 7.3 per cent was recorded for the period 2004–2008 (Figure 4.1.4), which included strong industry expansion, including mining and hydropower. However, the combined effect of political instability in neighbouring Thailand and the downturn due to the global financial crisis have affected the clothing industry, trade, tourism and foreign investment to slow GDP growth to below six per cent in 2009. Growth is expected to remain relatively strong, driven by ongoing hydropower projects, agro-processing industries, construction and other services (ADB 2009a).

Inflation has fallen to below 10 per cent after peaking at 10.3 per cent in 2008 (see Figure 1.7.3). To tackle inflation, the government has frozen the price of imported products such as petroleum and other commodities, imposed a ban on exports of glutinous and staple rice and regulated the price of other consumer commodities (ADB 2009a). As the government takes firm steps in revenue policy and administrative reforms, including the centralisation of tax collection to the central government from the provinces, a strong revenue performance could balance the deficit (World Bank 2008). As well, the government increased expenditure on health, education and funding of the Southeast Asian Games which were held in Vientiane in December 2009. Also, the 450th anniversary celebrations for Vientiane as the capital in 2010 will contribute to growth and provide many jobs during the time of the transition out of the global financial crisis.

The GDP per capita at current price increased from US$151 to US$674 during the period 1988 to 2007 (Figure 4.1.5), which represents an annual increase in income per capita of US$28. Since the Lao economy remains largely agricultural, with more than 70 per cent of the labour force employed in this sector, the GDP itself relies heavily on a good harvest.

Over the past two decades, agriculture accounted more than 50 per cent of GDP, while the industry and service sectors had a relatively small share (Figure 4.1.6). However, agriculture's contribution to GDP has fallen to about 42 per cent, while industry's contribution has increased (from about 15 per cent in 1989 to more than 30 per cent in 2007) due to the mining of copper, gold, other minerals and hydropower development. The services sector remains unchanged, contributing about 25 per cent to GDP.

Despite prospects of economic growth above seven per cent from 2003 to 2008, poverty has fallen by less than one per cent

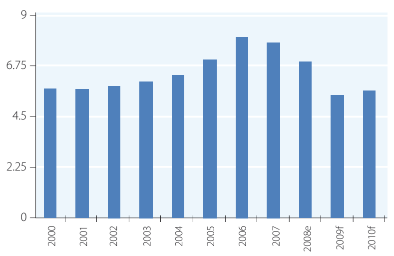


Figure 4.1.4 Lao PDR's GDP growth rate (% annual). *Source*: World Bank Database 2009 and Asian Development Bank, 2009; e, expected; f, forecast.

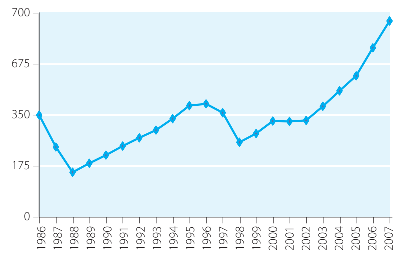


Figure 4.1.5 Lao PDR's GDP per capita at current prices (US$). *Source*: IMF Database, April 2009.

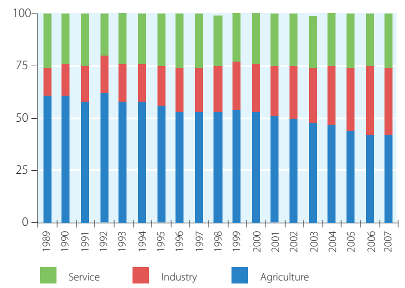


Figure 4.1.6 Percentage of GDP by sector (Lao PDR). *Source*: World Bank Database, 2009.

annually from 2002 to 2008. Several constraints hinder growth and job creation in the private sector, including poor infrastructure, cumbersome regulations, limited availability of skilled labour and finance and inadequate land security (World Bank 2009a).

The great challenge for the government is to maintain economic growth through diversifying the economy, stabilising the financial base and sustainable natural resource development, including mining, hydropower and agriculture.

Pace of economic development in Thailand

After a rapid recovery from the Asian financial crisis in 1997–1998, Thailand's economy experienced an average GDP growth rate of five per cent from 2000 to 2007 (Figure 4.1.7), with an increase in GDP per capita from about US$700 to almost US$3000 (Figure 4.1.8). Trend analysis of the GDP by sector shows that the service sector contributed almost 50 per cent of GDP since the early 1960s, remains strong over time and has played a significant role in improving the standard of living in Thailand (Figure 4.1.9). Industry has expanded gradually from a share of about 20 per cent of GDP in the 1960s to almost 45 per cent of GDP in 2007. This healthy and fast growing economy has contributed to job creation and become an attractive place for migration from other parts of the region. The contribution of agriculture to GDP has steadily declined. The shift from the agricultural base to the industry and service sectors is part of the transition from a developing to a developed economy.

The global financial crisis combined with some political instability in recent years has led to a fall in investment and slowing in demand leading to a fall in GDP growth to 2.8 per cent in 2008 down from 4.8 per cent in 2007. Further, the GDP fell to minus two per cent in 2009 (Figure 4.1.7). According to the Thailand Economic Monitor (2009), the outlook for private investment remains negative, with recovery primarily dependent on a recovery in global demand, which is not expected until 2010. Private consumption is also expected to be generally flat due to low consumer confidence and worsening labour market prospects.

During the crisis Thailand experienced low inflation while other LMB countries experienced rising high inflation. This is due to lower energy prices in Thailand and the slow growth in the economy. In 2008 inflation was recorded at 5.5 and it fell to 0.5 in 2009. In the first five months of 2009 commodity prices fell 1.1 per cent from the same period in 2008, mostly driven by energy prices, which were about 25 per cent lower, as well as energy-related prices such as transportation, vehicle operation and utilities (World Bank 2009b). The Thailand Economic Monitor (2009) reported that increased excess capacity in the economy and a stable new level in global oil and food prices in 2009 will maintain core inflation (excluding fresh food and energy) below one per cent.

From the mid-1980s to the mid-1990s, GDP per capita tripled from US$1000 to US$3000. Immediately before the global financial crisis, GDP per capita reached almost US$4000. Thailand is the fastest growing economy in the LMB and during the last decade became one of the 'ASEAN-4' tiger economies (with Indonesia, Malaysia and Philippines).

Some of the challenges for Thailand's economy are to improve its infrastructure development, reduce heavy regulatory burdens and increase the skilled labour force.

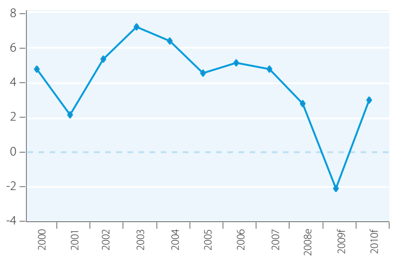


Figure 4.1.7 Thailand's GDP growth rate (% annual). *Source*: extracted from the World Bank Database 2009 and Asian Development Bank, 2009; e, expected; f, forecast.

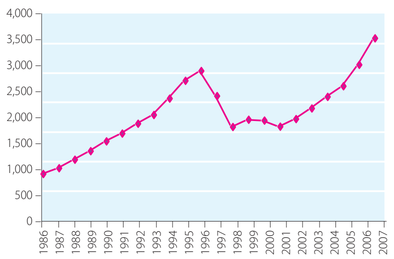


Figure 4.1.8 Thailand's GDP per capita at current prices (US$). *Source*: IMF Database, April 2009.

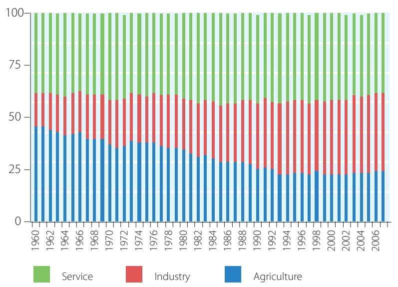


Figure 4.1.9 Percentage of GDP by sector (Thailand). *Source*: World Bank Database, 2009.

Pace of economic development in Viet Nam

Rapid growth in Viet Nam since the 'doi moi' reforms of the late 1980s have contributed to impressive declines in the incidence of poverty from 37 per cent in 1998 to 29 per cent in 2002, and 13 per cent in 2008 (Thanh Nien Daily 2009). With its strong economic performance, Viet Nam has become attractive as a country for foreign investment with a cheap, well-educated labour force and large domestic market.

The economic growth rate was about 7.6 per cent annually from 2000 to 2007 (Figure 4.1.10) and GDP per capita increased from US$400 to almost US$900, buoyed by the continued expansion of investment in infrastructure, labour-intensive manufacturing and service activities (Figure 4.1.11). Because of the global financial crisis, GDP growth fell to about six per cent in 2008 and 4.5 in 2009, the lowest level in almost a decade and a sharp drop from the 8.5 per cent in 2007. At the same time, inflation rose to 25 per cent in 2008, the highest in the LMB. In 2004 inflation was 9.5 per cent and it has stayed relatively high ever since. Inflation in consumption goods and market assets is due to global influences such as high oil and other commodity prices, a large inflow of foreign exchange relative to economic size, which generates liquidity surplus and overvaluation of the exchange (Ohno 2008).

However, the drop in GDP growth rate is much less than in other LMB countries as the government began addressing the threat of an overheated domestic economy decisively, starting in late 2007 (ADB 2009c). In response to the first shock of the current crisis, the authorities shifted emphasis from growth to stabilisation in March 2008. In late 2008, they shifted once more to supporting economic activity through large interest rate reductions, injections of liquidity, and a fiscal stimulus package (ADB 2009c). Growth slowed to 6.2 per cent in 2008 from about 8.5 per cent in 2007.

The share of GDP by sector has shifted markedly from agriculture to the industry and service sectors. In the late 1980s, agriculture comprised more than 40 per cent of GDP, while service and industry contributed

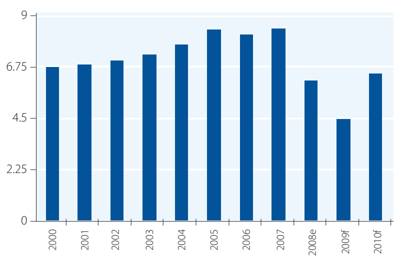


Figure 4.1.10 Viet Nam's GDP growth rate (% annual). *Source*: Extracted from the World Bank Database 2009 and Asian Development Bank, 2009; e, expected; f, forecast.

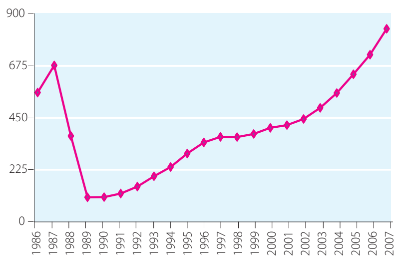


Figure 4.1.11 Viet Nam's GDP per capita at current prices (US$). *Source*: IMF Database, April 2009.

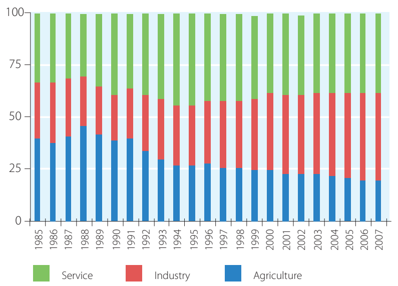


Figure 4.1.12 Percentage of GDP by sector (Viet Nam). *Source*: World Bank Database, 2009.

about 30 and 25 per cent to GDP, respectively (Figure 4.1.12). In 2007, industry's contribution to GDP rose to more than 40 per cent, while agriculture contributed only about 20 per cent. The rapid expansion of the industrial sector has been due to growth in infrastructure, mining, oil production, construction and an opening of trade policies.

Despite the positive economic prospects, challenges remain to strike a balance between stimulating growth without fuelling inflation and increasing the deficit (ADB 2009d).

Public and private investment trends in the LMB

Private investment in the LMB is taking place at a rapid and unprecedented pace. Increases in the world price for oil and gas have increased investor interest in alternative energy including hydropower development. Investment in mining and water resources related industries, such as irrigation, is also increasing.

Trade liberalisation in the Mekong Basin has improved, translating to an increase in regional trade and foreign direct investment (FDI) (UNCTAD 2006).

Opportunities for private sector investment in water and related resources, such as hydropower, navigation, large scale irrigation, forestry, aquaculture and tourism, will continue to increase in the LMB countries. For many areas of water resource investment in the LMB, private sector investment is now outweighing public sector (MRC 2009a).

The influx of private sector capital to the region is increasing steadily (Figure 4.1.13).

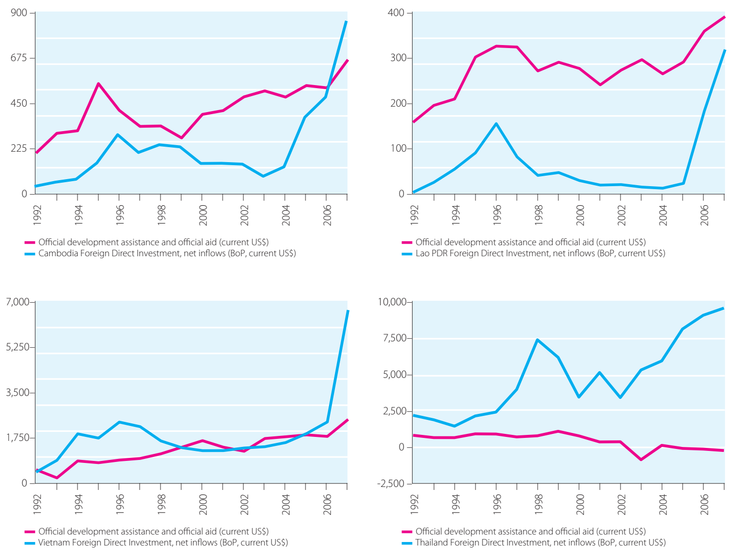


Figure 4.1.13. Foreign direct investment (FDI) and official development assistance (ODA) (current million US$) *Source*: Extracted from the World Bank Database 2009.

Cambodia's private investment was nearly US$900 million in 2007, exceeding the official development assistance (ODA) of nearly US$700 million in the same year. Capital inflow to Lao PDR increased in 2007 and FDI is expected to overtake ODA in coming years. Private sector investment in Viet Nam and Thailand was $US7 billion and $US10 billion respectively in 2007, which far exceeded the ODA. Furthermore, Viet Nam and Thailand have become potential investors in the LMB. Implementation of planned and proposed hydropower developments will involve a large increase in FDI and most of the current proposals for hydropower development in the Lower Mekong Basin will be led by the private sector.

A large number of concessions for agricultural land and open cast mining have been awarded in Cambodia and Lao PDR in recent years, mostly to foreign investors, to develop export-oriented agriculture and forestry projects. In Lao PDR for instance, rubber cultivation reached about 12,000 ha in 2006 and there are plans for this to increase to nearly 200,000 ha by 2010.

The increase in private sector investments is also expected to have implications for fisheries, irrigation, livestock, water supply, drainage, flood control, transboundary projects and other sectors.

4.2 FORESTS AND FORESTRY

Economic development, at both the global and national level, continues to exert considerable pressure on the forests of the lower Mekong countries. Population growth, expanding infrastructural developments and policy impacts from both within and outside the forestry sector are collectively influencing the forest landscape. Increasing demand for agricultural and forest products and the requirement for agricultural land is driving deforestation and degradation, with associated reduction in carbon stocks, biodiversity and watershed related values.

Environmental protection policies and measures to promote reforestation are gaining support in some countries although the overall rate of forest loss in the LMB countries has risen since the turn of the millennium (Table 4.2.1). The quality of forest resources also remains in decline as primary (undisturbed) forests are converted to secondary (regrowth) forests and monoculture plantations expand and substitute for natural forest in national forest cover figures. Where environmental protection measures have been stringently applied on a large scale, forest degradation has been displaced to neighbouring countries and significant efforts will be required to control such effects in the future (Meyfroidt and Lambin 2009).

Industrial wood production levels in the LMB have fallen as a result of resource depletion and forest protection measures. Development of industrial tree plantations has been held back by social and tenure issues as well as market and technical constraints. However, demand for forest products remains high. For example, expansion of the region's furniture industry has, in large part, been due to growth in Viet Nam, where employment increased by 28 per cent per year over the period 2001–2006 (FAO 2008a). Thailand has almost doubled production of paper products over the last decade. Although high demand for forest products has encouraged plantation development, logging in primary forests and protected areas remains widespread. As a consequence, forests in Cambodia and Lao PDR, where logging bans have not been imposed, have increasingly supplied manufacturers in Viet Nam (Katsigiris et al. 2004; EIA/Telapak 2008). Development of land for industrial cropping and for rubber production, in particular, has also become a serious threat to forests on sloping lands where watershed and biodiversity values are often highest.

In contrast to the overall trend in the LMB, changes in forest resources in Thailand and Viet Nam have begun to follow a different course to Lao PDR and Cambodia. In Viet Nam, forest area is expanding following protection measures, tenure reform and large government reforestation programmes. Similarly, in Thailand, forest protection measures implemented two decades ago, but without equivalent levels of reforestation, are having effect. Trees are also regrowing on abandoned agricultural land in Thailand and although the overall forest area is still falling, the rate of loss has slowed in relation to changes in driving variables such as population and economic production. Figures suggest that Lao PDR and Cambodia are still in the first stages of forestry development. Resource extraction and agricultural expansion remain dominant and, in spite of well intentioned forest policy, measures to conserve, protect and sustainably manage forest resources have yet to be fully demonstrated while plantation establishment rates remain low.

Forest cover

Forest area in the LMB countries totals 54 million hectares and accounts for 43 per cent of the land area (FAO 2005a). Forest cover in Lao PDR and Cambodia is considerably higher than in Viet Nam and Thailand, where population densities are several times greater (Table 4.2.1). Overall, a total of 1.55 million hectares of forest was cleared in the LMB countries between 1990 and 2005 and an increase in the rate of forest loss was recorded after 2000. The overall trend, however, masks opposing developments between countries (Figure 4.2.1). In Viet Nam, forest cover has been increasing at two per cent per year – equating to a total gain of more than 3.5 million hectares between 1990 and 2005. During the same period, Thailand lost just less than 1.5 million hectares. Overall rates of deforestation were highest in Lao PDR and Cambodia, where losses amounted to about 1 and 2.5 million hectares respectively. In Cambodia, the rate of forest loss increased substantially after 2000 although the current economic slowdown may temper this trend in coming years (FAO 2005a).

If deforestation continues at the 2000–2005 rate, Cambodia will have lost an additional 2.7 million hectares of forest by 2020, Lao PDR and Thailand will have lost 1.1 million and 800,000 hectares respectively while Viet Nam will increase its forest cover – mostly through plantation development – by 4.4 million ha.

A recent review of forest cover change 'hotspots' highlighted the rapid rate of loss of forest resources and relative absence of sustainable management in the region (Stibig et al. 2007). Hotspots of forest conversion appear in Lao PDR, Viet Nam and Cambodia and large areas of small and scattered change are evident in northern Thailand where encroachment into protected areas and losses at forest edges are prevalent (Lakanavichian 2006). In Lao PDR, Viet Nam and Cambodia most areas of loss are in evergreen and semi-evergreen forests located in hilly zones and along mountain ranges. Changes to both evergreen and deciduous lowland forests have also been recorded in the flatlands of Cambodia, central and southern Lao PDR and central Viet Nam. Additionally, forest change hotspots are frequently located in border areas, such as between Lao PDR, Cambodia and Viet Nam and between Thailand and Cambodia (Stibig et al. 2007).

The qualitative aspects of national forest resources are further illustrated in Table 4.2.2 which shows the proportion of forest area by designation in the LMB countries. Despite the lowest forest cover overall, Thailand reported the largest area of primary forest, while modified natural and semi-natural forests dominate in Lao PDR and Cambodia. In Viet Nam, natural forest resources have been heavily exploited and growing stock has fallen to very low levels (FSIV 2009). In general, the extent to which plantation establishment programmes have been pursued relates to the degree to which natural forest resources have been depleted (Katsigiris et al. 2004). This is most apparent in Viet Nam, where primary forest area continues to fall to very low levels while the area of forest plantations is substantial and increasing rapidly. In Cambodia, plantation forests are an insignificant part of the national forest area and the rate of increase has been low while rates of clearance of natural forest have remained high. In Lao PDR, rates of establishment of tree plantations have increased in recent years although the national stock remains modest. In Thailand, teak and pulp plantations constitute a large and expanding component of the national forest resource.

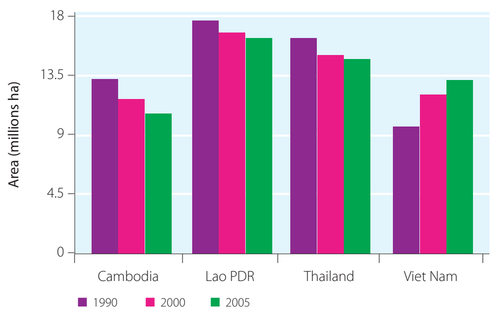


Figure 4.2.1 Forest cover in LMB countries.

Table 4.2.1 Area of forest in the LMB countries in 2005 and rate of change in forest area

	Forest area 2005 (000s ha)	Forest area per capita (ha)	Forest cover 2005 (%)	Annual change in forest area (%)	
				1990–2000	2000–2005
Cambodia	10,447	0.75	59	-1.1	-2.0
Lao PDR	16,142	2.74	70*	-0.5	-0.5
Thailand	14,520	0.22	28	-0.7	-0.4
Viet Nam	12,931	0.15	42	2.3	2.0

Source: FAO 2005a; *The figure for Lao PDR is based on 10% canopy cover and 5 m minimum tree height; bamboo areas and unstocked forest and shifting cultivation areas that will be restocked are also included. Forest cover determined by the Lao Forest Inventory and Planning Division in 2004 using 20% canopy cover and 10 m minimum tree height equalled 41.5%.

Table 4.2.2 Natural and plantation forest area in the LMB countries in 2005

	Total forest (000s ha)	Total natural forest (000s ha)	Natural forest[1]		Plantation forest	
			Primary Forest (000s ha)	Modified natural & semi-natural Forest (000s ha)	Plantation Forest (000s ha)	Per cent of total forest in plantations (%)
Cambodia	10,447	10,388	322	10,066	59	0.6
Lao PDR	16,142	15,918	1490	14,428	224	1.4
Thailand[2]	14,520	11,421	6451	4970	3099	21.3
Viet Nam	12,931	10,236	85	10,151	2695	20.8
Total	54,040	47,963	8348	39,615	6077	11.2

[1]Primary forest is forest unmodified by human activity whereas modified natural forest and semi-natural forest are modified to an increasing extent (see FAO 2005a for full definitions). [2]Figures do not include private plantations.

Causes of deforestation and forest degradation

The primary reason for forest conversion in continental Southeast Asia is establishment of cash crop plantations and agriculture, which in recent years have had a greater impact on forest cover than logging (Stibig et al. 2007). The overall trend in the region is largely due to the expansion of cultivation of a relatively small number of agricultural crops. In Cambodia, Lao PDR and the highlands of Viet Nam the production of rubber, cashew nuts, coconut and sugarcane, and in highland areas, cacao, coffee and tea has been a major cause of forest conversion. In coastal zones in Viet Nam demand for land for shrimp ponds and agriculture has resulted in loss of mangrove forests. Shifting cultivation in the uplands of northern Lao PDR and Thailand has resulted in loss of mostly secondary forest. Rubber has been a particularly important cause of forest conversion in Lao PDR, Cambodia, Thailand and the central highlands of Viet Nam (Stibig et al. 2007).

Although rates of rural population growth are expected to fall in the LMB countries over the coming decade, and in Thailand and Viet Nam will be very low, expansion of road networks will bring renewed pressure on forests (UN Population Division 2006). Demands for agricultural products for export are likely to replace subsistence demands as urbanisation continues. Increased access is therefore likely to be closely associated with future deforestation. Increasing market access, resource extraction and agricultural conversion will also increase incentives for wood production and establishment of tree plantations. The granting of land concessions in Lao PDR and Cambodia, where all forest is state owned, became an important issue in 2007 and 2008 following huge increases in demand for land and agricultural commodities. In Lao PDR, granting of concessions was suspended and in Cambodia claims were made of widespread sale of land to foreign investors (Global Witness 2009).

The road density and rates of expansion are highest in Viet Nam and Thailand and important road developments are also crossing Lao PDR and Cambodia (WDI 2009). Trans-boundary forests are particularly vulnerable and new economic corridors in the region are already having an impact. Road developments undertaken as part of the Greater Mekong Sub-region programme are having a direct impact on forest cover and on the accessibility of forest areas. Concerns are that the programme will increase access to and facilitate illegal trade in wildlife, timber and other forest products. The 1500 km long 'East-West Economic Corridor' links the Indian and Pacific Oceans through Union of Myanmar, Thailand, Lao PDR and Viet Nam and passes close to or through a number of protected areas. The areas particularly affected include the northwest and southern parts of Lao PDR and northeast Cambodia (Stibig et al. 2007). In Lao PDR, Cambodia and Viet Nam, protected areas close to areas of development are also threatened by biodiversity and resource loss (Corbett 2008). In Viet Nam, for example, the planned Ho Chi Minh Highway, now under construction, will cross 13 protected areas (ICEM 2003).

Climate change and forest adaptation

In Southeast Asia, it is expected that climate change will result in higher temperatures, increased risk of flooding and increased occurrence of extreme rains and associated landslides (IPCC 2007). With increased road building, log extraction and agricultural development in more marginal areas, landslides are liable to become much more frequent in the region. Other possible climate change impacts are increased incidence of fire, forest diebacks, and spread of pests, pathogens and invasive species. Climate change will also directly affect tree physiology, forest growth and biodiversity (SLU 2008). Adaptation of forest management will be necessary to avoid future reductions in the climate change mitigation capacity of forests, as well as more general reductions in the flow of forest related goods and services. Assessments of forest health and productivity and institutional strengthening are of central importance in managing responses to climate change impacts. Specific areas of interest are likely to include maintaining the health and vitality of natural forests, taking future climate change into consideration in planning plantation establishment, developing effective fire suppression and control systems and implementing measures to control insect and disease outbreaks. (See section 3.5 for a general discussion of the impacts of climate change on the region).

Protection forests

A combination of steep hill slopes, high intensity rainfall, dry seasons and highly erodible soils hinders the sustainable management of upland forests and agricultural lands in the LMB countries (Sidle et al. 2006). Natural forests, where fertilisers and pesticides are seldom used, are preferable as land cover for water supply catchments than agriculture, habitation and industrial development (Hamilton 2008). Riparian buffer zones are particularly important in preventing sediments and pollutants from entering rivers and in stabilising river banks. Although regulations preventing logging in riparian zones and on steep slopes are generally included in forest harvesting guidelines in most countries, they are not always followed. Erosion control and entrapment of sediments is also relevant in coastal ecosystems where removal of mangroves can lead to loss of land, saline intrusion and exposure of coastal populations and assets to increased risk from coastal hazards (FAO 2006a; Forbes and Broadhead 2007).

Logging, road and trail construction and forest conversion all increase surface erosion and slope instability in tropical uplands while surface erosion is usually low in undisturbed forest catchments (Sidle et al. 2006). Climate change related increases in the frequency and severity of storms and increased road building in sloping areas are likely to result in increased incidence of landslides in the region (see the box opposite). Although trees are unlikely to have any impact on deep landslides resulting from continuous heavy rainfall and waterlogging of soils or large earthquakes, they play an important role in averting landslides under less extreme conditions (Hamilton 2008). Deep-rooted trees and shrubs strengthen shallow soil layers and improve drainage, thereby reducing the probability of shallow landslides. Transpiration from extensive tree canopies can also decrease soil water content and reduce landslide risk (Dolidon et al. 2009). Conversion of forests on sloping land reduces rooting strength for up to two decades even with subsequent regeneration, and increases landslide risk (Sidle et al. 2006). It is particularly important to maintain forest cover in slip-prone areas where slopes are greater than 45–55 per cent, or are concave or where soils have low cohesion or are shallow and cover bedrock (Megahan and King 1985).

The total area of forest with protection as a designated function varies greatly across the four lower Mekong countries (Table 4.2.3). In Viet Nam, almost half of all forests are designated with protection as their primary function. Utilisation of plantations for protection has become particularly important with a tripling in area between 1990 and 2005 to 900,000 ha. Protective plantations in Thailand also increased in area from 0.66 to 1.1 million ha between 1990 and 2005. These figures reflect the fact that conservation and protection of forests has become a primary policy objective in both countries. Implementing a switch towards forest protection has, however, often been associated with complications at the field level. These include, for example, reductions in forest products supply; 'export' of logging to neighbouring countries; denial of access and use rights of forest dependent people; and proliferation of illegal logging.

Cambodia, the least mountainous country in the region, has a relatively low proportion of its forest designated for protection. Lao PDR, the most mountainous country in the region with 87 per cent of its land classified as uplands, has the highest proportion of land area designated as protection forest. The area has, however, fallen recently and a national system of managed protection forests has yet to be established. Much of the forest within watershed areas is reported to be highly degraded and in 1993 only 11 per cent was covered by dense forest and 44 per cent lacked any forest cover at all (MAF 2004).

Table 4.2.3 Area of forest designated for protective functions in LMB countries (2005)

	000s ha	% forest area	% land area
Cambodia	3031	29	17
Lao PDR	12,654	78	55
Thailand	9725	67	19
Viet Nam	12,931	100	40
Total	38,341	31	71

Commercial logging

Commercial logging has peaked in the LMB countries but still continues in previously less accessible areas. Overharvesting of high value species and breaking of cutting cycles to extract newly marketable species have left stocking densities low and ecosystem composition greatly altered. High impact and excessively heavy logging has also damaged remaining stands and reduced the commercial viability of production forests.

Between 1990 and 2005 the area of forest designated primarily for production in LMB countries increased by slightly less than one million hectares. Contrasting trends were evident in the region with a net reduction of 0.6 million hectares in Viet Nam and increases in Cambodia and Lao PDR of 1.1 m and 0.3 m ha respectively (Figure 4.2.2). With greater stability in the permanent forest estate in Thailand, little change in area designated for production was recorded. An increasing percentage of the production forest area in the region comprises plantations, with most resources situated in Thailand and, increasingly, Viet Nam. In Viet Nam the area of productive plantations increased from 1.4 to 1.8 m ha between 2000 and 2005. An increase to just 223,000 ha was also reported in Lao PDR. Statistics for Cambodia and Thailand indicated no change in area between 2000 and 2005 although in Thailand, increasing areas of private plantations outside of designated forest areas are not included in official statistics.

In response to resource depletion and environmental concerns, governments have implemented various measures to protect remaining forests around the LMB. In Thailand, logging was banned in natural forests and most state owned plantations in 1989 and in Viet Nam logging was banned in most natural forests in 1997 (Brown et al. 2001). In Cambodia, a logging moratorium was announced in 2001, after which a system was established for auctioning and monitoring annual coupes by the Forestry Administration (Forestry Administration 2009). In Lao PDR, a log export ban has been imposed to encourage more domestic processing and reduce forest degradation. There have, however, been doubts over the efficacy of enforcement and it has been estimated that about 500,000 cubic metres of logs move every year from Lao PDR to Viet Nam (EIA/Telapak 2008).

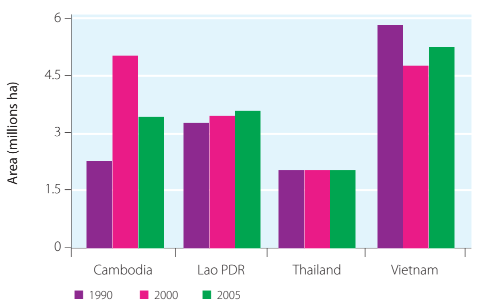


Figure 4.2.2 Forest area designated primarily for production.

With respect to the quality of logging, Cambodia is the only country in the region where implementation of a national code of harvesting practice is mandatory and, in general, reduced impact logging is not widely practised in the LMB (FAO 2009; Wilkinson 2009). In Lao PDR, the national code of harvesting practice is not yet implemented on an operational basis and the capacity of the logging companies is very limited. In Cambodia, a national code of harvesting practice has been in place since 1999 and although the Forestry Administration carries out evaluation, results have not been made public. Implementation of the code has also been curtailed by the logging moratorium. Viet Nam has reduced impact logging regulations and guidelines, but these are not yet widely implemented and forest companies lack knowledge of reduced impact logging techniques and related supervisory capacity.

In combination with the effects of heavy logging and subsequent forest drying, fire has become a major cause of forest loss in the region and poses a serious threat to ecosystem stability. Across the region, upland farmers use fire as a low-cost way of clearing land and cattle farmers use it to stimulate vegetation regrowth. Low intensity fires are also used to reduce forest fuel loads and prevent devastating fires. Uncontrolled and unmanaged fires, however, lead to large-scale forest damage every year and, in Thailand for example, fire prevention is one of the Royal Forest Department's most important and costly activities (DNP 2009). With road densities rising and human activity – including logging – increasing in previously isolated areas it is likely that the frequency of forest fire will rise in coming years. Without concerted intervention, such effects are likely to cause spiralling forest degradation as has been seen in Borneo (Curran et al. 1999, 2004).

Uncontrolled fires lead to large-scale forest damage every year.

Fuelwood consumption

Fuelwood is a major source of energy for heating and cooking in rural areas, while the use of charcoal is less widespread. Fuelwood is often collected from trees outside of forests and is therefore not generally associated with deforestation but commercial collection of fuelwood and wood for charcoal has had major impacts, especially in mangrove areas. Wood energy is also used for industrial purposes, particularly those associated with large wood processing facilities (FAO 2008b). However, there is little quantitative information on commercial and industrial consumption of wood energy.

Woodfuel consumption in all the LMB countries accounts for about four and a half times reported industrial roundwood consumption. It is expected to fall in coming years as a result of urbanisation, slowing rates of rural population growth, increasing income and increased availability of alternatives to fuelwood and charcoal (Figure 4.2.3). Estimates suggest that woodfuel consumption in the LMB will fall by nine per cent between 2010 and 2020 (Broadhead et al. 2001).

Recently, the focus on wood has been revived as a result of climate change concerns and high oil prices. When sustainably harvested and used with modern conversion technology, wood offers high rates of carbon and energy efficiency. Prices are, however, generally not competitive with fossil fuels and wood is often less profitable to grow than alternative crops. In the absence of high fossil fuel prices, future developments in large-scale use of wood for heat and power production will depend on climate change policy and related subsidies and incentives – notwithstanding technological breakthroughs.

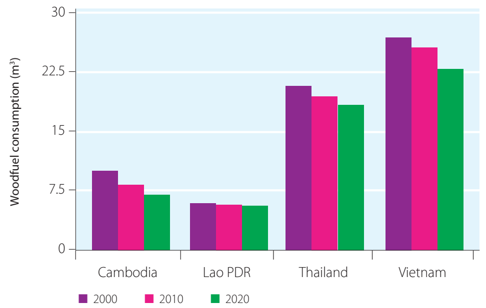


Figure 4.2.3 Estimated woodfuel[1] consumption in Lower Mekong Basin 2000–2020.

[1]Woodfuel applies to the sum of wood used directly as fuel ('fuelwood') and wood for making charcoal, both for domestic and industrial purposes.

Non-timber forest products

Non-timber forest products (NTFPs) support the livelihoods of many thousands of forest dependent people in the LMB and are particularly important for providing a 'safety net' during times of scarcity. They also provide income for rural people and supply markets with a wide array of plant and animal products including foods, medicines, exudates and dyes. As economic growth has advanced in the region, demand has grown swiftly and while sustainable production systems have been developed for some NTFPs – often through domestication and cultivation – others have been overharvested due to a lack of attention to, or difficulties in implementing, sustainable management. NTFPs have been commercialised and cultivated to a greater extent in Thailand and Viet Nam than in Cambodia and Lao PDR, where products are still largely supplied from natural forests.

It is likely that NTFPs will be exploited ahead of the rate at which timber resources are depleted and dependent populations will face hardship if other means of livelihood support are unavailable. At the same time, biodiversity values associated with wild NTFPs are likely to be lost.

In Asia, the most economically significant NTFPs, in approximate order of importance, are rattan and bamboo, medicinal plants, essential oils, resins, pine nuts, mushrooms, spices and herbs, fodder, animal products, honey and lac (FAO 2002). China and India dominate global trade in NTFPs, followed by Indonesia, Viet Nam, Malaysia, the Philippines and Thailand. The main NTFPs from the LMB countries are shown in Table 4.2.4.

Rattan is the most important internationally traded NTFP, although Asian rattan resources are diminishing due to overexploitation and forest loss and few countries still have significant stocks. In Thailand, Viet Nam, Lao PDR and Cambodia, the long-term sustainability of rattan-processing industries has been undermined by unsustainable harvesting. Investment in industrial-scale rattan plantations is negligible and future supply is insecure. Due to diminishing supply, Thailand has banned harvesting of rattan in natural forest and export of rattan in its raw form (DNP 2009). Rattan has been planted on a small scale but private investment has been stemmed by a lack of technical expertise, the long rotation period and inadequate promotion. Thailand has more than 200 rattan furniture factories but only three large factories export their products. A local supply shortage means that these factories import rattan from around the region but volumes are decreasing and the value of rattan exports has declined considerably in recent years due to the supply constraints (DNP 2009).

Bamboo is by far the most commonly used NTFP in Asia and international trade in bamboo products has increased dramatically in the last decade (FAO 2002). China and Thailand are the main international suppliers of bamboo and within the LMB Viet Nam also exports. Bamboo is becoming widely used as a raw material for industrial products, including construction poles, panelling, flooring and pulp. Bamboo from natural forests is still important in Lao PDR and in mountain forests in Viet Nam but increasingly, it is also being grown as a crop. Bamboo shoots supply a rapidly expanding export market, with Thailand the world's second largest producer and exporter after China.

Tropenbos International

Forests supply people in many parts of the LMB with firewood and other household needs.

As well as rattan and bamboo, numerous other products, many gathered from natural forests, are commercially important. Extensive pine forests in the region provide products including resins, seeds and mushrooms. In Thailand, resin has been tapped from pine trees for centuries and it is estimated that the pine resin industry has the potential to create 25,000 jobs in rural areas (DNP 2009). Oleoresin and gums are obtained from two native pine species, *Pinus kesiya* and *P. merkusii* but only the latter is being tapped commercially. Pine forests are located mainly in the north and northeast and, allowing for mixed stands, amount to about 216,200 hectares. Tapping dipterocarp trees is another important source of income for many forest dwellers in Thailand, Cambodia and elsewhere but the extent of the activity is not well quantified. Thailand is also the second largest lac producing country after India with supply coming from planted forests in the north and northeast of the country. Viet Nam also produces lac and exports about 300 tonnes annually (FAO 2002).

The key challenge in managing NTFPs is for forest dependent people to achieve sufficient economic benefit while ensuring that subsistence values are not lost through commercialisation and unsustainable harvesting. Unfortunately, however, as demand increases it generally happens that benefits are less likely to be captured by forest dependent people. Many other issues are involved in equitable NTFP development: poor statistical information, unpredictable harvest levels, unknown ecology and management, indistinct property rights and ownership, lack of information and business know-how at the local level, poor quality control and marketing, and low investment.

Table 4.2.4 Main non-timber forest products in LMB countries

Country	Main NTFPs
Cambodia	Resin, rattan and bamboo, mushrooms, medicinal plants and incense
Lao PDR	Medicinal plants, food (nuts, fern roots, fruits), fibres, exudates (damar resin, oleoresin, benzoin), incense, spices, orchids
Thailand	Bamboo, rattan, lac, honey, gums and resins, spices, medicinal plants, food and bark for tanning and dyeing
Viet Nam	Handicrafts (rattan and bamboo), resin, essential oils, medicines, spices, mushrooms and honey

Source: FAO 2002

Tropenbos International

Rattan resources are diminishing due to overexploitation and forest loss.

NTFP management in Viet Nam – from national to local

The most important areas for NTFP production in Viet Nam include bamboo (mostly within natural forests); rattan (about 382,000 ha within natural forests); resin trees covering an area of 256,000 ha; and cinnamon trees covering 81,000 ha. Pine resin and essential oils are also of significant importance. In 2004, the total export turnover of NTFPs was US$200 million, 2.5 times that in 1999.

State management of NTFPs concentrates on creating a legal framework for conservation and development. At the provincial level, the Department of Agriculture and Rural Development grants licences for bamboo exploitation in production and protection forests. District people's committees grant licences to forest owners including households, individuals and communities and issue regulations concerning NTFPs. Since 1992, the government has encouraged investment in forests and preferential interest rates are given where NTFP management is included. The government also reduces taxes in relation to NTFP planting and has recently released an action plan for 2007–2010 on NTFP protection and development. A project on NTFP preservation and development will run between 2006 and 2020. By 2020 the following changes are expected:

- NTFPs are expected to represent 20 per cent of total forest production and export turnover is expected to increase at an average of 15–20 per cent per year. Bamboo and rattan are, however, increasing at more than 30 per cent per year
- 1.5 million highland rural labourers will be employed in collecting, processing and trading NTFPs, accounting for half the total forestry sector labour force
- 15–20 per cent of income in rural households will be from NTFPs.

However, if the land allocation program stalls, management of NTFPs will be undermined and depletion of stocks is likely to result.

Source: FSIV (2009)

Overall, the depletion and unsustainable management of NTFPs and the slow development of production management systems parallels the general forest management situation in the region. Despite the high dependence on NTFPs among forest users, there are many barriers to income generation, including security of tenure, lack of processing skills and limited market access (CFI 2006). Low profits and sustainability are other constraints. The diversity of NTFPs, the unique and divergent ecology of different species, and the need for relatively sophisticated techniques and institutions for successful management mean that only some products are likely to become more widely marketed while others remain as minor products.

Forest biodiversity

The countries of the Mekong Basin form a large section of the Indo-Burma biodiversity hotspot. (Conservation International defines 34 global biodiversity hotspots as regions containing at least 1500 species of endemic vascular plants and having lost at least 70 per cent of their original habitat.) A wide variety of ecosystems are represented in the region, including mixed wet evergreen, dry evergreen, deciduous, and montane forests as well as shrublands and woodlands on karst limestone outcrops and mangroves. The regional pattern of forest cover change shows that, apart from less accessible and mostly mountainous areas, most of the remaining forest cover is affected by change and that areas of change frequently overlap with protected areas and national parks. This situation indicates a severe challenge for the biodiversity of the region, and indeed the world, given the levels of species richness in Southeast Asia (Stibig et al. 2007).

As well as changes in forest cover, the region is threatened by the 'empty forest syndrome'. Uncontrolled exploitation of wild plants and animals is having a devastating effect on the region's biodiversity (TRAFFIC 2008). Huge demand for wildlife for food, medicine, pets, display and fashion, particularly from China, has led to increased trafficking and many wildlife species with high commercial value are now rare, endangered or locally extinct – including the tiger, Asian elephant, freshwater turtles and tortoises, agarwood and numerous wild orchid species. The collection of non-timber forest products is eroding biodiversity values and most of the main trade routes from Lao PDR and Cambodia are directly linked to protected areas (ICEM 2003). The trade not only undermines biodiversity but also curtails sustainable development and poverty alleviation for those dependent on wildlife for subsistence. This is particularly so in less developed areas within the region. Development of roads and infrastructure, expansion of logging and encroachment into pristine areas has increased access to wildlife and levels of extraction have risen markedly in the past decade. Increasing purchasing power in the region has been another key driver. The variability and complexity of wildlife trade chains, the porosity of borders and difficulty in guarding large areas against the threat of wildlife removal makes wildlife depletion difficult to address. Governance improvements and increased sustainable resource management efforts along with law enforcement are the main means suggested to tackle the decline.

Biodiversity crisis in Southeast Asia

Forests are the home for much of the biological diversity in Southeast Asia, which contains four of the world's 25 'biodiversity hotspots'. So, forestry related decisions and activities have considerable repercussions. Reduction of forest cover has a significantly greater impact on levels of biodiversity than other threats such as invasive species, climate change or nitrogen deposition.

In combination with climate change and the increasing frequency of El Niño events, reduction in forest density and forest fragmentation can lead to increasing chances of catastrophic fire and a resultant acceleration of species losses. The wildlife and bushmeat trade has reached unprecedented levels in Southeast Asia with greater forest access and increasing demand behind the upsurge. CITES and other international agreements often remain unenforced and much of the supply originates in 'protected' areas.

In the midst of this predicament, the biodiversity of Southeast Asia remains under-researched in comparison with South and Central America and sub-Saharan Africa and protected areas are often protected in name only.

Containing and reversing this loss will take a multi-national and multi-disciplinary effort involving public awareness raising, adequate protection and economic incentives for conservation.

Based on Sodhi et al. (2004).

Protected area systems have expanded rapidly and, including areas managed at the local and provincial levels, cover about one-fifth of the total land area in Cambodia, Lao PDR, Thailand and Viet Nam (Table 4.2.5). Most of these areas, which are in forested uplands, have been established during the past three decades (ICEM 2003). Currently, 66 per cent of remaining natural forest in Thailand falls within the national protected area system. Areas of relatively undisturbed forest still large enough to contain most of its original biodiversity range from only two per cent in Lao PDR and Viet Nam to five per cent for Thailand and 10 per cent for Cambodia (Dauvergne 2001).

In Lao PDR, Cambodia and Viet Nam, protected areas next to areas of development are under serious threat of biodiversity loss (Corbett 2008). Timber, wildlife and other non-timber forest products are being severely overharvested, causing damage to habitats and environmental services and also undermining local people's subsistence. Degradation is resulting from logging, conversion to plantations, mining, unmanaged harvesting of NTFPs and organised hunting of wildlife for medicines, skins and meat. The trend is likely to worsen given the scale of planned investment near the reserves, in roads, dams and electrification schemes, and the low capacity for resource management, law enforcement and governance.

Table 4.2.5 Forests and protected areas (2003)

	Cambodia	Lao PDR	Thailand	Viet Nam
Protected areas as a per cent of land area	21	21	19	8
Estimated forest in existing and proposed protected areas as a per cent of total forest	40	39	65	26

Jeremy Broadhead

Many wildlife species with high commercial value, including numerous orchid species, are now rare, endangered or locally extinct.

4.3 AGRICULTURE AND IRRIGATION

Crops in the Lower Mekong Basin

Agricultural production in the LMB has been shaped by a drive towards modernisation and trade expansion as well as the sector's continued importance for food security and as a source of income (Baumüller 2008). Crops are grown in both upland and lowland (floodplain) areas of the basin. Forms of upland agriculture vary considerably depending on cultural practices and local soil and topographic conditions. Major upland farming systems include shifting and semi-shifting cultivation and rainfed crops with little irrigation. A significant trend is the spread of plantations for commercial production of rubber and energy crops, both as a result of a rise in energy prices (and related demand for biofuels) as well as increased demand for agricultural commodities more generally. Expansion of agriculture often encroaches into forest areas (see section 4.2).

Agriculture in the uplands is typically less intensified than in the Mekong floodplains and other lowland areas, where most crop production takes place. Lowland rice farming systems include wet season rice, floating rice, flood recession rice, dry season irrigated rice and multi-crop production systems (Table 4.3.1). The various regions of the LMB produce between one and three harvests a year. The main harvest is the wet season crop, with smaller numbers of farmers also planting in the dry season, both with and without irrigation. Some farmers in the Viet Nam delta also grow a third crop late in the year (MRC 2005a).

Agriculture across the basin involves a mix of subsistence and commercialised production. In general, farming households focus first on production to meet household needs and then sell whatever surplus they produce. Although there are large regional differences, it is mainly lowland households that have gradually made a transition into more commercialised modes of agricultural production, especially in northeast Thailand and the Viet Nam delta. This shift towards commercialisation is much less pronounced in the (often remote) upland areas of the basin in Cambodia and Lao PDR (MRC 2005a).

Most crop production takes place in the Mekong floodplains and other lowland areas.

Upland agriculture and shifting cultivation in Lao PDR

Shifting cultivation has played an important role in upland agro-ecosystems throughout mainland Southeast Asia including, within the LMB, significant areas in the Central Highlands of Viet Nam, northeast Cambodia, and the sloping lands of Lao PDR. However, as shifting cultivation is practised in the most remote parts of the basin, it is difficult to measure both its geographical extent and its productive output. About two million hectares were estimated to be under shifting cultivation in 2000, with 25 per cent of the land area classified as forest (MRC 2005a).

Among the LMB countries, shifting cultivation is most significant as an environmental and social challenge in Lao PDR. In 2000, about 39 per cent of the total population depended on this type of production (Thomas 2004). After clearing and burning a plot of forest land, these upland farmers cultivate it for one or two years and then move on leaving the plot for forest regrowth. In Lao PDR, glutinous rice is generally the main crop in the first year, with many other crops, such as maize, tubers and roots, cucurbits, cruciferae, peppers, sunflower and groundnut, grown as well (Ducourtieux et al. 2005). Fallow periods of 10–20 years are needed for the land to regain its initial fertility (MRC 2005a).

The negative impacts of shifting cultivation have been a dominant theme of government policy for the past 20 years and the Seventh Party Congress proposed to eliminate the practice completely by 2010 (CPI 2006). Between 1990 and 2001, the area under shifting cultivation declined from 249,000 ha to 110,000 ha according to national statistics (Thomas 2004) and was further reduced to 29,400 ha in 2005, with 72,870 ha of the reclaimed area being planted to industrial trees (CPI 2006). However, some satellite imagery suggests that the area under shifting cultivation is actually increasing (Linquist et al. 2006).

The environmental impacts of shifting cultivation depend on the intensity with which it is practised and especially the length of the fallow period. The 'carrying capacity' of shifting cultivation is under pressure because of a decrease in available land due to hydropower schemes, reclassification of forests as protected areas and the granting of logging concessions. Such pressures and simultaneous changes in upland areas can trigger a cycle where increased land pressures lead to shortened fallow periods, causing a loss of soil fertility and declining crop yields, as well as increased soil erosion, downstream siltation, flooding and drought (MRC 2005a). However, traditional forms of shifting cultivation are sometimes blamed for upland degradation when the cause may have more to do with large-scale logging. Policy measures to reduce shifting cultivation have often intensified poverty for ethnic minorities and adversely affected their cultural identities (Chaudhry and Muanpong 2005).

Rice

More than 10 million hectares of the LMB's total cultivated land is used to produce rice: the staple for most of the basin's inhabitants, who, on average, consume between 100 kg per head per year (Thailand) and 162 kg per head per year (Lao PDR) of milled rice (MRC 2005a).

In Cambodia, rice production has slowly increased in both area and yield since the early 1990s due to ongoing post-war rehabilitation and infrastructure reconstruction. Between 2000 and 2005, the total wet season area increased from 1.93 million ha to 2.08 million ha while the dry season area grew from 233,000 ha in 2000 to 321,000 ha in 2005. Average yields at the same time increased from less than 2 t/ha to 2.48 t/ha, with distinct differences between wet and dry season yields (Table 4.3.2).

Table 4.3.1 Proportion of rice grown in different production systems: Cambodia, Lao PDR and northeast Thailand

	Cambodia (%)	Lao PDR (%)	Northeast Thailand (%)
Irrigated	11	12	11
Rainfed lowland	84	67	84
Deepwater	3	0	3
Upland	2	21	2

Source: Bell and Seng (2004); N.B. the data only provide an approximate order of magnitude, and different sources provide often varying figures dependent on methodologies applied and sources of data.

Table 4.3.2 Rice production in Cambodia, Lao PDR and northeast Thailand

	Wet season		Dry season		Total	
	2000	2005	2000	2005	2000	2005
Cambodia[a]						
Area harvested (000 ha)	1846	2094	233	321	2079	2414
Production (000 ton)	3333	4734	708	1252	4041	5986
Yield (ton/ha)	1.8	2.3	3.0	3.9	1.9	2.5
Lao PDR[b]						
Area harvested (000 ha)	627	675	92	61	719	736
Production (000 tons)	1812	2297	390	271	2202	2568
Yield (ton/ha)	2.9	3.4	4.3	4.4	3.1	3.5
Northeast Thailand[c]	[d]		[d]		[d]	
Area harvested (000 ha)	4675	4305	138	112	4813	4417
Production (000 tons)	9046	7914	451	358	9497	8272
Yield (ton/ha)	1.9	1.8	3.3	3.2	2.0	1.9

Notes: [a]FAO-RDES: Cambodia, Agriculture, Forestry and Fisheries Statistics in Cambodia 2005–2006; [b]FAO-RDES; dry season rice = irrigation rice; wet season includes both upland and lowland rice production; [c]Office of Agricultural Economics; [d]data for 2001 (*Source*: MRC 2005a)

Rice is also the dominant crop in Lao PDR, with a total area of 736,000 ha in 2005. Rice production in the country can be classified into three broad ecosystems: irrigated lowland, rainfed lowland and upland (Linquist et al. 2006). Lowland rice is grown in bunded fields and the soil is flooded for at least part of the crop season. Upland rice is grown as a rainfed dryland crop, usually only planted during the wet season, and often associated with shifting cultivation on steep slopes (Linquist et al. 2006) (see the box opposite). The most important rice production system in the country is wet season lowland rice, which has expanded continuously since 1996. Dry season irrigated rice, on the other hand, rapidly increased between 1995 and 2001 but has declined considerably since then.

In northeast Thailand, more than 80 per cent of the cultivated area is used for growing rice, or a mix of rice and upland crops (MRC 2005a). The three main rice cropping systems are: *lower paddy land* – planted annually with rice in the wet season and faces risks of flooding and temporary waterlogging; *middle paddy land* – the most productive, with better water control and reduced flood risk; and *upper paddy land* – planted (if at all) to drought-resistant, short-duration rice varieties. The harvested area under rice production in northeast Thailand fell slightly between 2000 and 2005 (Table 4.3.2).

The Mekong Delta is Viet Nam's major rice growing area, accounting for nearly half the farms in the whole country. Rice is produced in up to three cropping seasons: winter–spring, summer–autumn (mid-season) and wet season–long duration. Farm production is increasingly diversifying, with

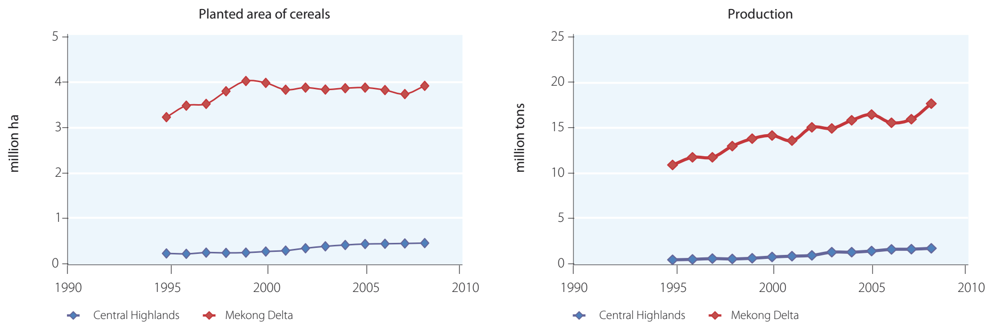
smaller proportions of annual and perennial crops and greater levels of animal husbandry, aquaculture and mixed production (GSO 2007). About 60 per cent of the rice grown in the Viet Nam delta is irrigated and yields are considerably higher than in the other countries. Although the agricultural area in the delta has declined over the last two decades (Table 4.3.3), productivity increases have led to an overall rise in production (Figure 4.3.1). Yields are lower in the Central Highlands, where irrigation is limited.

Along with their main use for growing rice, paddy fields provide many other benefits (see the box below) that need to be accounted for in the assessment of costs and benefits associated with agricultural development. On the negative side, expansion of agriculture poses considerable challenges in terms of loss of biodiversity and forest cover and increased environmental pollution from agricultural inputs, including agro-chemicals (see below).

Table 4.3.3 Change in area of agricultural production in the Mekong Delta and Central Highlands (2001–2006)

	Mekong Delta		Central Highlands	
	2001	2006	2001	2006
Agricultural production land (000s ha)	2619	2567	1256	1615
Annual crop land (000s ha)	2120	2032	522	757
… Paddy land		1893		161
Permanent crop land (000s ha)	499	535	743	859

Source: GSO 2007



Source: General Statistics Office of Viet Nam

Figure 4.3.1 Planted area and production of cereals in the Mekong Delta and the Central Highlands of Viet Nam.

Multifunctional role of paddy fields in the LMB

Paddy fields in the LMB provide farmers with more than rice; they fulfil multiple important roles, including fisheries production, flood mitigation and nurturing aquatic ecosystems (MRC 2007).

Fish and other aquatic organisms, such as frogs and shellfish, which are an important food source as well as providing income for rural households (see section 2.4), spend at least part of their lives in flooded paddy fields.

With the expansion of urban areas into paddy fields, their role in flood mitigation needs to be considered. Around the city of Roi-Et in northeast Thailand, for example, the area of paddy land was reduced from about 4300 ha to 3140 ha between 1987 and 2005. A recent MRC project estimated that this reduction in area would equate to a reduced water holding capacity of about 4.6 million m^3 (MRC 2007).

Other crops

While rice is the major agricultural commodity produced in the LMB, a range of other crops are also grown. These include maize, fruit and vegetables, oil crops, fibre crops and cash crops such as coffee, tea, sugarcane and tobacco. Many of these can offer higher economic returns if market demand expands.

In Cambodia, other food crops, which were traditionally considered secondary to rice, have grown in popularity due to local rice deficits and the clearing of upland areas suitable for their cultivation (FAO/UNDP 1994). Maize production, in particular, has increased as a result of this trend (Table 4.3.4). High-value commercial crops such as soy, mungbean and vegetables have also been planted over a larger area.

In Lao PDR, the area cultivated for maize fluctuated during the 1990s (MRC 2005a) but between 1999 and 2005 it more than doubled (Table 4.3.4). Coffee (the country's major agricultural export earner) also expanded and, over the same period, vegetable production increased greatly, mainly due to demand in urban centres and exports to Thailand. The harvested area of vegetables increased from 7168 ha in 1990 to 118,509 ha in 2003.

In northeast Thailand, diversification into non-rice crops has taken place to a greater extent than in the other LMB countries. However they still only cover about 20 per cent of the cultivated area in the region. Vegetables, legumes, kenaf and tobacco are sometimes combined with rice in paddy lands. In unbunded upland fields, cassava, kenaf, sugarcane and legumes (including groundnuts and mungbean) are often grown as monocrops. The largest increase was in the area of sugarcane which expanded corresponding to a decrease in the area of cassava (Table 4.3.4).

Whereas rice is the agricultural mainstay in Viet Nam's Mekong Delta, perennial and tree crops dominate in the Central Highlands. The area of major non-rice crops in the Mekong Delta (with the exception of soybean) all declined between 1999 and 2005 (Table 4.3.4).

Table 4.3.4 Area of selected (non-rice) crops

	Cambodia (ha)		Lao PDR (ha)		Northeast Thailand (ha)		Viet Nam Mekong Delta (ha)		Viet Nam Central Highlands (ha)	
	1999/00	2005	1999	2005	2000	2003	1999	2005	1999	2005
Maize	59,739	61,757	40,700	86,000	334,000	263,107	39,000	34,900	60,100	236,600
Cassava	14,003	28,560		6765	646,000	491,370	9200	6400	32,300	89,400
Soybean	34,945	114,890	6800	9535	38,000	11,196	9100	14,000	11,200	26,600
Sugarcane	8375	4498	4700	5500	206,000	596,557	102,800	64,100	27,900	26,700

Source: MRC 2005a
Note: areas for Cambodia and Lao PDR are harvested area; areas for Viet Nam are planted area.

Potential and trends

In both northeast Thailand and the Viet Nam delta, land resources have already been brought under intensive production and there is little scope to expand. Modest potential exists in northern Thailand and the Central Highlands but, compared to Cambodia and Lao PDR, the area is small.

Rice-based agriculture in the LMB is likely to remain the most important commodity and over time production will improve sufficiently to outstrip population growth (MRC 2005a). Improved crop production will come from a larger area under irrigation and small increases in grain yield. The area devoted to higher-value crops, such as vegetables and fruit, will expand at the expense of rice, but will remain a small proportion of the total and irrigated agricultural area. Some of the trends are summarised in Table 4.3.5.

Table 4.3.5 Production trends and drivers in the Mekong region

	Thailand	Viet Nam	Cambodia	Lao PDR
Current production	Large-scale production of sugar and rubber (mainly for export) and rice (two-thirds of rice production is for local consumption)	Rice the main agricultural crop (for food and export) Rapidly expanding production of sugar (for domestic use) and rubber (for export)	Rice the main agricultural crop (for subsistence) Sugar production until recently for household consumption Rubber cultivation a new but growing trend	Rice the main agricultural crop (for subsistence) Rubber cultivation a new but growing trend Sugar rapidly increased recently, but still small
Likely expansion of sugar, rice and rubber	Rice expansion limited Sugarcane expansion absorbed by agricultural land Most significant expansion in rubber (although still only small share of total area of rubber cultivation nationwide)	Some rice expansion and contraction for domestic consumption Most significant expansion in rubber, followed by sugarcane	Rice expansion through migration Rubber expansion greatest Sugarcane expansion more limited (although unclear)	Most significant expansion in rice, followed by sugarcane Rubber expansion most rapid, but comparatively small area
Likely expansion of other crops	Cassava and eucalyptus already widespread Jatropha at an experimental stage	Mainly fruit trees and tea, also cacao Coffee area expected to decrease, shift to high quality varieties	Tree crops (teak and acacia), cassava (minor) Countrywide expansion of jatropha	Mainly maize expansion Also coffee, vegetables, oil crops and cassava

Source: Baumüller (2008)

Water availability is one of the most critical constraints determining the current and future potential for agricultural production. In the monsoonal climate of the Mekong region, with its strongly seasonal rainfall distribution, farmers, who mostly use rainfed production systems, have multiple strategies to cope with rainfall variability. These range from investment in on-farm storage and pumps to cropping patterns that allow for rainfall shortfalls during the rainy season, and to the adaptation of appropriate crop varieties that can withstand temporary crop water shortages. In northeast Thailand, for example, farmers often employ different strategies on their generally more drought-prone upper paddy fields than on the flood-prone lower fields (Rigg 1985). Even so, shortfalls in water supply can have profound impacts on agricultural production, both for individual farmers and on a regional scale. Such events have occurred repeatedly over the last 50 years, with the most recent exceptional drought experienced between 2003 and 2005 when an atypical rainfall pattern, particularly the changes in rainfall distribution towards the end of the monsoon season, had a critical impact on agricultural production throughout the LMB (see the box on p. 116.).

Tropenbos International

Vegetables grown on small plots of land provide a source of income for many people in the LMB, such as this Vietnamese woman tending a crop of spring onions.

Irrigation: status, opportunities and challenges

Irrigation is used in many different agro-environments of the LMB. As well as enabling dry season production (and in some cases a third crop) it also helps stabilise agricultural production during the wet season. Because of the different socio-economic conditions found throughout the basin, the focus of irrigation development and management differs considerably between the four countries. While in Lao PDR and Cambodia food security is still a major concern, the focus in both Thailand and Viet Nam is one of intensifying production. Diversification in irrigated agriculture has been slow in the LMB. Despite potential returns and lower water requirements, farmers have been reluctant to invest substantially in non-rice production. Access to markets, poor facilities for dry season irrigation, rapidly changing prices and adversity to risk have all contributed to a slow development towards crop diversification, outside the Mekong Delta (MRC 2009a).

There are large differences in water use and irrigation regimes in the LMB, from 'purely rainfed' (where water is solely supplied through rainfall) to 'irrigated' (regular irrigation throughout the growing season), with a variety of stages in between (MRC 2005a).

Much of the informal irrigation sector is developed, financed, operated and maintained by individual farmers, communities or local businesses. In Cambodia, for example, local communities are implementing ring dike systems in the flood plains of the Tonle Sap basin, including some quite large systems (Someth et al. 2009). Throughout the basin, individual farmers are developing farm ponds and using water pumps to irrigate their otherwise rainfed fields. In northeast Thailand, for example, both ponds and pumps are an integral part of water-use strategies (Floch and Molle 2009).

Governments in the LMB countries have recognised that institutional reform is needed to improve the performance of existing infrastructure. These reforms include both water pricing and cost recovery policies, the setting up of water user associations, as well as institutional and legal reforms and policies (Hoanh et al. 2009).

In Cambodia, for example, the main policy approach is to transfer small and medium-scale irrigation schemes to communities of farmer water users. The Ministry of Water Resources and Meteorology has launched a program on participatory irrigation management and development to establish farmer communities as legal entities (Molle 2007). In Thailand, attempts have been made to establish water-user associations since the early 1980s (Molle et al. 2002) and in Lao PDR policies were introduced in the 1990s for irrigation management transfer, aiming to hand over operation and maintenance to farmers. However, success has been modest, and it has been argued that it is time to look beyond these policies in an attempt to increase efficiency and improve the provision of water services (Mukherji et al. 2009).

Irrigation water use

The irrigation sector is the largest water user in the LMB, consuming an estimated 41.8 billion m^3 of freshwater resources (MRC 2005a). More than half of this water use takes place in the Mekong Delta (26.3 billion m^3), followed by Thailand (9.5 billion m^3), Lao PDR (3.0 billion m^3), Cambodia (2.7 billion m^3) and the highlands of Viet Nam (0.5 billion m^3). The different water use strategies

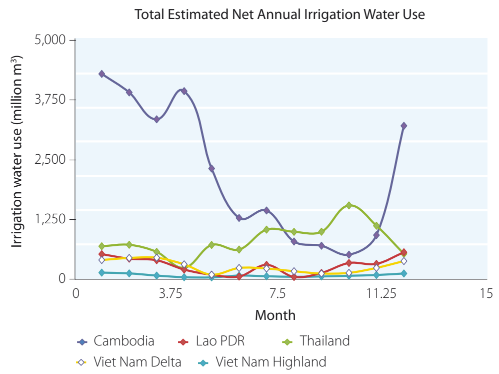


Figure 4.3.2 Total estimated net annual irrigation water use in the Lower Mekong Basin.
Source: adapted from MRC (2005a).

range from supplementary water use during the wet season to fully irrigated multi-cropping strategies, and are reflected in Figure 4.3.2.

The status of irrigation in the LMB

The area under irrigation has expanded gradually in all four LMB countries. Most of the installed irrigation infrastructure is found in northeast Thailand and the Viet Nam delta. A recent assessment of irrigation in the LMB recorded almost 15,000 individual irrigation projects, varying from small to large-scale, and from gravity to pump-fed irrigation (MRC 2009a).

Since 1990, with grants and loans from development partners, the Government of Cambodia has made significant investments in irrigation development.

Dry-season rice production in Lao PDR is fully dependent on irrigation water supplies and has only become significant since the installation of more than 7000 diesel and electric pumps in the mid 1990s. According to national statistics, the achievement of the self-sufficiency target was mainly due to the increase in wet-season production. Irrigation is also used for vegetable production.

In northeast Thailand, over the past 10 years the area of irrigated agriculture has been fairly static and, despite large investments, actual water usage remains low outside the wet season.

Irrigation in the Viet Nam delta is used to grow rice, upland crops and fruit trees, as well as a significant area of brackish water shrimp production. In the Central Highlands, production is far less, with an area of irrigated rice estimated at only 141,684 ha in the wet season and 76,184 ha in the dry season.

The total area under irrigation in the LMB is estimated at four million hectares, comprising 3.5 million hectares in the wet season, and 1.2 million hectares in the dry season. As well, about 1.5 m ha is used to grow a third crop (Table 4.3.6).

Low market prices for rice, that have continued up until the recent food crisis (see p. 181), have limited production in the dry season. Consequently, wet season rice is the most common crop in the region. Most wet season rice in irrigation schemes is cultivated under water-use regimes that include either informal or occasional irrigation. In northeast Thailand, for example, irrigation schemes are mainly used to provide supplementary irrigation to wet season crops and used in a minor way during the dry season (MRC 2005a) when the irrigated area is as low as 10–15 per cent of the installed irrigable area.

Table 4.3.6 Area of irrigated rice and other crops (2007)

Country	Irrigable area	Rice (ha) 1st season	Rice (ha) 2nd season	Rice (ha) 3rd season	Non-rice crop area (ha)	Annual irrigated area (ha)
Cambodia	504,245	273,337	260,815	16,713	12,172	563,037
Lao PDR	166,476	166,476	97,224	-	6977	270,677
Thailand	1,411,807	1,354,804	148,255	-	252,704	1,755,763
Viet Nam	1,919,623	1,669,909	739,594	1,478,740	329,740	4,217,983
• Delta		1,528,225	663,410	1,478,740	294,899	3,965,274
• Highlands		141,684	76,184		34,841	252,709
Total LMB	**4,002,151**	**3,464,526**	**1,245,888**	**1,495,453**	**601,593**	**6,807,460**

Source: MRC (2009a)

Potential and challenges for the irrigation sector

After many years of low and stagnating commodity prices, recent price hikes have triggered renewed interest in irrigated agriculture, both by governments and donor organisations as well as by farmers who have returned to rice production because of the higher prices. Triple cropping has increased in parts of Hau Giang and An Giang provinces in the Mekong Delta, for example (Hoanh et al. 2009).

Irrigation in Southeast Asia in general (FAO 2007), and the LMB in particular (Hoanh et al. 2009; MRC 2009a), is at a crossroads. The general consensus is that rice production in Southeast Asia will have to increase in the long term (Mukherji et al. 2009), mostly through increases in production from existing irrigation schemes.

Among the potential opportunities for irrigation development in the LMB are changes in the wet and dry season flow regime, resulting from a large number of planned storage projects which will shift the river discharge (both in the Mekong mainstream and major tributaries) from the wet to the dry season. These proposed developments would reduce flood peaks and result in higher water availability in the dry season. At the same time, rising water levels would reduce the current pumping lifts, on which much of the dry season irrigated infrastructure relies.

Whether these increases in dry season flow will be used for irrigated agriculture in the LMB will largely depend on current constraints to dry-season irrigated agriculture. While in some areas water availability is the limiting factor, market demand and access and/or labour shortage are much more limiting in others. Furthermore, in the LMB, in general, pump irrigation developments have not been very successful; pumping in Cambodia, for example, is a critical limiting factor, as existing farming methods are difficult to reconcile with the costs and logistics of pumping (MRC 2009a).

There are a number of ongoing irrigation developments in the LMB and the latest basin development plan predicts that dry season irrigation will increase significantly in Lao PDR, Cambodia and Thailand, while the area in Viet Nam will remain stable (Table 4.3.7). At the same time, the best irrigation sites in the basin have largely been developed (Hoanh et al. 2009), and new sites tend to be more marginal with less attractive returns.

Among the plans for irrigation development in the LMB are a series of water transfer schemes that aim to move water from areas seen as water abundant to those with water shortages. Northeast Thailand has long been seen as a target area to further augment irrigation water supplies by bringing in water from outside the region and transferring it to the Chi-Mun basin (Molle and Floch 2008).

Although some progress has been made, early efforts to improve irrigation performance in Southeast Asia's paddy fields concentrated on improving water-use efficiency without always achieving user participation and empowerment (MRC 2009a). In addition, with little attention given to improving how irrigation systems are designed and operated, farmers have rarely experienced the promised improvements in water delivery (Mukherji et al. 2009).

The LMB faces two main challenges in regards to irrigation (Hoanh et al. 2009): i) strengthening the 'hardware' (infrastructure) and the 'software' (the institutions of existing irrigation schemes); and ii) finding ways of improved water governance for new irrigation developments in the region.

Scheme modernisation needs to include more than the rehabilitation of physical infrastructure. It should aim at improving water services, respond to farmers' needs and adapt water delivery systems for multiple users (FAO 2007). But while it is generally acknowledged that modernisation involves the transition from supply-driven to demand-driven management, in practice, very little structural change has occurred. Modernisation of irrigation systems and their management is urgently required (FAO 2007).

Agricultural productivity

Although living standards have generally increased markedly in the LMB, significant areas of poverty remain. Agricultural productivity in the LMB, which is also expressed as land and water productivity, has a critical influence on both rural welfare and the economic growth that ultimately helps alleviate poverty. Agricultural productivity also strongly influences food security. Growth in productivity can increase and stabilise food supplies, as well as increasing people's ability to purchase food. 'Water productivity' broadly denotes the outputs (goods and services) derived from a unit volume of water.

Rice

Rice yields in the LMB range from 1.0 to more than 5.0 t/ha, with the highest yields in the delta region of Viet Nam, moderate yields in some parts of Lao PDR and the Viet Nam highlands and the lowest yields in Cambodia and northeast Thailand. The regions of highest productivity are those of highest rainfall or irrigation water use. Drought is a major production constraint for rainfed lowland rice, being particularly severe in northeast Thailand. It also affects large areas of rice cultivation in Lao PDR and Cambodia (Fukai 2001). In these countries, late-season drought is common, causing yield losses as high as 35 per cent in Thailand (Jongdee et al. 1997, see section 3.4).

In all regions, productivity increased from 1993 to 2004, with the increase being more prominent in Lao PDR and Viet Nam. For Cambodia and Thailand, the yield has been more or less consistent since 2000 with slight variations from year to year. The population has, however, also increased, and thus the increase in yield per capita is much less than that of yield alone (Figure 4.3.3).

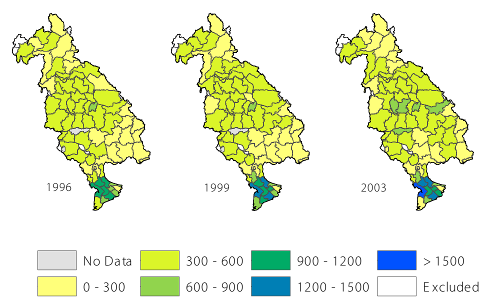


Figure 4.3.3 Rice production per capita (kg/capita), 1996, 1999, and 2003.

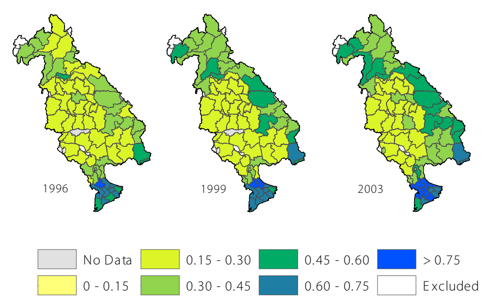


Figure 4.3.4 Water productivity of rice ($/m³), 1996, 1999 and 2003.

Water

Patterns of water productivity of the major crops in terms of production per unit of evapotranspiration (kg/m³) are similar to those for yield: high in the delta region of Viet Nam, moderate in Lao PDR and the central highlands of Viet Nam and low in Cambodia and northeast Thailand. Productivity in terms of US$/m3 is, however, distinctly different (Figure 4.3.4). The productivity of rice, maize and soybean (US$/m³) has declined since 1997, probably as a result of the 1997 Southeast Asian economic crisis. For example, while the farm-gate price of rice has remained stable in the local currencies, its dollar price has fallen because of their devaluation against the US dollar.

The gross value of production (GVP) of rice per unit of harvested area follows the same pattern as yield, i.e. lower in Cambodia and Thailand but GVP per capita is different. Per capita GVP of rice is higher in northeast Thailand than in Lao PDR and Cambodia. This is because the rate of population growth is falling in Thailand, but is rising in both Lao PDR and Cambodia.

Rice contributes about 90 per cent towards the overall gross value of crop production in the delta region, central Cambodia and the eastern part of northeast Thailand. The contribution of rice to GVP fell in Lao PDR, some provinces of Thailand and the central highlands of Viet Nam, with the GVP from other crops in some areas being higher than the GVP from rice in some years. GVP per capita for all crops is highest in Thailand, Lao PDR and Viet Nam.

Cropping intensity is defined as the ratio of total cultivated area of crops grown in a year to the total agricultural area. In the LMB, the cropping intensity of rice remains stable, being highest in the delta (130 per cent) and lowest (15 per cent) in the Central Highlands of Viet Nam. Overall cropping intensity has increased in Lao PDR, Cambodia and the Central Highlands of Viet Nam and remained static for northeast Thailand. In the Mekong Delta, overall cropping intensity increased gradually until 1999 and has remained almost constant since.

Water productivity of crop production per unit volume of rainfall falling on the agricultural area of each province is higher in Lao PDR and the delta than in Thailand, Cambodia and the Central Highlands of Viet Nam. In terms of the volume of rainfall falling on the total area of the province, water productivity is the lowest in Lao PDR because much of the rain there falls on non-agricultural land that is not used to grow crops (if water productivity of forests was included the results would probably be different).

Crop water productivity in terms of evapotranspiration in Lao PDR is almost twice that of Cambodia and northeast Thailand. Although the delta is the most intensively farmed and productive region of the LMB, the crop water productivity is lower than that in Lao PDR and lies midway between that of Lao PDR and Cambodia.

Source: (Mainuddin et al. 2008).

Table 4.3.7 Increases in dry season irrigation

	Current situation	20-year plan scenario	Increase (%)
Lao PDR	97,224	329,952	239
Thailand	148,255	427,741	189
Cambodia	260,815	378,917	45
Viet Nam	739,594	739,594	0
LMB total	1,245,888	1,876,204	51

Source: MRC 2009b.

Agricultural inputs and farm mechanisation

Fertilisers and pesticides

Since the early 1990s, the use of commercially produced fertilisers and pesticides has increased considerably in the LMB, as governments have promoted the cultivation of cash crops and greater cropping intensities. Between 1990–92 and 2003–05, fertiliser consumption almost tripled in Thailand and Viet Nam, and almost doubled in Cambodia (Table 4.3.8). In general, fertiliser use in Viet Nam and Thailand are greater than in Cambodia and Lao PDR, where the imported fertiliser is mostly applied to vegetables and fruit trees, with the remainder being applied for dry season rice production and upland crops.

Table 4.3.8 Changes in fertiliser use

	Fertiliser use (100 g/ha of arable land)	
	1990–92	2003–05
Cambodia	19	31
Lao PDR	31	n.a.
Thailand*	598	1407
Viet Nam*	1299	3309

Source: World Development Indicators, *data are for the whole country

The composition of applied fertiliser has progressively changed over the past 5–10 years in response to research showing that most soils in the LMB are deficient in phosphorus and becoming increasingly deficient in potassium (MRC 2005a). Imbalanced fertiliser application is particularly evident in the Mekong Delta where farmers apply nitrogen at 180–200 kg/ha (Nhan 2003) but phosphorus and potassium are applied at very low rates.

Pesticide use in the LMB is still low compared with western countries, but has sharply increased in Cambodia, Thailand and Viet Nam, while in Lao PDR the government restricts use of pesticides. As most applied pesticides are imported, the total import value of pesticides (Figure 4.3.5) provides an indication of the growth in use even though not all imported pesticides are used in the agricultural sector.

Pesticide use in Viet Nam is much higher than in the other LMB countries, especially in the intensively farmed Mekong Delta. Farming system specialists in Viet Nam are concerned at the level of pesticide use in the delta, and do not consider dry season rice paddies to be suitable for rice-fish production (MRC 2005a).

Farm mechanisation

Mechanisation of farm activities has the potential to increase farm productivity and improve production. For example, replacing animal traction with engine-powered tractors will vastly speed up land preparation, thereby improving the timing of cropping patterns, and in some cases enabling multiple cropping. However, agricultural equipment is expensive to purchase and operate. Adaptation of tractor-powered land preparation, engine driven water pumps,

combine harvesting and mechanical threshing are therefore also dependent on the cost and availability of labour. In the same way that labour costs and agricultural practices vary across the basin, so does the extent of farm mechanisation.

Since the 1990s, investment in agricultural machinery has increased greatly in Thailand and Viet Nam while in Lao PDR and Cambodia farm mechanisation is still at low levels (Table 4.3.9). In Lao PDR, for example, less than 10 per cent of land is prepared by tractor, while mechanical threshing is gradually increasing in the lowlands. In Thailand and Viet Nam, land preparation using tractors is almost universal, either to compensate for high labour costs (Thailand) or to enable extra cropping (Viet Nam) (Table 4.3.10). All four countries use engine-driven or electric pumps to pump irrigation water.

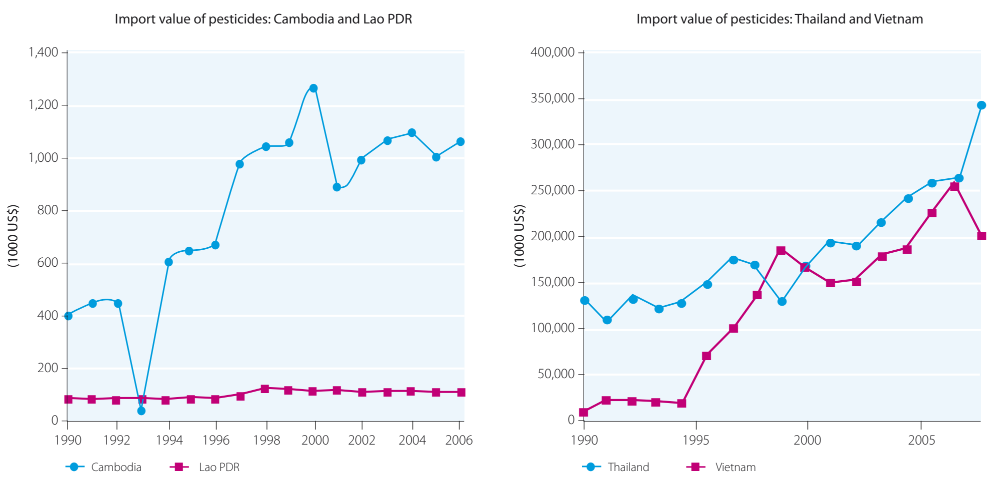


Figure 4.3.5 Import value of pesticides (1990–2006).
Source: FAOStat (2009); Thailand and Viet Nam values are for the whole country.

Table 4.3.9 Use of agricultural machinery in the LMB

Country	Agricultural machinery (tractors per 100 km² of arable land)	
	1990–1992	2003–2005
Cambodia	3	9
Lao PDR	11	11
Thailand*	39	256
Viet Nam*	60	247

Source: World Development Indicators, *data are for the whole country.

Table 4.3.10 Extent of farm mechanisation in the LMB

Country	Tractor land preparation (%)	Mechanical harvesting (%)	Machine threshing (%)	Machine milling (%)
Cambodia	16	0	30	75
Lao PDR	Less than 10	0	50	95
Thailand	95	50	100	100
Viet Nam	100	0	100	95

Source: MRC 2005a

Agrarian change and agricultural labour

The changes in farm inputs and mechanisation of production are embedded in wider changes in the rural areas of the LMB. Urbanisation and the associated decline in the percentage of rural population is a phenomenon found in all four to varying extents (Table 4.3.11). Other common trends are diversification in occupations and livelihoods – having multiple occupations is becoming more common – and a shift in the balance of household income from farm to non-farm (Rigg 2006).

These trends are most visible in northeast Thailand. Between 1970 and today, the northeast region has undergone considerable economic growth and the non-agricultural economy (both in the region and the country as a whole) has absorbed increasing numbers of rural people, drawing them away from farming. In recent years, agricultural expansion in Thailand has declined as a result of the increasing importance of other sectors in the economy (Coxhead and Southgate 2000), with an 'exodus of young labour' (Funahashi 1996). As a result of these wider changes in rural livelihoods, there is a shortage of agricultural labour. Labour-saving agricultural practices, such as farm mechanisation and direct seeding of rice, have been adopted to cope with these structural changes.

While this trend is marked in northeast Thailand, it is also occurring in other parts of the LMB. In Lao PDR, for example, the Vientiane plain (one of the most important agricultural areas of the country) is increasingly becoming a peri-urban environment as the expanding city of Vientiane attracts increasing numbers of farmers into paid labour. Other parts of rural Lao PDR are also being drawn into the wider non-agricultural and regional economies, as farmers are reported to frequently work in neighbouring Thailand. This, in turn, means that Lao farmers perceive labour shortage as one of the most important constraints for agricultural production (Schiller et al. 2001).

Table 4.3.11 Percentage of rural population to total population

	Rural population (% of total)	
	1990	2007
Cambodia	87	79
Lao PDR	85	70
Thailand*	71	67
Viet Nam*	80	73

Source: World Development Indicators; *data are for the whole country

The food crisis: impacts and future trends

Since 2006, the world food market has experienced considerable increases in commodity prices. Agricultural commodity prices rose sharply in 2006, 2007 and peaked in 2008, while more recently prices have declined again. The FAO food price index for different groups of basic food commodities is shown in Figure 4.3.6, and highlights the fact that soaring prices occurred in all major food commodities, including dramatic increases in the region's most important crop – rice (Figure 4.3.7).

Reasons for the price increases are many and include both supply and demand pressures (FAO 2008c). On the supply side, these included weather-related production shortfalls, a gradual reduction in the level of stocks (mainly cereals) since the 1990s and increasing fuel costs. On the demand side, reasons included an emerging market for agricultural commodities. Commodities which have traditionally been predominantly grown as food and/or feed are increasingly being grown as raw material for producing biofuels. With soaring fuel prices, many governments have implemented policies to support the biofuel sector and have subsidised production. Other relevant factors include the operation of financial markets, short-term policy action and exchange rate swings (FAO 2008c).

In the medium term, analysts suggest that commodity prices will not remain at the record levels observed during 2007 and 2008. However, the most recent OECD and FAO study (OECD-FAO 2009) has suggested that, without exception, average real prices are likely to remain above those observed during the last two decades. Two independent projections (FAPRI 2006; OECD-FAO 2009) suggest that the price of rice will be in the order of US$400/ton in the medium term. Thailand, Viet Nam and India will account for virtually all of the net growth in world rice exports of the next 10 years with growth rates projected to grow annually by 3.9 per cent in Thailand and 3.6 per cent in Viet Nam (FAPRI 2006).

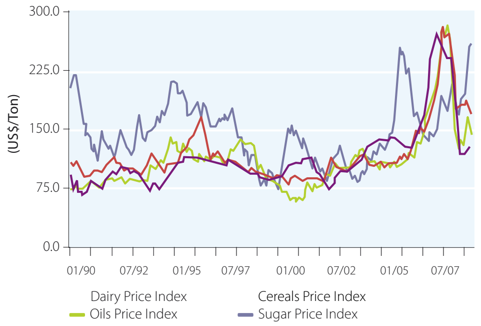


Figure 4.3.6 Monthly FAO price indices for basic food commodity groups. *Source*: FAO (www.fao.org).

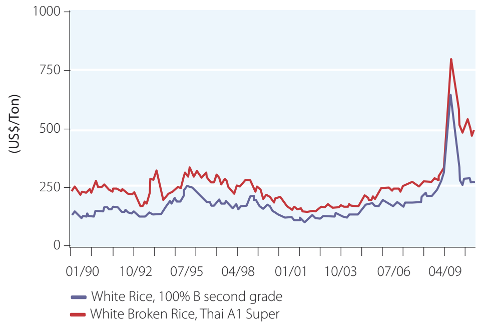


Figure 4.3.7 Trend in rice prices (199–2009). *Source*: FAO (www.fao.org).

Livestock production

Livestock production in the LMB is important as a source of haulage, natural fertiliser, cash income and additional dairy protein for the people of the region. Large animals, in particular, provide financial security to people in subsistence economies, functioning as valuable tradeable assets, while smaller animals, such as pigs and poultry, are equally often raised to provide farm households with a major source of animal protein.

Table 4.3.12 Livestock numbers in the LMB (000s)

	Cambodia		Lao PDR		Thailand*		Viet Nam*	
	2000	2007	2000	2007	2000	2007	2000	2007
Cattle and buffalo	3686	4174	2185	2457	6313	8224	7025	9721
Sheep and goats	–	–	122	230	181	362	372	544
Pigs	1934	2790	1446	2260	6558	8381	20,194	26,561
Poultry	20,749	22,200	14,885	25,200	252,843	222,985	196,100	226,000

Source: FAO (2009) *data are for the whole country.

In Thailand, livestock production has remained at comparatively stable levels, but in the other LMB countries it has grown considerably over the past two decades (Table 4.3.12). In Cambodia, the livestock sector is dominated by smallholders. Poor families raise chicken and often a number of pigs, while richer farmers frequently own a pair of draught and breeding cattle. Although few in number and representing less than one per cent of livestock owners, emerging large-scale commercial businesses are entering the livestock industry (FAO 2005b). The dominant mixed-livestock farming system is rice based, whereby rice production is heavily dependent on cattle and, to a lesser extent, buffalo, for draught power and manure. Most households in rural areas keep chickens. Milk production is also primarily in the hands of smallholders and the few intensive production units are located in areas close to Phnom Penh. Over the past two decades meat supply has grown due to an increase in the number of animals while productivity (defined by carcass weight) remains low.

In Lao PDR, most (if not all) livestock production is traditional, extensive and with low inputs. The greatest difference exists between the predominantly lowland areas of the Mekong corridor and the sloping uplands (FAO 2005c). Cattle and buffalo are mostly found in the central region, where they graze on the vacant cropping area for most of the year and also extensively on the slopes. Pig production is an important livelihood activity for highland people and most farmers raise chickens. Commercial pig production and poultry operations, which are found near population centres such as Vientiane, are mostly small cottage industries with few employees. Like Cambodia, supply of meat has increased, with most of the growth due to more animals, rather than productivity gains.

Thailand made great strides in the 1990s to establish a thriving poultry industry and become one of the world's leading exporters of broilers, ranked fifth in 2003 after the United States, Brazil, France and the Netherlands before the outbreak of avian influenza (FAO 2006b).

Between 1990 and 2002, total production of meat increased from 1.9 million tons to 2.3 million tons. The largest annual growth rate was for poultry meat (six per cent). At the same time, beef and buffalo production fell by 3.6 per cent (FAO 2005d).

In Viet Nam, livestock plays an important role as an income source for many agricultural households (Maltsoglou and Rapsomanikis 2005). Livestock production is almost exclusively in the hands of small farmers, who own about 40 per cent of cattle, 75 per cent of poultry and 80 per cent of pigs. Semi-intensive and intensive pig and dairy farms are growing fast (FAO 2005e). Meat and milk production have increased over the past two decades, both in aggregate and per capita terms, and domestic meat demand is met by local supply. An increase in the number of animals and productivity gains both contributed to the growth in output for pork and poultry.

Significant scope exists to increase livestock production, particularly in Lao PDR where large areas of potential pasture land are available and the government is actively encouraging upland households to switch to animal husbandry as an alternative to shifting cultivation. However, increasing the capacity of livestock production is constrained by the low quality of forage and fodder, inadequate animal health services and low productivity of native species.

It is likely that numbers of large animals will continue to increase significantly over the next 20 years as crop production increases and meat prices improve.

Sompong Phengchan

Livestock represent a tradeable asset and a measure of financial security to people in subsistence economies.

4.4 SUSTAINABLE HYDROPOWER DEVELOPMENT

Hydropower status and trends

Hydropower is an important energy resource for all people living in the Mekong Basin – both now and for the future. The region as a whole has considerable potential for hydroelectric development at all scales, from large multi-purpose projects to feed national power grids to micro-scale projects for rural electrification or local supply. Mekong government policies promote the use of water resources to generate electricity, not only for national needs, but also to catalyse mutually beneficial expansion of cross-border power trade in support of regional economic integration and energy security goals.

Slightly more than 10 per cent (3235 MW) of the estimated 30,000 MW of hydroelectric potential on the lower Mekong has been developed, mainly in the past two decades. Private sector developers are advancing new proposals for large hydropower schemes under regulatory systems introduced to encourage investment in strategic infrastructure for water and energy. Proposals exist for further large-scale hydropower development on Mekong tributaries and, since 2006, at least 11 sites on the Lao, Lao–Thai and Cambodian reaches of the lower Mekong mainstream. The latter would represent about 15,200 MW of installed capacity. Most of the developers responding to the government calls for private sector partners, and their financing sources, are from the Asian region (MRC hydropower database).

China recently completed its fourth large dam on the Lancang–Mekong in Yunnan province. Four more mainstream dams are under construction or planned before 2025. The cascade in Yunnan will represent some 15,200 MW of installed capacity. This represents electrical supply to about 75 million people, at current average per capita electricity use in the Greater Mekong Subregion (GMS) (920 kWh/head/year).

The Mekong has thus become one of the most active regions in the world for hydropower development with a comparatively high number of large hydropower projects planned, relative to the size of the basin. Along with this interest, the need to balance the opportunities and risks of hydropower development with strategies for overall sustainable development of the basin has come to the fore.

The optimisation of overall development performance of hydropower projects often involves tradeoffs between multi-purpose water uses. Tradeoffs between power production and flood management are well-known (e.g. partially drawing down reservoirs in advance of major flood events at the expense of power generation); similarly, water may be released through fish passage structures to improve fish passage to maintain viable fish populations, leaving less water to pass through turbines. Optimisation may also include non-consumptive and consumptive water allocation tradeoffs; such as optimising non-consumptive releases from dams to enhance navigation or fisheries functions downstream, or consumptive withdrawals of water from reservoirs to increase crop yields or municipal water supply.

The cross-border trade in power between Mekong countries will largely determine the scale and pace of hydropower development in the lower Mekong. In 2003, all six governments of the GMS signed an Intergovernmental Agreement on Power Interconnection and Trade. A 'road map' to implement the 2003 agreement and, as an initial step, develop a regional power interconnection master plan was supported by the ADB. Environmental sustainability is stated as a key aspect of the road map (ADB 2009e). The road map builds on a series of bilateral MOUs and agreements developed by the Mekong governments over the past two decades. These are framework agreements to expand cross-border power trade that authorise the respective power entities in each country to negotiate a power purchase agreement for specific hydropower projects. (The approval of any individual project is subject to concluding one of these agreements).

Thailand signed a MOU for power trade with Lao PDR in 2003 for up to 3000 MW. This was to accommodate imports of power from the Theun Hinboun (187 MW) and Huay Ho (126 MW) hydropower projects in Lao PDR. The quantum of power under the MOU was raised to 5000 MW in 2006 and subsequently raised to 7000 MW to accommodate additional Lao exports, such as those anticipated from the Nam Ngum 2, Nam Ngum 3, and Nam Theun 2 projects (TNMC 2009). Thailand has entered into similar agreements with Cambodia and other GMS countries. Lao PDR, in addition to the MOU with Thailand, has power trade agreements with Cambodia and Viet Nam. Yunnan Province and Viet Nam, similarly, have agreements to cover cross-border trade between the China Southern Power Grid and Electricity of Viet Nam (EVN) to supply electricity to six provinces in Viet Nam.

The future cross-border power trade depends on what is specified by the individual power development plans of Mekong countries. External factors such as international energy price volatility will be important, including what support the international community offers the Mekong region to move to a lower-carbon electricity generation future.

Hydropower development on Mekong tributaries

All hydropower projects built so far in the LMB are located on the tributary systems. By 2009, 2612 MW of capacity was installed on lower Mekong tributaries and a further 3574 MW was under construction (Table 4.4.1).

The dams (existing and under construction) are located on tributary systems that flow into the Mekong River, from the mainstream reach in northern Lao PDR to the mainstream reach above Kratie in Cambodia. A number of the projects form cascade-type developments on the same tributary systems.

Viet Nam has advanced most rapidly in the past decade, developing tributary hydropower potential in its Mekong sub-basins. Although Thailand has additional development potential on Mekong tributaries, it has not proposed any plans to pursue large

Table 4.4.1 Installed capacity of existing, under construction and planned/proposed hydropower projects in the LMB (2009)

	Installed capacity (MW)			
Country	Existing	Under construction	Planned / proposed	Total
Cambodia	1	–	5589	5590
Lao PDR	662	2558	17,686*	20,906
Thailand	745	–	–	745
Viet Nam	1204	1016	299	2519
Total	2612	3574	23,574	29,760

*Lao PDR and Thailand share borders on two of the proposed mainstream dams. These projects are included under Lao PDR in this table.

Source: Hydropower database, Basin Development Plan, MRC (2008). The planned/ proposed and total columns includes mainstream project potential.

projects in these sub-catchments (TNMC 2009). Lao PDR and Cambodia are pursuing a number of projects inviting private sector participation. Of the total of 124 existing, under construction and potential tributary projects identified in the MRC hydropower database in 2009, more than 70 per cent are in Lao PDR and 10 per cent are in Cambodia.

The Sesan, Sre Pok, Sekong (3-S) tributary system shared by Viet Nam, Lao PDR and Cambodia (Figure 4.4.1) illustrates the scale and pace of hydropower development on tributaries of the lower Mekong. Of the total 41 identified sites in the 3-S basins, 17 projects are operating, or at various stages of construction; eight projects are at detailed design stage and a further 16 planned or potential projects are cited in master plans or national power development plans and thus scheduled for construction before 2025. While dams in the 3-S basin are mostly designed and financed for hydroelectric generation, some are multipurpose and have proposed irrigation, flood management and reservoir fisheries functions.

Hydropower projects on Mekong tributaries are being developed for both national electricity supply and for cross-border power trade. An example of a tributary dam that serves both domestic and export markets is the 1070 MW Nam Theun 2 trans-basin scheme in the Lao PDR commissioned in 2009 (Figure 4.4.2). Nam Theun 2 sells a substantial portion of its output (995 MW) to the Electricity Generating Authority of Thailand (EGAT). It also supplies 75 MW of generating capacity (five per cent of the electricity generation from the project) to Electricité du Laos (EDL) for national needs.

The rapid pace of tributary hydropower development highlights the importance of assessing the cumulative impacts of the tributary dams, including the impacts on tributary river flow regimes, fish passage, water quality and sediment flow. This cumulative impact will become increasingly important as the number of dam projects in the LMB continues to increase in the foreseeable future.

Equally important is the scope to optimise the overall development performance of hydropower dams in the same tributary system and to build in the flexibility to adaptively manage reservoirs. Adaptive management is important because development needs and values will change over time, such as how basin stakeholders value hydropower production versus other multi-purpose uses of the reservoirs.

Countries are starting to use strategic environment assessment (SEA) and cumulative impact assessment (CIA) tools. For example, the first CIA for the basin was prepared for the Government of Lao PDR as part of the decision for Nam Theun 2 in 2005. It considered cumulative impacts of the project in terms of flows and water level changes in the Mekong mainstream on top of the influence of dams in China (ADB 2009e).

A pilot SEA being prepared for the 3-S tributary system considers not only the cumulative impacts of what may be up to 41 dam developments in the 3-S basin, in the portions of the basin residing within each country, but also the cumulative trans-boundary impacts.

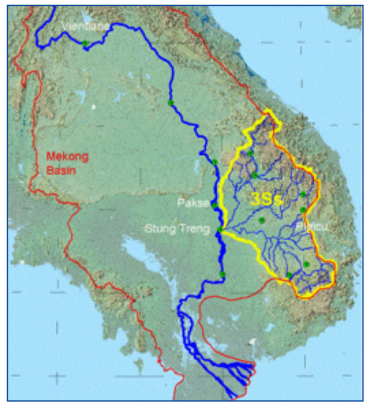


Figure 4.4.1 The Sesan, Sre Pok, Sekong (3-S) tributary system.
Source: ADB Regional Technical Assistance (3Ss study) http://reta.3sbasin.org/

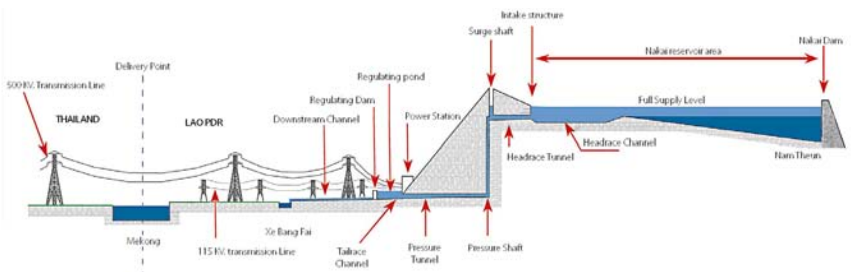


Figure 4.4.2 Nam Theun 2 supplies 75 MW of generating capacity to Electricité du Laos (EDL) and (995MW) to the Electricity Generating Authority of Thailand (EGAT).
Source: www.adb.org.

Hydropower development and management on the Mekong mainstream

The upper Lancang–Mekong cascade

The Lancang–Mekong cascade includes two large seasonal storage projects: Xiaowan, which started filling in 2009 and Nuozhadu, which is now at the design stage and is expected to be commissioned before 2015. These two dams together represent more than 90 per cent of the total reservoir storage volume of the dam cascade, which amounts to about 30 per cent of the mean annual runoff in this reach of the river (see p. 58, Figure 4.4.3).

The comparatively small Ganlanba reservoir at the lower end of the cascade will be operated as a regulation reservoir. This function is to absorb daily variations in hydropower peaking discharges from the upstream dams, and release a more regular flow immediately downstream into Lao PDR and Myanmar. Prior to completion of Ganlanba, the existing Jinghong project will perform the role of regulating downstream releases (MRC 2009b).

While the Yunnan dams are built primarily for hydropower supply they also have intended navigation, flood control and water supply functions (Table 4.4.2).

With the first four dams already in operation, downstream effects of the Lancang–Mekong cascade will become increasingly apparent. Water level fluctuations are now discernible in the dry season between Chang Saen in Thailand and Luang Prabang in Lao PDR. MRC modelling studies show that primary effects on the flow regime in the lower Mekong mainstream include lower flood flows in the wet season

Table 4.4.2 Status of existing and planned mainstream hydropower dams in the Lancang–Mekong cascade in Yunnan Province, PRC (January 2010)

Project	Status	Storage (MCM) total / active	Expected installed capacity (MW)	Commissioning
Manwan	operational	920 / 257	1500	1993–1996
Dachaoshan	operational	933 / 367	1350	2001–2004
Jinghong	operational	1233 / 249	1750	2008
Xiaowan	filling and commissioning stage	14,560 / 9900	4200	2009–2011
Gonguoqiao	under construction	510 / 120	750	2012
Nuozhadu	under design	22,400 / 12,300	5500	2014
Ganlanba	under design	– / 0.2	150	before 2025
		Total :	30400	

Sources: (i) Adapted from the presentation, Lancang River Hydropower Development (New Progress) presented by the China Hydropower and Water Resources Planning & Design General Institute Vientiane, Laos, 28 July, 2009 (2) Norplan and EcoLao, Cumulative Impact Assessment and Nam Theun 2 Contributions, Final Report to Government of Lao PDR and Asian Development Bank, October 2004 (except Jinghong: People's Daily Online, 19 June 2008).

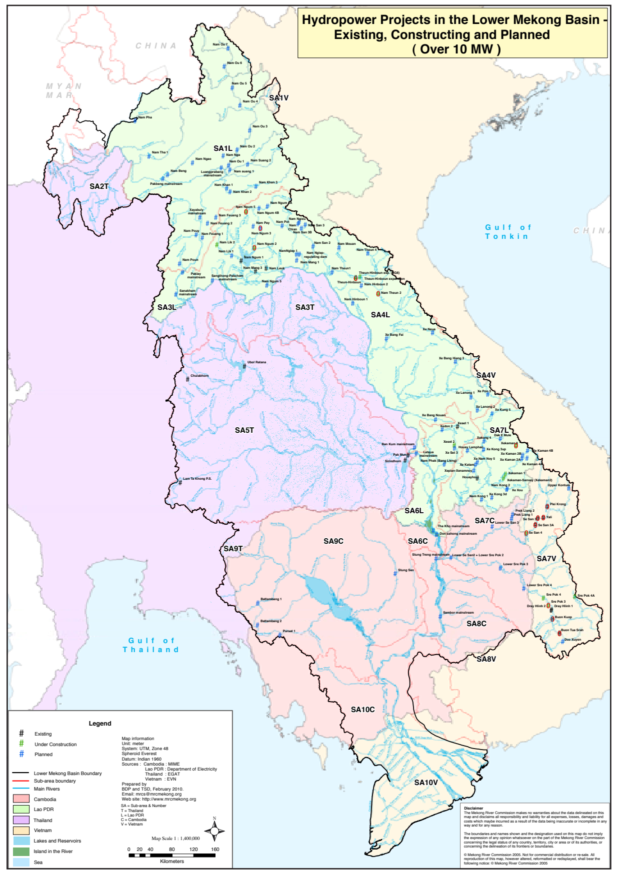


Figure 4.4.3 Proposed, planned and constructed mainstream and tributary dams in the Mekong River Basin.

and a shift in the time of the peak flood, and higher river flows in the dry season.

Apart from the issues associated with changes in flow regulation, the combined effect of sediment trapping in reservoirs in the Lancang–Mekong cascade and sediment trapping by the reservoirs of tributary dams in the lower basin needs careful assessment (see p. 72).

The Lower Mekong Basin

The proposed mainstream hydropower projects in the lower Mekong vary in scale from 360 MW to 3300 MW. The 11 proposed dams would span at least part of the mainstream channel (Table 4.4.3). Generally, the dams located in Lao PDR would form long (up to 100–120 km) reservoirs within the existing channel. Some of them would also have some inundation outside the mainstream channel, especially around the tributaries that intersect the reservoirs.

The two proposed projects in Cambodia (Stung Treng and Sambor), where the topography is relatively flat, would involve more extensive inundation outside the Mekong mainstream channel.

The proposed mainstream dams vary in head from 6 m to 35–40 m (e.g. between the normal water level of the reservoir and water level downstream of the dam) although the actual physical structures for the dam would be higher. They are characterised as low-head dams or run-of-river dams, although some daily regulation would result in variations in water levels downstream, potentially up to a few metres, or more. By comparison, the eight dams that are completed or under construction in China vary from 67 m to 248 m head (for Jinghong and Xiaowan respectively). The proposed mainstream dams have become potentially more economically viable due to the ability to generate more power in the low flow season because of the dams in China.

Cumulative impacts of the mainstream dams are now being assessed in a similar way to the approaches for the tributary dams of the 3S area. A strategic environment assessment is being prepared for the planned mainstream dams in the LMB.

Table 4.4.3 Proposed mainstream hydropower projects in the Lower Mekong Basin

Project	Country	Installed capacity (MW)
Pak Beng	Lao PDR	1230
Luang Prabang	Lao PDR	1410
Xayaburi	Lao PDR	1260
Pak Lay	Lao PDR	1320
Sanakham	Lao PDR	1200
Pak Chom	Lao PDR–Thailand	1079
Ban Koum	Lao PDR–Thailand	1872
Lat Sua	Lao PDR	800
Don Sahong	Lao PDR	360
Stung Treng	Cambodia	980
Sambor	Cambodia	3300
	Total	14811

Source: MRC Basin Development Plan (status 4 February 2009)

Planning process for mainstream dams

The 1995 Mekong Agreement requires that proposals for mainstream hydropower projects are discussed extensively among all four LMB countries prior to any decision being taken (under the MRC's Procedures for Notification, Prior Consultation and Agreement).

While the building of one or all of the proposed mainstream schemes would bring opportunities for economic development of the region, mainly through enhanced electricity supply and improved conditions for inland navigation, these projects will inevitably be accompanied by other development and environmental risks in the four countries.

4.5 DOMESTIC WATER SUPPLY AND SANITATION

Drinking water and sanitation coverage

Millions of people in the LMB, especially in rural areas, lack access to one of the most basic human needs, safe drinking water and sanitation. About 80 per cent of the LMB population have access to safe drinking water and about 60 per cent have access to hygienic sanitation facilities (UNICEF and WHO 2008, Table 4.5.1).

Table 4.5.1 Drinking water and sanitation coverage in 1990 and 2006

Country	Year	Population (million)	Improved drinking water (%)			Improved sanitation (%)		
			Total	Urban	Rural	Total	Urban	Rural
Cambodia	1990	9.7	n.a.	n.a.	n.a.	n.a.	n.a.	n.a
	2006	14.2	65	80	61	28	62	19
Lao PDR	1990	4.1	n.a	n.a	n.a	n.a	n.a	n.a
	2006	5.8	60	86	53	56	87	38
Thailand	1990	54.3	95	98	94	78	92	72
	2006	63.4	98	99	97	96	95	96
Viet Nam	1990	66.2	52	87	43	29	62	21
	2006	86.2	92	98	90	65	88	56

Source: Progress on drinking water and sanitation, UNICEF and WHO, 2008; n.a., data not available

The Millennium Development Goal (MDG) targets for water supply and sanitation are:

- By 2015 to reduce by one-half the proportion of people without access to hygienic sanitation facilities
- By 2015 to reduce by one-half the proportion of people without sustainable access to adequate quantities of affordable and safe water
- By 2025 to provide water, sanitation and hygiene for all (WHO/UNICEF/WSSCC 2001).

At the national level, all LMB countries are on-track to achieve these targets (UNICEF and WHO 2008) and Thailand has already achieved the target (see section 2.2). Cambodia's progress towards access to safe water indicates the likelihood of achieving more than the 2015 target as the country has achieved a much higher rate of access by 2006 compared with the targets set for 2005 (30 per cent and 68 per cent for rural and urban populations respectively). The same trend was observed for rural populations' access to improved sanitation (19 per cent in 2006 compared to the target of 12 per cent in 2005). Progress in urban areas, however, was much slower and below the target, a position that could be partly explained by the large influx of rural poor into urban areas.

Lao PDR has made significant progress from a situation where 28 per cent of the population had access to a safe water source and less than one in three households had access to some kind of latrine in the 1990s (Government of Lao PDR and UN 2008), although disparities exist and remote provinces and districts with poor roads tend to have lower coverage.

In Viet Nam, the much lower progress among disadvantaged households compared to the national average creates a major challenge for the country to achieve its target of 80 per cent of households accessing clean water and 70 per cent accessing standard latrines. National surveys show that 40 per cent of households in the most disadvantaged target areas depend on unsafe water from rivers, lakes and ponds for cooking and only 13 per cent use hygienic latrines. Among the Kinh and Hoa ethnic groups, only six per cent lack access to safe drinking water whereas the rate is 57 per cent for other ethnic groups (Ministry of Planning and Investment Viet Nam 2008).

Domestic water use and sources

Domestic water demand in the LMB usually represents small volumes relative to total withdrawals. Current total demand for domestic water is about three billion m^3 per year or about 0.7 per cent of Mekong annual flow, which is estimated as 457,000 million m^3 per year (MRC 2005c). Total domestic water use is normally determined by both population and lifestyle; including access to water and level of development. Use is generally higher in urban areas than in rural areas and consumption increases significantly with the availability of piped water (Table 4.5.2).

Table 4.5.2 Present demand per capita and trends for LMB domestic water use

Country	Average per capita use (litres/day)			
	Year 2000	Year 2007	Year 2030	Year 2060
Cambodia	32	Rural = 90 Urban = 130	Rural = 100 Urban = 150	Rural = 100 Urban = 170
Lao PDR	64	Rural = 60 Town = 140 Urban = 180	Rural = 80 Town = 160 Urban = 200	Rural = 100 Town = 160 Urban = 200
Thailand	115	Rural = 50 Town = 120 Urban = 250	Rural = 70 Town = 170 Urban = 270	Rural = 100 Town = 200 Urban = 300
Viet Nam	67	Rural = 60 Urban = 100	Rural = 80 Urban = 150	Rural = 100 Urban = 175

Source: Lao PDR - Water Supply Authority; Thailand - Provincial Waterworks Authority; Cambodia - Capacity Building for Water Supply System in Cambodia Phase 2; Viet Nam-Ministry of Construction.

Based on water use figures and a number of population growth scenarios, projected domestic water use for the LMB countries is estimated in Table 4.5.3. Domestic water use is predicted to increase by 50 per cent and 125 per cent of the current level in 2030 and 2060 respectively, although estimated total withdrawals in 2060 would still only be 1.3 per cent of the Mekong's annual flow.

All major cities and provincial towns in northeast Thailand and Viet Nam have piped water but the capacity of supply systems is often insufficient for requirements. In Lao PDR and Cambodia, only major towns have piped water. The major sources of water supply in this region are surface water (rivers, lakes, etc) and groundwater. Most people in rural areas depend on groundwater, using shallow wells while most urban supplies are drawn from reservoirs and rivers, although many towns in Thailand rely on groundwater. Sixty per cent of groundwater abstraction in Thailand is used for domestic supply. In Viet Nam, about two-thirds of town water supplies are drawn from surface water with the remainder from groundwater (MRC 2005c).

Table 4.5.3 Present domestic water use and trends for the LMB

Country	Annual domestic water use (million m^3)			
	Year 2000	Year 2007	Year 2030	Year 2060
Cambodia	127	520	936	1544
Lao PDR	116	239	447	862
Thailand	935	1123	1377	1743
Viet Nam	443	545	1032	1803
Total LMB	1621	2427	3792	5952

Domestic waste water and treatment

Withdrawals for domestic water supply are unlikely to produce major environmental impacts, except on a very local scale, since they generally represent a small fraction of overall withdrawals. The major environmental issue associated with domestic water is the threat to water quality resulting from disposal of contaminated waste water. Potential impacts include:

- reduced recreational amenity
- threats to human health due to microbial contamination
- impacts on irrigation and other uses due to decreased water quality
- eutrophication and toxicity causing algal blooms, fish/invertebrate kills and/or disruption of fish migration
- changes in ecosystem function due to increased turbidity and nutrient loadings.

A review of the potential impacts of municipal and industrial waste water from Phnom Penh and Vientiane on downstream uses, including environment and fish migration concluded that the risks of trans-boundary impacts from effluent releases were likely to be low due to the large dilution factors operating in the Mekong (Hart 2001). Long-term monitoring indicated similar conclusions (MRC 2008). Local impacts, however, may be more pronounced, particularly in the dry season when flows are reduced. If dry season flows were to be reduced substantially due to off-take in upstream areas for example, increased intrusion of marine waters in the delta could threaten domestic supplies in areas relying on shallow groundwaters.

Urban and peri-urban wetlands, such as That Luang Marsh in Vientiane (see box on p. 93), provide natural purification functions by removing excessive nutrients and toxins from agricultural, industrial and municipal waste water before it enters the Mekong mainstream.

Management of water services

The processes for regulating and supplying water services vary in each country. The major towns and cities have a range of government owned water supply corporations or schemes controlled directly by water departments and agencies. At the local level, local authorities usually manage the supply schemes. Supply comes from either surface water, groundwater or a mix of both.

The major trans-boundary integrated water resource management (IWRM) issue relates to the effectiveness of these organisations and arrangements and to the efficiency of the services they provide. Both these factors influence supply and demand and while most of the impacts occur at the local level, trans-boundary impacts may also occur. Establishing a 'network' of water supply agencies in the four countries would help to improve overall operating efficiency and more effectively address any trans-boundary issues.

4.6 NAVIGATION

Waterborne trade and tourism

For thousands of years the Mekong River has been an important conduit for people and goods between the many towns situated along its banks. Traditional forms of trade in small boats linking communities continue today, however the river is also becoming an important link in international trade routes, connecting the six Mekong countries to each other, and also to the rest of the world.

The potential for waterborne trade varies substantially depending on the conditions of the river, and the port and waterway facilities available at particular locations. In a region with challenging topography and under-developed land-based transport alternatives, inland waterway navigation will enable countries along the banks of the Mekong to open up markets and realise economies of scale.

Although road transport is cheaper than inland waterway transport (IWT) on a per unit basis (Figure 4.6.1), these benefits do not persist for larger volumes of cargo being transported over longer distances. This cost comparison highlights the advantage of inland waterway transport as a regional transport link moving large volumes of cargo over long distances.

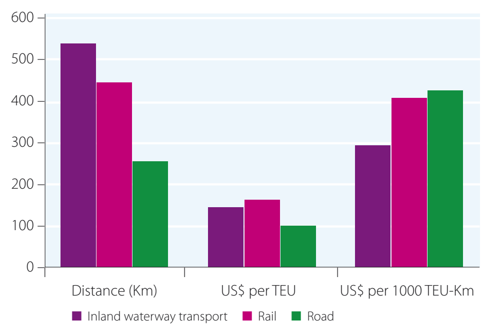


Figure 4.6.1 Relative costs of different modes of transport in the Mekong corridor.

Sources: Master Plan for Waterborne Transport on the Mekong River in Cambodia (2006).

*TEU=20-foot equivalent unit, a measure used for capacity in container transportation.

Trade in the upstream parts of the Mekong

Narrower and more turbulent sections of water in the upstream parts of the Mekong River (above the Khone Falls, Lao PDR), coupled with large annual water level variations continue to present a challenge to the development of trade and transport. The seasonal variations in water level directly affect trade in this section of the river (Figure 4.6.2). Volumes of trade being shipped decrease by more than 50 per cent, primarily due to the reduced draughts available during the low water season (June–January).

Despite these difficulties, the Mekong River is already an important link in the transit chain between Kunming and Bangkok with about 300,000 tonnes of goods shipped via this route each year. The volume of this trade is expected to increase by 8–11 per cent per year (Vrenken 2008). Port infrastructure is being expanded to accommodate the expected growth in traffic, with new facilities planned for Chiang Saen port.

In Lao PDR, 50 and 100 DWT vessels are primarily operated for regional trade, the main types of cargo carried are timber, agricultural products and construction materials.

Thailand imports a wide variety of products from China, including vegetables, fruit, agricultural products and fertilisers. The main exports from Thailand are dried longan, fish oil, rubber products and consumables. Nearly all the ships carrying cargo to and from Chiang Saen Port are 300 DWT Chinese flag vessels.

Hydropower development on the river is expected to increase water levels during the dry season, which will effectively boost shipping capacity and its associated economic benefits.

The volume of trade moving by inland navigation more than doubled between 2004 and 2007. The economic downturn affected trade through Chiang Sean port in 2008, as demand for consumer based products in Thailand and China declined (Figure 4.6.3). However, the underlying growth in trade volume provides a solid foundation for future growth in this sector. Improvements in waterway capacity, as well as port and vessel efficiency, will see waterway transport expanding its share of the upper Mekong transport network.

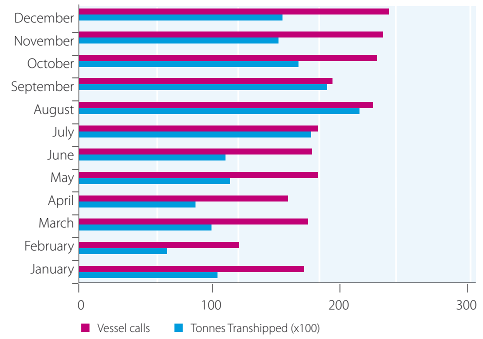


Figure 4.6.2 Monthly averages (2005–2008) of cargo throughput and vessel calls in the port of Chiang Saen, Thailand.

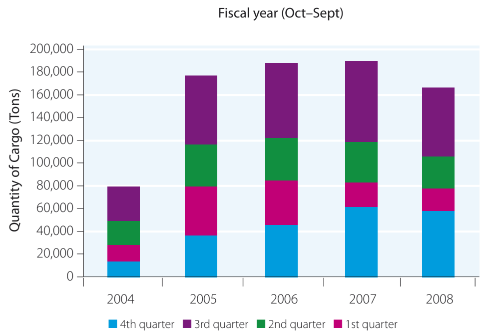


Figure 4.6.3 Cargo volumes between Chiang Saen and Yunnan ports (2004–2008).

Trade in the lower Mekong

Waterborne trade in the lower Mekong countries of Viet Nam and Cambodia has grown significantly, with trends in container traffic at Phnom Penh port and general cargo through Can Tho port both showing steady increases until 2009 when a decrease in cargo volumes can be attributed to the global financial crisis and a subsequent decline in demand for the export of garments to the US (Figures 4.6.4 and 4.6.5).

In 2009, Mekong trade received a significant boost with the opening of a new deep-water port at Cai Mep in Viet Nam. This new port has generated a renewed focus on the Mekong River as a trade route. The Cai Mep container terminals can accommodate vessels with a draught of 15.2 m, equivalent to the largest container ships in the world. These mother vessels sail directly to Europe or the United States, which means that goods can be shipped internationally to and from Phnom Penh with only a single trans-shipment at Cai Mep.

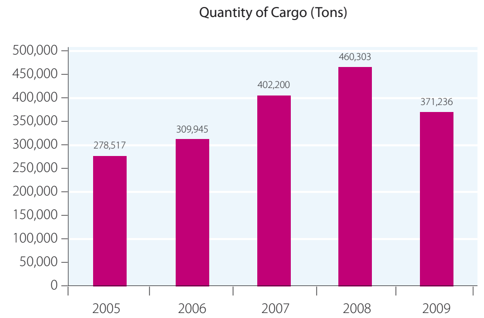


Figure 4.6.4 Phnom Penh autonomous port – cargo movements.

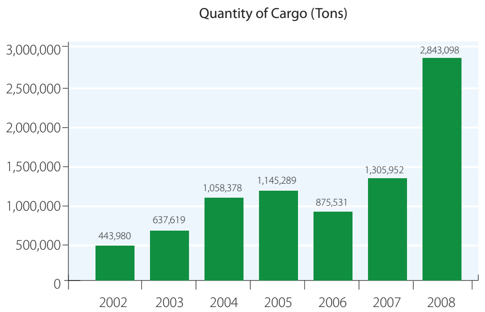


Figure 4.6.5 Can Tho cargo movements

In Cambodia, 5000 DWT vessels are operated from Phnom Penh port; the main types of cargo exported are garments, agricultural products and construction materials.

In Viet Nam, the Mekong River can carry 5000 DWT vessels with drafts up to 8 m all the way to Cambodia, while the Bassac River allows for vessels up to 10,0000 DWT. The Can Tho port uses river-sea vessels to connect the South China Sea with Viet Nam. The main types of cargo exported are rice, vegetables, wood products and consumables.

Waterborne tourism

The pristine waterways of the Mekong region are an ideal vantage point for visitors wanting to sample the mixture of natural beauty and historic cultures found throughout the basin. The trend in visitor arrivals to the four MRC Member States shows a steady increase. Tourist attractions along the waterways of the Mekong make the river an important link for tourists, as well as an attraction in its own right (see section 4.8).

The growth in tourist numbers is being experienced along the length of the river. Although only a small proportion of visitors travel by boat, the Mekong River has a number of unique natural and cultural attractions that could be developed as potential tourist destinations.

Tourism in the upper Mekong continues to grow. Between 20,000 and 25,000 tourist cruise passengers a year take trips on this part of the river. More than 85 per cent of these people travel between Houei Sai and Luang Prabang. This trip is an important component of the increasingly popular link between Chiang Mai and Luang Prabang. As well, an increasing number of cruises travel upstream to Yunnan and in the south of Lao PDR.

In the lower Mekong, tourist cruises take place on a different scale than in the upper basin. Better navigability and access to the ocean allow the river to be used for coastal and international cruise liners. In these stretches vessels of 2000–4000 t can travel upstream to Phnom Penh and vessels of up to 1200 t can continue to Siem Reap (except between January and April when water levels are too low). As a result of this accessibility, 71,889 visitors arrived in Cambodia by water in 2008, while in the same year Viet Nam had 157,198 people visiting by boat (Vrenken 2008). The major boost, however, will come when a new range of shallow draught river cruise ships arrive. Many of these 120 m long cruise 'barges' are currently under construction, while some are being shipped in from other international rivers such as the Nile and the Danube.

Legal agreements for freedom of navigation

For more than 75 years, the Mekong has been regarded as an international river, enabling countries throughout the basin to become trading partners. This cooperation has served as the basis for a number of navigation agreements. These legal frameworks play an important role in developing the navigation potential of the river and ensuring navigation without frontiers.

The most important legal agreements pertaining to navigation on the Mekong River include:

- Agreement between China and Lao PDR on Freight and Passenger Transport along the Lancang–Mekong River, adopted in November 1994.
- Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin, Article 9, Freedom of Navigation, 5 April 1995, Chiang Rai.

Any new hydropower proposals are required to include guidelines for the planning, design, construction and operation of navigation locks to compensate the head created by the dams, thus guaranteeing the passage of boats on the Mekong mainstream.

- Hanoi Agreement between Cambodia and Viet Nam on Waterway Transportation, 13 December 1998.
- Agreement between and among the Governments of the Lao PDR, the Kingdom of Thailand, and the Socialist Republic of Viet Nam for Facilitation of Cross border Transport of Goods and People, (amended at Yangon, Myanmar), signed in Vientiane, 26 November 1999.
- Agreement on Commercial Navigation on Lancang–Mekong River among the governments of the People's Democratic Republic of China, the Lao People's Democratic Republic, the Union of Myanmar and the Kingdom of Thailand, adopted at Tachileik, 20 April 2000.
- Phnom Penh Agreement between Cambodia and Viet Nam on the Transit of Goods, 7 September 2000.
- New Agreement on Waterway Transportation between Viet Nam and Cambodia, facilitated by MRC, signed in Phnom Penh, 17 December 2009.

Many of these agreements only pertain to specific stretches of water or regions on the river (Figure 4.6.6).

Figure 4.6.6 Territorial scope of primary legal agreements affecting navigation in the Mekong Basin.

Notwithstanding the benefits and many practical results of existing legal agreements for freedom of navigation, the practical implementation of cross-border navigation on the Mekong does not measure up to international standards of river law, free trade and competition. The Mekong's potential as an artery for cross-border navigation is yet to be realised. This is partly due to non-physical obstacles to vessel movement originating from the deficient legal framework.

Some of the international navigation regimes on the Mekong operate more to impede than encourage navigation development. The coexistence of multiple conventions relating to navigation leads to uncertainties about the exact legal status of the river. Furthermore, national contract laws and standards on technical issues, safety and environmental protection vary so greatly that they are a threat to regional trade potential.

Fragmentation of national laws, in particular navigation rules and procedures applicable to inland waterway transport and the absence of internationally harmonised liability rules, is a major practical barrier to further development and promotion of inland waterway transport. In turn, this legal uncertainty prevents inland waterway carriers from developing international routes and traders from using inland waterway transport, because of uncertainty about their rights and obligations if disputes arise or damage occurs.

A lack of consistent safety standards has the potential to damage the environment and hence be detrimental to people who rely on the river for their livelihoods. MRC Member Countries have acknowledged the lack of standards and harmonised regulations for safety and environment (including the carriage of dangerous goods) for inland waterway navigation in the Lower Mekong Basin.

In order to provide a strong framework for international shipping in the region, it is necessary to establish cross-border legal agreements for freedom of navigation and harmonise national regulations.

The MRC has worked with Cambodia and Viet Nam to establish the agreement on waterway transportation, which represents a major breakthrough in bilateral economic relations, and was signed in December 2009.

This agreement and the process of formulating it will serve as a model for another legal agreement for freedom of navigation between Lao PDR and Thailand. Any new agreement will need to be compatible with the Quadripartite Agreement of 2000 (between People's Republic of China, Union of Myanmar, Lao PDR and Thailand) to ensure a simple and consistent set of rules and regulations for inland navigation. The long-term goal is to establish a harmonised set of regulations across the basin that will simplify the process of international trade and transport.

Waterway conditions – navigability

The Mekong is still a wild river and navigation conditions vary greatly along its length. Work to improve safety for traffic on the river involves a series of projects to survey and mark the river's natural navigation channel. This work benefits all users, from small traditional boats in the upper reaches to 4000 t container ships in the lower Mekong.

One of the best methods of making a river safer and more efficient for navigation is by marking the channels with buoys and beacons – so called navigational aids. Designing an aids to navigation system on a wild river such as the Mekong requires the collection of large amounts of information to ensure the correct positioning of buoys and beacons.

In contrast to the placid conditions and commercial vessel traffic in the lower river, the upper river features many areas of rapids, with smaller, more agile vessels negotiating these difficult areas. Annual water levels in the upstream parts of the river can vary by more than 15 m, making it difficult to see submerged rocks and presenting a design challenge for aids to navigation systems.

Innovative navigational aids for highly variable waters

The MRC is piloting an innovative combined buoy and flexible beacon channel marking system to use in the Mekong's upper stretches. The design features a metal base plate and coil spring, chemically anchored to rocks, as the foundation for a 6 m tall carbon fibre pole. The coil spring absorbs heavy debris floating down the river and a durable reflective flag is attached to the top of the pole. These markers indicate the channel at low to medium water levels. A 50 m chain with attached buoy is also anchored to the base plate to indicate the correct navigation channel during high-water periods. This combination system ensures that all users of the river are able to find the correct channel regardless of the time of year or conditions.

As well as physical aids to navigation, the Mekong River is now on a par with other international rivers with the provision of modern information systems to facilitate navigation safety and efficiency. Electronic navigation charts have been produced for the Mekong, Vam Nao and Bassac Rivers in Viet Nam (Figure 4.6.7). These provide automated vessel navigation and guidance as well as real-time moving map displays for navigators. Automatic identification systems (AIS) now facilitate instant vessel location and tracking, which allows port operators to schedule vessel arrivals and departures, improving efficiency and reducing overall shipping costs (Figure 4.6.8). These systems also allow masters to identify other vessels on the river, helping to reduce collisions and providing critical location information in the event of an accident.

Real-time data on river heights provided by tidal monitoring stations at the mouth of the Mekong and Bassac Rivers are increasing the daily transit window for vessels entering the river system and improving shipping safety.

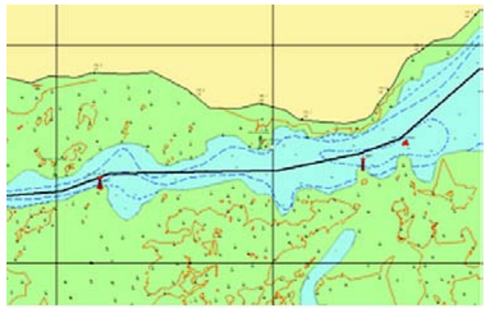


Figure 4.6.7 Mapping of dangerous areas for navigation showing channel and aids to navigation (1:2000).

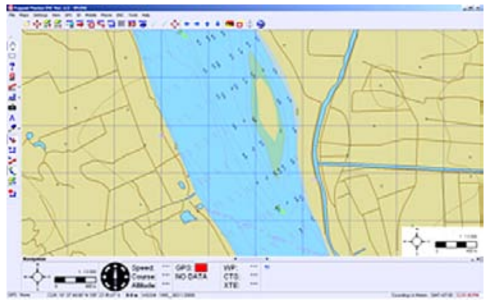


Figure 4.6.8 Electronic navigation chart display software.

Navigation and hydropower

Planning for hydropower development is happening and dams could present a threat to long-haul and cross-border river transportation on the Mekong. At the same time, the dams associated with hydropower development offer an opportunity to improve the navigability of the river by providing more reliable and consistent water depths that will facilitate larger vessel capacities. If the dams proceed, then article 9 of the Mekong Agreement requires that navigation locks are incorporated into hydropower developments. It is also logical that the design, construction, maintenance and operation of all ship locks along the river should be subject to common standards and guidelines.

Lock dimensions must accommodate traffic increases over a 50-year timeframe. Transportation of heavy cargo, such as mined products, containerised waterborne transportation and the introduction of inland cruise vessels will inevitably increase in years to come and the size of ship locks needs to accommodate this expansion. Based on experience from other countries, the forecast for navigation development in the upper Mekong is as follows:

- medium-term envisaged capacity – 300 DWT (equivalent to Class V of the National Standard of the People's Republic of China)
- long-term envisaged capacity – 4 x 500 DWT linked with dams that change the river's characteristics (derived from the navigation strategy formulated under the Quadripartite Agreement of 2000).

Preliminary dimensions have been determined based on a number of factors, including benchmarking with international experience, recommendations by the International Inland Navigation Association, assessments of Chinese waterway classifications in the case of rivers associated with hydropower developments and economic studies. These results will be updated to reflect the future assessments but the preliminary guidance for minimum lock dimensions is: length, 120 m (minimum); width, 12 m; and depth, 4 m.

Development of Mekong navigation in the upper reaches depends on the incorporation of appropriate navigation facilities into hydropower developments as well as designing the hydropower cascade to ensure a reliable channel is available between major ports. These issues highlight the need to incorporate navigation requirements into an integrated development plan for the basin.

Waterway safety and environment

Efficiency and safety of waterborne transport go hand in hand with environmental management of waterways. Although it is widely known that waterborne transportation is the most environmentally friendly mode of transportation, it is also well known that increased waterway use can have negative impacts, including increased pollution from passing shipping, increased risk of spillages from shipping accidents and safety risks for existing river users.

River freight produces on average one-fifth the amount of CO_2 per ton per km of that produced by road freight. Shifting cargo from trucks to barges will reduce fuel consumption per ton carried. If larger barges can be used, the reduction will be even greater (Figure 4.6.9). A reduction in fuel consumption implies a similar reduction in CO_2 emissions.

All types of river regulating works – rock blasting, reef removal, sand and gravel extraction, river re-shaping and dredging – will have an impact on river morphology (Collileux and Fruchart 2009). There are currently no river regulating works being carried out in any of the LMB countries and the MRC will continue to focus on improving navigation through measures such as the installation of channel markers and automatic identification systems which adapt the vessels and operations to the waterway rather than the waterway to the vessels and operations.

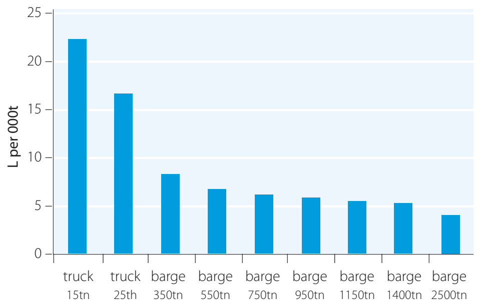


Figure 4.6.9 Fuel consumption in litres/1000 ton/km for trucks and barges of different capacities.

Source: Vrenken 2008.

Port and passenger services

A number of the larger river and sea ports in Viet Nam have implemented environmental management plans for the handling of waste, loading and unloading cargo and receiving wastes from cargo and vessel operations. Environmental monitoring has been established in some ports to monitor the presence of pollutants but there is no consistent and uniform approach to determine the environmental impacts of increased navigation and waterway use.

Elsewhere along the Mekong River ports have limited equipment and resources to respond to dangerous cargo leakages and oil pollution into the river. Contingency plans have not been developed to ensure authorities can respond effectively to emergencies. A clear reporting and communication process has not been established to ensure that ministries of public works and transport, departments of environment, local authorities and other line agencies are notified of any incidents. Consequently, there is no incident investigation process to determine the root cause of incidents to prevent them recurring and ensure that risk mitigations are properly implemented and evaluated.

Further investment would enable provision of resources for preventing and responding to oil spill pollution, to maintain local ports and ensure compliance and monitoring activities are implemented at regional and local levels.

Analysis of the risks of increased numbers of passengers and tourist cruises will enable adequate safety measures to be implemented. Rules and regulations ensuring passenger vessels are equipped with lifesaving and fire fighting equipment and communications are not monitored or enforced. A review of the safety of passenger services would help vessels and port authorities to ensure they can prevent and respond appropriately to navigational emergencies.

Incident reporting

Despite the installation of aids to navigation, an AIS and other safety measures, a large number of accidents still occur. Accurate incident and accident data are not presently available, however reports from local authorities and communities confirm that accidents have occurred, resulting in loss of life, cargo and oil pollution.

Incident reporting and investigation systems would ensure the effective investigation of incidents, to prevent any recurrence and to share lessons learned throughout the inland waterway transport sector. Development and effective coordination of emergency response systems would also ensure vessels, ports and local authorities could respond to emergencies.

Carriage of oil and dangerous goods

The trade of oil, gas and petroleum products between Viet Nam and Cambodia has increased significantly over the past few years. The carriage of dangerous goods on the Mekong River and its tributaries is the highest risk navigation activity and any incident would have major implications for the environment. Despite this, sufficient environmental protection measures have not been implemented to ensure the correct handling of dangerous goods. Provisions for pollution prevention and contingency plans in case of an accident are also limited. While the International Maritime Organisation regulates the shipping of dangerous cargoes by sea, there are no international rules for inland rivers.

Ferry crossings continue to provide an important link for carrying oil and gas road tankers across the Mekong River between Lao PDR and Thailand. There are no standard practices of loading and unloading these ferries and no environmental safeguards have been developed or implemented to prevent incidents, oil spills or loss of cargo. Furthermore, there are no requirements for the carriage of dangerous goods or any specific standards, rules or regulations that apply to ferry operations on the Mekong River.

Oil and gas terminals

Oil and gas terminals are located on the Mekong River in Cambodia and Viet Nam. Most of these terminals have developed standard operating procedures for bunkering, fuel transfer and other critical operations. The storage of oil, gas and petroleum is a major concern for the Mekong River. The terminals have developed response plans for fire fighting and other emergencies but a number of them do not have sufficient contingency plans or adequate equipment and resources to respond to oil spill emergencies. More investment is required in training, oil spill cleanup equipment and resources to ensure oil and gas terminals can prevent and respond appropriately to such emergencies.

Environmental monitoring plans have not been implemented consistently across all the oil and gas terminals to ensure monitoring of air, soil and water emissions. Regular monitoring of groundwater, well water and surface water quality in areas surrounding the terminals for the presence of contaminants and pollution would address the problem.

4.7
MINING AND OTHER INDUSTRIES IN THE LOWER MEKONG BASIN

Archaeological evidence suggests that mining has been carried out in the LMB as far back as the Bronze Age although little is known about ancient mining communities or the techniques they used. Recent discoveries of a large bronze drum at the Lane Xang Minerals (MMG) Sepon Concession in Lao PDR, as well as copper ore mining and processing plants that may date to the Bronze Age have generated renewed interest in the area (Oz Minerals 2008).

Much of the information in this section is derived from a report by Tucker (2009) which investigated large-scale foreign investments in Cambodia and Lao PDR. Recent changes in legislation and the direct encouragement of foreign investment by the LMB countries have led to a marked increase in mining activity. A large number of mining concessions have been granted over the past five years, however there are few currently producing mines within the basin. Cambodia and Lao PDR hold the highest number of active mining projects, while Viet Nam has few active projects within the LMB (Figure 4.7.1). The two principal forms of mining are artisanal and small–medium scale mining.

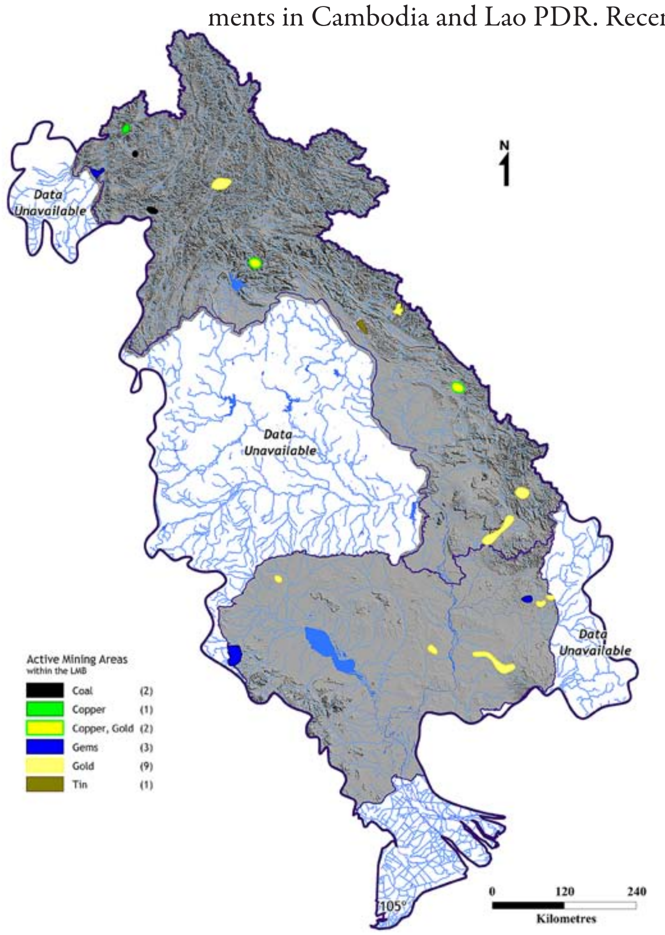


Figure 4.7.1. Active mining zones (including traditional artisanal areas) within the LMB. The size of the areas has been slightly exaggerated to assist in visibility; actual affected land area is significantly smaller.

Artisanal miners are essentially subsistence workers, who plant crops during the rainy season and pan for gold in the dry season. The current high price of gold on the world market has seen an increase in this kind of activity. Artisanal mining is mostly limited to gems and gold.

Small–medium scale mining outfits usually consist of as few as 10, up to a maximum of 150 workers, but typically number about 20. Mining equipment includes basic hand drills, compressors, and tractors/loading equipment, most of which is often old and poorly maintained. Small-scale operators are often, but not always, legal operators. Small-scale mining and quarrying operations are common for industrial minerals and rocks, such as limestone, gypsum, phosphates and ornamental stone (Shingu 2006). An industry of particular note, whose visual impact outweighs the scale of operation, is the sand and gravel which carries out dredging and direct mining when dry season low-water levels allow access.

The past decade has seen the arrival of large multinational mining enterprises to the LMB, particularly in Lao PDR. These operations are capital intense with substantial investments in both plant and infrastructure. They are generally managed by listed companies, as in the case of both the Lane Xang Minerals (MMG) Sepon concession and the Phu Bia Mining (Pan Australian) concession in Lao PDR, and have structured management systems regarding employees, health and safety, the environment and local community issues. They are also large enough to negotiate direct agreements with the host government. Large and medium-scale mines in the LMB include gold, copper, lead, zinc and coal.

The following provides a brief overview of the scale of mining activity in each of the LMB countries.

CAMBODIA

Mining in Cambodia is mostly small scale and partly mechanised, for example, the Pailin gem mining area, a small number of quarries and dredging for gravels and sand. As yet, there is little in the way of large-scale mining.

LAO PDR

As of June 2009, a total of 75 mining licences have been granted in Lao PDR, a further 185 exploration and prospecting licences have been granted and a further 314 applications are under consideration. The sector plan for sustainable development of the mining sector in Lao PDR (World Bank 2006) lists 35 producing mines. These consist of five national mines, eight foreign investment mines, seven Lao–foreign joint ventures and the remaining 15 mines are run by local investors.

Apart from the Sepon and Phu Kham mines, mining is managed on a very small scale with typically about 20 workers. The arrival of the two large companies coupled with a rise in the price of gold has led to renewed interest among the local population in artisanal mining.

THAILAND

Although mining makes a significant contribution to the Thai economy, little information is available on activity within the LMB.

VIET NAM

Active mines operate in many parts of the country. Within the Mekong Delta there are some notes of peat deposits but no information on exploitation. Dredging is quite active although recent agreements limit production to local usage only.

Large amounts of sand and gravel have been dredged from channels of the Mekong River leading to a government directive banning the export of these materials. However, companies may continue to dredge river sand and gravel to supply construction projects in Viet Nam (Look at Viet Nam 2009).

Mineral potential of the LMB

The mineral potential of the Lower Mekong Basin remains largely untapped, with potentially significantly more mineral deposits than those currently being mined. The major prospective deposits are gold, copper, lead, zinc, phosphates, potash, oil/gas, coal and gems (principally corundum, i.e. rubies and sapphires).

There is a great deal of interest from international investors to gain access to the prospective areas of the LMB. It follows that mining will continue to grow in importance both in terms of impact and economic contributions. About 40,000 km^2 is held under concession for mineral exploration within Lao PDR and Cambodia (Figure 4.7.2). Mineral concession data for Thailand and Viet Nam are not readily available.

Lao PDR has two major metal mines (copper and gold): the Sepon mine, operated by MMG and the Phu Kham deposit operated by Pan Australian Resources.

Copper

Two copper-rich mines are active in the LMB, both are in Lao PDR and both are semi-mechanised. Lao-China Oriental Mineral Development Ltd operates a mine in Long District, Luang Namtha Province. The copper occurs as sulfide mineralisation with minor near surface oxidation.

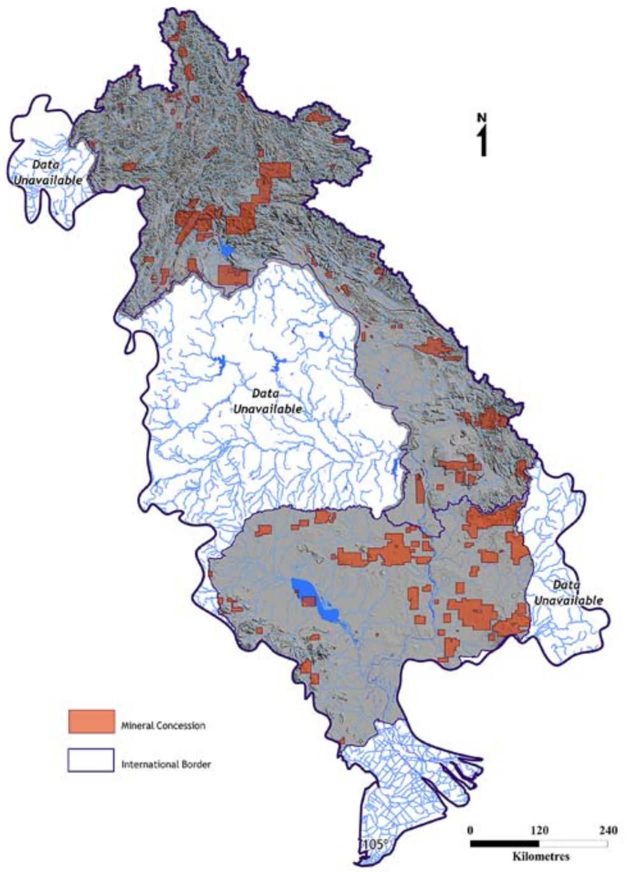


Figure 4.7.2 Mineral concessions within the Lower Mekong Basin (Lao PDR and Cambodia). These areas do not reflect actual mining but simply those areas currently being surveyed for mineral potential.

Communications with locals in the district indicate that the mine is almost exclusively operated by Chinese labour.

Gold

As well as the Phu Kham and Sepon deposits, several other areas are being mined for gold in Lao PDR and Cambodia. Lao-China Joint Venture Mining Industry Ltd has a small mining concession for gold in the Lak Sao area, Bolikhamsay Province, Lao PDR. This is a partly mechanised above ground and underground (minor) operation.

The vast majority of gold prospecting consists of artisanal mining of small vein or alluvial deposits. As well, there is one known dredging operation in southern Lao PDR on the Se Kong river. Other reports of localised mining in Lao PDR include the Lak Sao area of Bolikhamsay Province, the Xaysomboun area of Vientiane province and Attapeu Province. In Cambodia, the main areas for localised artisanal mining are Andong Meas, Rattanakiri Province and the Prek Te River area, Mondulkiri Province.

The Loei belt of Thailand, well known for its gold mineral resources, lies within the LMB and extends into the Sanakham region of Lao PDR. Research could only identify one project advanced to the mining stage, the Phu Thap Pha gold mining concession granted to Tungkum Limited (TKL), which is majority owned and operated by Tongkah Harbour Public Company Limited.

The mine, which began operating in September 2006, mines 1200–1500 ton of ore per day. In 2006, 176,785 tons of ore were mined, milled and processed and the company expects to process about 440,000 tons of ore per annum. In 2007, TKL produced 17,485 ounces of gold (www.tongkahharbour.com).

Other metals

Eight mining concessions have been granted for tin in Lao PDR but there is little activity in the other countries. Five of the concessions are centred around the Phon Tiou area, Khammouane Province in central Lao PDR. Tin has been mined since at least the 1970s and possibly earlier. Antimony is mined from a small deposit near the Chinese and Burmese borders with Lao PDR in Sing District, Luangnamtha Province (Ministry of Energy & Mines 2009).

Coal

Most coal deposits identified so far in the LMB consist predominantly of lignite (a low calorific value coal often requiring an accelerant to assist combustion). A total of seven mining concessions have been granted for coal in addition to the Hongsa lignite deposits. Lao PDR's coal reserves are estimated to be 347 Mt, and lignite resources at the Hongsa deposit in Sayabury Province are estimated to be about 700 Mt (USGS 2007).

A number of coal deposits have been discovered in the provinces of Oudomxay, Saravan, Sayabury, Vientiane and Xiengkhouang in Lao PDR. The state-owned Agriculture Industry Development Enterprise produced 35,000 t of anthracite coal from Vangvieng District in Vientiane Province in 2005 (the latest year for which data has been reported). Lignite production was exported to Thailand and anthracite was used locally (mainly by the cement plants in Vangvieng, Vientiane Province).

Although Thailand has a long history as a producer of coal (mainly lignite) there are currently no mines operating within the LMB. There is little potential for and no active mines or exploration for coal within Cambodia or within the Mekong Delta in Viet Nam (Wu 2009).

Gems

The two regionally famous areas for gem mining in the LMB are the Bokeo sapphire deposits in northern Lao PDR and the Pailin area of western Cambodia. The Bokeo region has a long history of artisanal mining for sapphires. Deposits are alluvial defined by the current streams and the associated alluvium along the valley bases in the region. Gem Mining consolidated a portion of the key deposits into a single operation with the granting of a concession in 1994. The company later collapsed and the area has since been divided into concessions for a number of companies.

Cambodia has several areas of gem deposits and mining is active in two of them. The first is centred at Pailin along the western border with Thailand, producing both sapphires and rubies. The second less well known area is Ratanakiri Province which produces mostly zircon and some amethyst.

Industrial minerals and rocks

The basin has great potential for industrial rocks and minerals, from facing stone to potash and cement. Mining is generally small scale with moderate mechanisation for quarries and dredging operations.

Impact of mining on water resources

Environmental controls remain limited in this emerging industry. Companies tend to follow the environmental policies of their country of origin. In Lao PDR, recent updates to environmental policy have improved the ability of the Lao government to manage environmental incidents and to require stricter control and incident reporting.

The main areas of concern are:

- sedimentation (mostly dredging & local artisanal mining)
- chemical or metallic contamination (cyanide, direct spills, tailings leakage)
- acid mine drainage (run-off) and other acid generation (acid rain from sulfur dioxide generated during coal burning)

Sedimentation

The main source of erosion associated with mining operations is construction of in-haul roads. Primary concerns associated with project development and operations are related to the impact of sediment on local fisheries resources and the use of cyanide in the recovery process, as well as the potential impact on surrounding water resources (Sengupta 1993).

Where there is a large degree of artisanal mining, particularly in smaller tributaries, sedimentation becomes much more obvious and its direct effects greater. Dredging operations not only increase the amount of silt suspended in water but also the general disturbance levels on the bottom of the river.

Chemical or metallic contamination

A study of the major areas of artisanal mining and the amount of mercury used in these areas in Lao PDR (Huidobro 2007) found two areas stood out as having significant to heavy mercury usage.

The first is on the Sekong River, Attapeu Province where 25 operating units are reportedly under way and a number of new mining projects are planned. About 500 m^3 of aggregate are excavated per hour, yielding 0.6–2.5 g of gold per m^3. During the extraction process mercury is mixed with the concentrate derived from the sediment. The recovered amalgam is then heated with acid to dissolve the mercury and purify the gold. Although most of the mercury is recovered and reused, small amounts of the mercury-acid mix may be released into the environment.

The second area is in the Nakadok Village area (near Lak Sao, Bolikhamsay Province) where copper plates covered with mercury are used to capture fine gold particles from crushed ore. Tailings from these operations (both primary and alluvial), which are likely to contain elevated levels of mercury, are contained in ponds. Traditional alluvial mining has been practised here using pans for more than 100 years. Gold in the Nam Thop River was coarse enough to allow miners to remove it from the concentrate with their fingers. However, much of the coarse gold has been extracted by a Chinese company that began mining in the area in about 2004.

Environmental contamination – an impact of gold mining in Cambodia

Despite the fact that gold mining has effectively ceased, mining tailings discarded alongside the banks of the Prek Chas River continue to act as a serious source of pollution in which leachate from the tailings, including unrecovered cyanide and heavy metals present within the ore, migrate to the river. The river, which is the sole water source for the area, remains seriously polluted as a result of the gold mining activity. According to local people, the water is completely unusable and fish and other aquatic fauna, which were abundant in the past, have disappeared. Cases of cattle death due to the consumption of water from the river were also reported. Measurement of groundwater pH revealed relatively high acidity (from 4.4 to 5.6). Most wells used by local people as a source of drinking water had a pH of 5.3–5.6. According to a well owner in new Sampeou Loon village, the well water corroded water containers and its pH was 4.4. Typical pH values for groundwater are between 7 and 8 (Howard, 1998). These results indicate that acidic compounds have polluted the water sources and, considering the activity undertaken in the area, cyanide or other gold processing acids are prime suspects. People surveying the gold processing site also reported a strong smell of acid in the air which made breathing difficult. This air contamination represents a significant hazard for workers on site, as well as a source for airborne dispersion of pollutants further afield.

Source: Sotham (2004)

Primary ore mining is now preferred because it provides greater profit. This has resulted in nearly a complete shift away from alluvial mining. Primary ore mining requires an economic input that would involve the coordinated efforts of many impoverished people, or external investment or seed money. Mercury amalgam is burned over an open flame without the use of retorts and in very enclosed spaces. Small amalgams are also burned on a spoon over a kitchen fire, inside the house. This process only takes a few minutes, but no precautions are taken while burning the mercury. Although the project constructed and presented the village with retorts to minimise mercury vapour released during the gold extraction process (Huidobro 2007), use of these retorts was not in evidence during recent site visits (R. Wust pers. obs.).

A study of artisanal and small-scale mining (Sotham 2004) detailed the main contaminants in four of the larger gold mining areas in Cambodia. The report found common use of mercury for amalgam with little or no knowledge of health risks. The four areas studied all have a long history of local artisanal mining and some degree small-scale mining. The more readily accessible gold has diminished leaving the need for more advanced methods. In some places the use of mercury is being replaced by cyanide heap leach techniques.

Cyanide

Only one significant incident involving cyanide has been reported to date for mining in Lao PDR, that being a cyanide spill from the Phu Kham heap leach plant site. Little information is available and the company has since upgraded its control of toxic chemicals and environmental safeguards. No further incidents have been reported.

In 2005 a cyanide spill was reported at the Phu Bia gold mine in Lao PDR. The cyanide killed fish in the nearby rivers and poisoned villagers within at least 3 km of the mine site (Rainforest Information Centre 2009).

There has been clear evidence of stream contamination from small-scale mining using cyanide in Cambodia. In particular, cyanide has been commonly used in the Sampeou Loon area. In 2004, studies showed that the stream was contaminated and although no details of symptoms of cyanide poisoning were confirmed, there were reports of sickness among the local population (Barron 2004; Sotham 2004).

Acid generation/spills

Where sulfide bearing rocks are exposed to air and water, acid is generated as part of the oxidation process. While it is common practice in large-scale mining to plan to specifically limit acid generation and transportation, smaller-scale operations rarely include comprehensive waste management systems. In Lao PDR, both the Phu Kham and Sepon mining operations continually monitor for spills and acid generation from waste rocks (noted from respective sustainability reports). There is no current information available from other mine sites in Lao PDR. However, the studies of artisanal mining in Lao PDR conducted by the Global Mercury Project (Huidobro 2007) indicate that tailings and waste material from mining around the Nakadok area were not controlled but simply discharged into the environment.

Acid may also be generated from the interaction of sulfur and nitrogen discharge from coal-fired power stations. Visible evidence of this can be seen in the limestone areas in Vang Vieng District, Lao PDR, where lignite is used to power cement factories.

Acid generation from mining is Cambodia is limited with mining localised and artisanal. Very few mines delve deep enough to recover primary (unoxidised) material and, as a result, there is limited acid generation from these sites. There is some indication that acid generating waste has contaminated stream systems (see the box on p X) but there is no data on the extent of contamination or its direct environmental or health effects. Little information is available about acid generation from mining in Thailand (within the LMB) and Viet Nam does not have mines in the LMB that are likely to produce acid generating waste material.

Mining outlook

As the world economy recovers from the global financial crisis, demand for the natural resources lying below the ground of the LMB will increase. The mining sector in Lao PDR, for instance, saw a major increase in investment with approved funding of US$2.2 billion in the first nine months of 2009 (Vientiane Times 2009). Managing the sustainable development of these natural resources in a way which will bring much needed employment and prosperity to the people of the LMB will present challenges to governments, the multinational companies and civil society.

Legal infrastructures across the LMB requires strengthening and greater enforcement. Environmental and mining legislation is being updated but is being outpaced by demand. Policing and implementation of laws remains problematic. This is most evident with artisanal and small-scale mining where remediation is basically non-existent. There is no planning for containment of tailings and waste management.

As artisanal mining will no doubt continue at current scales, a programme to upgrade knowledge and safe waste disposal practices is urgently needed. Some programmes have improved their practices with highly toxic chemicals such as mercury. Similar programmes are required for other processing systems and especially for waste management.

Land and livelihood issues for villagers/landholders in areas of mining concessions need to be considered. Companies concerned about their international reputation are more likely to uphold obligations to respect environmental and social laws. Developing the means and legal surety to attract good corporate citizens to invest should be a priority.

Small-scale miners and local mining companies require adequate governmental oversight and policing. This requires an upgrading of government officials' knowledge of sound mining practice, environmental safeguards and mitigation techniques. A similar campaign to introduce and require local miners to follow such measures would be highly advantageous.

Mining has the potential to bring much needed prosperity to rural communities in the LMB but it will remain a challenge to ensure that economic progress does not lead to environmental degradation.

Impact of other industries on water resources

Industrial development in the Lower Mekong Basin is at an early stage, however the rapid increase in urbanisation is expected to continue (Table 4.7.1) along with the growth of the industrial sector. Northeast Thailand and the Mekong Delta are the most advanced industrial areas in the region. Industrial development in Cambodia and Lao PDR is occurring almost exclusively in the capital cities, Phnom Penh and Vientiane.

Table 4.7.1 Urbanisation trend and forecast 1999–2030, degree of urbanisation (%)

Country	1999	2005	2010	2015	2020	2025	2030
Lao PDR	23.0	26.4	29.5	32.7	36.0	39.3	42.6
Thailand	21.1	23.7	26.2	29.3	32.5	35.8	39.1
Cambodia	23.0	26.6	29.7	32.9	36.2	39.5	42.8
Viet Nam	20.0	20.6	22.1	24.3	27.3	30.4	33.7

Source: (UNESCAP/ADB 2000)

Industrial development in the LMB can be categorised into i) mining and quarrying (see previous section), ii) manufacturing (food, textiles and chemicals), and iii) electricity, gas and water.

In Thailand's part of the basin, the main industrial products are agricultural inputs and processed food. Other industries include production of precious stones and jewellery, cement, sugar, refined oil, synthetic fibres, textiles, vehicle parts and assembly, paint and steel. NakhonRatchasima is the main industrial centre of the northeast.

In Lao PDR and Cambodia the industrial sectors are small and industrial development is at an early stage. However, the sector is growing quickly, especially mining and electricity in Lao PDR. Production of tin concentrates is an important industrial activity in Lao PDR and a number of small-scale manufacturing industries exist, producing, for example, beer, cigarettes, detergents, rubber footwear and chemicals.

The main constraints to industrial development in Cambodia are the lack of power and raw materials. The major water using industries are food processing and textiles. The textile industry is growing rapidly in both countries.

Viet Nam is experiencing rapid industrialisation. The Mekong Delta comprises mainly agro-industries, such as rice milling and polishing, breweries and canneries, as well as aqua-food processing industries. The number of industries is moderate, partly due to a lack of infrastructure and transport facilities.

Industrial water use and sources

Water is necessary for all industrial activities but the quality and quantity of industrial water demanded varies significantly by

country, industry and particular uses, ranging from high water quality for the beverage industry to brackish water or treated municipal effluent for cooling purposes. Water demand is often considered under the following headings (MRC 2005):

- Cooling water demand: usually abstracted directly from rivers or storage water from rainfall and returned with little overall loss.
- Major industrial demand: factories using 1000–20,000 m^3/day or more for such industries as paper making, chemical manufacture, iron and steel production, oil refining etc. Such supplies are often obtained from private sources.
- Large industrial demand: factories using 100–500 m^3/day for food processing, vegetable washing, drinks bottling, ice making, chemical products etc. These supplies are frequently drawn from the public supply.
- Small to medium industrial demand: factories using less than 50 m^3/day comprising many types to make a wide range of products. Most will take their water from the public supply.

Estimates for current and future surface industrial water demand in the LMB are shown in Table 4.7.2.

Table 4.7.2 Estimates of present industrial water demand and trends for the LMB

Country	Annual industrial water use (million m^3)			
	Year 2000	Year 2007	Year 2030	Year 2060
Lao PDR	12	20	47	190
Thailand	94	140	239	581
Cambodia	13	20	108	331
Viet Nam	44	122	149	837
Total LMB	163	302	543	1,939

Most private industries in the LMB use groundwater or surface water from rainfall and water withdrawals are generally not reported to the authorities. Industrial water withdrawals from streams are estimated to be about 5–30 per cent of demand in the dry season. However, total surface industrial water withdrawals are only about 0.4 per cent of the total Mekong River flow.

Industrial waste water and treatment

Water pollution from industrial sources has been identified in the LMB, especially in the capital cities of Vientiane and Phnom Penh, and more generally in northeast Thailand and the Mekong Delta. Generally, treatment of industrial wastewater is limited and handling and disposal of industrial hazardous waste are insufficient. So far, industrial water pollution is mainly concentrated around factories and downstream of major urban areas. Overall, the Mekong River and most tributaries are considered relatively healthy. However, with increasing industrialisation more severe water discharge problems will occur and inter-sectoral conflicts over water quality demands will increase.

Industrial activity in the Thai part of the LMB is dominated by manufacturing (including agro-industry, but also some textiles, light assembly and rubber processing). Industrial wastes are expected to increase as the sector expands. Over the next 10 years pollution loading is expected to increase by 87 per cent. Industrial development is also increasing the amounts of hazardous wastes. In northeast Thailand for example, the generation of hazardous wastes is expected to increase by about 72 per cent over the next five years. All factories are required to have their own waste water recycling system to allow the settling out of contaminants before water is released.

Industrial waste-water management in Cambodia is very poor, few factories have waste-water treatment facilities and control of industrial waste-water discharge is not enforced. Of the approximately 194 factories in Phnom Penh, only eight have on-site primary treatment and their effluents generally exceed Cambodia's water quality standards. Another pollution problem relates to gemstone mining activities in the western part of the country (see previous section).

In Viet Nam, water pollution is a serious issue, especially in rivers and canals near urban centres. Most industrial waste water is discharged without proper treatment. Hazardous wastes are generated by the fastest growing sectors such as steel, electronics, and chemicals. Overall, there are no systems in place for the handling, storage, or treatment of hazardous wastes. In the Mekong Delta, where development of industry has been relatively slow, existing industries have caused quite serious water pollution (e.g. organic contamination from breweries and canneries). Heavy industry is beginning to occur with the initiation of a steel rolling mill of 120,000 t/year capacity in Can Tho.

Pollutants in waste water from the aquafood processing industry have high levels of biochemical oxygen demand (BOD), nitrogen and suspended solids. Livestock farms in the LMB have caused pathogen contamination and BOD pollution.

4.8 TOURISM

Status and trends in the Lower Mekong Basin

Over the past three decades, international tourism has developed rapidly in the LMB and riverine environments in particular have become major attractions for tourists.

Tourism now makes a strong contribution to GDP in all the LMB countries of between 10 and 20 per cent (Table 4.8.1), similar to the contribution of exports of goods and services. In 2007, the LMB countries attracted 21.4 million international visitors, some 2.4 per cent of all international tourist trips, generating about US$20 billion. The contribution to GDP and employment has been stable over the past five years and is expected to be at a similar level looking 10 years ahead (Table 4.8.1). The contribution to GDP growth has been at a similar level as the contribution to the GDP although with more fluctuation from year to year until the onset of the global financial crisis from which point it has been close to zero or negative. Forecasts looking about 10 years ahead indicate that the contribution to growth will be about five per cent in the longer term (WTTC 2009a, 2009b, 2009c, 2009d).

International tourist arrivals in Cambodia in 2007 were more than eight times higher than in 1995. In Lao PDR international tourist arrivals have not increased at such high rates, but the receipts have increased substantially in recent years e.g. by about 30 per cent per year from 2003 to 2007, probably indicating a shift from the domination of budget travellers like backpackers (MRC 2010). The average growth rate in international tourist arrivals to Viet Nam was about 12 per cent per year and to Thailand about nine per cent per year from 1995 to 2007. Until the onset of the global financial crisis in the second half of 2008, predictions for tourism growth for international tourist arrivals and receipts in the LMB (as elsewhere) appeared very positive. The United Nations World Tourism Organisation (UNWTO) was forecasting about 40,000,000 international arrivals annually by 2020 – an almost 100 per cent increase compared with the 2008 figures. The highest growth was predicted for Lao PDR and Viet Nam (UNWTO 2001). The global financial crisis has made such forecasting more uncertain, but the outlook remains promising over the medium and long term. In the past, international tourism has been highly resilient and the UNWTO forecasts are likely to prove reasonably accurate. It is

Table 4.8.1 Importance of tourism for LMB economies

	Contribution to GDP (%)			Contribution to employment (% jobs)		
	2005	2008E	2019F	2005	2008E	2019F
Cambodia	20.7	18.7	15.3	16.2	14.6	12.0
Lao	11.1	11.4	9.3	8.8	9.1	7.4
Thailand	14.6	15.0	15.6	10.9	11.3	12.1
Vietnam	12.0	13.8	13.0	9.6	11.0	10.4

(WTTC, 2009a, 2009b, 2009c, 2009d) E: Estimate – national statistical data awaiting final quality assurance; F: Forecast

Table 4.8.2 International tourist arrivals and receipts (US$ million) in LMB countries in selected years

	Cambodia		Lao PDR		Thailand		Viet Nam	
	Arrivals	Receipts (US$ m)	Arrivals	Receipts (US$ m)	Arrivals	Receipts (US$ m)	Arrivals	Receipts (US$ m)
1995	220,000	n.a.	346,000	n.a.	6,952,000	n.a.	1,351,000	n.a.
2003	701,000	389	636,000	87	10,004,000	7822	2,429,000	1400
2007	1,873,000	1400	900,000	202	14,464,000	15,573	4,172,000	3461

(UNWTO 2009)

important to note that the growing middle classes within the LMB countries themselves are making a highly significant contribution to the industry (MRC 2010).

Tourist attractions

Riverine environments figure prominently in much of the region's tourism. In Lao PDR, where backpackers predominate, the most popular destinations are along the Vientiane/Luang Prabang corridor, including Vang Vieng, and the World Heritage site of Luang Prabang, along with the Siphandone region (4000 islands) in the south of Lao PDR. In Cambodia, most tourism is centered on the capital Phnom Penh and in Siem Reap, dormitory to the ancient Angkor complex and adjacent to the Tonle Sap Great Lake. An example of a tourism attraction entirely dependent on the Mekong River and its ecosystems is dolphin watching at the deep pool in Stung Treng/Kratie, downstream of the Siphandone region in Lao PDR. In Viet Nam, the Mekong Delta, an area of great natural beauty, is an attractive and developing tourist destination. Day trips to Thoi Son Island, for example, allow tourists to experience the culture and the riverine environment of the Mekong Delta with boats and walking as the only means of transport. Although much of Thailand's tourism is centered around marine/beach environments and the allures of Bangkok, other popular destinations include Chiang Mai and Chiang Rai in the north where much of the tourism in 'nature based'. These destinations are located either on or adjacent to rivers or other major bodies of water. Chiang Rai is located on a tributary of the Mekong River and close to the Golden Triangle area where Lao PDR, Myanmar and Thailand meet and share the waters of the Mekong. River cruise tourism is one example of water dependent tourism that is developing in various places along the Mekong River in the LMB (see section 4.6).

As well as being a vital economic resource for local residents, riverine environments are a major resource for tourism development. Primary tourist attractions are frequently 'natural', and rivers, forests and other environmental features are valued because they are perceived to be visually pleasing. They are also valued by tourists as resources for other activities, such as rafting, trekking and climbing and as a scenic backdrop for activities on the river banks, such as picnicking. However, along with local residents, who use rivers and their resources for a variety of economic, cultural and recreational purposes (e.g. agriculture, festivals, fishing, forestry and industrial development), tourists and those who provide them with support facilities also have an impact on the physical and built environment. Tourism may also sometimes involve competing with local people for access to scarce shared resources.

Impacts of tourism on the environment

There is no hard evidence to suggest that tourism has led to widespread, large-scale deterioration in the water and related resources of the LMB. However, it is possible to highlight both negative and positive impacts at some popular tourist destinations as well as at more exclusive sites. In towns heavily reliant on tourism (e.g. Siem Reap, Luang Prabang and Chiang Rai), some negative bio-physical impacts are evident. These include air and noise pollution, overloaded systems of waste water and sewage disposal, and inadequate garbage collection and disposal. Ancient monuments are most at risk, while rivers are polluted by waste water, refuse from restaurants and other tourist facilities, as well as by the discharge of fuel from boats. Similar effects on water and related resources, although at an early stage, can be found at destinations such as Vang Vieng and, to a lesser extent, in Siphandone and the Stung Treng/Kratie corridor.

In urban centres dependent primarily on large-scale tourism, air pollution from traffic and construction, and inadequate disposal of waste water, sewage, solid waste and garbage, have led to the pollution of wells, rivers and streams. Other negative impacts on water and related resources include riverbank erosion and water pollution due to urban construction.

In emerging tourist destinations, existing public facilities are under pressure and the need for new or improved systems of waste water disposal, sewerage and garbage disposal is evident, as even low-scale tourism can have negative impacts, as has for example been found in the Stung Treng/Kratie corridor (MRC 2010).

Remedies for such problems include raising public consciousness through litter prevention and anti-pollution campaigns, effective management, better planning and more stringent implementation of controls, improvements to the urban infrastructure, and even new population centres (as planned for Luang Prabang to conserve the World Heritage site). Damage to ancient buildings can be minimised by rationing visitors by number or time, controlling visitor flow, and reducing access to especially vulnerable sites. Similar measures can be taken to minimise biophysical impacts in such fragile environments as the LMB wetlands.

Generally, perceived positive impacts of tourism on the biophysical environment include increased pride in and awareness of the need to conserve the LMB's water and related resources as well as improved infrastructure and waste treatment systems.

Economic impacts of tourism

Irrespective of the type of tourism involved, whether 'cultural tourism' in Siem Reap and Luang Prabang or nature-based tourism in Siphandone, Vang Vieng and the Mekong Delta, stakeholders find that tourism brings considerable economic benefits, most notably jobs and income to local residents and communities, and increases the standard of living of those most involved in tourism. Destinations not yet receiving many tourists see tourism as potentially economically important and, even at remote sites which hardly receive any tourist visits, boat owners and other groups serving the few visitors appreciate the annual income, which is much in excess of the average wage (MRC 2010). On the negative side, tourism has resulted in inflation in the price of land, property and some foodstuffs and the economic benefits are not always spread widely, which has led to an increased inequality in incomes of local residents.

Socio-cultural impacts of tourism

Socio-cultural impacts are also considered largely beneficial and include increased respect for local culture, arts and crafts, knowledge of the outside world and friendship with tourists. As problems in towns have arisen and facilities subsequently been improved, often with the assistance of aid programmes, residents' awareness of environmental matters appears to have also grown. In nature-based tourist areas too, tourism has reportedly led to a greater consciousness of the value of the environment (MRC 2010). However, at some sites, disputes have arisen between different interest groups over plans to reduce tourism's environmental impacts and increase conservation on the one hand versus increasing tourism development on the other. In the World Heritage site of Luang Prabang, for example, local residents feel that tourism has changed the character of the town, a situation that could also arise in other areas with very particular culture and livelihoods as tourism grows, e.g. Thoi Son Island in the Mekong Delta.

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5
DEVELOPMENT IN THE MEKONG RIVER BASIN

5.1 EMERGING TRENDS AND DRIVERS

Developments on a national and basin level

Fluctuating oil and natural gas prices can make hydropower development financially more attractive to private investors. Global food shortages and rising prices can make irrigation more profitable in the LMB while irrigation development may attract investments from foreign entities that seek more diversified food types. As well, global climate change might change future water availability (see section 3.5).

All of these global emerging issues provide additional incentives for the development of significant water infrastructure in the Mekong Basin, including storage projects. The challenge is to develop these projects within an integrated water resource management (IWRM) context, and with an emphasis on developing multi-purpose projects within a basin perspective.

BASIN-LEVEL AND NATIONAL-LEVEL DEVELOPMENTS

The region's predicted population growth brings with it increased demand for electricity and food resources, and thus increased pressures on the basin's water resources in the dry season. Also, higher living standards bring changes in attitudes to flooding and food shortages, which require innovative approaches and policies to both flood protection and irrigation expansion on the delta floodplains in Cambodia and Viet Nam.

All governments of the LMB wish to develop water resources for irrigation, hydropower and other uses, and to produce benefits for the many millions who live in poverty in rural areas. These needs must be balanced by consideration of the existing needs of subsistence farmers who supplement what they grow by fishing and gathering food and other materials from forests and wetlands.

The cascade of hydropower dams in China on the Upper Mekong Basin will considerably re-regulate flows, to the extent that higher flows will occur downstream in the dry season. This makes mainstream hydropower schemes in the LMB financially more attractive and opens up more irrigation potential. But it also raises the question of the degree of impacts that can be tolerated from barriers to fish migration, changes in sediment transport, and changes in ecosystems when the hydrological regime including the flood pulse is altered.

These expected increasing pressures on the basin's resources call for IWRM approaches to increase synergies between the policies and practices of the four governments.

NEW INVESTMENTS AND DEVELOPMENT ASSISTANCE

As the four LMB countries reform, develop government investment policies and clarify the rules for resource utilisation, opportunities will be increased for the private sector (and foreign 'state-owned' companies) in the development of water and related resources, such as hydropower, navigation, large-scale irrigation, and industry (including mining and tourism). In most of these areas, investment from the private sector now outweighs public sector investments (see section 4.1).

In comparison with public sector financed developments (perhaps supported by foreign aid), the emerging private sector

PRECEDING PAGE

The Mekong Basin is rich in natural resources, especially in the potential for using Mekong water to enhance economic growth and development, Thin Beun dam Lao PDR.

FACING PAGE

Opportunities are increasing for development of water and related resources in the Mekong Basin.

developments are driven by private sector goals about investment returns and adopt assessment processes according to government regulation and requirements. This raises the need for strong government regulatory systems and enforcement capacity, including improved skills and capacities for the central regulating and resource management agencies and stronger supporting laws and regulations.

Development of water and related resources

Average annual withdrawals for agricultural, industrial and other consumptive uses in the LMB are estimated at about 60,000 million m^3, or 12 per cent of the Mekong's average annual discharge. The most downstream end of the Mekong Basin, the Viet Nam delta, is by far the largest water user in the basin. Diversions from the river upstream of the delta are so far negligible. Lao PDR and Cambodia hardly use one per cent of their annual renewable water resources. Consumptive uses of water resources in the upper basin countries (People's Republic of China and Union of Myanmar) are also insignificant. Existing storage of water resources behind dams corresponds to less than five per cent of the average annual flow, and does not significantly redistribute water between seasons.

Agriculture is the most dominant water-related sector, particularly in Thailand and Viet Nam (see section 4.3). The water flows that reach the Viet Nam delta in the dry season are fully used for economic, environmental and social purposes, including combating seawater intrusion. The hydropower potential of the LMB is estimated at more than 30,000 MW and about 10 per cent of this potential has been developed to date (see section 4.4).

According to the socio-economic and sector plans of the LMB countries, all four countries are planning to develop water resources for irrigation, hydropower, flood management, domestic water supply and sanitation, and other uses to boost economic growth, reduce poverty and meet the UN Millennium Development Goals. In particular, the countries' hydropower and irrigation development plans will significantly affect how the basin's resources are used and consumed.

Ten large (>10 MW) hydropower projects are under construction on tributaries and many more are planned in the LMB, including 11 projects on the mainstream. Many of the hydropower projects on tributaries include significant reservoirs, which will increase dry season flows through the re-regulation of water resources from the wet season to the dry season. An additional 50 dams are planned for the next 20 years, mostly in Lao PDR.

Most of the LMB countries have ambitious plans for irrigation development. Water transfers from the Mekong mainstream have long been considered by Thailand to complement national approaches to alleviate droughts.

Development plans of this size and scope bring with them both synergies, or complementary effects between projects, and trade-offs, where benefits for one area or activity create disadvantages for others. For example, synergies can occur between hydropower, irrigation and upland watershed management – with some benefits occurring for all, while 'trade-offs' may take place, e.g. between hydropower development, fisheries and ecosystem productivity and biodiversity.

Trade-offs, in particular, require much analytical work and negotiation between countries, or between sectors. This can be supported by strong IWRM understanding and capabilities across the basin, and across institutions.

While developments on the tributaries have had some localised impacts, no impacts have been detected at the basin scale (see sections 1.3 and 3.1). However, this may change in future due to the large scale of planned development. If fully implemented, these developments would change the river's hydrological regime, create barriers to fish migration and reduce sediment and nutrient transport. These changes in turn would create follow-on effects for wetlands, ecosystems and people's livelihoods.

Trans-boundary issues

The trans-boundary issues that need to be addressed to assess the sustainability of the outlined scale and scope of basin development are numerous. Some of the key issues are outlined below.

WATER AVAILABILITY FOR USE

Dry season flows maintain a wide range of economic, social and environmental values in the LMB. The difficult questions relate to what level of environmental and social decline increased water use might cause, and what could be the acceptable limits, if any, of such a decline.

FISHERIES PRODUCTION

High annual fish yields are under pressure from several human-induced activities, including over-fishing, fragmentation and reduction of floodplains, and the blockage of migratory fish by dams. Preliminary results of recent modelling studies indicate that the migratory fish production potentially at risk from mainstream dams may amount to 40 per cent of current annual catch (about one million tons per year), depending on the number and location of the dams and other factors. Such a large potential decline in fish production would have very significant basinwide economic and social impacts. A part of the loss might be recovered by increasing reservoir and rice field fisheries.

FLOODPLAIN MANAGEMENT

If the current plans of most of the LMB countries are implemented, significant parts of the floodplains would be protected from flooding and developed for irrigated agriculture and other land uses. Such development is associated with potential significant trans-boundary impacts such as loss of biodiversity, reduction of fish production, and increased flood heights and velocities due to the diversionary effect of flood banks and roads.

NAVIGATION

The impact of mainstream barriers and dams on the integrated development and implementation of ports, river works, locks and regional waterways may affect trade and tourism as well as local river transport. The navigation sector offers great opportunities in trans-boundary cooperation in terms of regional harmonisation of navigation processes and schemes and environmental management, including bank protection and dredging (see section 4.6).

WETLAND MANAGEMENT

The annual floods which cover large areas of the LMB wetlands support diverse ecosystems and the large fishery production. Changes in the hydrological regime will change the wetlands and their functions. In particular, changes to the Mekong flood pulse are expected to have trans-boundary impacts e.g. for the flood plains in Cambodia, including the Tonle Sap Great Lake and the Mekong Delta.

OTHER ISSUES

The construction of dams may also affect river bank erosion and sediment movement downstream; sediment entrapment and flushing downstream and related impacts on riverine ecology (e.g. filling of deep holes); trans-boundary water inundation issues from the storage backwaters, and the passage of flood flows.

Preliminary results of the hydrological assessment of basin development scenarios suggest that one of the trans-boundary issues mentioned above –future water availability for use – is not a major problem. The water quantity demands of the scenarios considered for the foreseeable future (next 20 years) can be met in the dry season through the re-regulation of water from the wet to the dry season from storage dams that are being constructed and planned in the Upper Mekong Basin and Lao PDR.

Emerging IWRM challenges

The acceleration in water resources development brings both opportunities and threats. At the basin scale, integrated water resources planning is becoming a reality with the development of the IWRM-based Basin Development Strategy. At the national level, there are still fragmented water related responsibilities between national agencies and development still tends to be sector driven. Basin planning has identified the following overarching short-term IWRM challenges.

At the basin level demand is growing for a scenario-based and participatory planning approach to inform joint decision making by the LMB countries on an acceptable balance between resource development and resource protection. In particular, project proposals need to be reviewed to ensure that their potential impacts, including cumulative impacts, are acceptable from a sustanbility viewpoint and that they have been prepared following best practice guidelines.

At the national level there is considerable scope for institutional development and capacity building for IWRM (see section 5.2). This is especially timely for the recently established national water and environmental management agencies and their divisions and river basin organisations at the sub-basin levels. There is a need to further strengthen their coordination, steering and monitoring role for IWRM, engaging the line agencies responsible for sector planning.

At the project, level the main IWRM issue is the central and sector-oriented planning and development of large projects, especially hydropower. The single-purpose projects may often be less economically beneficial and efficient than multi-purpose projects, and they often increase the adverse effects downstream and upstream of the project.

5.2
IWRM GOVERNANCE AND STAKEHOLDER PARTICIPATION

IWRM at a basin scale

Water resources management in the LMB is a mix of a 'cooperative and coordinating model' at the basin scale (facilitated through the MRC) and four national models, where individual sovereignty, customs and administrative systems dominate. MRC, through its legal agreement, acts as a focal point for the cooperation, and to assist the Member Countries in achieving their basin-scale aims through provision of shared information, technical guidance and mediation. The agreement establishes a forward-looking framework and mechanisms for pursuing the concept of IWRM at the basin scale. It provides a platform for suitable stakeholder participation processes that cover all aspects of basinwide water management.

At the basin scale, the four countries, in 2005, endorsed an 'IWRM Strategic Directions' document and agreed to follow its general IWRM principles and guidelines in water resources development and protection, and in the development of IWRM governance systems.

The four countries have recognised the need, and value, of improving the links between basin-level and national-level water resource planning, and making them much more explicit. This is occurring through the second phase of the basin development plan programme, which is focusing on developing a common understanding of IWRM trans-boundary issues and problems, and of the importance of the environmental and social values and assets of the basin, and how these can be used and managed in future development. This will all be brought together in an IWRM-based Basin Development Strategy (see the box below)

IWRM-based development strategy

The Mekong basin cooperation model is built on 'cooperation, coordination and mutual respect'. So, developing a common understanding of IWRM trans-boundary issues and the importance of the environmental and social values and assets of the basin, and how these can be used and managed in future development, is the essential supporting foundation for basinwide sustainability.

The IWRM-based Basin Development Strategy will be a statement by the LMB countries of their intention to share, use, manage and protect the basin's resources in an equitable and sustainable way for economic growth and poverty reduction. The strategy will be adopted in 2010.

Having such a strategy will provide confidence that water can be allocated and used without significant unforeseen impacts. At the national level, this will make it easier to attract funding for projects, since developers will have some certainty about the water resources management processes against which proposals will be judged. At the basin level, this will provide incentives for a more beneficial implementation of agreed procedures under the 1995 Mekong Agreement.

IWRM governance at the national level

Large changes in IWRM have occurred in all the LMB countries over the past five years, particularly relating to developing clear statements of national water-related policy and strategy, and developing institutional and regulatory frameworks to support these policies. All countries made a commitment to IWRM at the World Summit on Sustainable Development in 2002.

Of major importance is the continued need to improve agency and staff capacities in IWRM, and to develop a suite of modern analytical tools, particularly hydrologic, environmental and socio-economic modelling packages – at the river basin and national levels – that countries can use to assess new policies and development proposals and ensure sustainable use of the basin's resources.

Cambodia has developed a number of statements on water policy and strategy over recent years. Work is now proceeding to develop a clear implementation plan, or road map, that will more clearly guide the various sector agencies in water planning activities and allow the Ministry of Water Resources and Meteorology to monitor progress and compliance and foster the links to basin-scale activities, through close cooperation with the Cambodian National Mekong Committee.

A Law on Water Resources has recently been approved, which establishes IWRM as a fundamental principle for water planning and management and specifies the processes for national and river-basin-level water planning. This law is now being made operational. A Tonle Sap Authority has been established to coordinate water development and planning in that sub-basin. Basin forums could according to the law be established in some river basins and watersheds, advising on water planning and management issues. Irrigation scheme management is being transferred to the farmer level.

Lao PDR is developing a national water resources policy and strategy which will provide a clear perspective for all sector agencies to follow in water resource planning. Its implementation will occur over the next five years and will be monitored by the Water Resources and Environment Administration (WREA).

The new policy and strategy will more clearly define agency roles and responsibilities and remove any overlap between agency functions. The Water Resources Law (from 1996) will be revised to provide WREA with clear legal backing and authority to manage national and river basin-level water resources. Provincial agencies are expected to be given greater responsibilities for water resource planning and management, and devolution of management of irrigation schemes has occurred to farmer level. Water planning will occur at a river-basin level and river basin organisations are being trialled to assess the appropriateness of this approach.

Thailand has undergone various water policy and strategy reforms over the past 10 years, emanating from the 1997 Constitution that guarantees the right of communities to protect and manage the environment and natural resources. The country has been subdivided into 25 river basins and river basin committees are becoming the main bodies for participatory water resources management at the basin and local level.

The National Water Resources Committee has developed a national water policy and strategy statements that guide the work of the basin committees and water-related agencies. The committee monitors progress of water resources planning and management against the endorsed policy and strategy.

The IWRM institutional framework has been strengthened since the establishment of the Department of Water Resources (DWR) within the Ministry of Natural Resources and Environment. Basin committees have a well-structured mandate and broad membership that allows all stakeholder groups in a basin to contribute and participate. They operate in a way that is similar to what is acknowledged as international best practice guidelines for participatory river basin planning and management.

Supporting initiatives now being addressed are the drafting of a river Water Resources Law, strengthening the basin committees, creating and developing information networks and systems for IWRM, and developing guidelines and plans for flood control and mitigation.

Viet Nam has created a National Water Resources Council and developed a comprehensive national water resources strategy that identifies the major challenges for IWRM in the country, priority activities and actions that are to be followed, and the agencies responsible for participating in the work. It gives a clear roadmap for addressing emerging water resource problems in an integrated and participatory way.

The current Law on Water Resources is under review. Water resources planning is based on river basins rather than administrative boundaries, and several basin organisations have been established. Overlap between water-related ministries is being clarified. Decentralised decision-making and management for water supply and irrigation have been introduced.

Stakeholder participation and consultation

New approaches to stakeholder participation and consultation are being developed in all the LMB countries. Such processes are a central part of IWRM. At the basin scale, stakeholder participation and consultation is a fundamental part of the MRC's activities. Access to information and engagement in the organization's activities and monitoring processes are key to this approach.

STAKEHOLDER ENGAGEMENT AT THE MRC'S GOVERNANCE LEVEL

MRC is developing a policy that will see representatives of civil society and other interest groups join government agencies and development partners in having a greater say in how the organization is managed. A consultative forum is proposed that would provide inputs to the decision-making bodies of the MRC – the Joint Committee and the Council – where the overall strategic direction of the organization is agreed.

STAKEHOLDER ENGAGEMENT AT THE MRC PROGRAMME LEVEL

Most of the MRC programmes develop their own stakeholder participation processes. The BDP programme, for example, organises stakeholder forums at the regional, national and sub-basin levels, operates a public submissions website, and conducts stakeholder surveys and IWRM training. The MRC disclosure policy supports stakeholder engagement though improved access to information.

Working with NGOs to further improve these processes for transparent basinwide dialogue, and encouraging the development of national approaches to public participation that relate well to the basin perspective, are key priorities for the next few years. All of the strategic and management links (Table 5.2.1) must be effective for the full benefits of IWRM to be realised.

Table 5.2.1 Indicative management arrangements for IWRM

Management level and strategy	Purpose of strategy or plan	Coordination or management body	Partner, supporting or implementing bodies
Basin-scale: IWRM-based Basin Development Strategy	Guides water-related development and management in the LMB	MRC	National resource management agencies
National: National IWRM Strategy (linked to basin-scale strategy)	Plans the actions to achieve national goals, follows an IWRM approach Takes account of the basin-scale strategy	• MOWRAM, Cambodia • WREA, Lao PDR • MNRE, Thailand, • MONRE, Viet Nam	National planning and sector agencies, private and non-government stakeholders, NMCs
Sub-basin: Sub-basin IWRM Strategy	Plans the actions for local-level socio-economic and resource protection, in accordance with the national IWRM strategy	• River basin organisation • Province level coordinating mechanism	National sector agencies (province level)
Watershed: Watershed plan of action	Provides information into sub-basin level plans	Watershed committee	Districts and commune agencies, local communities

5.3 THE MEKONG RIVER COMMISSION COOPERATION

Although the Mekong River acts as a national border in some places, the activities of people on the river seldom stay within the boundaries of one country. Human activity upstream can have serious impact downstream or across surrounding areas.

A demarcation is often drawn between environmental and economic goals but, in the Lower Mekong Basin, these objectives are closely related, with water and water resource management being critical to the economic development of the whole region.

Mekong water resources and aquatic biodiversity underpin the potential for hydropower, agriculture and forestry, fisheries, navigation and trade. Together, these industries contribute billions of dollars to the regional economy.

The riparian countries share a range of trans-boundary benefits through the water resources of the Mekong Basin. For example, the beneficial effect of floods on agriculture; the benefit of alluvial silt deposits; and the importance of the Tonle Sap reverse flow on the cycle of fish breeding. Far from being a point of conflict, trans-boundary water use in the Mekong is an opportunity for cooperation and improved development across the region.

However, issues of population expansion, pollution, deforestation, mining, a growing demand for electricity and food and pressure to use the river system to lift the basin countries out of poverty is putting pressure on water resources. All of these pressures also have potential trans-boundary impacts as has been outlined in the previous chapters of this report.

The MRC's role is to support the governments of the Lower Mekong Basin to manage water resources – helping the Member Countries to exploit the river network in a sustainable way.

Why is multilateral cooperation important?

All of the riparian countries have different needs when it comes to water resource management – and these are often related to their levels of socio-economic development. The difference in economic power translates to differences in regional political power and the potential for dominance of the water resources of the basin. This applies both within the LMB and also between the lower and upper basin countries.

Differences in population density translate to significant differences in water-use requirements. For example, more water is needed for irrigation in Thailand and Viet Nam where there are higher concentrations of productive agricultural land, than in Cambodia and Lao PDR, which are more intensively forested.

While demand for water resources is spread unevenly between countries across the basin, so too are the resources themselves. Thailand and Viet Nam may be more energy hungry than other riparian countries, but almost all of the hydropower potential of the basin is located in Cambodia, and especially Lao PDR (see section 4.3). China has begun the process of constructing a cascade of hydropower dams on the mainstream of the Mekong, which is bound to have long-term trans-boundary impacts.

In recent years, Southeast Asian countries have started to take a regional approach to coordinating economic, social and environmental development and the countries of the Mekong Basin are no exception, with all or some of them being active in the Asian Development Bank's Greater Mekong Subregion (GMS), and the Association of South East Asian Nations (ASEAN).

ASEAN has identified economic promotion and sustainable development of the Mekong River Basin as a major area of focus with a specific emphasis on traffic/transportation, trade and human resources development. In 2004, ASEAN Heads of State agreed on enhancing economic cooperation and integration among Cambodia, Lao PDR, Myanmar and Viet Nam to promote development.

The ASEAN Secretariat is a partner to the MRC Secretariat and Member Country governments and works with the Asian Development Bank, the GMS and other donors to identify opportunities for Mekong support.

Cooperation also exists between the MRC, GMS, ASEAN and upstream countries China and Myanmar, which have been official Dialogue Partners to the MRC since 1996.

A cooperation agreement between China and ASEAN agreed to in 2004 includes a section on Mekong River Basin development cooperation which covers areas such as improving navigational safety on the Lancang–Mekong, expanding environmental impact assessments and the management and monitoring of water quality.

In 2008, the MRC and the Government of China agreed to extend the range of cooperation activities and signed an agreement for a further five years of continuing dialogue. China agreed to increase the amount of hydrological information about the Lancang–Mekong River that it provides to the MRC during the flood season. Visits to China by MRC staff to look at measuring stations and the data centre in Kunming and on the Yangtze River were crucial to helping countries in the LMB upgrade measuring equipment, train government staff and establish the data centre at the Provincial Bureau of Hydrology and Water Resources, Yunnan Province, China. Sharing of hydrological data from China contributes to MRC daily regional flood forecasts.

Achieving cross-border cooperation

The MRC is working to increase cooperation between the riparian states to identify potential trans-boundary issues for negotiation, mediation and conflict prevention; and to develop mediation and conflict management capacity. Although almost all MRC programmes take a regional trans-boundary approach, some specific activities have been fostering dialogue between riparian nations.

The MRC plays a key role in promoting a river basin perspective through the lens of integrated water resources management (IWRM) principles, as discussed in the previous section. This means ensuring that decisions related to one sector, for example hydropower development, also reflect the existing uses and future needs of others, such as agriculture, water supply, fisheries, aquatic ecosystem protection, flood management and water quality.

This structured trans-boundary approach to river governance helps ensure the sharing of the trans-boundary benefits of water-use. Examples include the following:

Hydropower – The MRC works to understand how countries can mitigate the trans-boundary environmental risks of hydropower by researching and making sure all governments and developers have access to information about processes in the river system and the consequences of development proposals. It is also taking a lead role in facilitating negotiation and dialogue between countries when upstream developments will

have a trans-boundary impact, by administering a formal notification and consultation process between affected countries when dams are planned (see section 4.3).

The Basin Development Plan – focuses on realising the economic value of the Mekong for development and poverty alleviation – specifically by:

- Promoting freedom of navigation
- Promoting regional integration
- Promoting water use for such activities as agriculture
- Promoting sustainable hydropower

Talking to the neighbours – the MRC gives the four member countries a collective bargaining chip when negotiating with upstream countries. Cooperation with China and Myanmar, the two Dialogue Partners, has been evolving through the MRC and a dialogue mechanism has been established. This is a framework of cooperation under which joint activities are undertaken. Both countries now regularly participate in MRC technical meetings, contributing to the dialogue on flood, fisheries and navigation issues. This has also led to an increase in transparency from China, which now also shares information on development plans for dams on the Lancang-Mekong river upstream projects. The MRC and China are working on sharing information about dam designs and the impoundment of water in Chinese dams and the Chinese government has agreed to be part of the MRC's strategic environmental assessment of hydropower dams.

Identifying areas of conflict – The MRC has identified a range of potential trans-boundary 'hotspots' or critical areas of potential conflict, which includes seven critical areas or issues within the Mekong River Basin. Building on this initiative, a project has begun on the Lao/Cambodian border to help address potential problems at the Strung Treng wetlands site, where illegal and destructive fish harvesting activities, increased pressure on wetlands due to increasing human population in the area, threats to the endangered Mekong dolphin and change in flow and hydrological patterns due to developments in the upper stream of the Mekong River have the potential to cause conflict.

MRC's Vision for the Mekong Basin: An economically prosperous, socially just and environmentally sound Mekong River Basin

MRC's Mission Statement: To promote and coordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well being by implementing strategic programmes and activities and providing scientific information and policy advice

Laos forest dwellers.

History of the Mekong River Commission

The Mekong River Commission was founded in its current form with the signing of the 1995 Mekong Agreement, which established the rules and procedures of the organisation. It has its origin in the Mekong Committee, and the Interim Mekong Committee, which were in force between 1957 and 1995.

In 1957, just three years after Cambodia, Laos, and Viet Nam obtained independence from France both the United Nations and US government released separate reports that highlighted the huge potential for hydropower and irrigation development on the Mekong.

These reports were influential and largely responsible for arousing political interest in creating a trans-boundary organisation to manage Mekong water resources. The Mekong Committee was established the same year as the release of the two reports and irrigation and hydropower subsequently became a priority focus for the organisation. The relatively unexploited Mekong was seen by the newly independent riparian countries as a powerful potential economic resource; and trans-boundary cooperation an essential part of the drive for the development of the Lower Mekong.

The committee was initially part of the United Nations, with its Executive Agent being chosen from the rank and file of the UN Development Programme. The UN saw the Mekong Committee as a means of managing water and water resources to promote economic growth – and to help lift the region out of poverty. It hoped that the organisation would form a precedent for managing other trans-boundary river systems in poverty-stricken regions.

The committee's focus on hydropower intensified further in the early '70s as it became a more forceful advocate for large-scale dams and other projects. The release of the 1970 indicative basin plan called for 17 potential long-term development projects on the mainstream by the year 2000.

However, progress toward building these hydropower schemes, and trans-boundary cooperation in general, was hampered by ongoing regional conflict.

In 1975, Cambodia, Lao PDR and Viet Nam all underwent regime changes. The US abandoned support for the Mekong Committee due to embargoes it imposed on Cambodia (withdrawn in 1992), Lao PDR (withdrawn in 2004), and Viet Nam (withdrawn in 1994). International aid agencies and other donors, most notably the Scandinavian and Japanese governments, stepped in to replace the gap in financial support and continue to do so to this day.

By 1977 it was becoming clear that Cambodia would be unable to participate in the committee due to the rise of the Khmer Rouge. The committee passed a declaration, which resulted in the establishment of the Interim Mekong Committee in January 1978. The smaller three-country committee was also politically weaker and limited in scope to study large-scale projects and implement a few small-scale ones, almost exclusively in Thailand. The role of the organisation began to shift to data collection.

In 1987, the interim committee released a revised basin plan which called for less hydropower development than the 1970 plan. In 1991, Cambodia requested re-admission. Although this was initially opposed by the Thai government, negotiations over Cambodia re-joining the organisation culminated in a new structure altogether, with the signing of the April 1995 Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin. The committee was renamed the Mekong River Commission (MRC) with four member countries: Cambodia, Lao PDR, Thailand and Viet Nam; and two Dialogue Partners: the People's Republic of China and the Union of Myanmar.

The MRC works with National Mekong Committees in each country to develop procedures for water utilisation to try to ensure 'reasonable and equitable use' of the Mekong River system. It rejects the ambitious irrigation and hydropower schemes planned in the 1970s and has adopted a more holistic approach to protecting the water resources of the basin to help all member countries to exploit the river network without damaging it. There is a greater emphasis on better management and preservation of existing water resources in the member countries than in previous years.

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5. MEKONG COOPERATION TOWARDS SUSTAINABLE DEVELOPMENT

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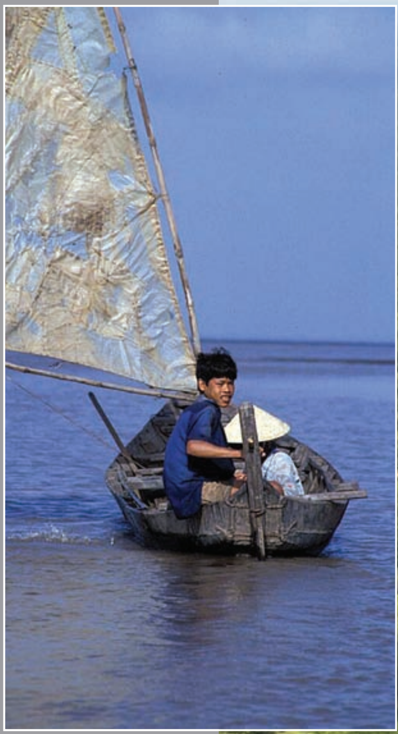

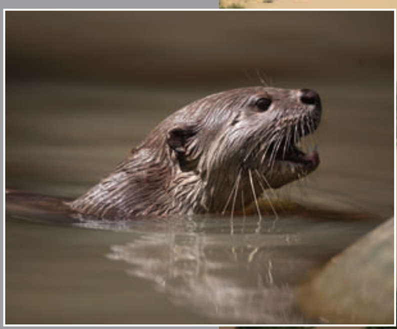

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