Mekong River Commission
For Sustainable Development

STATE OF THE BASIN REPORT 2018

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Foreword

The Mekong River Commission's (MRC) State of Basin Report is a flagship product of the organisation and an integral part of the MRC's strategic planning cycle. Compiled about every five years based on the facts and figures of the available data and information, the report assesses conditions within the basin and the impacts, both positive and negative, that development and use of the water and related natural resources are having. The report thus provides a comprehensive basis for the Member Countries and other key stakeholders to discuss and determine appropriate actions by which to realise the MRC's aims for optimal and sustainable development of the basin as set out in the 1995 Mekong Agreement.

This is the third State of Basin Report published by the MRC, but the first to be presented within a new framework of a comprehensive and consistent set of indicators that address all aspects of the MRC's mission. The MRC's Indicator Framework and this report cover five critical dimensions associated with this mission: environmental, social and economic conditions, climate change and cooperation. In addition, and for the first time, this SOBR includes a review of conditions within the upper Mekong basin, known as the Lancang Basin in China.

This report recognises that, in recent years, development pressures have increased as a result of growing populations and expanding economies. Whilst living conditions within the basin generally are rapidly improving, this has come at some considerable cost to the environment. Key areas of concern that require our specific attention are the seemingly permanent modification of mainstream flow regime, the substantial reduction in sediment flows due to sediment trapping, the continuing loss of wetlands, the deterioration of riverine habitats and the growing pressures on capture fisheries. At present, although temperature and sea level rise are the only discernible impacts of climate change within the basin thus far, I am pleased to note that Member Countries are actively putting measures in place to address the predicted future changes.

This report also recognises that use of the water and natural resources within the basin is giving rise to substantial economic benefits. At present, we should take note that these have not been equally shared as some Member Countries have only recently started to develop their potential. Concerns naturally exist, however, at the evident trade-offs between some of these developments and their negative impacts upon the environment.

The 1995 Mekong Agreement recognises the need for active cooperation between Member Countries in order to achieve their collective aims for the basin. Whilst the foundations for cooperation have been established through the joint efforts of all parties, we must all take note that the challenges identified in this report underscore the need to further strengthen cooperation through enhanced basin planning and strengthened ties with the upstream dialogue partners. Furthermore, I also recognise that increased efforts are needed to find better and more cost-effective ways for the MRC to fulfil its core function of monitoring relevant conditions within the basin.

In the light of the above, this State of Basin Report concludes by offering six key recommendations for Member Countries, partners and stakeholders to consider when next updating the Basin Development Strategy:

A. Continue and enhance monitoring of flow conditions and water quality

B. Develop and implement a MRC Data Acquisition and Generation Action Plan

C. Address the problem of reduced sediment concentrations

D. Address the need to take urgent action to preserve and protect remaining environmental assets

E. Adopt a more proactive approach to basin planning and the management of trade-offs between sectors and countries

F. Maintain and strengthen cooperation with Dialogue Partners and other stakeholders

I do believe that this State of Basin Report, with its new approach structured around the MRC's Indicator Framework, does indeed provide us with a comprehensive overview of conditions within the Mekong basin. It brings into focus critical issues we must seek to address in the coming years if we are to truly fulfil the aims and objectives set out in the 1995 Mekong Agreement.

I am also pleased to note that much new and up-to-date data and information have been collected during the development of this document. As for the Upper Mekong Basin part, the MRCS has used MRC data and assessments as well as publicly available official and published academic sources. However, it is important for readers to note that the quality and reliability of data and information used for the Upper Mekong Basin may not be the most up to date information. Thus, the information on the Upper Mekong Basin part of the basin may be subject to further refinement and may not be applicable for use beyond the scope of this report.

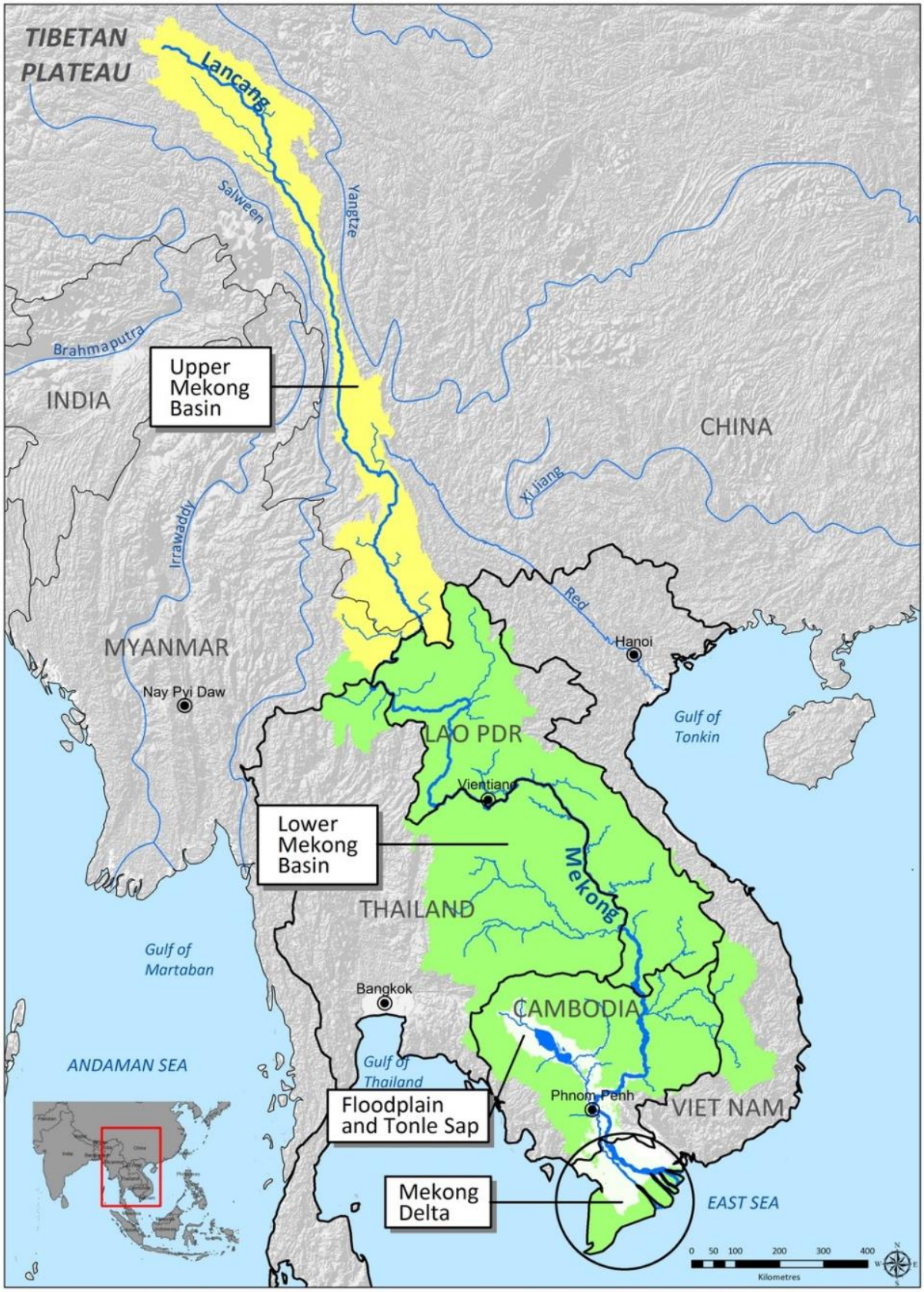
I look forward to all parties working together to build upon this report and to agree and implement necessary actions that will serve to enhance the state of the basin to the benefit of all future generations.

An Pich Hatda

Chief Executive Officer

Mekong River Commission Secretariat

The Mekong River Basin



Executive Summary

Introduction

The Mekong River Commission's (MRC) State of the Basin report (SOBR) aims to provide an overall picture of the Mekong River Basin in terms of its ecological health and the social and economic circumstances of its people, and the degree to which the cooperation between riparian countries envisaged under the 1995 Mekong Agreement is enhancing these conditions. In addition, and for the first time, this report also includes reviews of conditions within the upper basin in PR China and Myanmar, both dialogue partners of the MRC, in order to better understand the dynamics of change that are occurring within the basin.

The refreshed strategic planning process adopted by the MRC has facilitated the Member Countries to collaboratively explore ways by which optimal and sustainable development may be achieved and regional benefit sharing promoted. The process follows a five-year planning cycle in which the SOBR is to be a key input for the updating of the Basin Development Strategy. In this planning cycle, the SOBR can be seen as an instrument in: (i) establishing the key issues that the next Basin Development Strategy should address and (ii) measuring the effectiveness of implementing the current Basin Development Strategy (2016-2020).

In this regard, the SOBR is intended to provide (to the extent that data are available) a statement of past trends and current conditions within the basin, which will be updated and compared at five yearly intervals to track changes brought about by the cooperation envisaged under the Mekong Agreement. The SOBR also seeks to highlight significant issues as well as apparent development opportunities that the Member Countries may wish to take up. Further studies, such as future scenario assessments as were undertaken under the BDP Programme in 2011 and more recently under the Council Study in 2017, are likely to be needed thereafter to determine the best way by which to address the issues and opportunities raised in the SOBR [1].

Dimension	Strategic indicators
Environment	❑ Water flow conditions in mainstream ❑ Water quality and sediment conditions ❑ Status of environmental assets ❑ Overall environmental condition
Social	❑ Living conditions and well-being ❑ Employment in MRC water-related sectors ❑ Overall social condition
Economic	❑ Aggregate economic value of MRC water-related sectors ❑ Contribution to basin economy
Climate change	❑ Greenhouse gas emissions ❑ Climate change trends and extremes ❑ Adaptation to climate change
Cooperation	❑ Equity of benefits from the Mekong River system ❑ Benefits derived from cooperation ❑ Self-finance of the MRC

In contrast to earlier versions of the SOBR published in 2003 and 2010, the 2018 SOBR and future SOBRs are to be structured around a set of indicators, referred to as the MRC Indicator Framework. The framework comprises a hierarchy of water related strategic and assessment indicators supported by monitoring parameters, all of which are intended to provide a full and integrated picture of how the cooperation between countries through the MRC is benefiting and impacting upon the basin and each country. This framework will also be used when future basin-wide scenarios are assessed to ensure a consistent approach to planning and monitoring of basin developments.

At the highest level, the MRC Indicator Framework is structured around five dimensions, being environment, social, economic, climate change and cooperation, within which 15 strategic indicators (see box) have been agreed by the Member Countries to provide policy level decision takers with a concise set of information relating to the development and management conditions within the basin.

1 In the MRC's planning cycle, the SOBR normally precedes scenario assessment, which in turn underpins the updating of the Bain Development Strategy. In the current period, a preliminary version of this SOBR was prepared in 2015, in advance of concluding the scenario assessments under Council Study in 2017, thus preserving the sequence of the MRC's planning cycle.

Underpinning these strategic indicators, some 55 draft assessment indicators were selected to provide more detailed information and to support the evaluation of the strategic indicators. This report follows this structure and seeks to quantify and/or provide commentary on each of the strategic and assessment indicators.

Environmental dimension

Three strategic indicators have been selected to characterise the environmental conditions within the LMB. These are:

- ❑ Water flow conditions in mainstream
- ❑ Water quality and sediment conditions
- ❑ Status of environmental assets

(i) *Water flow conditions in the mainstream*

The condition of mainstream flows is regularly monitored in accordance with MRC's Procedures (and Guidelines) for the Maintenance of Flows on the Mainstream (PMFM). The Guidelines set thresholds within which flows are expected to be maintained. In addition, the timing and onset of wet season flows is considered a valuable indicator as it influences, inter alia, the triggering of fish migration.

It was found that both **dry season and wet season flows** over the last five years are generally in conformity with PMFM thresholds, with occasional but apparently not systemic exceptions. **Reverse flow in Tonle Sap**, which is a function of the size of floods in the mainstream pushing water up to the Tonle Sap Lake (which then flow back out during the flood recession period), are also broadly in line with the Guidelines, with the maximum (severe) flow threshold breached on average 10 days per year and the more modest low flows threshold somewhat more frequently. Continued monitoring is recommended, particularly with respect to Tonle Sap reverse flows. It is noted also that the **timing of onset of wet season flows** has been quite variable in recent years along with the lengths of the wet season. It is also observed that **below average flows are seen during the flood recession period**, particularly in the downstream reaches of the mainstream.

Whilst the findings above demonstrate that the requirements of the PMFM are generally being met, the flow monitoring data for Chiang Saen (the northern most station in the LMB mainstream) shows that, although total annual flow volume remains broadly the same, flood season flows have reduced somewhat and the dry season flow is markedly increased following the development of the large reservoirs in China. The data for Kratie show a similar but less marked increase in dry season flows. However, the data for Tan Chau show no discernible trend as yet, notwithstanding the increases predicted in both the modelling undertaken in MRC's Scenario Assessments reported in 2010 and the recent MRC Council Study in 2017.

In part the reasons behind this are that the augmentation of dry season flows provided by the reservoirs of the Upper Mekong Basin (UMB) becomes a smaller proportion of the total flow the further downstream this is considered. Furthermore, the dry season flows at Tan Chau are influenced, especially in the early part of the dry season, by outflows from Tonle Sap, which are in turn a function of the magnitude of the preceding flood season flows (2015 was a particularly mild flood season). The variability of Tonle Sap outflows is of a similar magnitude to the predicted flow augmentation at Tan Chau.

Previous modelling studies predicted that, in the short term (2020), the UMB dams plus the other existing and under-development storages in the LMB, would provide sufficient storage to regulate mainstream flows in a manner that would allow for a significant increase in abstractions upstream of Tan Chau (in line with national plans) without diminishing critical dry season flows into Viet Nam. Beyond 2020, further development of tributary storage was thought to be needed to cope with long term irrigation development plans of the countries. Such a conclusion, if shown correct, is of immense significance in so far as, in contrast to many river basins around the world, there appears to be sufficient resource to meet all likely future consumptive demands with only a relatively small further increase in LMB tributary total storage.

The evidence presented in this SOBR is that, thus far, the predicted modest augmentation of dry season flows at Tan Chau is not yet evident, bringing into question whether the earlier modelling studies provided a correct forecast of flows or not. Either way, this evidence raises the question as to whether additional abstractions upstream can be countenanced or not at this time.

(ii) *Water quality and sediment conditions*

Water quality conditions within the LMB are regularly monitored in line with the MRC's Procedure for Water Quality Monitoring (PWQ) and Technical Guidelines (TGWQ), taking into consideration the requirements for human health, aquatic life and agricultural use. Between 2010 and 2017, water quality for the protection of human health was almost always good or very good along the mainstream, with only a few stations during 2010-14 occasionally having a lower but still acceptable rating.

For aquatic life, records for 2010-17 show that the average rating across all stations has been good, with only one station in Viet Nam, My Tho, having consistently a lower rating due to failure to meet targets for total phosphorous and nitrate-nitrite. For agricultural use, over the same period, again only one monitoring station, My Tho again, was rated less than very good. This was due to a failure to meet the target for electrical conductivity in 2016 only.

The data show no apparent trend over time and therefore there should be no immediate concern over water quality conditions within the LMB in the near future. Nevertheless, with increasing industrialisation, growth in urban centres and rising fertiliser and pesticide use, continued monitoring of water quality is recommended.

Suspended sediment concentrations have been monitored since 1994, demonstrating that the concentration and the variability of suspended sediment have decreased considerably since 2001. At Chiang Saen, sediment flows have decreased from about 85 Mt/yr to 10.8 Mt/yr, meaning that the sediment contribution from China to the Mekong mainstream sediments has decreased to about 16% of all sediments in the LMB as compared to about 55% historically. A similar trend is seen downstream at Pakse, where average loads have decreased from 147 Mt/yr to 66 Mt/yr between 1994 and 2013.

These changes in sediment concentrations, brought about by the construction of storage reservoirs principally in China, signal a substantial and seemingly permanent change in the river's morphology. Impacts of these changes can be expected all along the river as it seeks to readjust to its new regime. Furthermore, few nutrients will reach the remaining wetlands and the delta and coastal building processes will be modified. Understanding how these changes will impact on the river, the environment and the socio-economic development of the LMB needs to be strengthened, so that coping strategies can be determined.

Salinity intrusion within the Viet Nam delta is a function of the flow volumes that reach Viet Nam. Typically, each year, a total of 1.85 million ha are affected annually be elevated salt concentrations. There are no time-series data available to demonstrate whether there are any trends in the extent of area affected, although the fact that dry season flow volumes at Tan Chau have changed little in recent years suggests that the area affected is unlikely to vary much.

(iii) *Status of environmental assets*

The **LMB wetlands** are important biodiversity hotspots which play an important role in the economy, society and culture of the region. Nevertheless, LMB wetlands are being gradually either lost or degraded, mostly as a result of agricultural and other developments. With a little over 100,000km^2 of wetlands left in the LMB in 2010, MRC has estimated that less than two per cent of the original wetland area in the Mekong Delta remains. Data for the extent of wetlands in 2015 are being compiled at present and are expected to show a continued reduction in area. If this trend continues, the remaining wetlands may all but disappear, with the consequent impacts that will have on the bio-diversity of the basin. Steps are urgently needed to go beyond assessing individual projects and to develop a strategy by which all, or at least a large number, of the remaining wetlands can be both protected and nurtured on behalf of future generations.

Exposed sandy and rocky **riverine habitats** are important habitats for vegetation, herpetofauna and birds in the dry season. Deep pools in the LMB are recognised as important geomorphic features, providing refuge and spawning habitat for a variety of fish species. Whilst no up-to-date information is available to state whether there has been a significant change overall in their condition, it is expected that rising dry season water levels from increased flow regulation, together with backwaters from planned reservoirs and the resulting changes in sediment concentrations, pose a threat to these environmental assets. Well-prepared and sensitive design guidance remains important to minimise these potentially damaging impacts remains important.

The Mekong River system hosts one of the most diverse and prolific **freshwater capture fisheries** in the world. Recent estimates of the biota of the greater Mekong region include up to 1,148 species of fish, as well as 20,000 plant species, 430 mammals, 1,200 birds and 800 reptiles and amphibians. However, accelerating economic development, population growth and increased consumption patterns are placing pressure on the environment. Currently, 14 species listed as critically endangered (including the Irrawaddy dolphin and Mekong giant catfish), 21 species are listed as endangered and a further 29 species are considered vulnerable.

Over the last decade and a half, the amount of reported wild fish catch has risen from 0.4 MT in 1991-92 to 2.3MT in 2015. However, fishing effort has increased and smaller fish now make up an increasing proportion of the total catch. Separately, with increased urbanisation, changing consumption patterns and growing export markets, the aquaculture sector is growing rapidly and is increasingly important to the basin's economy and food security. **Aquaculture production** has grown significantly from 0.7 MT in 2002 to 2.1 MT in 2012, 86% of which was in Viet Nam. With growing pressures on capture fisheries from new developments and increased consumption, a proactive approach is needed to manage the sector in a sustainable manner.

Ecologically significant areas encompass a range of different ecosystem types, including rivers, wetlands, forests and grasslands. A substantial number are under some form of protection as Ramsar sites, biosphere reserves, national parks and others. After decades of declining forest cover there are recent signs of an increase in forested area, especially in Lao PDR. Increasing protection for important natural habitats should over time help support the LMB's threatened plants and animals. Connecting habitats through biodiversity corridors and taking a cooperative landscape approach to management and enforcement of regulations with the engagement of local communities will be important.

Social dimension

Two strategic indicators have been selected to characterise the social conditions within the LMB. These are:

- Living conditions and well-being
- Employment in MRC water-related sectors

(i) *Living conditions and well-being*

Living conditions and well-being are characterised in this report in terms of **food, water and health security and access to electricity**. At present the analysis for some strategic and assessment indicators is limited due to a lack of socio-economic data, both in terms of applicability to conditions within the basin and the degree of disaggregation of those data to identify variability within the basin. As a result, the approach taken here uses the best available evidence, often national level data, in the cases of some monitoring parameters diverging from the approach required by the Indicator Framework. Examples are also provided of specific situations in individual Member Countries of data available within the LMB. It is to be noted that further development of this analysis along the lines envisaged by the indicator framework will require significant additional data.

That said, overall living conditions and well-being the in LMB have improved significantly over the last fifteen years. All countries have experienced improvements in **food security** with greater access to adequate levels of nutrition, declines in undernourishment and declines in levels of malnutrition. Indicators of **water security** have generally improved, including access to potable water supplies. Although drought susceptibility remains a problem in some areas, this may be off-set by a decline in dependence on agriculture for livelihoods.

There are some indications that damage due to flooding is increasing, although again this may be the result of greater investment in the region putting more capital assets at risk. Health security indicators have also seen improvement in terms of improved access to basic sanitation and access to health services.

Health outcomes have seen significant improvements with declining mortality rates and increased life expectancy. **Access to electricity** has also improved rapidly, Thailand and Viet Nam have close to 100% access even in rural areas, and Lao PDR has improved access significantly in recent years. Cambodia has made improvements in electrification but continues to perform badly, with low levels of service particularly in rural areas.

Nevertheless, there remains **significant variation in performance between LMB countries** largely reflecting the differing stages of development. There is also likely to be substantial sub-national variation in performance which is not picked up by these largely national level indicators.

(ii) *Employment in MRC water-related sectors*

Employment in MRC water-related sectors is assessed in terms of **economic security** and **gender equality in employment and economic engagement**. As above, insufficient data have been made available to fully address the requirements of the Indicator Framework and to explore the assessment indicators to the depth they merit.

The main water related economic sectors in the LMB are agriculture, fisheries and navigation and to a somewhat lesser extent, hydropower, tourism and forestry. **Employment in water related sectors** in the LMB remains high, although the importance of direct employment, particularly in agriculture is declining as work opportunities in other sectors (often services and manufacturing located outside the LMB) develop. Employment in capture fisheries also remains important for livelihoods, although often as a source of secondary or supplemental employment. Tourism also stands out as an important source of employment in the LMB, and one that is likely to grow rapidly. Employment in navigation is also likely to be significant in some parts of the basin, such as the delta and potentially to grow rapidly in the future.

At the same time, the **poverty rate** has fallen dramatically across all LMB countries, approximately halving in the last decade and by around three-quarters since the turn of the century. This indicates increased economic security across the basin and is probably linked closely to changes in patterns of employment and improved productivity in the primary sectors.

Limited evidence on **gender equality** in employment and economic opportunity has been available. Gender disaggregated data on employment in agriculture and related sectors points to small but persistent differences in male and female employment patterns. However, the implications of these differences are difficult to interpret with regard to gender equality. The Gender Parity Index (GPI) for primary school enrolment, on the other hand, is a concrete indicator of continuing gender disparities in the region, with boys clearly getting preferential access to primary education, particularly in Lao PDR and Cambodia.

Overall, available data points to general improvement across most social indicators. However, the analysis is limited by the lack of comprehensive sub-national data for the LMB. It is likely that there is significant variation in terms of all indicators at the provincial and sub-provincial level.

Understanding this geographic variation is critical to achieve a better understanding of the causal factors determining these outcomes, and ultimately the design and targeting of appropriate policy interventions. Moreover, the availability of sub-national data would allow the development of more accurate estimates of indicator values for the LMB than is currently the case when using national level data. This approach is particularly problematic for Thailand and Viet Nam, for which the population within the LMB only constitutes a small share of national population.

Economic dimension

Two strategic indicators have been selected to characterise the economic conditions within the LMB. These are:

- ❑ Aggregate economic value of water-related sectors
- ❑ Contribution to basin economy

(i) *Aggregate economic value of water-related sectors*

This Strategic Indicator is defined as the net economic output of water-related economic sectors in the Lower Mekong Basin. However, for the purposes of this report, and due to data limitations, this has been modified to the "gross economic output of water related sectors in the LMB". Not all sectors have been possible to assess so far due to data limitations.

Irrigated agriculture is the main water user in the basin. It has grown from virtually nil in the 1950's to in excess of 5.7 million hectares (Mha) in 2013 (nearly 80% of which is in Viet Nam), with a total economic value of US$ 7.7 billion per year. As noted above, obtaining accurate figures on irrigation and irrigated coverage is not easy, particularly given that significant amounts of irrigation are in small schemes, which are not necessarily included in the official records. However, given the likelihood and significance of further expansion of irrigation, improved monitoring appears to be very important to guide strategic management of the basin.

The Mekong basin has considerable potential for **hydropower development**, serving both domestic and export markets, enhancing both regional economic integration and energy security. By 2015, 59 hydropower projects of between 1 MW and 4,200 MW had been developed in the LMB with a total installed capacity of 10,017 MW, representing some 35% of the total estimated technical hydropower potential for the LMB. The gross economic value of hydropower production has increased from US$ 0.55 billion per year in 2005 to over US$ 2 billion in 2015 (excluding investment and other related development costs), over 50% of which accrues to Lao PDR with a further 40% to Viet Nam.

The Mekong River has long been an important **inland waterway for traditional cargo and passenger transpor**t between the numerous riverine communities along the Mekong. In addition, the river has also emerged as an increasingly important international trade route connecting the six riparian states, and the lower reaches of the basin to the sea and wider international markets. The IWT cargo in 2007 was worth US$ 6.8 billion annually and, notwithstanding stiff competition from road transport, IWT cargo has since risen to 23 million tons in 2014. Over the same period, total passenger numbers have risen from 37.6 million annual to 69.4 million, over 800,000 of whom were tourists.

Sand mining in the LMB is extensive and provides a critical input into construction and industrial sectors. Extraction of sand in the region has increased rapidly with the increased demand, much having been driven by infrastructure upgrading on the delta, as well as for export to regional markets. Data for sand and sediment mining activities in the basin is not systematically collected, but the sector is believed to be worth in the order of US$ 175 million annually.

An evaluation has been made of **wetlands** and the services they provide. Although there are a number of caveats to the method used, the annual value of wetlands in 2010 is estimated to have been US$ 2.9 billion, down from US$ 3.6 billion in 2003, due to a 20% reduction in the extent of wetlands during that period. It seems probable that the current value is somewhat less for similar reasons.

The overall unit value of **capture fisheries** in LMB is derived from first-sale prices of wide variety of fish species. Based on average first-sale prices in each of the four Member Countries, the economic value of the 2.3 million tonnes of annual capture fish production was calculated at about US$ 11.2 billion, representing about 65% of the total value of all types of fisheries production. Of this, the economic value from capture fisheries in Thailand is the largest at US$ 6.3 billion and Cambodia second at US$ 2.8 billion annually.

The economic value of **reservoir fisheries** is significantly lower based on a yield of 230,000 ton annually worth US$1.2 billion in 2015, up from US$ 0.7 billion in 2010. In contrast, **aquaculture** has grown rapidly and was valued in 2015 at US$ 5.8 billion, up from US$4.6 billion in 2010 and US$0.7 billion in 2003. Viet Nam is by far the largest producer, accounting for 86% of the basin's production value.

Timber is an important good supplied from the forests of the LMB. At present, and despite regulation, wood it is not extracted in a sustainable manner in some LMB countries and is a key source of forest loss. Initial estimates made of **forestry** output value in the LMB suggest that the annual sustainable fuelwood production in the LMB 2010 could be worth up to US$ 0.4 billion, and that by 2016 the gross economic value of annual sustainable timber production in the LMB could be up to an estimated US$ 1.4 billion.

Since 1980, international **tourism** has developed rapidly in all the LMB countries. Tourism now makes an important contribution to GDP in all the LMB countries ranging from 5% in Viet Nam to 11% in Cambodia. In 2016, the LMB countries attracted around 51 million international visitors generating about US$65 billion. However, figures for tourism to the LMB specifically have not been available, although the national figures for Cambodia (US$3.5 billion in 2016) and Lao PDR (US$0.7 billion in 2016) may provide some guide to international tourism in the LMB in these two countries (but not so in Thailand and Viet Nam as most of their sites are outside the basin). Nevertheless, the value of tourism to the basin is clear, as is the rapid growth in the sector. In this context, it is important to stress the significance of sustaining the riverine environments in order to continue attracting tourists to the basin.

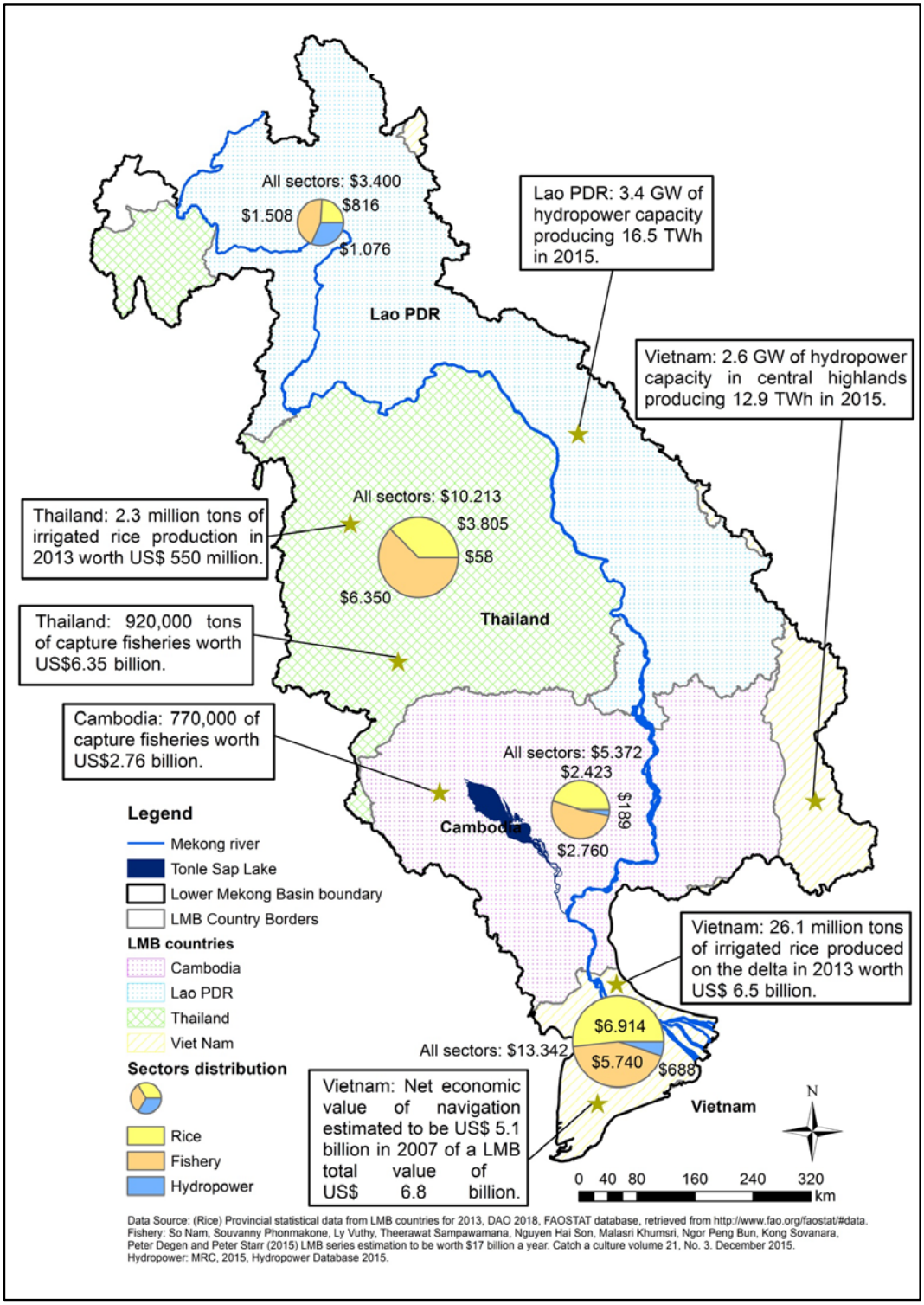
Estimates of **river bank and coastal erosion** have been generated for the LMB countries with the exception of Thailand. These show a wide disparity between estimates of eroded area between countries, reflecting possibly different geomorphological conditions, gaps in the data, and also different assessment methodologies making comparisons difficult. Over the seven-year period the value of land lost in Lao PDR is in aggregate estimated to be US$ 0.7 million, or about US$ 100,000 per year. Estimates for Cambodia have not been possible to make and reported losses in Viet Nam in recent years, whilst prompting concern, are very limited. However, coastal erosion is seen as a large and growing problem in the delta, where it has been estimated that 500 ha of land is being lost annually, worth about US$ 12.5 million per year.

The economic value of **flood damages** is annually reported by the Member Countries for the Annual Mekong Flood Reports. Data for 2010-2014 shows that the annual cost varied between US$ 0.02 billion (2012) up to US$ 0.5 billion (2011), with an average of this 5-year period of US$ 0.2 billion per year. Damages and losses are indicated for floods, in general, but damages and losses related to river floods or flash floods are not specified. While this is too short a time-series to determine a trend with any confidence, there is some indication that damages are possibly increasing, probably as a consequence of greater investment in areas susceptible to flooding.

Overall, in aggregate, the annual economic value of the water-related sectors listed above is almost US$ 35 billion per year, excluding tourism and forestry.

(ii) *Contribution to basin economy*

The contribution of basin economy made by the water-related sectors in the LMB is defined as the contribution to overall economic, food and energy security within the Basin and beyond. These are characterised by assessment indicators covering these sectors contribution to national GDP, food grain supply, protein supply and power supply.



Understanding the economic value and country incomes from all sectors within the Lower Mekong Basin

Data was unavailable to allow the calculation of the contribution of all MRC water-related sectors in the LMB to national GDP or sectoral GDP. However, sufficient data was available to allow the estimation of the share of key MRC water-related sectors attributable to production in the LMB, namely rice production, fisheries, hydropower and tourism.

The share of **national rice production** within LMB areas of Cambodia (84%) and Lao PDR (69%) is high reflecting the large proportion of these countries within the LMB. The share of national rice production produced in the LMB areas of Thailand and Viet Nam is lower at around 40-51%, reflecting the large proportion of these countries outside the LMB. Overall, the LMB produced 48.2 million tons of rice in 2013, around 51% of the 93.6 million tons of rice produced in the four LMB countries as a whole.

Protein supply from the rice sectors in 2013 and 2014 represented between 58% for Viet Nam and 68% for Thailand up to 131% for Lao PDR and 152% for Cambodia, expressed as a percentage of national demand. The fisheries sector (capture, reservoir and aquaculture) met between 8% (Viet Nam) and 25% (Cambodia) of national demand of the LMB countries.

LMB hydropower sources are clearly important for all LMB countries, accounting for 10% of electricity demand. According to the available data, Lao PDR obtains practically all its supply from LMB hydropower. Cambodia also obtains over a third of its electricity supply from hydropower plants in the basin. Thailand has the lowest share of LMB hydropower in its generation mix, including significant hydropower imports from Lao PDR. Finally, Viet Nam also generates around 9% of its demand in the LMB from plants in the central highlands.

The broad picture of the LMB as with the LMB countries as a whole is one of economic growth and productivity improvement. This is clear from increased production in sectors such as rice production and hydropower generation, as well as navigation, tourism, aquaculture. Overall, water and water related sectors in the LMB remain significant contributors to the national economies of LMB countries. The high shares of national production in all these sectors in Cambodian and Laotian portions of the basin reflects both share of the national territory of these countries in the basin. Similarly, the lower share of LMB located production in these sectors in national production in Thailand and Viet Nam reflects a lower portion of national territories in the LMB

US$ million

		Cambodia	Lao PDR	Thailand	Viet Nam	Total
Rice production 2015	LMB production	2,423	816	3,805	6,914	**13,958**
	LMB share of national production (%)	*84%*	*69%*	*40%*	*51%*	***51%***
Total fisheries 2015	LMB production	3,001	1,508	6,718	5,740	**16,967**
	LMB share of national production (%)	*89%*	*91%*	*67%*	*25%*	***45%***
Hydropower 2015	LMB production	189	1,076	58	688	**2,011**
	LMB share of national production (%)	*32%*	*100%*	*0%*	*8%*	***9%***
Tourism 2017	LMB total	2,100	557	15,640	2,898	**21,195**
	LMB share of national production (%)	*86%*	*91%*	*37%*	*22%*	***36%***

There remain significant difficulties with accurately estimating the economic contribution of natural resources such as wetlands, sand mining, timber forests and capture fisheries leading to uncertainty around the values of these resources. Similarly, enumerating flood and erosion damage remains problematic. The development and expansion of hydropower and agriculture in the basin can be expected to have a negative impact on the economic productivity of some of these sectors. Without better valuations for these sectors it is difficult to identify and properly assess these trade-offs. Better data collection on all sectors is important but for these sectors, where economic values are less transparent and harder to establish, it is a priority.

Climate change dimension

Three strategic indicators have been selected to characterise the economic conditions within the LMB. These are:

- Greenhouse gas emissions
- Climate change trends and extremes
- Adaptation to climate change

(i) *Greenhouse gas emissions*

Greenhouse gas emissions of the LMB countries currently contribute less than 2% of the global emission. A first estimate is that for the LMB only this is even far below 1%, again compared to the total global emission. However, emission rates are growing faster than the global average increase due to rapidly developing economies and high rates of population growth. Electricity generation, industry, transportation, and agriculture are the main sectors contributing to GHG emission.

(ii) *Climate change trends and extremes*

A variety of trends have been examined in order to understand the extent of climate change already occurring within the LMB.

Tropical storms show neither an increasing or decreasing trend and are likely to remain constant. However, with rising sea levels the impact of storms might be greater, with a greater extent of damage. Temperature is gradually increasing by about 0.2°C per decade following the global trend. Whilst the number of cold days is expected to decrease, the number of hot days in a year exhibits no clear pattern as yet.

Clear evidence for changes in precipitation patterns have also not been found so far, which aligns with IPCC projections. However, a small increase in annual precipitation might happen after 2050. The extent and severity of flooding remains a critical component of the LMB and needs to be monitored carefully. However, for the last ten years, no clear trend can be seen in the extent of flooding, possibly as a result of increased regulation. In the future, MRC basin-wide assessments of climate impact on flood behaviour suggests that flooded areas might increase by 2060 for floods of all return intervals by betweenf 4,6% and 27.3%. The extent and severity of drought show a more favourable trend, suggesting that drought conditions seem to be reducing slightly, although models are predicting a potential increase of the drought in the future due to rising temperature and changes in rainfall patterns.

An overall judgement regarding the strategic indicator "climate change trends and extremes" is that climate change is happening already in the LMB, markedly in terms of rising temperatures and sea levels, and needs to be high on the agenda of the MRC.

(iii) *Adaptation to climate change*

Adaptation to climate change is defined as the extent to which the basin community is taking action to prepare and live with the effects of climate change. A number of these possible actions have been reviewed.

In terms of institutional response to climate change, all Member Countries have developed policies, strategies and/or plans to respond to climate change and have established both operational and oversight bodies to oversee adaptive actions. Furthermore, all Member Countries have ratified the United Nations Framework Convention on Climate Change (UNFCCC) and have submitted at least two National Communications to the Convention, acknowledging the importance of climate change adaptation and stressing the need for increased research in order to develop and implement effective response measures.

In addition, all four countries have ratified the Kyoto Protocol. At a regional level, in 2018 the MRC released the Mekong Climate Change Adaptation Strategy and Action Plan (MASAP), which provides guidance on climate change mainstreaming and implementation adaptation measures across the LMB.

With regard to physical measures to address climate change, drought protection is provided by irrigation facilities and through storage of water. At present, approximately 36% of land cultivated for rice and maize (the main food grain crops) is provided with irrigation. Water storage in the basin (including in China) is approaching 14% of the mean annual run-off, which is planned to increase to over 20% in the next two decades. Few data are available on the extent of (and investment in) flood protection works, although clearly much work has been done, particularly in the main flood plains.

Disaster management at regional level is provided by MRC through the Regional Flood Management and Mitigation Centre in Phnom Penh. The centre supports Member Countries on Disaster Management throughout the LMB and provides flood forecasting over an area of approximately 43,000 km^2 in Cambodia and Viet Nam where the Basin's highest population densities can be found.

Studies are ongoing to identify the degree of vulnerability of people as well as infrastructure to floods and droughts and other climate change factors within the LMB. Understanding these relationships is a prerequisite to determining the extent of vulnerability to climate change and what to do about it.

On the one hand, therefore, it may be seen that measures such as irrigation, water storage and flood protection have long been practiced in the LMB, whilst the capacity to measure and interpret trends in climate change within the region is still at an early stage. Clearly, each Government has shown its commitment to tackling the issue and the next step is to ensure that spatial and development planning in the LMB fully mainstreaming climate change concerns in a coordinated and consistent manner.

Cooperation dimension

Three strategic indicators have been selected to characterise the economic conditions within the LMB. These are:

- Equity of benefits from the Mekong River system
- Benefits derived from cooperation
- Self-finance of the MRC

(i) *Equity of benefits from the Mekong River system*

The benefits derived from the Mekong River system cover social, economic and environmental dimensions. Thailand and Viet Nam continue to draw the greatest economic benefits, particularly from agriculture and fisheries, including aquaculture, and agriculture. However, Lao PDR is increasing its economic performance from Mekong resources through investment in hydropower and there is some evidence of greater irrigation abstractions and enhancements of capture fisheries in Cambodia.

The environmental benefits are shared across the four countries with increased dry season flows seen in Lao PDR and Thailand more than Cambodia and Viet Nam at this stage. Wetland areas across all countries have declined substantially but could be under greatest ongoing threat in Cambodia and Viet Nam. The decline in sediment transport will affect all countries with likely impacts on fish and agricultural productivity, river and coastal erosion and to some potentially navigation also. The catch per unit effort of fish appears to be in decline in all countries, although more fish and other aquatic resources are being produced through aquaculture especially in Viet Nam.

Social conditions are generally higher in Thailand and Viet Nam due to their greater economic resources, although over recent decades all countries have made considerable progress on indicators of food, water and health security, as well as access to electricity.

(ii) *Benefits derived from cooperation*

A substantial level of cooperation is evident among Member Countries towards the objectives of the 1995 Mekong Agreement. Joint projects cover a range of MRC water-related sectors including in relation to integrated flood plain management, strategic planning and strengthened coordination, and navigation. The PNPCA process is being used by countries to notify the other countries of projects with potential trans-boundary impacts, notwithstanding some misunderstanding of the rights afforded to Member Countries during the process, and the not always satisfactory reconciliation of issues identified even when substantial re-design occurs.

Further measures are needed however to improve the exchange of information and data, improve water use monitoring and to elevate cooperation to a level that includes the joint environmental monitoring effort, joint review of national water related sectors development planning every 5 years and joint overall planning of future strategic development as a means of optimising sustainable development and management of the basin's resources.

(iii) *Self-finance of the MRC*

The MRC appears to be on track to its 2030 objective of self-finance. In each of the past two years, the proportional contribution by Member Countries to the MRC budget has increased and is forecast to continue increasing through to 2020.

State of the Upper Mekong River Basin

As the MRC and LMB stakeholders need to develop and manage the Mekong basin taking into account developments and changes in the Upper Mekong Basin, the State of Basin report includes a description of the situation in the Upper Basin, where the river is known by PR China as the Lancang River. Reviews have been made of those parts of the basin within the territory of both Myanmar and China, referred here to as the UMB-C and UMB-M respectively. The review of the Upper Mekong part is based on MRC data and information as well as official and credible secondary sources from academia and international organizations.

The UMB as a whole covers a total surface area of 186,356 km^2, which corresponds to 23.2% of the entire basin. Over 88% of the UMB lies within China and just 11.6% in Myanmar. On average, the UMB-C contributes approximately 18% of annual Mekong discharge, with an additional 1%-4% coming from Myanmar.

The UMB in China has been rapidly developed over recent years, with land use changes, industrial activities and hydropower construction and operation all affecting the river in various ways. In particular dam development has led to major changes in seasonal flows and sediment loads. Both are noticeable in the Lower Mekong Basin, with the impact on flow regime becoming progressively less visible further downstream. At Chiang Saen, the mostly northerly mainstream monitoring station in the LMB, average dry season flow in 2010-2017 has increased by 35% in comparison with 2000-2009, while flood season flows were reduced by 31%.

The commissioning of the Chinese reservoir cascade has also had a substantial impact on the sediment budget of the river, with clear reductions of 60-70% in sediment concentrations observed directly downstream of the main dams. This, along with sand mining in both the Upper and Lower Mekong mainstream, has its implications across the basin, with total sediment loads at Pakse having fallen by 55% in 2015 compared to historic levels. These reductions in sediments have implications throughout the mainstream up to the delta and coastline, the full consequences of which in the LMB may yet to be seen.

Further alterations of the flow regime are expected over the next decades, as rising temperatures due to climate change are projected to shift the snowmelt contribution to streamflow to earlier months. An additional dam cascade is planned in Xizang (northern part of the Upper Mekong), which will further expand the storage capacity in the UMB in China, although these reservoirs will only impact on a minor part of flow volumes from a basin-wide perspective. Dam development in the lower part of the UMB in China (in Yunnan province) can be considered largely complete, with about 10 dams, including 2 large storage reservoirs. Recent cancellation of the Mengsong Dam is regarded as positive for the maintenance of transboundary fish migration.

The development of storage capacity in the UMB in China has not only significantly altered river dynamics, but also provides an unprecedented opportunity to manage 18% of the overall Mekong flow volume. This illustrates the importance of continuing efforts to strengthen cooperation between China and the lower riparian countries to ensure effective Upper and Lower Mekong basin-wide river basin management, in order to allow for sustainability of all benefits provided by the river.

The UMB in Myanmar is largely undeveloped as a consequence of its remoteness and social and political issues. However, in recent years, rapid land use changes have seen a considerable part of previously natural forests converted to cropland, plantations and mining areas, and hydropower development has also started to take off.

Data availability on environmental indicators is quite limited, although with 4% of Mekong streamflow contributed from Myanmar the impact of UMB-M developments on basin-wide hydrology is small.

The completed and planned development of storage capacity in the UMB has significantly altered river dynamics, but also provides an unprecedented opportunity to manage a substantial part of the overall Mekong flow volume and thereby affect all water-related sectors, particularly in the upper reaches of the LMB.

Conclusions and recommendations

The following sets out the main conclusions that can be drawn from the assessments made in this report in terms of the management and development challenges and opportunities for MRC to achieve its aims.

(i) *Summary of key conclusions on the State of the Basin*

In its new format, this State of the Basin Report follows a structured approach to assessing the current status and past trends of conditions in the Mekong River basin. This approach, which is built on the foundation laid by the newly constructed MRC Indicator Framework, is intended to provide a comprehensive basin-level view of those conditions most relevant to the aims and intent of the MRC in fostering optimal and sustainable development and management of the basin's water-related resources.

The main conclusions that can be drawn from the findings of this report in terms of the management and development status, challenges and opportunities to achieve MRC's aims have been structured around the 13 agreed strategic indicators [2] and the associated key questions (one for each indicator), intended to articulate the underlying issues that each strategic indicator is intended to address. These overall conclusions, which are set out in full in Chapter 9, are summarised in tabular form overleaf. The key messages for each of the five dimensions covered by this report are:

2. The current version of the MRC-IF has a total of 15 strategic indicators. Two of these (Overall Environment Condition and Overall Social Condition) represent the combined evidence of the other strategic indicators within the Environment and Social dimensions, respectively. As a result, specific conclusions and recommendations are not presented separately for these two strategic indicators.

- ***Environmental conditions***: Reservoir developments in the basin have caused a significant change in the flow regime of the Mekong and are contributing to the observed substantial decrease in sediment concentrations. The long-term consequences of these changes need to be managed to minimise environmental harm whilst leveraging the benefits of more secure dry season flows. The loss of wetlands and riverine habitats continues alongside increasing pressures on capture fisheries and urgent actions are needed to protect remaining assets before they are lost.
- ***Social conditions***: Living conditions within the basin are improving, but much better information is needed to identify specific water sector impacts and to determine where vulnerabilities lie.
- ***Economic conditions***: Substantial economic benefits are being derived in water-related sectors, but a comprehensive assessment of equity between countries and trade-offs between sectors is not yet possible with the available data. A pro-active and cooperative approach to basin planning is needed to achieve optimal and sustainable development of the basin in line with MRC's aims.
- ***Climate change***: Both temperature and sea level are rising, but other predicted aspects of climate change are yet to be evident. Member Countries are all engaged in managing climate change and this should be reinforced through MRC's supra-national basin planning efforts.
- ***Cooperation***: New challenges arising from flow regime changes, sediment reductions and growing pressures on environmental assets and fisheries reinforce the need to build upon the existing cooperation through regional planning and joint projects, investments and monitoring.

(ii) *Progress towards achieving relevant SDGs in the Mekong-Lancang Basin*

As noted in this report, the MRC's aims overlap many of the UN's seventeen Sustainable Development Goals (SDG). Whilst SDG 6 (Clean water and sanitation) is seen as the strongest connection, it has been recognised that MRC's policies, strategies and activities have relevance also to Goal 2: Zero hunger; Goal 7: Affordable and clean energy; Goal 13: Climate action; Goal 14: Life below water; and Goal 15: Life on land.

Each of the selected six Goals has associated with it a set of targets and indicators determined by the United Nations. Not all these targets and indicators are directly relevant to MRC. In some cases, data are currently not available either at all or specific to the LMB part of each Member Country, notwithstanding the relevance of the SDG. In some instances, the SDG indicators are simply not covered by the existing MRC-IF and this SOBR.

Nevertheless, wherever possible a review on the current status of these indicators is provided in Section 9.2.7 of this report. The key points arising from this review are summarised below.

Summary of conclusions and challenges and recommended priority actions

🟢 *No immediate concerns* 🟡 *Some significant concerns to address* 🔴 *Considerable concern, urgent action needed* ○ *Insufficient data to form a view, requires action to address knowledge gaps*

Strategic indicators	Key strategic questions		Status /condition	Challenges	Recommended priority actions	BDS Recommendation
Environment						
Water flow conditions in mainstream	*Are the conditions of water flow in the Mekong mainstream acceptable?*	🟡	Generally compliant with PMFM, but induced changes in flow regime are of some concern	Managing the impacts of an apparent decrease of wet season flow during the recession period, the increase in dry season low flows and the increase in daily fluctuation in flows experienced in some reaches of the mainstream.	Continue monitoring programmes and, in addition to PMFM reporting, monitor decreases in wet season flows and daily fluctuations and consider implications of impacts that may arise,	A
					Improve monitoring of water use for various sectors to ensure balance is maintained with increased development	B
Water quality and sediment conditions	*Are the conditions of water quality and sediment acceptable?*	🔴	Generally compliant with PWQ, but sediment concentrations much reduced	Identifying and implementing practical measures to mitigate the effects of reduced sediment concentrations and minimise further reductions	Continue the sediment and water quality monitoring programmes.	A
					Address the implications of reduced sediment concentrations through mechanisms to better manage sediment flows and mitigate transboundary impacts of reduced concentrations	B
Status of environmental assets	*Are key environmental assets in the Mekong basin being adequately preserved and protected?*	🔴	Loss of wetlands and riverine habitats continues, pressure on capture fisheries becoming evident	Taking urgent action to protect remaining assets and to better manage fisheries	Agree clear regional objectives, joint strategies and action plans for protecting and sustainably managing the remaining environmental assets and fisheries.	A
				Addressing the lack of sufficient data on wetland and riverine habits	Establish regular monitoring and data collection to address knowledge gaps and conservation activities for wetlands and other environmental assets including fisheries.	B
Social						
Living conditions and well-being	*What social benefits, direct and indirect, are being derived from water resource developments in the Mekong basin?*	🟡	Living conditions improving but water sector impacts unclear	Provincial and district levels data needed to better understand relationship with water-related sectors alongside greater consistency of data quality and accuracy.	Review and refinement of indicators and develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Insufficient data to form a view, requires action to address knowledge gaps*

Strategic indicators	Key strategic questions	Status /condition	Challenges	Recommended priority actions	BDS Recommendation
Employment in MRC water-related sectors	*How are the river-related livelihoods in each country being affected by land and water management decisions?*	○ *More information is needed to form a view*	*As above*	*As above*	*B*
Economic					
Aggregate economic value of MRC water-related sectors	*What economic value does each Member Country derive from the use of the Mekong river system within the water-related sectors?*	○ *More information is needed to form a view*	Comprehensive data on all water-related sectors need to be assembled and analysed. Promotion of economic development consistent with the aims of the 1995 Mekong Agreement.	Review and refinement of indicators and develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps. Adoption of pro-active regional planning to promote optimal and *equitable* development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims	B E
Contribution to basin economy	How important is the economic value of the water-related sectors to the economy of the basin?	○ *More information is needed to form a view*	*As above*	*As above*	B/E
Climate change					
Greenhouse gas emissions	*To what extent is the Mekong Basin contributing to global GHG emissions?*	● LMB countries (as a whole) emission is about 1.5% of global total	Promote development practices within the basin that minimise GHG emissions consistent with each country's Nationally Determined Contribution under the Paris Agreement	Promotion of development practices that minimise GHG emission. Develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	E B

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Insufficient data to form a view, requires action to address knowledge gaps*

Strategic indicators	Key strategic questions		Status /condition	Challenges	Recommended priority actions	BDS Recommendation
Climate change trends and extremes	*Is there evidence of climate change within the basin?*	●	Some evidence of rising temperatures and sea-levels. Flood damages are also higher. Other CC impacts are not seen.	Continued monitoring needed Continued assessment of potential future CC impacts based on latest available global and regional forecasts	Incorporate sea level rise as an indicator in future SOBR. Continue hydro-meteorological data collection programmes.	B A
Adaptation to climate change	*How resilient are the current water infrastructure and plans to climate change?*	●	All countries have policies and strategies in place and 166 climate adaptation projects identified (2016)	To ensure that climate change is fully factored into development plans and that resilience is assured	Adoption of pro-active regional planning to address climate change and promote optimal and equitable development through increased cooperation	E
Cooperation						
Equity of benefits from the Mekong River system	*How well is Mekong basin development moving towards optimal and sustainable development?*	○	Significant development in all countries, *but equity considerations need more data as above*	Adoption of pro-active regional planning to promote equitable use of basin's resources, together with establishment of a clear mechanism to define equity of benefit and trade-off arising from development in throughout the basin in water-related sectors	Adoption of pro-active regional planning to address climate change, promote optimal and equitable development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims	E
Benefits derived from cooperation	*What is the added value of cooperation under the 1995 Mekong Agreement facilitated by MRC?*	●	US$838m of projects supporting cooperation identified in National Indicative Plans	*As above*	*As above*	E
Self-finance of the MRC	*Is the MRC on-track to self-finance by 2030?*	●	MRC budgets in line with achieving self-finance by 2030, alongside renewed commitments to this end	Retain focus on core function activities and look to ways to improve efficiency in delivering these	Identify smart and cost-effective approaches to basin monitoring and information and knowledge sharing	B

Note: BDS recommendations A – E are elaborated in Section 9.3.2

SDG2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Evidence points to the adequacy of Dietary Energy Supply nationally in 2016 in all four countries. Undernourishment, wasting and severe wasting have declined too, although there are evidently areas still to address. Drought resilience has improved with the expansion of irrigation coverage.

SDG6 Ensure availability and sustainable management of water and sanitation for all

As noted above, this SDG is the most relevant to the interests and activities of the MRC. Access to safe water supplies and sanitation is improving within the LMB and already widespread in many areas. Water quality remains generally good for both human and ecological purposes. Despite significant reported increases in irrigation coverage, mainstream flows continue to be within acceptable limits. MRC has policy, procedures and strategic guidelines in place covering entire LMB for equitable and sustainable use of Mekong water resources. The one major concern is the decline in wetland areas, deforestation and threats to eco-systems.

SDG7 Ensure access to affordable, reliable, sustainable and modern energy for all

In 2016 nationally, 100% of households in Viet Nam and Thailand had access to electricity and 87% of the total population and 80% of the rural population had access in Lao PDR. Cambodia reports overall access at 58% in 2016 rising to 72% in 2018. No data are available for the LMB by energy source.

SDG13 Take urgent action to combat climate change and its impacts

All four Member Countries have ratified UN Framework Convention on Climate Change and Kyoto Protocol. All also have relevant adaptation policies, strategies and institutional arrangements in place. Current National Indicative Plans for 2016-20 identify US$ 827million of projects directed towards realising the sustainable potential of the LMB taking into account climate change.

SDG14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development

Whilst MRC's mandate does not extend to use of oceans, it is evident that the reductions in sediment and nutrient flows in the mainstream are likely to impact upon coastal fisheries. It is also seen that shoreline protection is threatened with the reduction in mangrove areas. However, none of the SDG14 indicators are actually covered by the indicators reported upon in this SOBR.

SDG15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

At a policy level, all four Member Countries have committed, inter alia, under the 1995 Mekong Agreement, to "utilize the waters of the Mekong River system in a reasonable and equitable manner" and have established procedures and cooperative planning and monitoring systems to fulfil this commitment. Throughout the LMB 255 protected areas have been established covering 27% of the LMB. However, wetland areas and forestry have declined considerably over the last 50-100 years. Pressures are increasing on capture fisheries and remaining environmental assets, and urgent action is needed to address these issues.

MRC will need to consider further how best support Member Countries in monitoring progress toward the SDG for future editions of the SOBR.

(iii) *Recommendations for updating the Basin Development Strategy*

In accordance with MRC's strategic 5-year planning cycle, the State of the Basin Report seeks to inform and help shape the updating of the MRC's Basin Development Strategy (BDS).

The BDS is a high-level document which identifies the key issues faced in developing and managing the water and related resources of the LMB and sets out a strategy by which the Member Countries agree to address these issues

and promote optimal and sustainable development of the basin in line with the aims and intent of the 1995 Mekong Agreement. The BDS provides the rationale for and is implemented primarily through the MRC's Strategic Plan at regional level and through four National Indicative Plans.

Based on the conclusions presented in this report, the following six recommendations are made for consideration when updating the Basin Development Strategy.

Recommendation (A): Continue and enhance monitoring of flow conditions and water quality

With increasing development in the basin and the onset of climate change impacts, the need for hydro-meteorological, flow, water quality and sediment monitoring is of ever more importance. Changes in flow regime noted in this report may lead to undesirable impacts on both environmental assets and riverine communities as well as to opening the potential for increased irrigation abstractions, and need to be observed carefully. These monitoring programmes are designated as core functions of the MRC and it is recommended that they should remain so with sufficient budgets and resources allocated as needed.

Recommendation (B): Develop and implement a MRC Data Acquisition and Generation Action Plan

Preparation of this State of Basin Report and of the recent Council Study as well as other MRC projects and studies and the implementation of MRC Procedures and Guidelines have all been constrained by the availability of data. Comprehensive programmes to monitor environmental assets (including fisheries), water use, agriculture, land use, socio-economic and macro-economic aspects and some aspects of development infrastructure, including hydropower and flood control projects, are needed to fill these gaps.

Given that the costs of implementing the required monitoring programmes need to be kept to a reasonable minimum as the MRC move towards self-finance, smart ways of basin monitoring need to be considered for which some studies and surveys may be needed to accredit new methodologies. As above, MRC data acquisition and generation action plan and data storage and management must be seen as a priority core river basin management function across all MRCS Divisions, with responsibilities at regional and national levels set out and appropriate investment included in MRC annual budget plans.

Recommendation (C): Address the problem of reduced sediment concentrations

Sediment concentrations in the mainstream are observed to be much reduced largely as a consequence of reservoir sediment trapping. The consequences in the short, medium and long term of diminished sediment concentrations on the river's morphology, bank stability, flood plain productivity, delta building processes and the productivity of coastal waters need to be fully understood in order that agreement can be reached on a sediment management plan on how best to manage sediments within the system and to mitigate the transboundary impacts of reduced concentrations.

Recommendation (D): Address the need to take urgent action to preserve and protect remaining environmental assets

Whilst there are clearly many environmental issues potentially to deal with, this report highlights two key transboundary issues that are believed to be central to future plans for the LMB. These are:

- **Wetlands and key river habitats**: This report highlights the enormous historic loss of wetlands in the Mekong Basin, which is continuing unabated today, jeopardising the long-term health of the basin's eco-system. A shared appreciation of the pressures on wetlands and river habitats from alternative land uses, changing flow regimes and climate change is needed as a first step towards identifying and prioritizing areas that may be brought under protection and the necessary trade-offs that this may involve. Thereafter the MRC should facilitate agreement on basin-wide objectives, joint strategies and action plans for protecting and sustainably managing the remaining environmental assets.
- **Fisheries productivity**: Whilst overall production of capture fisheries appears not to be falling, this report highlights the growing pressures arising not only from human-induced changes to the river systems, but also from changes in fisheries practices. A comprehensive understanding is needed of how fisheries may change in

the future with and without further habitat changes, with and without regulation of capture fisheries practices and with future changes in consumption patterns in the light of socio-economic development. Building such an understanding is critical to jointly implement the currently approved strategies (Basin-wide Fisheries Management Strategy, BFMS) with Member Countries and relevant stakeholders to support and maintain the sector in the future.

Recommendation (E): Adopt a more proactive approach to basin planning and the management of trade-offs between sectors and countries

This report highlights the new opportunities and threats arising from changes in flow regime of the mainstream, sediment flows and climate change. The report also demonstrates the Member Countries' willingness to increase cooperation through joint projects and an increased focus on those of basin-wide significance. Given the Member Countries' commitment to optimal and sustainable development, a more proactive stance to basin planning is required as mandated by Art. 24 of the Mekong Agreement. Such an approach would allow the MRC, working as it does with all Member Countries and significant stakeholders, to create platforms to discuss benefit sharing and trade-off between national development plans and thereby to determine the best ways by which to develop the basin given the current circumstances and the legitimate aims and concerns of each Member Country.

The results of this new approach would enable the "Development Opportunities" section of the BDS to proactively provide strategic guidance to national planning for the basin across all water-related sectors in line with the aims of the 1995 Mekong Agreement (see overleaf).

Therefore, it is recommended that the adoption of a more proactive approach to basin planning and management of trade-offs by creating of various platforms for enhancing the discussion and negotiation about the better basin planning including enhancing the benefit sharing among Member Countries and sectors and management of trade-off between sectors and countries are required.

Potential development opportunities

Category	Opportunities*
Environmental management	To **preserve and leverage the remaining wetlands** and regionally significant environmental assets, including **riverine habitats**, for both ecological purposes and enhancing bio-diversity, including **fish** and **other aquatic organisms**, and to extend and promote greater tourism income.
	To continue to invest in **rehabilitation and improvement of forest areas** to better manage catchments, enhance the lifetime of storage reservoirs and contribute to reducing GHG.
	To implement **measures for managing mainstream and tributary floods** in a manner sensitive to environmental needs and climate change (including sea level rise), recognising the ecological benefits of floods as well as the rising cost of flood damage as a result of changing use and value of flood plains prompted by growing economies and expansion of urban and industrial centres.
Economic development	Further **develop hydropower** to promote regional energy security and cross-border trade and contribute to great security in dry season water availability.
	Increase abstractions for irrigation (whilst taking steps to improve irrigation efficiencies) to address and target drought protection, household food and water security needs and the economic value of the basin's resources.
	Improve inland water transport (navigation) by taking advantage of greater water depths in the dry season throughout the mainstream and in some tributaries.

Note: (*) It is important to be mindful of the potential downsides of development opportunities, the need to carefully consider trade-offs and the potential consequences of climate change.

Recommendation (F): Maintain and strengthen cooperation with Dialogue Partners and other stakeholders

The MRC has long-recognised the importance of maintaining active dialogue with its upstream riparian neighbours. As with managing interplay of competing demands and development impacts within the LMB, so too must the MRC appreciate the development aspirations and challenges of its upstream neighbours in order to arrive at good outcomes that satisfy both upstream and downstream needs.

Given the range of short- and long-term issues identified in this report, it is recommended that cooperation with the Dialogue Partners is not only maintained but also further strengthened through the exchange of data and technical ideas and resources.

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Abbreviations and acronyms

AAGR	Average annual growth rate
ACMECS	Ayeyarwady-Chao Phraya-Mekong Economic Cooperation Strategy
ADB	Asian Development Bank
AGGI	Annual Greenhouse Gas Index
AMFR	Annual Mekong Flood Report (of the MRC)
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
ARI	Annual Recurrent Interval
Art.	Article (of the MRC Agreement)
ASEAN	Association of South-East Asian Nations
ATSPT	Average Tolerance Score Per Taxon
BDS	Basin Development Strategy (of the MRC)
CAIT	Climate Data Explorer website of World Resources Institute, Washington DC
CBD	Convention on Biological Diversity
CC	Canopy cover (density)
CCI	Climate Change Initiative (of ESA)
CCAI	Climate Change and Adaptation Initiative (of the MRC)
CDI	Combined Drought Index
CDM	Clean Development Mechanism
CH_4	Methane
CHIRPS	Compressed High Intensity Radar Pulse
CLMV	Cambodia-Laos-Myanmar-Vietnam cooperation initiative
CO_2	Carbon dioxide
CO2e	Carbon dioxide equivalent
COD	Chemical Oxygen Demand
CPI	Consumer Price Index
CS	Council Study (of MRC, aka: Study on Sustainable Management and Development of the Mekong River including Impacts of Mainstream Hydropower Projects)
CSO	Central Statistical Organisation (of Myanmar)
DSMP	Discharge Sediment Monitoring Project (of the MRC)
EAC	Electricity Authority of Cambodia
ECAF	Economic Commission for Asia and the Far East of the United Nations (now ESCAP)
EHM	Ecological Health Monitoring Programme (of the MRC)
EIA	Environmental impact assessment
EPA	US Environmental Protection Agency
EU	European Union
ESA	European Space Agency
ESCAP	Economic and Social Commission for Asia and the Pacific (of the United Nations)
FADMP	Fish Abundance and Diversity Monitoring Programme (of the MRC)
FAO	Food and Agriculture Organisation (of the United Nations)
FAOSTAT	Official statistics database of FAO
FGD	Focus Group Discussion
fRNB	Fraction of non-renewable biomass
g	Gramme

GERES	German Environmental Survey (of German Environment Agency)
GDP	Gross Domestic Product
GHG	Greenhouse gas
GHI	Global Hunger Index
GMS	Greater Mekong Sub-region (of the ADB)
GPI	Gender Parity Index
GPCC	Global Precipitation Climatology Centre
GWh	Giga Watt Hour
ha	hectare
HCMC	Ho Chi Minh City, Viet Nam
Hg	Mercury
IFC	International Finance Corporation (of the World Bank)
IHLCA	Integrated Household Living Conditions Assessment (by UNDP)
ILO	International Labour Organisation (of the United Nations)
IPCC	International Panel on Climate Change
IPCC-AR5-SPM:	IPCC Fifth Assessment Report, Summary for Policy Makers
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
IWT	Inland waterway transport
JCCCN	Joint Committee on Coordination of Commercial Navigation on the Mekong
JMA	Japanese Meteorological Agency
Kg	Kilogramme
km	kilometre
kwh	kilowatt hour
Lakh	100,000
LARReC	Living Aquatic Resources Research Centre
LCOE	Levelised Cost of Electricity
LDC	Least Developed Countries
LMB	Lower Mekong Basin
LMWRCC	Lancang Mekong Water Resources Cooperation Center
LNDO	Lahu National Development Organization (Thailand)
LUCF	Land use change and forestry
m	metre
MEA	Millennium Ecosystem Assessment
mg/l	Milligrams per litre
MASAP	Mekong Climate Change Adaptation Strategy and Action Plan (of the MRC)
MCM	Million cubic metres
Mha	Million hectares
MIMU	Myanmar Information Management Unit (of the United Nations)
MLC	Mekong Lancang Cooperation
MLDP	Development Plan of International Navigation on the Mekong-Lancang River
Mm3	Million cubic metres
MNPED	Ministry of National Planning and Economic Development (Myanmar)
MODIS	Moderate Resolution Imaging Spectrometer (of NASA)
MoEE	Ministry of Electricity and Energy, Myanmar

MONRE	Ministry of Natural Resources and Environment
MPN	Most probable number
MRC	Mekong River Commission
MRCS	Secretariat of the Mekong River Commission
MRC-IF	MRC Indicator Framework
MRC-IS	MRC Information System
MRC-WUMS	MRC Water Use Monitoring System
mS/m	Millisiemens per metre
Mt/yr	Million tonnes per year
MW	Mega Watt
MWh	Mega Watt Hour
NAPA	National Adaptation Programme of Actions (under UNFCCC)
NASA	National Aeronautics and Space Administration (of the United States)
NBS	National Bureau of Statistics (of PR China)
NEMC	National Energy Management Committee (of Myanmar)
NIP	National Indicative Plan (of the MRC's member countries)
NGO	Non-governmental organisation
NMC	National Mekong Committee
NOAA	US National Oceanic and Atmospheric Administration
NTFP	Non-timber forest products
OAAs	Other aquatic animals
OAPs	Other aquatic plants
OECD	Organisation for Economic Cooperation and Development
PA	Protected area
Pb	Lead
PDIES	Procedures for Data and Information Exchange and Sharing (of the MRC)
PDG	Preliminary Design Guidance (of the MRC)
pH	Logarithmic scale of the acidity or basicity of an aqueous solution
PMFM	Procedures for the Maintenance of Flows on the Mainstream (of the MRC)
PNPCA	Procedures for the Notification, Prior Consultation and Agreement (of the MRC)
PWQ	Procedures for Water Quality (of the MRC)
PWUM	Procedures for Water Use Monitoring (of the MRC)
RFMMC	Regional Flood Management and Mitigation Centre (hosted by MRC)
SDG	Sustainable Development Goals (of the United Nations)
SID	Special Improvement District
SIMVA	Social Impact monitoring and vulnerability assessment (of the MRC)
SMDI	Soil Moisture Deficit Index
SOBR	State of the Basin Report (of the MRC)
SPI	Social Progress Indicator
SPI	Standardised Precipitation Index
SRI	Standardised Runoff Index
TACT	Technical Assistance and Coordination Team (of the MRC)
TbEIA	Transboundary Environmental Impact Assessment
TEU	Twenty-foot equivalent unit
TPR	Three Parallel Rivers (of Yunnan Province, PR China)

TRMM	Tropical Rainfall Measuring Mission (joint mission of NASA and Japan Aerospace Exploration Agency)
UMB	Upper Mekong Basin
UMB-C	Portion of Upper Mekong Basin in China
UMB-M	Portion of Upper Mekong Basin in Myanmar
UN	United Nations
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNODC	United Nations Office on Drugs and Crime
US	United States
US$	United States dollar
WB	World Bank
WFP	World Food Programme
WCMC	World Conservation Monitoring Centre (of the United Nations)
WQMN	Water Quality Monitoring Network (of the MRC)
WTTC	World Travel and Tourism Council
WWF	World Wildlife Fund

1. Introduction

1.1 Purpose and scope of this report

The MRC State of the Basin report (SOBR) aims to provide an overall picture of the state of the Mekong Basin in terms of its ecological health, the social and economic circumstances of its people and the degree to which the cooperation between riparian countries envisaged under the 1995 Mekong Agreement[3] is enhancing these conditions.

In accordance with the MRC's Basin Development Strategy 2016-2020, the SOBR forms an integral part of the MRC's strategic planning cycle, which normally covers a five-year period (see Box 1 overleaf). In this role, the SOBR is intended to reflect on the aims and commitments of the 1995 Mekong Agreement, to determine progress towards achieving these aims and to identify issues that the Member Countries need to consider when updating the Basin Development Strategy for the next planning cycle.

In this regard, the SOBR is intended to provide (to the extent that data are available) a statement of past trends and current conditions within the basin, which will be updated and compared at five yearly intervals to track changes brought about by the cooperation envisaged under the Mekong Agreement. The SOBR also seeks to highlight significant issues as well as apparent development opportunities that the Member Countries may wish to take up. Further studies, such as future scenario assessments as were undertaken in 2010 and more recently under the Council Study, are likely to be needed thereafter to determine the best way by which to address the issues and opportunities raised in the SOBR.

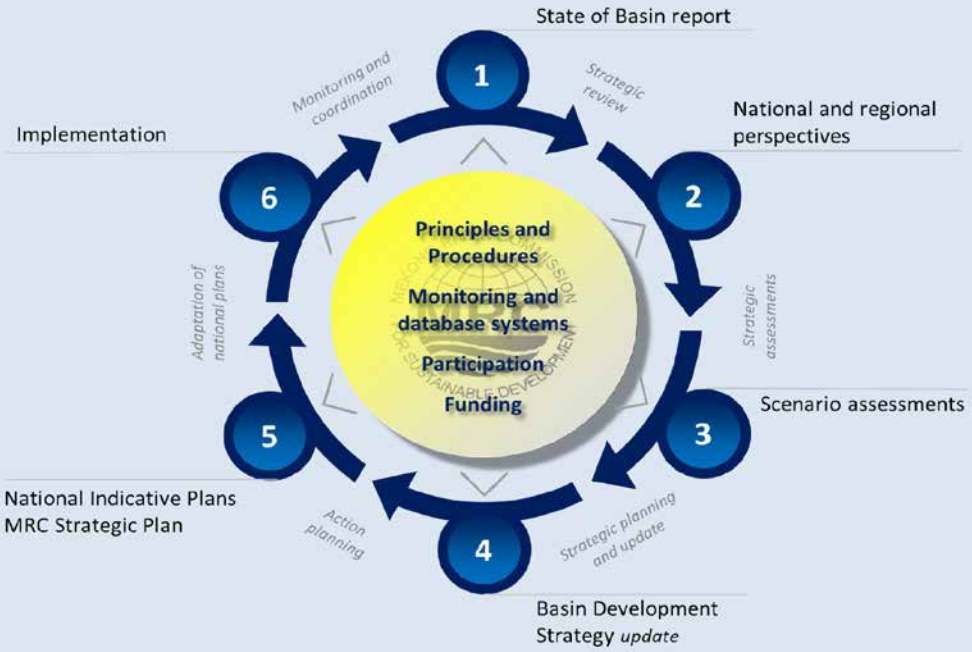
In contrast to earlier versions of the SOBR covering the Lower Mekong Basin (LMB) and published in 2003 and 2010, this SOBR introduces two new features. Firstly, this report is structured around the newly prepared MRC Indicator Framework with the intent that this framework will provide a consistent and comprehensive approach to both reporting of strategically relevant conditions within the basin and to the assessment of alternative future development scenarios in the lead up to updating the Basin Development Strategy. Secondly, for the first time this report also incorporates chapters on the conditions within the Upper Mekong Basin (UMB) to better understand the dynamics of change that are occurring within the basin.

In summary, this report summarizes the broader developments in the Mekong region and tracks and evaluates the trends in the values of the indicators and monitoring parameters of the MRC Indicator Framework. It is a technical report that can be used for a range of general and specific purposes:

- To inform a broad audience on the social, environmental and economic status and trends in the Mekong Basin;
- To record and evaluate the development impacts, positive and negative, within the Mekong Basin as a measure of the effectiveness of the implementation of the Basin Development Strategy;
- To highlight the development opportunities and issues arising, which could be explored through scenario assessment or need to be addressed in the next update of the Basin Development Strategy;
- To provide decision makers with concise and relevant information on the issues they consider relevant in determining the benefits and impacts derived from basin- wide cooperation; and
- To provide relevant information on how well MRC achieves its vision of "an economically prosperous, socially just and environmentally sound Mekong River Basin".

3 The Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin, signed by the Governments of The Kingdom of Cambodia, The Lao People's Democratic Republic, The Kingdom of Thailand, and The Socialist Republic of Viet Nam on 5 April 1995 at Chiang Rai, Thailand

Box 1: The MRC planning cycle



The MRC's planning cycle has been evolved over time to meet the organisation's needs as reflected in the various commitments in the 1995 Mekong Agreement, inter alia, to promote optimal and sustainable development equitably within the basin. The six main steps in the cycle are:

- The State of Basin Report (SOBR) reviews the impacts of past and current developments on conditions within the basin. The SOBR is structured around the five dimensions of the MRC Indicator Framework to ensure a comprehensive approach is adopted, the results of which can be periodically updated to measure change. The SOBR highlights the important issues relevant to the MRC achieving its long term aims and objectives.
- National and regional perspectives of the SOBR findings are then invited from Member Countries and other concerned stakeholders with a view to establishing whether changes are needed to the Basin Development Strategy, particularly with regard to the near-term focus of cooperative actions deemed necessary.
- Scenario assessments are conducted as needed to investigate the impacts of alternative future development pathways to determine the most efficacious approach to addressing both the immediate concerns above and to promote long-term optimal and sustainable development. Scenarios are assessed using the same indicators as the SOBR as set out in the MRC indicator framework.
- Drawing on the national and regional perspectives and the findings of any scenario assessments undertaken, the MRC then updates its Basin Development Strategy (BDS) for the purposes of guiding basin-level development and management activities. The BDS establishes broad responsibilities and timelines for management activities and looks to promote projects and programmes that will lead to enhancement of conditions within the basin.
- National Indicative Plans and the MRC Strategic Plan covering the ensuing five years are then drawn up to promote effective implementation of the BDS. The former identifies and promotes specific projects and activities at the national level. The latter sets the agenda for at the regional level for the MRC (to a large part specific to the MRCS), including steps to build cooperation and joint activities with upstream dialogue partners and with other relevant regional bodies.
- MRC has a responsibility to monitor the implementation of these plans and the consequential impacts of these on conditions within the basin. The results of these monitoring programmes then feed into the next State of Basin Report.

By adopting an evidence-based approach using indicators founded on quantifiable monitoring parameters, the SOBR is intended to promote and inform discussion between all stakeholders in the Basin including, but not limited to, a number of key strategic questions as illustrated in Box 2 below. The findings of this report, presented in Chapter 9, are built around answering these 13 important questions.

Box 2: Key strategic questions underpinning the MRC Indicator Framework

Environment	❑ Are the conditions of water flow in the Mekong mainstream acceptable? ❑ Are the conditions of water quality and sediment conditions acceptable? ❑ Are key environmental assets in the Mekong basin being adequately preserved and protected?
Social	❑ What social benefits, direct and indirect, are being derived from water resource developments in the Mekong basin? ❑ How are the river-related livelihoods in each country being affected by land and water management decisions?
Economic	❑ What economic value does each Member Country derive from the use of the Mekong river system within the water-related sectors? ❑ How important is the economic value of the water-related sectors to the economy of the basin?
Climate change	❑ To what extent is the Mekong Basin contributing to global GHG emissions? ❑ Is there evidence of climate change within the basin? ❑ How resilient are the current water infrastructure and plans to climate change?
Cooperation	❑ How well is Mekong basin development moving towards optimal and sustainable development? ❑ What is the added value of cooperation under the 1995 Mekong Agreement facilitated by MRC? ❑ Is the MRC on-track to self-finance by 2030?

1.2 Structure of this report

The approach and methodology underpinning the SOBR is described in the remainder of this Chapter 1, including an overview of the MRC Indicator Framework.

Chapter 2 introduces the Mekong Basin and describes the development context within which the remainder of the report is set.

In Chapters 3 to 7, the status and trends of selected water-related indicators in the environment, social, economic, climate change, and cooperation dimensions are described.

Chapter 8 provide a picture of conditions within the Lancang River Basin (UMB) in Myanmar and PR China respectively.

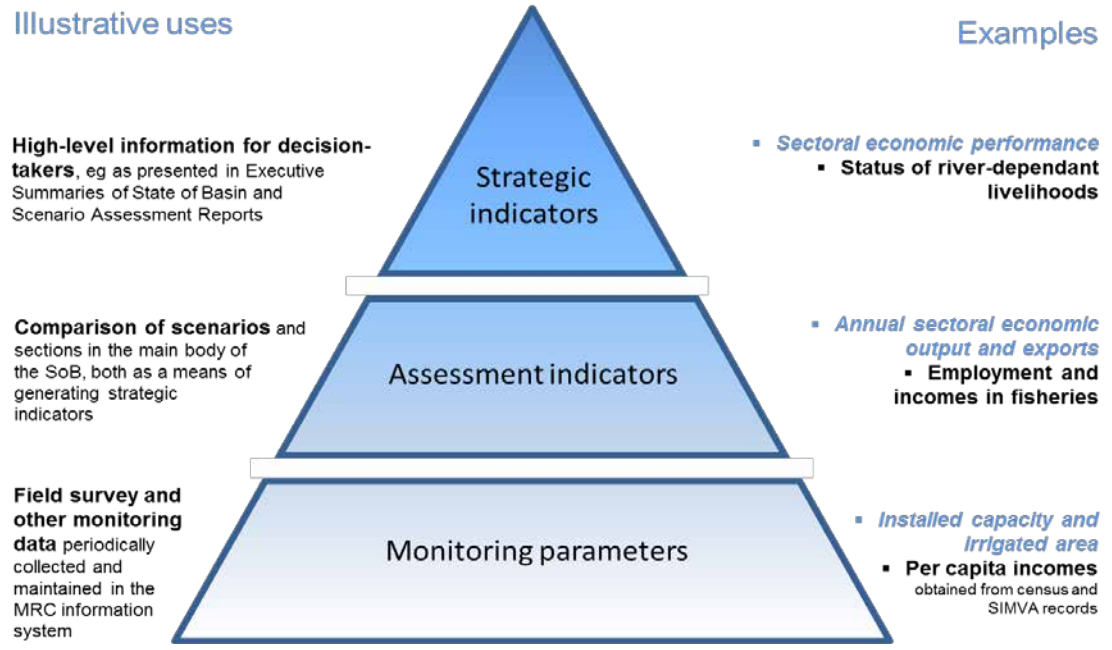
Chapter 9 draws together conclusions on the state of the basin, reflects on the impact these have on the UN's Sustainable Development Goals (SDGs) and makes recommendations for consideration in updating the Basin Development Strategy for the period 2021-2025.

1.3 Approach and methodology employed

1.3.1 The MRC Indicator Framework

In 2014-2015, MRCS under the coordination of BDP developed a common indicator framework for monitoring, assessment and reporting on the state of the basin, called 'the MRC Indicator Framework'. The framework comprises a hierarchy of water related strategic and assessment indicators supported by monitoring parameters (Figure 1.1).

Figure 1.1 Illustration of a hierarchy of indicators



At the highest level, 15 draft strategic indicators are selected to provide policy level decision makers with a concise set of information relating to the development and management conditions within the basin. The strategic indicators are set within the dimensions of social, environmental, economic, climate change and cooperation issues to provide a full and integrated picture of how the cooperation between countries through the MRC is benefiting and impacting upon the basin and each country.

At the second level, 55 assessment indicators were selected to provide more detailed information and to support the quantification of the strategic indicators. Assessment indicators will also provide the basis for comparing development scenarios.

At the lowest level, approximately **160 monitoring parameters were identified** to support the quantification of the assessment and strategic indicators for this SOBR. Each monitoring parameter is derived from an identified set of monitoring data according to a prescribed methodology. Most of monitoring data are those already collected by each Member Country.

It is emphasised that the MRC Indicator Framework is prepared for applications at the basin-wide scale. For other applications at sub-basin or local scales, a somewhat different set of indicators and supporting monitoring parameters will likely be needed. MRC has undertaken several studies in the past to identify more detailed data requirements for monitoring specific issues of interest to Member Countries. A case in point is the recent MRC report on "the development of indicators for wetland health and function in the Lower Mekong Basin: tools for assessment, management and monitoring" (August 2015).

The MRC Indicator Framework will support basin development and management over the long-term. The consistent use of a similar indicator framework for each subsequent SOBR will greatly improve the possibilities to evaluate long-term trends in basin conditions. Such evaluations will facilitate the identification of key opportunities and issues that scenario assessments should explore and that the Basin Development Strategy should address.

1.3.2 Assessment approach and methodology

Each of the technical chapters 3 – 7 cover a single dimension of the MRC Indicator Framework and are structured in a consistent manner demonstrating the approach and methodology used in compiling the report on that dimension, as described below.

- ***Introduction to the dimension*** – Describes the relevance of the dimension to the 1995 Mekong Agreement and setting out the assessment framework within that dimension.
- ***Each strategic indicator*** – For each strategic indicator within the dimension, a brief description is provided of how that strategic indicator is to be evaluated based on the findings for each related assessment indicator. The section then works through the evaluation of each assessment indicator and concludes with an evaluation of the strategic indicator, based on the foregoing, including a commentary on differences between countries.
- ***Each assessment indicator*** – For each assessment indicator within each strategic indicator above, the sub-section starts with a description of the methodology used for evaluation of each assessment indicator, then reports on the status of each monitoring parameter and lastly sets out the evaluation of each assessment indicator based on these.
- ***Overall conditions in the basin*** – Finally in each technical chapter, an assessment is made of the overall conditions within the basin by reference to the assessment of each strategic indicator within the dimension and any differences between countries. Where indicators suggest conditions merit highlighting, these will be set out with a commentary tracing the cause of these conditions back through assessment indicators to the monitoring parameters triggering the cause. Where appropriate, these "causes" may be elaborated (for instance, by mapping a monitoring parameter) so that readers understand where and why they are arising.

1.4 Relevance of UN Sustainable Development Goals (SDG)

The Sustainable Development Goals (SDGs) are a collection of 17 global goals set by the United Nations in 2015. The goals were developed to succeed the Millennium Development Goals (MDGs) which ended in 2015. Unlike the MDGs, the SDG framework does not distinguish between "developed" and "developing" nations. Instead, the goals apply to all countries.

The goals are broad and somewhat interdependent, yet each has a separate list of targets to achieve. Achieving all 169 targets would signal accomplishing all 17 goals. The SDGs cover social and economic development issues including poverty, hunger, health, education, climate change, gender equality, water, sanitation, energy, urbanization, environment and social justice (see Figure 1.2) [4].

4 Press release – UN General Assembly's Open Working Group proposes sustainable development goals (PDF). Sustainabledevelopment.un.org. 19 July 2014. Retrieved for Wikipedia 2016-10-18.

Figure 1.2 UN Sustainable Development Goals

The aims and intentions of the MRC were established in 1995 under the Mekong Agreement, some 20 years before the SDGs were formulated. Nevertheless, it is evident that as a central player in the development and management of the water and related resources within the Mekong Basin, the MRC's aims overlap many of the UN's SDGs.

This was reconfirmed at a two-day MRC International Conference, held in April 2018, where the relevance of the MRC's work and activities, within the framework of its objectives set out in the 1995 Mekong Agreement, was seen as comprehensive for achieving sustainable development. Furthermore, the delegates at that conference noted that SDG 6 (Clean water and sanitation) is connected to all 17 SDGs, and particularly to SDGs on gender, hunger, inequality, energy, environment, climate change, infrastructure, peace and institutions, and partnerships[5] .

At a subsequent meeting of MRC's Expert Group on Environmental Management (EGEM) in December 2018, it was determined that the primary linkages to the SDGs are to; (i) Goal 6: Clean water and sanitation; (ii) Goal 2: Zero hunger; (iii) Goal 7: Affordable and clean energy; (iv) Goal 13: Climate action; (v) Goal 14: Life below water; and (vi) Goal 15: Life on land.

The findings of this report endeavour to set out in Section 9.2.7 illustrate the current status of the stipulated indicators for each of these six Sustainable Development Goals, to the extent that data relevant to the LMB are currently available within MRC.

5 Short Report by the Chief Executive Officer of the MRC Secretariat, Pham Tuan Phan, on the outcomes and key messages of the International Conference http://www.mrcmekong.org/assets/Uploads/Report-on-outcomes-and-messages-of-IC-by-MRCS-CEO-at-Ministerial-Meeting2.pdf

2. Setting and context

2.1 Overview of the Mekong Basin

2.1.1 Development setting

The Mekong River rises in the Himalayas in PR China at an elevation of about 5,000m, where it is known as the Lancang River. It is the world's 12th longest river, flowing for almost 4,763 km through Myanmar, Lao PDR, Thailand and Cambodia into the East Sea (referred to also as the South China Sea) in Viet Nam. It has the world's 8th largest flow, with a mean annual discharge of approximately 446 km^3, and its basin is the world's 21st largest by area, draining 810,000 km^2.

As one of the great rivers of the world, the Mekong River is closely linked with the culture and development of the countries through which it flows. For millennia, the river's abundant resources have nurtured a unique and rich ecosystem as well as sustained the livelihoods of those living in the basin.

Development of water resources within the basin can be traced back to irrigation schemes constructed around Angkor Wat in the 12th century. Although it is believed that these systems started to fall into disuse by the 14th century, they and the temple complex itself bear testament to the ingenuity of these early engineers.

However, it is only in the last 125 years that significant changes to the landscape of the basin have occurred. Viet Nam began investing a century ago in improvements to navigation and drainage in the fertile areas of the Mekong delta. Since the late 1960s, significant national benefits have been created when large areas were brought under irrigation by farmer-owned low-lift pumps and the land has become amongst the most productive areas in the world with double-and even triple-cropping of rice, a wide range of tropical fruits, and extensive shrimp cultivation. Hydropower development also took place in the central highlands, where Viet Nam is an upper riparian.

In Thailand's part of the basin, development also took off in the 1960s with many small and large dams constructed to capture the highly seasonal flows of Thailand's Mekong tributaries for irrigation and hydropower. However, only a small part of the agricultural land is being irrigated in the wet season and much less in the dry season. Improvement of water security in Northeast Thailand remains a key issue for the government to address alongside socio-economic development for this less-developed part of the country.

Large-scale water resources development in Cambodia and Lao PDR is of more recent date. Lao PDR prepared a master plan in 1993-94 to develop its vast hydropower potential, which it is now developing. Cambodia has commenced developing the largest remaining irrigated agricultural potential in the region, in the undeveloped Cambodian delta, linked to major investments in flood control, and elsewhere linked to hydropower development.

Nevertheless, following nearly 50 years of internationally sponsored planning efforts, by the end of the 20th century, these developments had not significantly impacted upon the flow regime of the Mekong River mainstream, nor on its rich ecology.

However, by 2010, when the first cumulative impact assessments were undertaken by MRC, a different picture began to emerge.

Whilst recent studies (Ruiz-Barradas et al, 2018) remind that most of the Mekong's mainstream flows are generated within the LMB, the development of large storages in the upper basin within China have already brought about a permanent change to the low flow regime of the Mekong mainstream. It is now foreseen that ultimately all dry season consumptive demands on the river can be met with the existing and planned storages within the lower basin. This opens the door for the riparian countries to further develop the Mekong's water resources and, in doing so, to more equitably share the benefits of these resources than was apparently the case in 2000.

Climate change, sea level rise, demographic changes, rising social demands and expectations for livelihoods and water, food and energy security, together with greater environmental awareness of development risks, will all undoubtedly shape the future development of the Mekong Basin. Each presents significant challenges for the riparian countries individually and collectively.

2.1.2 Institutional setting

Development planning of the Lower Mekong Basin dates from 1952 when the UN Economic Commission for Asia and the Far East (ECAFE – now ESCAP) presented a first report on flood control and water resources development. This was followed in 1956 by the US Bureau of Reclamation's "Reconnaissance Report – Lower Mekong Basin", which also emphasized the need for extensive data gathering and for studies on agriculture, fisheries, navigation and education.

The following year, drawing on an ECAFE report on "Development of Water Resources in the Lower Mekong Basin", the four LMB governments issued a Joint Declaration that led, later in 1957, to establishment of the Mekong Committee under a "Statute of the Committee for Coordination of Investigations of the Lower Mekong Basin".

The Mekong Committee remained the central institution for LMB cooperation for the next 37 years. The Committee was heavily supported by the United Nations and other countries throughout this period. The Committee, which changed its name in 1965 to the "Committee for Coordination of Comprehensive Development of the LMB", oversaw implementation of extensive studies and preparation of several plans for the lower basin. By 1975 the Committee was able to sign a "Declaration of Principles" with robust rules, particularly on mainstream development. However, Thailand did not uphold the declaration due to its intention to irrigate its northeast part with Mekong water.

Internal conflict within Cambodia in 1976 led to the country's disengagement from the Mekong Committee for 14 years, during which time the other three countries established an Interim Mekong Committee as a holding measure. Peace came at last to the Mekong Basin in 1989, providing the necessary stability and opportunity for real and effective cooperation between Cambodia, Lao PDR, Thailand and Viet Nam. Following the Paris peace agreement of 1991, negotiations between the four countries began in 1994 for a new agreement that would take the Mekong Committee out of the UN system and create a separate inter-governmental organization under international treaty law.

The Mekong River Commission (MRC) was established in 1995 by the governments of Cambodia, Lao PDR, Thailand and Viet Nam with the purpose of promoting cooperation in the management and development of the water and related resources of the Mekong River Basin to achieve the full potential of sustainable benefits to all basin countries. PR China and Myanmar, who share the basin as well, are dialogue partners of MRC and are increasingly engaged in discussions about the future management of the basin.

The MRC is presided over by a Council made up of ministerial level representation from each country. The Council is supported by a Joint Committee that meets normally four times a year to oversee and direct the activities of the MRC. National Mekong Committees, which are not included under the institutional structure set out in the 1995 Mekong Agreement, have been established by each Member Country to coordinate national inputs to the MRC. The Mekong River Commission Secretariat (MRCS) provides technical support to the Joint Committee. The MRCS is presently organised into four divisions covering Planning, Environmental Management, Technical Support and Administration.

MRC activities are governed by the rules set out in the 1995 Agreement. In several important cases, these rules are supplemented by Procedures and Guidelines agreed by the MRC Council.

The Agreement describes the aims and intent of the four Member Countries in entering into this agreement and provides a clear framework for the MRC to work within (see box).

Box 2: Overview of the 1995 Agreement on the Cooperation for the Sustainable Development of the Mekong River basin

- **Policy**: The Agreement sets high-level goals that are to be achieved through implementation of the Agreement, viz.: social and economic development, environmental protection and inter-dependent sub-regional growth and cooperation.
- **Key instruments**: The Agreement provides for a set of rules of procedure (Art.5) by which to utilize the Mekong's waters in a reasonable and equitable manner in each country, the basis for determining an acceptable set of flow conditions in the shared mainstream (Art.6), a rolling planning process (Art.2 et al) to determine a programme of joint actions by which to fulfil the goals of the Agreement and associated investment opportunities (Art.24B), and a set of rules for monitoring water utilization (Art.26).
- **Principles**: The Agreement provides guidance on how the MRC will act in implementing the Agreement, allowing that many developments are subject to notification only, whilst others require active consultation and/or prior agreement, providing always that these activities do not cause harm to others (Art.7 et al).
- **Areas of Cooperation**: The Agreement defines also the areas of cooperation covered by the Agreement in Article 1, being (but not limited to) irrigation, hydropower, navigation, flood control, fisheries, timber floating, recreation and tourism.

Starting in 2010, the Prime Ministers of the four member-states have held summits of the Mekong River Commission every 4 years. The first one was in Hua Hin (Thailand), the second in Ho Chi Minh City (Viet Nam) in 2014, and the third in Siem Reap (Cambodia) in 2018. The first one had a motto "Meeting the Needs, Keeping the Balance", the last one headlined "One Mekong, One Spirit". These summits have re-iterated the commitments of the four member-states to the 1995 Mekong Agreement.

This State of the Basin Report, prepared some 23 years after signing the Agreement, to a large part reflects on the progress being made by the member-states towards achieving their goals.

2.2 Land cover and key environmental features

2.2.1 Physiographic features

The elevation of the Lower Mekong Basin ranges from just over 2,800 m above mean sea level to zero at the coast of Viet Nam. Mountain ranges are found throughout the basin and are evidence of a long and complex tectonic history (Brookfield 1998; Carling 2009; Workman 1975). Four key physiographic regions as described in the Planning Atlas of the Lower Mekong Basin (MRC, 2011) include the Northern Highlands, the Khorat Plateau, the Tonle Sap Basin and the Mekong Delta.

The Northern Highlands include the upland areas of northern Lao PDR and northern Thailand. In this region the Mekong River as well as its major tributaries are constrained in steep-sided valleys. In isolated places, such as near Chiang Saen and Huay Xai, the Mekong and its tributaries broaden and have developed floodplains. The Khorat Plateau is a basin that has been uplifted and tilted such that it now lays perched at an elevation of about 300 m above mean sea level.

The Plateau is rimmed by mountains on all sides with the Phu Phan Uplift dividing it into two sub-basins: the Sakhon Nakhon/Savannakhet Basin to the north, and the Min/Chi Basin to the south. Most of the central region of the Khorat Plateau however is flat or gently folded. The major rivers draining this area (Songkhram, Chi and Mun rivers) have low-gradients and wide floodplains.

The Tonle Sap Basin is a "large dome like geological structure that has been 'unroofed' through erosion, leaving a rim of hills standing above the alluvial plains in the centre of the basin" (MRC 2010a). The western and central parts of the basin are characterised by a low gradient and low-relief landscape. The Tonle Sap basin is bounded in the north by the ridge that forms the southern edge of the Khorat Plateau and the Cardamon Range in the southwest.

The Mekong Delta plain covers an area of 62,520 km^2. The Delta begins at Phnom Penh where the Mekong River splits into two main distributary channels: the Mekong and Bassac rivers, which further downstream split into nine smaller channels that discharge into the South China Sea (Nguyen *et al.* 2000). The Delta plain can be divided into two regions: the inner delta plain located upstream and dominated by fluvial (river) processes, and the outer delta plain located nearer the sea and subject to marine processes such as the influence of tides, waves and ocean currents (Nguyen *et al.* 2000; Ta *et al.* 2002). The outer delta is of slightly higher elevation than the inner delta due to the formation of sand dunes and ridges near the coast.

2.2.2 Land cover

Land cover within the Lower Mekong Basin is delineated into 19 types (Table 2.1). Using the most recent land cover layers for the LMB (2010), two land cover types comprise the majority (51%) of the total area. These are broadleaved deciduous forest (28.9%) and paddy rice (22.5%). These types represent a combination of natural and human influenced covers. For this report, natural covers are considered to be forest types (including bamboo, mangrove and flooded forest), shrub-land and grassland, and natural water bodies. In 2003 the land cover type covering the largest area was broadleaved evergreen forest (29.9%).

Monitoring of land cover change in the LMB—which can be an indirect indicator of human use— provides insight into landscape level dynamics (Figure 2.2). A good example of this is the disappearance of crops in the region around Luang Prabang in northern Lao PDR in the 1990s. Around 50 per cent of the LMB consisted of forest cover in 2003, a decrease of around 35 per cent from 1993 and 1997. According to the UN Development Program (UNDP, 2013), in 2013 Lao PDR was 40 per cent forested and the rate of forest loss has slowed. Indeed, as illustrated in Chapter 3 of this report, forest cover is now increasing and in 2015 was up to approximately 46 per cent.

The land cover types that increased the most in area across the LMB between 2003 and 2010 (Figure 2.1) were shrub-land (+7.9%), broadleaved deciduous forest (+7.6%), industrial plantation (+3.3%), annual crop (+1.6%) and orchard (+1.4%). Those that decreased the most in area between 2003 and 2010 were broadleaved evergreen forest (-19.5%), paddy rice (-2.3%), and grassland (+0.8%).

Table 2.1 Relative frequency of land cover basin-wide in 2003 and 2010 (MRC, 2016)

Land cover	2003		2010		Change
	Km²	%	Km²	%	%
Broadleaved deciduous forest	133,024	21.3	180,436	28.9	+7.6
Paddy rice	154,995	24.8	140,540	22.5	-2.3
Shrub-land	20,988	3.4	70,587	11.3	+7.9
Broadleaved evergreen forest	186,798	29.9	65,177	10.4	-19.5
Annual crop	42,500	6.8	52,461	8.4	+1.6
Industrial plantation	4,760	0.8	25,343	4.0	+3.3
Urban area	15,690	2.5	15,780	2.5	+0.0
Water body	12,135	1.9	14,667	2.4	+0.4
Orchard	3,663	0.6	12,123	1.9	+1.4
Shifting cultivation	14,242	2.3	9,724	1.6	-0.7
Grassland	13,880	2.2	8,637	1.4	-0.8
Aquaculture	2,101	0.3	6,886	1.1	+0.8
Bamboo forest	9,167	1.5	5,700	0.9	-0.6
Flooded Forest	4,360	0.7	4,886	0.8	+0.1
Coniferous forest	232	0.0	3,900	0.6	+0.6
Bare soil	2,851	0.5	3,843	0.6	+0.2
Marsh/swamp area	913	0.2	1,866	0.3	+0.6
Forest plantation	480	0.1	1,498	0.2	+0.2
Mangrove	1,839	0.3	1,303	0.2	-0.1

Figure 2.1 Land cover changes in the Lower Mekong Basin between 2003 and 2010 (MRC, 2016)

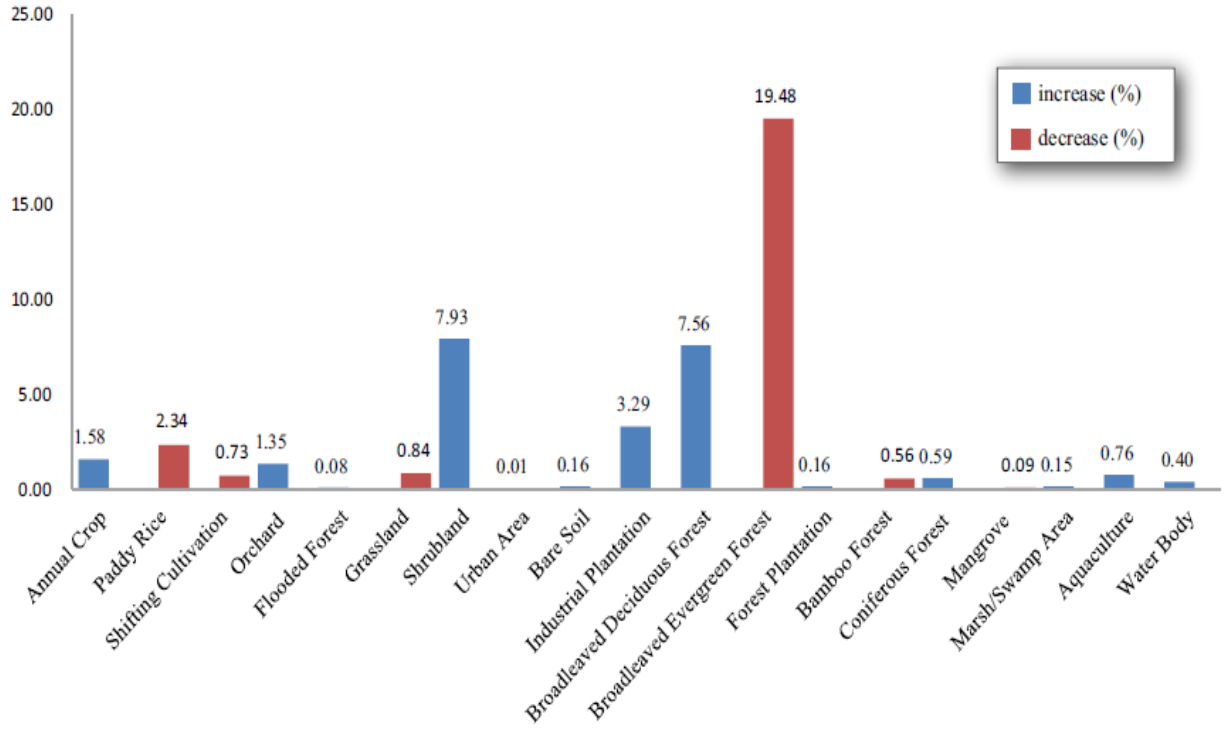
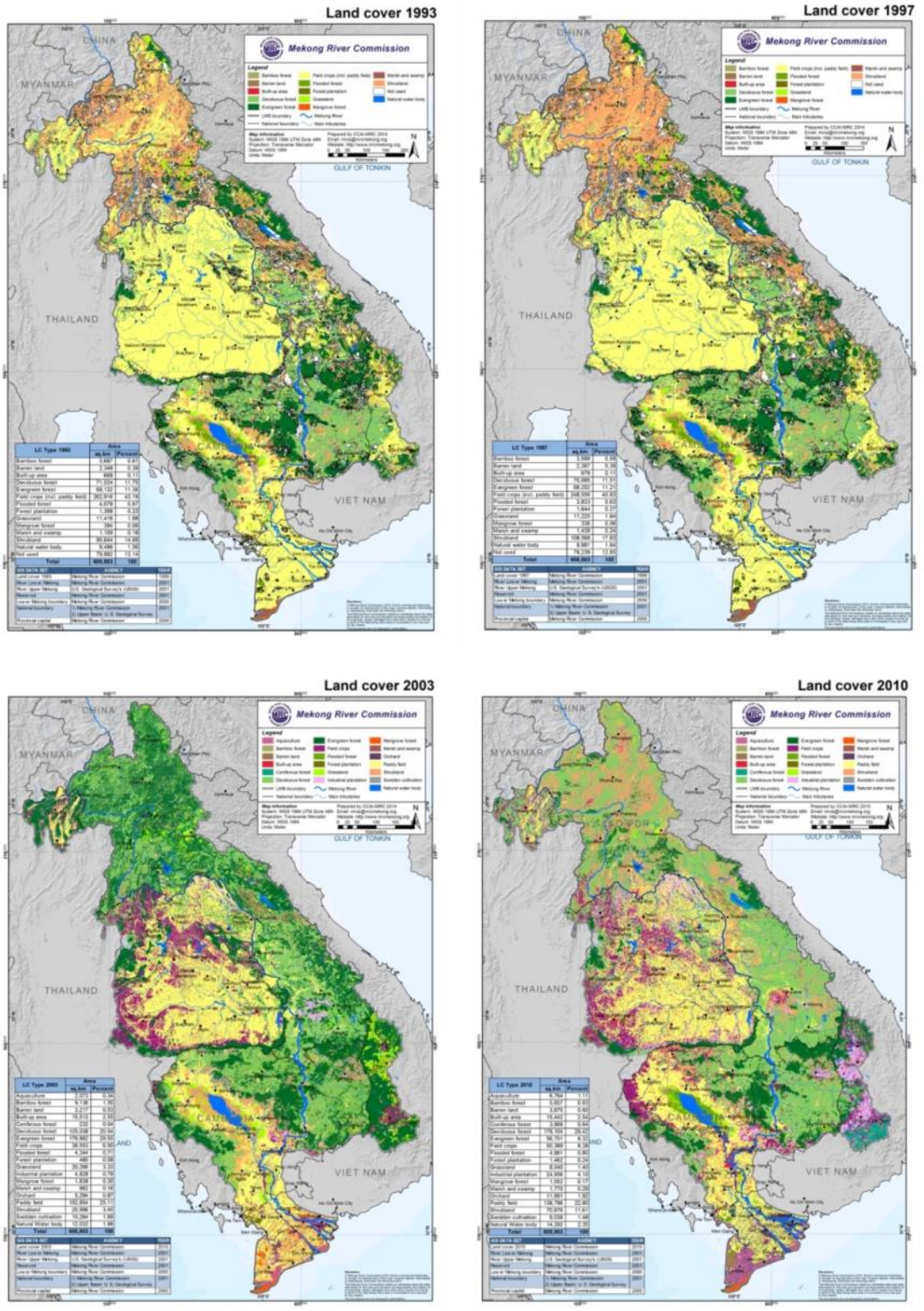


Figure 2.2 Land cover maps of the Lower Mekong Basin for (a) 1993 (b) 1997 (c) 2003 and (d) 2010

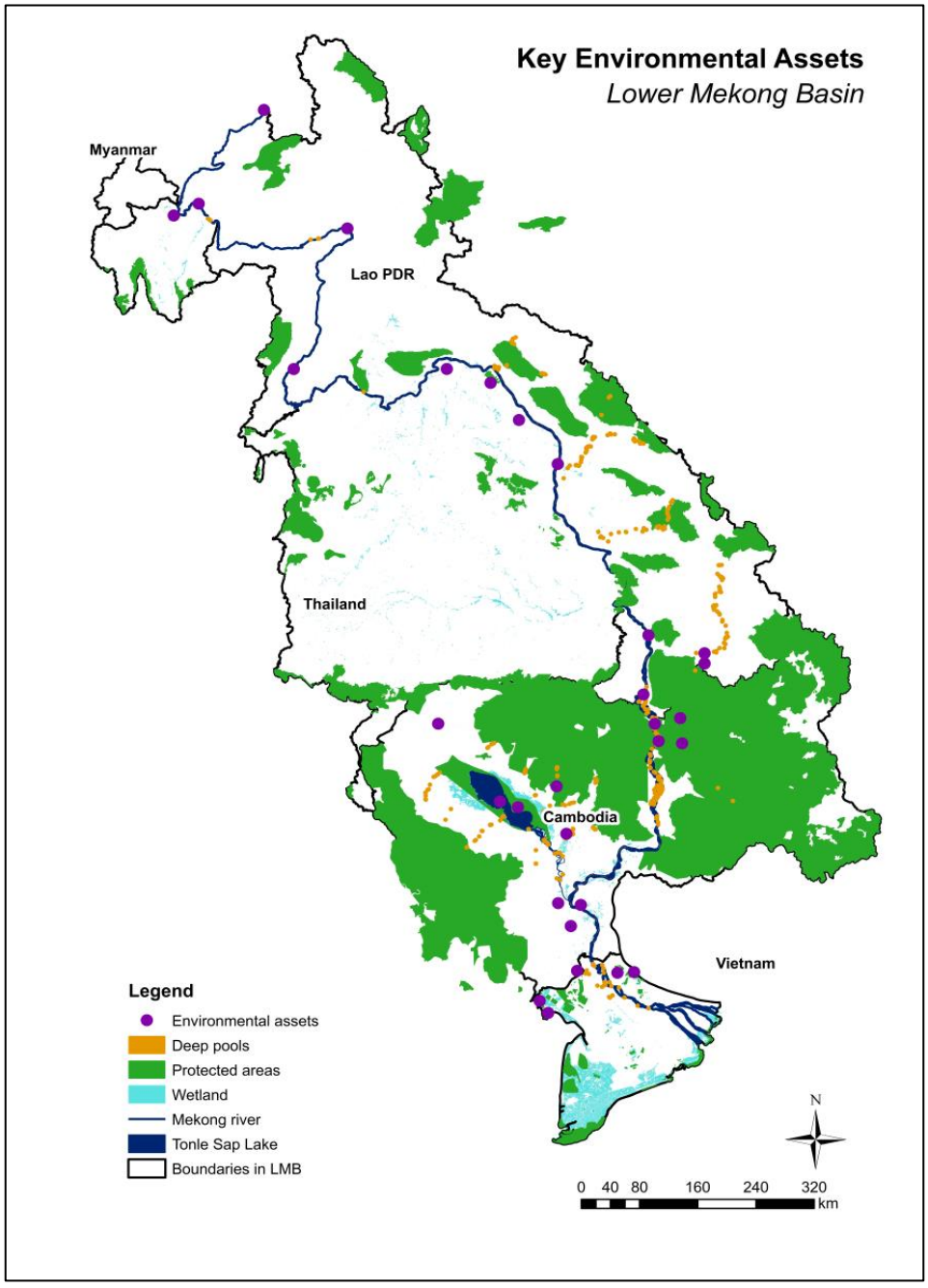


Source: MRC Information System. Note that different land cover categories were used in 1993 and 1997

2.2.3 Key environmental features

The Mekong River Basin is recognized as a global biodiversity hotspot, comprising 12 habitat types from highlands to coastal waters, including peat swamps, subterranean streams and crater lakes. It encompasses fourteen ecoregions consisting of a range of important forest types, both deciduous and evergreen, from montane environments to lowland flooded areas.

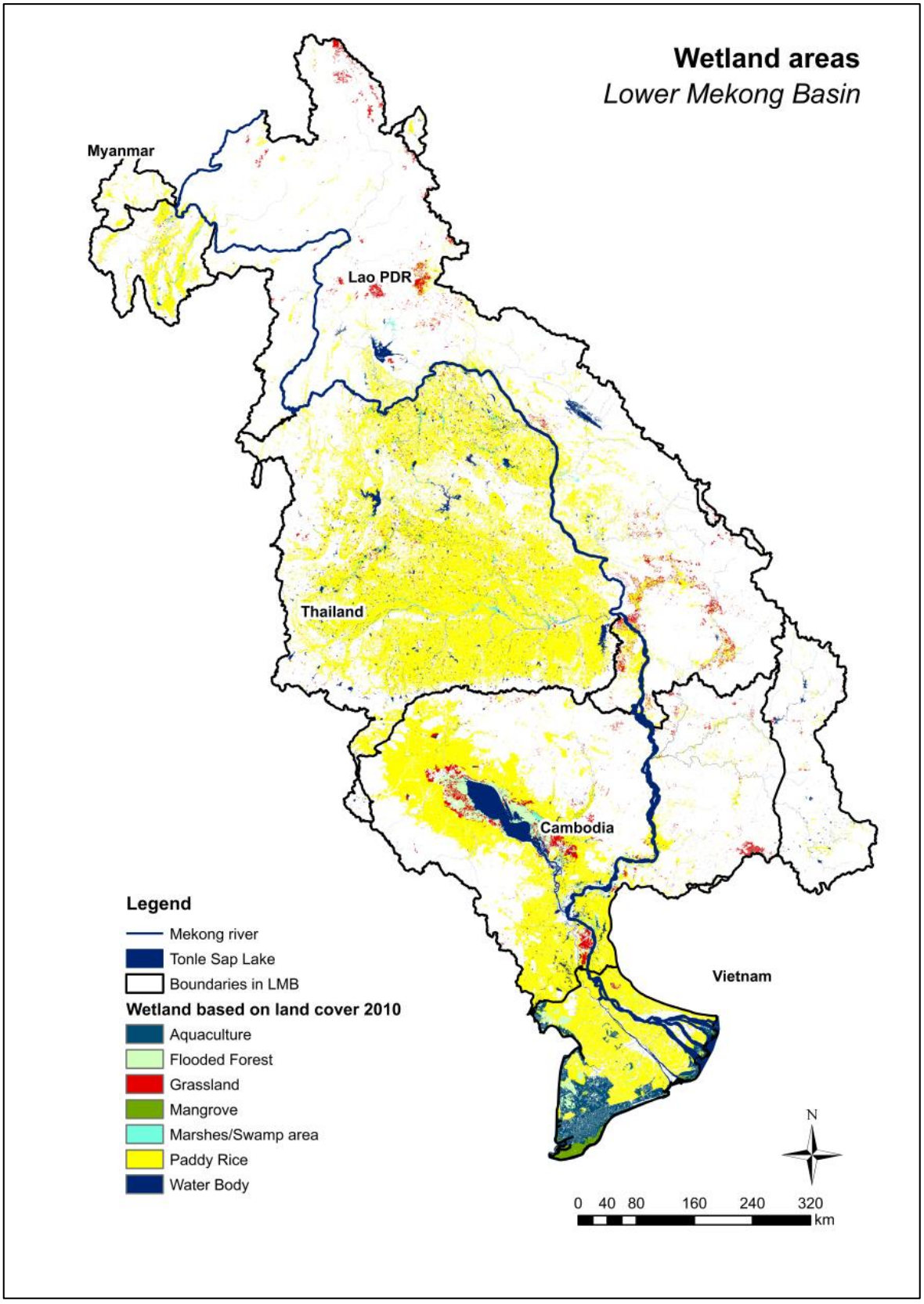
Figure 2.3 Key environmental features of the LMB



Source: MRC Information System

Note: Wetlands includes paddy fields but for clarity paddy fields are not shown here (see Figure 2.4 for all wetland areas)

Figure 2.4 Wetland areas of the LMB



Source: MRC Information System

Member Countries previously identified about 32 environmental hotspots in the LMB (MRC 2010b). These are ecologically sensitive areas of national, regional or international significance containing rich biodiversity, a large number of important species at risk and areas important for migrating species or supporting key ecological processes (MRC 2010b). They included 10 Ramsar sites, three Biosphere Reserves, 12 Protected Areas, 29 Important Bird Areas (IBAs) and four Greater Mekong Region Sub-region (GMS) hotspots (see Figure 2.3 and Figure 2.4). Since then, additional Ramsar sites have been declared and important conservation forest areas given additional protections. Recognising the value of the natural resources to the livelihoods of the basin's communities, the Lower Mekong Basin has one of the most extensive protected area networks in the world.

The river system itself includes many important environmental features. Deep pools and rapids and seasonally flooded forests together provide diverse habitats and food for fish and Other Aquatic Animals (OAAs). Exposed sandy habitat is critical for vegetation, amphibians, reptiles and birds in the dry season. The availability of exposed sandy habitats depends on the creation and maintenance of sandbars, banks and islands through alluvial deposition, and the exposure of the deposits. Inundated sandy habitat is also important for insects that require a sandy substrate for life-cycle processes. Rocky habitats are important for the nesting of certain species and for macroinvertebrates and vegetation communities that depend on inundation for life-cycle processes.

Deep pools in the LMB are recognised as important geomorphic features, providing refuge and spawning habitat for a variety of fish species (Halls *et al.* 2013). Conlan *et al.* (2008) found that sediment pulses move through bedrock pools in northern Lao PDR on an annual basis, highlighting the link between the sediment and flow regimes for maintenance of the features. Given the dependency of these features on the balance between the timing and magnitude of flow and sediment delivery in the LMB, deep pools can also be considered good geomorphic indicators of channel functioning.

Important wetland areas of the Lower Mekong Basin include flooded forests, seasonally inundated grasslands, permanent rivers, streams and lakes, marshes, swamps and mangrove forests. Flooded forests in particular afford a highly significant, if not the primary, source of biomass in Mekong floodplains and therefore play a critical role in the productivity of LMB ecosystems (MRC, 2017).

The seasonal inundation of forested areas is essential to the carbon and nutrient cycles of the LMB, providing food and habitat for fish and other aquatic animals. The floodplains around the Tonle Sap Great Lake are a key feature in this cycle as the flood pulse first fills the lake and then recedes, providing cues for fish migration and carrying nutrient rich water down the Tonle Sap River to the Mekong Delta.

2.3 Demographic situation

Based upon 2015 estimates there are approximately 65 million people living within the LMB. Thailand and Viet Nam account for a little over a third of the population in the LMB each, Cambodia a fifth and Lao PDR the remainder. There is a large variation in population distribution throughout the LMB. The large, sparsely populated mountainous areas of the LMB in Lao PDR have relatively low population densities. Cambodia's population density is almost double that of Lao PDR, and Thailand's a little higher, and the Vietnamese portion of the basin has a relatively high population density (Table 2.2).

Table 2.2 Population and population density in the LMB 2015

Country	Population in LMB (million)	Share of LMB population (%)	Share of national population (%)	Land area within basin (Km²)	Population density (pax/Km²)
Cambodia	13.4	22	86	156,435	86
Lao PDR	6.2	10	91	206,620	30
Thailand	25.4	39	37	203,060	125
Viet Nam	19.8	31	22	66,773 6	297
Total	**65.0**	**100**	**-**	**632,888**	**103**

Source: Global Population Data 2015, World Bank 2018, MRC, 2010, State of the Basin Report.

These broad patterns of population distribution obscure significant variations in population density associated with the geographical characteristics of the basin. The relatively fertile flood plain, riverine and deltaic areas have higher population densities and host most major urban population centres in the basin, including the Phnom Penh, Vientiane, Udon Thani and Ubon Ratchaathani and Can Tho.

Upland areas high in river catchments which have limited land suitable for intensive agricultural production tend to be more sparsely populated, such as much of northern and eastern Lao PDR and eastern Cambodia. The main exceptions to this are Viet Nam's central highlands and some upland areas in the Thai portion of the basin, much of which is under quite intensive agricultural production and have moderate levels of population density (Figure 2.6).

Figure 2.5 Population growth in LMB countries and the LMB area 1960 - 2016

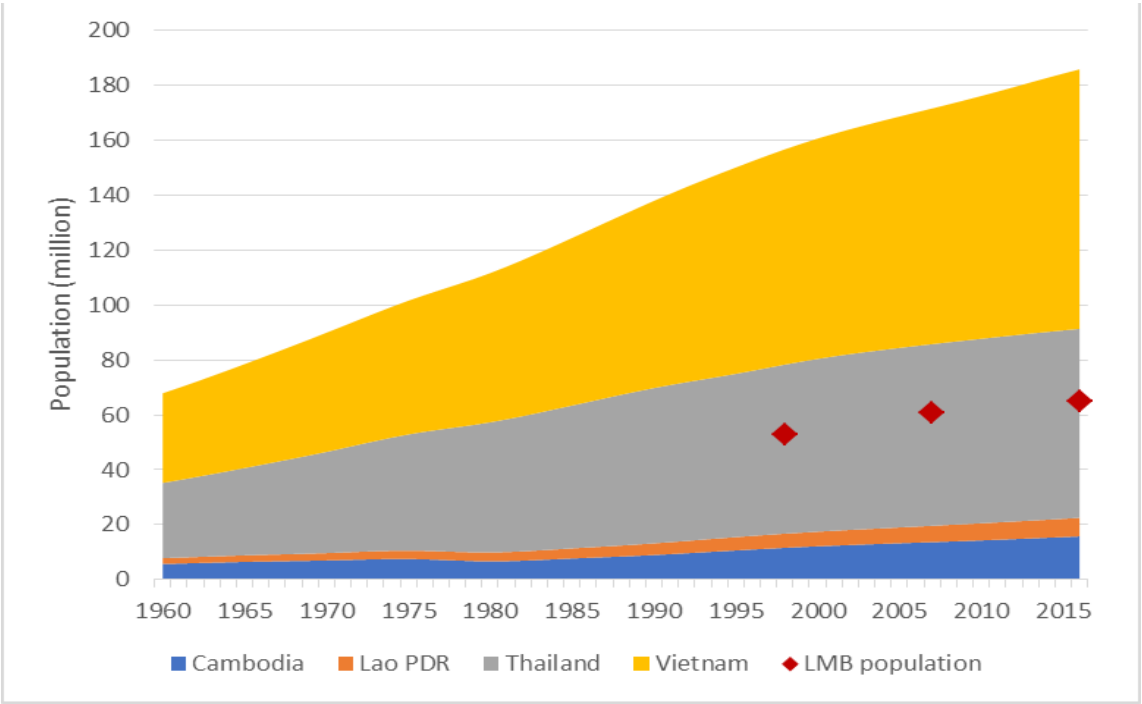
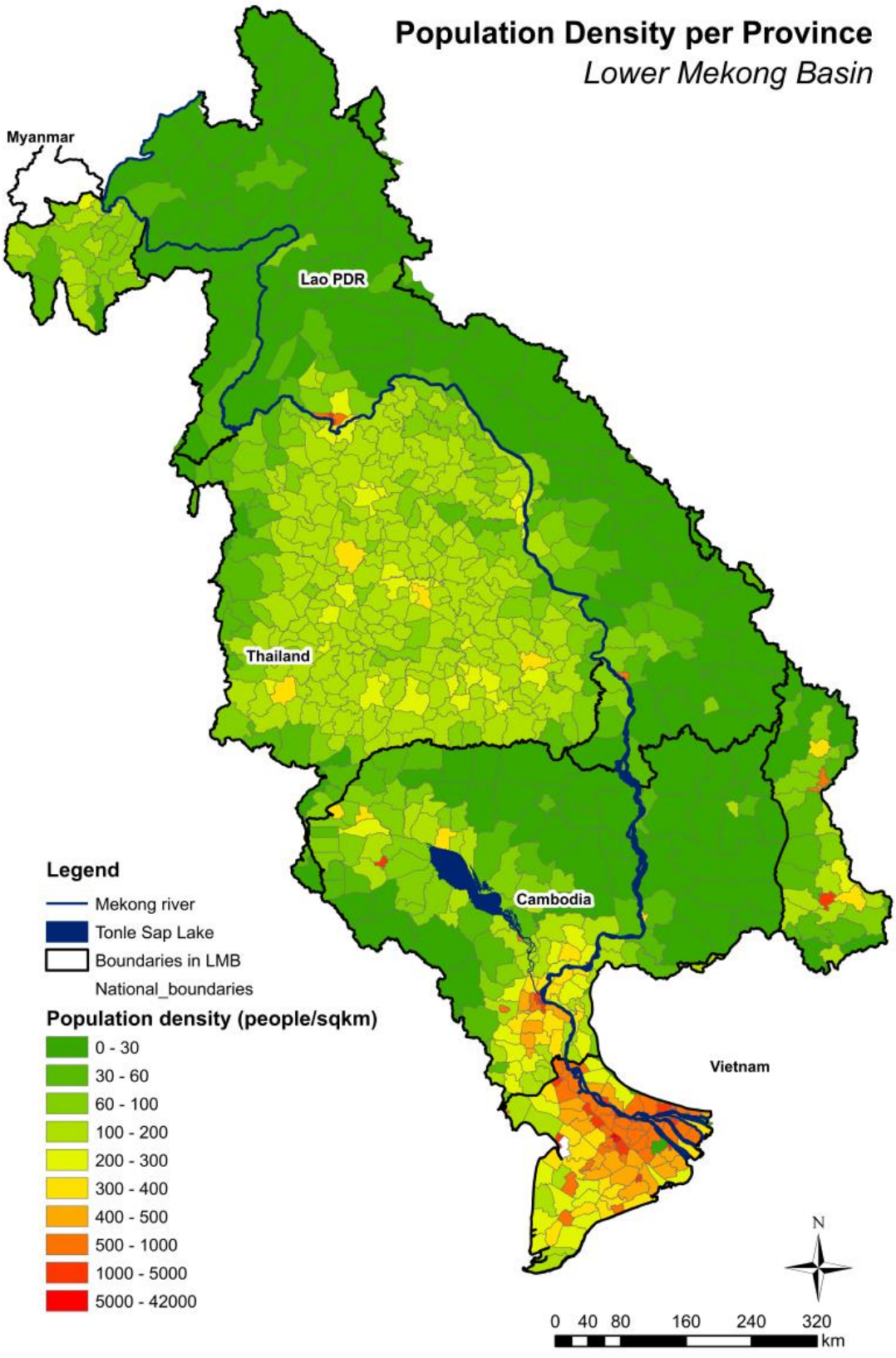


Figure 2.6 Population density by province in the LMB

6 34,373 Km² in the Mekong Delta and 32,400 Km² in the Central Highlands.

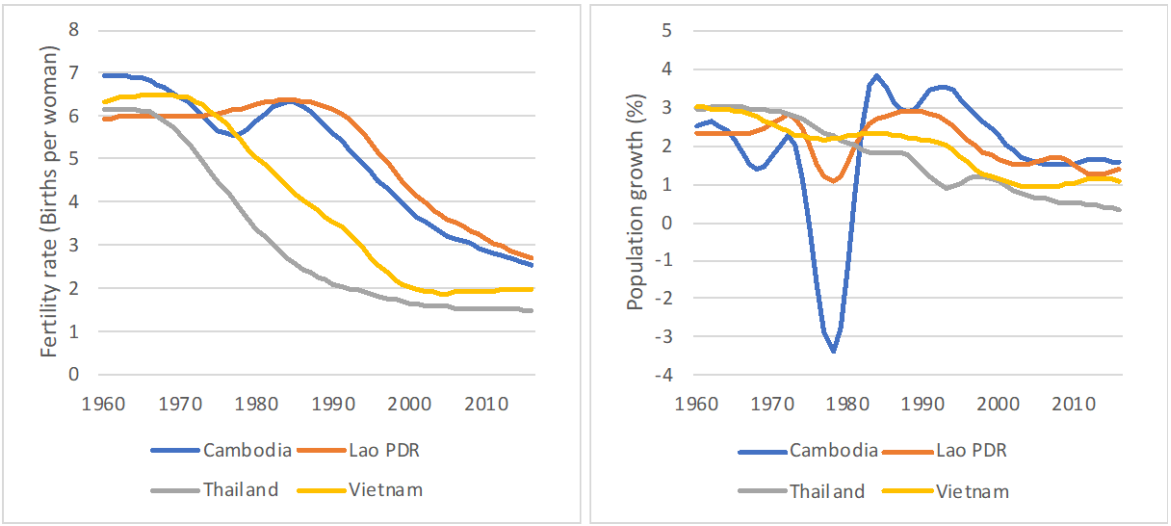

Population Density per Province
Lower Mekong Basin
Myanmar
Lao PDR
Thailand
Cambodia
Vietnam
Legend
Mekong river
Tonle Sap Lake
Boundaries in LMB
National_boundaries
Population density (people/sqkm)
0 - 30
30 - 60
60 - 100
100 - 200
200 - 300
300 - 400
400 - 500
500 - 1000
1000 - 5000
5000 - 42000
N
0 40 80 160 240 320
km

Population levels in the LMB have increase significantly, population estimates based upon census data for 1995-2000 put the population at approximately 53 million (Hook et al 2003), and for the 2005-2009 period at approximately 60.6 million (MRC 2011). This represents growth of for population of around 14% between 1995 – 2000 and 2005-2009, and approximately 7% between 2005-2009 and 2015.[7] Figure 2.5 compares the growth in national populations with that of the LMB population, from these figures it is clear that LMB population growth has been higher than that of the LMB countries as a whole as the basin has increased its share of population over approximately the last two decades. These general trends obscure a more nuanced pattern of population change which is characterised by two major trends, declining population growth and increasing urbanisation.

All LMB countries have seen significant decreases in population growth rates since the 1990s. However, there are large differences in national patterns, over the last two decades (1996-2016) population growth in Thailand (0.67%) and Viet Nam (1.09%) growth has slowed considerably. Whereas Cambodia (1.87%) and Lao PDR (1.58%) are still experiencing rapid growth – albeit at a rate that has much reduced since the 1990s (Figure 2.5).

Most of the difference in population growth rates between LMB countries can be explained by declining fertility rates as countries enter their demographic transitions (Figure 2.7). Thailand experienced a rapid decline in fertility rates between the mid-1960s and mid-1990s, Viet Nam entered its transition a little later with a similar decline in fertility rates between the mid-1970s and the end of the century. However, Cambodia and Lao PDR did not experience a secular decline in fertility rates until the late 1980s.

Figure 2.7 Fertility rates (right) and population growth rates (left) for LMB countries 1960 - 2016



The second significant population dynamic affecting the demographic composition of the LMB is the process of rapid urbanisation in all LMB countries. The expansion of employment opportunities in and around urban areas is generating significant rural-urban migration, both within countries and across national borders. Despite lower natural population growth rates in urban areas, high in-migration rates mean urban areas are seeing much higher population growth than rural. Between 1996 and 2016 Cambodia's urbanisation rate increased from 17.1% to 20.9%, that of Lao PDR increased from 18.2% to 39.7%, Thailand's from 30.5% to 51.5% and that of Viet Nam from 22.6% to 34.2%. These figures probably underestimate the extent of rural-urban migration as much of it is temporary or otherwise unregistered with government authorities. While the basin population is still predominately rural, large and growing centres of urban population (such as Phnom Penh, Vientiane and Can Tho) form an increasing share of LMB population, in 2015 urban population in the basin was estimated to be around 10.9 million people.[8]

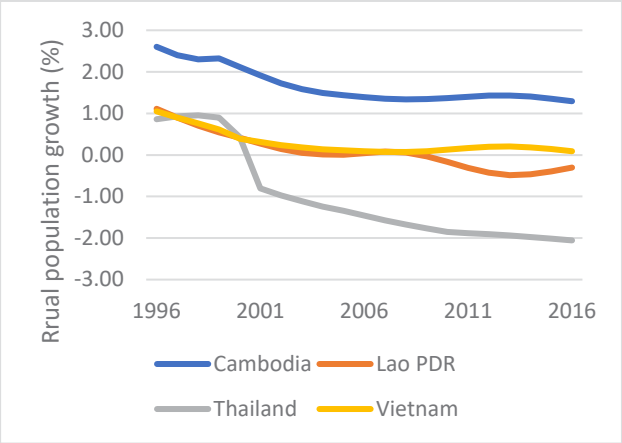
7 It should be noted that national censuses of the fur LMB countries are conducted in different years

8 Based upon GIS analysis of 2015 gridded population data, urban areas were regarded as all those with population densities in excess of 1,000 pax/Km^2

At the same time, and as a direct consequence of population movement, rural population growth is slowing. Rural population has been shrinking in Thailand since around 2000, in Lao PDR since 2008, and growth in Viet Nam is only 0.09%. Cambodia continues to see relatively high rural population growth, still at 1.29% in 2016. Again, given the likely extent of un-enumerated migrants, these figures probably underestimate the decline in rural populations.

As a result of migration to urban centres within and outside the basin some areas of the basin are experiencing a decline in rural populations such as in the Mekong Delta and North-eastern Thailand (Nguyen 2010).

Figure 2.8 Rural population growth in LMB countries 1996-2016



2.4 Economic setting

The economy of the LMB is developing rapidly and under-going significant structural change. Economic performance varies considerably between countries reflecting their differing development histories and economic contexts. Considering the four LMB countries as a whole, Thailand's economy accounts for around 68% of GDP, Viet Nam approximately 27%, with remaining 5% divided between Cambodia (3%) and Lao PDR (2%) (Figure 2.9). GDP per capita figures serve to emphasize national differences. Thailand's per capita GDP in 2016 was approaching US$6,000, approximately six times per capita GDP in Cambodia, and around three times that of Viet Nam and Lao PDR.

Thailand's rapid growth phase took place in the decades prior to the Asian Financial Crisis, since then its growth rates have moderated, averaging around 3.4 % between 2006 and 2016. Growth in the other three LMB countries continues to be rapid, averaging about 6.1% in Viet Nam over the same period and exceeding 7% in Cambodia and 7.8% in Lao PDR.

These differences are also reflected in the developing structure of the LMB national economies. The development of industrial and services sectors has been central to GDP growth in all LMB countries, with a particular focus on export-oriented manufacturing industry and the promotion of FDI. Growth in these higher-value added sectors has far outstripped growth in the agricultural sector and as such the relative share of the agricultural sector in GDP declined. In Thailand, the relative decline in the sector occurred during its high-growth phase, in 1960 agriculture accounted for over 36% of GDP, but by 1992 agriculture accounted for around only 8% of GDP approximately, the same level as in 2016. The other LMB countries have been going through this economic transition over the last two decades (Figure 2.10).

Figure 2.9 GDP in LMB countries (left) and GDP growth rate (right) 1996-2016

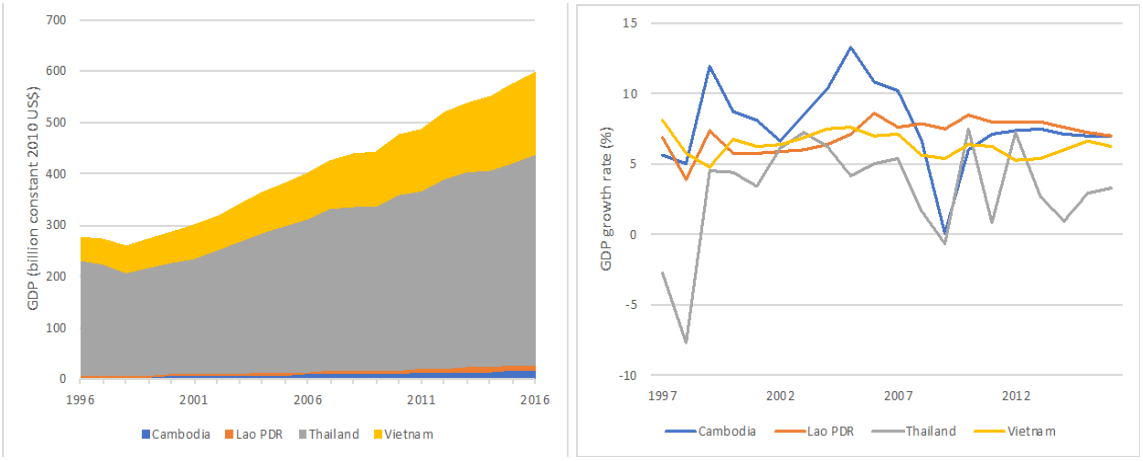
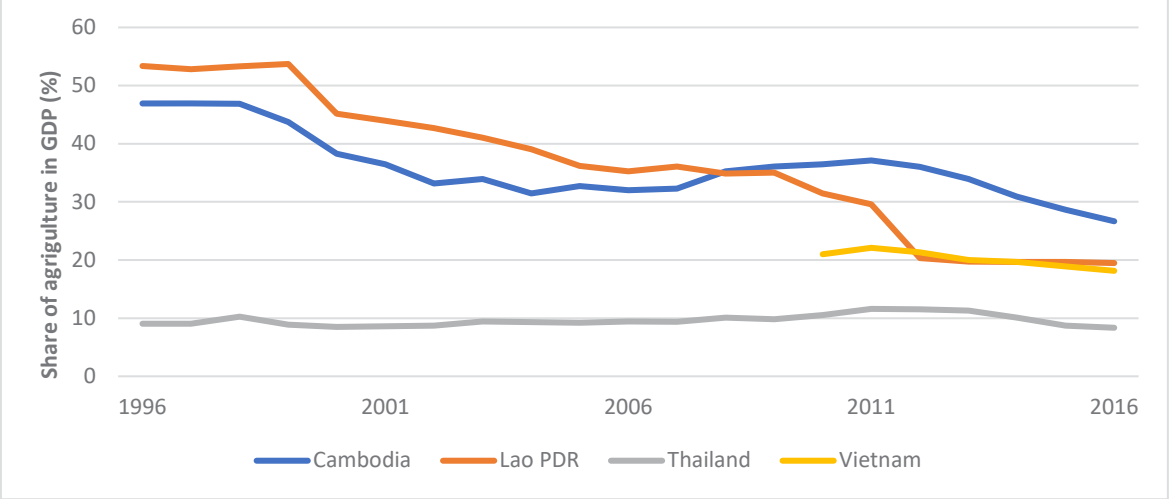


Figure 2.10 Share of agriculture in GDP LMB countries 1996 - 2016



World Bank, 2018, World Development Indictors Database, retrieved from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators# 19 June 2018

Nevertheless, all LMB countries still have large rural populations which are predominantly employed in agriculture. The sector is therefore critical to maintaining food security and realizing poverty reduction efforts. The sector also provides important inputs for the manufacturing sector. Environmental status and trends

3. Environmental status and trends

3.1 Introduction

The environment dimension of the MRC Indicator Framework reflects the MRC's intent to protect the environment, natural resources, aquatic life and conditions, and ecological balance of the Mekong River Basin from pollution or other harmful effects. Impacts may result from any development activities and uses of water and related resources in the Basin, as reflected in Article 3 of the 1995 Mekong Agreement.

To this end, and in accordance with the 1995 Mekong Agreement, the Member Countries have committed to maintaining mainstream flow and water quality conditions within certain limits as expressed in the Procedures for the Maintenance of Flows on the Mainstream (PMFM) and the Procedures for Water Quality (PWQ) and their accompanying technical guidelines. In addition, the Member Countries have committed under Article 7 of the Mekong Agreement to make every effort to avoid, minimize and mitigate harmful effects that might occur to the environment, especially the water quantity and quality, the aquatic (eco-system) conditions, and ecological balance of the river system, from the development and use of the Mekong River Basin water resources or discharges of wastes and return flows.

In line with these commitments, the MRC conducts jointly with the Member Countries a comprehensive monitoring programme of mainstream flows and water quality. These programmes have been supplemented by the Discharge Sediment Monitoring Project (DSMP), which has been actively monitoring mainstream discharge and sediment with a unified standard since 2009. In addition, since its inception, the MRC has been engaged in wide-ranging studies and data collection programmes to promote better understanding of the natural environment and fisheries of the LMB and the implications for these of water resource developments.

Strategic indicators	Assessment indicators
Water flow conditions	❑ Dry season flows - compliance with PMFM
	❑ Flood season peak flows - compliance with PMFM
	❑ Tonle Sap reversal flows - compliance with PMFM
	❑ Timing of onset of wet season flows
Water quality and sediment conditions	❑ Water quality and ecological health - compliance with PWQ
	❑ Sediment transport
	❑ Salinity intrusion in the delta
Status of environmental assets	❑ Wetland area
	❑ Condition of riverine habitats
	❑ Condition and status of fisheries and other aquatic resources
	❑ Condition and status of ecological significant areas
Overall environmental condition	❑ Overall assessment based on the above indicators

Four strategic indicators have been selected by which to judge whether the objectives as reflected in the 1995 Mekong Agreement are being met. These four indicators are (i) water flow conditions [9], (ii) water quality and sediment conditions, (iii) status of environmental assets, and (iv) overall environmental condition. These strategic indicators are supported by twelve assessment indicators, as above.

This Chapter provides an assessment of the status and trends associated with each of these indicators.

9 Mainstream flow conditions are subject to MRC Procedures for Mainstream Flow Management (PMFM). Whilst this Procedure has been approved by Member Countries, the flow thresholds in the accompanying Technical Guidelines have as yet to be finally agreed.

3.2 Water flow conditions

3.2.1 Assessment methodology

The natural hydrological regime of the Mekong is characterised by various processes of which the two major ones are: the southwest monsoon between May and November is the main driver of the annual flood pulse of the Mekong River with a distinct seasonality in the annually hydrological regime between a wet season and a dry season. In addition, individual storm events including cyclones which are caused by tropical depressions and usually formed in the South China Sea, pour down intense rainfall over the Lower Mekong Basin and therefore generate distinct individual peaks to the wet season flows. These generally occur during July-October.

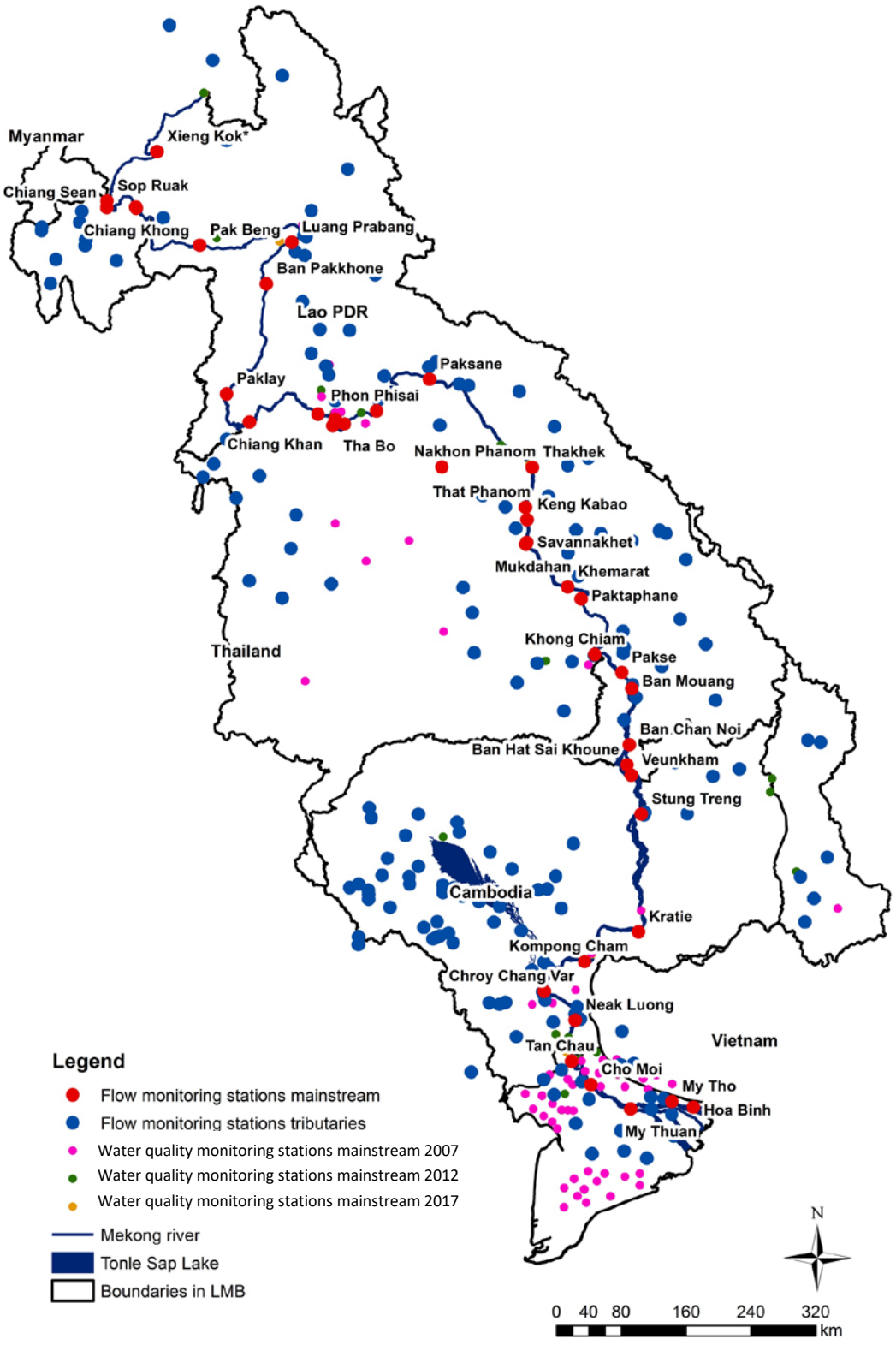
Maintaining water flow conditions is considered as one of the core functions of the MRC and the Member Countries have committed under Article 7 of the Mekong Agreement "to make every effort to avoid, minimize and mitigate harmful effects that might occur to the environment, especially the water quantity and quality, the aquatic (eco-system) conditions, and ecological balance of the river system, from the development and use of the Mekong River Basin water resources or discharges of wastes and return flows".

This commitment has been further defined in the Procedures for the Maintenance of Flows on the Mainstream (PMFM). In the PMFM the LMB Countries have agreed to "cooperate in the maintenance of the flows on the mainstream from diversions, storage releases, or other actions of a permanent nature, except in the cases of historically severe droughts and/or floods". More specifically it was agreed: (i) to maintain of not less than the acceptable minimum monthly natural flow during each month of the dry season; (ii) to enable the acceptable natural reverse flow of the Tonle Sap River to take place during the wet season; and (iii) to prevent average daily peak flows greater than what naturally occur on the average during the flood season.

Based on this Mekong Agreement and the PMFM a **strategic indicator** has been defined called "water flow conditions", which is further defined as "the extent to which water flow conditions have departed from agreed reference points considered necessary for a sustainable environment". The derived assessment indicators from this strategic indicator are:

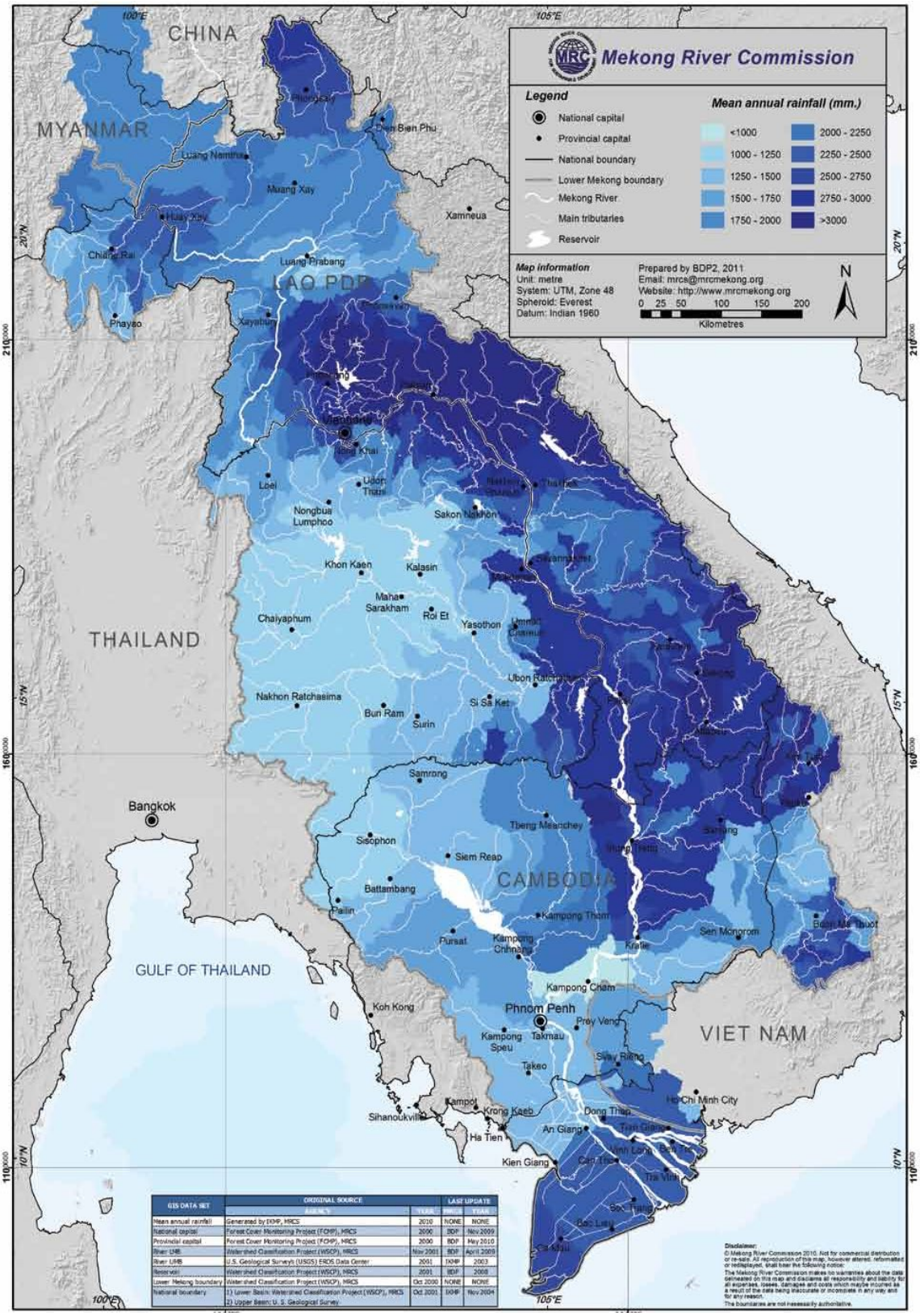
- Compliance of dry season flows with the PMFM
- Compliance of flood season flows with the PMFM
- Compliance of Tonle Sap reverse flows with the PMFM
- Change in the timing of onset of wet season flows

Figure 3.1 MRC flow and water quality monitoring networks



Source: MRC Information System

Figure 3.2 Mean annual rainfall



Source MRC-BDP-Atlas 2011

The **monitoring parameters** to assess these assessment indicators were obtained from the MRC Hydrological Database. Data quality checking and converting observed water levels to flows using rating curves was performed for the main river discharge stations. The four assessment indicators as agreed upon in the Indicator Framework refer to the thresholds values as defined in the PMFM.

An approach on the amount of theoretical maximum water availability and its origin can be evaluated using rainfall only (Table 3.1 and Figure 3.2). In theory, assuming that all precipitation will result in runoff to the main stream, Lao PDR, Thailand, and Cambodia (in decreasing order) are the three leading contributors to Mekong basin water in summer (and spring and fall). Interestingly, Viet Nam with summer rainfall larger than Thailand, Cambodia, China, and Myanmar ranks fifth in contribution to precipitation volume, just above Myanmar's, because of the small area of the Mekong basin within its boundaries.

The Chinese contribution to Mekong basin water ranks fourth in summer (and for much of the year). Such a theoretical approach is interesting but ignores the complexity of the hydrology where evaporation (natural and human-induced), runoff factors, groundwater recharge, base flow, topography, amongst others, play a paramount role in the actual availability of water in the Mekong. Relying on accurate flow observation is therefore critical.

Table 3.1 Precipitation over the entire basin and per country. Two precipitation datasets were compared: the in situ gauge-based GPCC(1979–2013) and the satellite-based TRMM (1998–2015)

Mekong basine and the contry subbasins	Source	Annual (Jan-Dec)			Dry period (Nov-Mar)			Wet period (Apr-Oct)		
		Mean (mm/day)	Volume (1000 m3/s)	Volume %	Mean (mm/day)	Volume (1000 m3/s)	Volume %	Mean (mm/day)	Volume (1000 m3/s)	Volume %
Mekong basin	GPCC	4.20	460.09	100.0	0.86	34.42	100.0	6.58	424.69	100.0
(798 981 km2; 100%)	TRMM	4.39	482.84	100.0	0.94	38.48	100.0	6.86	444.38	100.0
Thailand Sb	GPCC	4.01	117.89	25.6	0.60	7.41	20.9	6.44	110.48	26.0
(211 706 km2; 26.5%)	TRMM	4.25	125.01	25.9	0.65	7.94	20.6	6.82	117.08	26.4
Lao Sb	GPCC	5.08	134.40	29.2	0.82	9.09	25.7	8.12	125.32	29.5
(190 444 km2; 23.8%)	TRMM	5.26	139.25	28.8	0.89	9.81	25.5	8.39	129.44	29.1
China Sb	GPCC	2.45	56.64	12.3	0.59	5.65	16.0	3.79	50.90	12.0
(165 967 km2; 20.8%)	TRMM	2.55	58.69	12.2	0.52	5.02	13.0	3.99	53.68	12.1
Cambodia Sb	GPCC	4.77	102.36	22.2	0.89	7.94	22.4	7.55	94.42	22.2
(154 363 km2; 19.3%)	TRMM	5.09	109.23	22.6	1.09	9.72	25.3	7.96	99.51	22.4
VietNam Sb	GPCC	5.16	35.16	7.7	1.43	4.05	11.4	7.82	31.11	7.3
(49 861 km2; 6.2%)	TRMM	5.15	35.65	7.4	1.63	4.70	12.2	7.66	30.94	7.0
Myanm Sb	GPCC	3.71	13.74	3.0	0.82	1.28	3.6	5.77	12.46	2.9
(26 650 km2; 3.3%)	TRMM	4.05	15.01	3.1	0.84	1.29	3.4	6.35	13.73	3.1

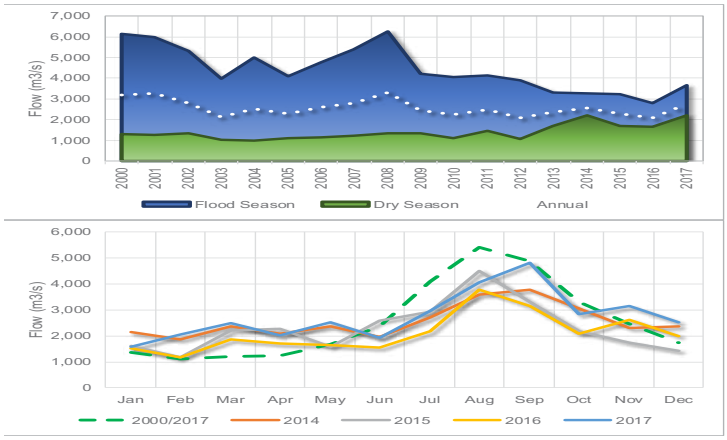
Source: Ruiz et al. 2018

Accurate measurement of flows is challenging especially in complex river sections where bank erosion and sedimentation take place. Also, flow measurements in sections under tidal influence and the reversal flow system below Tonle Sap are virtually impossible. Over recent years MRCS has made substantial efforts to improve the flow monitoring system and to derive more accurate rating curves. This is process requiring continuous efforts to ensure the high level of information required to monitor the water flow conditions in the Mekong mainstream.

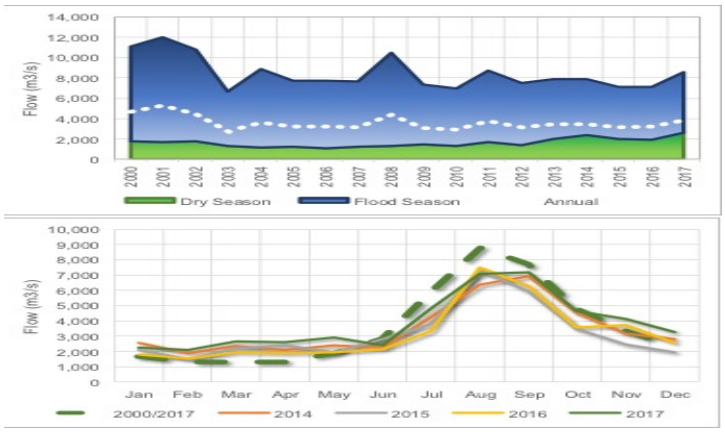
The overall flow conditions in the Mekong mainstream show some interesting changes since the year 2000. Streamflow records for the station at Chiang Saen, the point where the Mekong becomes the Lower Mekong (border of Myanmar, Thailand, Lao PDR and China), for Chau Doc at the border with Viet Nam and for intermediate stations including Kratie are presented in Figure 3.3.

Average annual flow at Chiang Saen is about 2500 m3/s, and since 2010 flood season flows have been reduced drastically. This change was in total volume as well as in variability. At the same time, dry season flows were higher than ever. The change in average annual flows since 2000 is slightly declining, but over the last five years a small increase has been observed.

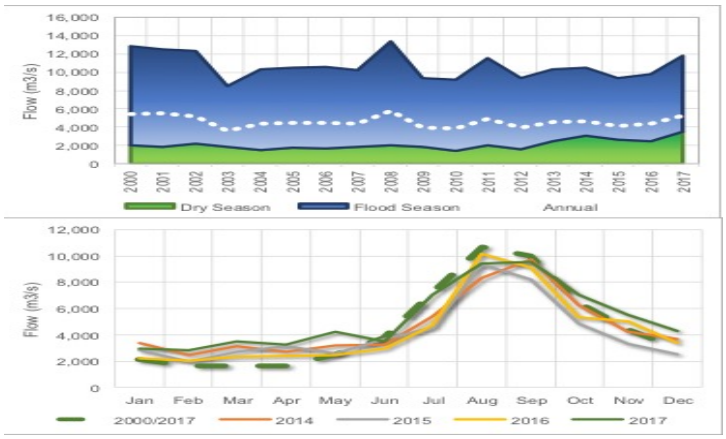
Figure 3.3 Stream flow at key mainstream stations



Chiang Saen

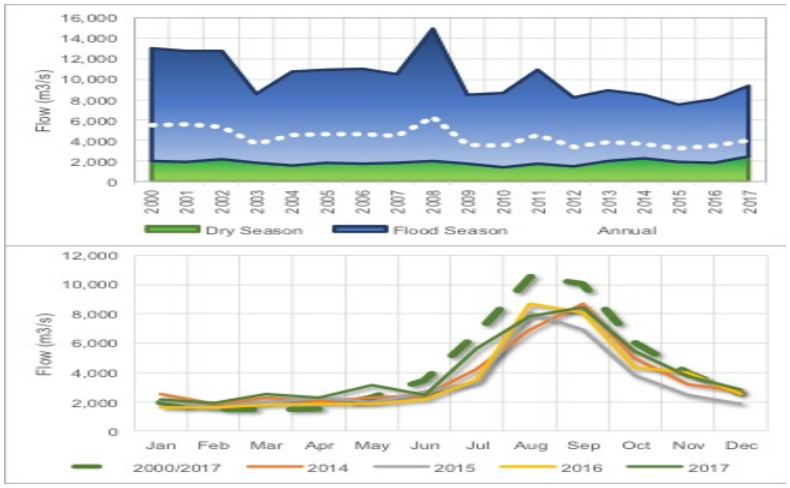


Luang Prabang

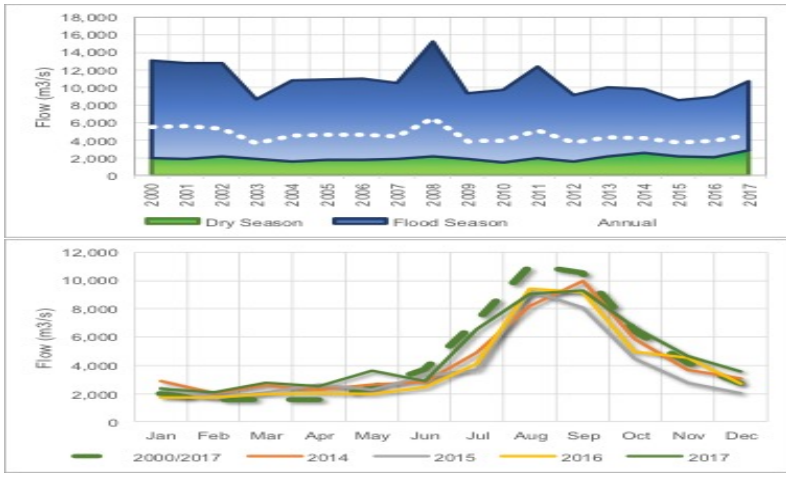


Chiang Khan

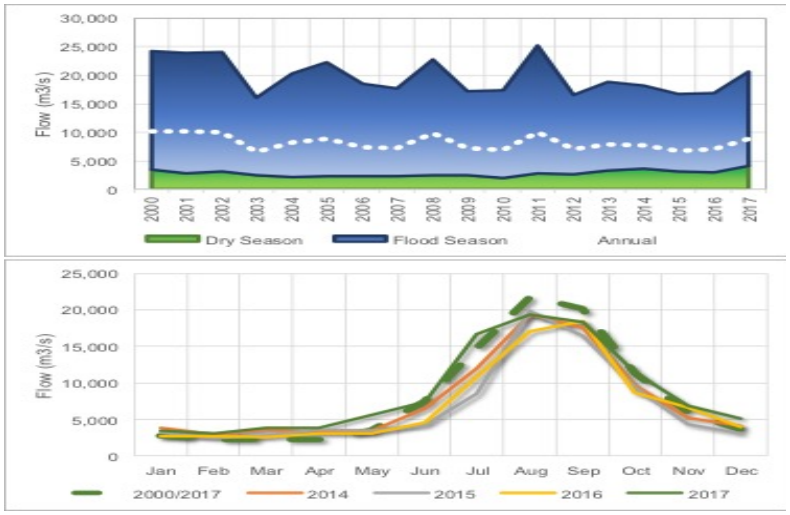
Figure 3.3 Stream flow at key mainstream stations *(continued)*



Vientiane

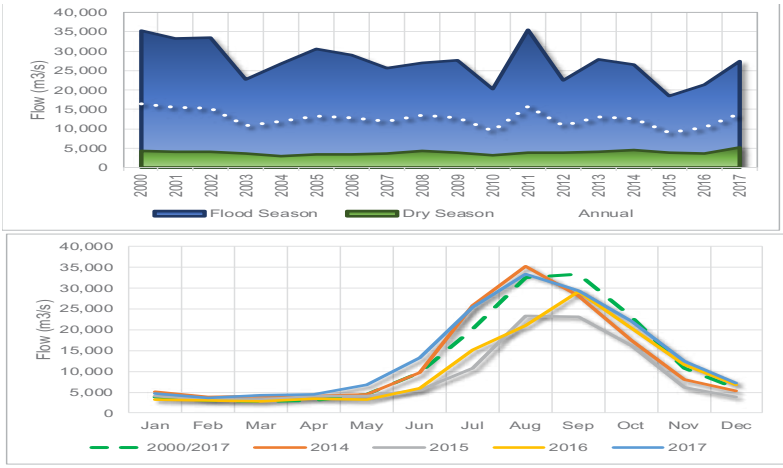


Nong Khai

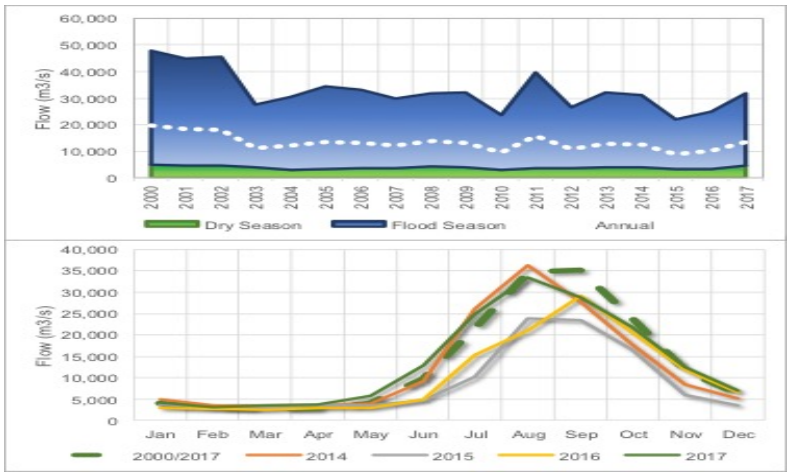


Nakhon Phanom

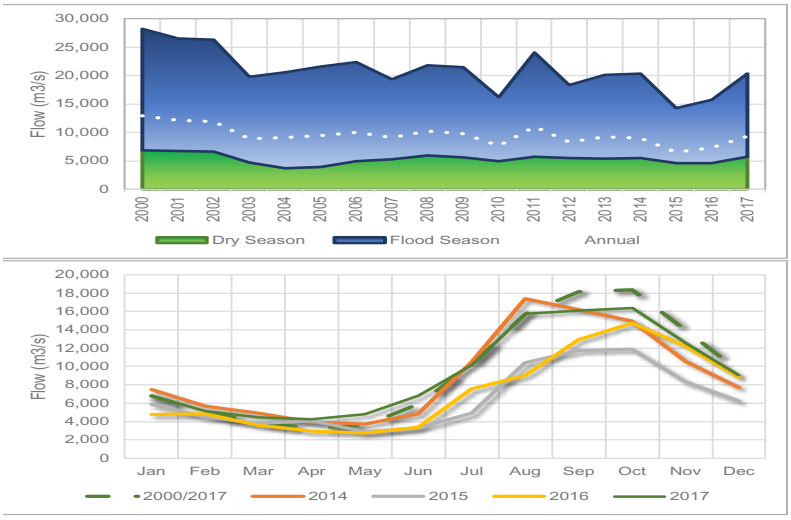
Figure 3.3 Stream flow at key mainstream stations *(continued)*



Mukdahan

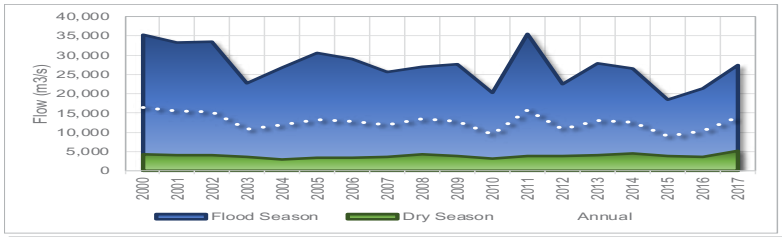


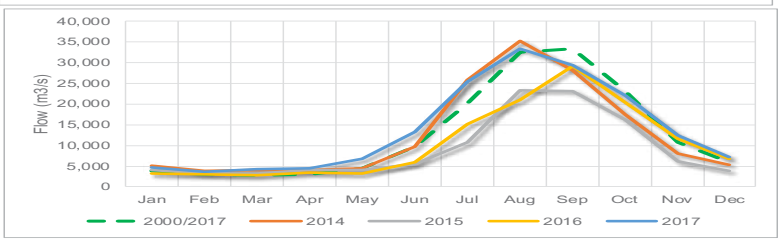
Pakse



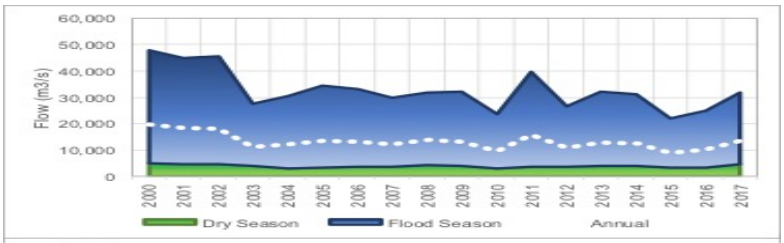
Stung Treng

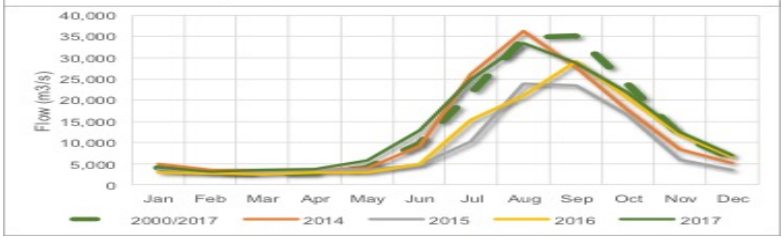
Figure 3.3 Stream flow at key mainstream stations (continued)



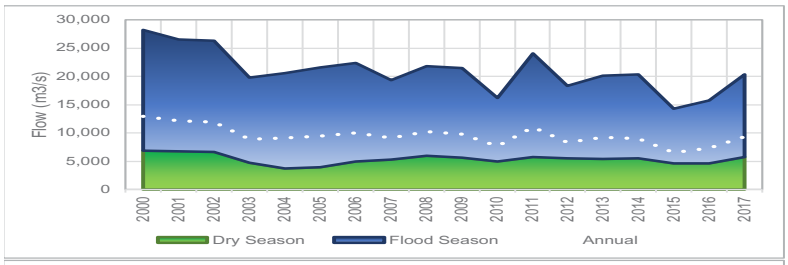


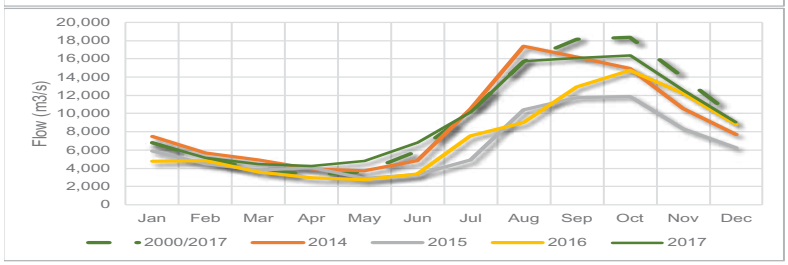
Kratie





Kampong Cham





Tan Chau

Data source: MRC flow monitoring. Annual flows for flood and dry season and annual flows (top) and monthly flows for the more recent years (bottom). Note that the annual average flows are the dotted white lines.

Flow downstream in the Mekong at Kratie is about five times bigger compared to the flow at the Chinese border, indicating more rainfall than consumption and evaporation in the catchment areas of Cambodia, Lao PDR, Thailand, and Viet Nam (Table 3.2). As shown in the table, it appears that flows at Nong Khai are lower than Chiang Khan and Kratie flows are lower than Stung Treng. Inaccuracies in flow measurements might be a reason for this, but more likely is that complex processes of inflows and abstractions are at play in these reaches.

Streamflow station Kratie shows a similar trend as Chiang Saen, although less pronounced: slightly declining annual flows, a small increase in dry season flow and reduced flood season flow. Those trends have occurred over a relatively short period and are likely to be due to human influences. Potential trends in flows by climate change can only be evaluated over longer time horizons.

Table 3.2 Observed flows and trends for the Mekong mainstream stations over the period 2000-2017

StatION	Code	Average flow (m3/s)			Trend (m3/s per year)		
		Annual	Dry Season	Flood Season	Annual	Dry Season	Flood Season
Chiang Saen	TH_010501	2,572	1,394	4,420	-34	48	-155
Luang Prabang	LA_011201	3,581	1,636	6,756	-46	48	-184
Chiang Khan	TH_011903	4,539	2,059	8,518	-23	62	-140
Nong Khai	TH_012001	4,465	1,949	8,602	-56	28	-176
Nakhon Phanom	TH_013101	8,410	2,908	17,397	-148	22	-375
Mukdahan	TH_013402	8,712	3,108	17,954	-71	71	-266
Khong Chiam	TH_013801	9,100	2,904	19,274	-75	59	-267
Pakse	LA_013901	10,312	3,288	21,742	-107	81	-401
Stung Treng	KH_014501	13,036	3,982	27,827	-284	28	-790
Kratie	KH_014901	12,756	3,874	27,319	-186	28	-511

Source data: MRC flow monitoring records

Table 3.3 Changes in observed flows and trends for the main streamflow stations over the period 2000-2017 as percentages

Station	Trend (% per 10 year)		
	Annual	Dry Deason	flood Season
Chiang Saen	-13%	34%	-35%
Luang Prabang	-13%	29%	-27%
Chiang Khan	-5%	30%	-16%
Nong Khai	-13%	15%	-20%
Nakhon Phanom	-18%	8%	-22%
Mukdahan	-8%	23%	-15%
Khong Chiam	-8%	20%	-14%
Pakse	-10%	25%	-18%
Stung Treng	-22%	7%	-28%
Kratie	-15%	7%	-19%

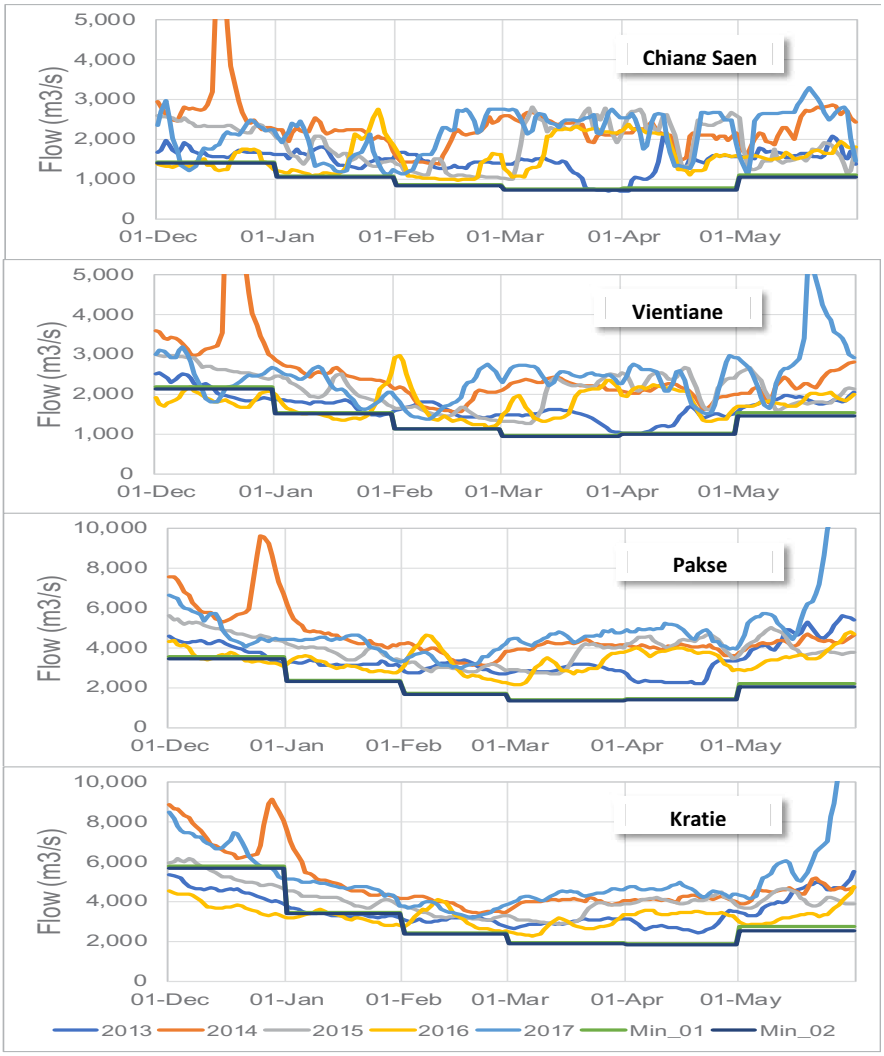
3.2.2 Dry season flow

The PMFM (Procedures for the Maintenance of Flows on the Mainstream) defines three seasons:

- Dry season runs from December to May (6 months)
- Wet season is from June to November (6 months)
- Flood season covers a period from July to October (4 months).

Dry season flow is essential for water supply to people, agriculture, fisheries and nature in the Mekong basin. The dry season is defined in the PMFM running from December to May (six months). The actual definitions of required dry season flows and threshold values have been discussed frequently within the MRC. Countries might use slightly different periods and also some of the PNPCAs use a slightly different definition. However, overall conclusions will not differ when using slightly different season definitions. It was also concluded that not one threshold value should be evaluated but a range based on various statistical analyses. For a select number of locations in the mainstream those minimum flow levels were defined for December to May and observed flows were evaluated against those values.

Figure 3.4 Dry season flow 2013-2017 compared to PMFM minimum flow requirement range



Source data: MRC flow monitoring records. Note the different scale at the y-axes.

Figure 3.4 presents dry season flow for upstream and downstream flow stations for two selected locations along the mainstream over recent years. For both Chiang Saen and Kratie those defined minimum flows are met during most of the dry season and in most years. The most critical months are December and May, especially for the year 2016. Also for other locations (Table 3.4), in most years the PMFM defined minimum flows were maintained except for the relatively dry year 2016. Overall, maintaining low flows is achieved quite satisfactorily and only during some specific dry years are threshold values not met.

An extreme event with high flows during the dry season was observed at Chiang Saen in December 2013. The cause of the extreme event was attributed to abnormal high rainfall in the northern part of the Lower Mekong Basin. This extreme event at Chiang Saen is unique in historically observed records of the Mekong River, at least for December. This high flow event was observed down to Kratie, although it was less pronounced.

Table 3.4 Number of days during the dry seasons of 2013-2017 when flow was below the threshold values as defined in the PMFM

	Days (in 5 years)	
Station	**Severe low flows**	**Low flows**
Chiang Saen	31	37
Vientiane	69	85
Pakse	16	22
Kratie	129	146

Source data: MRC flow monitoring records

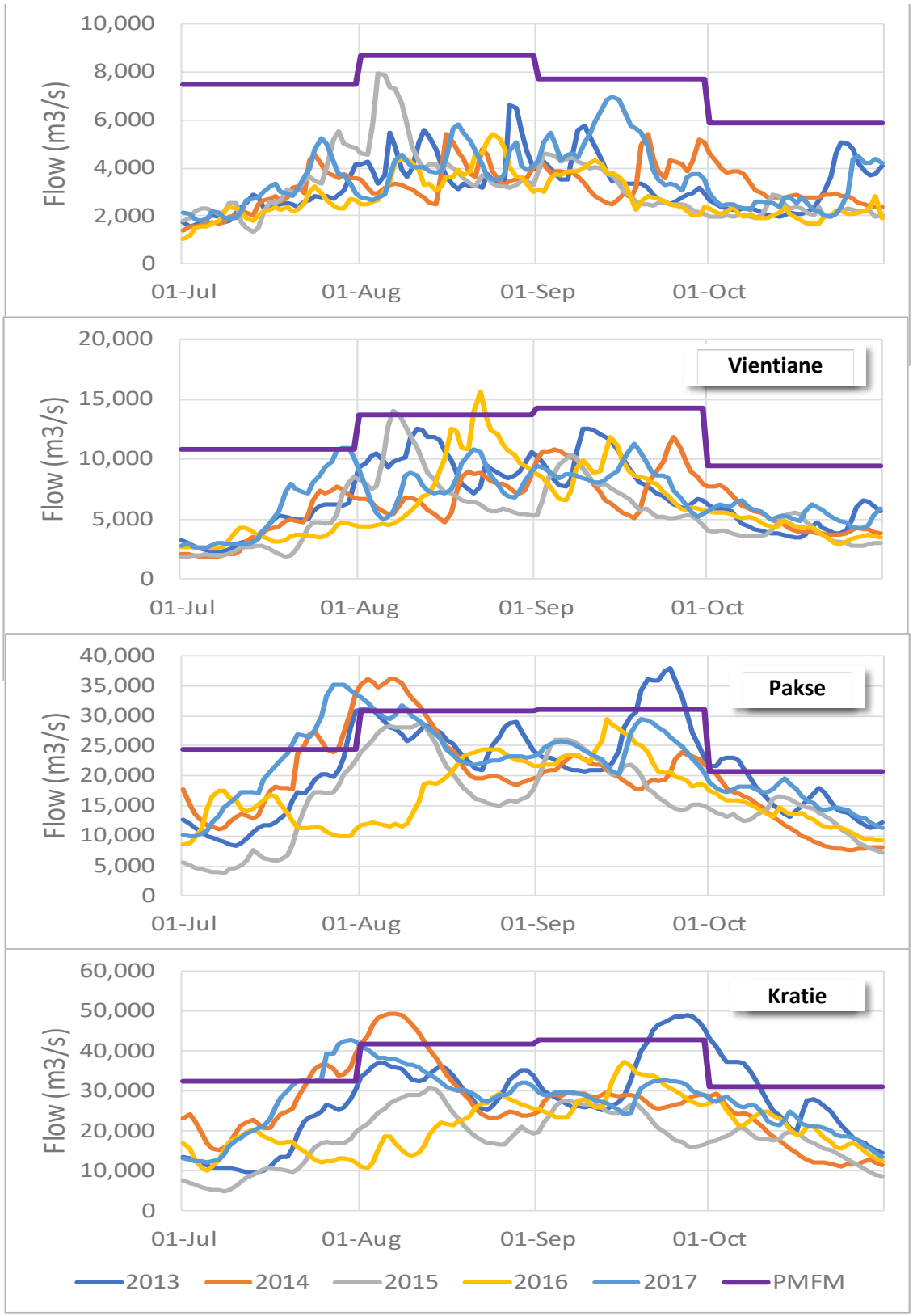
3.2.3 Flood season flow

The flood season runs from July to October (four months) and maximum threshold values that should not be exceeded have been defined for some select mainstream stations as agreed in the PMFM. Daily observed flows of the Mekong mainstream in the flood season were evaluated against those threshold values.

Figure 3.5 demonstrates this methodology for two locations: Chiang Saen and Kratie. At Chiang Sae daily flows since 2013 never exceeded the defined threshold values and only at the beginning of August 2014 were levels close to the thresholds. The same peak is visible at Kratie with a delay of about one week and is much flatter, not exceeding the PMFM threshold values. In 2014 and 2017 at the end of July and beginning of August high flows were measured at Kratie. Since those high flows are not showing up for Chiang Saen, the origin must be in the Lower Mekong catchment areas and caused by high rainfall in the LMB.

For other locations in the mainstream the number of days that flows exceed the PMFM defined threshold values is shown in Table 3.5. For most locations, the number of days is relatively small and on days that those threshold values are exceeded it is only by a relatively small amount.

Figure 3.5 Flood season flows 2013-2017 compared to PMFM average daily peak flow threshold maximum flows



Source data: MRC flow monitoring records. Note the different scale at the y-axes.

Table 3.5 Number of days during the flood seasons of 2013-2017 when flow exceeded threshold values as defined in PMFM

Station	Days (in 5 years) with high flows
Chiang Saen	0
Vientiane	5
Pakse	57
Kratie	49

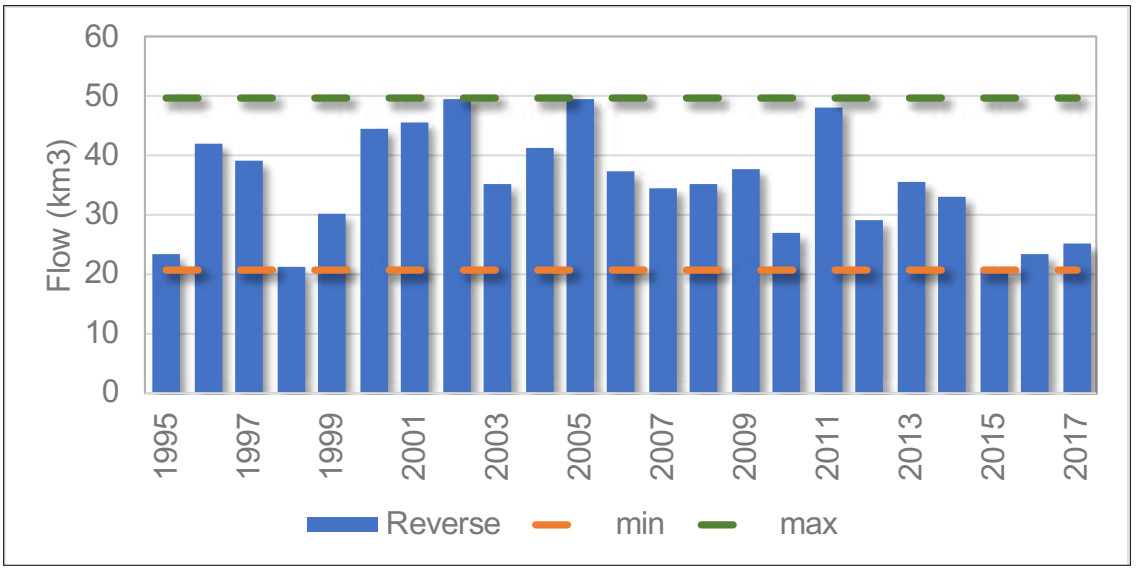
Source data: MRC flow monitoring records.

3.2.4 Tonle Sap reverse flow

The downstream Mekong has a unique hydrologic feature which occurs during the flood season from June to October, when massive floodwater from the Mekong River flows upstream on the Tonle Sap River and into Tonle Sap Lake. When the water level of the Mekong River becomes high in the flood season, water is pushed into the lake (reverse flow), and when the water level of the Mekong River recedes in the dry season, water flows from the lake to the Mekong River (outflow). The water level at Phnom Penh port is an indicator. If it is higher than water level in the lake, the water starts to flow towards to the lake. In November, after the water level in the lake is higher than water level in Phnom Penh Port, it starts to flow back to the Mekong River.

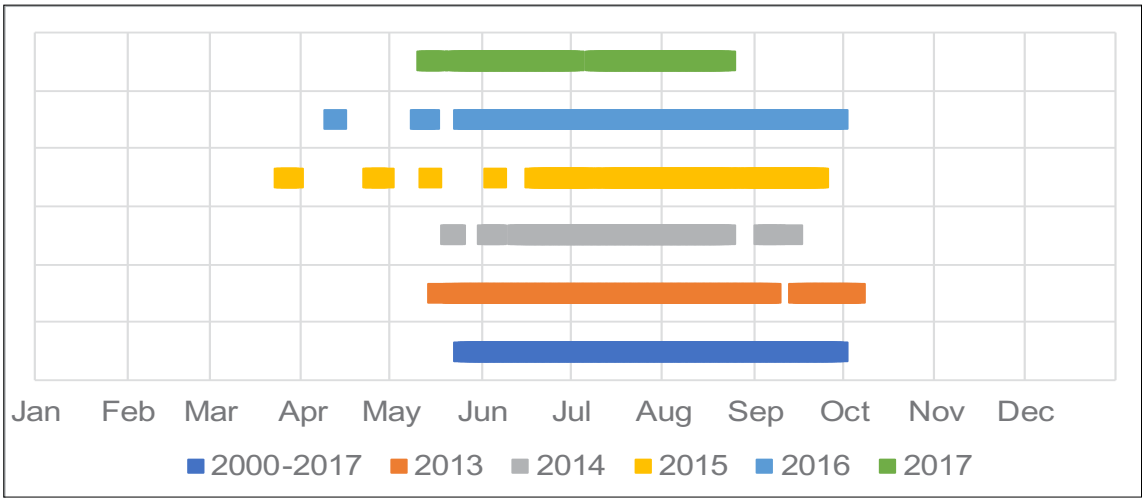
The reverse-flow in the Tonle Sap River is assessed by using discharge measurements from Prek-Kdam station during the years 1995-2017. Prek-Kdam station is regarded as an outlet point of the lake. During 2013-2017, reverse flow volumes were usually falling in between the historical maximum and minimum band of 1995-2017 (Figure 3.6). During the period 2015 to 2017 reverse flows were relatively low with about 9 km^3 lower compared to the long-term average. Timing of reverse flow when water is pushed into the Tonle Sap is an important factor. An early start means more water can be pushed into the lake. Figure 3.7 indicates that the start of the reverse flow has been early over the last five years compared to the long-term average. The end of the reverse flow also tends to be earlier in recent years.

Figure 3.6 Total annual, long-term minimum and maximum volume of reverse flow to Tonle Sap for 1995-2017



Source data: MRC flow monitoring records.

Figure 3.7 Periods of reverse flow to Tonle Sap for the years 2013 to 2017 and the long-term average (2000-2017)



Source data: MRC flow monitoring records.

3.2.5 Timing of onset of wet season flows

The start and end dates of the hydrological wet season vary from year to year. It is defined that the wet season of the Mekong flows begins and ends when discharge rises above and fall below the annual mean discharge. In other words, the wet season is that period of the year when flows are above their long-term annual mean discharge of 1995-2017. For the downstream parts of the Mekong a clear start and end of the wet season can be observed (Figure 3.8). For the upstream parts, e.g. at Chiang Saen, this is less clear as also during the dry season flows above the long-term average occur quite often.

The wet season of 2015 was relatively short with an overall starting date of 15 July and an end before 1 November. In contrast, the wet season of 2017 was long and lasted from about 10 May until 20 November.

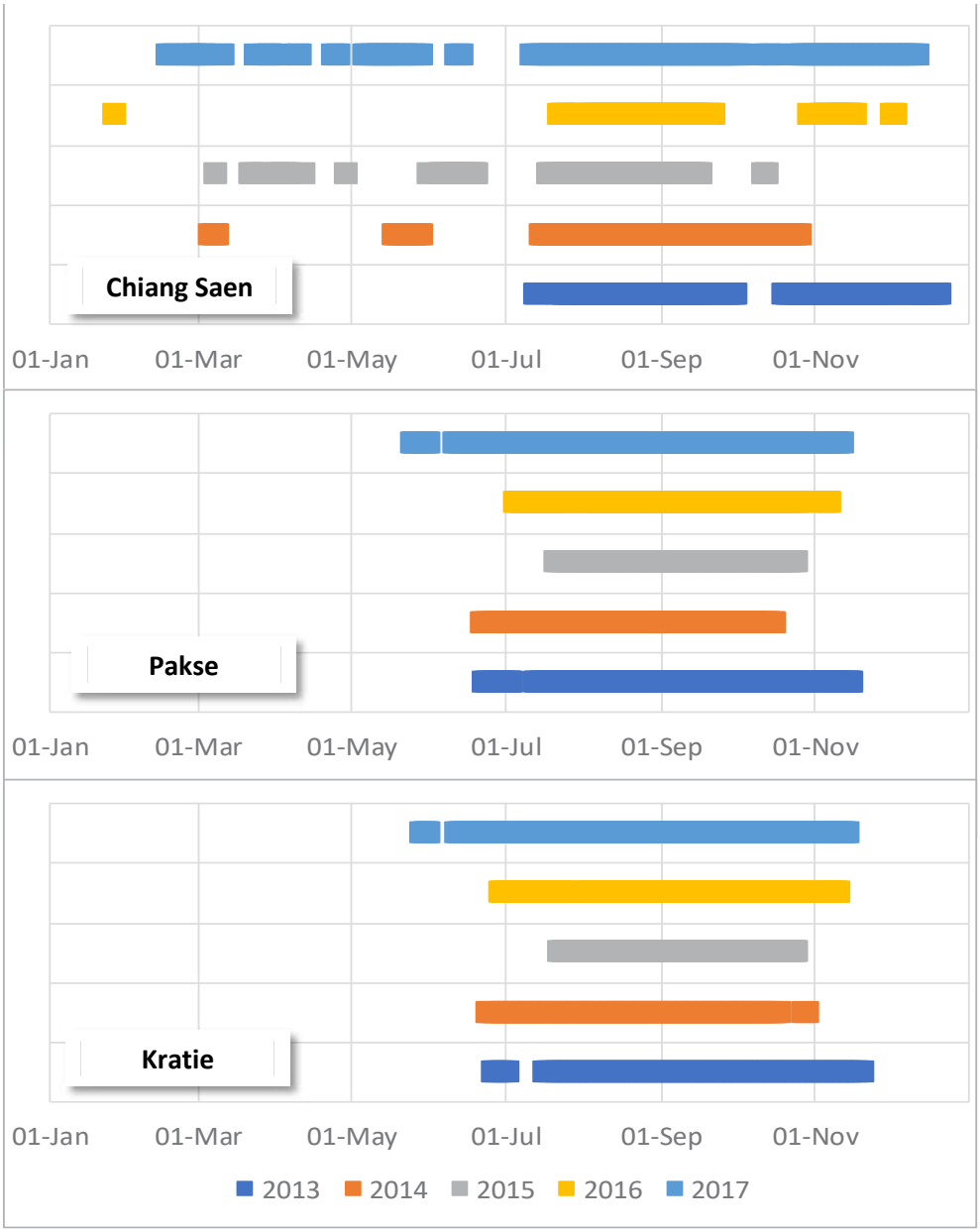
3.2.6 Assessment of water flow conditions

Fast growing economies of the Mekong Region demand extensive water resources development. Although the water resources development enhances regional energy security and agriculture production, it puts direct pressure on the natural flow regime of the Mekong.

Flooding within the Mekong basin is a frequently occurring natural process that brings benefits (such as habitat and migration cues for fish and deposition of nutrient rich sediment on agricultural lands) as well as the negative impacts of flood damage during extreme events. The traditional way of managing floods in the Mekong has been to increase the resilience and adaptability of the population to 'Live with Floods'. Looking to the future though, the combined impacts of climate change and a changing society and infrastructure are increasing the requirements to protect people and assets while managing development by multiple sectors.

The Mekong is a major transboundary river that has a complex hydrological regime driven by yearly rainfall events from different parts of the catchment. The local floodplains play an important role in attenuating the resultant flood waters as they are conveyed downstream. Changes in upstream characteristics can lead to downstream impacts and progressive loss of floodplain throughout the basin is likely to cause higher and more damaging floods.

Figure 3.8 Start and end of the wet seasons defined as flows above the long-term annual average (1995-2017).



Source data: MRC flow monitoring records.

Data available for a comprehensive analysis of flood protection requirements is very sparse at the MRC and there has been a disconnect between the physical hydrology of the main river that has significant data and for example the location and standard of flood protection which is almost totally lacking. The analysis of the need and future cost benefit of flood defence for the corridor can thus only be a first estimate that demonstrates the order of magnitude of the issue and the impact of changes with development (MRC Council Study, 2017).

Based on the analysis against each of the Assessment Indicators in the previous sections the strategic indicator "water flow conditions" can be classified as satisfactory:

(a) **Dry season flows** are reasonably maintained and in general the number of days that do not meet the threshold values as defined in the PMFM are limited to a maximum of 10 days average per year (severe low flows). The threshold for not meeting the more modest low flows threshold happens more frequently and might require specific attention.

(b) **Flood season flows** over recent years did not reach alarming levels.

(c) **Tonle Sap reverse flows** are somewhat lower over recent years compared to the long-term averages. The onset and end of the reverse flow were both 10-20 days earlier.

(d) The **timing of onset of wet season flows** have been quite variable over recent years and the period of wet season flows can vary substantially between years.

3.3 Water quality and sediment conditions

3.3.1 Assessment methodology

The water resources of the Mekong River and its tributaries are a source of drinking water and are essential for agricultural use including for food grain production, fruit and vegetable crops, and riverbank gardens. Good water quality and adequate sediment transport are therefore critical to the health of the Lower Mekong Basin environment, the dependent biological resources and for the protection of human health. Sediment and associated nutrient transport is important for fish populations and the fertility of floodplain soils downstream. The annual flood delivers this nutrient rich sediment to the floodplain where it replenishes fish habitat and feeds future crops.

The **Strategic Indicator** "water quality and sediment conditions" is defined as "the extent to which water quality and sediment conditions have departed from agreed reference points considered necessary for a sustainable environment". The associated assessment indicators for this strategic indicator are:

- Water quality and ecological health
- Changes in sediment transport
- Extent of salinity intrusion in the delta

Each assessment indicator is evaluated using relevant monitoring parameters to inform a judgement about the overall water quality and sediment conditions within the Lower Mekong Basin. Water quality and ecological health monitoring parameters for these **assessment indicators** are obtained from the MRC's Water Quality Monitoring and Ecological Health monitoring programmes. Sediment loads and salinity levels are sourced from hydrological monitoring stations at relevant locations throughout the LMB.

3.3.2 Water quality and ecological health

Preserving the Mekong River's good water quality is essential to secure the health of riverine communities and the future of the river's aquatic life. Recognising that water quality issues are trans-boundary by nature, MRC Member Countries agreed in 2011 to the regional *Procedures for Water Quality* with the objective to maintain good/acceptable water quality and to promote the sustainable development of the Mekong River Basin.

To implement the *Procedures for Water Quality,* MRC Member Countries follow the technical guidelines, which include four chapters:

- Technical Guidelines for the Protection of Human Health
- Technical Guidelines for the Protection of Aquatic Life

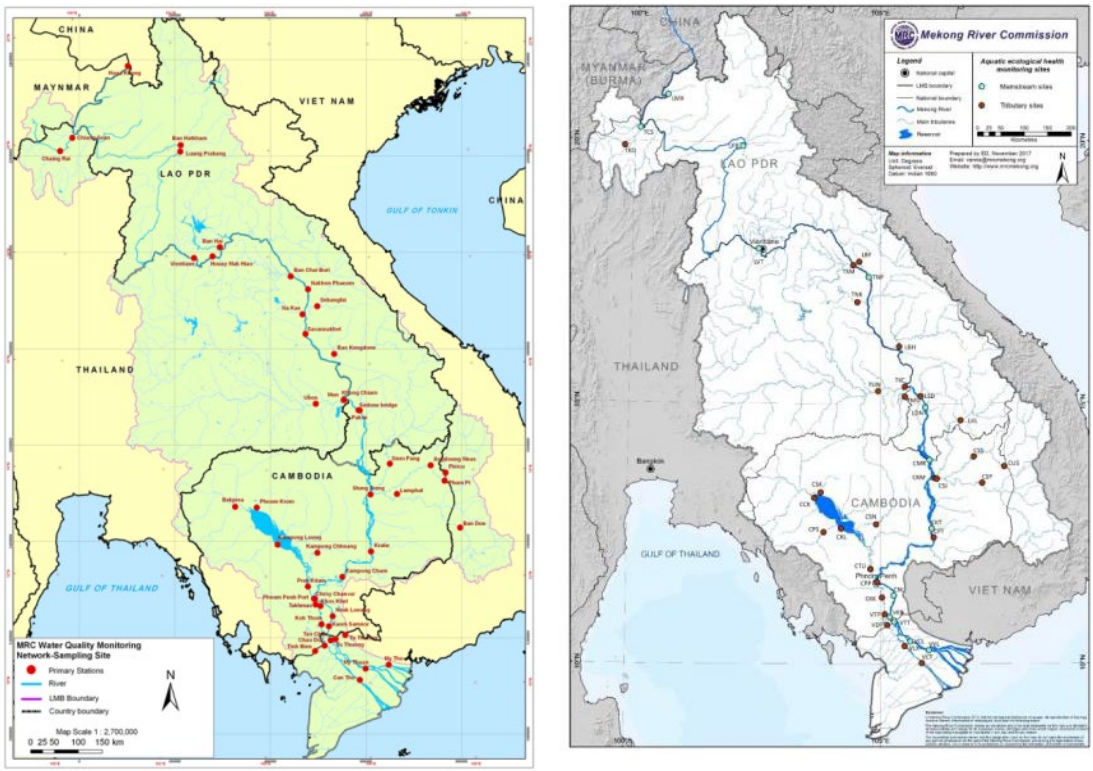
- Technical Guidelines for Water Quality Emergency Response and Management
- Cooperation Framework for Implementation of the Procedures for Water Quality

These Technical Guidelines define the scope, purpose and arrangements for monitoring water quality and the criteria and target values for a range of important monitoring parameters. These target values and their use in calculating three water quality indices (for the protection of human health, the protection of aquatic life, and agricultural use) are the agreed reference points for assessing the water quality component of the strategic indicator.

The Water Quality Monitoring Network (WQMN) was established by three of the Member Countries in 1985, and joined by Cambodia in 1993. The network has provided a continuous record of water quality in the Mekong River and its tributaries since that time. From 2010-2017, the MRC and Member Countries, conducted routine monthly monitoring of water quality of the Mekong River and its tributaries at 48 stations, of which 17 are located in the Mekong River, five are located in the Bassac River and 26 on the Mekong tributaries (Figure 3.10).

The Ecological Health Monitoring (EHM) program was developed between 2003 and 2008 and is undertaken on a biennial basis. There are 41 monitoring locations across the LMB (Figure 3.10) with eight each in Lao PDR, Thailand and Viet Nam, and 17 in Cambodia.

Figure 3.9 Maps of (a) water quality and (b) ecological health monitoring stations on the Mekong and Bassac Rivers and tributaries



Source: MRC Water Quality Monitoring and Ecological Health Monitoring Programmes

(i) *Water quality*

The water quality ratings for the protection of human health, aquatic life and for agricultural use are presented in Table 3.6, Table 3.7 and Table 3.8 respectively. Between 2010 and 2017, water quality for the protection of human health was almost always good or very good. Only a few stations had on occasion a rating less than this, in 2010 and 2014. For the last three years, the average across all stations was very good.

Table 3.6 Water quality ratings using the index for the protection of human health

No.	Station Names	Rivers	Countries	2010	2011	2012	2013	2014	2015	2016	2017
1	Houa Khong	Mekong	Lao PDR	B	A	B	B	C	A	A	B
2	Chiang Saen	Mekong	Thailand	B	A	B	B	B	B	B	B
3	Luang Prabang	Mekong	Lao PDR	B	A	B	A	B	B	B	A
4	Vientiane	Mekong	Lao PDR	B	A	B	B	B	B	B	A
5	Nakhon Phanom	Mekong	Thailand	B	B	B	B	B	B	B	B
6	Savannakhet	Mekong	Lao PDR	A	A	B	B	C	B	B	B
7	Khong Chiam	Mekong	Thailand	B	A	B	B	B	B	B	B
8	Pakse	Mekong	Lao PDR	A	A	A	B	A	B	B	A
9	Stung Trieng	Mekong	Cambodia	A	A	A	A	A	A	A	A
10	Kratie	Mekong	Cambodia	A	A	A	A	A	A	A	A
11	Kampong Cham	Mekong	Cambodia	A	A	A	A	A	B	A	A
12	Chrouy Changvar	Mekong	Cambodia	A	A	A	A	A	A	A	A
13	Neak Loung	Mekong	Cambodia	A	A	A	A	A	B	A	A
14	Krom Samnor	Mekong	Cambodia	A	A	B	A	A	B	A	A
15	Tan Chau	Mekong	Viet Nam	B	B	A	A	A	A	A	A
16	My Thuan	Mekong	Viet Nam	C	A	A	B	A	A	A	B
17	My Tho	Mekong	Viet Nam	C	B	B	B	B	A	B	B
18	Takhmao	Bassac	Cambodia	A	A	A	B	C	A	B	A
19	Koh Khel	Bassac	Cambodia	B	A	B	B	A	B	A	A
20	Koh Thom	Bassac	Cambodia	A	A	B	B	A	A	A	A
21	Chau Doc	Bassac	Viet Nam	C	B	B	A	A	A	A	B
22	Can Tho	Bassac	Viet Nam	C	B	A	A	A	A	A	A
AVERAGE				B	A	B	B	B	A	A	A

Source: MRC Water Quality Monitoring programme data

Legend:

A: High Quality	All measurements are within objectives virtually all of the time
B: Good Quality	Conditions rarely depart from desirable levels
C: Moderate Quality	Conditions sometimes depart from desirable level
D: Poor Quality	Conditions often depart from desirable level
E: Very Poor quality	Conditions usually depart from desirable level

Between 2010 and 2017, only one monitoring station, My Tho in Viet Nam, consistently had a rating for the protection of aquatic life below good quality. Apart from Can Tho between 2010 and 2013, all other stations had at least good quality, with the number of stations with very good quality increasing substantially in 2016 and 2017 (Table 3.7). The average rating across all stations has been good in every year since 2010. The consistently lower rating for the My Tho station was due to a failure to meet the water quality targets for total phosphorous and total nitrite and nitrate.

Table 3.7 Water quality ratings using the index for the protection of aquatic life

No.	Station Names	Rivers	Countries	2010	2011	2012	2013	2014	2015	2016	2017
1	Houa Khong	Mekong	Lao PDR	A	A	B	B	B	B	B	B
2	Chiang Saen	Mekong	Thailand	B	A	B	B	A	B	B	B
3	Luang Prabang	Mekong	Lao PDR	B	A	A	B	B	B	A	B
4	Vientiane	Mekong	Lao PDR	A	A	A	B	B	A	A	A
5	Nakhon Phanom	Mekong	Thailand	B	A	B	B	A	A	B	B
6	Savannakhet	Mekong	Lao PDR	A	A	A	B	B	B	A	A
7	Khong Chiam	Mekong	Thailand	A	A	A	B	A	A	A	B
8	Pakse	Mekong	Lao PDR	A	A	A	B	B	B	A	A
9	Stung Trieng	Mekong	Cambodia	B	B	B	B	B	B	B	A
10	Kratie	Mekong	Cambodia	B	B	B	B	B	B	A	B
11	Kampong Cham	Mekong	Cambodia	B	B	B	B	A	B	A	A
12	Chrouy Changvar	Mekong	Cambodia	B	B	B	B	B	B	A	A
13	Neak Loung	Mekong	Cambodia	B	B	B	B	B	B	A	A
14	Krom Samnor	Mekong	Cambodia	B	B	B	B	B	B	A	A
15	Tan Chau	Mekong	Viet Nam	B	B	B	B	B	B	B	A
16	My Thuan	Mekong	Viet Nam	B	B	B	B	B	B	B	B
17	My Tho	Mekong	Viet Nam	C	C	B	C	C	C	D	C
18	Takhmao	Bassac	Cambodia	B	B	B	B	B	B	B	B
19	Koh Khel	Bassac	Cambodia	B	B	B	B	B	B	B	B
20	Koh Thom	Bassac	Cambodia	B	B	B	B	A	B	B	B
21	Chau Doc	Bassac	Viet Nam	B	B	B	B	B	B	B	B
22	Can Tho	Bassac	Viet Nam	C	C	C	C	B	B	B	B
AVERAGE				B	B	B	B	B	B	B	B

Source: MRC Water Quality Monitoring programme data

Legend:

A: High Quality	All measurements are within objectives virtually all of the time
B: Good Quality	Conditions rarely depart from desirable levels
C: Moderate Quality	Conditions sometimes depart from desirable level
D: Poor Quality	Conditions often depart from desirable level
E: Very Poor quality	Conditions usually depart from desirable level

Between 2010 and 2017, only one monitoring station, again My Tho in Viet Nam, has ever recorded less than 'no consequence for agricultural use' based on electrical conductivity, with a rating of 'some consequence' in 2016. All other stations recorded 'no consequence for agricultural use' in all years (Table 3.8). The average rating across all years since 2010 was no consequence for agricultural use. For the individual water quality monitoring parameters, pH, dissolved oxygen levels, and chemical oxygen demand across all years since 2010 were good, only rarely exceeding the thresholds used in the calculation of the index for the protection of aquatic life and human health. There was no

apparent trend over time in any of these parameters across the Mekong water quality network. One extreme reading of COD, approximately ten times the threshold occurred at Vientiane, Lao PDR in 2014 although the cause of this reading is not clear.

Table 3.8 Water quality ratings for agricultural use

No.	Station Names	Rivers	Countries	2010	2011	2012	2013	2014	2015	2016	2017
1	Houa Khong	Mekong	Lao PDR	A	A	A	A	A	A	A	A
2	Chiang Saen	Mekong	Thailand	A	A	A	A	A	A	A	A
3	Luang Prabang	Mekong	Lao PDR	A	A	A	A	A	A	A	A
4	Vientiane	Mekong	Lao PDR	A	A	A	A	A	A	A	A
5	Nakhon Phanom	Mekong	Thailand	A	A	A	A	A	A	A	A
6	Savannakhet	Mekong	Lao PDR	A	A	A	A	A	A	A	A
7	Khong Chiam	Mekong	Thailand	A	A	A	A	A	A	A	A
8	Pakse	Mekong	Lao PDR	A	A	A	A	A	A	A	A
9	Stung Trieng	Mekong	Cambodia	A	A	A	A	A	A	A	A
10	Kratie	Mekong	Cambodia	A	A	A	A	A	A	A	A
11	Kampong Cham	Mekong	Cambodia	A	A	A	A	A	A	A	A
12	Chrouy Changvar	Mekong	Cambodia	A	A	A	A	A	A	A	A
13	Neak Loung	Mekong	Cambodia	A	A	A	A	A	A	A	A
14	Krom Samnor	Mekong	Cambodia	A	A	A	A	A	A	A	A
15	Tan Chau	Mekong	Viet Nam	A	A	A	A	A	A	A	A
16	My Thuan	Mekong	Viet Nam	A	A	A	A	A	A	A	A
17	My Tho	Mekong	Viet Nam	A	A	A	A	A	A	B	A
18	Takhmao	Bassac	Cambodia	A	A	A	A	A	A	A	A
19	Koh Khel	Bassac	Cambodia	A	A	A	A	A	A	A	A
20	Koh Thom	Bassac	Cambodia	A	A	A	A	A	A	A	A
21	Chau Doc	Bassac	Viet Nam	A	A	A	A	A	A	A	A
22	Can Tho	Bassac	Viet Nam	A	A	A	A	A	A	A	A
AVERAGE				A	A	A	A	A	A	A	A

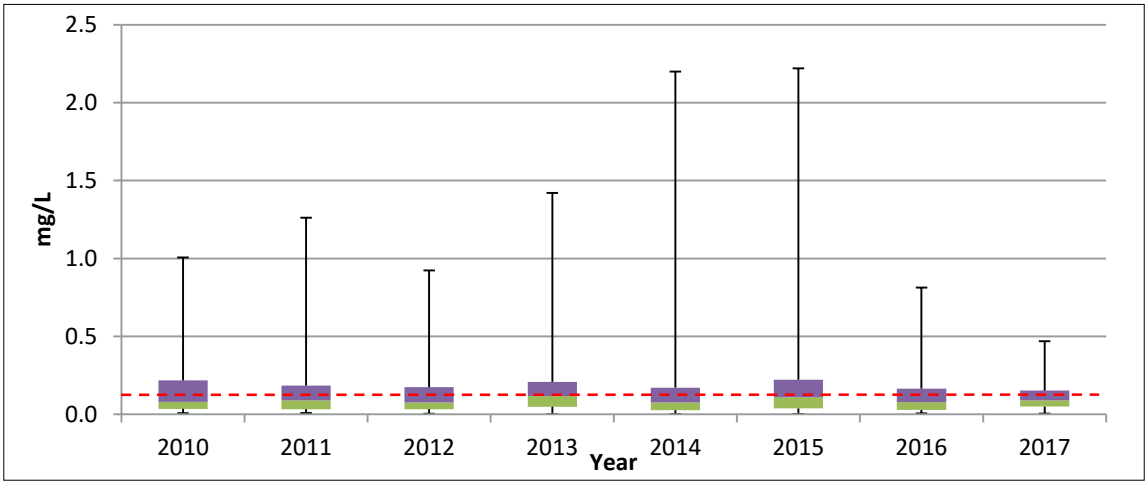
Source: MRC Water Quality Monitoring programme data

Legend:

		Degree of Consequence		
Irrigation Raw Water	**Unit**	**None (A)**	**Some (B)**	**Severe (A)**
Electrical Conductivity				
General Irrigation	mS/m	<70	70-300	>300
Paddy Rice	mS/m	<200	200-480	>480

Total Phosphorous levels across all years since 2010 were generally good, although frequently exceeded the threshold used in the calculation of the index for the protection of aquatic life. Stations with a median reading above that threshold (0.13) in 2017 were Chiang Rai in Thailand, and Back Prea, Phnom Krom, and Kampong Loung around Tonle Sap in Cambodia. There is no apparent trend over time in Total Phosphorous levels across the Mekong water quality network (Figure 3.10).

Figure 3.10 Average annual Total Phosphorous across all water quality monitoring stations in the Lower Mekong Basin.

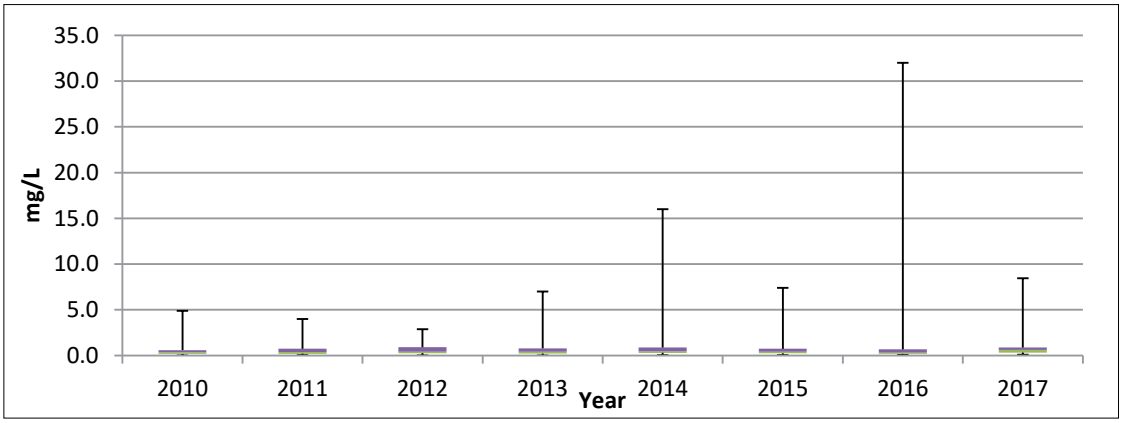


Dashed red lines indicates the threshold used in the calculation of the index for the protection of aquatic life (0.13).

Source: MRC Water Quality Monitoring programme data

Total Nitrogen levels across all years since 2010 were generally good, with an average of median readings across all years of 0.4 mg/L. Stations with the highest median readings in 2017 were Houa Khong and Pakse in Lao PDR, and Ban Don and My Tho in Viet Nam. There is no apparent trend over time in Total Nitrogen levels across the Mekong water quality network (Figure 3.11).

Figure 3.11 Average annual Total Nitrogen across all water quality monitoring stations in the Lower Mekong Basin.



Source: MRC Water Quality Monitoring programme data

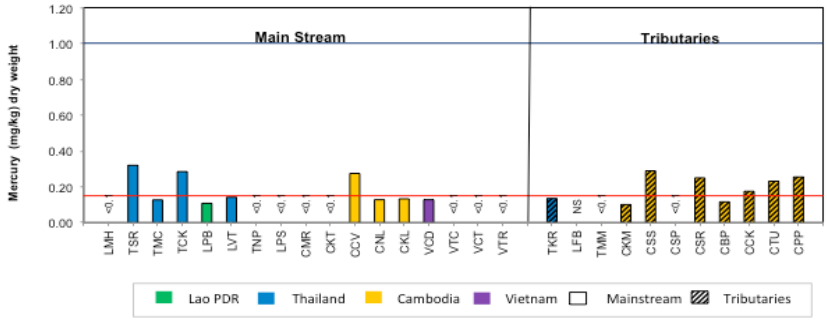
Biological Oxygen Demand has only been recorded in one year since 2010 and at half of the 48 monitoring stations across the LMB. Only one reading in that year, 2017, was above the threshold for the protection of human health, at Thong Binh on the Cai Cai River in Viet Nam.

Total Suspended Solids across all years since 2010 were recorded with an average of median readings across all years of 45 mg/L. Stations with the highest median readings in 2017 were Houa Khong, Vientiane, Savannaket, Bankengdone, and Pakse in Lao PDR, and Phnom Krom, Back Prea and Kampong Cham in Cambodia. There is no apparent trend since 2010 in Total Suspended Solids across the Mekong water quality network, although in the last two years a small number of extreme readings (>1,500 mg/L) have been recorded in May of each year at Phnom Krom and Kampong Cham and would merit further investigation.

Electrical conductivity across all years since 2010 was good, only rarely exceeding the thresholds used in the calculation of the index for the protection of human health and aquatic life and for having consequences for paddy rice and general irrigation. There is no apparent trend over time in Electrical Conductivity across the Mekong water quality network although in the last two years a small number of very high readings (>200 mS/m) have been recorded at Houa Khong in Lao PDR, at Chiang Rai in Thailand and My Tho in Viet Nam. Again, further investigation as to the cause of these readings would be useful.

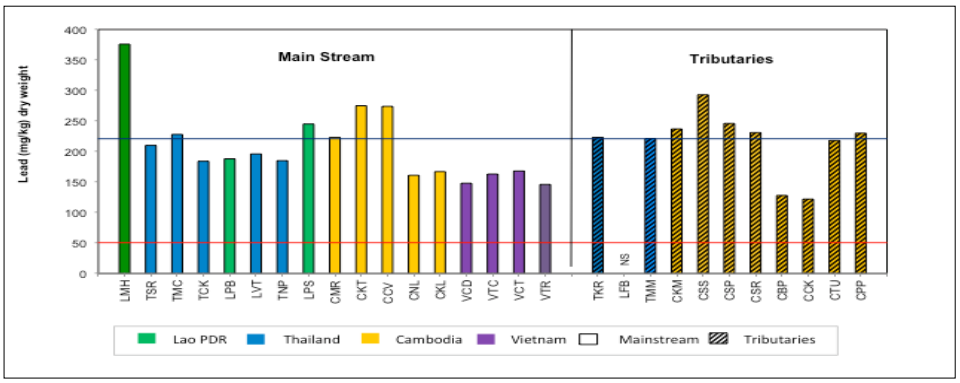
Heavy metal concentrations are not routinely collected as part of the MRC Water Quality Monitoring Programme. However, among the toxic pollutants measured in 2011 as part of the MRC's multi-media monitoring and assessment program (MRC, 2014), mercury (Hg) and lead (Pb) were those of greatest concern. Although mercury levels in water generally were low, the MRC's multi-media monitoring and assessment program identified that sediment mercury levels at many stations exceeded the ANZECC upland sediment quality criteria (Figure 3.12 and Figure 3.13)[10]. Mercury was also the only heavy metal that was found in much higher levels in fish compared to sediments, indicating bio-accumulation of this metal. Mercury levels in fish could be of concern for human health if levels increase. Studies indicate that mercury in the Mekong River is of anthropogenic origin but further investigation is needed to identify the likely sources.

Figure 3.12 Comparison of Mercury (Hg) levels in sediment in the mainstream and tributaries (MRC, 2014)



Source: MRC, 2014. Horizontal red and blue lines indicate ANZECC upland and lowland river thresholds, respectively

Figure 3.13 Comparison of Lead (Pb) levels in sediment in the mainstream and tributaries (MRC, 2014)



Source: MRC, 2014. Horizontal red and blue lines indicate ANZECC upland and lowland river thresholds, respectively

10 Note that the MRC's multi-media monitoring and assessment program did not explicitly evaluate the suitability of ANZECC water guidelines in the Mekong River context and so these levels are provided for reference purposes only.

Lead in sediment exceeded the lower ANZECC quality criteria of 50 mg/kg dry weight at all monitoring station in the 2011 multi-media assessment program, and exceeded the higher criterion of 220 mg/kg dry weight at half. Compared to other studies the lead levels in water were high. Similar to mercury, the lead seems to be of anthropogenic origin but further studies are needed to identify potential sources and the distribution of lead in the Mekong River environment. Concentrations of other heavy metals did not exceed the lower ANZECC quality criteria of 50 mg/kg, and seem to mainly originate from natural sources such as rock and soil.

Faecal coliforms were recorded at 34 of the 48 monitoring stations between 2010 and 2017. In many cases levels were extreme with the Most Probable Number (MPN) of total colforms per 100 ml being well over the 2.2 per 100 ml recommended by the World Health Organisation for re-use in drinking water. Levels were highest around Tonle Sap and the lower Mekong and Bassac Rivers in Cambodia with median levels 20 and 30 times the World Health Organisation's recommended levels for wastewater use in agriculture (1000MPN/100ml), which is the interim target value for the protection of human health in the MRC's Technical Guidelines for the Implementation of the Procedures for Water Quality.

The water quality criteria for Total Organochlorine Pesticides used in the 2011 multi-media assessment program for the protection of aquatic life and human health was 0.05 mg/L. However, for all parameters the level of pesticides was below the detection level of the methods used in the study (Table 3.9). That was also the case in relation to detection in fish, indicating the health risk to consumers of fish is low and at a safe level. Cyanide concentrations can also be an indicator of fertiliser use. Concentrations from stations in the mainstream and tributaries were below the interim target values for the protection of human health and aquatic life. However, concentrations at a few stations located in upper tributaries exceeded these values. These were all in Thailand in areas containing plantations.

Table 3.9 Range (minimum – maximum) and average (± s.d.) of dissolved organic micro pollutants in the Mekong River mainstream and tributaries (MRC,2014)

Parameter	Total PCB (µg/L)	Hexachloro benzene (HCB)(µg/L)	Total Organochlorine Pesticide										Toxic Substances	
			p, p' -DDT (µg/L)	p, p' -DDE (µg/L)	p, p' -DDD (µg/L)	Endrin Aldehyde (µg/L)	Endosulfan Sulfate (µg/L)	Heptachlor (µg/L)	Heptachlor Epoxide (µg/L)	α-Hexachloro Cyclohaxane (µg/L)	γ-Hexachloro Cyclohaxane (µg/L)	Chlordane (CHL) (µg/L)	Cyanide (CN) (mg/L)	Phenols (mg/L)
THIS STUDY														
Mekong River Mainstream														
Min – Max	<0.15	<0.02	<0.012	<0.008	<0.012	<0.012	<0.012	<0.004	<0.004	<0.004	<0.004	<0.1	<0.001-0.014	<0.001-0.011
Avg ± SD	<0.15	<0.02	<0.012	<0.008	<0.012	<0.012	<0.012	<0.004	<0.004	<0.004	<0.004	<0.1	0.0025±0.004	0.0044±0.003
Tributaries														
Min – Max	<0.15	<0.02	<0.012	<0.008	<0.012	<0.012	<0.012	<0.004	<0.004	<0.004	<0.004	<0.1	<0.001-0.007	<0.001-0.009
Avg ± SD	<0.15	<0.02	<0.012	<0.008	<0.012	<0.012	<0.012	<0.004	<0.004	<0.004	<0.004	<0.1	0.003±0.003	0.005±0.004
WATER QUALITY STANDARD														
WQCA	-	-	-	-	-	-	-	-	-	-	-	-	0.005	0.005
WQCH	-	-	-	-	-	-	-	-	-	-	-	-	0.01	0.005

(ii) *Ecological health*

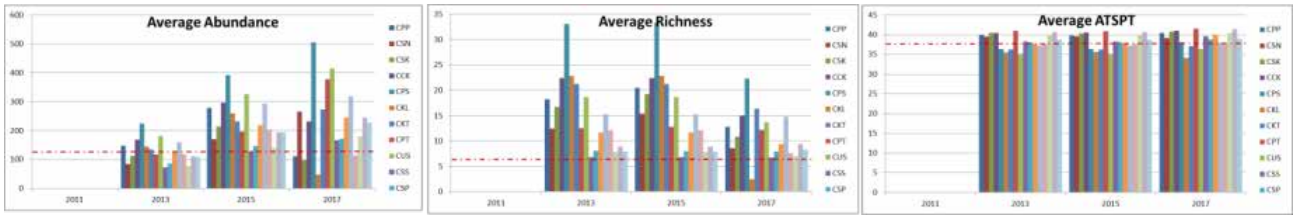
Three metrics of the health of the Mekong aquatic ecosystem are calculated for each of four groups of organisms considered to be effective indicators of the health of the aquatic environment: benthic diatoms, zooplankton, littoral macroinvertebrates and benthic macroinvertebrates. The metrics used are: average abundance, average richness and Average Tolerance Score Per Taxon (ATSPT). A healthy ecosystem is indicated by high abundance, high average richness, and low ATSPT. Each metric is calculated for individual samples of each group of organisms.

Diatoms

The average abundance of diatoms increased across all stations in Viet Nam, and over most stations in Cambodia between 2011 and 2017, with no obvious trend in Lao PDR and Thailand (Figure 3.14). Average species richness appears to have declined in Cambodia while increasing in Thailand and Viet Nam. Only one station (in Cambodia) recorded average richness below the target value in 2017. The Average Tolerance Score Per Taxon (ATSPT) at each monitoring station appears to be relatively stable in Cambodia and Viet Nam but has increased substantially at a number of stations in Lao PDR. In 2017, only two stations achieved an ATSPT score below the threshold, both in Cambodia.

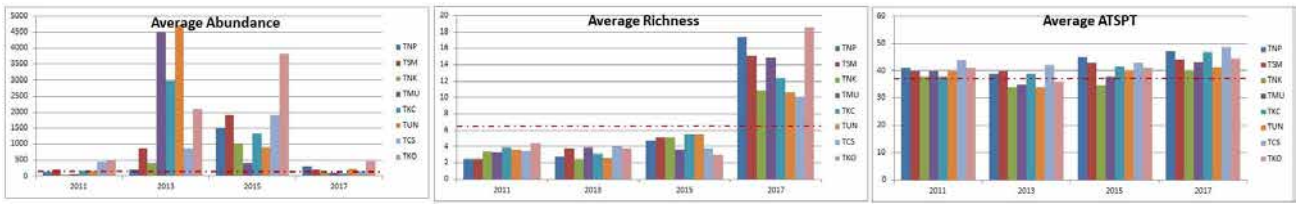
Figure 3.14 Average abundance, average richness and average tolerance score per taxon for Diatoms at each monitoring station in each country.

Cambodia

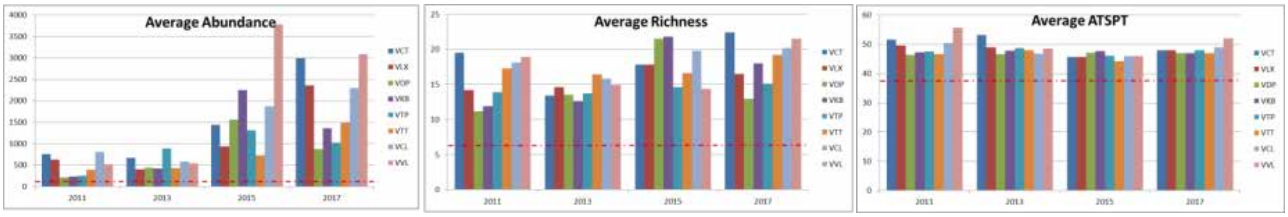


Lao PDR

Thailand



Viet Nam



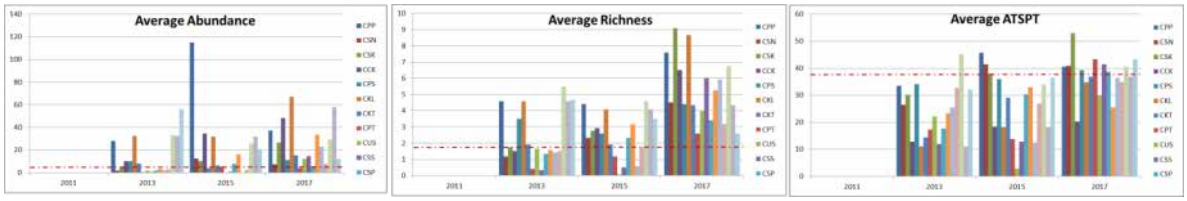
Source: MRC Ecological Health Monitoring programme data

Benthic macroinvertebrates

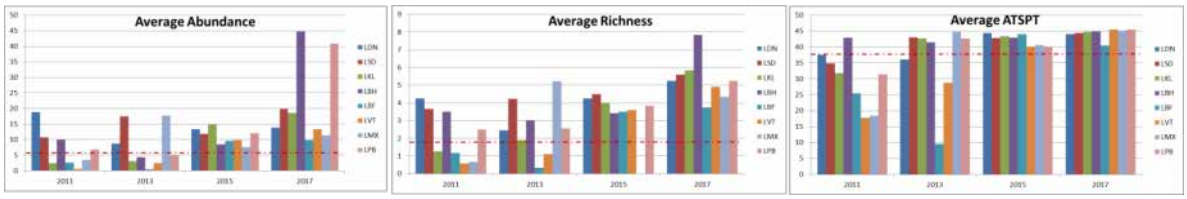
The average abundance of benthic macroinvertebrates appears to have increased across Cambodia and Lao PDR between 2011 and 2017, with no obvious trend in Thailand and Viet Nam (Figure 3.15). Average species richness appears to have increased across all countries except Viet Nam. Only one station (in Viet Nam) recorded average richness below the target value in 2017. The Average Tolerance Score Per Taxon (ATSPT) at each monitoring station appears to be increasing in Cambodia, Lao PDR and Thailand but has not changed substantially in Viet Nam. Between 2013 and 2015 ATSPT increased substantially in both Lao PDR and Thailand. In 2017, only eight stations achieved an ATSPT score below the threshold, all in Cambodia.

Figure 3.15 Average abundance, average richness and average tolerance score per taxon for benthic macroinvertebrates at each monitoring station in each country

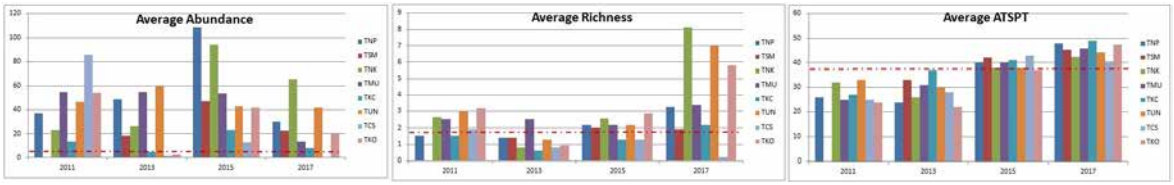
Cambodia



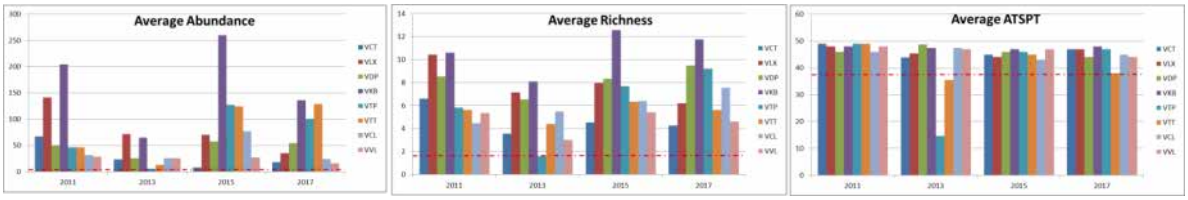
Lao PDR



Thailand



Viet Nam



Source: MRC Ecological Health Monitoring programme data

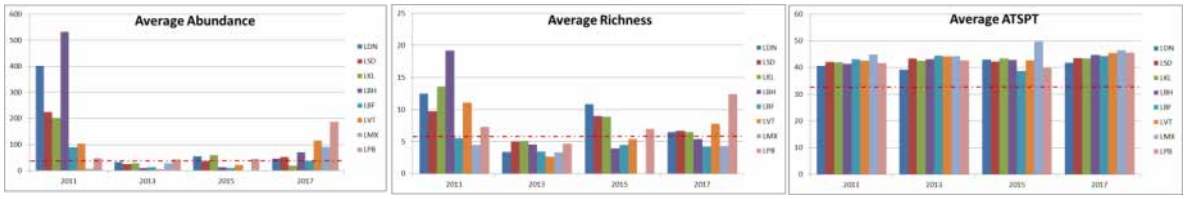
Littoral macroinvertebrates

The average abundance of littoral macroinvertebrates appears to have increased in Cambodia between 2011 and 2017 with no obvious trends in the other countries (Figure 3.16). Average species richness appears to have increased in Cambodia and Thailand but with no obvious trend in the other two countries. Eight stations recorded average richness below the target value in 2017. The Average Tolerance Score Per Taxon (ATSPT) appears to be increasing across all monitoring stations in each country. In 2017, no stations achieved an ATSPT score below the threshold.

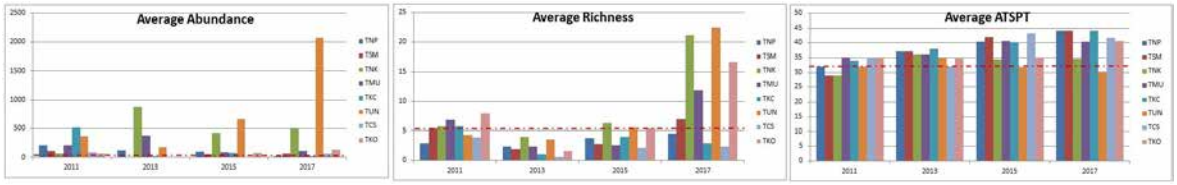
Figure 3.16 Average abundance, average richness and average tolerance score per taxon for littoral macroinvertebrates at each monitoring station in each country.

Cambodia

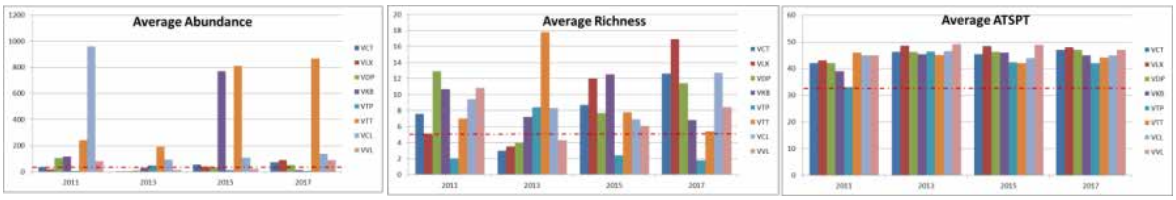
Lao PDR



Thailand



Viet Nam



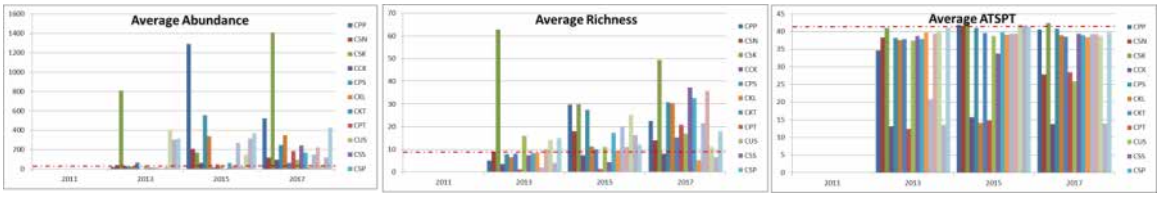
Source: MRC Ecological Health Monitoring programme data

Zooplankton

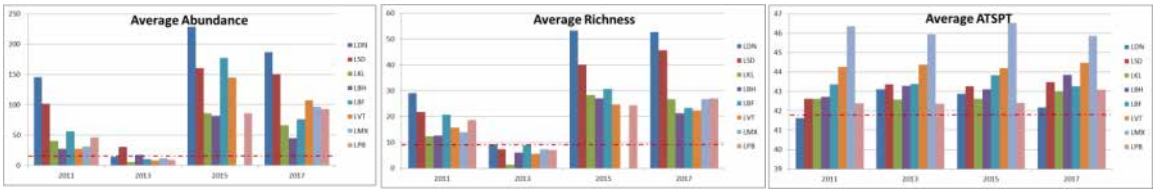
The average abundance of zooplankton appears to have increased in Cambodia and Lao PDR and decreased in Thailand between 2011 and 2017 with one station in Viet Nam recording an extreme increase in 2017 relative to earlier years (Figure 3.17). Average species richness appears to have increased in Cambodia, Lao PDR and Viet Nam but with no obvious trend Thailand. Seven stations recorded average richness below the target value in 2017, three in Cambodia and four in Thailand. The Average Tolerance Score Per Taxon (ATSPT) appears to be relatively stable across all stations and countries. In 2017, Cambodia achieved an ATSPT score below the threshold for all stations except one, while in Lao PDR and Viet Nam all stations had ATSPT scores above the threshold.

Figure 3.17 Average abundance, average richness and average tolerance score per taxon for zooplankton at each monitoring station in each country.

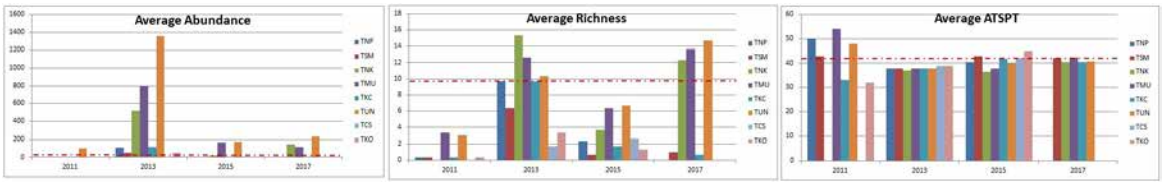
Cambodia



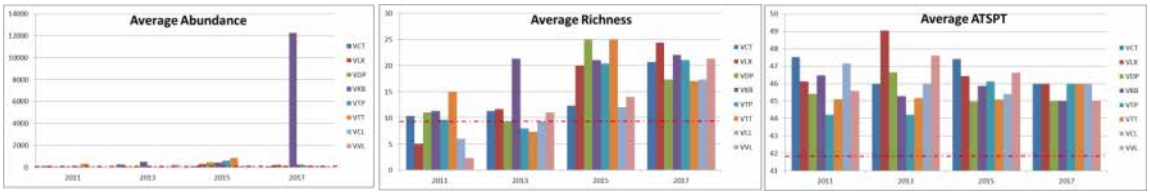
Lao PDR



Thailand



Viet Nam

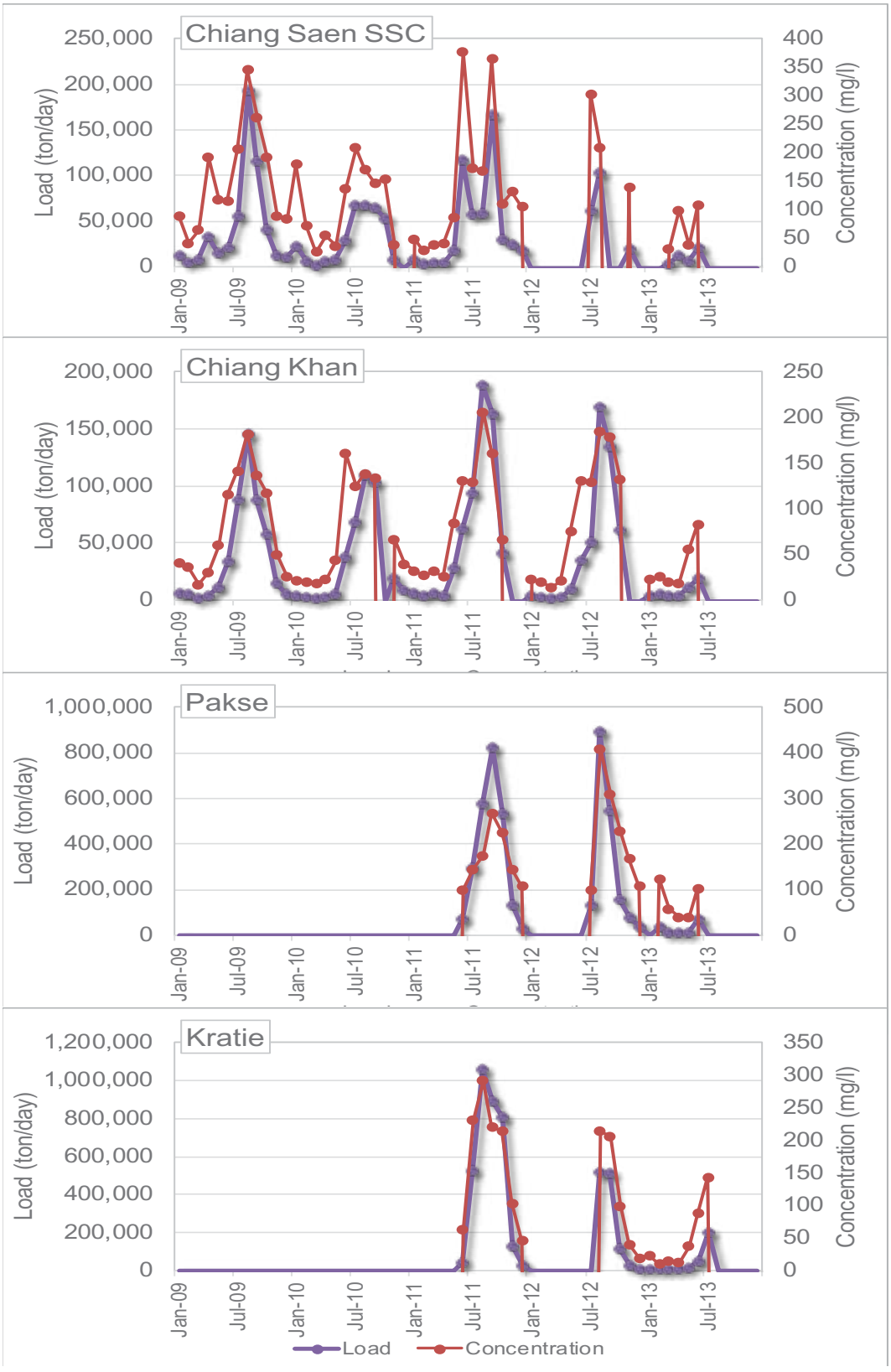


Source: MRC Ecological Health Monitoring programme data

3.3.3 Sediment transport

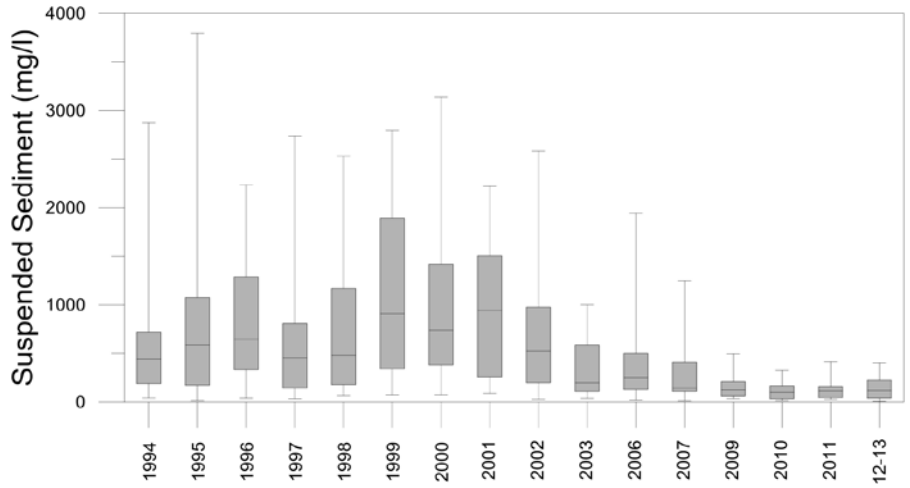
Sediments provide both nutrients and building materials, beneficial for the ecology and development respectively of the Mekong basin, but can also have negative impacts on navigation and water use. Sediment concentrations are difficult to measure and vary substantially in time and place. Suspended sediment concentrations and river flow at four stations are shown in Figure 3.18 using data from the MRC Discharge Sediment Monitoring Project (DSMP) project. A longer time-series from the same source at Chaeng Saen is given in Figure 3.19 for the period 1994 to 2013. It is clear that the concentration and the variability of suspended sediment have decreased considerably since 2001. Before that average concentrations were often above 500 mg/l, the globally accepted standard for drinking water.

Figure 3.18 Suspended sediment concentrations 2009-2013



Source: MRC Discharge Sediment Monitoring Project. Note: Axis scale differs for each station

Figure 3.19 Suspended sediment concentrations at Chiang Saen 1994-2013



Source: MRC Discharge Sediment Monitoring Project

Comparing current sediment loads with historical records show that the average annual suspended sediment load measured at the most upstream site (Chiang Saen) has decreased from about 85 Mt/yr to 10.8 Mt/yr. Suspended sediment inflow from China now accounts for about 16% of all sediments in the LMB as compared to about 55% historically. Downstream (at Pakse) average loads have decreased from 147 Mt/yr to 66 Mt/yr.

An extensive bed material survey was conducted in 2011. The grain-size distribution of bed material reflected the flow regime at the time of collection, with fine material present at sites during low flow, and coarser material present during the wet season. In terms of spatial distribution the bed materials generally showed a reduction in grain size in a downstream direction, with the percentage of gravels decreasing and percentage of silts increasing. Bedload composition was dominated by gravel, pebbles and coarse sand at Chiang Saen, fine and medium sand at Nong Khai, and coarse to fine sand at Kratie.

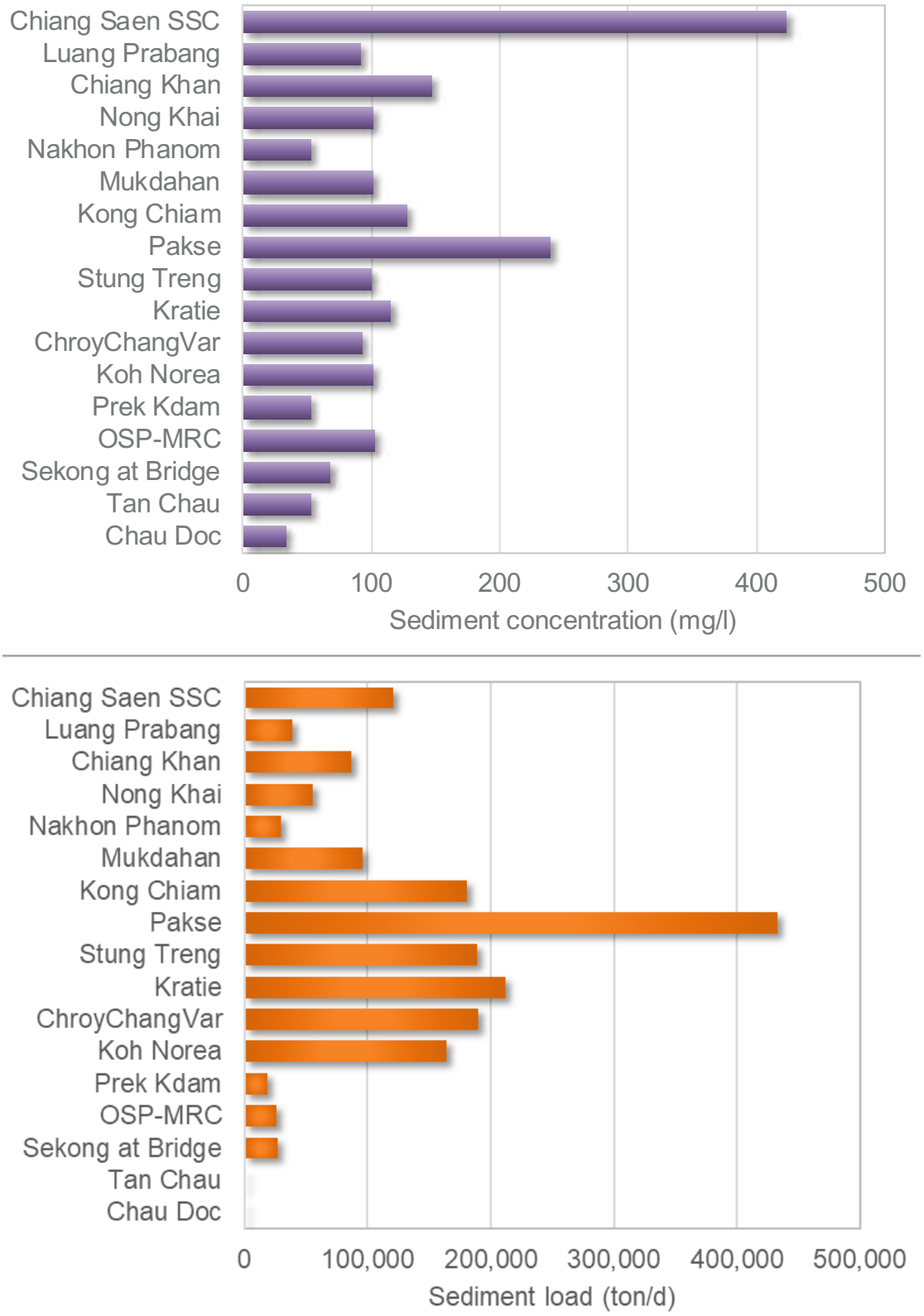
Bedload monitoring program is currently in place for 17 stations. Five to ten bedload samples are collected from each site up to 17 times per year, with the sampler deployed at each point for 1 minute. Monitoring results are summarised for the years 2014 and 2015 in Figure 3.20. It is clear that upstream higher sediment concentrations are monitored, while highest sediment load (in tonnes per day) are at Pakse.

3.3.4 Salinity intrusion in the Delta

Salt water intrusion in the lower Mekong delta is known to extend more than 50 km inland during the dry season and close to 2 million ha of land are affected by this. Salinity is a serious constraint to agriculture and rice yields are negatively affected by high salinity levels.

For the Water Quality Index for agricultural use in the Mekong Delta the following yield depression figures are applied for irrigated paddy rice: conductivity < 200 mS/m no yield reduction; conductivity between 200 and 480 mS/m: yield reduction of 10 to 50%; and conductivity > 480 mS/m: yield reduced by more than 50%. Figure 3.21 shows that especially during 2010, 2016 and 2017 average salinity levels for some sections in the mainstream are very high, having a negative impact on crop production.

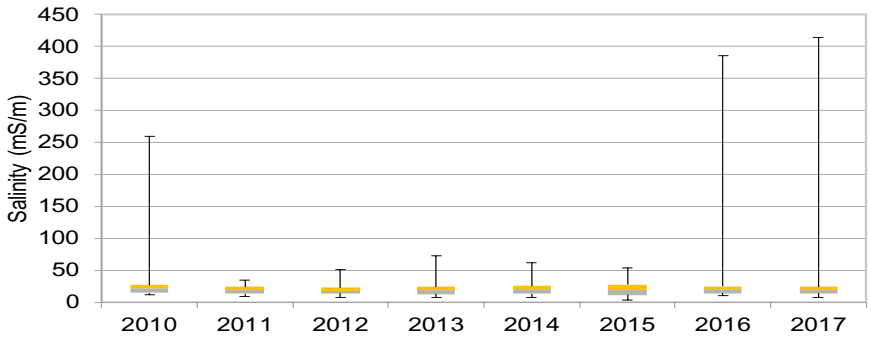
Figure 3.20 Average suspended sediment concentrations and load for 17 monitoring stations over the years 2014 and 2015



To get a complete picture of the overall salt intrusion MRC's DSF was used and it was concluded that a total of 1.852 million ha is affected annually be high salt concentrations. The distribution of areas affected by different levels of concentration is illustrated in Figure 3.22. Note that these data are somewhat outdated and new analysis on more recent data is needed.

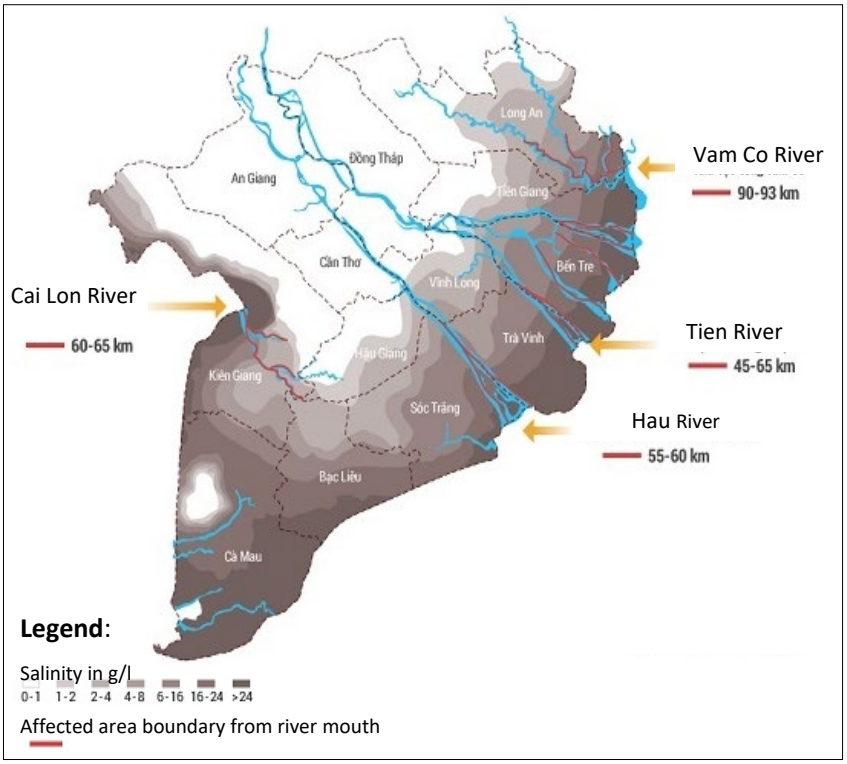
It can be concluded that the downstream parts of the LMB are affected by salinity. Exact areas and salinity levels and potential future changes are complex as many factors impact salinity process over space and time: changing flood protection, water regulation, upstream flows, sea level rise amongst others. Overall, salinity intrusion is expected to expand due to the decrease in water flow of Mekong River and higher sea levels (Council Study).

Figure 3.21 Mainstream stations salinity levels displayed as box and whisker plots



Note: The bars indicate the second and third quartiles of observations, while the error lines reflect the minimum and maximum of monthly observations.

Figure 3.22 Salinity intrusion in the Mekong Delta in 2015-16



Source: Southern Institute of Water Resources Research

3.3.5 Summary of water quality and sediment conditions

As illustrated in Section 3.3.2, indices for the protection of human health and aquatic life are good and the index for agricultural use demonstrates no consequence for agriculture based on electrical conductivity. Only a small number of samples exceeded the water quality guidelines for various parameters. Ecological health indices for average abundance and average richness were either stable or increasing. However, Average Tolerance Score Per Taxon increased for some biological groups in some countries between 2010 and 2017, indicating the taxa found at these sites were increasingly those more tolerant to pollution.

Although based on the MRC's Procedures for Water Quality water quality is not currently a problem across the LMB, there are a few instances of very high faecal coliform levels being recorded along with some high concentrations of other pollutants. FAO statistics indicate also that the use of fertiliser and pesticides is increasing (FAOSTAT 2015) and is an area to watch due to increasing risk of pollutant runoff with potential impacts on ecological health and the biota of wetlands and streams.

The decrease in sediment loads measured in the upper part of the Lower Mekong Basin since 2001 has been substantial, with the average annual load at Chiang Saen only around 13% of historical measurements. Given the importance of sediments to nutrient transport, erosion and deposition processes, maintenance of the delta, fisheries and agricultural production, this decline is alarming and raises important questions about how to mitigate the impacts of current and future development projects on the mainstream and tributaries.

3.4 Status of environmental assets

3.4.1 Assessment methodology

The environmental assets of the basin are many and varied and play an important role in sustaining livelihoods and contributing to the social and economic wellbeing of LMB communities. Wetlands in particular play a vital role in sustaining the basin's rich ecology. However, few natural wetlands remain, and further decline can be expected unless there is a concerted effort to better manage the basin's landscape and preserve key habitats.

Capture fisheries are under threat from land use changes, water infrastructure development, reductions in sediment flows and from fishing pressures. They represent an important source of protein underpinning food security within the basin, and also contribute to rural livelihoods. With increased urbanisation and changing consumption patterns, both reservoir fisheries and the fast-growing aquaculture sector are also important to the basin's economy and food security.

The Strategic Indicator "status of environmental assets" is defined as "the state of the most important environmental assets and aquatic resources of the Lower Mekong Basin". The associated assessment indicators for this strategic indicator are:

- Extent of wetland area
- Condition of riverine habitats
- Condition and status of fisheries and other aquatic resources
- Condition and status of ecologically significant areas

Each assessment indicator is evaluated using relevant monitoring parameters to inform a judgement about the overall status of the environmental assets of the basin. Monitoring parameters are obtained from the MRC's wetland database, studies commissioned by the MRC and from member country reporting.

3.4.2 Wetland area

The LMB wetlands are important hotspots of biodiversity and play an important role in the economy, society and culture of the region due to the resources and ecosystem services they provide. They offer various non-marketed and marketed benefits including fisheries, Other Aquatic Animals and Plants (OAA/Ps), vegetation, and non-timber forest products. Local people and communities obtain a substantial proportion of their incomes, daily foods and livelihoods from these resources (Sansanee, 2003; & EOEARTH, 2011). Wetlands protect people and cities from floods and natural disasters; clean wastewater flowing out of urban, agriculture and industrial areas; and store water for irrigated agriculture. Ecosystem services of LMB wetlands include water provision, regulation, purification, and groundwater replenishment (Ten Brink *et al.*, 2013).

Despite the substantial benefits they provide to local communities and the environment, LMB wetlands are threatened and being gradually degraded. The total area of wetlands in the Lower Mekong Basin is subject to some uncertainty due partly to different definitions and different delineations of wetland type, and partly due to a lack of up-to-date and available data. Nevertheless, with population growth there have been impacts on wetlands with reclamation and conversion to rice fields, increased urban runoff, increased riverine navigation, intensification of agriculture and aquaculture with increased use of fertilizer and pesticide and increased discharge of urban waste water (MRC 2003; 2010a). Ongoing developments, such as the expansion of agricultural and urban/industrial areas with year-round flood protection, puts pressure on the remaining wetlands. MRC has estimated that less than two per cent of the original wetland area in the Mekong Delta remains (MRC 2010a).

The wetland typology used under the MRC project to review the LMB wetland inventory and management systems and update the database and maps identifies eleven types of wetland with a total area of 102,386 km^2 in 2010 (Table 3.10). The largest wetland type is freshwater wetlands which includes flooded forests and inundated grasslands, and areas around Tonle Sap and elsewhere used for recession rice agriculture.

A comparison of wetland environments using the wetland database and wetland related areas based on land cover categories (Figure 3.11) identifies substantial overlap between freshwater wetlands and areas of paddy rice, particularly around Tonle Sap and in the Mekong Delta.

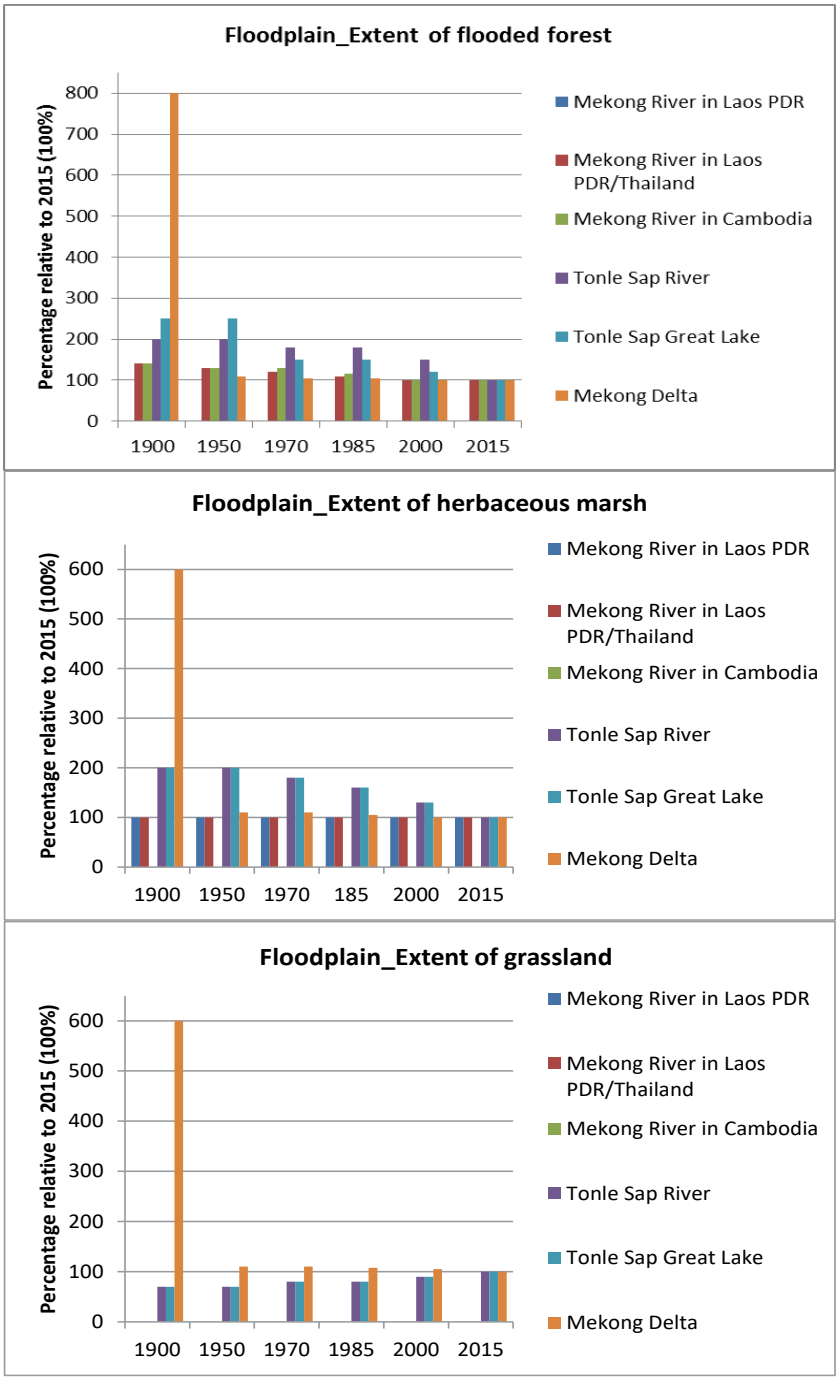
Table 3.10 Wetland area (km^2) in 2010 by type and country within the LMB

Wetland type	Cambodia	Lao PDR	Thailand	Viet Nam	Total
Estuarine intertidal				6,088	6,088
Estuarine subtidal				4,192	4,192
Freshwater wetland	41,661	8,440	8,816	16,598	75,515
Lake	3,045	603	1,697		5,344
Pond	15		2		17
Saline Lake			66		66
Marine coastal intertidal	29			7,357	7,386
Estuarine lagoon				13	13
Marine coastal subtidal				194	194
Riverbank	25	24			48
Riverine	1,375	1,128	567	452	3,521
Total	**46,150**	**10,195**	**11,148**	**34,894**	**102,386**

Source: MRC wetland database

The land cover analysis (MRC, 2016) shows that the largest loss of wetland related area between 2003 and 2010 was for mangroves and grassland areas with a substantial increase in the area of aquaculture. Marshes and swamp areas increased significantly over the same period, more than doubling in area (Table 3.11). Note that the percentage changes Table 3.11 are the change in proportional coverage of the basin as a whole, not the percentage change in area for each land cover type (i.e. in 2010 mangrove covered 0.08 per cent less of the basin than it did in 2003, but this is a reduction in mangrove area of approximately 30 per cent).

Figure 3.23 Floodplain extent of (a) flooded forest; (b) herbaceous marsh; and (c) grassland: historic abundance estimates as % relative to 2015 (100%)



Source: BioRA report for the Council Study (MRC, 2017a)

Table 3.11 Changes in wetland related landcover types between 2003 and 2010

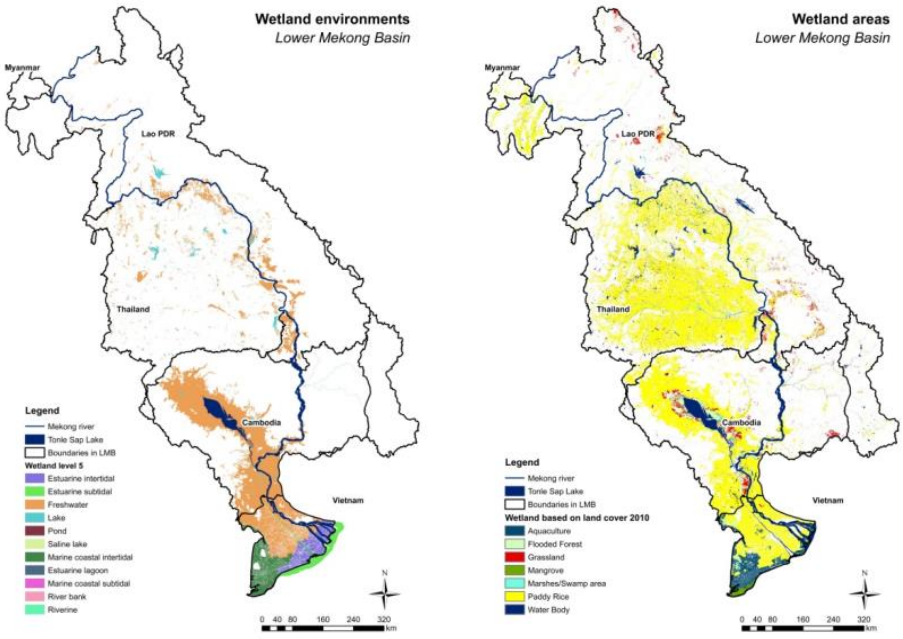
Land cover	2003		2010		Change
	Km²	%	Km²	%	%
Paddy Rice	154,995	24.81	140,540	22.47	-2.34
Water Body	12,135	1.94	14,667	2.35	+0.41
Grassland	13,880	2.22	8,637	1.38	-0.84
Aquaculture	2,101	0.34	6,886	1.10	+0.76
Flooded Forest	4,360	0.70	4,886	0.78	+0.08
Marsh/Swamp Area	913	0.15	1,866	0.30	+0.15
Mangrove	1,839	0.29	1,303	0.21	-0.08

Source: MRC land cover database

The Council Study (MRC, 2017a) also presented findings of losses in wetland area in the mainstream zones as modelled from 1900 to 2015. The Delta region, in particular, showed losses in the extent of flooded forest (which in the Council Study included Mangroves) in the early part of last century.

Losses of flooded forest around the Tonle Sap Great Lake and Tonle Sap River were estimated to have had a more gradual decline over the modelled period (Figure 3.23a); results which were replicated for herbaceous marshes (Figure 3.23b). Despite a substantial reduction in the extent of floodplain grasslands in the Mekong Delta region between 1900 and 1950, this vegetation community was estimated to have increased slightly in the Tonle Sap Great Lake and Tonle Sap zones over the modelled period, including between 2000 and 2015 (Figure 3.23c). Note that these results from the Council Study were estimated for zones along the mainstream corridor, not the whole of the LMB. Nevertheless, they are a useful indicator of the decline in wetland habitats likely to have occurred more broadly.

Figure 3.24 Map of (a) wetland types based on habitat; and (b) wetland areas determined by landcover analysis for 2010 in the LMB



Source: MRC wetlands and land cover databases

Updated wetland mapping currently being undertaken by the MRC and Member Countries should provide improved understanding of the overall state of wetland areas and of each specific wetland type.

3.4.3 Condition of riverine habitat

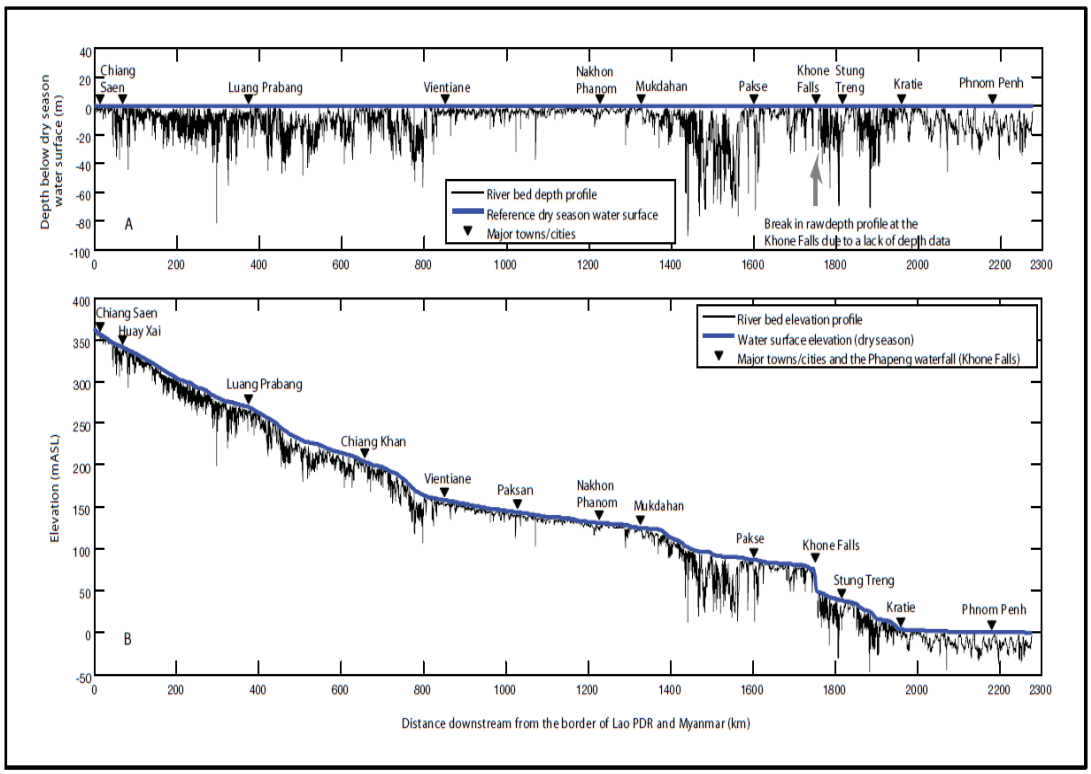
The condition of riverine habitat can be considered by examining the status and trends of some key habitat types important for fish and other biodiversity: (i) within the river channel; and (ii) in the riparian zone. The extent of riverbank erosion is also an indicator of the balance of sediment supply and transport relevant to healthy geomorphological function.

Within the river channel, exposed sandy habitat represents important habitat for vegetation, herpetofauna and birds in the dry season. The availability of exposed sandy habitats depends on the creation and maintenance of sandbars, banks and islands through alluvial deposition, and the exposure of the deposits in the dry season. Inundated sandy habitat is as an important indicator for riverine health as many insects require a sandy substrate for life-cycle processes.

Deep pools in the LMB are recognised as important geomorphic features, providing refuge and spawning habitat for a variety of fish species (Halls *et al.* 2013). Conlan *et al.* (2008) found that sediment pulses move through bedrock pools in northern Lao PDR on an annual basis, highlighting the link between the sediment and flow regimes for maintenance of the features.

Given the dependency of these features on the balance between the timing and magnitude of flow and sediment delivery in the LMB, deep pools can also be considered as good geomorphic indicators of channel function. The occurrences of deep pools are evident in Figure 3.25, which presents the thalwag long-section of the length of the Mekong River in the LMB (MRC, 2011).

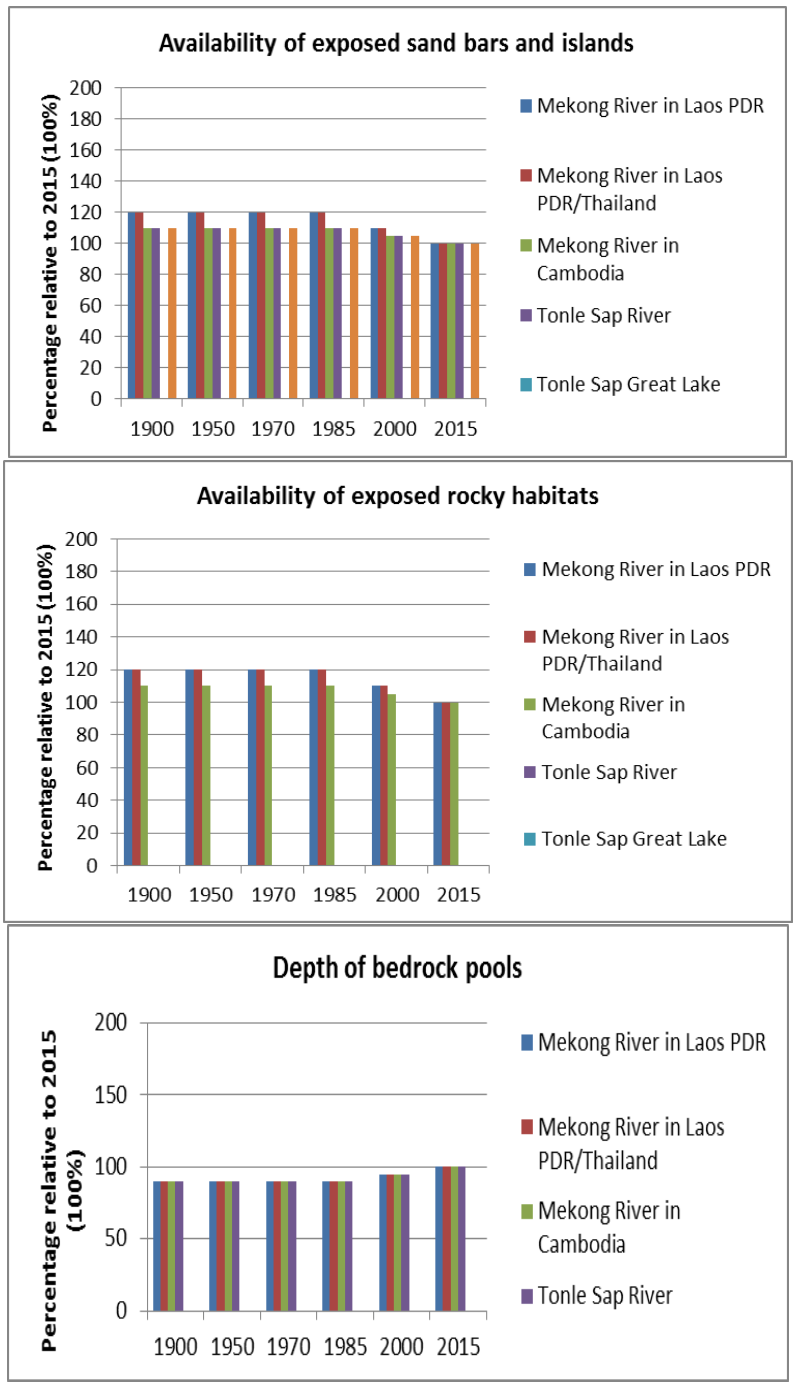
Figure 3.25 Thalwag long-section of the LMB showing occurrences of Deep Pools (MRC, 2011)



(i) *Channel habitats (sand bars, rocky habitats, deep pools)*

Estimates from the Council Study (MRC, 2017a) show a decline in the availability of exposed sand bars and rocky habitats and an increase in the depth of deep pools in the dry season since 1985 (Figure 3.26). This is attributed to higher dry season water levels and the greater erosive power of the flow due to the more sediment depleted water originating from upstream (MRC, 2017a).

Figure 3.26 Availability of (a) exposed sandy habitat; (b) exposed rocky substrate; and (c) depth of bedrock pools, in the dry season as a percentage relative to 2015 (100%)



Source: BioRA report for the Council Study (MRC, 2017a). Percentage estimates relate to the descriptors in Table 3.12.

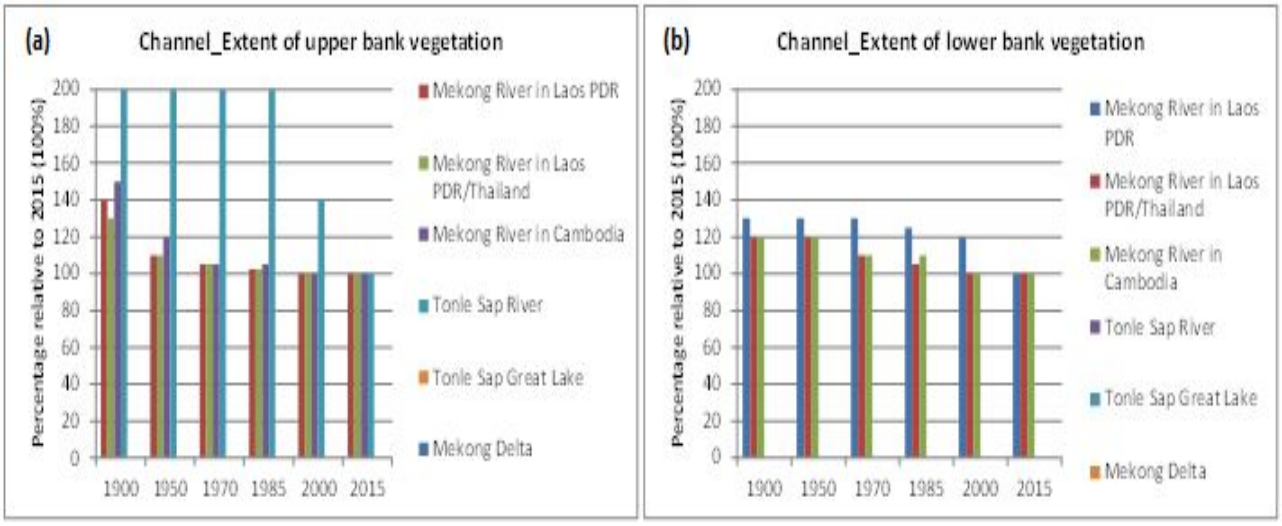
Table 3.12 Percentage estimates used for Council Study modelling of available channel habitats (MRC, 2017)

%	Exposed Sandy habitats in dry season	Exposed rocky habitats	%	Deep Pools
120	Increased exposure associated with lower erosion rates and lower flows in the dry season associated with the unregulated flow regime	Increased exposure associated with flows in the dry season under the unregulated flow regime	90	Shallower depths in the dry season and deeper during the wet season associated with lower dry season flows and higher wet season flows prior to river regulation
100	2015 conditions – present level of exposure reflecting increased bank erosion and higher flows in the dry season due to water level changes associated with flow regulation	2015 conditions – reduced exposure due to higher flows in the dry season	100	2015 conditions – increased depth during low flow associated with the increase in flow levels, decreased depth during the flood season due to reduced peak water levels associated with flow regulation
50	Additional reduction in exposure associated with increased erosion flows during dry season and decreased flows during wet season as compared to 2015	Decreased exposure associated with higher flows during dry season and decreased flows during wet season as compared to 2015	110	Increased depth during dry season and decreased depth during wet season as compared to 2015 associated with potentially greater flow regulation

(ii) *Riparian habitat*

The extent of riparian vegetation cover was also modelled for the Council Study (MRC, 2017). In all mainstream zones, the extent of both upper and lower riparian vegetation is estimated to have declined (Figure 3.27). In most areas, much of this decline occurred prior to the 1970s. However, river bank vegetation along the Tonle Sap River is estimated to have declined more recently and more substantially than in other zones.

Figure 3.27 Channel extent of (a) upper bank vegetation; and (b) lower bank vegetation: historic abundance estimates as a percentage relative to 2015 (100%)



Source: BioRA report for the Council Study (MRC, 2017a)

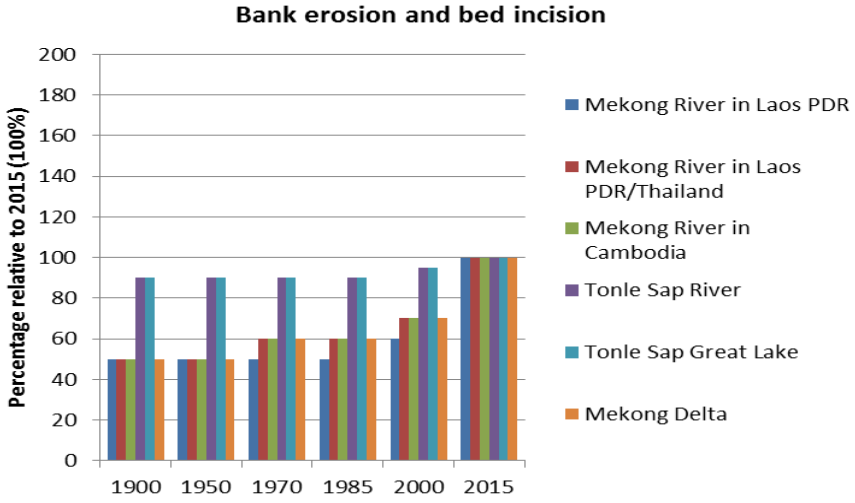
(iii) *Riverbank erosion*

The incidence and rate of riverbank erosion is important for determining the physical structure of the river channel and associated floodplains, and effects habitat availability and quality. Bank erosion is controlled by the hydraulics of the river and the availability and characteristics of sediment. In most natural river systems, the rising limb of a high

flow event will induce bank erosion, whilst deposition associated with the falling limb will aggrade banks, resulting in a dynamic equilibrium (e.g. erosion and deposition do not occur in the same place, but are in balance at a reach scale).

There are no long-term systematic investigations of bank erosion in the LMB, and thus no maps or datasets showing the past or present distribution of erosion across the basin. In the absence of quantitative assessments of erosional trends in the LMB, the Council Study estimated the status and trends of river bank erosion using expert opinion drawing from an understanding of changes to sediment supply, sediment transport and flow in the Mekong, and how these changes are likely to have translated into bank erosion based on fluvial geomorphology principles, and field observations. Considering a range of global and local influences, river bank erosion is estimated to have increased from the 1950s in most zones of the mainstream including the Mekong Delta, and more recently around the Tonle Sap Great Lake and Tonle Sap River (Figure 3.28).

Figure 3.28 Bank erosion and bed incision: historic estimates as a percentage relative to 2015 (100%)



Source: BioRA report for the Council Study (MRC, 2017a)

3.4.4 Condition and status of fisheries and other aquatic resources

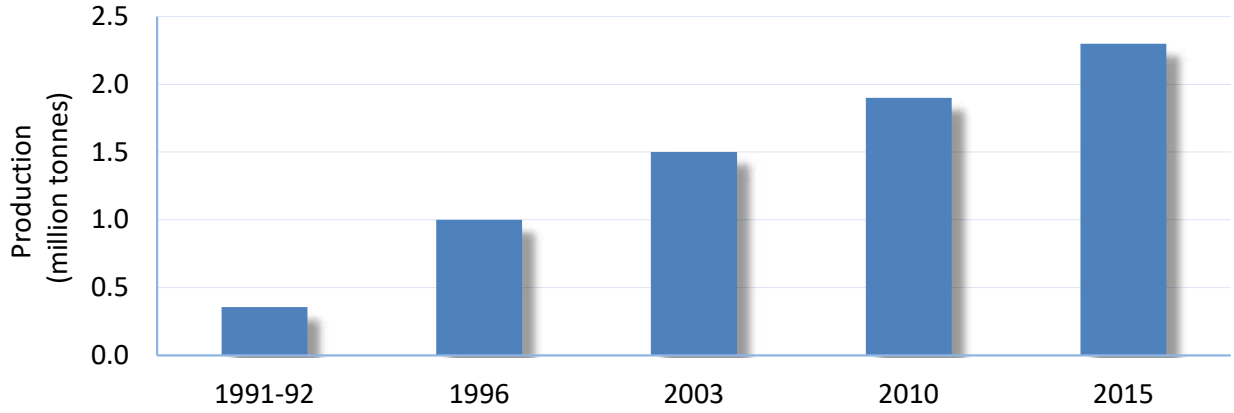
The Mekong River system hosts one of the most diverse and prolific freshwater capture fisheries in the world. The largest fisheries catch occurs in the extensive floodplain in central Cambodia and the Mekong Delta of Viet Nam. A recent review of MRC monitoring programme data and other studies from multiple sources estimated there are 1,148 fish species in the Mekong Basin, making the LMB one of the places with the highest fish biodiversity per square kilometre in the world. Although not yet fully described as new species are discovered every year, recent estimates of the biota of the greater Mekong region include 20,000 plant species, 430 mammals, 1,200 birds and 800 reptiles and amphibians. However, accelerating economic development, population growth and increased consumption patterns are placing pressure on the environment. The Mekong Basin fauna includes 31 species listed as critically endangered (including the Irrawaddy dolphin, Mekong giant catfish and Giant barb), 62 species listed as endangered and a further 95 species whose status is vulnerable.

Capture fisheries are an important source of protein and income for those living in the LMB. There is no clear indication the level of fish being caught threatens fish populations, but some monitoring studies have observed a reduction in catch rates in some areas, as well as a reduction in large and medium-sized fish species, including river catfishes, cyprinid and carnivorous fishes and a domination of small species, both of which could be interpreted as signs of overfishing. Other reasons for these changes in catch rates and the size of fish being caught could include reduced sediment and nutrient transport to floodplain areas important for fish productivity, and the disruption of fish migration routes.

(i) *Capture fisheries production*

Capture fisheries production in the LMB is higher than anywhere else in the world. In 1996, the MRC estimated annual production at one million tonnes including a small contribution from aquaculture (Jensen, 1996), up from an earlier estimate of only 357,000 tonnes (MRC, 1992) from a fisheries sector review. The estimate was later raised to 1.5 million tonnes (MRC, 2003) and then 1.9 million tonnes (MRC, 2010a). Based on a recent study classifying aquatic habitats into broad zones (major flood zones, rain-fed zones and permanent water bodies), the "most likely" capture fisheries yield from the basin has been estimated at 2.3 million tonnes (Hortle and Bamrungrach, 2015) (Figure 3.29). The higher figure does not necessarily reflect increased production of capture fisheries but tends to be attributed to the application of better estimation methods. Catches were composed of white fishes (34 per cent), black fishes (50 per cent) and grey fishes (16 per cent) (Baran *et al.*, 2013).

Figure 3.29 Total capture fisheries production in the Lower Mekong Basin from the early 1990s to 2015.



Source: MRC, 1992; MRC 1996; MRC, 2003; MRC, 2010a; Hortle & Bamrungrach, 2015

Under the 2015 habitat-based approach, equal proportions of fish production (45%) derive from river-floodplain habitats in the major flood zone (moderate-high yield over a moderate area) and from rice fields and associated habitats in the rain-fed zone (low-moderate yield over a very large area), with a minor contribution (about 10%) from reservoirs and other large permanent waterbodies outside the major flood and rain-fed zones. This assessment does not include separate yield information from the estuarine zone and so is probably conservative for some habitats.

The latest estimate of basin-wide yield of 2.3 million includes more than 1 million tonnes from "rainfed zones", which are mainly rice fields but also other wetland crops and associated habitats outside the "major flood zone" (permanent water bodies including most major rivers, the Tonle Sap system and seasonally flooded land including recession rice fields).

These rain-fed habitats, mostly former forest areas, were found to generate low to moderate yields over large areas, especially in Thailand where fisheries yields from such habitats were estimated to be as high as almost 700,000 tonnes and, to a lesser extent, Cambodia where such yields were estimated at 180,000 tonnes. The fisheries yield from un-stocked rain-fed habitats has been estimated at 50 – 100kg/ha/year. In Battambang province in northwest Cambodia, a study of all wet-season catches at 10 river flooded rice fields of 25 ha each found average yields of 119kg/ha/year with fish comprising 77 per cent of the catch, and other aquatic animals 23 per cent. Yields of more than 200kg/ha/year have been reported from the Mekong system in northeast Thailand.

Agriculture is the main threat to fisheries yields in such rain-fed habitats (high-yielding rice varieties resulting in shallower water and increased use of pesticides). But it may be possible to maintain or even increase fisheries yields by maintaining water depths, improving connectivity, developing refuge ponds and promoting integrated pest management.

Reservoir fisheries outside the flood zone are estimated to contribute about 10 per cent of the annual fisheries yield, or about 230,000 tonnes. Almost half of the yield from these water bodies comes from Thailand and a quarter from Lao PDR (Hortle and Bamrungrach, 2015). Reservoir fisheries are often stocked with various species of fish and other aquatic animals.

In Thailand, stocking giant freshwater prawns has been particularly successful, especially at Pak Mun Reservoir in Ubon Ratchathani Province. To improve fisheries management and help reverse a long-term decline in fish catches, stocking has also been undertaken at Ubol Ratana Reservoir in Khon Kaen Province (Suchart, 2014).

In Viet Nam, stocking has been considered a major part of reservoir fisheries for more than 50 years. Most of the species stocked are exotic. In the Central Highlands, stocking activities have been important to a fisheries co-management model pioneered by the MRC at Easoup Ha Reservoir in Dak Lak Province in 1999. Under the co-management model, one of the first in Viet Nam, local fishers belong to a union whose members pay fees that are mainly used to finance stocking every year. At Ea Kao Reservoir, also in Dak Lak Province, a private company manages the fishery. The company lets local indigenous people catch non-stocked species. Others have to pay a fee, including those engaged in recreational fishing (Phuc, 2014).

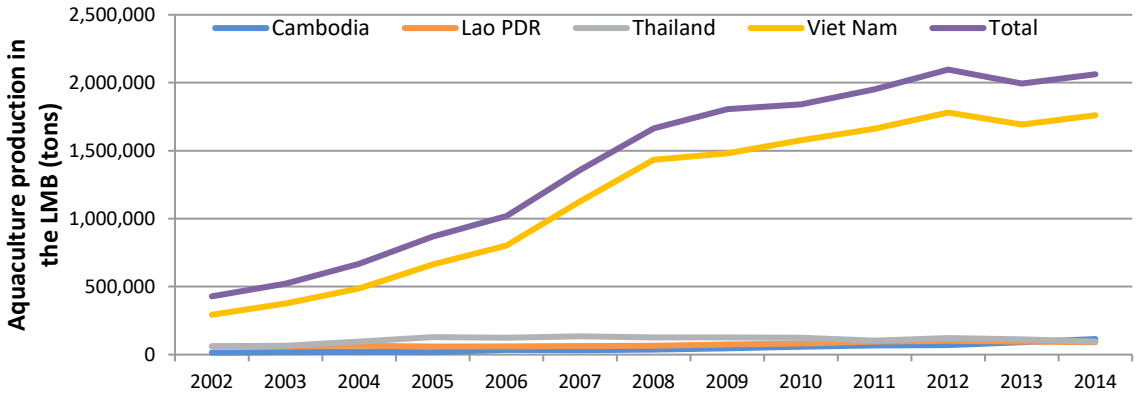
In Cambodia and Lao PDR, governments organize annual events in which stocking takes place. Cambodia stocked more than 33 million fingerlings at National Fish Day events between 2003 and 2013. These events focus on indigenous species. Cambodia has also stocked 130 tonnes of brood fishes in community areas and sanctuaries as well as 6 million prawns (Sam, 2014). In Lao PDR, stocking is widely practiced in both hydropower and irrigation reservoirs with a focus on seven native and seven exotic fish species (Sinthavong, 2014).

(ii) *Aquaculture production*

Aquaculture has been growing rapidly in the Lower Mekong Basin with total production reaching 2.1 million tonnes in 2012, up from 1.8 million tonnes in 2010 and less than 0.7 million tonnes in 2002 (Figure 3.13). The average annual growth rate has been around 17 per cent (±7 per cent), which is three times faster than the world average of 5.6 per cent in the decade to 2014 (OECD/Food and Agriculture Organization of the United Nations, 2015).

Viet Nam is by far the largest producer (1.8 million tonnes in 2012) with Thailand a distant second followed by Lao PDR and Cambodia. Most of the production is concentrated in the Mekong River Delta. Despite a dip in 2013, since 2012 aquaculture production in the Mekong Delta in Viet Nam has continued to grow strongly, up by more than 37,000 tons (Figure 3.30). Production in Lao PDR declined from 2012 to 2014.

Figure 3.30 Aquaculture production in the LMB



Source: National statistics on aquaculture in Cambodia, Lao PDR, Thailand, Viet Nam

(iii) *Catch per unit of effort*

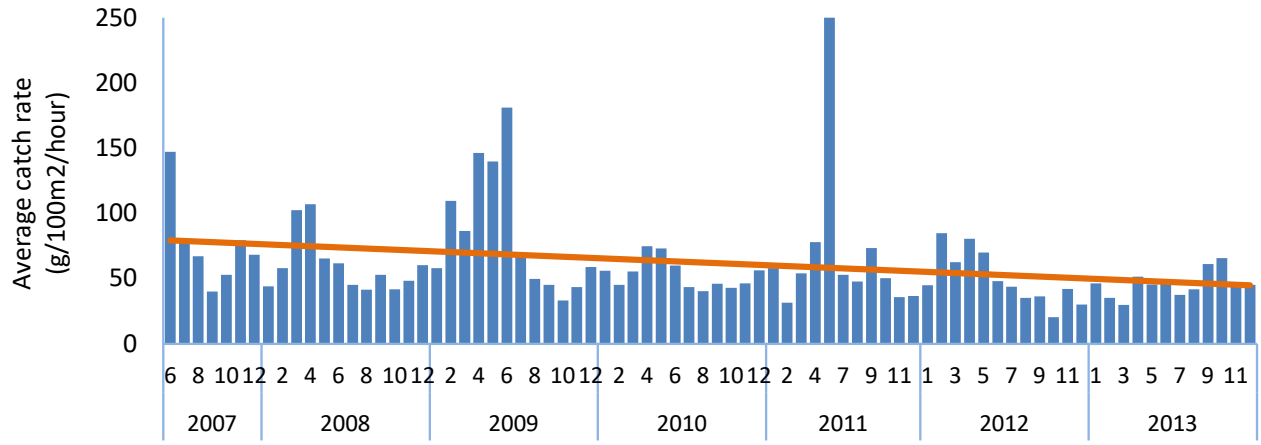
The Mekong River Commission has supported key regional capture fisheries monitoring programmes to help monitor the status and trends in capture fisheries in the Lower Mekong Basin since the 1990s. The following present changes in fish catch rates relative to fishing effort observed from those monitoring programmes.

Stationary gillnet fishery: Under the Fish Abundance and Diversity Monitoring Programme, fishers report catches and fishing effort from a number of fisheries in different habitats in each of the four LMB countries. At least 26 types of fishing gear were reported. Gillnets were the type of gear most commonly used by fishers within all major habitat types and during most months in all four countries. Data from eight selected monitoring locations is presented below.

(a) Ou Run, Mekong River, Stung Treng Province, Cambodia

At Ou Run in Stung Treng Province in Cambodia, it has been observed that catches of stationary gill net fisheries peak around the middle of the year at the beginning of the wet season (May-June). Catch rates in this location vary with the trends decreasing over seven years of daily monitoring since mid-2007. The average catch was reported at around 75 grams per 100 square metres per hour between 2007 and 2009 and fell to around 55 grams per 100 square metres per hour between 2010 and 2013 (Figure 3.31).

Figure 3.31 Average catch rates of stationary gill nets in the Mekong River, Stung Treng Province, Cambodia

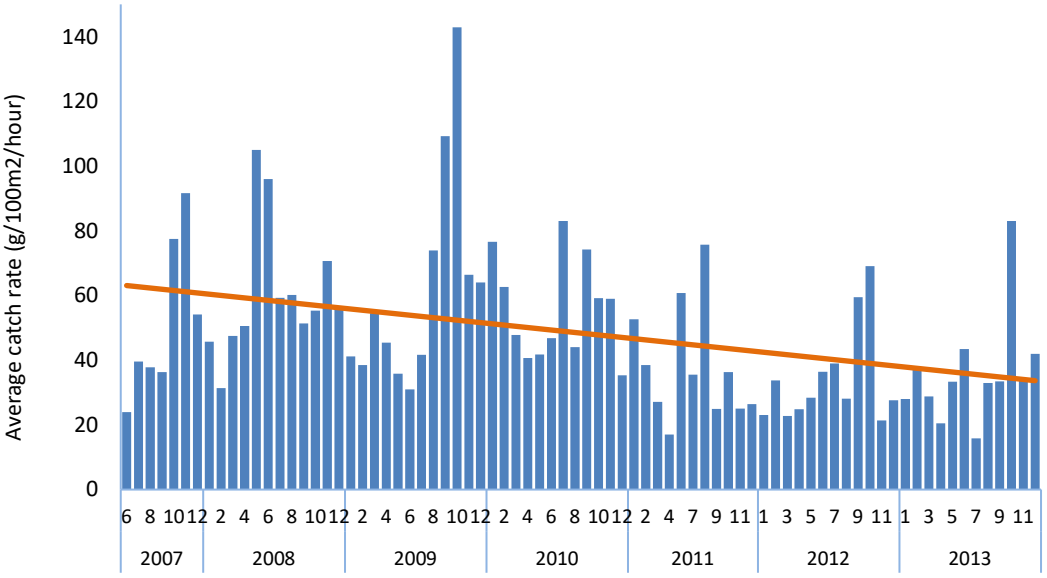


Source: MRC fisheries database

(b) Koh Khnhe, Mekong River, Kratie Province, Cambodia

Catch rates of stationary gillnets from the Mekong River at Koh Khnhe reveal a similar trend to those at Ou Run in Stung Treng Province. The peak catches are observed at the beginning of the rainy season in May or June with the overall trend declining over the monitoring period (Figure 3.32). The average catch rate of stationary gillnets was around 60 grams per 100 square metre per hour between 2007 and 2009 and fell to around 40 grams per 100 square metre per hour between 2010 and 2013. In summary, the average catch rates from stationary gillnets in the Mekong mainstream in Cambodia fluctuated with a downward trend, noticeably since 2010.

Figure 3.32 Average catch rates of stationary gill nets in the Mekong River, Kratie Province, Cambodia



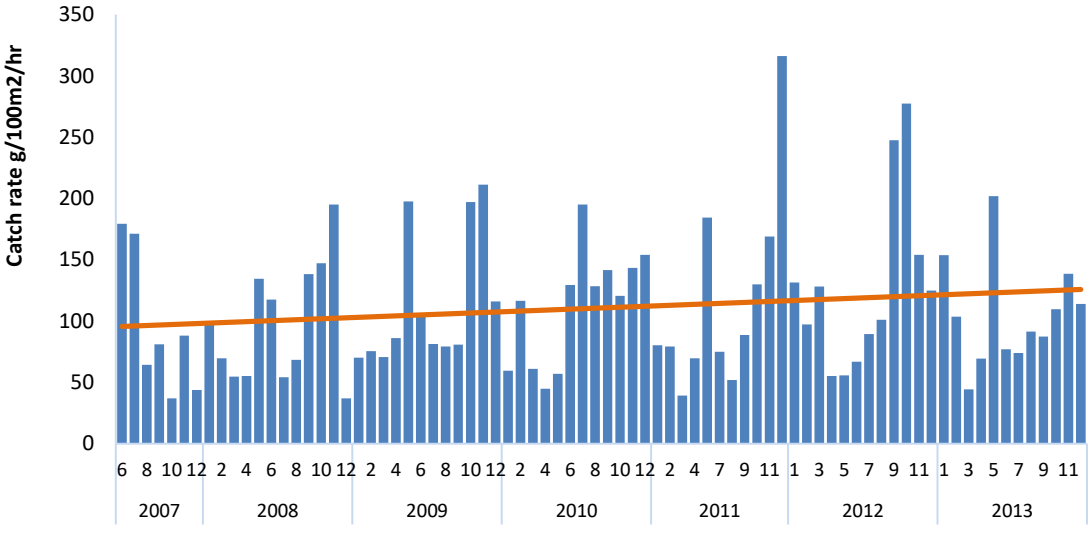
Source: MRC fisheries database

(c) Fang, Sesan River, Ratanakiri Province, Cambodia

Catch rates of stationary gillnets reported from the Sesan River indicate that peak catches occur twice a year. The first peak takes place at the onset of wet season in May-June and the second in the early dry season from October to December. This pattern of peak catch rate may reflect the migration time of many fish species. Wet season migration is for spawning and early dry-season migration is for dry-season refuge in deep pools in the mainstream.

Catch rate trends in Sesan River have oscillated with a slight increase observed between 2010 and 2012 (Figure 3.33). On average, the catch rates of stationary gillnets were around 103 grams per 100 square metres per hour between 2007 and 2009. The catch rate showed a slight increase to around 116 grams per 100 square metres per hour between 2010 and 2013.

Figure 3.33 Average catch rates of stationary gill nets in the Sesan River, Ratanakiri Province, Cambodia

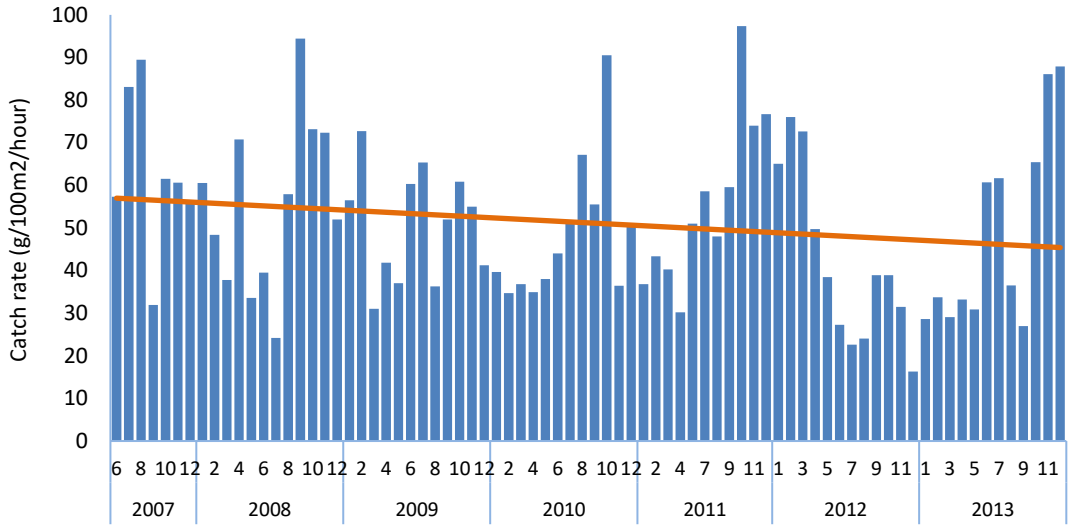


Source: MRC fisheries database

(d) Pres Bang, Sekong River, Stung Treng Province, Cambodia

In the Sekong River, peak catch rates of stationary gillnets are observed in the dry season (October-Jan/Feb). In contrast to the Sesan River, catch rate trends in the Sekong showed a slight decrease over the monitoring period (Figure 3.34). On average, the catch rate of stationary gillnet was around 55 grams per 100 square metre per hour between 2007 and 2009. The rate fell to around 48 grams per 100 square metres per hour between 2010 and 2013.

Figure 3.34 Average catch rates of stationary gill net in the Sekong River, Stung Treng Province, Cambodia

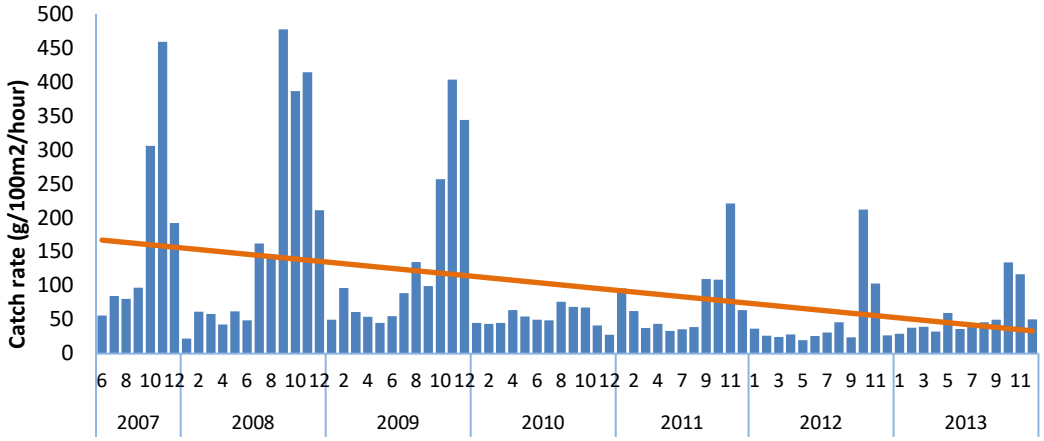


Source: MRC fisheries database

(e) Day Lo, Sre Pok River, Ratanakiri Province, Cambodia

In the Sre Pok River, peak catch rates of stationary gillnets were observed in the dry season (October-December). Catch rates in the Sre Pok showed a downward trend over the monitoring period (Figure 3.35). On average, the catch rate of stationary gillnets was around 163 grams per 100 square metre per hour between 2007 and 2009, falling to around 61 grams per 100 square metre per hour between 2010 and 2013.

Figure 3.35 Average catch rates of stationary gill nets in the Sre Pok River, Ratanakiri Province, Cambodia

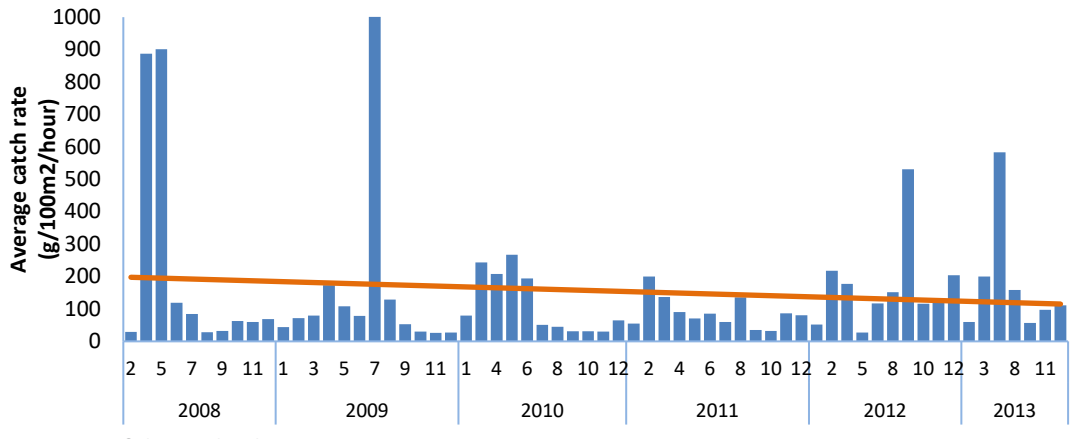


Source: MRC fisheries database

(f) Ban Pha O, Mekong River, Luang Prabang, Lao PDR

Peak catch rates of stationary gillnets in the Mekong River at Ban Pha O, Luang Prabang Province, Lao PDR were reported in the late dry season (March-May). Catch rates in Ban Pha O varied with a slight decrease over the monitoring period (Figure 3.36). On average, the catch rate of stationary gillnets was around 171 grams per 100 square meters per hour between 2008 and 2010, falling to around 140 grams per 100 square meters per hour between 2011 and 2013. However, large catch rates in April-May 2008 and in July 2009 may influence the long-term trend. Otherwise, catch rate trends of stationary gillnet at this location were varied at an average of 156 grams (± 58 grams) with no significant change between 2008 and 2013.

Figure 3.36 Average catch rates of stationary gillnets in the Mekong River, Luang Prabang Province, Lao PDR

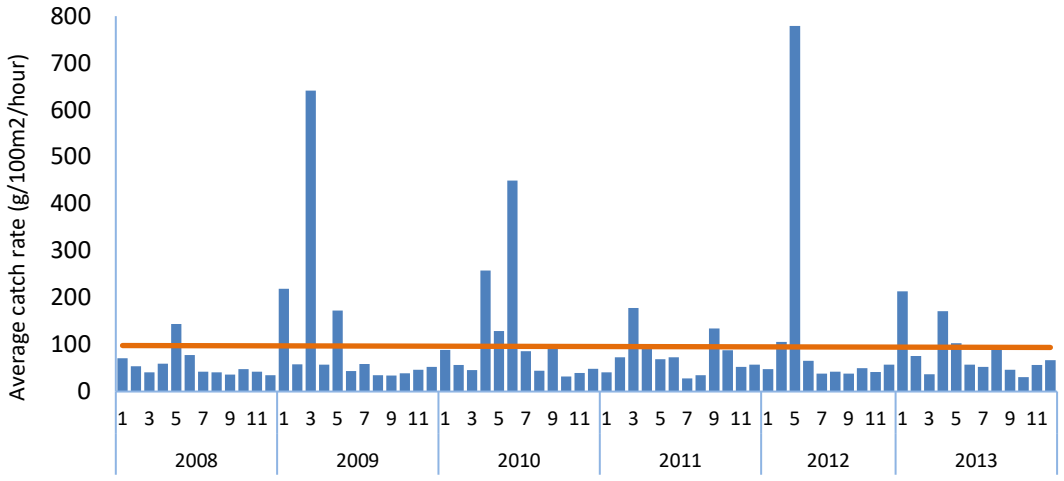


Source: MRC fisheries database

(g) Ban Hat, Mekong River, Champassak, Lao PDR

Similar to Ban Pha O, average catch rates of stationary gillnets in the Mekong River at Ban Hat, Champassak Province, Lao PDR present some variations with no change in the long-term trend (Figure 3.37). The average catch rate was around 96 grams (± 30 grams) per 100 square metres per hour from 2008 to 2013.

Figure 3.37 Average catch rates of stationary gillnets in the Mekong River, Champassak Province, Lao PDR

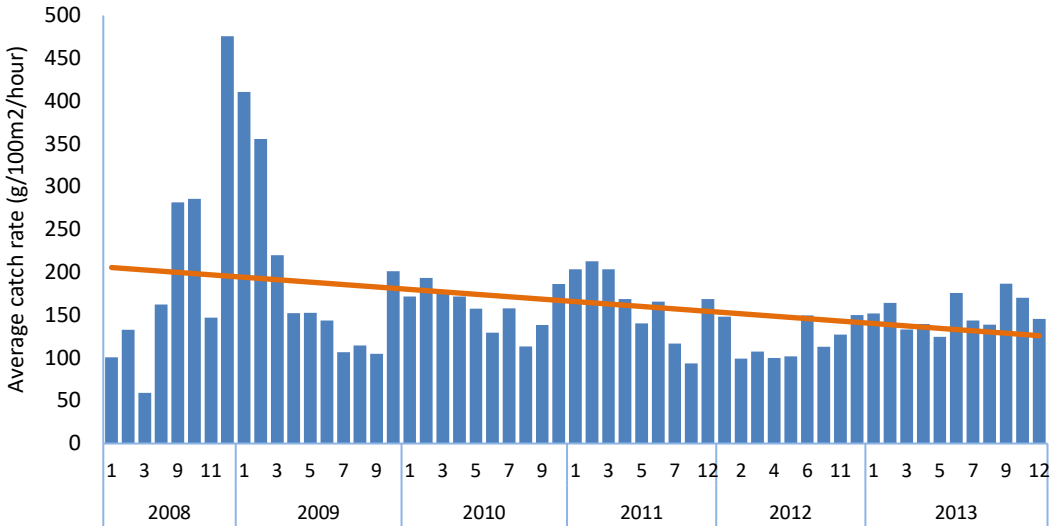


Source: MRC fisheries database

(h) My Thuan, Mekong River, An Giang Province, Viet Nam

Catch rates of stationary gillnets reported from My Thuan, Mekong River, An Giang Province, Viet Nam indicate a decreasing trend over the period from 2008 to 2013 (Figure 3.38). The average catch rate of stationary gill nets was around 200 grams (± 58 grams) per 100 square metre per hour between 2008 and 2009, falling to 162 grams (± 16 grams) in 2010-2011 and 139 grams (± 12 grams) in 2012-13.

Figure 3.38 Average catch rates of stationary gillnet in the Mekong River, An Giang Province, Viet Nam

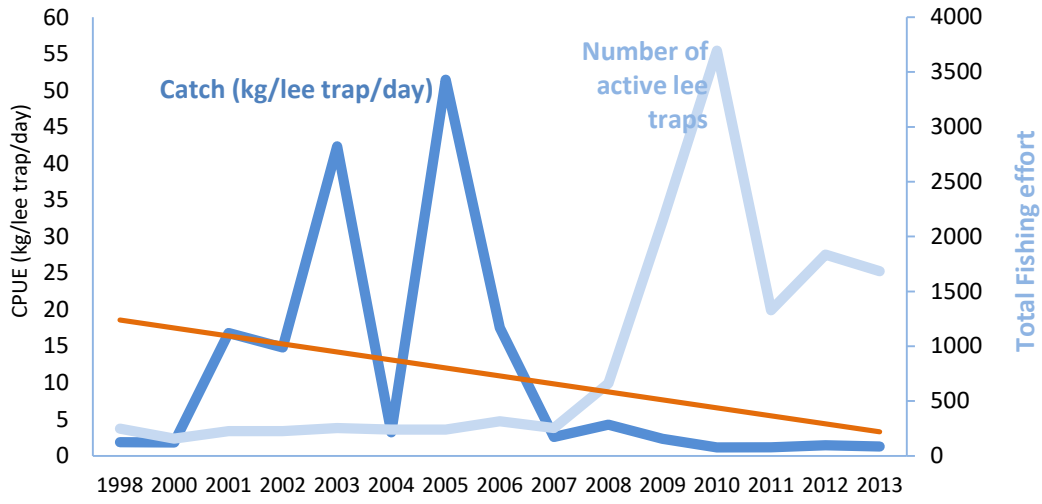


Source: MRC fisheries database

(i) Lee trap fishery, Hoo Sam Yai, Mekong River, Lao PDR

- The lee trap fishery has been monitored since 1994 with the MRC Fisheries Programme supporting monitoring by the Living Aquatic Resources Research Centre (LARReC) since 2005. Halls et al. (2013) recorded catch and effort of the fishery since 2008. As indicated in Figure 3.39, the average catch rate of the fishery was highest in 2005 at 51 kg per lee trap per day. The average catch rate dropped sharply to only 18 kg in 2006 and continued to decrease until 2013 (Figure 3.39).

Figure 3.39 Average catch rates versus effort of lee trap fishery in southern Lao PDR



Source: MRC fisheries database

(j) Bagnet (dai) fishery, Tonle Sap River, Cambodia

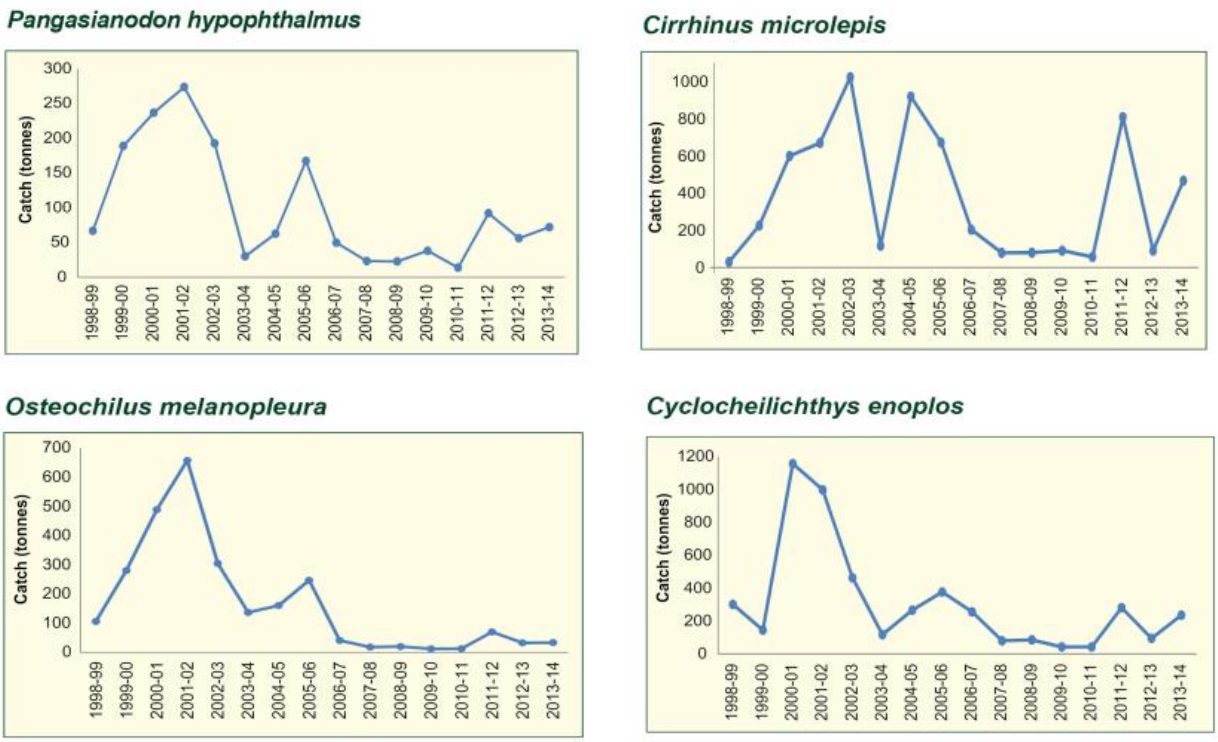
The MRC and the Cambodian Fisheries Administration have been monitoring the dai fishery on the Tonle Sap River since the 1995-96 season. The fishery targets small mud carps migrating downstream from the Tonle Sap Lake from the end of the wet season in October to March. Established about 140 years ago, the stationary bagnet (dai) fishery is a very useful indicator of Cambodia's inland fisheries and could also be a good indicator of overall Mekong fisheries and their ecological health. Changes in the size of catches since 1995 largely reflect the impact of annual floods on fish growth (Halls *et al.*, 2013; Ngor *et al.*, 2015).

Although there is no compelling evidence of a decline in biomass, fish weight or species competition attributable to increased fishing pressure in response to a growing population (Halls *et al.*, 2013), catches of some large and medium-sized species were found to have declined between 1998 and 2014 (Figure 3.40) (Ngor *et al.*, 2015). By contrast, catches of small mud carps trended upwards over the same period.

(iv) *Fish size*

The total lengths of some fishes have been declining (Ngor *et al.*, 2015) (Figure 3.42). This may indicate declining production of large high-value species accompanied by increased production of small low-value species that are short lived. Factors behind declining catches of some large and medium-sized fishes may include increased fishing effort, hydrological and hydraulic changes, habitat degradation, loss of habitat connectivity and climate change.

Figure 3.40 Catch trends of large and medium-sized fish species at dai fishery, Tonle Sap River

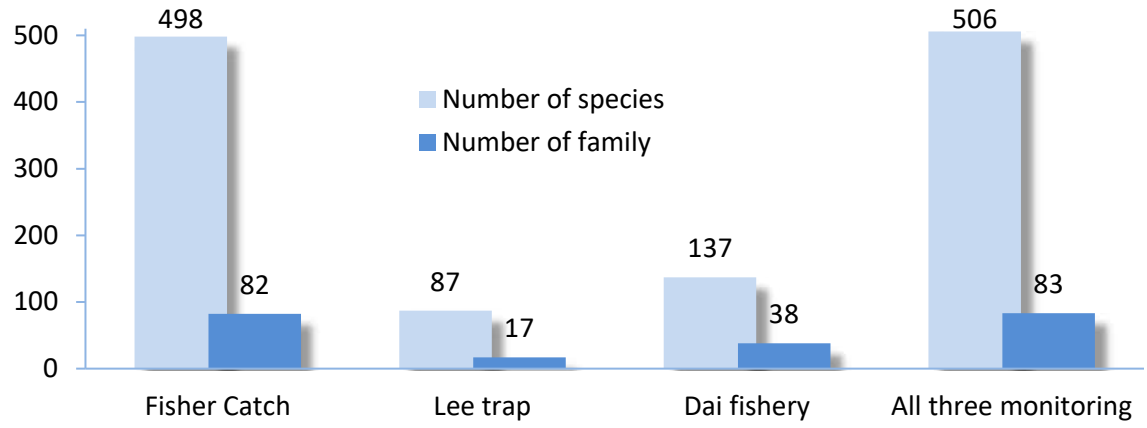


Source: Ngor et al., 2015

(v) Fish diversity

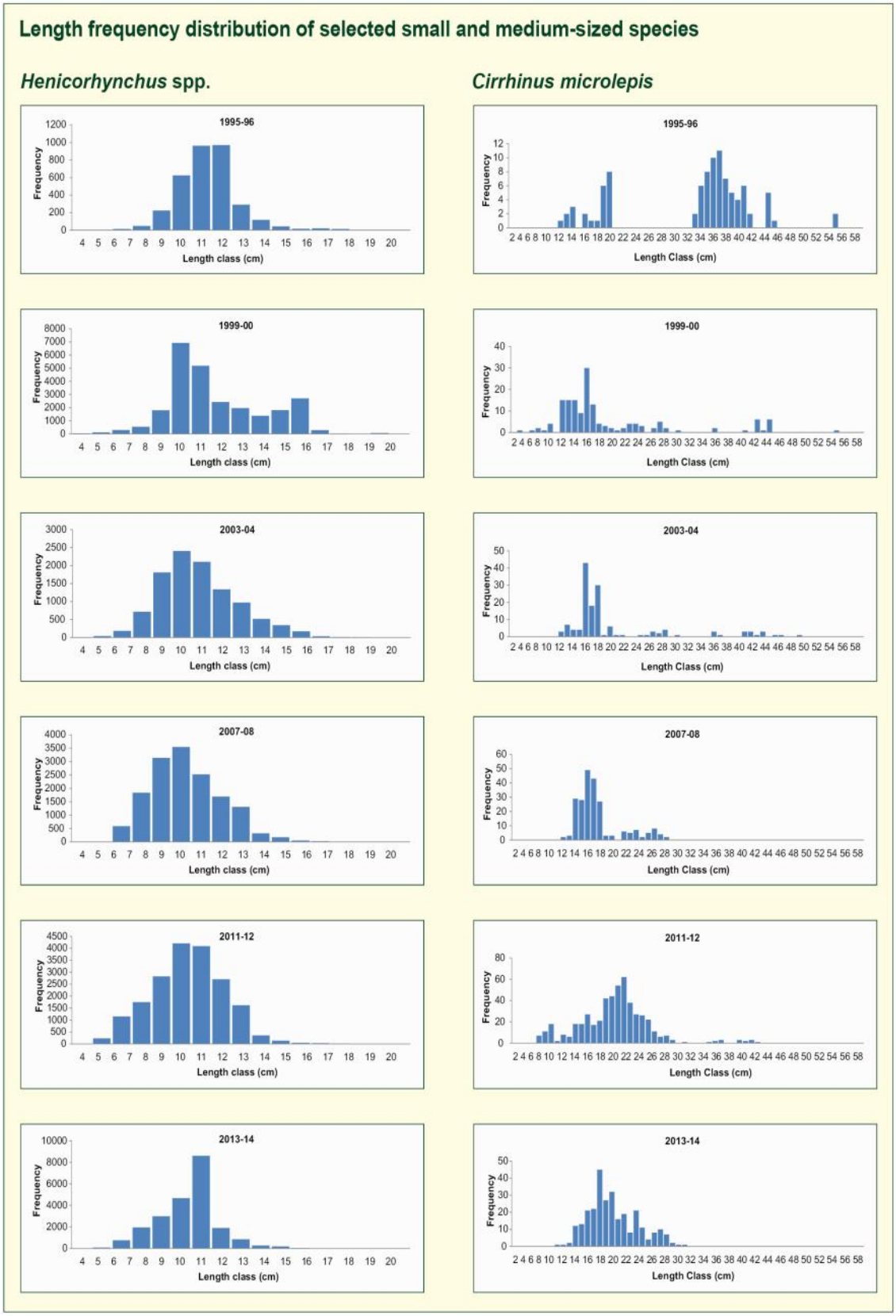
The Mekong River system hosts one of the most diverse and prolific freshwater capture fisheries in the world. The largest fisheries occur in the extensive floodplain in central Cambodia (including the Tonle Sap System and the area south of Phnom Penh) and the Mekong Delta of Viet Nam. As noted earlier, an estimated 1,148 fish species are present in the Mekong Basin. Figure 3.41 illustrates the number of fish species reported by each MRC fisheries monitoring programme. As noted earlier, the updated Mekong Fish Species Database identifies 474 species having been recorded across all MRC fish monitoring programmes since 2003.

Figure 3.41 Number of species and families caught in various MRC fisheries monitoring programmes



Note: The total species and family numbers are not the sum of the three monitoring programmes because some species were recorded in multiple programmes

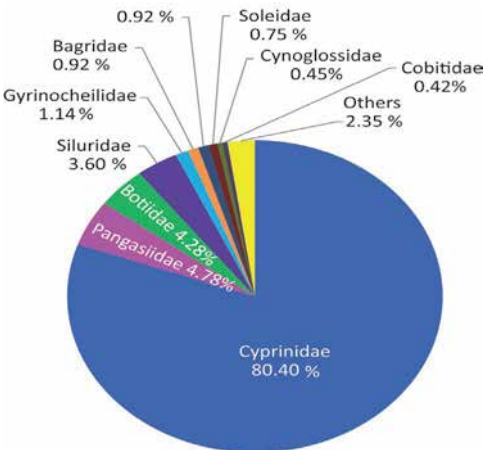
Figure 3.42 Length frequency distribution of Henicorhynchus spp. and Cirrhinus microlepis



Source: Ngor et al., 2015

Catch composition of capture fisheries in the LMB is dominated by one fish family: Cyprinidae (minnows and carps). Results from MRC monitoring programmes since the late 1990s indicate that fish from this single family contributed around 80 per cent of total reported catches. Ten fish species make up around 98 per cent of the total catch (Figure 3.43).

Figure 3.43 Fish catch compostion of top ten fish species in LMB recorded by MRC fisheries monitoring programmes (Hortle and Bamrunggrach, 2015)



Fish of the Lower Mekong Basin can also be classified according to guilds. For the Council Study (MRC, 2017a) the guild framework developed by Welcomme *et al.* (2006) was used. This framework classifies fishes based on similar migratory or trophic behaviour (Welcomme *et al.* 2006). The guild framework helps facilitate the identification of species within the assemblage that are most likely to be impacted by basin development, such as in-channel dams, in a similar manner.

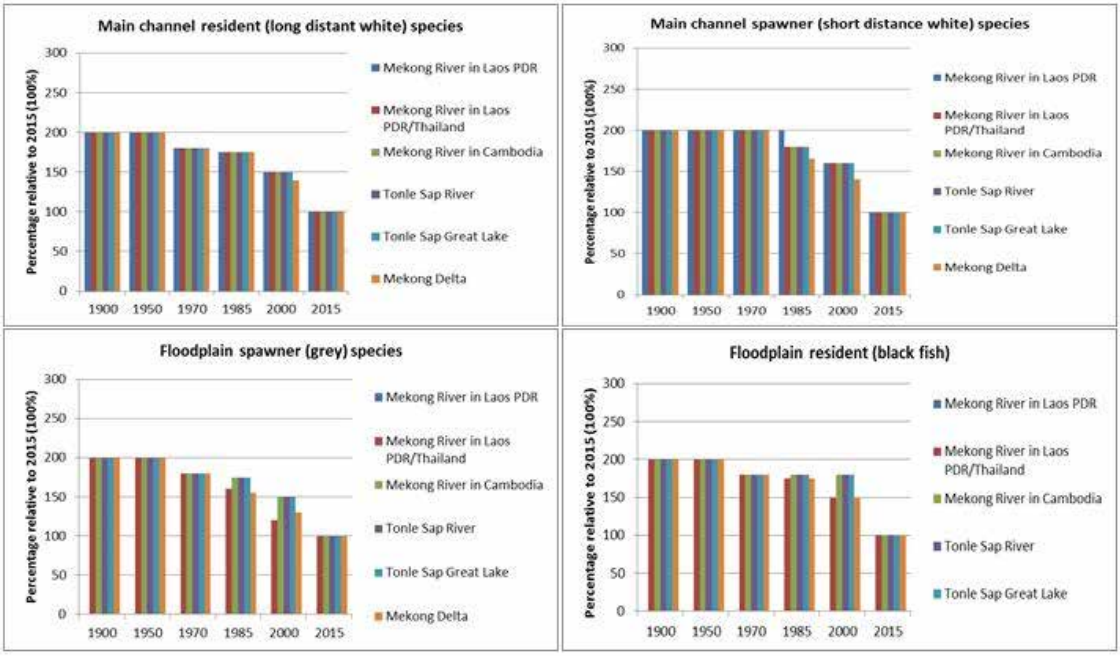
Table 3.13 Distribution of fish species amongst focal areas by guild (MRC, 2017)

Guild	Council Study Zone/Focal Area							
	Mekong River							
	China border to Pak Beng	Pak Beng to upstream of Vientiane	Vientiane to Nam Kam town	Nam Kam to Stung Treng	Stung Treng to Kampong Cham	Tonle Sap River and Cambodian floodplains (excluding those in other zones)	Tonle Sap Great Lake	Viet Nam Delta from border to the sea
Rhithron resident species	67	83	77	69	27	6	19	0
Main channel resident (long distant white) species	9	11	11	14	11	8	7	10
Main channel spawner (short distance white) species	41	68	73	72	50	47	40	41
Floodplain spawner (grey) species	29	58	57	60	44	42	49	40
Eurytopic (generalist) species	19	28	30	31	26	26	27	25
Floodplain resident (black)	20	32	32	29	24	22	24	24
Estuarine resident species	0	0	0	22	23	30	22	208
Anadromous species	0	0	0	2	2	3	1	4
Catadromous species	0	0	0	1	1	1	1	3
Marine visitor species	0	0	0	4	4	9	6	283
Total	**185**	**280**	**280**	**321**	**224**	**207**	**208**	**653**

Note: Species may be present in more than more focal area.

Figure 3.44 illustrates the estimated decline in several of these guilds, especially since the 1970s, as presented in the Council Study (MRC, 2017a), although all ten guilds had an estimated decline of a similar magnitude across all mainstream regions of the LMB. The number of species in each zone identified for the Council Study is presented in Figure 3.47.

Figure 3.44 Modelled historic abundance of fish species (% relative to 2015)



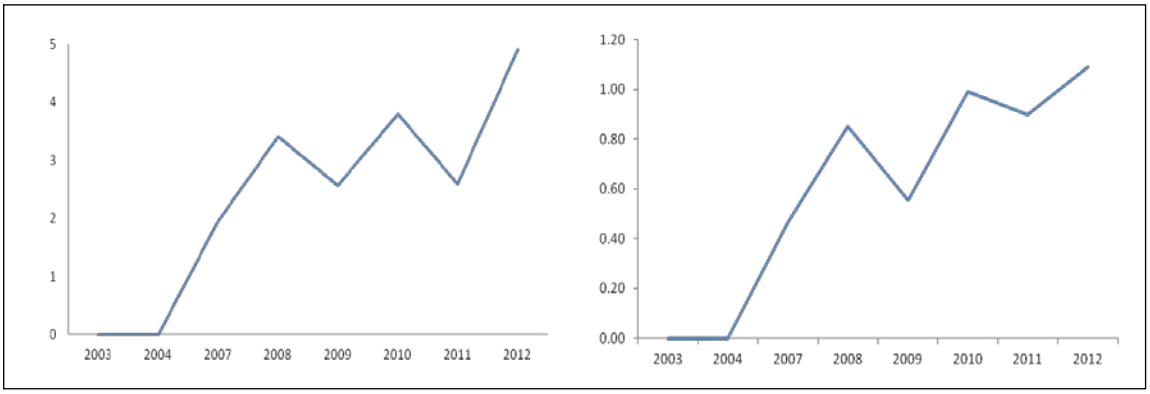
Source: BioRA report for the Council Study (September 2017a)

(v) *Diversity and abundance of introduced species*

An exotic or introduced species refers to 'a species occurring outside its natural range' (Welcomme and Vidthayanon, 2003). Fishes are introduced from their place of origin by intent or accident mainly for aquaculture, wild stock enhancement and ornamental purposes. In the Mekong Basin, Welcomme and Vidthayanon (2003) listed 32 introduced species.

Suckermouth catfish is considered as one of the most invasive species in the Mekong Delta. The abundance of this species in the catch in An Gian Province is increasing (Figure 3.45). The catch of suckermouth catfish from a brush park fishery in Dong Thap Province made up of about 23 per cent of the total catch, and up to 25 per cent in a fyke net fishery (Vu *et al.*, 2013). Similar trends have been observed for tilapias.

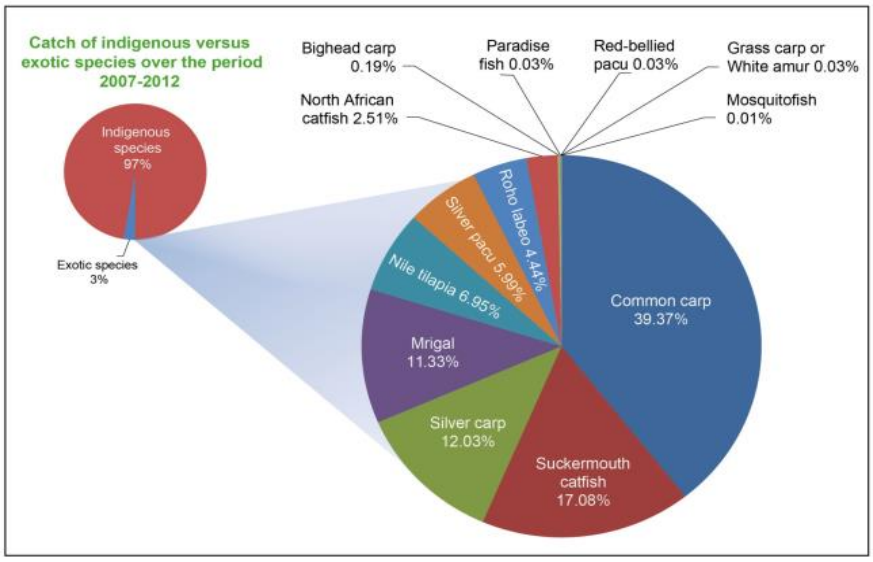
Figure 3.45 Catch proportion of suckermouth catfish (Pterygoplichtys disjunctivus) (left) and tilapia (Oreochromis spp.) (right) in An Gian Province



(Source: Vu et al., 2013)

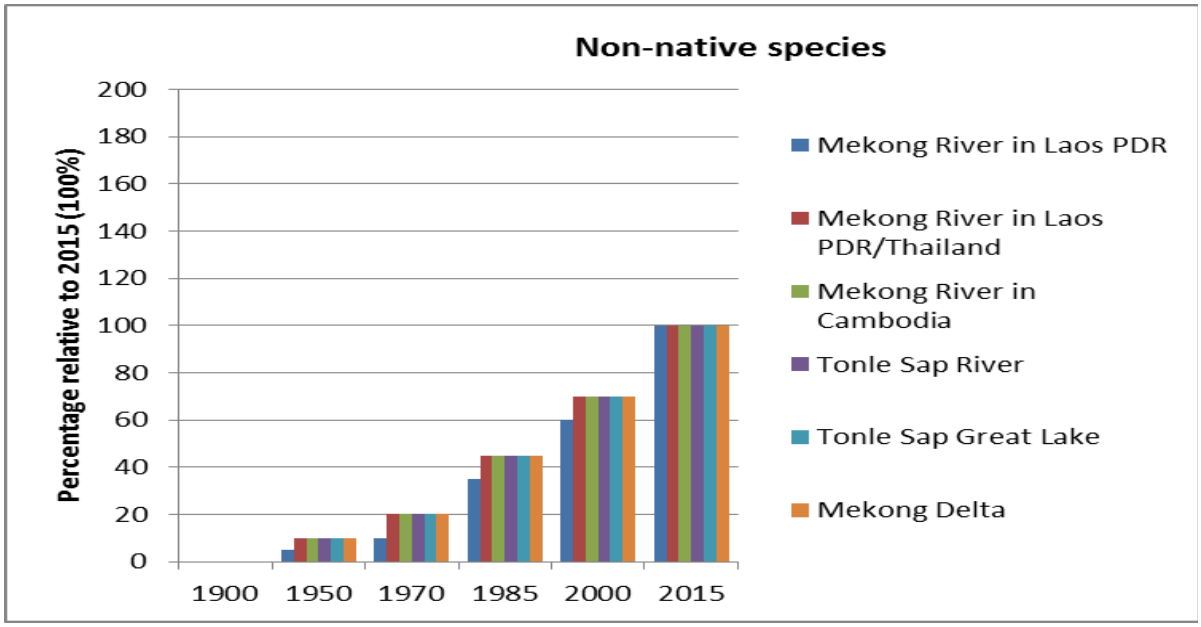
The long-term Fish Abundance and Diversity Monitoring Programme of the MRC Fisheries Programme (2007-2015) show that exotic fish species contributed around three per cent to the total reported catch from the Mekong mainstream, its major tributaries and surrounding floodplains of the LMB. Catch was composed of at least 13 fish exotic species of which common carp, suckermouth catfish, silver carp, mrigal, tilapia, silver and red pacu and rohu were among the most common (Figure 3.46).

Figure 3.46 Overall catch proportion of indigenous versus exotic fish species in the LMB



The proliferation of exotic fish species is a relatively recent phenomenon in the LMB (MRC, 2017a), especially the Delta and in areas around fishing facilities in Northern Laos and Thailand. The numbers have increased both as a result of escape from fish farms and through deliberate stocking. They are estimated to have exploded in their contribution to catches in recent years (Figure 3.47), partly because they are predominately generalist species that can exploit the niche made available through lost migratory species. This group of fish (i.e. generalist exotic species) is a good indicator of environmental degradation.

Figure 3.47 Non-native species: historic abundance estimates as a percentage relative to 2015 (100%)



Source: BioRA report for the Council Study (MRC, 2017a)

(v) *Diversity and abundance of other aquatic organisms*

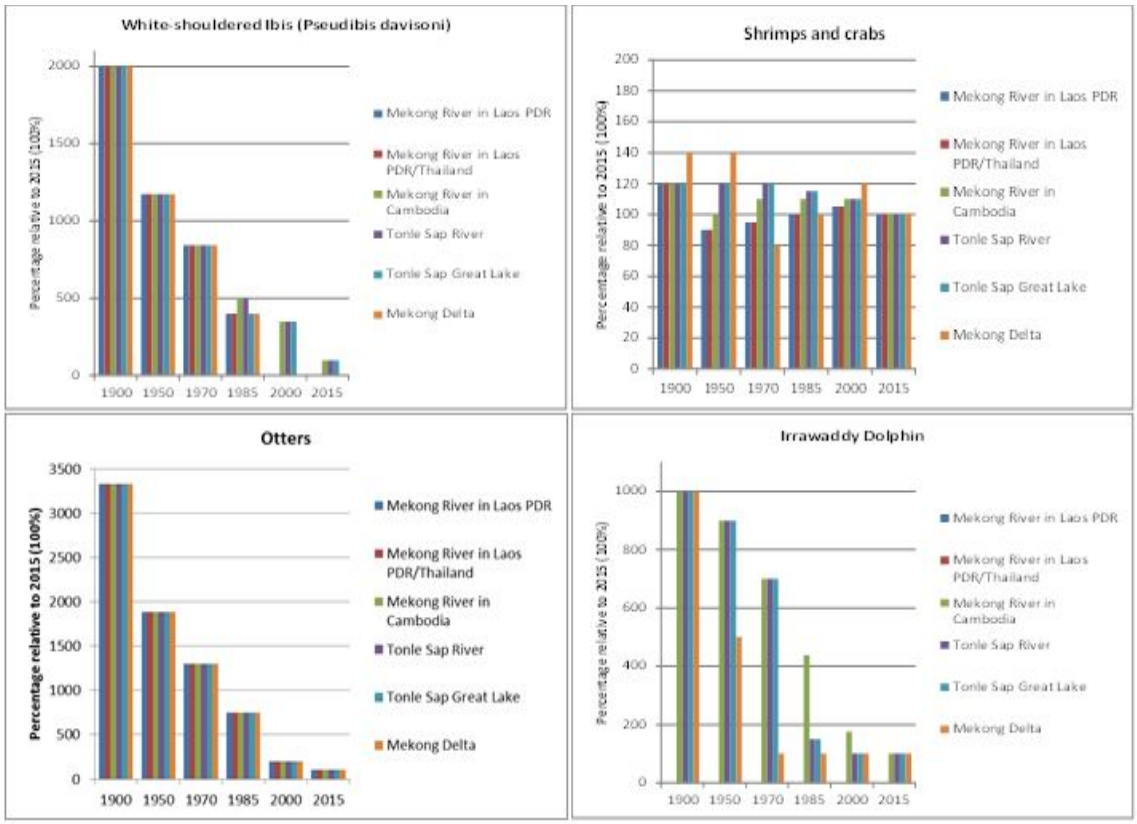
The Mekong River Basin is part of a recognized as a global biodiversity hotspot[11], comprising habitat types from highlands to coastal waters, including peat swamps, subterranean streams and crater lakes. Mekong wetland biodiversity plays an important role in the livelihoods of many LMB people including for food supply, medicines, building materials, and cooking fuel as well as for aesthetic and cultural purposes (Critical Ecosystems Partnership Fund, 2011).

The loss of wetland area combined with infrastructure development, habitat degradation and the introduction of exotic species, overexploitation and illegal wildlife trade, has likely contributed to a considerable loss of species and an increase in the number of threatened species. Figure 3.48 shows some examples that indicate the modelled decline in abundance of much biota has occurred since significant land use changes began some 125 years ago and has accelerated during recent decades as a result of increasing pressures (MRC, 2017a).

Without effective environmental management, the trend in species diversity loss is expected to continue. The development of dams and other infrastructure on floodplains will continue to threaten the diversity and abundance of fish species.

11 The Mekong Basin is the major part of the Indo-Burma Global Biodiversity Hotspot as designated by Conservation International.

Figure 3.48 Modelled historic abundance of selected biota (% relative to 2015)



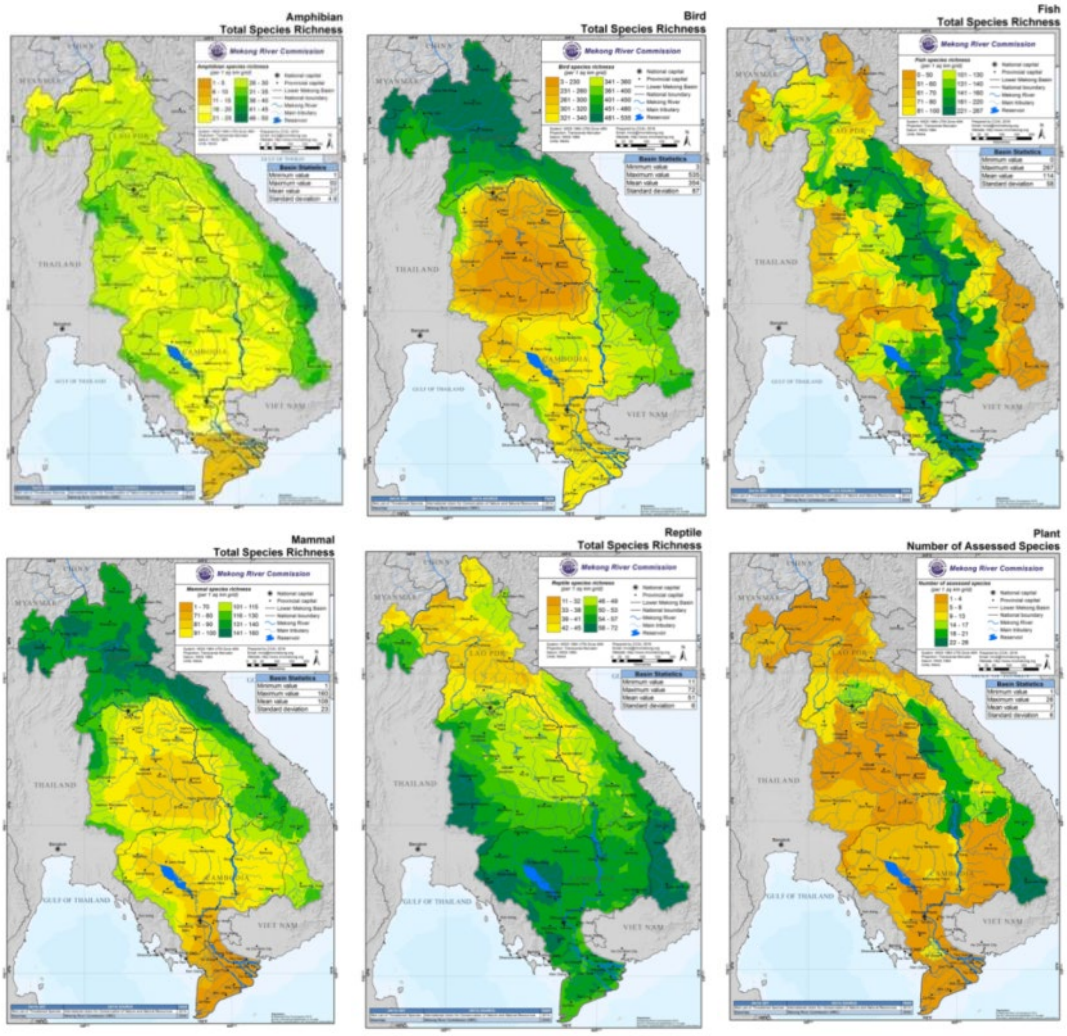
Source: BioRA report for the Council Study (September 2017a)

As identified above, biodiversity of the Lower Mekong Basin (LMB) are already under significant pressure. Analysis of the IUCN Red List spatial data indicates a total of one extinct, 31 critically endangered, 62 endangered, and 95 vulnerable species across the LMB (Table 3.14).

Table 3.14 Numbers of LMB species assessed for the IUCN Red List per Red List category (MRC, 2017b)

Red List Category	Amphibians	Birds	Fish	Mammals	Reptiles	Plants
Extinct	-	-	1	-	-	-
Critically endangered	-	10	13	7	1	-
Endangered	4	12	23	20	2	1
Vulnerable	12	19	32	23	8	1
Near Threatened	10	48	22	10	3	4
Data Deficient	35	2	201	23	29	4
Least Concern	83	728	401	193	131	46
Total	**144**	**819**	**693**	**276**	**174**	**56**

Figure 3.49 Species richness of (a) amphibians; (b) birds; (c) fish; (d) mammals; and (e) reptiles.



Note: For plants, the floristic diversity of the Mekong is not reflected in the IUCN Red List data and so (f) shows only the plants in the LMB that were assessed by the MRC for vulnerability to climate change (MRC, 2017b).

Amphibians

Analysis of the Red List spatial data indicates there are at least 144 amphibian species present in the LMB, of which at least 30 (21%) are endemic to the region. Of the 144 amphibian species known to occur in the LMB, 16 (11%) are globally threatened with extinction (Table 3.14), including four Endangered species and 12 Vulnerable species. A further 10 (7%) are Near Threatened. Major threats to LMB amphibians include logging and wood harvesting, affecting 92 (64%) species; non-timber agriculture affecting 90 (62.5%) species; pollution, in the form of agricultural and forestry effluents, affecting 44 (30.5%) species; the development of housing and urban areas affecting 42 (29%) species; and modifications to natural fire regimes affecting 41 (28.5%) species.

Figure 3.49 shows that, in terms of species richness, amphibians are most diverse at the peripheries of the LMB, and in particular along the Viet Nam-Cambodia and Viet Nam-Lao PDR borders, where richness can reach up to 50 (though more typically 31 to 40) species. In the west of the LMB patches exist where amphibian richness reaches 30 to 40 species, while in the majority of the LMB's interior typical amphibian richness is between 21 and 30 species. Amphibian richness is lowest in the south of the LMB where at locations close to the coast between 11 and 15 species are thought to occur.

Birds

Analysis of the Red List spatial data indicates there are at least 819 bird species present in the LMB, of which at least 27 (3%) are endemic to the region. Of the 819 bird species known to occur, 41 (5%) are globally threatened with extinction (Table 3.14), and a further 48 (6%) are Near Threatened. Major threats to LMB birds include non-timber agriculture affecting 100 (12%) species; hunting and collecting of terrestrial animals, affecting 93 (11%) species; logging and wood harvesting, affecting 73 (9%) species; natural systems modifications, in the form of dams and other water management operations, affecting 56 (7%) species; and habitat shifts and alterations resulting from climate change and severe weather, affecting 45 (5.5%) species.

Figure 3.49 shows that, in terms of species richness, LMB birds vary widely between locations. Species richness is particularly high in the north of the LMB (particularly in Lao PDR), where as many as 535 species are thought to occur at some locations. As one moves southward, bird richness declines, although the total number of species remains high along the eastern periphery of the LMB (predominantly in Lao PDR, but also small areas of Cambodia and Viet Nam) where numbers are typically above 360 species at any given location. Bird richness is lowest in the centre of the LMB (Thailand) where between three and 230 species can occur at any given location. Moving further south into Cambodia and Southern Viet Nam, bird richness increases again to between 260 and 360 species. The exception to this is a small area in western Cambodia, where up to 400 bird species are thought to occur.

Fish

Analysis of the Red List spatial data indicated that there are at least 692 freshwater fish species present in the LMB, of which at least 159 (23%) are endemic to the region. Although as noted earlier, a total of 1,148 fish species are estimated to be present based on catch data and a range of studies that were used to inform the MRC Council Study. The Siamese Flat-barbelled Catfish (*Platytropius siamensis*), which was present in the region, was declared extinct in 2013. Of the 692 extant freshwater fish species known to occur in the LMB 68 (10%) are globally threatened with extinction (Table 3.14), and a further 22 (3%) are Near Threatened. Major threats to LMB freshwater fish include pollution, in the form of agricultural and forestry effluents, affecting 359 (52%) species; Fishing and the harvest of aquatic resources, affecting 303 (44%) species; and natural systems modifications, in the form of dams and other water management operations, affecting 286 (41%) species.

Figure 3.49 shows that, in terms of species richness, LMB freshwater fish species are most diverse (up to 108 species at a given location) at locations along, or directly next to, the main channel of the Mekong River. The only exception to this is in the north of the LMB (in Lao PDR) where species numbers drop to around 51 to 60, even on the main river channel. Broadly speaking, numbers of freshwater fish species become lower as one moves further away from the main river channel. At most locations on the eastern, western and northern peripheries of the LMB the number of freshwater fish species present is between zero and 30.

Mammals

Analysis of the Red List spatial data indicated that there are at least 276 mammal species present in the LMB, of which at least 23 (8%) are endemic to the region. Of the 276 mammal species known to occur, 50 (18%) are globally threatened with extinction (Table 3.14), and a further 10 (4%) are Near Threatened. Major threats to LMB mammals include agriculture and aquaculture, in the form of non-timber crops affecting 178 (64%) species, and, to a lesser extent, wood and pulp plantations, affecting 35 (17%) species; the hunting and collecting of terrestrial animals, affecting 134 (49%) species; logging and wood harvesting, affecting 84 (30%) species; and the development of housing and urban areas, affecting 60 (22%) species.

Figure 3.49 shows that, in terms of species richness, LMB mammals are most diverse in the north of the LMB, and in particular in Lao PDR, where between 131 and 160 species are estimated to occur at most locations. Mammal species richness appears to decline as one moves southward across the LMB, although the number of mammal species present remains relatively high (>100 species per grid cell) at the eastern and western peripheries. Mammal species richness is lowest in the far south of the LMB (southern Viet Nam), where the number of species per grid cell is estimated to be 70 or less at all locations.

Reptiles

Analysis of the Red List spatial data provided a list of 174 reptile species known to be present in the LMB, of which nine (5%) are endemic to the region. Of the 174 LMB reptile species that have been assessed for the IUCN Red List, 11 (6%) are globally threatened with extinction (Table 3.14), and a further three (2%) are Near Threatened. Major threats to these reptiles include agriculture and aquaculture, in the form of non-timber crops affecting 107 (61%) species; fishing and the harvest of aquatic resources, affecting 56 (32%) species; logging and wood harvesting, affecting 51 (29%) species; the development of housing and urban areas, affecting 33 (19%) species; and the hunting and collection of animals, also affecting 33 (19%) species.

Figure 3.49 shows that, in terms of species richness, reptiles are most diverse in the southern half of the LMB, and in particular on the eastern and western peripheries, where up to 72 species (of those with available range maps) per grid cell can occur. Across the remainder of the southern LMB, and in small areas in the north (e.g. a small area of Thailand, bordering Lao PDR and Myanmar) numbers are typically between 50 and 57 species per grid cell. Reptile richness appears to be lowest in the far north of the LMB, where as few as 11 species per grid cell are thought to occur. In most of the remainder of the northern LMB numbers of reptile species (of those assessed) typically range between 39 and 49 species.

Plants

Red List assessments of LMB plants are far from comprehensive, and an analysis of the Red List spatial data provided information on a total of only 56 species from 19 families – far from representative of such a floristically diverse region (the Mekong Basin, in its entirety, is estimated to contain around 20,000 plant species[12]. Of these 56 plant species, none are endemic to the LMB, two (3.5%) are globally threatened with extinction (Table 3.14), and a further four (7%) are Near Threatened. Major threats to these plants include logging and wood harvesting, affecting 35 (62.5%) species; marine and freshwater aquaculture, affecting 33 (59%) species; habitat shifts and alterations resulting from climate change and severe weather, affecting 33 (59%) species; the development of housing and urban areas, affecting 32 (57%) species; and agriculture and aquaculture, in the form of non-timber crops affecting 30 (54%) species.

3.4.5 Condition and status of ecological significant areas

A number of environmentally significant areas have been identified in the LMB. These are ecologically sensitive areas of national, regional or international significance containing rich biodiversity, a large number of important species at risk and areas important for migrating species or supporting key ecological processes. They include Ramsar sites, Biosphere Reserves, Protected Areas such as National Parks and National Conservation Forest Areas, Important Bird Areas and Greater Mekong Region Sub-region (GMS) hotspots (Table 3.15).

12 http://www.mrcmekong.org/topics/environmental-health/

Table 3.15 Summary of the number and area of protected areas of different categories across the Lower Mekong Basin

	Cambodia		Lao PDR		Thailand		Viet Nam	
	No.	Area (km²)	No.	Area (km²)	No.	Area (km²)	No.	Area (km²)
Ramsar wetlands	4	733	2	148	3	48	4	620
Bio reserve					1	328	3	23,601
Important wetlands	24	12,552	26	12,511	39	16,014	18	827
National Protected Area / National Conservation Forest Area / National Park	11	16,189	24	37,681	26	3,824	6	3,425
National Protected / Biodiversity Corridor	3	14,279	2	772				
GMS Hotspot			3	4,162	3	25		
Important Water Bird Areas					4	6	15	2,541
Wildlife Sanctuary	10	24,606			10	6,674		
Multiple Use Areas	5	4,097						
Protected Landscape	8	1,493						
National Heritage Park	1	247			11	640		
World Heritage Site					1	22		
Fish Conservation Areas	58	1,200						
TOTAL	**125**	**75,396**	**57**	**55,274**	**98**	**27,582**	**46**	**31,014**

Source: Regional Review Report on Environmental Assets (EAs) with National and Regional Importance and Existing Studies, Policies, Strategies, and Action Plans, for the Management of EAs in the Lower Mekong Basin (LMB), MRC, 2019 Technical Note on Conceptual Framework for the Updated Methodology and Tool of Wetland Inventory (WI), MRC, 2018.

Following the adoption into force of the Ramsar Convention in Lao PDR in 2010, all countries have now signed and ratified all four of the key international conventions related to wetland issues: the Ramsar Convention, the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC) and the World Heritage Convention. Each country has at least two Ramsar sites of international importance within the Lower Mekong Basin listed. Based on 2012-2015 national reporting to the Ramsar Convention, the condition of Ramsar sites is not reported to have changed significantly for any country, although Lao PDR has reported that wetlands generally have deteriorated.

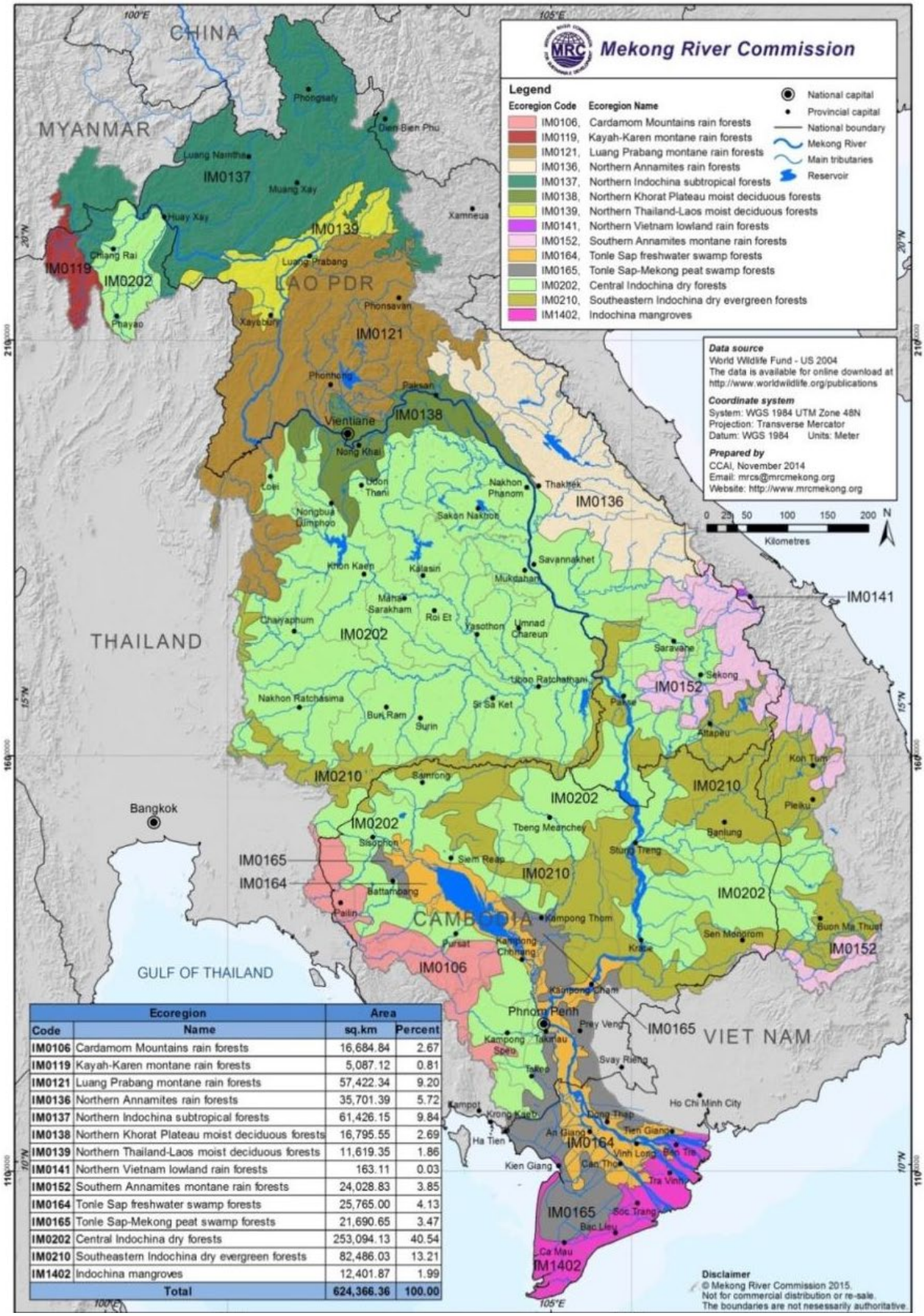
Considering all categories of protection, the Lower Mekong Basin has one of the most extensive protected area networks in the world. Notwithstanding the ongoing management and resourcing challenges to ensure conservation of critical biodiversity, in total the area subject to some form of protection easily meets the Aichi Biodiversity Target for 17% of terrestrial and inland waters to be protected by 2020. This achievement represents a strong statement by the government of each Member Country on the importance of conserving and equitably managing their shared natural heritage and the ecosystem services on which the regional economy depends. Of particular note are the large areas protected as national park in Cambodia and Lao PDR, as important wetlands in Thailand, bio-reserves in Viet Nam and more than 24,000 km² of wildlife sanctuaries in Cambodia, which has seen a recent increase from 24 to 52 in protected areas.

Within the Lower Mekong Basin (LMB) there are three broad terrestrial habitat types: Tropical and Subtropical Dry Broadleaf Forests (which comprise 54% of the area of the LMB); Tropical and Subtropical Moist Broadleaf Forests (which comprise 44%); and Mangroves (which comprise 2As described in Olsen *et al.* (2001).

The Dry Broadleaf Forests generally exhibit high annual rainfall but with extended dry seasons which can last several months. Seasonal drought is a major determinant of ecological process and biodiversity. They are less biologically diverse than rainforests yet harbour an abundance of large vertebrate fauna. The Wet Broadleaf Forests are characterised by low variability in annual temperature and high levels of rainfall. Forest composition is primarily semi-evergreen, evergreen and deciduous and contains some of the highest species diversity of any major terrestrial habitat type. Mangroves occur along the sheltered tropical and subtropical shoreline, subject to the ebb and flow of tides, fortnightly spring and neap tides, and seasonal weather fluctuations. They are comprised of around 60 species of salt-tolerant tree and are an important nursery habitat for many aquatic species. Within the LMB the three major habitat types are comprised of 14 Ecoregions (Figure 3.50). Different ecoregions are more or less dominated by natural and human land covers, with the higher elevation ecoregions generally exhibiting a greater dominance of natural land cover, particularly deciduous, evergreen and coniferous forest. These include the ecoregions of the Cardamom Mountains Rain Forests, the Kayah-Karen Montane Rain Forests and the Northern Khorat Plateau Moist Deciduous Forests amongst others. Lowland areas and those ecoregions with significant freshwater systems such as the Tonle Sap Freshwater Swamp Forests, the Central Indochina Dry Forests and the Indochina Mangroves ecoregions are dominated by annual crops and paddy rice.

All ecoregions of the LMB have been adversely affected by human activities and only have a portion of their natural habitat remaining. In some cases, this habitat consists of isolated remnants (e.g. Southern Annamites Montane Rain Forests) while in other cases there are still fairly large areas of contiguous habitat in place (e.g. South-eastern Indochina Dry Evergreen Forests). Using forest cover (not including plantation forests) as an indicator of natural habitat remaining, the average remaining forest cover of all 14 ecoregions in 2010 was 47 per cent. In total for the whole LMB the remaining forest cover across all ecoregions was 41 per cent. Between 2003 and 2010 forest cover declined in ten ecoregions, remained the same in two and increased in two (Table 3.16). Taken together all 14 ecoregions lost an average of 12 per cent of forested area between 2003 and 2010 (MRC, 2011).

Figure 3.50 Eco-regions of the Lower Mekong Basin



Ecoregion		Area	
Code	Name	sq.km	Percent
IM0106	Cardamom Mountains rain forests	16,684.84	2.67
IM0119	Kayah-Karen montane rain forests	5,087.12	0.81
IM0121	Luang Prabang montane rain forests	57,422.34	9.20
IM0136	Northern Annamites rain forests	35,701.39	5.72
IM0137	Northern Indochina subtropical forests	61,426.15	9.84
IM0138	Northern Khorat Plateau moist deciduous forests	16,795.55	2.69
IM0139	Northern Thailand-Laos moist deciduous forests	11,619.35	1.86
IM0141	Northern Vietnam lowland rain forests	163.11	0.03
IM0152	Southern Annamites montane rain forests	24,028.83	3.85
IM0164	Tonle Sap freshwater swamp forests	25,765.00	4.13
IM0165	Tonle Sap-Mekong peat swamp forests	21,690.65	3.47
IM0202	Central Indochina dry forests	253,094.13	40.54
IM0210	Southeastern Indochina dry evergreen forests	82,486.03	13.21
IM1402	Indochina mangroves	12,401.87	1.99
Total		624,366.36	100.00

The area of each ecoregion which is under some form of protected area management ranges from zero to 54 per cent (Table 3.16). The Northern Thailand-Laos Moist Deciduous Forests is the least protected (<1%) and the Cardamom Mountains Rainforest is the most protected (54%). There are, however, a range of different protection regimes in place (across all IUCN categories and beyond) allowing for different types of activities to occur, and regardless of the legal status management and enforcement is problematic in many places. Shifting cultivation, hunting and unsustainable harvest of wildlife and other non-timber forest products are reported as ongoing threats to habitat and biodiversity in many of the protected areas across the LMB.

Only three of 14 ecoregions are assessed as relatively stable/intact (WWF, 2015). Six are considered vulnerable and five are Critical/Endangered (Northern Khorat Plateau Moist Deciduous Forests, Northern Viet Nam Lowland Rain Forests, Tonle Sap-Mekong Peat Swamp Forests, South-eastern Indochina Dry Evergreen Forests and the Indochina Mangroves).

Following decades of declining forest cover it appears to be showing signs of increase, particularly in Lao PDR where Forest Cover Assessments by the Ministry of Agriculture and Forestry show an increase from 2010 to 2015 of 14,292 square kilometres or from approximately 40 per cent of the country to 46 percent. Upland forest cover in north and north-east provinces of Thailand has also increased from a low in 1998. The increase in area between 1998 and 2015 is approximately 20 per cent (Thailand Office of Forest Land Management), although it is unclear how much of this increase is plantation forest and how much is regenerated native forest.

In Viet Nam forest area across the country is increasing. From 2015 to 2016 a net increase of 1,100 square kilometres was recorded. However, this trend is not replicated in provinces within the LMB where forest cover declined from approximately 30 per cent in 2011 to 27 per cent in 2015. In Cambodia, forest cover has remained steady across all provinces between 2010 and 2014 (Cambodia Forestry Statistics).

In addition to this decline in area of forest cover within the LMB, according to the national report on Environment Status by MONRE, Viet Nam, in the period 2011-2015 the quality of natural forest continues to decrease. Much of the increase in forest cover is mainly due to plantations with low biodiversity values, while natural forests with high biodiversity have low conservation rates. In the period 1990-2013, the area of natural and planted forests increased, but the annual growth rate of the planted forest area is about six times higher than that of natural forests (MONRE Viet Nam, 2016).

3.4.6 Summary of status of environmental assets

Environmental assets of the Lower Mekong Basin remain under threat. The decline in wetland area appears to be continuing, particularly for sensitive areas such as mangroves, although updated wetland maps being prepared by MRC and Member Countries will be crucial for confirming current status.

An increasing amount of fish are being caught although there are concerning signs of over fishing as increasing effort is required to achieve the same production levels and smaller fish are making up an increasing proportion of the catch. The proportion of exotic species making-up the overall catch appears to be increasing. Aquaculture production continues to grow strongly. Where previously this growth in aquaculture had corresponded with a decline in mangrove areas in the Mekong Delta, aquaculture production is increasingly displacing rice fields, forestry lands and areas otherwise considered wastelands (MRC, 2017a).

The LMB remains one of the most biologically diverse regions of the world. However, there are many threatened plants and animals in the LMB as habitat fragmentation, water resource development, agricultural expansion, and harvest, among other threatening processes continues.

Table 3.16 Summary of area of forest cover and percentage change between 2003 and 2010 with ecoregion status as assessed by World Wildlife Fund for Nature

Ecoregion	Area in the LMB (km²)	Forest cover 2003 (%)	Forest cover 2010 (%)	Change 2003-2010 (%)	Area protected (%)	Status [13]
Cardamom mountains rainforest	16,688	81	57	-24	54	Relatively stable/ Intact
Kayah-Karen montane rainforests	4,555	71	57	-14	44	Relatively stable/ Intact
Luang Prabang montane rainforests	57,435	83	60	-23	16	Vulnerable
Northern annamites rain forest	35,709	82	70	-12	27	Relatively stable/ Intact
Northern Indochina subtropical forests	56,130	89	58	-31	19	Vulnerable
Northern Khorat Plateau Moist Deciduous Forests	16,799	33	18	-15	5	Critical/ Endangered
Northern Thailand-Laos Moist Deciduous Forests	11,622	88	49	-39	<1	Vulnerable
Northern Viet Nam Lowland Rain Forests	163	100	100	0	7	Critical/ Endangered
Southern Annamites Montane Rain Forests	24,034	80	75	-5	30	Vulnerable
Tonle Sap Freshwater Swamp Forests	25,768	1	14	+13	13	Vulnerable
Tonle Sap-Mekong Peat Swamp Forests	21,691	3	6	+3	3	Critical/ Endangered
Central Indochina Dry Forests	253,147	35	29	-6	11	Vulnerable
South-eastern Indochina Dry Evergreen Forests	82,504	70	56	-14	29	Critical/ Endangered
Indochina Mangroves	12,339	9	9	0	10	Critical/ Endangered

There are a large number of ecologically significant areas covering a substantial part of the LMB with a wide range of management regimes and protection systems are in place. Following decades of decline, forest cover appears to be increasing in some areas of the LMB, with Lao PDR in particularly showing a substantial increase between 2010 and 2015.

3.5 Summary of overall environmental conditions in the basin

Overall, monitoring of mainstream flows demonstrates that they remain compliant with PMFM requirements. Furthermore, records indicate that the increase in dry season minimum flows predicted as a result of increased storage within the basin, particularly in the UMB, are indeed occurring. Whilst augmentation is most apparent in the upper reaches of the LMB, natural variability in the lower reaches makes augmentation less obvious here. Flood season flows in both the upper and lower reaches of the LMB appear to be declining.

While water quality generally remains compliant with PWQ, the clear trend in decreasing sediment flows should be seen as a significant concern both for the reduction in nutrients feeding the natural biota and also for the morphological impacts on the delta and coastal region. Further studies are needed to determine a strategy to address this issue.

Overall wetland areas are decreasing, principally as a result of land use changes prompted by the economic development of the region, and are a small fraction of what they were historically. Wetlands play a vital role in sustaining the basin's rich ecology. Few remaining natural wetlands are left, and further decline can be expected unless there is a concerted effort to better manage the basin's landscape and preserve key habitats.

Capture fisheries are under threat with a variety of pressures increasing substantially in recent decades across all mainstream zones of the LMB (MRC, 2017a). The main pressures are agricultural land development including massive

13 Status determined for WWF, accessed 2015.

expansion of rice farming and deforestation, intensive fishing pressure, hydropower development, mining, sand mining, urbanization and industrial development and associated pollution (MRC, 2017a).

According to a statistical analysis from fisheries statistical monitoring programmes (e.g., Hall *et al.* 2013), total fish catch appears to be relatively stable in recent years. This finding, however, hides the considerable increase in fishing effort to maintain the same level of catch. This is illustrated by the declining catch per unit effort (in terms of gear, fishers) observed by fishers and by the MRC fisheries monitoring programmes, and the shift in fish species composition to smaller fishes, both of which are classic indicators of heavy fishing pressure (Welcomme, 2002). Also, the proportion of non-native 'exotic' fish has increased markedly in recent years and now contributes a notable proportion of the catch, especially in the Delta and upstream in the Luang Prabang area (MRC, 2017a). This is a worrying trend with potentially grave long-term consequences for the endemic fish fauna of the LMB.

Capture fisheries represent an important source of protein underpinning food security within the basin, and also contribute to rural livelihoods. With 13 fish species listed as critically endangered, 23 species listed as endangered and a further 32 species whose status is vulnerable, a proactive approach is needed to counter threats to bio-diversity and to manage capture fisheries in a more sustainable manner. With increased urbanisation and changing consumption patterns, both reservoir fisheries and the fast-growing aquaculture sector are also important to the basin's economy and food security.

Ecologically significant areas encompass a range of different ecosystem types, including rivers, wetlands and grasslands. A substantial number and area are under some form of protection as Ramsar sites, biosphere reserves, national parks and others. After decades of declining forest cover there are signs in some places of an increase in forested area, especially in Lao PDR and Thailand. Many species remain under threat with a large number of fish, birds, reptiles, amphibians and mammals listed as vulnerable, endangered or critically endangered. Increasing protections for important natural habitats should over time help support the LMB's threatened plants and animals. Connecting habitats through biodiversity corridors and taking a cooperative landscape approach to management and enforcement of regulations with the engagement of local communities will be important.

4. Social Dimension

4.1 Introduction

The social dimension of the MRC Indicator Framework reflects the MRC's intent to promote social development and the well-being of all riparian States as reflected in Chapter 1, Preamble, of the 1995 Mekong Agreement, which reaffirms the Member Countries'"determination to continue to cooperate and promote in a constructive and mutually beneficial manner in the sustainable development, utilization, conservation and management of the Mekong River Basin water and related resources for navigational and non-navigational purposes, for social and economic development and the well-being of all riparian States, consistent with the needs to protect, preserve, enhance and manage the environmental and aquatic conditions and maintenance of the ecological balance exceptional to this river basin".

Whilst the MRC does not undertake specific social improvement programmes, the intent is that water resource-related projects undertaken within the MRC mandate should have a significant and overall positive impact on socio-economic conditions within the basin. Three strategic indicators have been selected by which to judge whether these objectives are being met. These three indicators are (i) living conditions and well-being, (ii) livelihoods and employment in MRC water-related sectors [14], and (iii) overall social condition. These strategic indicators are supported by seven assessment indicators as follows:

Strategic indicators	Assessment indicators
Living conditions and well-being	❑ Food security ❑ Water security ❑ Health security ❑ Access to electricity
Employment in MRC water-related sectors	❑ Employment rate in MRC water-related sectors ❑ Economic security ❑ Gender equality in employment and economic engagement
Overall social condition	❑ Overall assessment based on the above indicators

At present the analysis for some strategic and assessment indicators is limited due to a lack of socio-economic data. It should be noted that further development of this analysis along the lines envisaged by the indicator framework will require significant additional data. The approach taken here uses the best available evidence. As a result, while the strategic and assessment indicators considered remain broadly the same, there has been some divergence from the monitoring parameters contained in the Indicator Framework.

4.2 Living conditions and well-being

4.2.1 Assessment methodology

The Strategic Indictor "Living conditions and wellbeing" is defined as the level of community resilience as derived from the key components of societal wellbeing that help reduce vulnerability: food, water and health security and access to electricity. The assessment indicators for this strategic indicator are (i) food Security, (ii) water security, (iii) health security, and (iv) electricity access. Each assessment indicator is evaluated with respect to monitoring parameters to reach a determination as to overall living conditions and well-being in the LMB.

14 MRC water-related sectorMRC water-related sectors are those mandated by the 1995 MRC Agreement under Article 1 as "including, but not limited to irrigation, hydro-power, navigation, flood control, fisheries, timber floating, recreation and tourism" and are otherwise referred to as "water resource-related sectors".

4.2.2 Food security

For the purposes of monitoring food security in the LMB, it is defined as the ability of basin communities and households to meet their food demands either through their own production of food grain and protein, or sufficient income to purchase food; and as evidenced by a lack of infant malnutrition. The following section looks at each of these indicators to derive an overall assessment of food security conditions in the LMB.

(i) *Ability to meet household food demand*

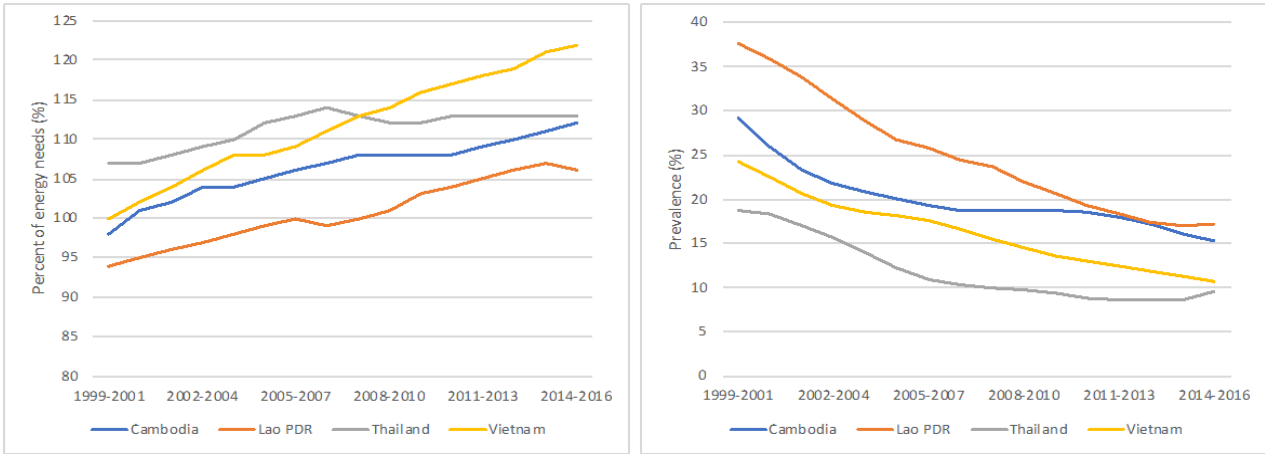
In seeking to establish the extent to which households are able to meet food demand, two indicators were considered. Since LMB specific data has not been available, national level data has been used. [15]The first is the average daily energy supply adequacy. This is an indicator of food availability and expresses the Dietary Energy Supply as a percentage of the Average Dietary Energy Requirement. The country's average supply of calories for food consumption (i.e. netting out any exported food and food production not used for human consumption) is normalised by the average dietary energy requirement estimated for the population. This provides an index of the adequacy of food supply in terms of dietary energy requirements (FAO 2018). The second indicator used is that of prevalence of undernourishment. This is the percentage of the population whose food intake falls below the minimum level of dietary energy requirements (UN, 2015). The Food and Agriculture Organisation (FAO) defined the minimum dietary energy requirement in Cambodia, Lao PDR, Thailand and Viet Nam in between 2006-2008 was 1,760, 1,700, 1,850 and 1,820 kcal/person/day respectively. Considered together, energy supply adequacy and prevalence of undernourishment allows an evaluation of whether undernourishment is a result of insufficient food supply or distributional considerations (FAO 2018).

Adequacy of dietary energy supply has improved considerably for all LMB countries between 1999 and 2016 (Figure 4.1). Cambodia and Lao PDR have both managed to move from a position where food supply was inadequate to meet dietary needs positions where food supply should be sufficient to meet these needs. Viet Nam has also moved from a marginal position where supply was almost balanced with dietary needs, to a positon where there is considerable surplus dietary energy supply. All three of these countries have seen rapid growth in availability over the last fifteen years. Thailand on the other hand, while reaching an adequate level of availability, has not increased its surplus since the mid 2000s.

At the same time the prevalence of undernourishment has declined in all LMB countries. Cambodia, Lao PDR and Viet Nam have seen rapid declines in levels of undernourishment since 1999. By 2016, Cambodia (15%), Lao PDR (17%) and Viet Nam (11%) had managed to reduce the levels of undernourishment experienced in 1999 by around 50%. Nevertheless, all three countries still have large populations experiencing undernourishment. Thailand has also managed to decrease levels of undernourishment over the same period, albeit from lower initial levels. However, since the mid-2000s the level of undernourishment has remained at around 10%. This mirrors the performance in the adequacy of dietary energy supply and suggests an issue with some groups facing chronic food insecurity.

15 While much more detailed evidence on food availability and consumption is available from the SIMVA social surveys conducted by MRC and used in the recent Council Study, these focus on a corridor 15 Km either side of the Mekong Mainstream. The rationale behind the choice of this corridor is that direct riverine influences tail off beyond 15 Km. That is to say, social and economic characteristics of populations in the corridor, due to their proximity to the mainstream are likely to be substantially different to the rest of the population. For these reasons national level data has been preferred as the basis for estimates.

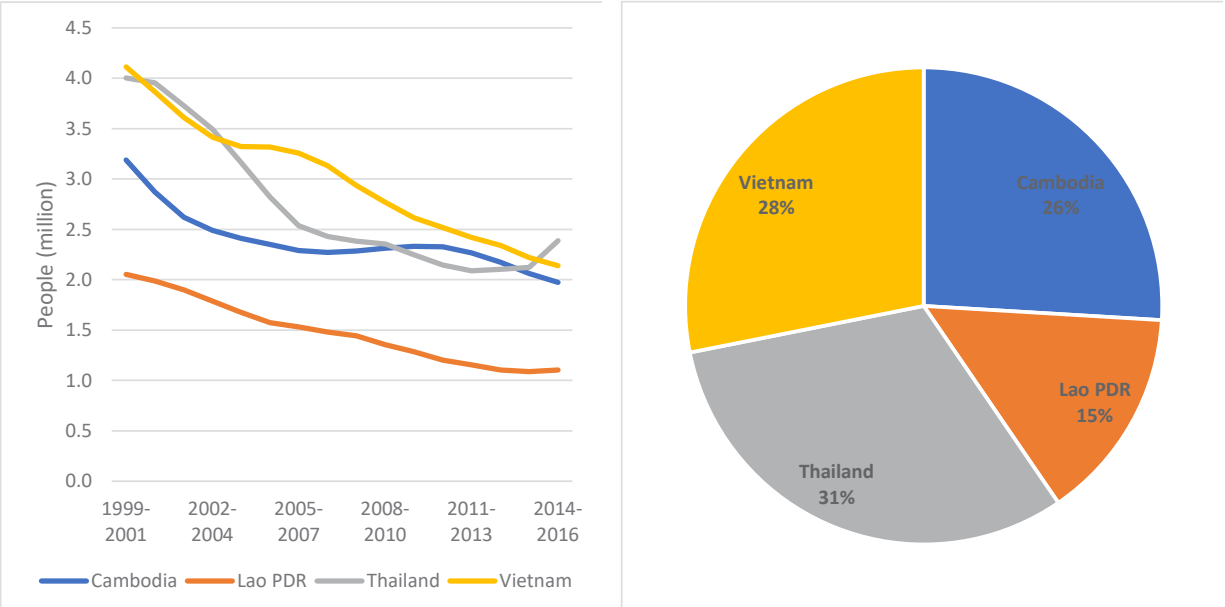
Figure 4.1 Adequacy of Dietary Energy Supply (%) from LMB country national data 1999-2016 (left) and prevelance of undernourishment share of population (%) in LMB countries 1999-2016 (right)



Source: FAOSTAT 2018

Figure 4.2 Figure 4.1is based upon an interpolation of population estimates for the LMB and national level undernourishment estimates to estimate the number of undernourished people in the LMB. Despite higher levels of undernourishment in Lao PDR and Cambodia, due to larger populations in Thailand and Viet Nam, the absolute number of undernourished people is highest in Thailand (2.4 million), then Viet Nam (2.1 million), with around 2 million and 1.1 million undernourished people in the Cambodian and Laotian portion of the LMB. Thus, despite the relative abundance of dietary energy supply in both Thailand and Viet Nam, based upon these figures undernourishment remains a problem. As with other indicators, in the case of Thailand and Viet Nam care needs to be taken in the interpretation of national level indicators. Nevertheless, given the socio-economic characteristics of the Thai and Vietnamese portions of the basin, if anything the undernourishment figures are likely to be under-estimates.

Figure 4.2 Number of people undernourished in LMB 1999 – 2016 (3 year average) (left) share of undernourished people living in LMB by country 2014-2016 average (right)

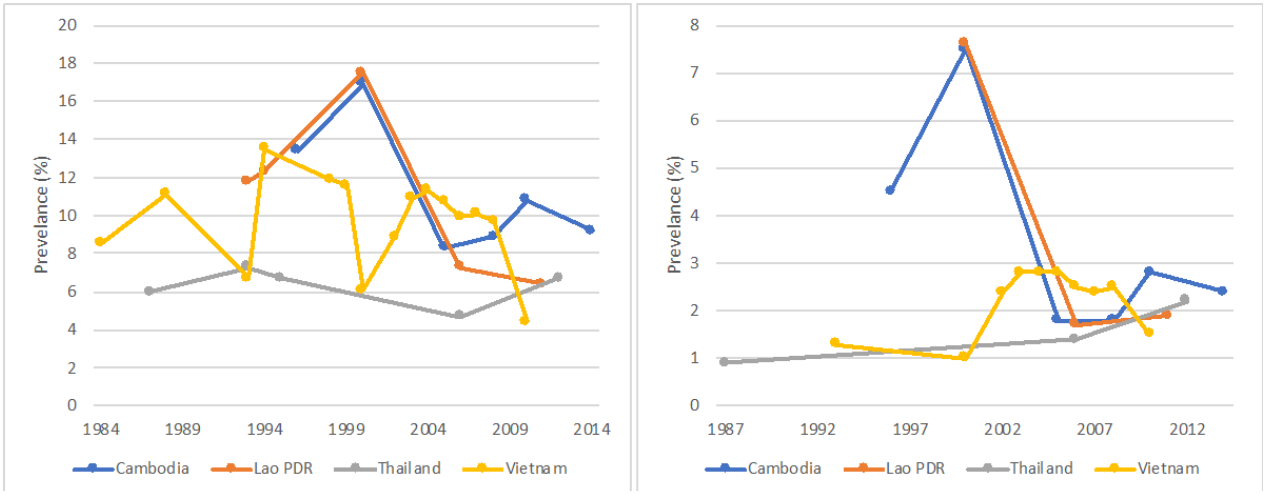


Source: FAOSTAT 2018; MRC population estimates

(ii) *Infant malnutrition*

Infant malnutrition is frequently used as an indicator of food security. Undernourished children have lower resistance to infection and are more likely to die from common childhood ailments, including diarrheal diseases and respiratory infections. Frequent illness saps the nutritional status of those who survive, locking them into a vicious cycle of recurring sickness and faltering growth. Figure 4.3 presents national level data for LMB countries on infant malnutrition showing figures for wasting and severe wasting.

Figure 4.3 Prevalence of wasting (% of children under 5)[16] (left) and prevalence of severe wasting, weight for height (% of children under 5) [17](right) from LMB country national data 1984 - 2014



Source: World Bank, 2018, Health Nutrition and Population Statistics Data Bank

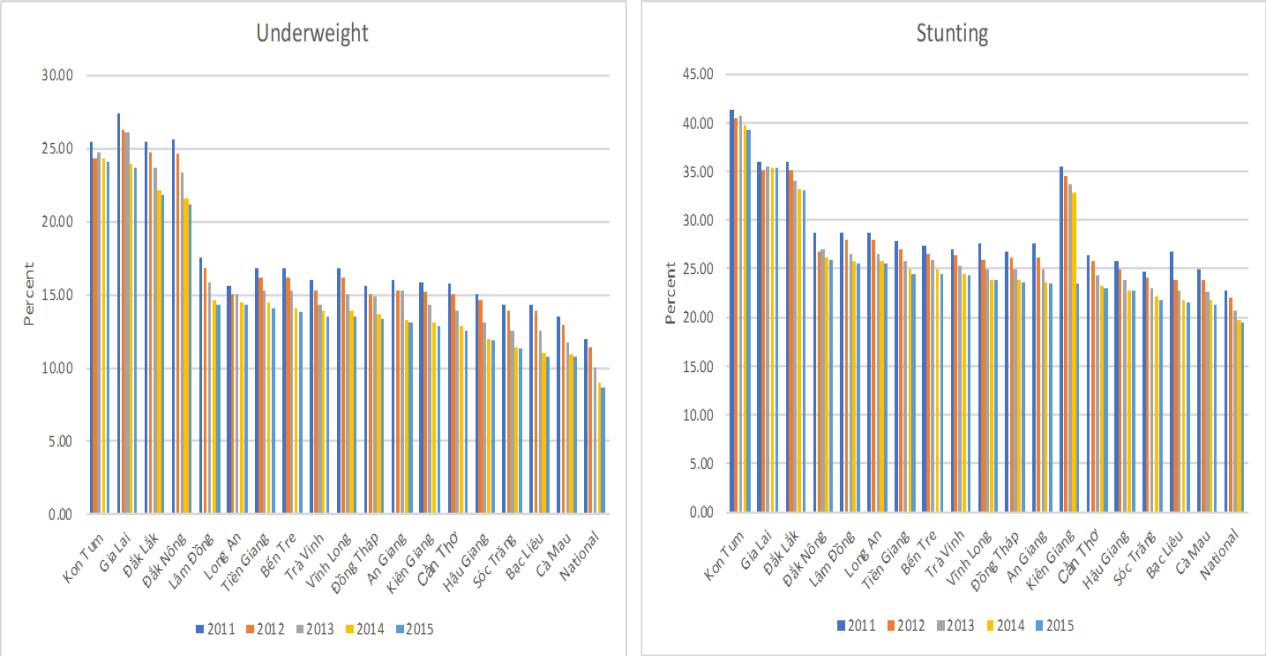
Whilst a full-time series has not been available, the data presented suggests that infant malnutrition remains a chronic problem in then LMB. Severe wasting has generally decreased over time, it remains relatively high in Cambodia. Overall, malnutrition in Cambodia seems to be on a downward trend, but an up-tick in wasting and severe wasting in 2010 suggests that populations still remain vulnerable. Lao PDR shows better performance and a secular decline in infant malnutrition indicators since the late 1990s, in 2012 wasting was as around 6.7% and severe wasting at 1.9%. Thailand by contrast has seen both wasting and severe wasting increase in recent years. Between 2006 and 2012 wasting increased from 4.7% to 6.7%, and severe wasting increased from 1.4% to 2.2% over the same period. Finally, Viet Nam has seen rapid declines in both wasting and severe wasting between 2008 and 2010, wasting fell from 9.7% to 4.4% and severe wasting fell from 2.5% to 1.5%.

There also remains significant variation within the basin at the sub-national level. For example, figures for Viet Nam show rates of malnutrition much higher than the national average in the provinces of the central highlands (Kon Tum , Gia Lai and Dak Lak). In all LMB provinces the level of malnutrition is higher than the national average, possibly reflecting the relatively rural character of LMB areas and relative to the national population as a whole. At the same time, infant malnutrition has been gradually reducing in all provinces 2011 and 2015 (Figure 4.4).

16 Prevalence of wasting is the proportion of children under age 5 whose weight for height is more than two standard deviations below the median for the international reference population ages 0-59.

17 Prevalence of severe wasting is the proportion of children under age 5 whose weight for height is more than three standard deviations below the median for the international reference population ages 0-59.

Figure 4.4 Infant malnutrition in LMB provinces of Viet Nam 2011 - 2015



Source: Viet Nam Provincial Statistical Yearbooks

4.2.3 Water security

Water security is defined as the ability of basin communities to meet their potable water demands for household use and demands for agricultural uses and be free from the risk of flooding. Water demands for both domestic and agricultural uses and to be free from flooding. Each component of water security is discussed in turn.

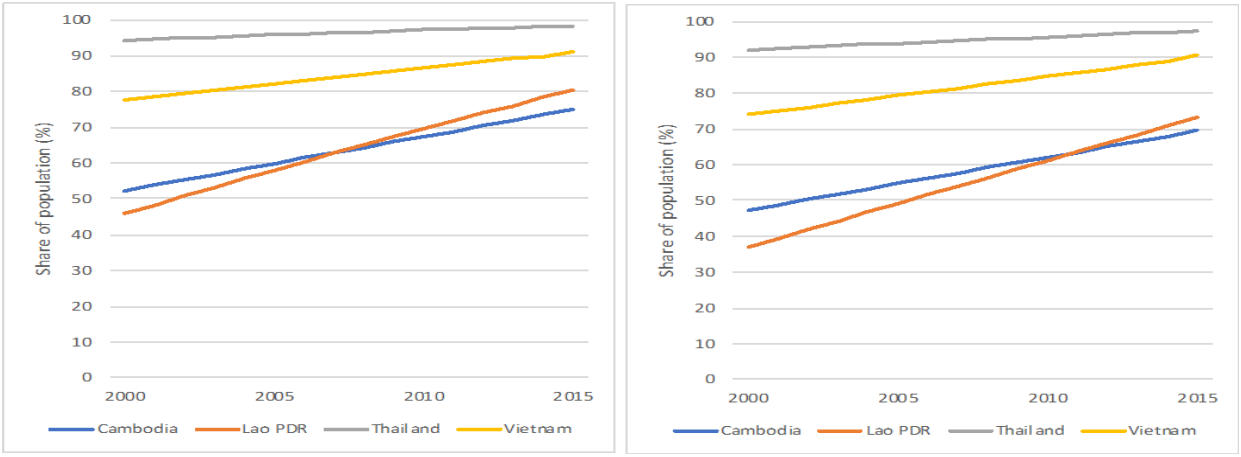
(iii) *Adequacy of domestic supply*

Access to safe drinking water is critical to well-being. Without safe drinking water, individuals can be prone to a range of diseases related to contaminated water supply. Lack of adequate safe drinking water and associated enteric diseases is a key cause of protein malnutrition amongst infants. Access to safe water supplies is therefore used as an important indicator of well-being for populations in the LMB.

Safe or potable water sources generally include piped water on premises (piped household water connection located inside the user's dwelling, plot or yard), public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs, and sometimes rainwater collection. Unfortunately, sub-national figures on the extent of safe water availability in the LMB have not yet been available, therefore national level data is used. Figure 4.5 report the improvements in the availability of safe water supplies for LMB countries.

All countries have improved water access substantially, although Thailand performs best with close to 100% of the population enjoying access to basic drinking water services in 2015, a little over 90% of the population in Viet Nam also had access to drinking water services in 2015, and the figures for Lao PDR and Cambodia were 80% and 75% respectively. Drinking water services in rural areas are marginally less extensive, in 2015 97% of Thailand's rural population had basic drinking water services, in Viet Nam 91%, in Lao PDR 73% and Cambodia 70%.

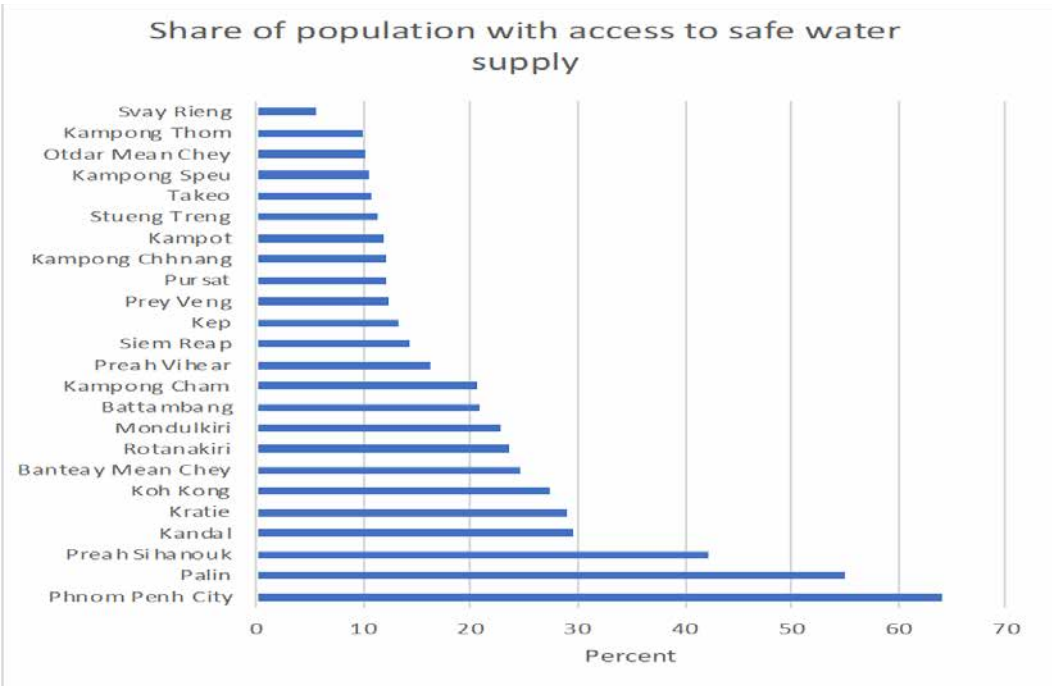
Figure 4.5 Share of people using at least basic drinking water services, total (left) and rural (right) from LMB country national data 2000 - 2015



Source: World Bank, 2018, World Development Indicators Database

It is unclear if these figures accurately reflect the situation in the LMB. Access is likely to be quite variable at the sub-national level and some LMB areas are likely to have lower rates of safe water access than the national level figures suggest, for example in the Mekong Delta and North Eastern Thailand. Figures for some Mekong Delta provinces have been available an illustrate the local variability of potable water availability in the LMB. For example, in Kien Giang province the proportion of the population with access to potable water supply was only around 76% in 2013, by 2016 this had increased to 87%, similarly Tian Giang increased from 91% in 2013 to around 99% by 2016. Other provinces such as Long An and An Giang have figures close to 100%. While not directly comparable to national level data, provincial level figures for Cambodia also indicate significant variation in access to water supplies with only 5.6% of the population of Svay Rieng province having safe drinking water in 2016, and in Kampong Speu and Kampong Thom the figure is around 10% (*Figure 4.6*).

Figure 4.6 Access to safe drinking water in Cambodia by province 2014



Source: Cambodia National Statistics

(iv) *Sufficiency of water for farming*

Given the variability of rainfall throughout the year many areas in the LMB are subject to drought risk. The form of drought varies including variation in wet season rainfall onset, duration and quantity in different areas, early onset of the dry season and the occurrence of periods without rain during the wet season. Droughts are relatively common throughout the LMB, with Cambodia and Thailand particularly susceptible. Irrigation provision can effectively mitigate drought risk through the provision of water during critical crop growing periods if needed.

The sufficiency of water for farming is therefore assessed with respect to drought incidence and the absence of irrigation systems. Drought incidence is indicated by the long-term average monthly incidence of consecutive dry-spell days. [18] Monthly long term average consecutive dry-spell days in the LMB vary significantly from as few as 0.78 days in Thua Thien Hue in Viet Nam to 13.35 days in Kalasin in Thailand. For the purposes of this assessment, any province with a long-term monthly average of consecutive dry-spell days of greater than 6 was regarded as suffering from drought risk, otherwise the province was not deemed susceptible to drought.

Table 4.1 shows over half the basin provinces are therefore deemed susceptible to drought, accounting for over half the LMB area and almost three quarters of the LMB population. Of the LMB countries Thailand and Viet Nam have the largest proportion of area and population susceptible to drought.

Table 4.1 Drought risk and water sufficiency for agriculture in LMB

Country	Provinces		Extent of LMB with drought risk		Percent of LMB at risk	
	Total in LMB	Percent with drought risk	Area of provinces affected (km^2)	Population affected (no.)	By area	By population
Cambodia	23	57%	104,072	5,638,791	67%	48%
Lao PDR	17	12%	24,155	748,182	12%	14%
Thailand	25	72%	154,768	19,888,476	82%	86%
Viet Nam	22	68%	50,250	18,702,202	73%	88%
Totals	87	55%	333,244	44,977,651	54%	73%

Source: Consultants' estimates based on drought data held in MRC-IS

Note: Provinces with drought risk are those where the average dry-spell number of days exceeds 6 days and the extent of irrigation coverage within that province is less than 25% of the province area.

Provinces with less than 25% irrigable area were deemed to have insufficient water availability to mitigate drought risk as defined above. Areas with drought risk but insufficient irrigable land were deemed to suffer from insufficient water resources for agriculture. Irrigation availability similarly varies considerably across the basin, with most provinces on the Mekong delta having around 100% availability of irrigation, whereas many LMB provinces in Cambodia and Lao PDR have little or no irrigable land. On the other hand, limited availability of irrigable land in Cambodia, Lao PDR and Thailand (falling below the 25% threshold defined above) means practically all areas at drought risk do not have sufficient irrigation.

The last three columns of Table 4.1 give the number of provinces, area and population of the LMB deemed to have insufficient water resources for agriculture, this amounts to a little under 50% of the LMB area and population.

18 Long term monthly average number of consecutive days of dry conditions (defined by a value of Combined Drought Index (CDI) less than -1).

In terms of country performance, Viet Nam and Lao PDR have the best water availability for agriculture. In the case of Viet Nam, this is mainly down to the extensive irrigation systems in the delta mitigating significant drought risks in that area. For Lao PDR, better water availability is generally the consequence of lower drought risk. Cambodia has little irrigable area meaning moderate drought risk is not mitigated. Finally, Thailand's LMB provinces have generally high drought risk but little irrigation infrastructure to off-set this risk, with around 82% of its LMB area and 86% of its LMB population susceptible to agricultural water shortages.

(v) *Freedom from floods*

Flooding is an important threat to livelihoods in many parts of the LMB. Different locations in the basin are prone to different sorts of flooding. Flash floods are frequent around Tonle Sap and in mountainous and hilly regions of the LMB. Pluvial flooding can occur on a localized basis across the basin as a result of heavy rainfall. However, fluvial flooding remains the most important and potentially damaging form of flooding and is the focus for the analysis here.

Seasonal fluvial floods are an annual occurrence in the LMB, in large areas of the Mekong Delta, the Cambodian flood-plains around the mainstream, as well as the large area of flooded forest around Tonle Sap. This flooding is a natural occurrence and much of the productivity of fisheries and agricultural systems in the lower reaches of the river depend upon these floods. For example, the flooded forest around Tonle Sap is an important feeding ground and nursery for capture fisheries in the LMB. Flooding also serves to replenish nutrients on agricultural land.

In contrast, extreme flood events in the region have been extremely damaging. Recent floods in Thailand in 2011, and Cambodia in 2011 and 2014 caused widespread damage. Crops and infrastructure are at particular risk form extreme flood events. Flooding also poses risks to human and animal health, with the spread of water borne diseases an important hazard. Table 4.2 gives the area and population affected by the maximum flood extent (for floods between 2013 and 2015). Note population data used for these estimates is for 2007.

Table 4.2 Area and popualtion exposed to flooding in maximum extent flood 2013-2015

Country	Flooded area		Affected population	
	Km²	Share (%)	No.	Share (%)
Cambodia	28,598	18.3	3,584,314	30.8
Lao PDR	1,892	0.9	77,344	1.5
Thailand	3,639	1.9	453,902	2.0
Viet Nam	19,755	28.9	8,950,303	41.9

Source: Consultants calculations based upon MRC data

The approach taken to assess the extent to which livelihoods in the LMB have been affected by flooding is firstly to calculate the proportion of the area in LMB provinces that have been affected by maximum flood extents. Flood affected area shares varied between 0% for provinces such as Khammuane in Lao PDR, Sekong in Cambodia and Chiang Mai in Thailand, up to in excess of 90% in Long An on the Mekong delta and Koh Kong in Cambodia.

Table 4.3 Number of LMB provinces categorised by flood risk

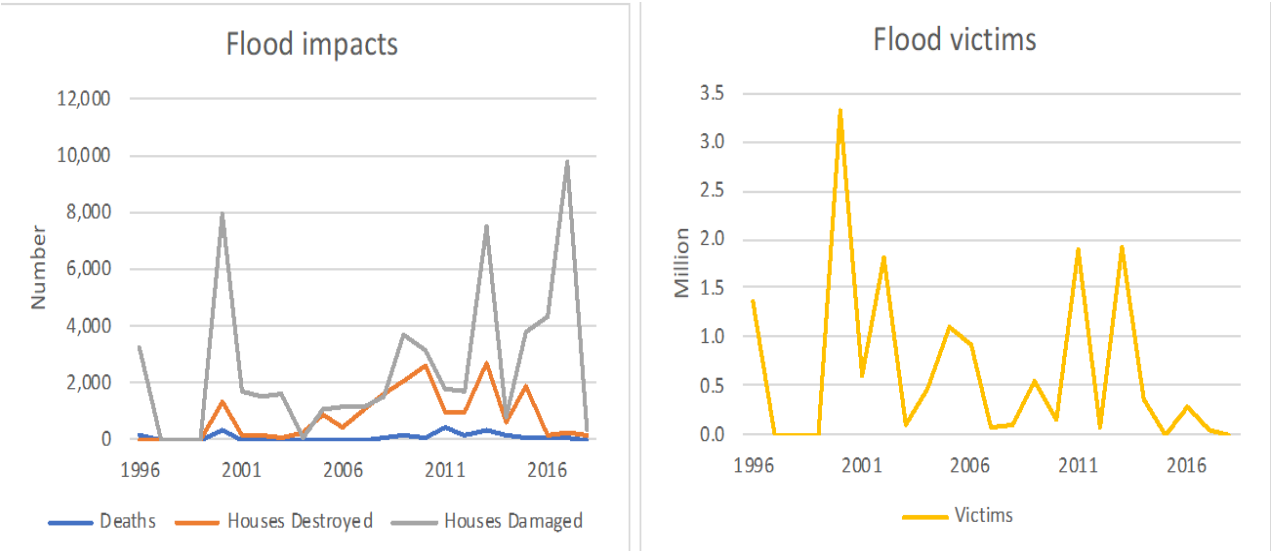
Country	Flood risk				
	Very low	Low	Medium	High	Very High
Maximum flood extent proportion of province area	0-20%	20-40%	40-60%	60-80%	80-100%
Cambodia	11	6	3	1	2
Lao PDR	17	-	-	-	-
Thailand	25	-	-	-	-
Viet Nam	9	5	2	5	1
Viet Nam	9	5	2	5	1

Source: Consultants calculations based upon MRC data

Flood risk was ranked on a five-point scale from very low to very high depending on the proportion of the province area affected by flooding (Table 4.3). The provinces falling into each risk category was then calculated. From this analysis, it is clear that all the most-high and very-high risk flood areas are in the flood plains of the LMB in Cambodia and Viet Nam.

Figures on flooding impacts for Cambodia, given below, illustrate the continuing severity of flooding impacts in the country, with millions of people affected by flooding. The is a wide variation in flooding impacts, depending on timing, severity and location of flood events, but over the 1996 – 2016 period there is no discernible trend in flood impacts in the country.

Figure 4.7 Flood impacts in Cambodia 1996 - 2016



Source: Cambodia National Committee for Disaster Management database, http://camdi.ncdm.gov.kh/DesInventar/profiletab.jsp?countrycode=kh855&continue=y#more_info

4.2.4 Health security

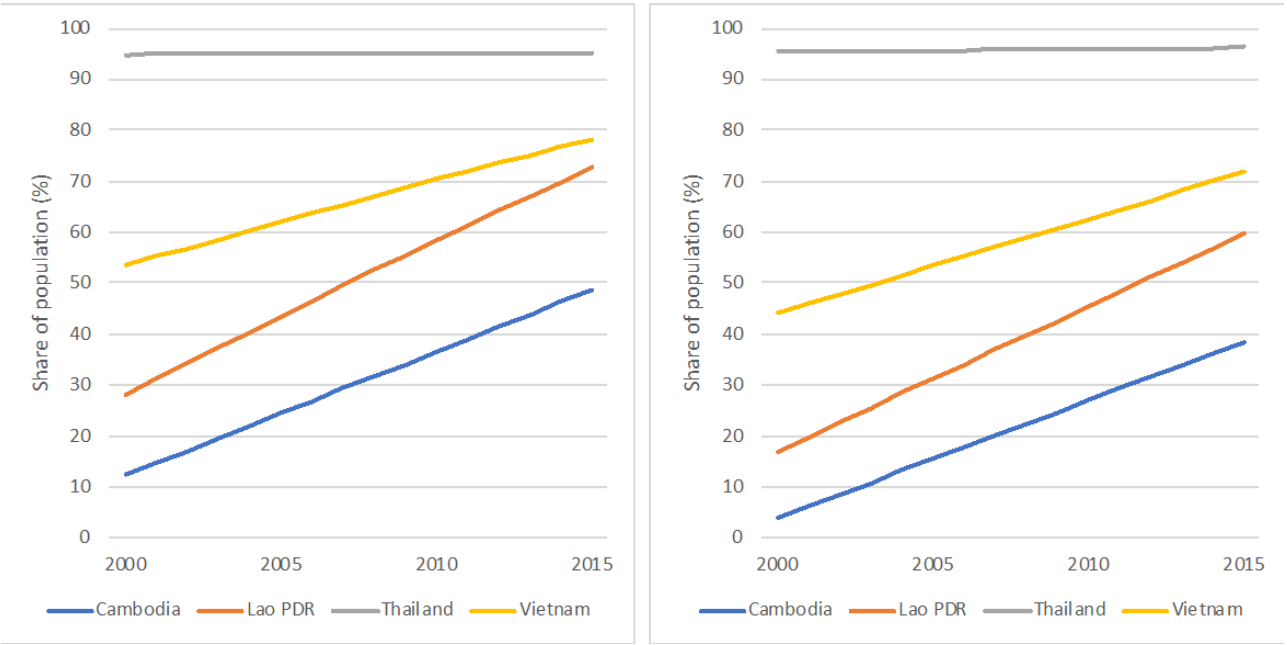
Public health is the foundation for well-being and livelihoods. The Health security assessment indicator seeks to assess the extent to which basin communities are able to minimise the risk of disease and mortality. This in turn is indicated by access to safe water supplies, access to sanitation, and access to health facilities, as well as by the incidence of disease. Access to safe water supplies has already been discussed in Section 4.1.3 above.

(i) *Access to sanitation*

Inadequate sanitation is an important cause of disease and improvements to sanitation are known to have significant beneficial impacts for public health. In particular, basic sanitation reduces diarrheal disease and worm infections, which affect children disproportionately, weakening them and making them more susceptible to other malnutrition, and opportunistic infections like pneumonia. As such access to sanitation is regarded as fundamental to human development and essential in addressing issues of disease. Access to adequate sanitation is also considered a human right.

Figure 4.8 gives the national share of people using at least basic sanitation in LMB countries for the years 2000 to 2015. As with other indicators, Thailand has the best performance, with around 95% of the population with access to basic sanitation since the beginning of the period. Reaching the last 5% of the population seems to be proving difficult as growth in access to sanitation has been limited over the period. In 2015 Thailand also had slightly higher rates of sanitation access in rural (96%) rather than urban areas (95%). This reflects Thailand's rapid urbanisation and issues surrounding urban housing and infrastructure.

Figure 4.8 Share of people using at least basic sanitation services[19], total (left) and rural (right) from LMB country national data 2000 - 2015



In 2015, Viet Nam (78%), Lao PDR (73%) and Cambodia (49%) still have substantial shares of population with access to sanitation. Unlike Thailand, in all three countries rural provision lags that in urban areas by around 10%. Growth in access to sanitation over the last 15 years or so has followed a similar trajectory in Viet Nam and Cambodia, with Cambodia lagging Viet Nam's performance in sanitation provision by about 20 years. Lao PDR, on the other hand, has

19 Access to basic sanitation is defined as, "The percentage of people using at least basic sanitation services, that is, improved sanitation facilities that are not shared with other households. This indicator encompasses both people using basic sanitation services as well as those using safely managed sanitation services. Improved sanitation facilities include flush/pour flush to piped sewer systems, septic tanks or pit latrines; ventilated improved pit latrines, compositing toilets or pit latrines with slabs." World Bank, 2018, World Development Indicators Database.

managed relatively rapid growth in the provision of basic sanitation, moving from around 28% provision in 2000 to around 73% by 2015. If this trend continues, it is likely to pass Viet Nam's level of provision in the next five years.

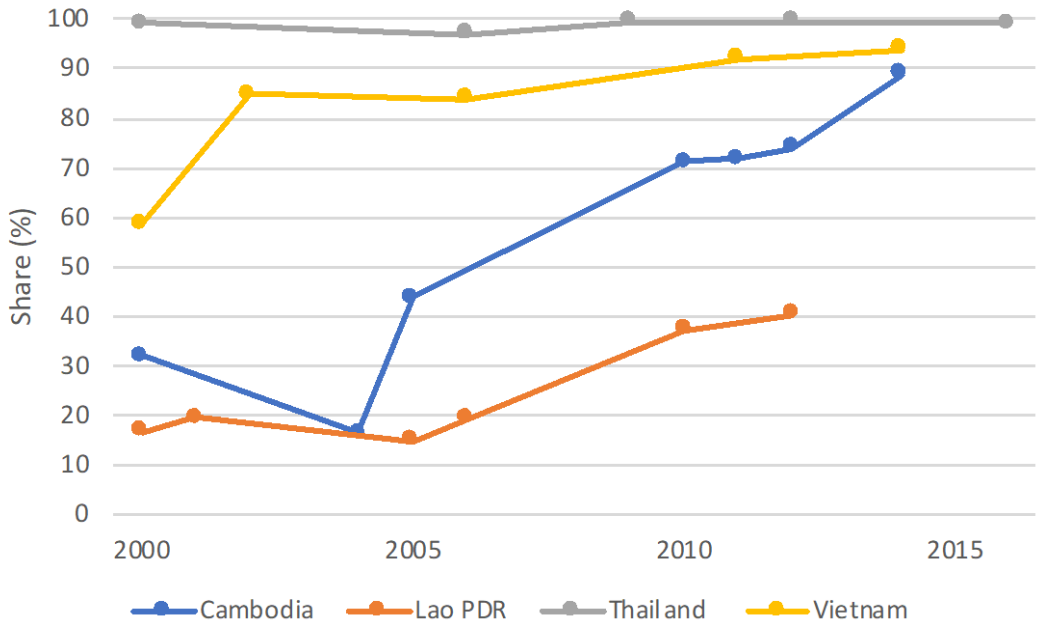
The lack of basic sanitation provision in the LMB is an area of concern in all four countries. In Thailand, the concern centres on the lack of progress in extending services to the last 5% of the population. In Viet Nam, Lao PDR and Cambodia, the concern relates to the significant portions of the population, particularly in rural areas without access to basic sanitation. This concern is particularly acute in Cambodia, where less than half the national population have access to basic sanitation, and in rural areas less than 40% of the population.

As noted above, national figures for Cambodia and Lao PDR are likely a relatively good guide to LMB conditions. Relying on national figures to assess the conditions in the Thai and Vietnamese portions of the basin is more problematic. For example, partial data for the delta area illustrates the variability in sanitation provision in Viet Nam, in 2016 the populations of Tra Vinh (45%), Kien Giang (54%), Vinh Long (59%), Ben Tre (65%) and Long An (71%), all had lower levels of access to basic sanitation than the national average, whereas An Giang (84%) and Tien Giang (75%) had levels of access higher than the national average.

(ii) *Access to health facilities*

Access to health services is a key component of public health. However, consistent data on access to health services in terms of adequate health facilities or health insurance cover in the LMB has not been available. The share of births attended by skilled health has therefore been taken as a proxy for access to health facilities. Births can be risky and complications at childbirth are an important cause of death and disability amongst women of reproductive age in developing countries. Based upon this observation, the assumption is that women with access to adequate health facilities would choose to have skilled medical staff in attendance at birth.

Figure 4.9 Share of births attended by skilled health staff from LMB country national data (2000 – 2016) [20]



20 Defined as "Births attended by skilled health staff are the percentage of deliveries attended by personnel trained to give the necessary supervision, care, and advice to women during pregnancy, labor, and the postpartum period; to conduct deliveries on their own; and to care for newborns." World Bank 2018.

Figure 4.9 shows available data for the share of births attended by skilled health staff in LMB countries between 2000 and 2016. [21]Thailand (99% in 2016), Viet Nam (94% in 2014) and Cambodia (89% in 2014) perform relatively well. Although both Viet Nam and Cambodia have some way to go to address the remaining portions to their populations without access to adequate healthcare, if the improving trend continues, full coverage may be achieved within the next decade. By contrast, Lao PDR performs poorly for this indicator. In 2012, only 40% of births were attended by skilled health staff. Given the past trend, the situation may have improved in the intervening years, however it is likely that Lao PDR still lags behind the other countries in terms of this indicator. This in turn suggests that access to health care in Lao PDR is poor and represents an area for ongoing concern and attention.

In the case of this indicator, given the high share of births attended by skilled health staff in both Thailand and Viet Nam, the issue of adequate representation of the LMB populations of these countries is less problematic. Nevertheless, it should be noted that in Viet Nam remote areas of the delta, central highland and North Eastern Thailand are likely to be precisely the areas where access to adequate health facilities is more difficult. It may be the case that some localised issues with lack of health provision persist in the Thai and Vietnamese portions of the LMB.

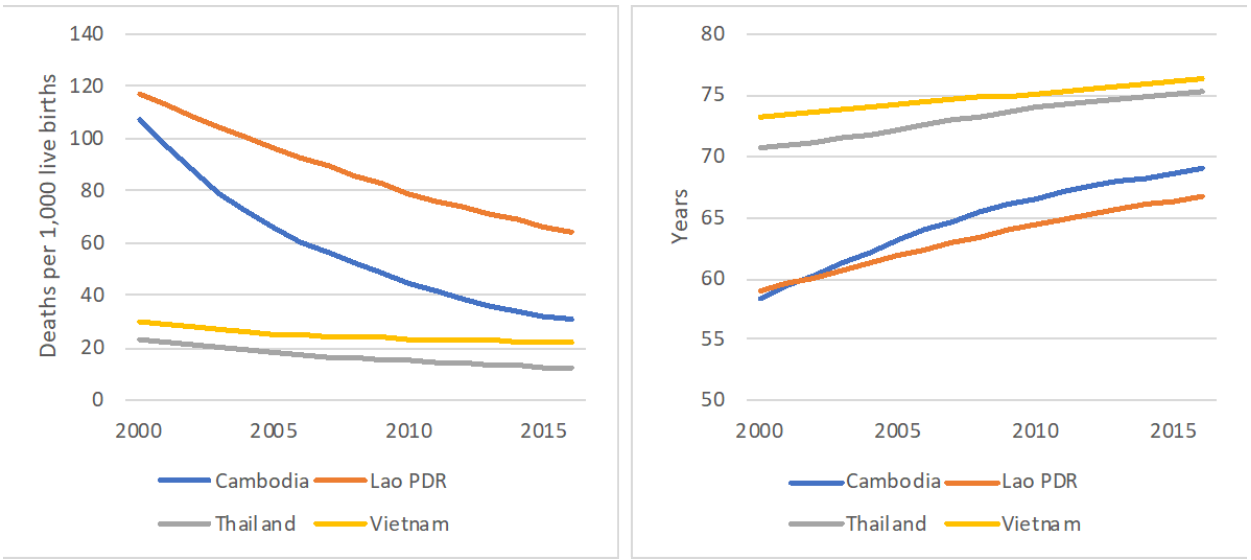
(iii) *Incidence of disease*

The third indicator of health security was defined by the Indicator Framework as incidence of key waterborne diseases (malaria, dengue and liver fluke). However, consistent data on the incidence or prevalence has not been available for these three diseases. Instead as a loose proxy of health outcomes in the LMB and to enable an identification of vulnerable populations two other parameters are considered, infant mortality rates and life expectancy available at the national level.

Infant mortality rates measure the deaths per 1,000 of infants under the age of one. Of the LMB countries Thailand performs the best with mortality rates dropping to 12.1 by 2016, which is roughly half infant mortality rates in 2000. Viet Nam had an infant mortality rate of 21.6 in 2016, down around a third from 2000. Cambodia's infant mortality rate in 2016 was 30.6, while still quite high this represents a dramatic fall from the 2000 levels of 107. As with access to health services, Lao PDR lags the other LMB countries with an infant mortality rate of 63.9 in 2016, although this also marks a considerable reduction from the 2000 level of 116.5.

Overall, all LMB countries have been on a downward trend. While Thailand and Viet Nam have lower levels of infant mortality, they also have lower rates of decline. Whereas Cambodia and Loa PDR have higher levels but have experienced a more rapid decline in recent years, suggesting long term convergence. It should be noted that all four LMB countries still have some way to go in achieving infant mortality rates similar to developed countries. For example, the OECD average was 5.9 deaths per 1,000 in 2016.

Figure 4.10 National level data forInfant mortality rate 2000-2015 (left) and life expectancy 2000 – 2015 (right)



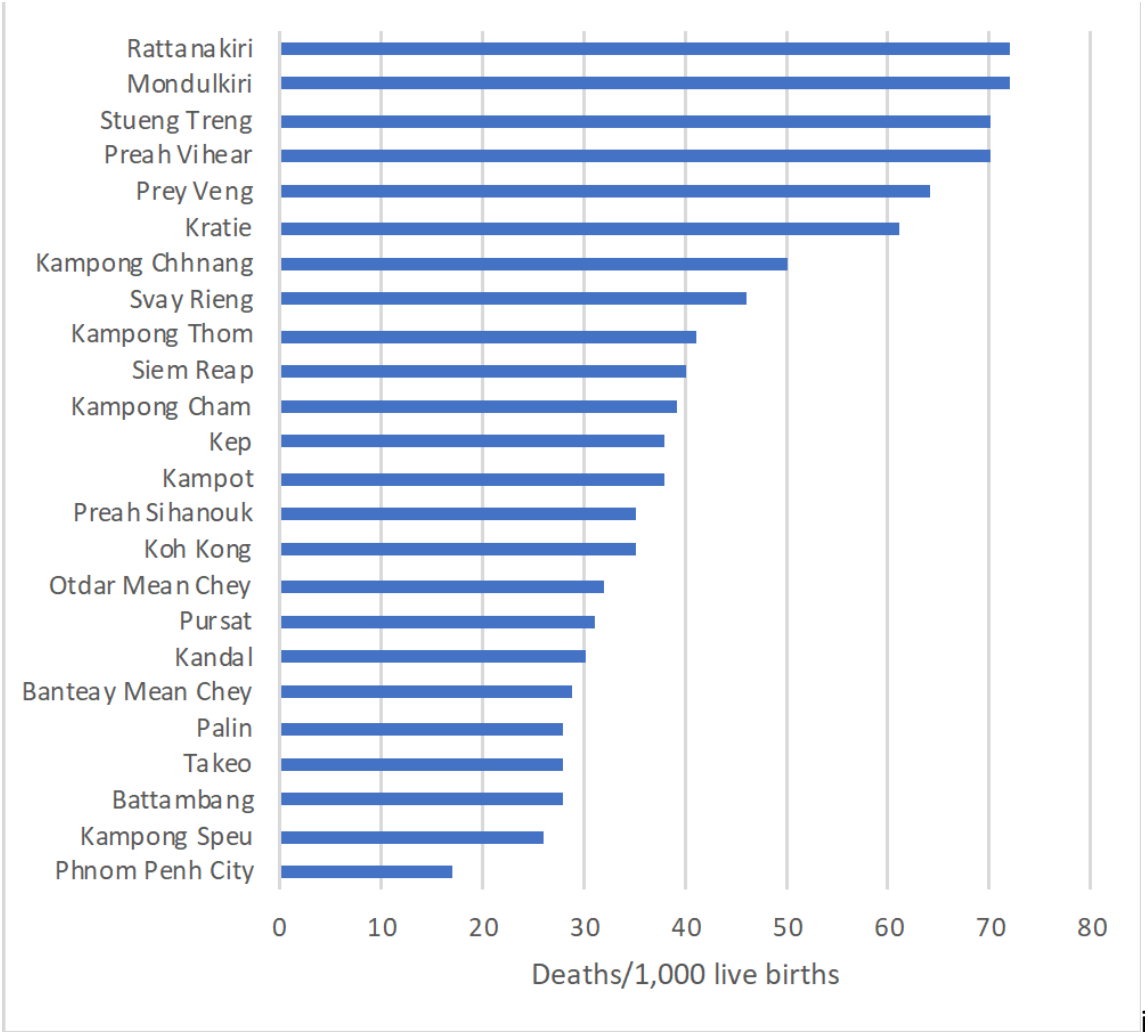
21 Data has not been available for all years (as indicated by line markers) and the time trend represented by the line is extrapolated.

Conversely, the average life expectancy at birth has increased in all LMB countries (Figure 4.10 right). However, in 2016 there was a significant gap between Thailand (75.3 years) and Viet Nam (76.3 years), and Cambodia (69 years) and Lao PDR (66.7 years). All countries have seen an increasing trend in life expectancy as health and welfare provisions improve. Slightly more rapid increases in life expectancy in Cambodia and Lao PDR in the last 15 years are probably reflective of greater room for improvement. As with infant mortality the LMB countries still have a considerable distance to travel, with average life expectancy at birth in OECD countries of 80.1 years in 2016.

As with other indicators, there is a major caveat in the interpretation of the Thai and Vietnamese figures in particular as being representative of conditions in the LMB. Moreover, it should be noted that life expectancy in particular is not only reflective of the development context, but a complex range of socio-cultural factors (such as diet). This may go some way to explaining the longer life expectancy in Viet Nam than Thailand. In this case, sub-national data and data disaggregated by social strata or group would be helpful in understanding in greater detail the health conditions in the LMB, and in particular identifying locations where interventions are likely to be needed.

As with other indicators there is also a significant variation in infant mortality rates between different areas within each LMB country. For example, Figure 4.11 gives the infant mortality rate by province for Cambodia in 2014. This shows very high infant mortality rates in the relatively sparsely populated areas in the east of the country, Mondulkiri and Ratanakiri both have rates of over 70 deaths per 1,000 live births. This compares to less than 20 deaths per 1,000 live births in Phnom Penh.

Figure 4.11 Infant mortality rate by province in Cambodia 2014



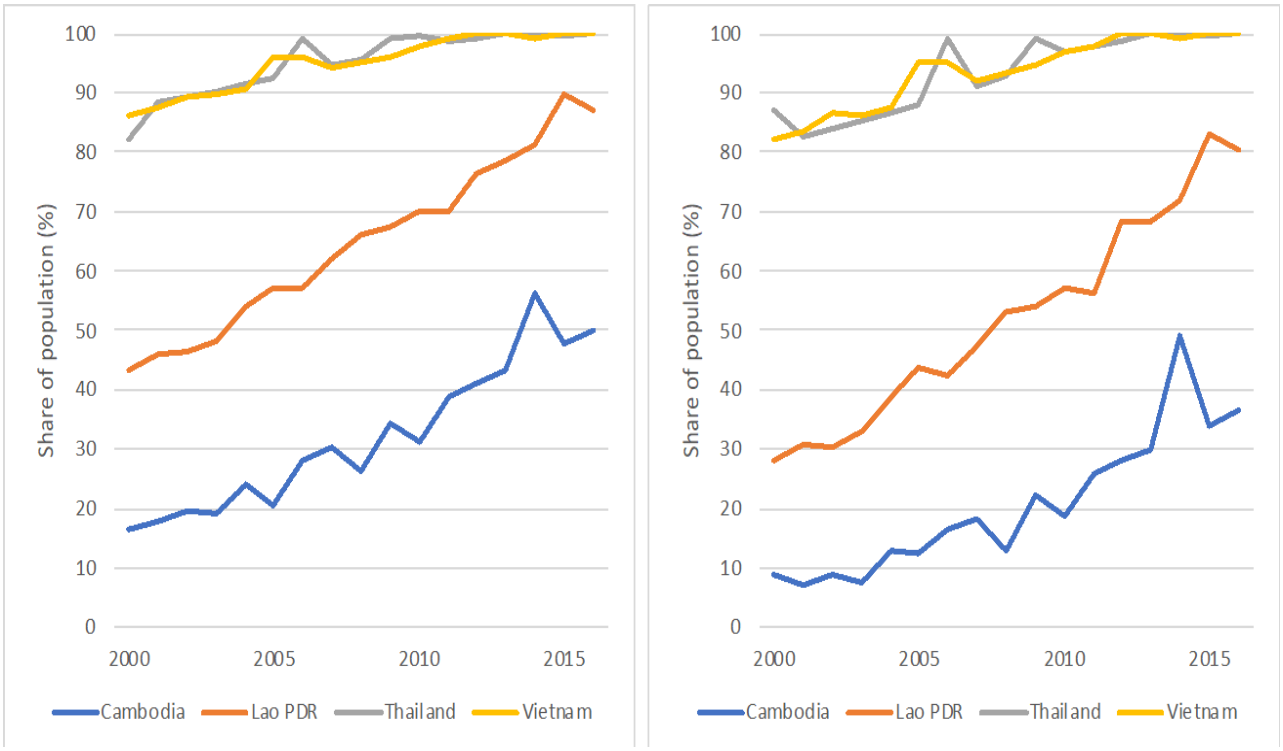
Source: Cambodian National Statistics

4.2.5 Access to electricity

Access to modern energy services is an import element of well-being. Electricity offers many benefits to households including cleaner and cheaper lighting, and cleaner cooking as well as providing access to a range of household amenities otherwise not available such as space cooling, food and medicines refrigeration, access to modern communications (television, phone charging and the internet) and can also supply a power source for household productive activities.

According to recent figures 100% of households in rural and urban areas in Viet Nam and Thailand had access to electricity in 2016. In Lao PDR, 87% of the total population and 80% of the rural population had access to electricity in 2016. Cambodia lags well behind with only around 50% of the total population having access to electricity, this drops to 34% in rural areas. However, these figures possibly overstate population access to electricity as they do not report the affordability of electricity, the quality of supply (which may be intermittent in many rural and remote areas) or households which rely on off-grid electricity provision. Updated figures from the Electricity Authority of Cambodia suggest that by 2016 58% of households had an electricity connection, and by 2018 that figure had increased to 72% (EAC 2018).

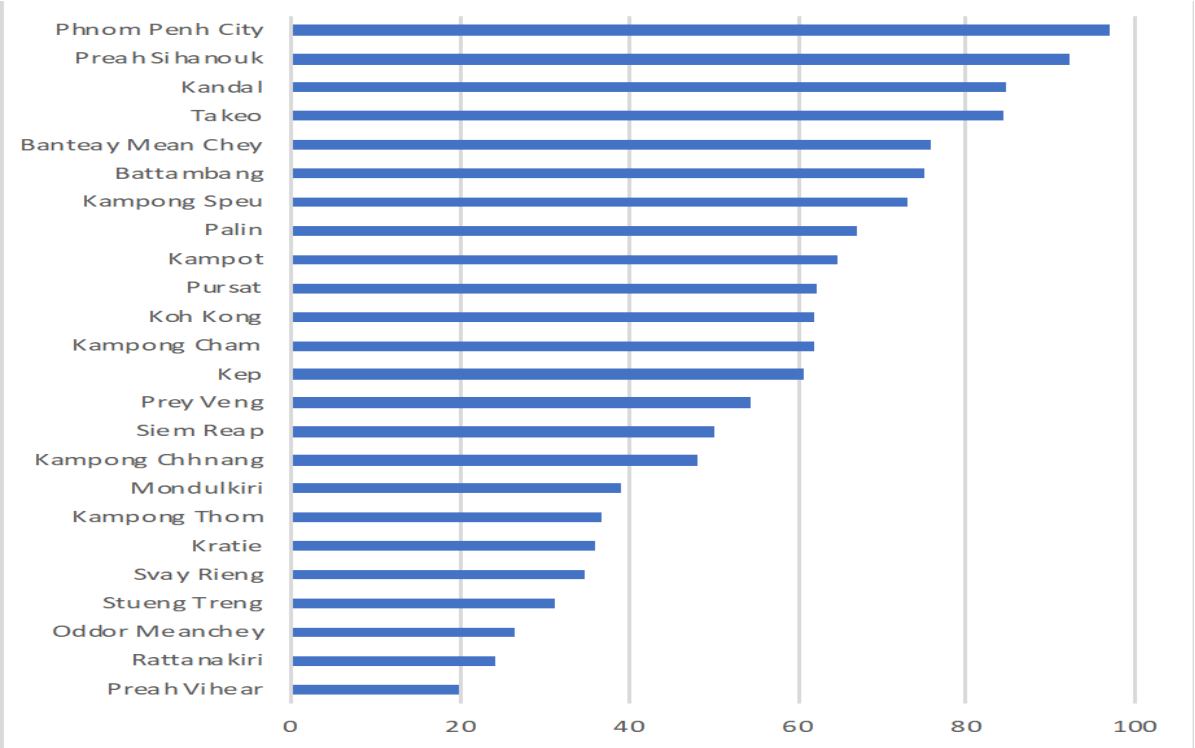
Figure 4.12 Share of people with access to electricty, total (left) and rural (right) from LMB country national data (2000 – 2016)



Source: World Bank, 2018, World Development Indicators Database

As with other statistics these is considerable variation in access to electricity at the sub-national level in Lao PDR and Cambodia. Figures for Cambodia (Figure 4.13) show much lower levels of electrification in the poorer and less populous eastern areas of the country.

Figure 4.13 Household electrification rate by province Cambodia 2016



Source: Cambodian National Statistics

4.2.6 Assessment of status of living conditions and well-being

Overall living conditions and well-being the in LMB have improved significantly over the last fifteen years. All countries have experienced improvements in both access to food and nutritional outcomes (as indicated by falling malnutrition levels), more extensive access to water for drinking and agriculture, access to basic sanitation, health facilities, falling mortality rates and increased life expectancy, and improved access to electricity. The only negative trend observable in the data has been increases in flood damages over recent years.

There remains significant variation in performance between LMB countries largely reflecting the differing stages of development. There is also likely to be substantial sub-national variation in performance which is not picked up by these largely national level indicators. It is imperative that comprehensive sub-national data be collected to allow a better understanding of sub-national patterns of socio-economic development, which can in turn lead to the identification of development issues and a means of addressing them.

4.3 Employment in MRC water-related sectors

4.3.1 Assessment methodology

The Strategic Indictor "Employment in MRC water-related sectors" is defined as the level of community resilience as derived from the key components of sustainable livelihoods that help reduce vulnerability: employment, economic security and gender equality. The assessment indicators for this strategic indicator are:

- Employment rate in MRC water-related sectors
- Economic security
- Gender equality and economic engagement

Each assessment indicator is evaluated with respect to monitoring parameters to reach a determination as to employment conditions in MRC water-related sectors in the LMB.

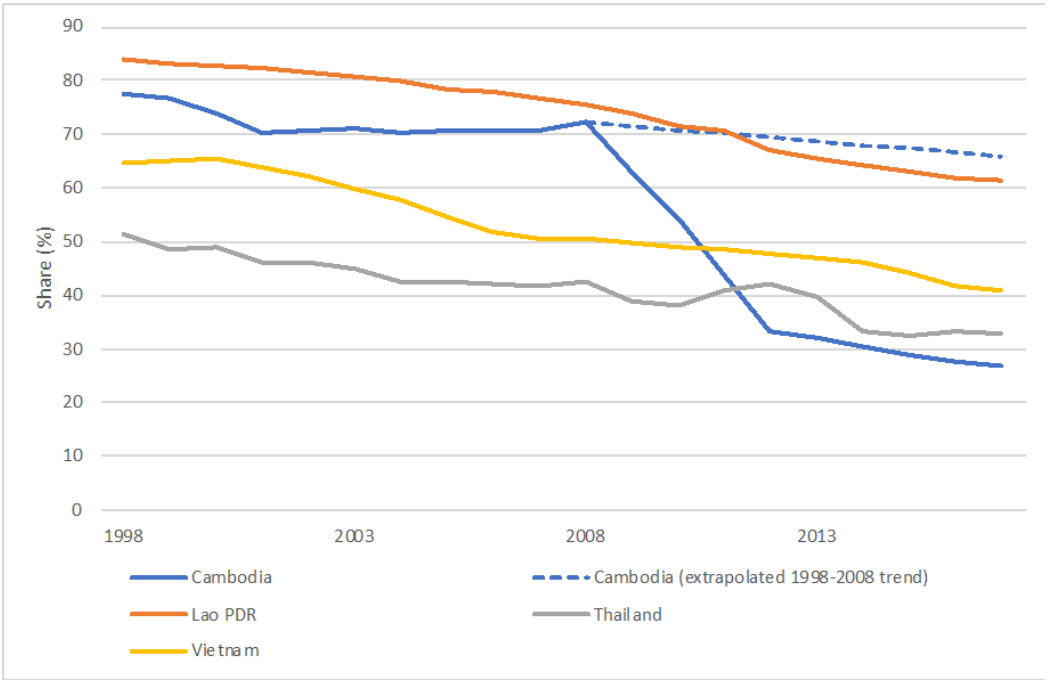
4.3.2 Employment rate in MRC water-related sectors

The main water related economic sectors in the LMB are agriculture, fisheries and navigation and to a somewhat lesser extent, hydropower, tourism and forestry. This indicator attempts to assesses the importance of employment in these sectors for the population in the LMB. For the purposes of this exercise the focus has been on primary employment although where data has been available figures on secondary employment have been noted (for example for fisheries).

(i) *Proportion of working age population employed in water related sectors*

ILO data on employment in LMB countries is reported in Figure 4.14 below showing the share of employment in agricultural, fisheries and forestry sectors. [22]Data for Cambodia seems problematic, as the share of employment in agriculture falls to around 27% by 2017 significantly lower than other counties in the basin, this is not in line with other data sources nor does it reflect the development pattern in Cambodia. To correct this the 1998 – 2008 trend has been extrapolated to 2017.

Figure 4.14 Employment in agriculture, forestry, fisheries from LMB country national data (1998-2017)



Based upon this data agriculture, fisheries and forestry sectors have collectively seen their share of employment decline over the last two decades. Employment in these sectors in Thailand had declined to around 33% by 2017 from 50% in 1998. Viet Nam is following a similar trajectory declining from around 65% in 1998 to 41% by 2017.

22 SIMVA data on employment in the mainstream corridor was not used as noted above the socio-economic characteristics of the population in the mainstream corridor are unlikely to be representative of the LMB as a whole.

Cambodia and Lao PDR have also seen significant declines in the share of employment in agriculture and related sectors. Both countries are on similar trajectories to Thailand and Viet Nam. Cambodia has seen the share of employment in agriculture and related sectors decline from 78% in 1998 to an estimated 66% in 2017, and Lao PDR has seen a decline from 84% to 61% over the same period. In the case of Thailand and Viet Nam, it is important to note that the national level data is likely to be misleading as regards employment trends in the LMB. The national decline in the employment share of agriculture, fisheries and forestry is likely to be a consequence of strong growth in employment in other sectors, and especially the manufacturing and service sectors. This growth is likely to be concentrated in and around urban areas and is closely associated with urbanisation trends. Most large urban areas in Thailand and Viet Nam lie outside the LMB (such as the Bangkok metropolitan area, Ho Chi Minh city and Hanoi).

Employment in agriculture and related sectors in the Thai and Vietnamese administered areas of the LMB is likely to be more important than national figures suggest. For example, provincial figures from Viet Nam suggest that in the more remote rural provinces of the central highlands and Ca Mau on the Mekong delta, that employment in agriculture is over 50% of the labour force. The figure for Gai Lai was over 63% in 2016. Notwithstanding the continuing importance of agriculture and related sectors employment in these sectors has declined significantly in recent years. Employment in agriculture in the delta provinces declined 24% between 2011 and 2016. Conversely, the central highlands have seen growth in employment in these sectors over the same period of around 6%. There is also likely to be a large variation in employment patterns between provinces in Cambodia and Lao PDR, although sub-national figures have not been available.

Estimates for those specifically engaged in fisheries based on Government and World Bank estimates indicate that more than five million people are actively engaged in fisheries in the Lower Mekong Basin. Almost two thirds of these people in these estimates are involved in fishing and more than a quarter are engaged in farming of fish and other aquatic animals such as freshwater prawns, shrimp and frogs, the rest are processors or traders (Table 4.4).

Table 4.4 People engaged in LMB fisheries

	Cambodia	Lao PDR	Thailand	Viet Nam	LMB
Fishers	1,009,190	526,300	1,065,900	689,910	3,291,300
Fish farmers	80,976	782,800	315,948	279,552	1,459,276
Processors	220,464	NA	NA	133,705	354,169
Traders	NA	NA	NA	72,786	72,786
Total	**1,310,630**	**1,309,100**	**1,381,848**	**1,175,953**	**5,177,531**

Source: National fisheries statistics (Cambodia, Lao PDR and Viet Nam) and estimates based on World Bank data (Thailand)

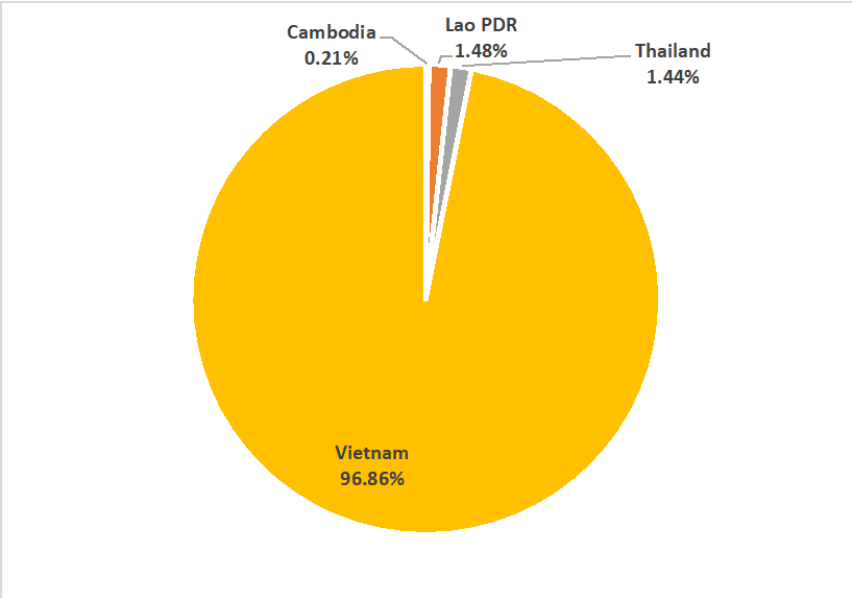
Separate studies (MRC, 2003; World Bank, 2012) suggest that these figures may underestimate the number of people either dependent on or otherwise engaged in fisheries, and that as many as two thirds of LMB households, or more than 40 million people, have some involvement in the fisheries sector in a part time or recreational capacity.[23]

Thus, the agricultural and fisheries sectors' contribution to employment has therefore not fully reflected the structural transformation in LMB economies. A large proportion of the population is, and will continue to be, dependent on agriculture and fisheries for the foreseeable future.

The navigation sector is also an important source of employment in the LMB. Available figures provide only rough estimates guidance as official estimates are not available. The MRC SIMVA study estimated that only around 65,000 people were employed in navigation in 2007. However, this is likely an underestimate as the sample frame focused upon rural communities, whereas most navigation employees are based in urban locations. Estimates based upon the size of the sector and crewing needs suggest around 780,000 people were employed in the sector in 2014, 96% of whom are Vietnamese (MRC 2017).

23 It should also be also be noted that fishing is an integral part of the livelihoods, culture and food security coping strategies of upland peoples who are mostly indigenous or ethnic minority groups showing the highest poverty incidences in the region (Xu & Daniel, 2011).

Figure 4.15 Share of navigtion sector employment by LMB country 2014



Employment in the hydropower sector in the LMB is not particularly significant. Very few figures for the sector are available. Estimates for Lao PDR in 2013 suggested that the sector employed around 21,000 workers in 2013 (World Bank 2014). This figure includes employees in the operations, maintenance and construction of hydropower projects. As such this figure is likely to be lower for other LMB countries with less active hydropower sectors. Therefore, it is unlikely the sector is a significant source of direct employment in the LMB.

By contrast tourism is likely to be a significant employer in areas of the LMB. Table 4.5 gives estimates of tourism sector employment based upon estimates produced by the World Travel and Tourism Council (WTTC). The WTTC produces national estimates only, to arrive at LMB estimates it was assumed that share of tourism employment in the LMB was directly proportional to the share of the national population in the LMB. This may over-estimate the LMB share of tourism employment in Thailand and Viet Nam which have a large number of tourist attractions outside the LMB.

Table 4.5 Employment in tourism 2017

	Country				
Employment	**Cambodia**	**Lao PDR**	**Thailand**	**Viet Nam**	**LMB Total**
Direct	849,680	103,740	864,690	542,960	**2,361,070**
Indirect	755,940	168,350	777,740	193,600	**1,895,630**
Induced	331,100	77,350	516,150	156,860	**1,081,460**
Total	**1,936,720**	**349,440**	**2,158,580**	**893,420**	**5,338,160**

Source: WTTC, 2018a, 2018b, 2018c, 2018d

Nevertheless, based upon these estimates it is clear that tourism is an important employer in the LMB. Moreover, if indirect and induced tourism employment is taken into account the importance of tourism employment in the LMB may increasingly rival other sectors such as fisheries. However, sustainable growth in the tourism sector within the LMB will depend to a large extent upon the maintenance of environmental assets (such as wetlands, forests, and biodiversity) which are a one of the major attractions to the LMB region.

4.3.3 Economic security

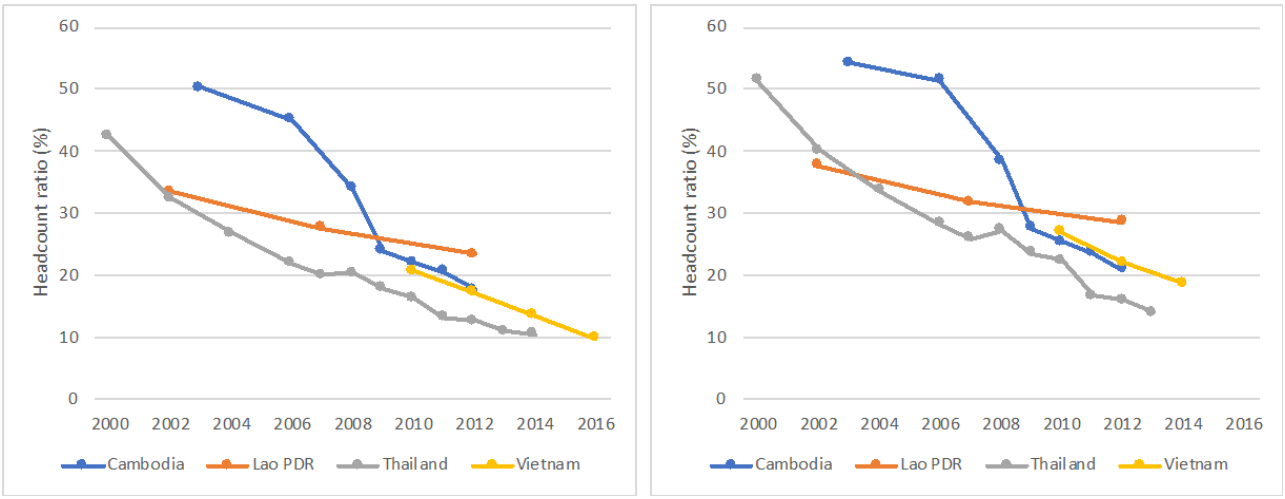
The economic security indicator as defined in the indicator framework is composed of two elements, sufficiency of household assets and income. However, in the absence of sufficient data on household assets and income poverty rate has been adopted as an indicator as a proxy for these monitoring parameters.

Poverty rate is commonly used metric, typically based upon a poverty line which identifies a basic level of income (expenditure) below which income (expenditure) is deemed insufficient to meet basic needs and the household or individual is classified as poor. International expenditure based poverty lines have been established for most countries which correct for differences in purchasing power and allow comparisons of poverty rates between countries.

However, data sets for all four LMB countries are not available therefore data based upon national poverty lines has been used. National poverty lines are set by government based upon differing socio-economic criteria and as such do not allow of a comparison between countries. Nevertheless, these figures do indicate the share of the population the government considers poor and are a guide to socio-economic performance.

National poverty line data for the four LMB countries is reported in Figure 4.16 between 2000 and 2016 for the total population and for the rural population. In all LMB countries the poverty rate has declined substantially over the last fifteen years. Cambodia's poverty rate has declined from 50% in 2003 to 18% in 2012, that of Lao PDR from 34% in 2002 to 23% in 2012, that of Thailand from 42% in 2000 to 11% in 2014 and that of Viet Nam from 21% in 2010 to 10% in 2016. As with other indicators, better progress in poverty reduction has been made in Thailand and Viet Nam than Cambodia and Lao PDR, reflecting their more advanced level of economic development. It is also worth noting that rural areas suffer from higher poverty incidence in general.

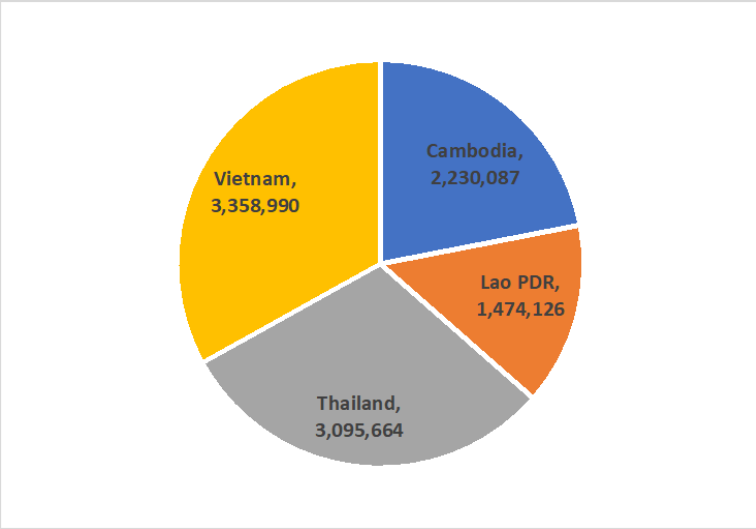
Figure 4.16 Poverty headcount ratio at national poverty line from LMB country national data (2000 – 2016), national (right) and rural (left)



Source: World Bank 2018

Despite the lower poverty rates in Thailand and Viet Nam it is worth noting that due to their large populations in the LMB they also account for the largest share of people below the poverty line in the LMB. Table 4.17 gives estimates for 2012 as that is the last year for which data is available for all countries. Estimates have assumed that the national poverty rates are applicable to LMB populations and used MRC population estimates to calculate the number of people below the poverty line in the LMB. Since 2012, both Viet Nam and Thailand have managed to reduce the number of poor substantially.

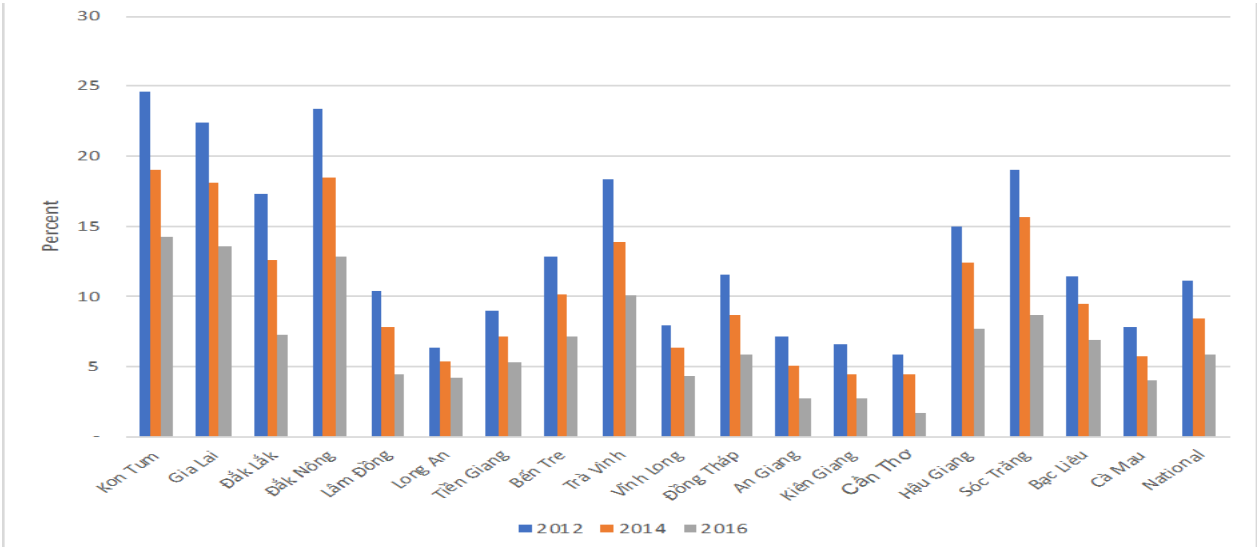
Figure 4.17 Population below national poverty lines in LMB 2012



Source: World Bank 2018

As with other indicators, there is likely to be significant variability in poverty incidence at the sub-national level. For example, figures from Viet Nam show that the poverty rate in Kon Tum was 14.2% in 2016 whereas those in Can Tho were 1.7%. These large variations are illustrated in Figure 4.18. Despite this variation it is also worth noting that following national trends poverty rates across all LMB provinces declined between 2012 and 2016.This sub-national variation also serves to highlight the difficulties of relying on national level data sets to estimate indicator values for the LMB.

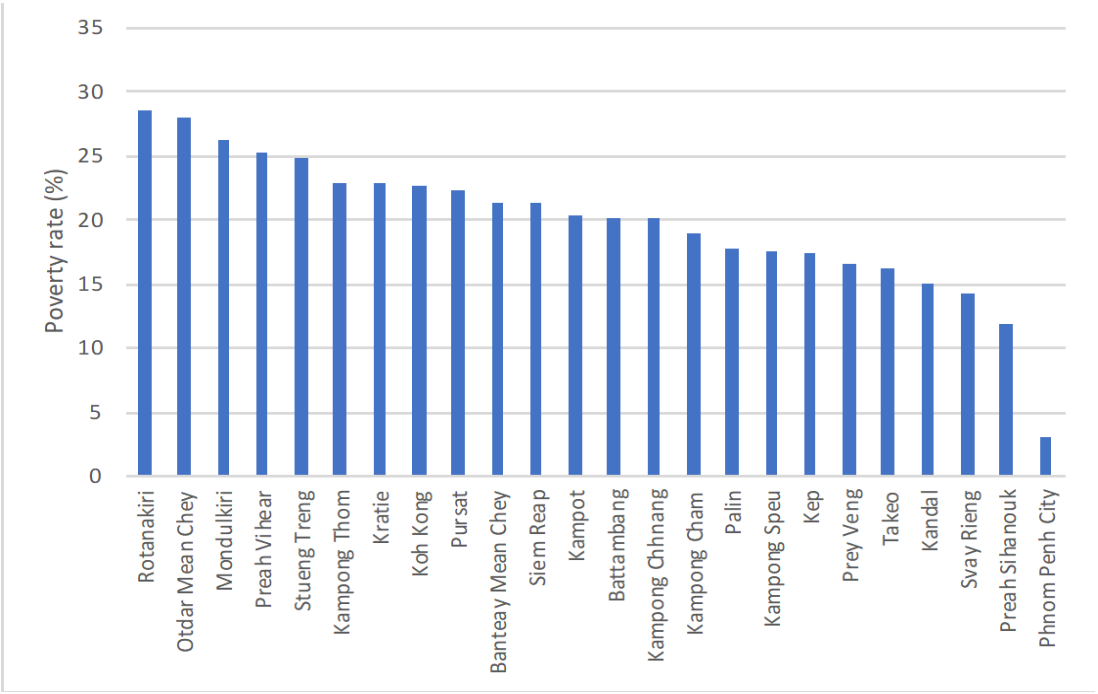
Figure 4.18 Declining poverty rate in Viet Nam's LMB provinces 2012-2016



Source: Viet Nam provincial statistical yearbooks

Similarly, poverty rates show significant variation between provinces in Cambodia. With the lowest rates in urban and more densely populated areas in the centre of the country. Eastern provinces still have relatively high rates of poverty.

Figure 4.19 Variation in provincial poverty rates in Cambodia 2016



Source: Cambodia National Statistics

4.3.4 Gender equality in employment and economic engagement

(i) *Gender equality in employment in MRC water-related sectors*

Limited data are available on equality of opportunity in MRC water-related sectors. ILO modelled data provides figures of the share of female and male employment in agriculture for LMB countries. These are given below in Figure 4.20. In general, there is only a small difference between the share of female employment in agriculture and related sectors and the share of male employment in these sectors. Moreover, in Cambodia, Lao PDR and Viet Nam the share of female employment accounted for by these sectors is consistently higher than the share of male employment. This contrasts with Thailand where the share of female employment in agriculture is lower than that for males.

In general, gender differentials in employment in these sectors seem relatively small. However, these figures do not capture differing gender roles within these sectors. These figures also do not capture differences in the extent of economic activity between men and women which may also be significant. Moreover, sub-national variations in female participation in MRC water-related sector employment may be important.

Figure 4.20 National level employment in agricultural, fisheries and forestry sectors by share of empoyment by gender 1998 – 2017

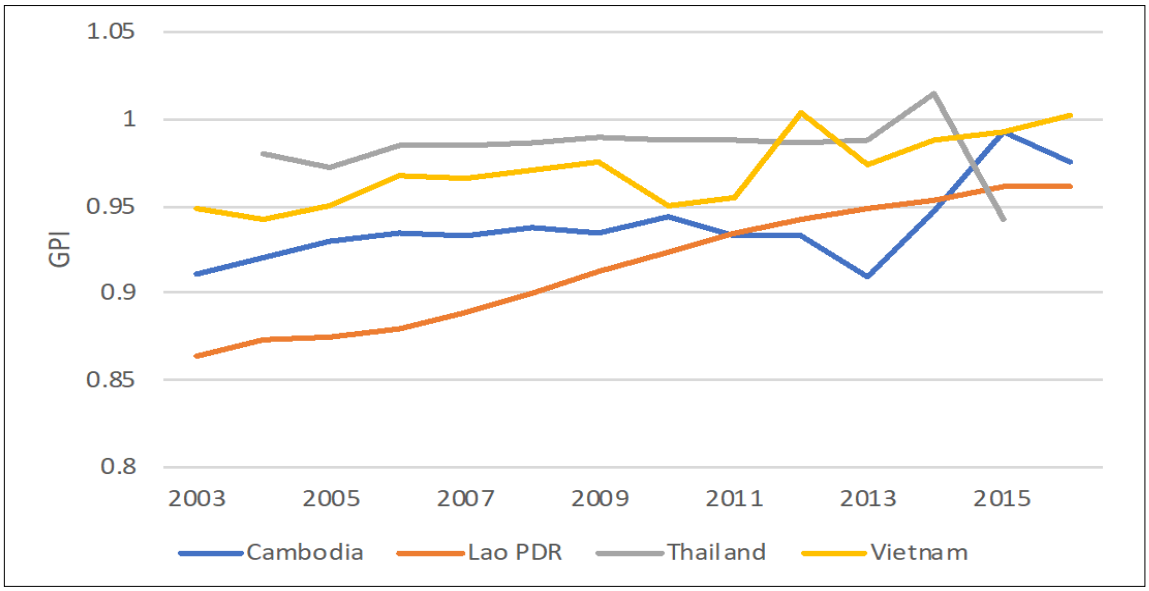
Source: World Bank 2018

(ii) *Gender equality in education*

The gender parity index (GPI) for gross enrolment ratio in primary education is the ratio of girls to boys enrolled at primary level in public and private schools. Values of less than one indicate a higher proportion of boys enrolled in primary education than girls, and values greater than one indicate a higher proportion of girls than boys enrolled.

The GPI for LMB countries is reported in Figure 4.21. All LMB countries have experienced significant and persistent gender differentials in primary school enrolment, with a greater level of male than female enrolment. However, all countries have also improved between 2003 and 2016. Viet Nam shows the best performance with gradual improvement in female enrolment between 2003 and 2016 and a GPI exceeding one in 2016. Thailand has shown less improvement over the period, and in 2015 seems to have experienced a relative decline in female enrolment after a GPI exceeding one in 2014. Cambodia and Lao PDR have also seen gradual improvement, however, GPIs in both countries indicate continuing gender differentials in primary enrolment rates.

Figure 4.21 Primary enrolment Gender Parity Index from LMB country national level data (2003-2016)



Source: World Bank 2018

4.3.5 Assessment of status of employment in MRC water-related sectors

Employment in water related sectors in the LMB remains high, although the importance of direct employment, particularly in agriculture is declining as work opportunities in other sectors (often services and manufacturing located outside the LMB) develop. Employment in capture fisheries also remains important for livelihoods. Tourism also stands out as an important source of employment in the LMB, and one that is likely to grow rapidly. Employment in navigation is also likely to be significant in some parts of the basin, such as the delta - again this sector is likely to grow rapidly in the future.

At the same time, the poverty rate has fallen dramatically across all LMB countries. This indicates increased economic security across the basin and is probably linked closely to changes in patterns of employment and improved productivity in the primary sectors.

Limited evidence on gender equality in employment and economic opportunity has been available. Gender disaggregated data on employment in agriculture and related sectors points to small, but persistent, differences in male and female employment patterns. However, the implications of these differences are difficult to interpret as regards gender equality. The GPI for primary school enrolment, on the other hand, is a concrete indicator of continuing gender disparities in the region, with boys clearly getting preferential access to primary education, particularly in Lao PDR and Cambodia.

4.4 Summary of overall social conditions in the basin

The broad picture of social development in the LMB shows that social conditions have improved substantially over the last two decades in all countries.

Food security has improved with greater access to adequate levels of nutrition, declines in undernourishment and declines in levels of malnutrition. Indicators of water security have generally improved, including access to potable water supplies. Although drought susceptibility remains a problem in some areas, this may be off-set by a decline in dependence on agriculture for livelihoods. There are some indications that damage due to flooding is increasing,

although again this may be the result of greater investment in the region putting more capital assets at risk. Health security indicators have also seen improvement in terms of improved access to basic sanitation and access to health services. Health outcomes have seen significant improvements with declining mortality rates and increased life expectancy. Access to electricity has also improved rapidly, Thailand and Viet Nam have close to 100% access even in rural areas, and Lao PDR has improved access significantly in recent years. Cambodia has made improvements in electrification but continues to perform badly, with low levels of service particularly in rural areas.

Turning to employment, the water-related sectors continue to be important for LMB livelihoods. Despite long term declines in the relative importance of the sector, agriculture remains the single largest source of employment in the LMB. Fisheries also constitute an important source of employment, although often as a source of secondary or supplemental employment. Tourism is of growing importance in the LMB and is likely to become increasingly important in the coming years.

Limited information has been available regarding gender equality in employment and economic engagement. Differential employment patterns for agriculture and related sectors have ambiguous implications. But evidence on gender disparities in access to education suggests an improving trend.

Overall available data pints to general improvement across most social indicators. However, the analysis is limited by the lack of comprehensive sub-national data for the LMB. It is likely that there is significant variation in terms of all indicators at the provincial and sub-provincial level. Understanding this geographic variation is critical to achieve a better understanding of the causal factors determining these outcomes, and ultimately the design and targeting of appropriate policy interventions. Moreover, the availability of sub-national data would allow the development of more accurate estimates of indicator values for the LMB than is currently the case when using national level data. This approach is particularly problematic for Thailand and Viet Nam, for which the population within the LMB only constitutes a small share of national population.

5. Economic Dimension

5.1 Introduction

The economic dimension of the MRC Indicator Framework reflects the MRC's the intent to promote economic development in all riparian States as reflected in Chapter 1, Preamble, of the 1995 Mekong Agreement through utilising *the waters of the Mekong River system in a reasonable and equitable manner in their respective territories* (Art.5). The Mekong Agreement further establishes under Article 1 that the areas of cooperation within the purview of the MRC are *all fields of sustainable development, utilization, management and conservation of the water and related resources of the Mekong River Basin including, but not limited to irrigation, hydro-power, navigation, flood control, fisheries, timber floating, recreation and tourism*.

Three strategic indicators have been selected by which to judge whether these objectives are being met. These three indicators are (i) economic performance of water-related sectors, (ii) contribution to basin economy and (iv) overall economic condition. These strategic indicators are supported by 18 assessment indicators as follows:

Strategic indicators	Assessment indicators
Aggregate economic value of water-related	❑ Economic value of agriculture
	❑ Economic value of hydropower
	❑ Economic value of navigation
	❑ Economic value of sand mining
	❑ Economic value of wetlands
	❑ Economic value of capture fisheries
	❑ Economic value of reservoir fisheries
	❑ Economic value of aquaculture
	❑ Economic value of forestry
	❑ Economic value of tourism & recreation
	❑ Economic losses from bank erosion
	❑ Economic cost of flood damage
Contribution to basin economy	❑ Contribution to national GDP
	❑ Contribution to national food grain demand
	❑ Contribution to national protein demand
	❑ Contribution to national power demand from basin hydropower
	❑ Annual basin hydroelectric production
Overall economic condition	❑ Overall assessment based on the above indicators

This Chapter provides an assessment of the status and trends associated with each of these indicators.

5.2 Economic value of MRC water-related sectors

5.2.1 Assessment methodology

The Strategic Indictor "Economic value of water-related sectors" is defined as the net economic output of water-related economic sectors in the Lower Mekong Basin. For the purposes of this report, and due to data limitations, this has been modified to the gross economic output of water related sectors in the LMB. The assessment indicators for this strategic indicator are given above in Section 5.1.

Overall economic conditions in the indicator framework are assessed using the "total net economic output of water related sectors in the LMB." For the purposes of this report, as per the comment above this has been modified to the "gross economic output of water related sectors", that is the sum of all the sectoral outputs identified above.

5.2.2 Economic value of agriculture

Despite the relative decline in the share of economic production attributable to agriculture in the LMB economies, the sector remains of critical importance for food security, for employment generation and poverty reduction, and export earnings.

(i) *Irrigated agriculture production*

Irrigation is the largest water user in the LMB and the area under irrigation has gradually expanded in all four LMB countries during the past two decades, from around 3.1 million hectares in 1995 to over 4 million hectares in 2013. While all countries in the LMB have expanded the area under irrigation, the vast majority of this irrigated land is in Viet Nam on the Mekong delta, with around 3.9 million hectares of irrigated land in 2013 (Figure 5.1).

The main irrigated crop in the LMB is rice. Table 5.1 shows estimates for the gross value of irrigated rice production in the LMB in 2013. The importance of irrigated rice production is illustrated from by the high annual output value of around US$ 7.7 billion. The figures also clearly illustrate the dominance of irrigated rice production in the Mekong delta, which accounts for around 84% of the economic value of production in the LMB.

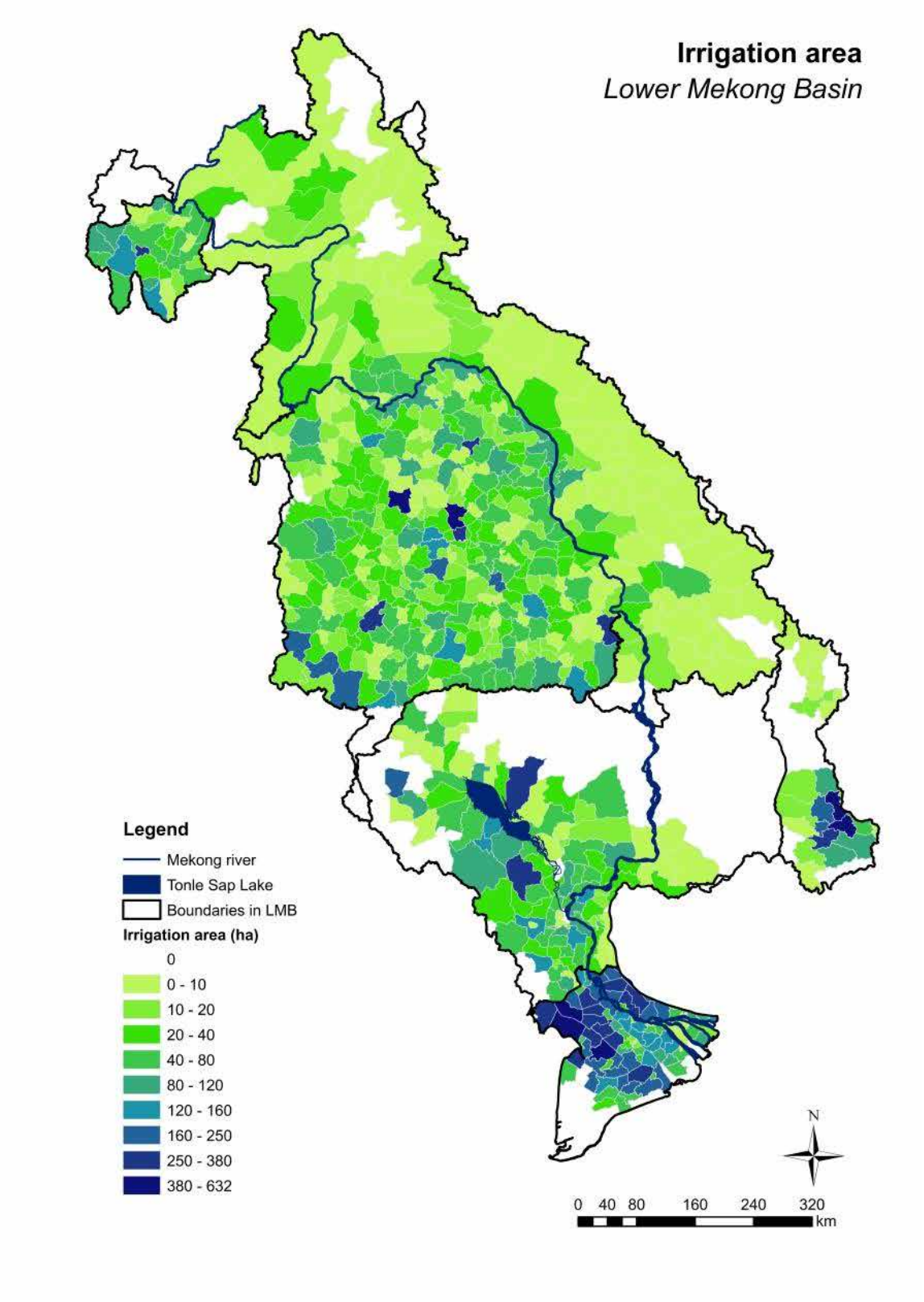
Table 5.1 Gross output value of irrigated rice in the LMB 2013

Country	Irrigated harvest area (Ha)	Irrigated production (ton)	Farm gate price (US$/ ton)	Economic value (US$)
Cambodia	483,446	2,118,710	267.567	566,896,786
Lao PDR	92,340	439,150	248.007	108,912,450
Thailand	598,805	2,264,495	243.777	552,030,805
Viet Nam	4,569,400	26,155,800	248.007	6,486,831,989
Total	**5,743,991**	**30,978,155**		**7,714,672,030**

Source: Production data from member countries, price data from FAOSTAT

Figures on irrigated maize production have also been available for the LMB. However, this is less significant than rice and has only been reported in Cambodia, with 18,358 hectares of irrigated maize in 2013. Irrigated maize production amounted to 73,974 tons and at a farm gate price of US$ 138 per ton, the total value of the crop was approximately US$ 10.2 million. Other crops (including vegetables) are also grown under irrigation in LMB, but data were only available for irrigated rice and maize.

Figure 5.1 Irrigated command area per province (km²)



Source: MRC Irrigation database

(ii) *Other agriculture aspects*

The Indicator Framework identifies recession rice production, riverbank gardens and rain fed cultivation as all further components of the sector contributing to the overall economic value of agriculture. Other agricultural production is likely to be important with the growth in industrial and cash crops such as rubber, pepper cassava and coffee. However, insufficient data are available to assess the value of these sub-sectors.

5.2.3 Economic value of hydropower

Hydropower is an important energy resource in the Mekong Basin. The region has considerable potential for hydro-electric development at all scales, from large multi-purpose projects to feed national power grids to micro-scale projects for rural electrification. Government policies promote hydro-power production for both national consumption and not only to meet national demands but also to expand cross-border power trade which will enhance regional economic integration and energy security.

By 2015, 59 hydropower projects of between 1 MW and 4,200 MW had been developed in the LMB (Figure 5.2). In total this represents an installed capacity of 10,017 MW, or 35% of the total estimated technical hydropower potential for the LMB of 28,543 MW (MRC 2015). Table 5.2shows the rapid expansion of the hydropower sector in the LMB, between 2005 and 2015 total installed capacity trebled from approximately 2.4 GW to 7.2 GW. At the same time, electricity production more than trebled from 9.4 TWh in 2005 to 32.4 TWh by 2015.

Table 5.2 Mekong based hydropower installed capacity and production 2005 and 2015

Country	2005		2015	
	Installed capacity (MW)	Annual Energy (GWh)	Installed capacity (MW)	Annual Energy (GWh)
Cambodia	-	-	400	1,990
Lao PDR	672	3,205	3,441	16,547
Thailand	737	885	737	885
Viet Nam	992	5,294	2,636	12,984
Total	2,401	9,384	7,214	32,406

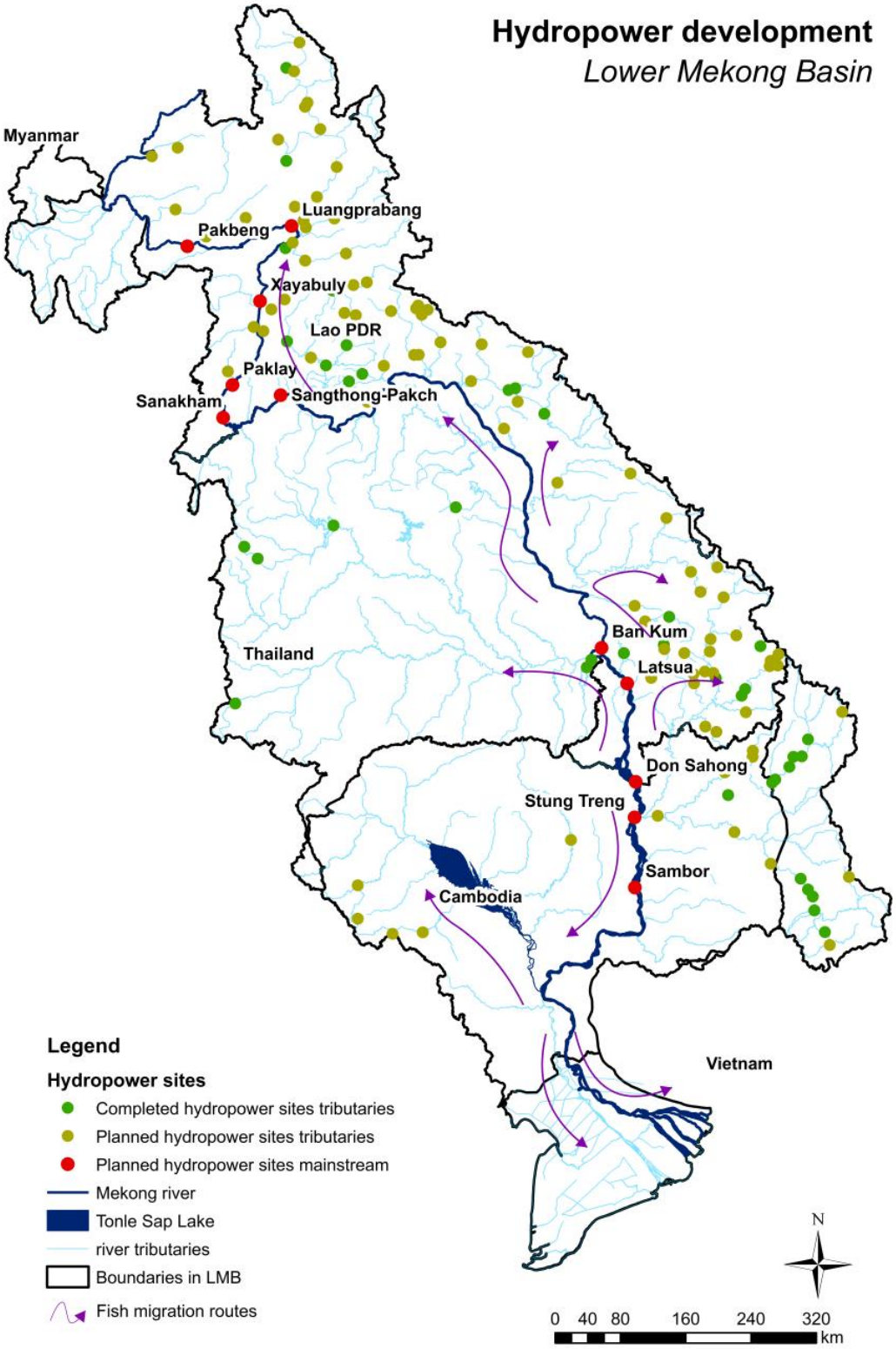
Source: MRC Hydropower Database 2015

Table 5.3 Gross economic value of LMB hydropower production

Country		2005		2015	
	Economic Price (US$/kWh)	Annual Energy (GWh)	Annual value (million US$)	Annual Energy (GWh)	Annual value (million US$)
Cambodia	0.095	-	-	1,990	189.05
Lao PDR	0.065	3,205	208	16,547	1,075.56
Thailand	0.066	885	58	885	58.41
Viet Nam	0.053	5,294	281	12,984	688.15
Total	-	9,384	547	32,406	2,011

Source: MRC Hydropower Database 2015; MRC, 2015, Guidelines for the Evaluation of Hydropower and Multi-Purpose Portfolios, Annex 1, Economics Practice Guide

Figure 5.2 Location of hydropower projects in the LMB



Sources: MRC Information System, MRC Hydropower database, MRC Planning Atlas

At the same time the gross economic value of hydropower production (Table 5.3) has increased from US$ 547 million in 2005 to over US$ 2 billion in 2015. However, it should be noted that these figures do not account for investment costs, or any other costs associated with social and environmental externalities.

5.2.4 Economic value of navigation

(i) *Cargo transport*

The Mekong River has long been an important inland waterway for traditional cargo and passenger transport between the numerous riverine communities along the Mekong. In addition, the river has also emerged as an increasingly important international trade route connecting the six Mekong countries, and the lower reaches of the basin to the sea and wider international markets.

At present, the average unit costs of inland waterway transport (IWT) are higher than road transport. However, for larger volumes of cargo being transported over long distances, IWT can have a cost advantage.

The development of IWT in the upper reaches of the Mekong (above the Khone Falls), is constrained by narrow and turbulent sections of the river and large seasonal variations in water levels. Nevertheless, the Mekong River does provide an important link in the transit route between Kunming and Bangkok. Overall, it is estimated that about 800,000 tons of IWT cargo are being shipped annually between China, Thailand, Myanmar and Lao PDR.

IWT trade in the lower Mekong river has also grown in recent years, with trends in container traffic at Phnom Penh port and general cargo through Can Tho port both showing steady increases. IWT trade received a significant boost with the opening of a new deep-water port at Cai Mep in Viet Nam where container terminals accommodate some of the largest container ships in the world. Cargo can therefore be shipped internationally to and from Phnom Penh with only a single trans-shipment at Cai Mep.

Over the past decade, volumes of cargo transported by IWT have increased significantly. Recent estimates for the LMB suggested that IWT cargoes increased from approximately 15 million tons in 2007 to 23 million tons in 2014, equivalent to an average annual growth rate of 6.4% (Table 5.4). This figure includes bulk cargo, petroleum products and TEUs (MRCS 2017).

The annual net economic value of cargo transportation in 2007 was estimated to be US$ 6.8 billion, of which Cambodia's share was US$ 1.1 billion, that of Lao PDR US$ 0.4 billion, Thailand US$ 0.2 billion and Viet Nam US$ 5.1 billion (MRCS 2017). Figures for the gross economic value of the sector have not been available.

Table 5.4 LMB cargo volume 2007 and 2014 (tons)

Country	2007	2014	AAGR 2007-2014 (%)
Cambodia	1,818,000	2,920,000	7.0
Lao PDR	523,000	748,000	5.2
Thailand	898,000	1,152,140	3.6
Viet Nam	11,615,000	18,050,000	6.5
Total	**14,854,000**	**22,870,140**	**6.4**

Source: MRCS 2017

(ii) *Passenger transport*

With regard to passenger transport, IWT provides an essential service in the upper reaches of the Mekong and it is estimated that about 50,000 passengers (including tourists) are being transported annually between China, Thailand, Myanmar and Lao PDR. Similarly, the number of passengers travelling on IWT transport (speed boats and cruise vessels) in the lower Mekong River is also significant and it is estimated that about 63,000 passengers (including tourists) are being transported annually in Cambodia and Viet Nam.

Table 5.5 LMB Annual passenger numbers for domestic pasengers and tourists 2007 and 2014

	Domestic passengers			Tourists		
Country	2007	2014	AAGR 2007-2014 (%)	2007	2014	AAGR 2007-2014 (%)
Cambodia	1,772,000	1,816,000	0.4	128,000	119,000	-1.0
Lao PDR	1,838,000	2,717,000	5.7	115,000	169,000	5.7
Thailand	117,000	134,000	2.0	208,000	237,000	1.9
Viet Nam	33,891,000	4,711,000	9.7	109,000	289,000	14.9
LMB Total	**37,618,000**	**69,378,000**	**9.1**	**560,000**	**814,000**	**5.5**

Source: MRCS 2017 Council Study: Report on navigation thematic area

No figure on the value gross output of the passenger sector is available at the present time.

5.2.5 Economic value of sand mining

As with the evaluation of the contribution of other economic sectors, the gross output value of sand mining is used to indicate the economic performance of the sector. Sand mining in the LMB is extensive and provides a critical input into construction and industrial sectors. Extraction of sand in the region has increased rapidly with the increased demand from the rapidly developing riverine economies. Much of the demand has been driven by infrastructure upgrading on the delta, as well as for export markets in Malaysia and Singapore (Thanapon and Manish 2017).

Data for sand and sediment mining activities in the basin is not systematically collected. The best available data on the extent and economic output of the sector is the recent study on the issue conducted by the WWF (Bavard et al 2013). This study estimates that based upon miner declarations approximately 35 million m3 or 55.2 million tons[24] were extracted from the Mekong mainstream in 2011. This figure represents a lower bound to likely sediment extraction in the LMB. Firstly, miners have an incentive to underreport the amount of sediment extracted to avoid royalties and taxes charged by amount. Given relatively weak government monitoring capabilities in the region the figure is likely to be higher. Secondly, this survey only covered the mainstream and did not cover extraction on Mekong tributaries. As such the figure is illustrative of the likely scale of sand mining activities in the LMB, but falls short of a realistic estimation of extraction in the LMB as a whole.

24 Density of 1.6 ton per cubic metre of dry sand.

Table 5.6 Sediment extraction volumes and percentage of grain-size categories per country in 2011

	Extraction (cubic meters per year)			
Country	**Sand**	**Gravel**	**Pebbles**	**Total**
Cambodia	18,748,503	2,044,940	0	20,793,443
Lao PDR	904,100	10,000	454,500	1,368,600
Thailand	3,677,200	857,740	0	4,534,940
Viet Nam	7,750,000	0	0	7,750,000
Total	**31,079,803**	**2,912,680**	**454,500**	**34,446,983**
%	*90*	*8*	*1*	*100*

Source: Bavard et al 2013

The value of mined sand essentially consists of the price of extraction and transport and therefore varies significantly. To obtain a reliable figure, the estimated sand values at the sites of extraction were used to obtain an overall output value. Global Witness (2010) estimated that the value of sand at point of extraction in Cambodia was US$ 3 per ton in 2010. Assuming this price is applicable across the LMB and adjusting for price increases between 2010 and 2011, the total value of sand extraction reported in Table 5.6 is approximately US$ 174.44 million (in 2011 prices). However, this is only an unofficial estimate of mined sand data in the region and the Member Countries do not accept the figures in Table 5.6 as the official figure for each country.

The official data for 2017 for Cambodia from the Ministry of Mines and Energy suggests much lower level of sand and sediment extraction, at around 10.2 million m3. This figure is for both the Bassac and the Mekong rivers, but is less than half the WWF estimates for 2013. This difference is unlikely to be driven by changes in the level of demand, which if anything is likely to have increased. Rather it may reflect policy changes between 2013 and 2017, or differences in data collection methodology.

5.2.6 Economic value of wetlands

There were approximately 102,386 Km^2 of wetlands in the LMB in 2010 (see Section 3.4.2). These wetlands provide a range of goods and services, and represent a critical contribution to livelihoods and the economy of the LMB. These are typically characterised and evaluated as ecosystem services (MEA 2005). In this context, wetland goods and services are defined in terms of the direct and indirect benefits people obtain from these ecosystems. Services are commonly grouped into provisioning, regulation and maintenance, and cultural services (Haines-Yung and Potschin 2012).

For example, wetlands provide provisioning services such as capture fisheries and other aquatic animals, and as a source of aquatic plants, they provide ecosystem regulation and maintenance functions such as ground water recharge, flood retention, pollution and waste breakdown and carbon sequestration, and they provide cultural services in terms of recreation and tourism, study and research and spiritual values.

Table 5.7 offers a summary of wetland valuation results from a comprehensive literature review of summaries available wetland valuation studies conducted in the LMB (WWF 2013). The table gives overall annual value of wetland ecosystem services as well as the services considered in the valuation figure. The annual value of ecosystem services is given in terms of an average value across a number of studies in US$ per hectare per year. It should be noted that valuations for the LMB are only available for freshwater wetlands (including flooded grasslands, flooded forest, marsh and swamps) and mangroves.

There are important limitations to the consideration of these figures. While mean values are cited here, the literature review found a large range of variation across the different valuation studies, this reflects differences in the type of wetlands, the level of use of wetlands and in the services they provide. The result is that there remains a significant

degree of uncertainty surrounding appropriate values.

Table 5.7 Summary of ecosystem service values

Land cover type and service	Mean annual value (US$/ha/year)
Freshwater wetlands	1,634
Local use of aquatic products	198
Water quality and flow services	1,436
Mangroves	2,670*
Local use of aquatic products	282
Coastal protection	2,243
Tourism and recreation	3,000
Carbon sequestration	100
Support for off-shore fisheries	45

Source: WWF, 2013, The Economic Value of Ecosystem Services in the Mekong Basin. What we know, and what we need to know. *Excludes tourism and recreation value of mangroves as highly location specific, also to avoid double counting as tourism is considered elsewhere in this report.

Another difficulty is that some of the ecosystem services offered by wetlands and incorporated in these valuations may also be counted elsewhere in the economic evaluation section, for example the local use of aquatic products may include capture fisheries, some of the value of water quality and flow services may be captured by different types of crop production which rely on these flows. This may mean that there is some double-counting, where services offered by wetlands may already be considered under different sector contributions, such as agriculture and capture fisheries.

Finally, the wetland categories used to report the valuation results do not necessarily accord with the general classifications of wetlands as used by the MRC (see Section 3.4.2). As a result, only cases where the broad wetland categorisation included in the available valuation material is in accords with the available MRC land-cover data.

Nevertheless, using these wetland valuation figures above and the wetland-related land cover data from the MRC (Section 3.4.2) where it is consistent with the valuation categories, Table 5.8 reports the value of freshwater wetlands and mangroves in the LMB for 2003 and 2010. Based upon this analysis, the 16, 692 Km^2 of wetlands in 2010 for which there is data provided services annually to a value of around US$ 2.8 billion: of this, mangroves contributed around US$ 350 million annually and freshwater wetlands contributed US$ 2.5 billion annually. Despite the size of this figure, the 2010 value represents a 21% decline from the 2003 figure of US$ 3.6 billion. This decrease is due to a decline in the area of mangroves and grasslands.

Table 5.8 Value of wetland ecosystem services in LMB based upon 2010 land cover figures

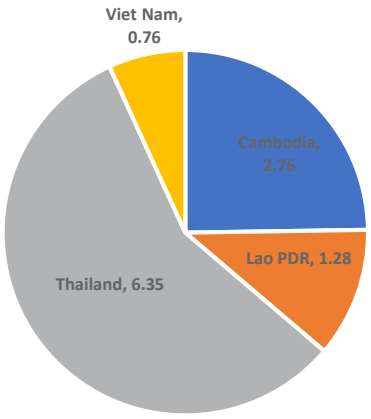
	Wetland area (Km²)		Annual value (million US$)		
Wetland type	**2003**	**2010**	**2003**	**2010**	**Change (%)**
Freshwater wetlands	19,153	15,389	3,130	2,515	-20
of which:					
Grassland	*13,880*	*8,637*	*2,268*	*1,411*	*-38*
Flooded forest	*4,360*	*4,886*	*712*	*798*	*12*
Marsh/swamp	*913*	*1,866*	*149*	*305*	*104*
Mangroves	*1,839*	*1,303*	*491*	*348*	*-29*
Total	**20,992**	**16,692**	**3,621**	**2,862**	**-21**

5.2.7 Economic value of capture fisheries

Based on a recent study classifying aquatic habitats into broad zones (i.e. major flood zones, rain-fed zones and permanent water bodies) using land cover data for 2003, capture fisheries production in the LMB was estimated to range from 1.3 to 2.7 million tonnes with the "most likely" yield of capture fisheries calculated at 2.3 million tonnes (Hortle and Bamrungrach, 2015). Thailand has the largest fish catch with 0.92 million tons, followed by Cambodia (0.77 million tonnes), Viet Nam (0.37 million tonnes) and Lao PDR (0.25 million tons). These overall production figures are higher than the previous estimates 1.5 million tons in 2003 (MRC, 2003) and 1.9 million tons in 2010 (MRC, 2010). It is important to note that this does not necessarily mean there has been an increase in capture fisheries production: rather, the higher numbers may be attributable to the application of enhanced estimation methods.

With regard to past trends in capture fisheries production, MRC's long term monitoring of fish catches indicate that there are annual fluctuations, but no clear or significant trends in overall level of fish production. However, it should be emphasised that the number of fishers (using both legal and illegal fishing gear) has increased and more efficient fishing gear (e.g. gill nets) is also being adopted. The rate of fish catch or catch per unit effort has therefore been declining in recent years.

Figure 5.3 Capture (including reservoir) fisheries estimated value (Billion US$) in the LMB 2015



The overall unit value of capture fisheries in LMB is derived from first-sale prices of wide variety of fish species. The value of capture fish in Thailand is high with an average price of US$ 6.9/kg in 2015. In comparison, the average capture fish prices in Cambodia and Lao PDR were estimated at US$ 3.6/kg and US$ 5.2/kg respectively while, in Viet Nam, the average price was much lower at US$ 2.1/kg. In 2015, the overall unit value of capture fisheries in LMB was therefore estimated at US$ 4.85/kg. However, it should be noted that high value fish are usually sold, whereas low value fish are often consumed directly by fisher households, meaning that these prices could overestimate the output value.

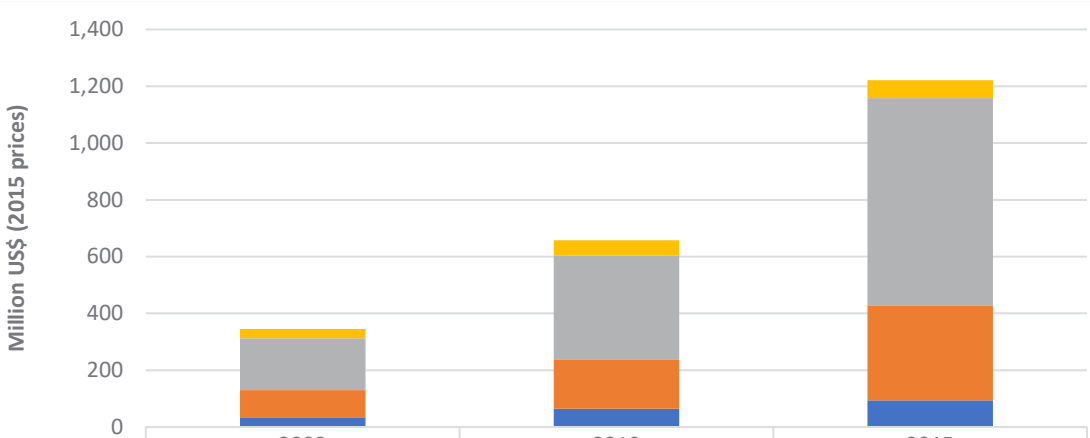
Based on average first-sale prices in each of the four Member Countries, the economic value of the 2.3 million tonnes of annual capture fish production was calculated at about US$ 11.15 billion (Figure 5.3). As such capture fisheries account for 65% of the total value of fisheries production.

5.2.8 Economic value of reservoir fisheries

Fisheries in large water bodies (mainly reservoirs) within the LMB, or 'Reservoir fisheries' are an important component of capture fisheries in the LMB. This is estimated to account for approximately 230,000 tons or 10% of the annual capture fisheries yield. Thailand accounts for about 50% of the yield from these water bodies and a further 25% comes from reservoirs in Lao PDR, which Cambodia and Viet Nam accounting for the remainder (Hortle and Bamrungrach, 2015).

Based on average first-sale fish prices in the Member Countries, the economic value of reservoir fisheries was estimated at US$ 1.22 billion, up from US$ 660 million in 2010 and about US$ 350 million in 2003. Thailand accounted for 60% of the total economic value, while Lao PDR contributed a further 27%. The economic values of reservoir fisheries are significantly lower in Cambodia and Viet Nam.

Figure 5.4 Economic value of reservoir fisheries in the LMB 2003-2015



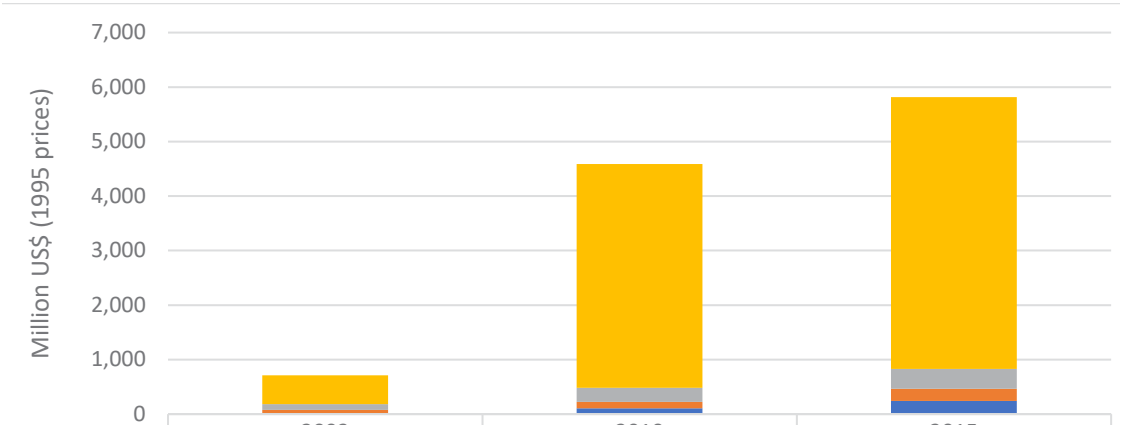
	2003	2010	2015
Vietnam	33	54	63
Thailand	182.9	365.7	731.4
Lao PDR	96	172.8	332.8
Cambodia	33.8	65	93.6

5.2.9 Economic value of aquaculture

Aquaculture production has been growing rapidly in the LMB. In 2002, total aquaculture production was estimated to be around 0.7 million tons: by 2010 this had increased to 1.8 million tons and again to 2.1 million tons by 2012. This is equivalent to an average annual growth rate over the decade of 11.6% (So Nam et al 2015). Viet Nam is by far the largest producer in the LMB with 1.8 million tons of fish produced in 2012. However, annual production growth in the Mekong Delta has slowed due to little recent increase in export demand.

Based on farm gate fish prices in the Member Countries, the economic value aquaculture production in the LMB was estimated at US$ 5.8 billion in 2015, up from US$4.6 billion in 2010 and US$0.7 billion in 2003 (Figure 5.5). Viet Nam is by far the largest producer, accounting for 86% of the basin's production value, followed by Thailand (6%), Cambodia (4%) and Lao PDR (4%).

Figure 5.5 Economic value of aquaculture in the LMB 2003-2015



	2003	2010	2015
Vietnam	528	4,103	4,984
Thailand	106	261	363
Lao PDR	62	115	229
Cambodia	18	109	239

5.2.10 Economic value of forestry

At the present time, no data on forestry output in the LMB has been made available. However, estimates based upon sustainable fuelwood extraction and timber extraction have been attempted to indicate the possible magnitude of forestry values in the LMB. Here the potential value of production for fuelwood and timber is estimated. A number of important caveats should be borne in mind. Firstly, estimates are for production from healthy, intact forests and it is not clear that all forests identified here are in good condition or indeed the estimates of area coverage are accurate. Secondly, estimates of sustainable production are for fuel wood or for timber, but not both. Thus, potential productivity figures for fuel wood and timber should be regarded as exclusive of one another.

The value of sustainable fuelwood production in the forested area was calculated using a similar approach to that used for defining sustainable forestry in CDM projects. Firstly, we adopted the biomass productivity figure defined for Cambodia in CDM methodologies, that assumes an annual woody biomass production of 4.09 t/ha/year (CDM 2007). [25]This was multiplied by forest area for each ecoregion (Section 3.4.5) to give a sustainable figure for the total production of woody biomass for the LMB which for 2010 was estimated to be around 84 million tons.

Price data was available only by volume of dry fuelwood at approximately US$12.51 per m3 (Joya 2015). [26] Mass of fresh biomass was converted to an equivalent volume of dry biomass, which was estimated to be 32 million m3 for the LMB. The total estimated value of potential sustainable annual fuelwood production is estimated to be US$ 402 million. It should be noted that this figure is the gross value of production and does not take into account the costs involved in fuelwood collection – which are likely to be mainly composed of labour involved in collection and transportation costs to market.

25 CDM SSC Working Group, 2007, Information note Default values of fNRB for LDCs and SIDs. Thirty-fifth meeting Report Annex 20.

26 This was obtained from Joya. R. 2015, Biomass Energy Consumption Patterns in Cambodia: Challenges and Opportunities. GERES Presentation. Green Business Forum, Phnom Penh. April 23 2015. Figure for 2014 was approximately US$ 12.00, inflated to 2017 value using Cambodia annual average CPI as reported in the World Bank, World Development Indicators. Some commentators mentioned that fuelwood prices had been depressed in recent years due to a supply glut caused by land clearance for concessions.

Table 5.9 Estimated annual sustainable fuelwood production and value in the LMB 2010

Ecoregion	Area forest cover outside PAs (Km²)	Sustainable biomass production (t)	Volume of dry biomass (m³)	Annual value (US$, million)
Cardamom mountains rainforest	4,376	1.79	0.69	8.6
Kayah-Karen montane rainforests	1,454	0.59	0.23	2.9
Luang Prabang montane rainforests	28,947	11.84	4.55	56.9
Northern annamites rain forest	18,247	7.46	2.87	35.9
Northern Indochina subtropical forests	26,370	10.79	4.14	51.8
Northern Khorat Plateau Moist Deciduous Forests	2,873	1.17	0.45	5.6
Northern Thailand-Laos Moist Deciduous Forests	5,695	2.33	0.89	11.2
Northern Viet Nam Lowland Rain Forests	152	0.06	0.02	0.3
Southern Annamites Montane Rain Forests	12,618	5.16	1.98	24.8
Tonle Sap Freshwater Swamp Forests	3,139	1.28	0.49	6.2
Tonle Sap-Mekong Peat Swamp Forests	1,262	0.52	0.20	2.5
Central Indochina Dry Forests	65,337	26.72	10.27	128.4
South-eastern Indochina Dry Evergreen Forests	32,804	13.42	5.15	64.5
Indochina Mangroves	999	0.41	0.16	2.0
Total	204,272	83.55	32.09	401.5

Timber is an important good supplied from the forests of the study area. At present, and despite regulation, wood it is not extracted in a sustainable manner in some LMB countries and is a key source of forest loss. It should also be noted that the very notion of sustainable timber extraction is increasingly contested. [27] Nevertheless, here we attempt to estimate what the gross value of potential sustainable production of timber from the LMB might be if forested areas were in a pristine condition.

Different tree species grow at different rates and are present in forests in varying densities. Therefore, what constitutes a sustainable level of timber production in an area typically depends upon the assemblage of tree species in a forest and their density. Determining the rate of sustainable production or annual allowable cut usually relies upon detailed inventories of the forest stock. In the absence of this data, and given the desire to ensure estimates are based upon what constitutes a sustainable level of production, we adopt production figure of 10 m3 per ha in a 35-year cycle, which is equivalent to an annual production volume of 0.29 m3 per ha (FAO 2018).

27 See for example, Zimmerman, B.L. and Kormos, C.F. 2012, Prospects for Sustainable Logging in Tropical Forests, Vol. 62 No. 5 BioScience

Table 5.10 Estimated annual value of sustinable timber production in LMB

Ecoregion	Area forest cover outside PAs (Km^2)	Sustainable timber production (m^3)	Annual value (US$, million)
Cardamom mountains rainforest	4,376	126,892	31.6
Kayah-Karen montane rainforests	1,454	42,165	10.5
Luang Prabang montane rainforests	28,947	839,470	209.0
Northern annamites rain forest	18,247	529,172	131.8
Northern Indochina subtropical forests	26,370	764,726	190.4
Northern Khorat Plateau Moist Deciduous Forests	2,873	83,306	20.7
Northern Thailand-Laos Moist Deciduous Forests	5,695	165,149	41.1
Northern Viet Nam Lowland Rain Forests	152	4,396	1.1
Southern Annamites Montane Rain Forests	12,618	365,918	91.1
Tonle Sap Freshwater Swamp Forests	3,139	-	-
Tonle Sap-Mekong Peat Swamp Forests	1,262	-	-
Central Indochina Dry Forests	65,337	1,894,780	471.8
South-eastern Indochina Dry Evergreen Forests	32,804	951,304	236.9
Indochina Mangroves	999	-	-
Total	**204,272**	**5,767,278**	**1,436.1**

Timber values also vary greatly depending on the type and quality of timber. For example, "luxury" timbers such as rosewoods can be worth in excess of US$ 800 m3. This compares to softwoods which were around US$ 100 m3 in 2016. Moreover, like other commodities timber prices can fluctuate significantly from year to year. Average Asia-Pacific export timber prices were used for non-coniferous timber from the ITTO (ITTO 2017). To address annual price fluctuations, an average price for timber of US$ 249 for the five years from 2012 – 2016.

The results of the valuation exercise are presented in Table 5.10. Based upon this the gross economic value of annual sustainable timber production in the LMB is estimated to be US$ 1.4 billion. For the purposes of these calculations, it is assumed that forests are in a more or less natural condition. If, as is likely the case, many of these forests are degraded, then possible levels of sustainable production of fuelwood and timber are likely to be much lower.

5.2.11 Economic value of tourism and recreation

Since 1980, international tourism has developed rapidly in all the LMB countries. Tourism now makes an important contribution to GDP in all the LMB countries ranging from 5% in Viet Nam to 7% in Thailand, 9% in Lao PDR and 11% in Cambodia. In 2016, the LMB countries attracted around 51 million international visitors generating about US$65 billion (Table 5.11).

Table 5.11 LMB International tourism arrivals and receipts 2006 and 2016

Country	International tourist arrivals (million)		International tourist receipt (billion current US$)		Change 2006 – 2016 (%)	
	2006	2016	2006	2016	Arrivals	Receipts
Cambodia	1.70	5.01	1.11	3.52	195	218
Lao PDR	0.84	3.32	0.16	0.71	294	346
Thailand	13.82	32.53	16.62	52.47	135	216
Viet Nam	3.58	10.01	2.85	8.25	179	190
Total	**20**	**51**	**21**	**65**	**155**	**213**

Source: World Bank, 2018, World Development Indicators Database

The sector has grown rapidly, with the 2016 figures representing a 155% increase in international arrivals and a 213% increase in tourism receipts since 2006. Moreover, these figures do not include domestic tourism which is also likely to have grown strongly with increasing economic activity leading to higher income levels and more disposable income in the region.

Figures for tourism to the LMB specifically have not been available. The national figures for Cambodia and Lao PDR, by and large, are a good guide to international tourism in the LMB as most tourist sites in these countries are within the basin. However, with the majority of tourist attractions in Thailand and Viet Nam outside the LMB, national figures are a poor guide to the likely importance of LMB tourism in these countries.

Nevertheless, the value of tourism to the basin is clear from the Cambodia and Lao PDR figures alone, as is the rapid growth in the sector over the last 10 years. In this context, it is important to stress the significance of sustaining the riverine environments in order to continue attracting tourists to the area.

5.2.12 Economic losses from bank and coastal erosion

Coastal erosion and river bank erosion are increasing problems in the LMB. Increased erosion is associated with lower sediment loads, water extraction and consequent land subsidence, climate change, more extreme flooding events and well as localised activities such as sand mining.

Estimates of river bank and coastal erosion have been generated for the LMB countries with the exception of Thailand, these estimates are reported in Table 5.12. Firstly, it should be noted that there is a wide disparity between estimates of eroded area between countries. This may be a reflect of differing geomorphological conditions. However, it is also likely to be due to different methodologies for estimating eroded area. Whereas estimates for Lao PDR and Viet Nam seem to be based upon actual land lost on the edge of water bodies as a result of erosion, those for Cambodia include land inundated by the Se San II hydropower plant, which will occupy around 33,650 ha when full. As a result, these estimates are much higher and are not a good guide to the costs of erosion due to land losses. For the purposes of this valuation the focus is only on the reported land losses in Lao PDR and Viet Nam. It should also be noted that in the case of Viet Nam, a substantial area remains under threat of erosion, with around 239 Ha being identified as at risk in 2017.

In estimating the value of land lost to erosion it was assumed that all land losses were of agricultural land, rather than residential land which would command a much higher value. The value of lost crops was not estimated as this data has not been available. In the absence of comprehensive and transparent land values typical values from recent resettlement projects were used. Table 5.13 reports the results of these estimations for Lao PDR and Viet Nam. Despite

much lower reported land loss in Viet Nam due to the much higher price of agricultural land overall reported costs of erosion over the last seven years are much higher.

Table 5.12 Areas of river bank and coastal erosion in the LMB 2011 – 2016 (ha)

Year	Cambodia	Lao PDR	Thailand	Viet Nam
2011	N/A	38.45	N/A	60.54
2012	N/A	18.81	N/A	4.21
2013	N/A	24.22	N/A	N/A
2014	16,576.83	14.46	N/A	0
2015	15,248.07	2.25	N/A	0
2016	22,701.87	21.3	N/A	0.52

Source: MRC estimates

Table 5.13 Valuation of land losses to erosion in Lao PDR and Viet Nam 2011-2017

	Lao PDR	Viet Nam
Land value (US$/ha)	4,750	25,000
Year	**Value of land lost (US$)**	
2011	182,638	1,513,500
2012	89,348	105,250
2013	115,045	-
2014	68,685	-
2015	10,688	-
2016	101,175	13,000
2017	93,100	-
Total	**660,678**	**1,631,750**

Coastal erosion is also a large and growing problem in the delta. Estimates suggest that 500 ha of land is lost annually to coastal erosion (Anthony et al 2015). Based upon the estimates above this represents a loss of land worth approximately US$ 12.5 million per year.

5.2.13 Economic cost of flood damage

The economic value of direct damages due to flooding is annually reported by Member Countries for the Annual Mekong Flood Reports (AMFRs), data for 2010-2014 is presented in Table 5.14. Damages and losses are indicated for floods, in general, but damages and losses related to river floods or flash floods are not specified.

The 2011 floods were particularly significant in the lower reaches of the LMB with considerable impact on the Cambodian floodplains and the delta in Viet Nam. Other riverine flooding in the LMB in recent years has been moderate. Flash floods do occur every year, predominantly in mountainous areas, and are typically associated with heavy rainfall events (such as those associated with tropical depressions and typhoons). While this is too short a period to determine a trend with any confidence, it does appear that damages are increasing, probably as a consequence of greater investment in areas susceptible to flooding.

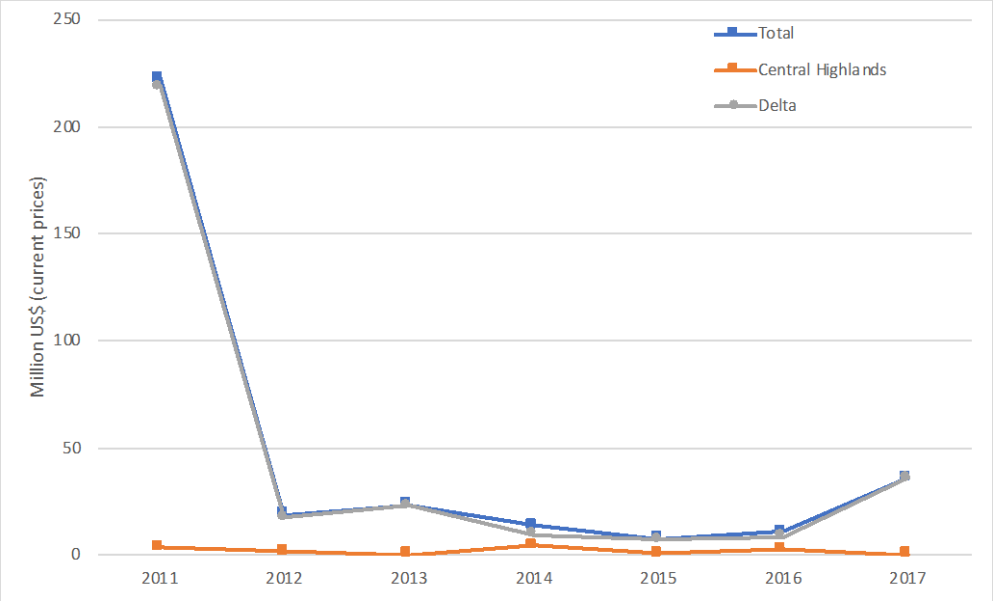
Figures for Viet Nam have also been reported up to 2017, these are given in Figure 5.6 below.

Table 5.14 Economic value of annual flood damage in the LMB between 2010 - 2014 (current US$ million)

	2010	2011	2012	2013	2014
Cambodia	No data	100-160	No data	No data	No data
Lao PDR	21	22	1.5	62	12
Thailand	47	-	-	210	6
Viet Nam	55	222.1	18.9	23.2	13.8
of which					
Delta Central	*55*	*218.6*	*17.3*	*23*	*9.3*
Highlands	*-*	*3.5*	*1.5*	*0.2*	*4.5*
Total	**123**	**442-502**	**18.5**	**295.2**	**26.4**

Source: Annual Mekong Flood Reports 2011 – 2014 and Viet Nam NMC

Figure 5.6 Economic vlaue of flood damage in Viet Nam 2011 – 2017 (current US$ million)



Source: Viet Nam NMC

The economic value of drought losses has not been considered separately as these are deemed to be implicit in crop production figures. Better, small area data on crop production, droughts and floods would allow a more accurate attribution of losses to droughts and flood events.

5.2.14 Assessment of aggregate economic value of MRC water-related sectors

At this point, sufficient data are not available to attempt an estimate of aggregate economic output for the sectors covered. Other difficulties include the partial nature of some data, different years of data availability and unspecified years for price data and unclear price estimation methodology for some prices.

5.3 Contribution of basin economy

5.3.1 Assessment methodology

The Strategic Indictor "Contribution of basin economy" is defined as the contribution of the Lower Mekong Basin water-related economic sectors to overall economic, food and energy security within the Basin and beyond. The assessment indicators for this strategic indicator are:

- ❑ Contribution of LMB water-related sectors to basin, national and regional GDP
- ❑ Contribution to food grain supply
- ❑ Contribution to protein supply
- ❑ Contribution to power supply

The contribution to the basin economy indicator is assessed based up the proportionate contribution of Lower Mekong Basin water-related economic sectors to overall economic, food and energy security in the basin, nationally and regionally.

5.3.2 Contribution of MRC water-related sectors to overall GDP

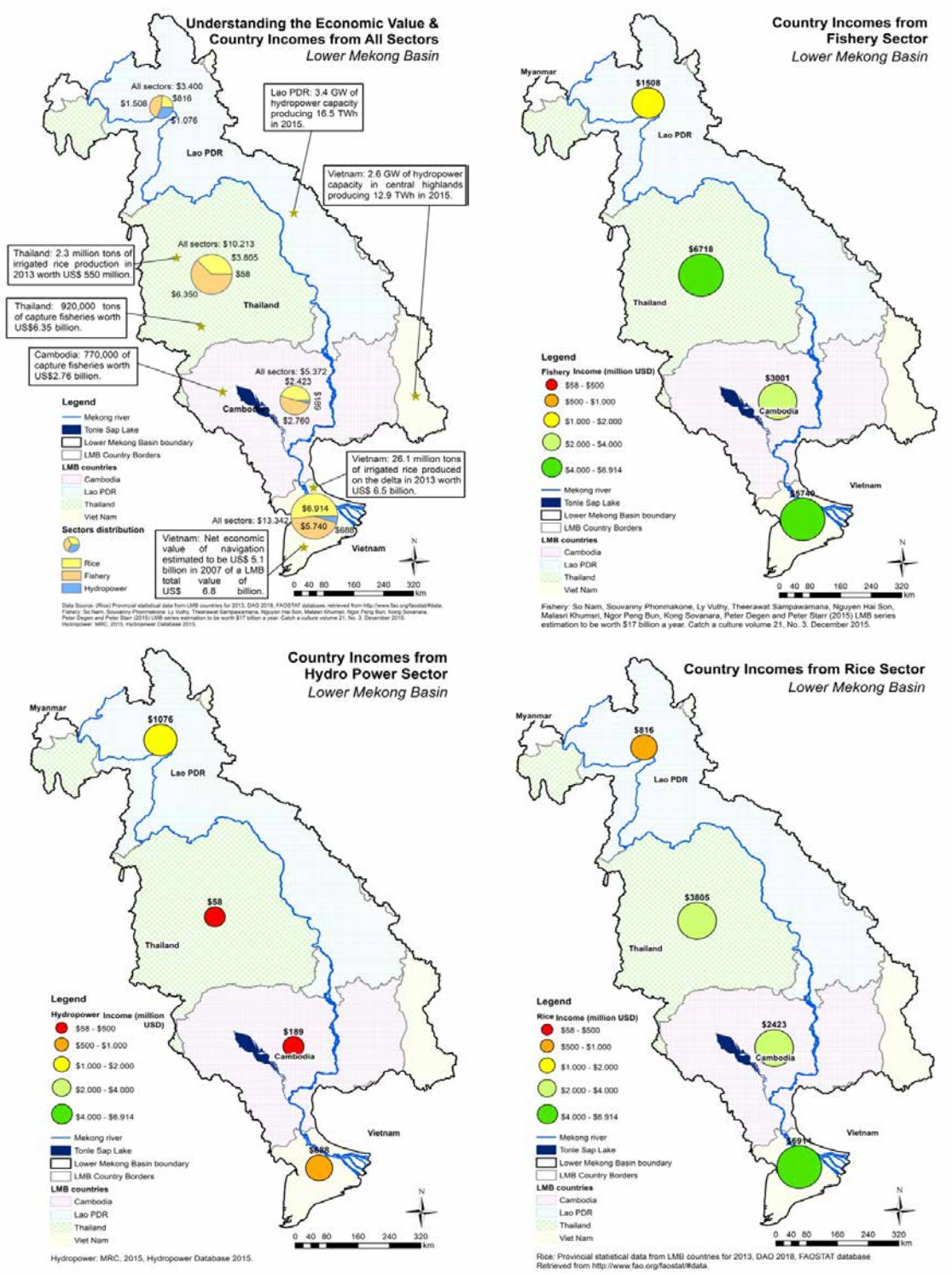
Data was unavailable to allow the calculation of the contribution of all MRC water-related sectors in the LMB to national GDP or sectoral GDP. Sufficient data was available to allow the estimation of the share of key MRC water-related sectors attributable to production in the LMB, namely rice production, fisheries, hydropower and tourism. The results of these calculations are given in Table 5.15 below. Data for similar time periods was not always available for each sector. Given relatively slow change in production figures for rice and fisheries, the figures allow an approximate understanding of the relative economic contribution of key water related sectors in the LMB.

Table 5.15 Contribution of key MRC water-related sectors to national economic output

	Cambodia	Lao PDR	Thailand	Viet Nam
Rice production 2015 (gross value)[1]				
National production (million US$)	2,873	1,181	9,585	13,540
LMB production (million US$)	2,423	816	3,805	6,914
LMB share of national (%)	84	69	40	51
Total fisheries 2015 (gross value)[2]				
National production (million US$)	3,364	582	9,974	23,379
LMB production (million US$)	3,001	1,508	6,718	5,740
LMB share of national (%)	89.2	913	67.44	24.6
Hydropower 2015 (gross value)[5]				
National production (million US$)	588	1,060	12,684	8,124
LMB production (million US$)	189	1076	58	688
LMB share of national (%)	32.2	100.0	0.5	8.5

Source: 1. Provincial statistical data from LMB countries for 2013, FAO 2018, production figure extrapolated to achieve 2015 estimates; 2. World Bank 2018, So Nam et al 2015.; 3. Note there is a significant disparity between the figures on LMB production and those on national fisheries production for Lao PDR, it was therefore assumed that LMB fisheries production was in proportion to LMB population; 4. This estimate uses national statistics reported by FAO and LMB fisheries statistics reported by Hortle and Bamrungrach 2015. Differing data collection methodologies may lead to an over estimation of the LMB share of Thai fisheries; 5.MRC hydropower database, IEA 2018; 6. WTTO 2018a, 2018b, 2018c, 2018d.

Figure 5.7 Visualisation of economic value and income derived from key water-related sources in the LMB

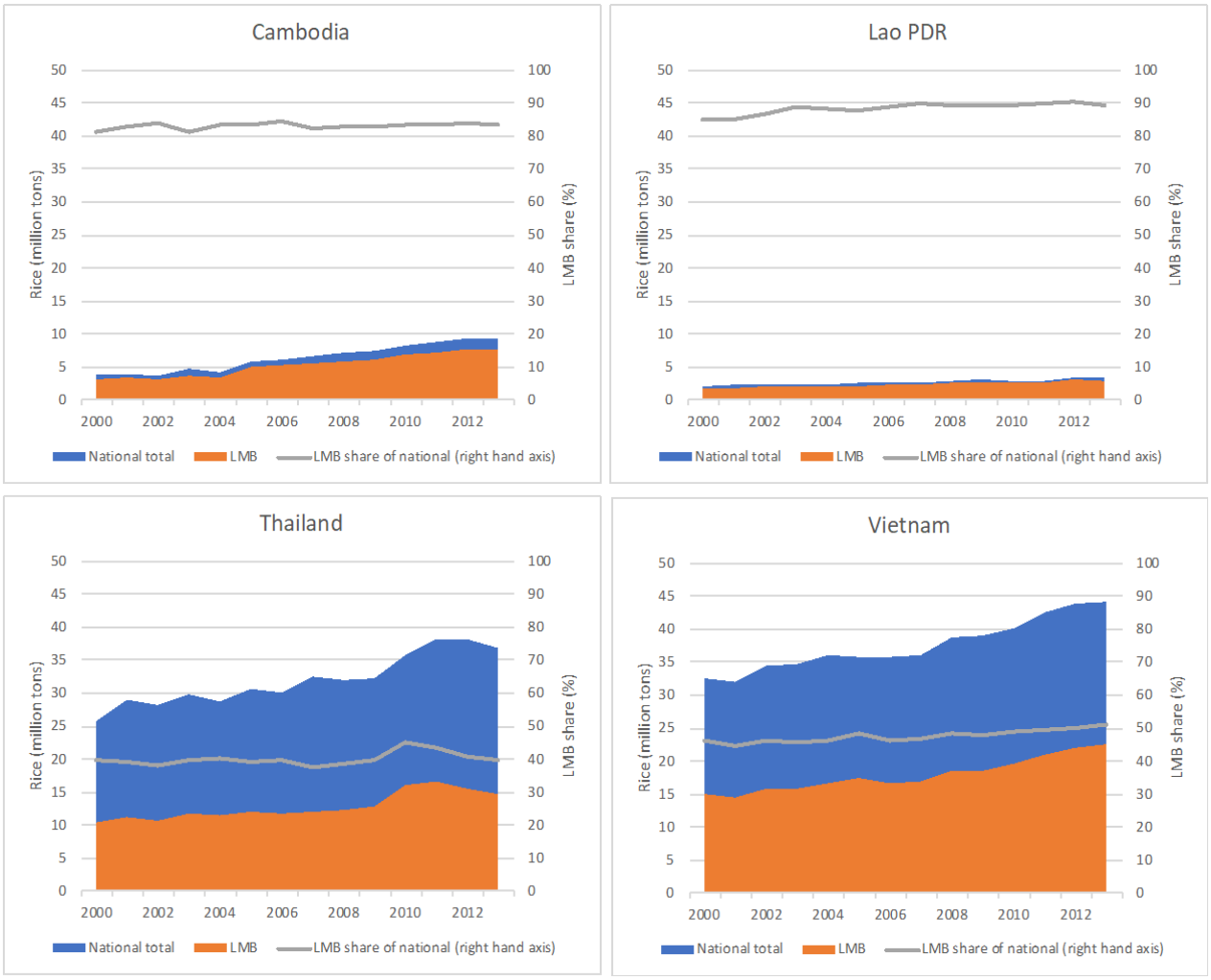


For the purposes of this analysis the economic value of water related sectors has been attributed to the country in which the sector production take place. However, this is subject to an important caveat. That an economic activity take place in a particular country does not mean that that country is able to capture all or even the majority of the economic value of the sector. For example, many hydropower projects are owned by foreign investors and profits are used to pay off debts to international banks, and the benefit of the electricity is enjoyed by consumers largely outside the country of production. Similarly, many of the economic benefits of rice production are enjoyed by consumers in importing countries.

5.3.3 Contribution to food grain supply

The contribution of the LMB to national food grain supply is measured as the share of national annual food grain production produced in the LMB. Rice is the predominant food grain crop in the region and dominates food grain production, so here we confine estimates of the LMB contribution to food grain supply to rice. Figure 5.8 shows the contribution of the LMB to rice national rice production for all four LMB countries between 2000 and 2013. In all four countries, national rice production has increased over the period, although at differing rates. The share of national rice production in the LMB has been stable over the period, suggesting that the productivity and expansion of the sector has grown at a similar rate within the LMB and in rice growing areas outside the basin.

Figure 5.8 Rice production in LMB countries as a share of national production 2000 - 2013



Source: FAO 2018, provincial statistical data

The share of national rice production in the within LMB areas in Cambodia and Lao PDR is high reflecting the large proportion of these countries within the LMB. The share of national rice production produced in the LMB areas of Thailand and Viet Nam is lower, reflecting the large proportion of these countries outside the LMB. Nevertheless, both Thailand and Viet Nam produce a large share of their rice in the LMB, whereas the area of Thailand in the LMB only accounts for around 36% of its land area it accounts for around 40% of its rice production. Similarly, the area of Viet Nam in the LMB is around 20% of its total land area, but accounts for around 50% of its rice production. Overall, the LMB produced 48.2 million tons of rice in 2013, around 51% of the 93.6 million tons of rice produced in the four LMB countries as a whole.

5.3.4 Contribution to protein demand

The indicator contribution to national and regional protein demand seeks to measure the degree to which protein demand in the LMB countries and region is met by LMB resources. As the focus in on water resource sectors we have focused here on two key MRC water-related sectors, rice and fisheries.

National protein demand was calculated based upon FAO data on average daily protein consumption per capita in each of the LMB countries. This was scaled up for the whole population to arrive at an annual national protein demand. Available dietary protein levels of rice and fresh fish were taken from FAO Food Balance Sheet estimates for the region. These were 7 grams of protein per 100 grams for rice and 10.6 grams per 100 grams for fish. Using these figures and LMB production figures for rice and fish it was possible to arrive at an estimate for total protein supply derived from thee LMB resources, and from this an equivalent share of national protein demand was derived.

Table 5.16 Protein supply from rice and fisheries sectors as share of national protein demand 2013 and 2014

Country	Protein consumption (g/capita/day)	National annual protein demand (tons/year) 2013	Rice		
			LMB Production (tons)	Total Protein (tons)	Share of national demand (%)
Cambodia	65.7	360,032	7,827,485	547,924	152
Lao PDR	68.9	163,328	3,050,053	213,504	131
Thailand	60.9	1,514,221	14,707,284	1,029,510	68
Viet Nam	81.7	2,727,172	22,530,279	1,577,120	58
Country	**Protein consumption (g/capita/day)**	**National annual protein demand (tons/year) 2014**	**Fisheries (capture, reservoir and aquaculture)**		
			LMB Production (tons)	**Total Protein (tons)**	**Share of national demand (%)**
Cambodia	65.7	365,978	871,895	92,421	25
Lao PDR	68.9	165,387	340,355	36,078	22
Thailand	60.9	1,520,303	1,041,044	110,351	7
Viet Nam	81.7	2,758,384	2,174,368	230,483	8

Source: FAO Food Balance Sheets 2018, MRC fisheries program, Country statistical Yearbooks, World Bank 2018

It should be noted that these figures are very general estimates. They take no account of other uses of fish and rice production other than food, nor do they take account of possible exports. Rather they represent the potential contribution to national protein supply. Overall it is clear that LMB resources potentially supply a high proportion of national protein demand in all four countries, even when considering two sectors.

5.3.5 Contribution to power supply

The contribution to national power supply indicator seeks to measure the importance of hydropower generation in the LMB for power supply in each of the LMB countries and for the LMB region more generally. The metric used to assess this is the proportion of national power demand (consumption) met by LMB hydropower generation. This is calculated as the percentage of domestic demand of domestic LMB hydropower generation minus exports plus imports. The results are reported in Table 5.17.

Table 5.17 Annual electricty demand and share supplied by LMB hydropower 2015

Country	Total annual electricity demand (Gwh)	LMB hydropower share (%)
Cambodia	5,990	33.2
Lao PDR	4,239	100.0
Thailand	172,090	6.7
Viet Nam	142,877	9.1
Total	**324,604**	**10.0**

Sources: MRC Hydropower database, EAC 2018, EPPO 2018, MEM 2017, MOIT 2017

LMB hydropower sources are clearly important for all LMB countries, accounting for 10% of electricity demand. According to the available data, Lao PDR obtains practically all its supply from LMB hydropower. Cambodia also obtains over a third of its electricity supply from hydropower plants in the basin. Thailand has the lowest share of LMB hydropower in its generation mix, including significant hydropower imports from Lao PDR. Finally, Viet Nam also generates around 9% of its demand in the LMB from plants in the central highlands.

5.3.6 Assessment of overall contribution of basin economy

The LMB and water related sectors within it continue to contribute significantly to the broader national and regional economy. The importance of water related sectors in the LMB is particularly marked when considering the contribution of rice production in the Mekong delta to national rice production in Viet Nam. Similarly, the importance if hydropower production to domestic power supply is important across the basin but particularly in Cambodia and Lao PDR, as are power exports from Lao PDR to Thailand.

5.4 Summary of overall economic conditions in the basin

The broad picture of the LMB as with the LMB countries as a whole is one of economic growth and productivity improvement. This is clear from increased production in sectors such as rice production and hydropower generation, as well as navigation, tourism, aquaculture. There remain significant difficulties with accurately estimating the economic contribution of natural resources such as wetlands, sand mining and capture fisheries leading to uncertainty around the values of these resources. Similarly, enumerating flood and erosion damage remains problematic.

The development and expansion of hydropower and agriculture in the basin can be expected to have a negative impact on the economic productivity of some of these sectors. Without better valuations for these sectors it is difficult to identify and properly assess these trade-offs. Better data collection on all sectors is important but for these sectors, where economic values are less transparent and harder to establish, it is a priority.

6. Climate change dimension

6.1 Introduction

The climate change dimension of the MRC Indicator Framework reflects MRC's recognition that climate change has great bearing on the long term sustainable development, utilisation, conservation and management of the Mekong Basin water and related resources.

Adaptation Capacity across Member Countries is variable with many communities vulnerable to the effects of increased frequency of extreme events, particularly floods, droughts and storms, as well as sea-level rise. In their Nationally Determined Contribution submissions and National Communications to the United Nations Framework Convention on Climate Change all countries have identified adaptation priorities across a range of domains, in particular in areas of disaster preparedness, emergency response and in agriculture and other natural resource sectors.

As a result, the Member Countries requested the MRC to take up a Climate Change and Adaptation Initiative (CCAI) in 2007 with the aim of enhancing the adaptive capacity of Member Countries including to determine potential impacts with greater certainty, and to reduce the impacts of climate change on the people and ecosystems of the LMB.

In 2018 the MRC released the Mekong Climate Change Adaptation Strategy and Action Plan (MASAP). With its emphasis on a basin-wide approach, the MASAP seeks to ensure that climate change adaptation is harmonised with effective strategies, plans at various levels and is applied at priority locations throughout the basin. The MASAP identifies seven strategic priorities for basin-wide adaptation to climate change. These are:

1. Mainstream climate change into regional and national policies, programmes and plans;
2. Enhance regional and international cooperation and partnership on adaptation;
3. Enable preparation of transboundary gender sensitive adaptation options;
4. Support access to adaptation finance;
5. Enhance monitoring, data collection and sharing;
6. Strengthen capacity on development of climate change adaptation strategies and plans; and
7. Improve outreach of MRC products on climate change and adaptation.

Four strategic indicators have been selected by which to monitor key aspects of climate change and the extent to which adaptation measures are in place. These three indicators are (i) greenhouse gas emissions, (ii) climate change trends and extremes and (iii) adaptation to climate change. These strategic indicators are supported by ten assessment indicators as shown overleaf.

Climate change is not just a threat for the Lower Mekong Basin, its impact is present and is affecting the livelihoods of millions that rely on the river's natural resources. Changes in temperature, rainfall, river flow and flooding as a result of climate change affect agriculture and fisheries and, as a result, reduce food security, especially for the poor. Additionally, a predicted rise in sea level will increase salinity and floods in the Mekong Delta, causing damage to crops in the most productive area of the basin.

The Mekong basin is expected to become even more affected by climate change in the future. Results of long-term climate model projections under various emission scenarios indicate that temperatures will increase and sea level will rise, while changes in rainfall and run-off may increase or decrease, depending on location within the basin.

Strategic indicators	Assessment indicators
Greenhouse gas emissions	❑ GHG emissions from LMB water-related sectors ❑ Relative contribution to global emissions
Climate change trends and extremes	❑ Tropical storm frequency and storm surge risk ❑ Changes in temperature ❑ Changes in precipitation ❑ Extent and severity of flooding ❑ Extent and severity of drought
Adaptation to climate change	❑ Institutional response to the effects of climate change ❑ Drought Protection ❑ Coverage of disaster warning systems ❑ Vulnerability to floods and droughts

The predicted changes in rainfall and temperature could cause greater variability in the hydrological regime of the Mekong. In the short-term, the climate variability change adds more uncertainty to the changes caused by the development activities. An increase in the risk of both floods and droughts is expected. Low-lying areas downstream of Kratie and in the Mekong delta would be particularly at risk.

In the Mekong delta, the most important factor related to flooding is expected to be sea level rise. Estimates indicate that approximately 30% of the delta would be inundated with a one metre sea level rise. The recently prepared Mekong Delta Plan of Viet Nam provides a long- term vision and strategy for the development and management of the delta in the face of climate change.

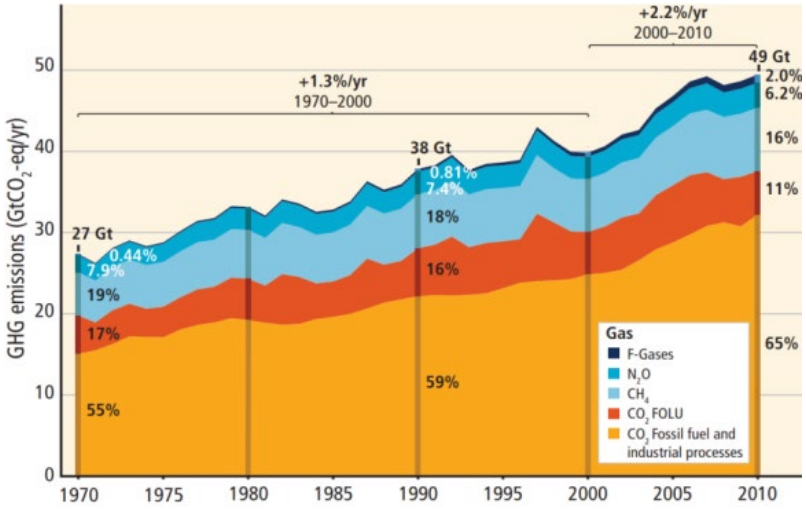
6.2 Greenhouse gas emissions

6.2.1 Assessment methodology

Greenhouse gas emissions data have been obtained from the various National Communications to the UNFCCC which are reported in the Climate Analysis Indicators Tool (CAIT). CAIT draws on key climate-relevant data from respected research centres, government agencies, and international bodies. As of June 2015, the platform contains sector-level greenhouse gas (GHG) emissions data for 185 countries and the European Union (EU) for the period 1990-2012, including emissions of the six major GHGs from most major sources and sinks. It also contains historical country-level carbon dioxide (CO2) emissions data going back to 1850, and energy sub-sector CO2 emissions data going back to 1971. With respect to country-level GHG emissions, there are several sources of emissions data widely used by the climate policy and science communities. The data reported directly by countries to the UNFCCC through their national GHG inventories generally include a six-gas inventory. The CAIT data sources were chosen based on criteria such as completeness and relative accuracy and country datasets are produced by applying a consistent methodology.

The Indicator Framework defines the strategic indicator "Green-House-Gas emissions from LMB water related sectors". The derived assessment indicator is almost the same with the refinement to look at the water related sector: "GHG emissions from LMB countries". However, the monitoring parameters are somewhat broadened and contain the relative contributions from the various sectors as well. Collecting data for the LMB region only is virtually impossible and therefore totals for the entire country are presented here.

Figure 6.1 Total global annual anthropogenic GHG emissions by gases 1970–2010



Source: IPCC-AR5-SPM.

6.2.2 GHG emissions

The GHGs emissions in each country were derived from the CAIT data base and present emissions for the entire countries, including areas outside the LMB. Total GHG emission for the four LMB countries is about 709 Mt CO2e in the year 2014 including land use changes and forestry emissions (or sinks). CAIT reported for all countries in the world a total of 47,351 Mt CO2e, so the LMB countries emission is about 1.5% of the global total. Adjusting those numbers on a per capita basis for the LMB only shows that only 0.5% of global GHG emissions is produced in the LMB.

GHG emissions in the LMB parts of the country are increasing with values increasing between 1.3% and 3.6% per year (2000-2014) (Table 6.1). Part of this increase can be attributed to population growth. Looking at the increase in GHG emission per capita an increase between 1.0% and 1.6% of CO2 is measured (Figure 6.3).

GHG emissions are often reported with and without the effects of land use change and forestry (LUCF). For two LMB countries (Thailand, Viet Nam) the difference between including or excluding LUCF is relatively small. For Viet Nam the contribution of LUCF has been always positive in the sense that LUCF were a sink Figure 6 .2. Till 2001 total CO2e emission for Viet Nam was even negative, so more GHG was captured than emitted. For Cambodia and Lao PDR about 50% of total emission can be attributed to changes in land use change and forestry activities.

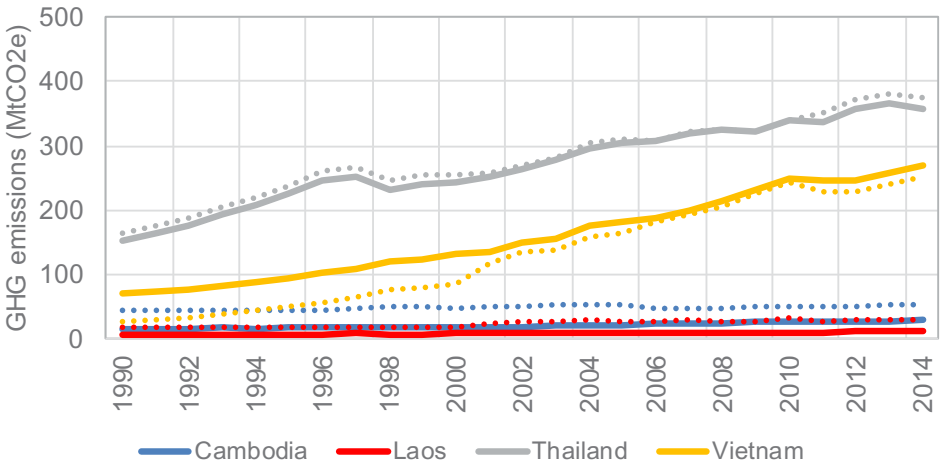
Emission specific per sector is not available for all LMB countries. For Thailand and Viet Nam, by far the largest GHG emitting countries, the energy sector (electricity generation and industrial use) are the major contributors (Figure 6.4 and Figure 6.5). For Cambodia and Lao PDR those GHG emissions are not available sector specific. Also, the agricultural sector contributes substantially to GHG emissions mainly by paddy rice farming which emits substantial amounts of methane (CH_4).

Table 6.1 Change in GHG emissions between 2000 and 2015 in percentage per year

	Cambodia	Laos	Thailand	Viet Nam
Total GHG emissions	3.6%	3.3%	1.3%	1.7%
Per capita GHG emissions	1.6%	1.4%	1.0%	1.2%

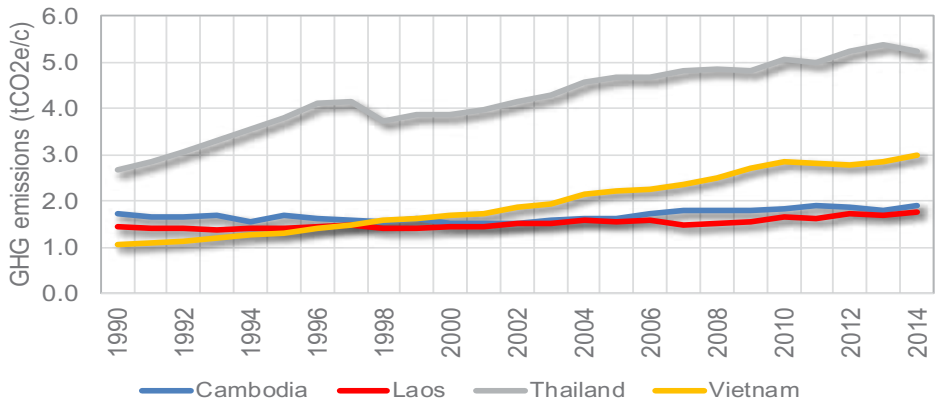
Source: CAIT data base, national data adjusted to share of people living in the LMB

Figure 6.2 Greenhouse gas emissions per country since 1990 (Mt CO_2)



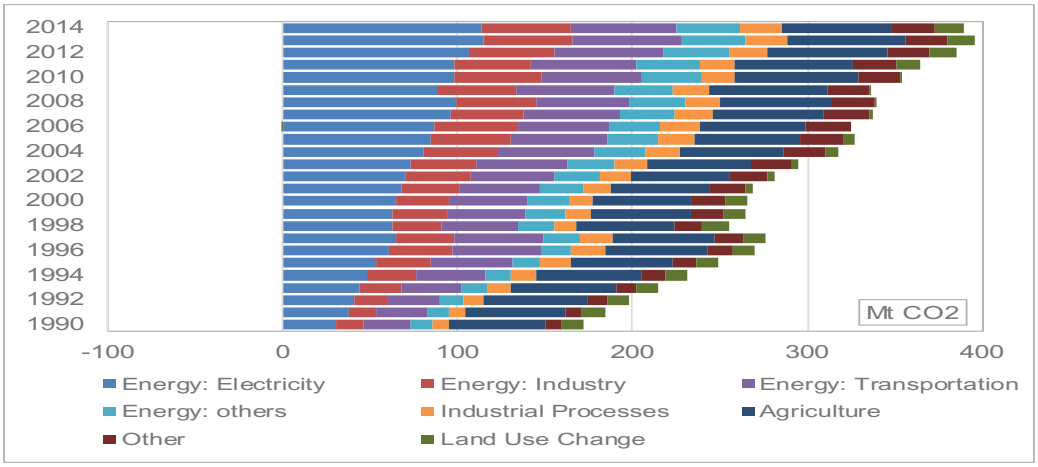
Source: CAIT data base. Note solid lines indicate totals for the entire country excluding land use changes and forestry. The dotted lines include land use changes and forestry.

Figure 6.3 Greenhouse gas emissions (Mt CO_2) per country per capita since 1990



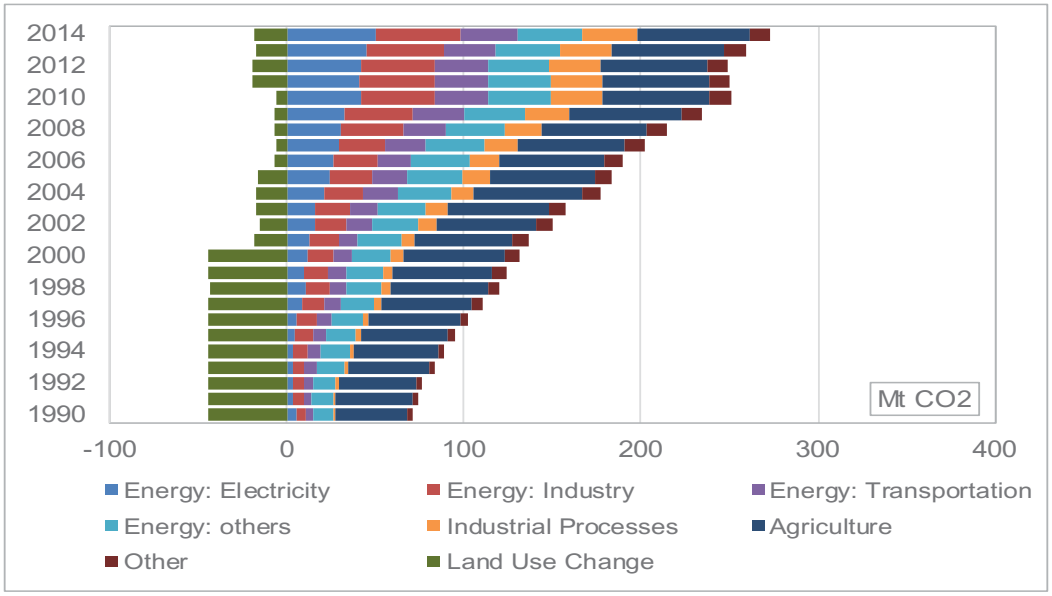
Source: CAIT data base. Note lines indicate totals for the entire country excluding land use changes and forestry.

Figure 6.4 Greenhous gas emissions (Mt CO^2) per sector for Thailand (entire country) since 1990



Source: CAIT data base.

Figure 6.5 Greenhouse gas emissions per sector for Viet Nam (entire country) since 1990



Source: CAIT data base.

6.2.3 Assessment of greenhouse gas emissions

Greenhouse gas emissions of the LMB countries contribute currently less than 2% of global emissions (CAIT data base). Due to relatively lower levels of heavy industry, a first estimate is that for the Lower Mekong Basin only the contribution is far below 1%, again compared to the total global emission. However, emission rates are growing faster compared to the global average increase by developing economies and population growth (IPCC, 2013). Electricity generation, industry, transportation, and agriculture are the main sectors contributing to GHG emissions.

6.3 Climate change trends and extremes

6.3.1 Assessment methodology

The strategic indicator "climate change trends and extremes" is evaluated by the following assessment indicators:

- Tropical storm frequency and storm surge risk
- Changes in temperature
- Changes in precipitation
- Extent and severity of flooding
- Extent and severity of drought

The monitoring parameters to assess those assessment indicators were obtained from various MRC and country data bases. Since countries contribute also to global data bases (e.g. World Meteorological Organization) those were also used as monitoring parameters. Similar, MRC and countries are also relying on public global data sources such as satellite derived parameters and were therefore also used as monitoring parameters.

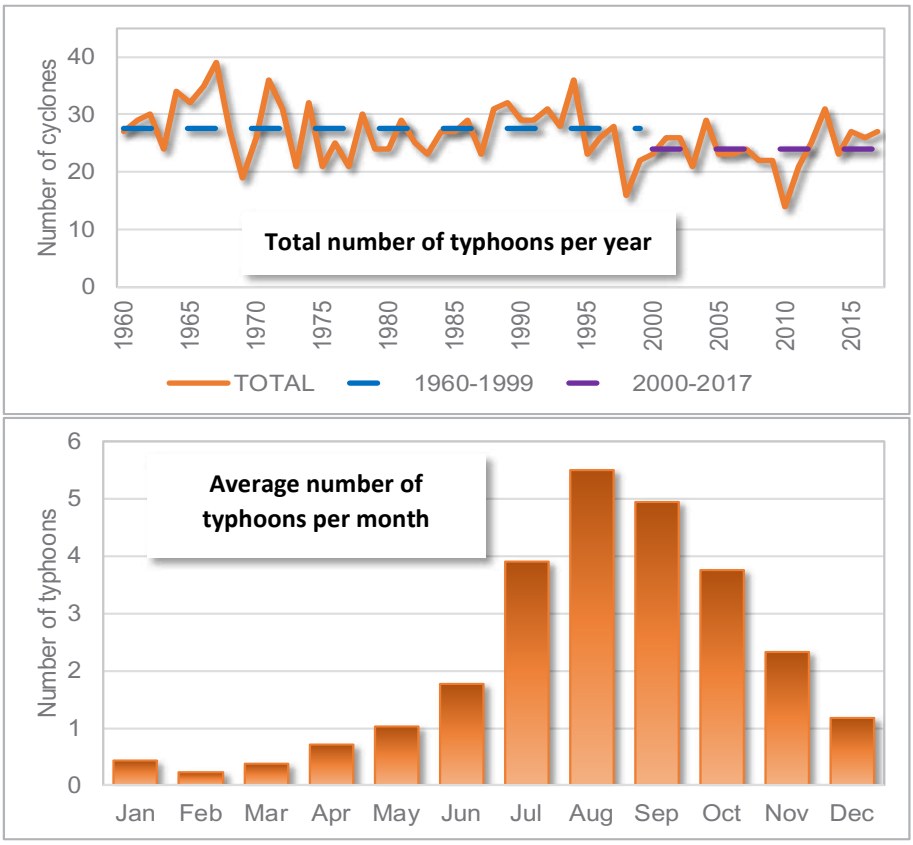
6.3.2 Tropical storm frequency and storm surge risk

Tropical storms and typhoons are having devastating impacts on the people in the Mekong region. Typhoon Haiyan, in November 2013, was one of the strongest typhoons ever recorded. Typhoon Nargis (May 2008) hit mainly Myanmar killing at least 130,000 people and submerging huge areas of the country. More recently, in December 2017 typhoon Tembin hit the region killing many people. Also, the July 2018 tropical storm Son-Tinh, where water levels in the mainstream raised rapidly with more than five meters over a few days in some areas, indicates the impact of tropical storms in the region. Given those devastating impacts tropical storms have, the big question is whether climate change will increase those impacts.

It is well-known that typhoons require specific conditions to develop of which sufficiently warm sea surface temperatures are one of those. Since climate change induces warming sea water an increase in typhoons can be expected. However, looking at the number of typhoons since 1960 a small decrease can be observed (Figure 6.6). The IPCC-AR5 came to the same conclusion that the number of hurricanes, cyclones and typhoons are not increasing. It is postulated that other important factors for typhoon development will be counter-act by climate change, and most climate models predict fewer tropical cyclones globally, and more of the strongest storms, with increased rainfall rates. Additional sea level rise will likely increase storm surge threats and damage.

The IPCC-AR5-SPM stated: "Projections for the 21st century indicate that it is likely that the global frequency of tropical cyclones will either decrease or remain essentially unchanged, concurrent with a likely increase in both global mean tropical cyclone maximum wind speed and rain rates"

Figure 6.6 Number of typhoons in the Mekong region between 1960 and 2017

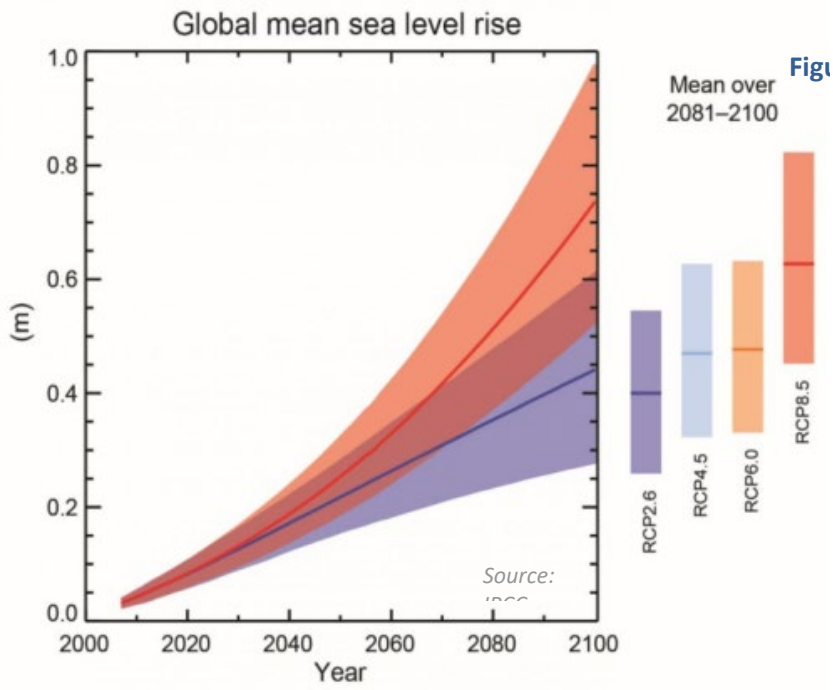


Source: Tropical Cyclone Information System from the Japanese Meteorological Agency

Sea level rise is a severe threat to the Mekong countries. A recent study of the World Bank (2018) summarized the four major dangers of sea level rise are: (i) land loss from the permanent inundation of low-lying coastal areas; (ii) intensification of inundation from cyclonic storm surges; (iii) loss of critical coastal wetlands, for example mangroves; and (iv) progressive salinization of soil and water.

The IPCC projects that global sea levels could rise from 26 cm to 98 cm by the end of the 21st century, depending on global emissions levels. Regional differences are likely to occur where for the Indian Ocean higher levels compared to the global averages are expected caused by various processes including changes in winds.

Figure 6.7 Projected sea level rise for various GHG emissions levels



6.3.3 Changes in temperature

Average annual temperature across the LMB ranges from a minimum of 22oC in Northern Lao PDR to a maximum of 28oC in the Mekong delta mainly due to differences in elevation, distances to oceans, and latitudes.

For the Mekong Climate Atlas the re-analysis CRU data set was used to detect trends in temperatures since 1901. Average mean temperatures show only moderate increases over the period of record (0.05°C per decade), with negligible increases between 1901 and 1980. An increasing trend is observed during the most recent period (0.22°C per decade). Such changes are in-line with global mean temperature increases reported in the IPCC's fifth assessment report. Unlike rainfall, temperature trends are very consistent between sub-areas, demonstrating that temperature changes are driven by larger scale atmospheric dynamics, whilst rainfall is often more locally controlled.

Actual observations from climate stations have been used to explore further those trends. For most stations a small increase in temperatures is observed. A typical example of such trends is shown in Figure 6.8 and Figure 6.9. Minimum and maximum temperatures are increasing by about 0.03oC per year. A clear trend in the coldest and hottest day in a year cannot be observed over this period of 32 years. However, looking at coldest days and hottest days below and above certain threshold values a trend is visible. Table 6.2 shows that the number of cold days in a year, in particular, will decrease at most locations. The number of hot days shows again a mixing trend with some stations experiencing more days above the threshold values of 35oC and 40oC, while for other stations less number of hot days in a year have been observed.

Figure 6.8 Temperature data and trends for Can Tho

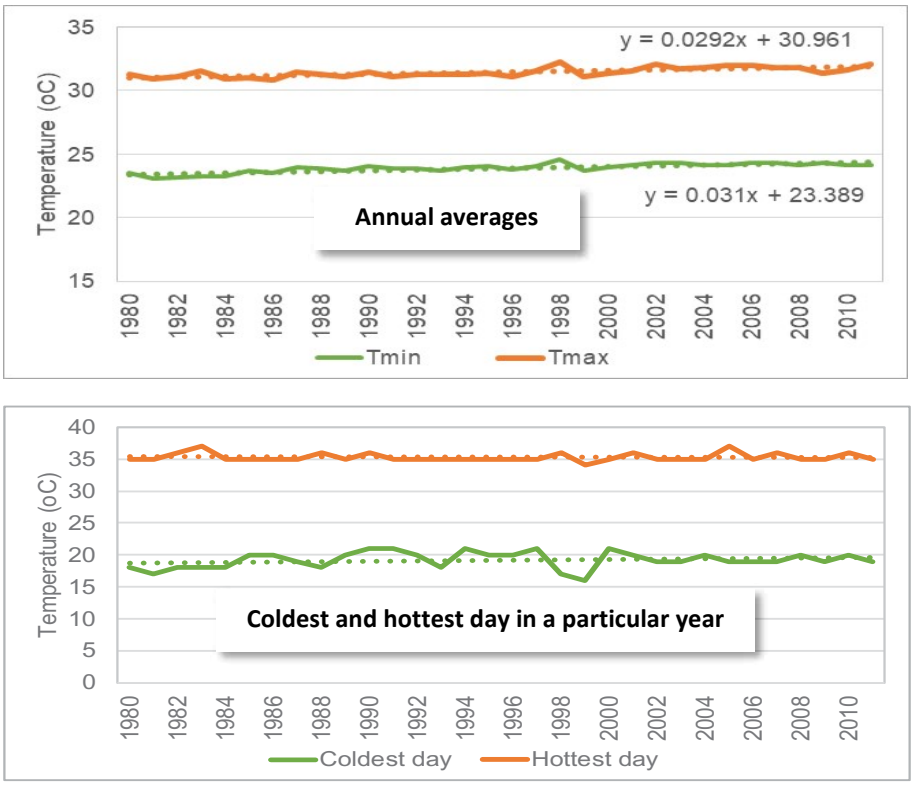


Figure 6.9 Temperature data and trends for Chiang Rai

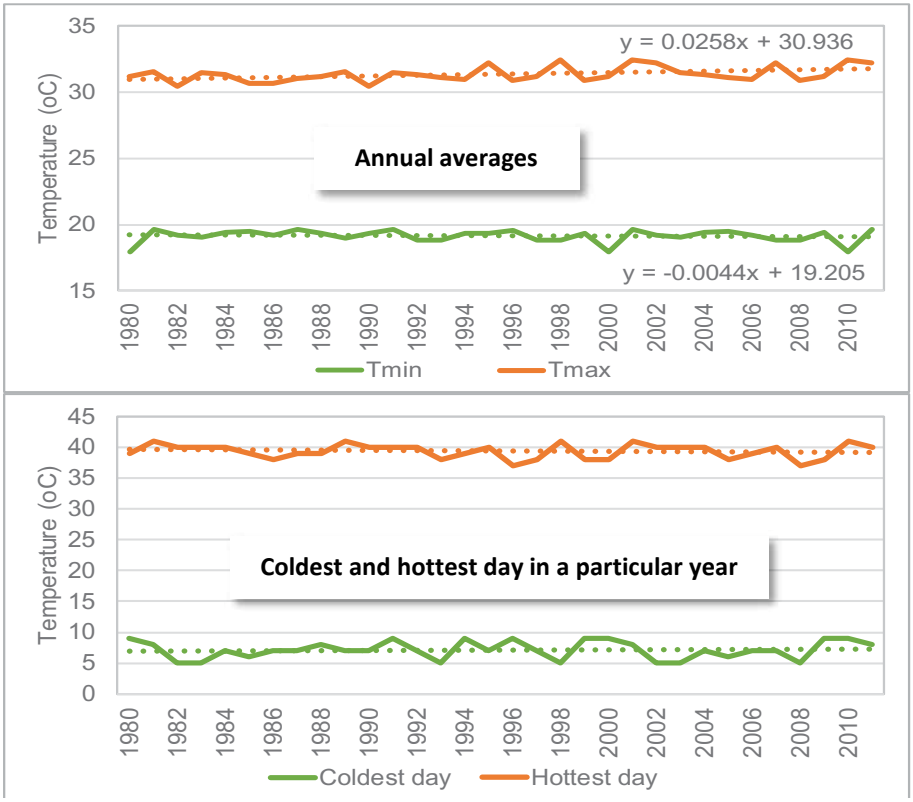


Table 6.2 Changes in number of cold days and number of hot days comparing the period 1980-1995 with 1996-2011

Station	<15 oC	<20 oC	>35 oC	>40 oC
Boun Me Thuot	-7.0	-37.3	-3.4	0.0
Ca Mau	0.0	0.0	-1.7	0.0
Can Tho	0.0	-1.4	0.4	0.0
Chau Doc	0.0	-0.3	11.9	0.0
Shiang Rai	5.1	0.8	-1.6	-0.4
Chiang Saen	1.5	2.5	5.0	-0.8
Khompot	0.0	0.0	2.3	0.1
Khon Kaen	-3.5	11.3	-24.9	-4.6
Kon Tum	-34.7	-94.1	0.0	0.0
Moc Hoa	0.0	1.2	-15.4	0.0
Mukdahan	-1.6	-5.3	14.8	3.3
Nong Khai	-2.1	-1.3	-1.1	1.1
Pakse	0.1	0.8	-112.6	-45.7
Pleiku	9.8	11.4	-4.5	0.0
Rach Gia	0.0	0.2	-1.8	0.0
Savannakhet	-0.3	-1.8	13.6	2.5
Sayabouli	-0.3	-1.8	-10.5	-3.6
Soc Trang	0.0	-0.4	-0.5	0.0
Thakhek	0.3	-1.6	13.7	3.1
Ubon	-2.6	-0.8	-17.6	-3.6
Udon Thani	-0.1	-2.3	6.8	0.7
Vientiane	-0.3	-1.8	0.1	-2.4

Negative numbers mean a decrease in number of days. Red colours indicate less cold days or more hot days during 1996-2011. Numbers are in average days per year

6.3.4 Changes in precipitation

Average annual rainfall across the LMB ranges from a minimum of 1291 mm per year in the Mun / Chi river basin to a maximum of 1992 mm per year in the Mekong delta, over the period 1901-2010 (Mekong Climate Atlas). These values are calculated by averaging rainfall across each sub-area based on the re-analysis CRU data set. Local variability is however much larger. Rainfall quantities as low as 1000 mm per year are observed in northeast Thailand, whilst more than 3000 mm per year is received close to the Gulf of Thailand. Trends in rainfall are difficult to assess with high confidence as most areas of the Asian region lack sufficient observational records to draw conclusions about trends in annual rainfall over the past century. The IPCC-AR5 states that in general rainfall trends, including extremes, are characterised by strong variability, with both increasing and decreasing trends observed.

Based on the analysis performed for the Mekong Climate Atlas it was concluded that the trend over the period 1901-2010 shows generally increasing rainfall in all seasons. However, the inter-decadal signal is less clear and periods of below and above average rainfall throughout the record period occur. The period 1901 to 1940 is characterised by strongly decreasing rainfall in all seasons, while the period 1941 to 1980 shows no trends. The period 1981 to 2010 exhibits large increases in the annual rainfall (+43 mm per decade).

The IPCC-AR5 projections indicate that more rainfall will be very likely occurring by towards the end of the 21st century. Under a low-emissions scenario substantial changes in rainfall patterns are not likely. More frequent and heavy rainfall days are projected over parts of South Asia although IPCC added that this projection is with a low confidence level.

Typical examples to demonstrate trends in observed precipitation are presented in Figure 6.11 and Figure 6.12. Annual trends in precipitation for Kratie over the period 1985-2017 are nearly stationary, with a very minor wetter tendency. The wettest day in a year show a negative trend looking at the entire period, but this is mainly due to a few years from 1987 to 1990. Also, no clear trend can be observed for the number of days in a year where rainfall exceeded 50 mm/d and 75 mm/d.

Data for Luang Prabang starting at 1960 show a small increase in total annual precipitation of about 100mm over 50 years. A positive trend is observed for the wettest day in a year, but again this trend is only minor and might be caused by just a few exceptional years. The number of days with more rainfall than 50mm and 75mm show quite some variation but a clear trend is difficult to assess.

6.3.5 Trends in streamflow

The observed changes in rainfall patterns might have an impact on long-term flows in the mainstream. Long-term flow records for Chiang Saen and Kratie (Figure 6.13) show a negative trend. This seems to be somewhat in contradiction to the small increasing trend in precipitation. However, higher temperatures induce higher evaporation rates meaning that less water is available for runoff. It should be also noted that changes in land use and land cover might also alter the long-term stream flow.

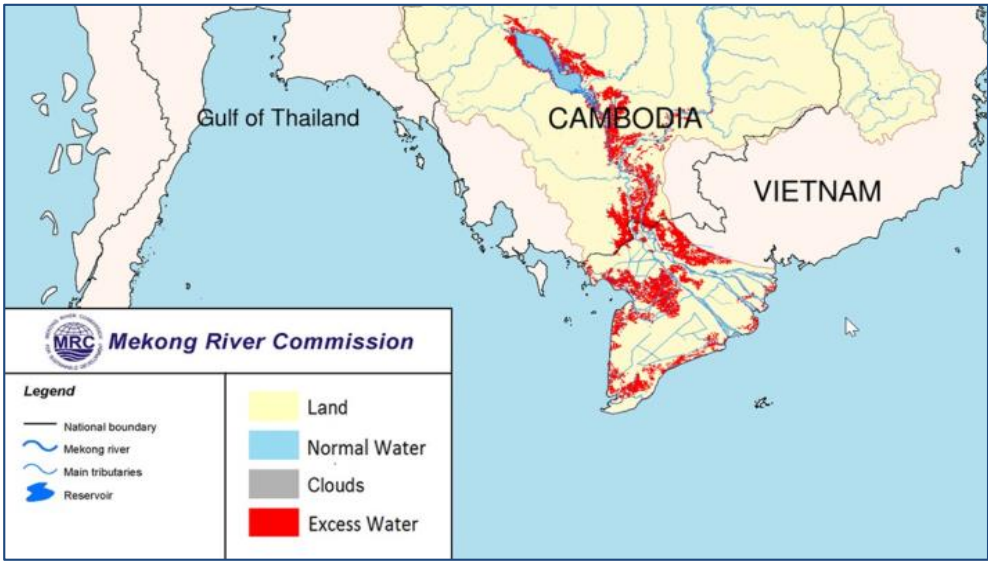
6.3.6 Extent and severity of flooding

Flooding within the Mekong basin is a frequently occurring natural process that brings benefits (such as fish and deposition of nutritious sediment on agricultural lands) as well as negative impacts of flood damage during extreme events. The MRC Council Study concluded that (i) flood damages will rise rapidly by a factor of 5-10 with development unless protection is provided; (ii) the trapping of sediments in the proposed dams in the Mekong Basin will increase river erosion and significant bank protection work will be needed; (iii) if uncontrolled, the loss of floodplain storage with development will result in higher river flood levels and increase flood levels and frequency or river and surface water flooding; (iv) climate change is highly likely to result in significant increases in floods especially in the upper part of the basin and the in the Mekong delta.

The annual Mekong Flood Reports present the flood peaks for the various monitoring stations per year. Table 6. 4 summarizes those observations for the period 2005 to 2015. Although the period is somewhat short to draw firm conclusions regarding trends, the three highest flows in Kratie occurred during the last five years. In the upper part of the LMB high daily flows have been reduced substantially since 2009 most likely because of dam development in the Upper Mekong.

The MRC and the member countries are increasingly using satellite data to monitor the state of the basin. Typical examples include rainfall, land use, flood and drought conditions. The Annual Mekong Flood Report 2016 gave an extensive overview on what is currently used and what can be used in the near-future. A typical example of use of satellite information by MRC is to assess he annual maximum flooded area. MRC has been embarked on a project to use MODIS satellite data to monitor the maximum flood extent. A typical example of such a map is shown in Figure 6.10.

Figure 6.10 Water extent map of 19th October 2014



Source data: MODIS satellite data

Figure 6.11 Trends in precipitation for station Kratie

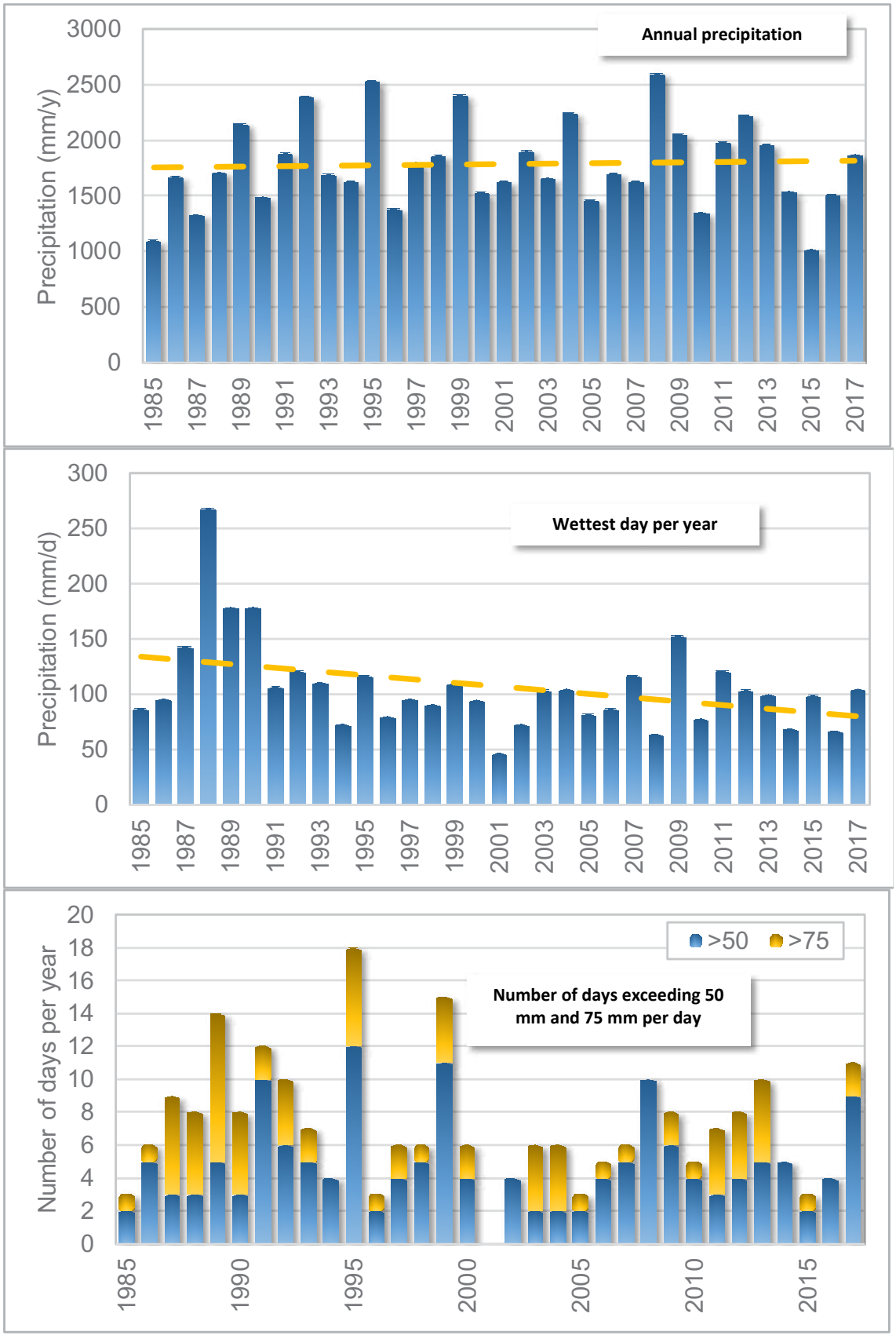
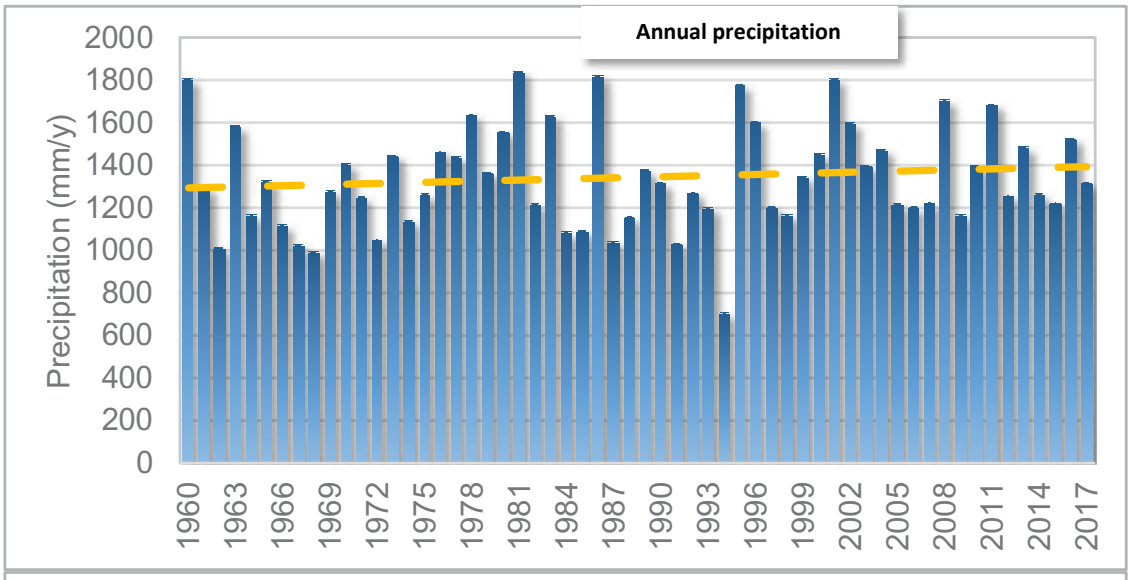
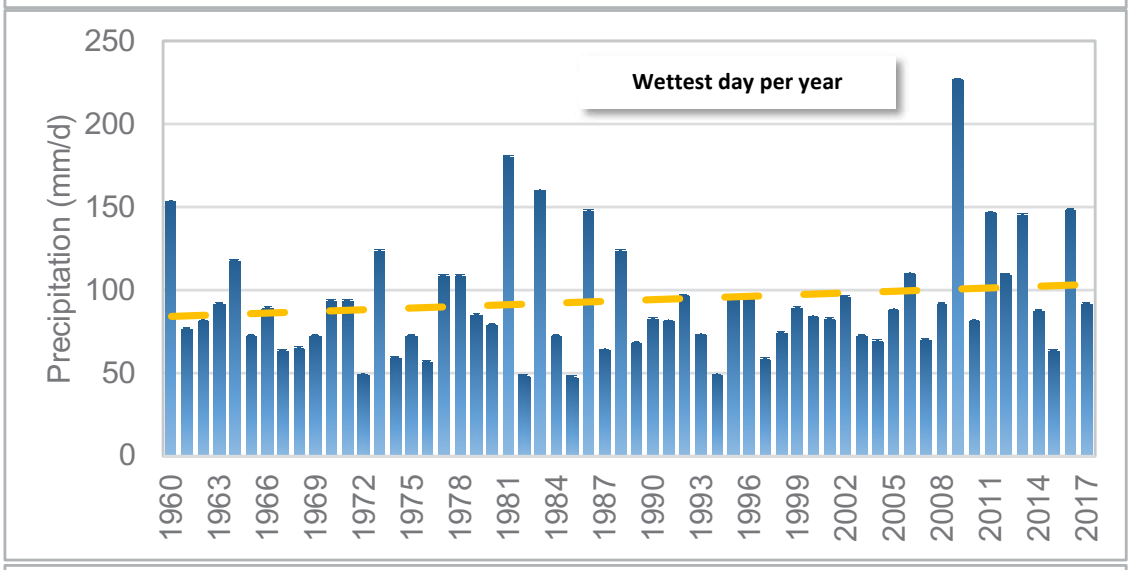


Figure 6.12 Trends in precipitation for station Luang Prabang


Annual precipitation
Precipitation (mm/y)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017


Wettest day per year
Precipitation (mm/d)
250
200
150
100
50
0
1960 1963 1966 1969 1972 1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017

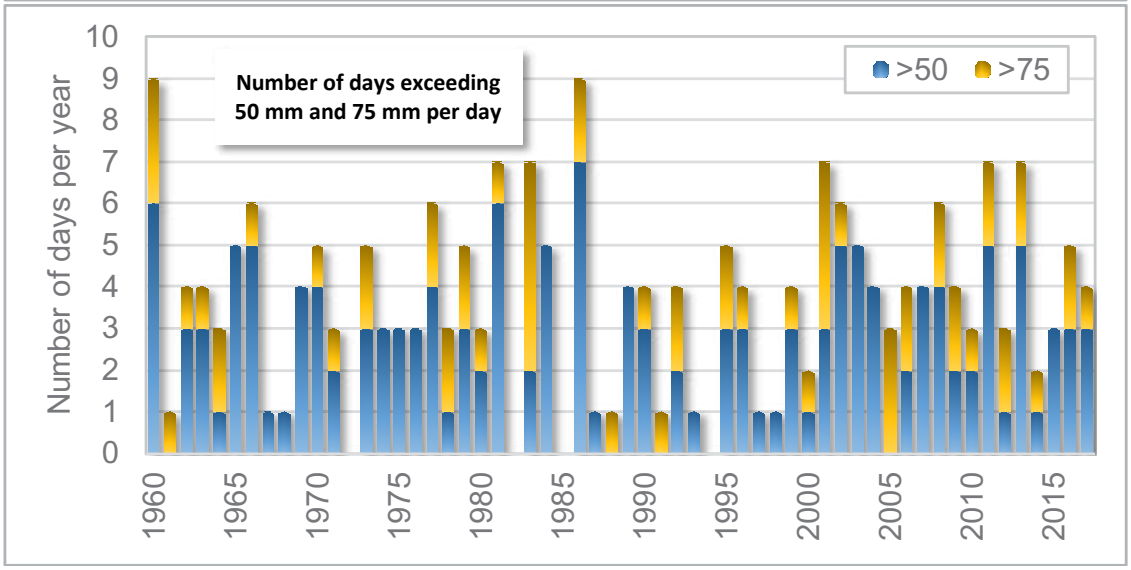
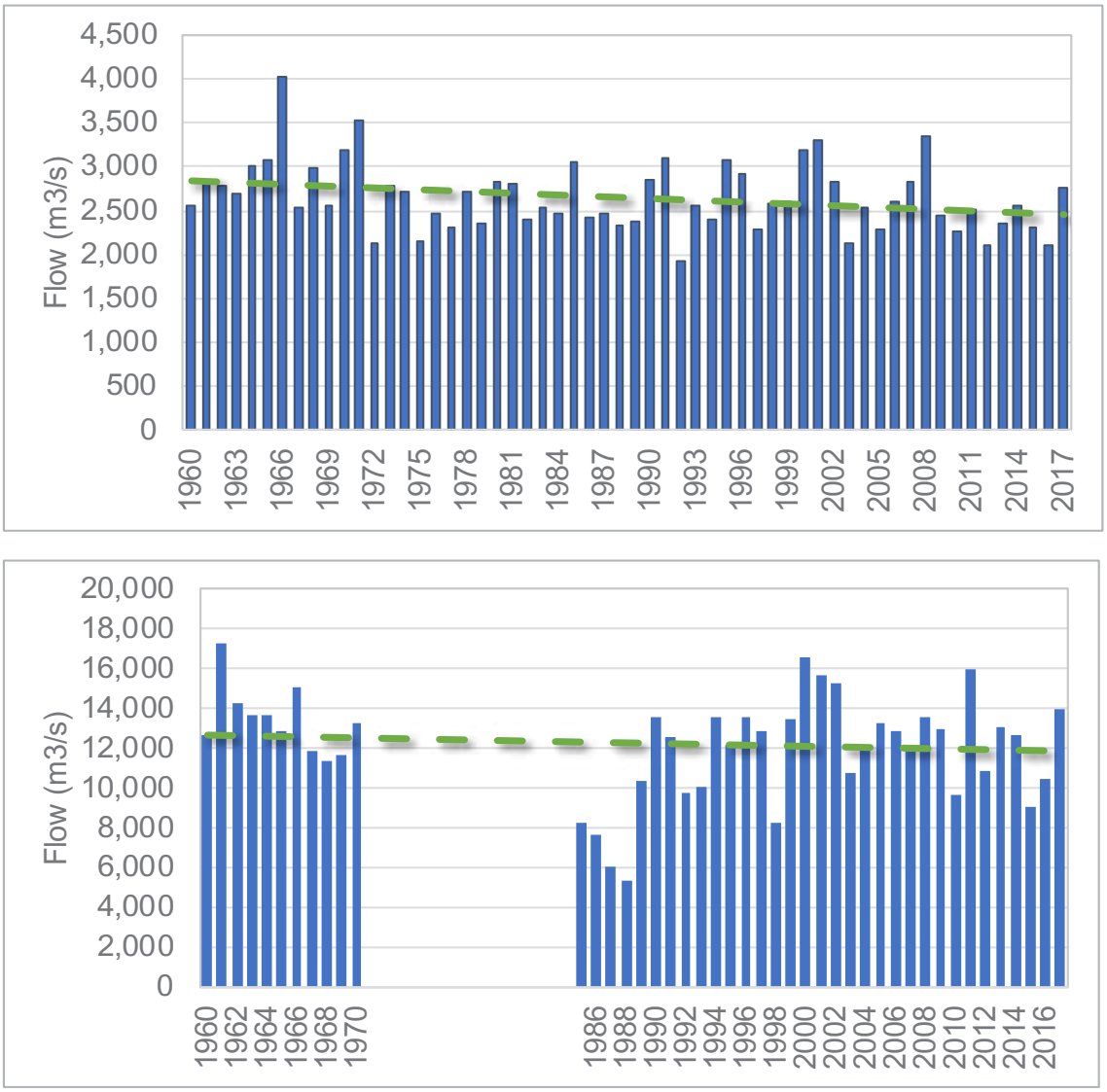

Number of days exceeding
50 mm and 75 mm per day
>50
>75
Number of days per year
10
9
8
7
6
5
4
3
2
1
0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015

Figure 6.13 Trends in annual streamflow for Chiang Saen (top) and Kratie (bottom). Linear trends are -67 m3/s in 10 years for Chiang Saen and -140 m3/s in 10 years for Kratie.



Based on those data the total flooded area is shown in Table 6.3, showing that 2013 and 2014 were years with extreme flooding. As expected most flooding occurred in Cambodia and especially in the Viet Nam part of the LMB.

Table 6.3 Flooded area per country

	Flooded Area (km²)		
	2013	2014	2015
Cambodia	28,318	17,025	2,165
Lao PDR	701	1,533	1,397
Thailand	2,870	2,167	1,195
Viet Nam	19,060	17,186	7,724

Source data: Water Extent maps

To assess the trend in flooding extent the Water Occurrence Change Intensity product is used. This database is also based on satellite information and was developed by the European Commission's Joint Research Centre. The map shows where surface water occurrence increased, decreased or remained invariant between 1984 and 2015. Both the direction of change (i.e. increase, decrease or no change) and its intensity are observed. Figure 6.14 and Figure 6.15 show clearly that for some regions in the LMB flooding has intensified and for other regions it has decreased but the overall trend shows an increase in flood extent (Table 6.4).

It should be emphasised that the nature of floods in upper and lower parts of the LMB is different in term of spatial and temporal resolutions. In the upper parts of the LMB pluvial floods (flash floods) occur that are somewhat of short duration (hours) and more local. The lower parts of the LMB are prone to fluvial floods (inundation) that are widespread and of long duration (days to weeks).

Table 6.4 Flood peaks for 10 discharge stations from 2005 to 2015 in m^3/s

Upstream → **Downstream**

	Chiang Saen	Luang Prbang	Chiang Khan	Nong Khai	Nakhon Phanom	Mukdahan	Kong Chiam	Pakse	Stung Treng	Kratie
2005	9,228	15,763	14,911	15,515	33,290	36,715	37,258	39,271	49,012	47,914
2006	11,409	14,757	13,825	13,870	24,448	25,609	29,104	31,284	44,309	45,069
2007	8,474	13,487	12,101	13,123	23,943	24,897	31,418	33,098	41,452	40,444
2008	12,970	23,116	22,124	23,564	32,385	34,125	33,237	34,875	41,931	40,842
2009	6,895	12,105	11,448	11,411	22,461	24,480	27,303	29,033	47,411	46,740
2010	5,774	10,652	11,784	14,432	25,007	26,767	30,537	32,539	36,170	36,637
2011	5,838	12,646	13,005	16,405	30,744	35,263	40,753	43,458	53,330	57,025
2012	7,967	14,525	13,265	15,578	23,188	23,819	24,737	26,936	35,514	36,589
2013	6,282	12,104	11,835	13,659	24,894	25,722	34,464	39,274	57,612	55,622
2014	4,855	11,399	11,643	12,329	23,482	25,686	33,881	37,228	55,770	56,323
2015	7,159	14,070	13,549	14,928	26,311	27,311	27,126	28,757	31,802	30,421

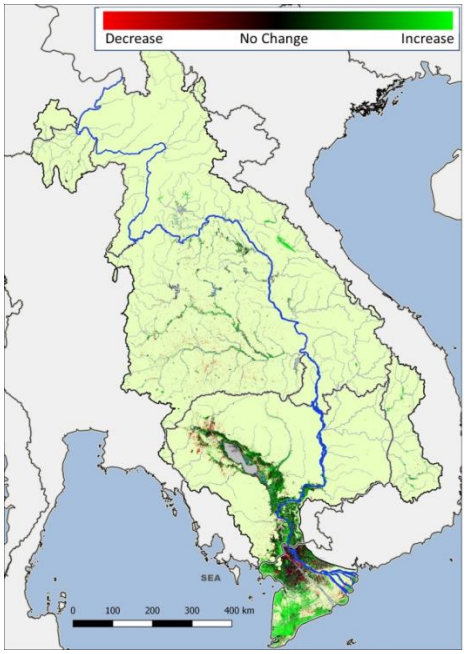
Source: Annual Mekong Flood Report 2015. Color scales (low = green, high = red) are provided by stations and the stations are from upstream to downstream. In this way, the origin of peak flows (e.g. from upstream or from tributaries) can be assessed quickly.

Flash floods in the LMB are caused by tropical storms (see section 6.3.2) and formation of the Inter-Tropical Convergence Zone (ITCZ) and are detected by the MRC's Flash Flood Guidance System, with warnings issued to national and local authorities. In 2015, warnings were detected for 136 districts in Viet Nam (including areas outside the Basin), 20 districts in Thailand, 963 villages in Lao PDR and 3 villages in Cambodia (MRC, 2016). There were four tropical storms in particular which caused severe flash floods in that year. In previous years, there has been some speculation about whether flash floods are being caused by dam operations in addition to rainfall. However, an investigation of one such event, a severe flash flooding event in December 2013, by MRC, CIWRHR (on behalf of LMCWRC) and IWMI showed that this event could be attributed solely to rainfall, and not dam operations as media reports at the time had suggested (MRC *et al.*, 2019).

6.3.7 Extent and severity of drought

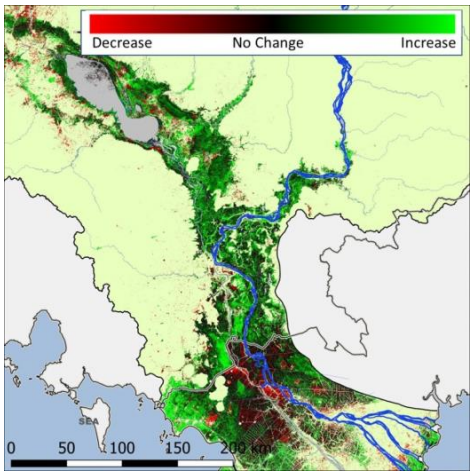
Droughts have significant economic, social and environmental impacts even for the LMB where water seems abundant during substantial parts of the year. Direct economic costs of drought are typically underestimated due to lack of physical damage to assets. Droughts develop gradually, persist for months or seasons, and often go unnoticed until a widespread water, food, energy, economic, health or environmental issue is triggered. At that time the drought is well underway, costs are already mounting, and the opportunity for proactive mitigation or adaptation is lost.

Figure 6.14 Changes in flooded areas between 1984 and 2015



Source: Water Occurrence Change Intensity; Joint Research Centre of the European Commission

Figure 6.15 Changes in flooded areas between 1984 and 2015



Source: Water Occurrence Change Intensity; Joint Research Centre of the European Commission

MRC acknowledged that droughts are an important factor affecting peoples live and the environment and established in 2015 Drought Management Programme Core Functions project. This has resulted in various outputs including the

LMB drought monitoring and forecasting system [28]. It is now well acknowledged that droughts can occur anywhere in the LMB and are generally classified into three categories:

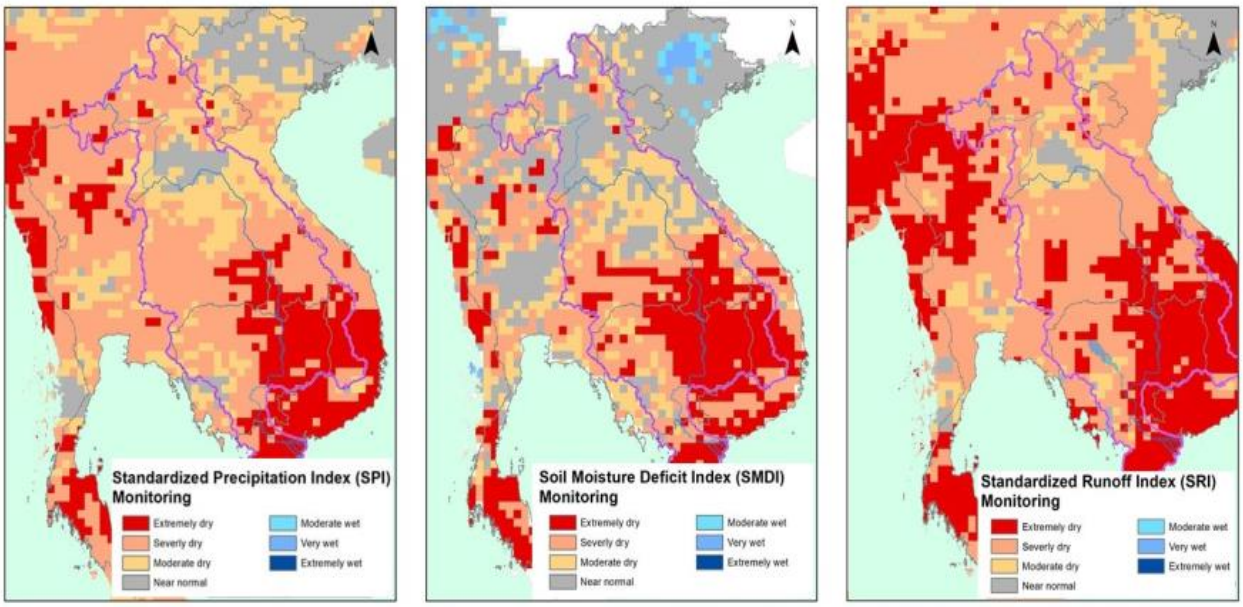
- Meteorological drought: refers to the extent and severity of drought in terms of deficits in precipitation from average conditions, possibly combined with increased potential evapotranspiration. The LMB locations most prone to meteorological drought are the western area of the Khorat Plateau in Thailand and southeast Cambodia.
- Soil moisture (or agricultural) drought: is a deficit of soil moisture (mostly in the root zone), and typically refers to a reduction in the availability of soil moisture to support vegetation growth (usually crop or pasture growth, hence the terms soil moisture drought and agricultural drought are often used interchangeably). For the LMB agricultural drought can refer to insufficient water to meet crop requirements and/or when the supply of water, or condition of water, is insufficient to maintain fodder supplies and normal growth for fisheries.
- Hydrological or water resources drought: implies a departure in surface or subsurface water supplies (e.g. streamflow, reservoir levels, groundwater level) from average conditions.

The Member Countries have refined those generally applied categories into the following six drought conditions [29] : (i) meteorological or climatologic, (ii) hydrological, (iii) agricultural, (iv) socio-economic, (v) water-management, and (vi) land use related.

Those drought stages are monitored and forecasted following World Meteorological Organization's defined indices: Standardize Precipitation Index (for meteorological drought), Soil Moisture Deficit Index (agricultural drought) and Standardized Runoff Index (hydrological drought). A typical example of the MRC drought monitoring and forecasting system is shown in Figure 6 16 for the 10th of April 2016. Drought was widespread over especially the south-eastern part of the LMB on that day.

Although, obviously, the three maps show a similar overall picture, the three indicators reflect different time horizons. SPI is calculated by monthly time steps starting from 1 to 72 months where longer-term steps reflect longer drought condition. SPI and SRI are similarly calculated, so they represent similar drought conditions. Whereas, SMDI is only weekly soil moisture anomaly analysis and therefore represents shorter drought conditions.

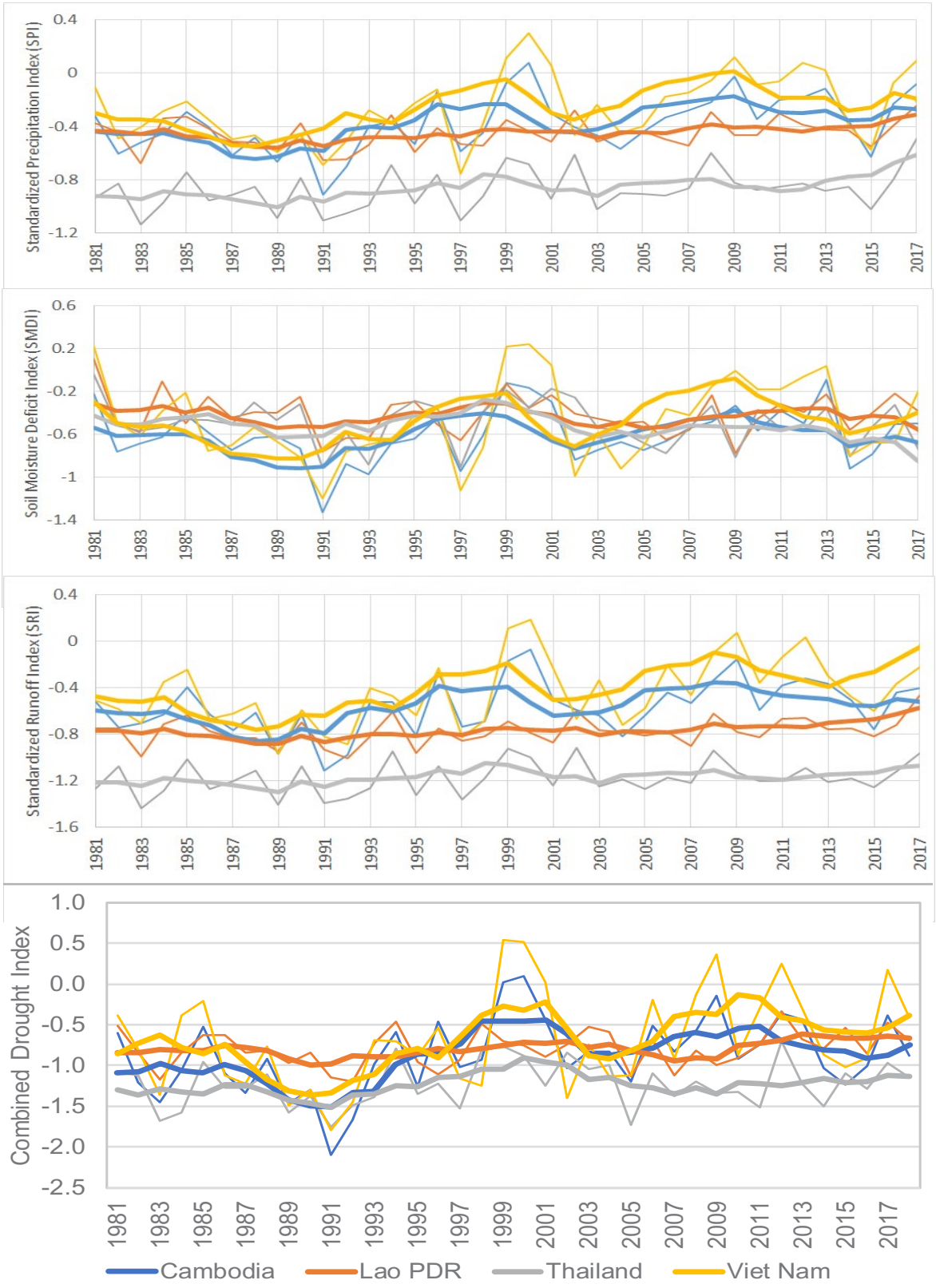
Figure 6.16 Examples of the LMB drought monitoring and forecasting system for 10th of April, 2016



28 http://mekong2.tengirri.com

29 MRC, 2011. Drought Management Programme 2011-2015

Figure 6.17 Various drought indices for the dry season (December to May) for 1981 to 2018



Note: Lower values mean dryer conditions compared to long-term averages. Thin lines reflect the annual values while the thick lines are the five years running averages

In terms of climate change it is interesting to look at trends in drought occurrence and severity. The Combined Drought Index is a combination of the SPI, SMDI, and SRI and is therefore suitable to provide an integrated picture of such trends. Figure 6.17 shows the CDI per country since 1981 up to 2018. Typical dry years are 1991 and 2005, while 1999 and 2000 were relatively wet. Also, the dry seasons of 2012 and 2017 were relatively wet. Drought conditions in the Viet Nam part of LMB seem to be somewhat more erratic compared to the other parts of the LMB. A clear trend over this period of over 35 years is somewhat difficult to assess, but a small increase in CDI (means less dry) can be detected.

6.3.8 Assessment of climate change trends and extremes

In 2007 the MRC Council proposed to include climate change as an important topic of its mandate. It was decided to develop a regional initiative that would provide knowledge, tools and capacity building to enable better adaptation to climate change across the Mekong basin. Currently, climate change is an integrated component of many strategies, studies and projects within the MRC and its member countries.

An overall judgement regarding the strategic indicator "climate change trends and extremes" is that climate change is happening already in the LMB and needs to be high on the agenda of the MRC. The specific assessment indicators confirm this overall judgement:

- GHG emissions in the four countries is about 1.5% of total global emissions. For the LMB itself this number is about 0.5%.
- Tropical storms are not showing any increasing or decreasing trend and are likely to remain constant. However, with rising sea levels the impact of storms might be bigger and more damage can be expected.
- Changes in temperature are gradually increasing by about 0.2°C per decade following the same global trend. The number of cold days is expected to decrease, but the number of hot days in a year does not show a consistent trend.
- Clear evidence for changes in precipitation patterns is not found so far. IPCC projections are neither indicating a clear trend, but a small increase in annual precipitation might happen after 2050.
- The extent and severity of flooding remains a critical component of the LMB. Over the last decades an increase in flooded areas and peak flows in downstream parts of the LMB has been monitored. For the last ten years, no clear trend can be seen.
- The extent and severity of drought show a favourable trend suggesting that drought conditions have been reduced slightly in the past. However, with increasing temperatures in the future and higher evaporation rates, droughts might become more severe.

6.4 Adaptation to climate change

6.4.1 Assessment methodology

Adaptation to climate change is understood as the extent to which the Basin community is taking action to prepare and live with the effects of climate change. The assessment methodology looks at the number of endorsed climate change policies and strategies within and across MRC water-related sectors at national and provincial level; and the growth in the financial resources available to respond to the effects of climate change.

6.4.2 Institutional response to the effects of climate change

(i) *Policies and strategies for climate change response*

Policy and institutional response is to be measured by the level of mainstreaming climate change adaptation into policies and strategies and the budgets allocated for climate change adaptation. The key national policies and strategies and institutional arrangements for mainstreaming climate change are identified in Table 6.5 [30].

The United Nations Framework Convention on Climate Change (UNFCCC) has been ratified by all four Member Countries and in accordance with their obligations, each country has now submitted at least two National Communications to the Convention and committed to a Nationally Determined Contribution. Consistent with UNFCCC guidelines the National Communications acknowledge the importance of climate change adaptation and stress the need for increased research in order to develop and implement effective response measures. They address measures necessary for sectors including agriculture, forestry, health, water resources and coastal resources. Under the Kyoto Protocol, which all four Member Countries have also ratified, parties are encouraged to develop national (and regional) adaptation programs.

Table 6.5 Key national policies and strategies and institutional arrangements for mainstreaming climate change adaptation

Country	Key national policies and strategies	Institutional arrangements
Cambodia	❑ Cambodia Climate Change Strategic Plan 2014-2023 ❑ National Action Plan for Disaster Risk Reduction 2014-2018 ❑ National Strategic Development Plan 2014-2018 ❑ Climate Change Action Plans across various sectors	❑ National Council for Sustainable Development (NCSD) [31] ❑ Climate Change Department, within the Ministry of Environment
Lao PDR	❑ Lao PDR National Strategy on Climate Change 2010, drawn from a number of sectoral strategies[32] ❑ Eighth National Socio Economic Development Plan (NSEDP-8)	❑ National Environment Committee ❑ Department of National Disaster Management and Climate Change within the Ministry of Natural Resources and Environment
Thailand	❑ Thailand's Climate Change Master Plan 2015-2050 ❑ Thailand's National Adaptation Plan 2015-2050 (draft) ❑ 12th National Economic and Social Development Plan	❑ National Climate Change Committee and related sub-committees ❑ Ministry of Natural Resources and Environment
Viet Nam	❑ National Climate Change Strategy 2011 ❑ National Environment Protection Strategy to 2020, with visions to 2030 ❑ Viet Nam Sustainable Development Strategy 2011-15	❑ National Steering Committee for the UNFCCC and Kyoto Protocol ❑ Viet Nam National Committee on Climate Change ❑ Ministry of National Resources and Environment

National Climate Change Strategy 2011

30 As reported by Member Countries in National Communications to the United Nations Framework Convention on Climate Change

31 From May 2015, has taken over functions of the National Climate Change Committee

32 National Environment Strategy, Forest Strategy, Agriculture Strategy, Strategy for Water Resources Development, Energy Strategy, National Disaster Strategy

Under the UNFCCC, a work program for Least Developed Countries (LDC) was established from 2001 and included the development by each country of a National Adaptation Programme of Actions (NAPA). The main content of the NAPA is a list and short profile of ranked priority adaptation activities, designed to facilitate the development of project proposals for implementation. Priority sectors addressed are agriculture and food security, water resources, coastal zones and early warning and disaster management. NAPA's submitted to the UNFCCC enable a country access to the LDC Fund to support implementation. Both Cambodia and Lao PDR have submitted NAPAs to the Convention.

At a regional level, the Climate Change and Adaptation Initiative of MRC has developed a Mekong Adaptation Strategy and Action Plan (MASAP) which seeks to provide guidance on mainstreaming adaptation, particularly transboundary, measures across the LMB. The MASAP was informed by a suite of basin-wide assessments of climate change on water and water related resources and sectors in the LMB and a review of existing practical measures across member countries.

(ii) *Budget for climate change response*

There are a multitude of climate change adaptation measures being implemented across the Lower Mekong Basin. As of early 2016, the CCAI database of climate change adaptation projects, which was based on national literature reviews in 2012-2014, identified 28 such projects in Cambodia, 34 in Lao PDR, 79 in Thailand, and 25 in Viet Nam across a range of sectors and at varying spatial scales. There may well be more adaptation projects being implemented in the Member Countries than contained in this list.

6.4.3 Flood protection measures

(i) *Area of land protected by embankments*

Areas protected against floods (partially or fully) provide protection also against the risk of higher floods caused by climate change. Assessments in 2010 suggest that by 2020, notwithstanding increased regulation of mainstream flows, flooded areas could increase by up to 6%. This is supported by the findings in this report (Section 3.2.3), which indicate that the combined impacts of climate change and changing society and infrastructure are increasing the need to protect people and assets. However, data on the spatial coverage of existing flood protection are not currently recorded at MRC, and no data have been made available to establish the extent and nature of flood protected areas.

6.4.4 Drought protection measures

(i) *Proportion of irrigated land that is irrigated*

Irrigation provides farmers with the capacity to withstand drought periods and to ensure that planting is done at appropriate dates. Irrigated harvest areas have been steadily increasing, rising from about 3.1Mha in 1995 to about 4.7Mha in 2013 and 5.1Mha by 2015. The estimated irrigated areas in 2000 and 2015 are summarised in Table 6.6. Substantial increases in irrigation coverage can be observed in both Cambodia and Viet Nam.

The fall in Thailand areas are most likely due to the exclusion of small-scale irrigation from the 2015 data. Overall, the area of paddy rice and maize with irrigation facilities has increased by 37% (an additional 1.37 Mha) over the five-year period, rising from 27% to 26% of all paddy land.

Table 6.6 Total irrigation areas in 2000 and 2015

Country	2000	2015	Change
Cambodia	273,337	479,763	*76%*
Lao PDR	204,161	237,883	*17%*
Thailand	1,265,917	903,592	*-29%*
Viet Nam	1,996,061	3,489,111	*75%*
Total irrigated area	**3,739,476**	**5,110,350**	*37%*
LMB rain-fed area	10,314,524	8,932,443	*-13%*
Total rice plus maize area	**14,054,000**	**14,042,793**	***0%***
Percent with irrigation	*27%*	*27%*	

Source: MRC Irrigation database. Data for irrigation areas in 2010 from MRC Basin-wide Scenario Assessment Report (April 2011) and for rainfed area from Table 2.1 of this report. Maize represents a small but significant portion of the irrigated crops.

(ii) *Available water storage*

Reservoir storage operation re regulates stream flows, taking out peaks and slowly releasing flows downstream. Reservoirs in the Mekong Basin are mostly operated for the purpose of hydropower operation, which generally seeks to maximise energy output, for which the aim is to ensure the maximum carry over of storage from wet to dry season. This leads to sub-optimal flood protection, particularly in the instance of floods occurring later in the wet season. Nevertheless, all reservoirs contribute to some degree to reducing flood peaks and the risks of flooding downstream.

Table 6.7 Live reservoir storage in the Mekong Basin, Mm3

Year	2000	2020
Cambodia	-	2,600
Lao PDR	1,773	24,257
Thailand	3,100	3,399
Viet Nam	781	2,752
LMB total	**5,654**	**33,008**
China	257	23,293
Total	**5,910**	**56,301**
Percent of MAR	*1%*	*14%*

Source: MRC Hydropower database, updated 2015

The volume of live storage in the Mekong Basin is increasing, as illustrated in Table 6.7 above. As may be seen by 2020 and beyond total storage available is planned to exceed 14% of the river's mean annual runoff (MAR).

In the near term, a large proportion of that storage is located in the UMB on the Lancang River in China. However, the most severe flood-causing rainfall generally occurs in northern Lao PDR and the highlands of Viet Nam, where major new storages are planned after 2020.

6.4.5 Coverage of disaster warning systems

MRC hosts the Regional Flood Management and Mitigation Centre (RFMMC) in Phnom Penh which provides a service throughout the wet season to monitor and forecast mainstream floods. Warnings are disseminated through the MRC website and through relevant ministries, and the coverage may be seen as applying throughout the annually flooded areas in Cambodia and Viet Nam, an area of approximately 43,000 km^2 and in which the highest population densities of the Basin can be found. For drought forecasting, MRCS also recently have developed the drought forecasting system which is currently available in the MRC website during the whole year period and provide advance early warning system related to drought condition in the basin.

6.4.6 Vulnerability to floods and droughts

The quantification of the number of people vulnerable to change depends on the nature and magnitude of the "changes" under consideration. Studies are ongoing to identify the nature of impacts upon the population of the LMB as a consequence of climate change, be that directly as an increased exposure to flood or drought, to changes in crop yields affecting farming viability, or indirectly as a result of induced ecological changes. Understanding these relationships is a prerequisite to determining the extent of vulnerability to climate change.

6.4.7 Assessment of adaptation to climate change

Climate change adaptation efforts are in their early stages. While many studies and projects have been completed, it is unclear whether spatial and development planning in the LMB is fully mainstreaming climate change concerns as yet in a coordinated and consistent manner. As identified in their Nationally Determined Contributions to the UNFCCC, the adaptive capacity of Cambodia and Lao PDR in particular is low due to limited financial, technical and human resources. Thailand and Viet Nam also identify a need to improve adaptive capacity. Many communities across the LMB remain vulnerable to the effects of climate change, particularly extreme events including floods, droughts and storms, as well as sea level rise.

Within their national communications to the UNFCCC, countries have identified the following limitations and constraints to climate change adaptation.

Cambodia

Constraints and gaps to climate change adaptation include limited human capacity, the lack of reliable and comprehensive datasets and research in preparing a national greenhouse gas inventory, inadequate mitigation analysis and vulnerability assessments, a lack of technology awareness, policy and institutional shortfalls and significant financial constraints.

Human resource capacities relate to lack of knowledge and information on crop diversification and market engagement; and professional expertise across Ministries and relevant government institutions with greater effort required on teaching and research. In addition, there is a shortage of technical experts to undertake climate risk modelling, impact assessment and development of adaptation measures. Further research and analysis is required across a range of areas including:

- Flooding impacts, especially around Mekong River and Tonle Sap
- Extensification, intensification and diversification of rice production measures
- Better understanding of potential rainfall impacts
- The interaction of climate change with development impacts such as new dams etc.
- The impacts of climate change on the incidence of malaria
- The impacts of natural disasters on macroeconomic and budgetary performance

Cambodia identified the importance of technology transfer and investment, including in:

- Household safe water supply
- Rainwater harvesting from rooftops
- Wells, small reservoirs, small dams and micro-catchments for community water supply
- Mangrove management

Cambodia identified not only that there are inadequate financial resources, but also a lack of financial mechanisms in place to implement adaptation and mitigation options.

Lao PDR

Issues in responding to climate change identified by Lao PDR include:

- Concern about the lack of priority given to climate change relative to other concerns
- Lack of systems in place to monitor and evaluate actions
- Ensuring international development cooperation and foreign investment is aligned with sustainable development, the green economy and climate change strategies and plans
- Capacity to develop a longer-term climate change path
- Research and capacity development
- Policies and mechanisms for securing finance to address climate change priorities

Key issues identified in adaptation included:

- the need for more appropriate national climate scenarios to assess impacts and vulnerability
- lack of long-term historical data
- lack of long-term, comprehensive studies on sectoral impacts especially on agriculture, water resources, forests and public health
- lack of long-term socio-economic scenarios to assess vulnerability and adoption of adaptation measures
- shortage of technical experts
- weak local ownership of NAPA projects and need for accelerated implementation of projects

Lao PDR identified that technology transfer is inhibited by high up-front costs; lack of expertise; insufficient research and development; lack of integration of climate change needs in national technology development and innovation process, issues with property rights etc. Research and systematic meteorological observation are also required but are hampered by limited technical and human resources.

Lao PDR identified that awareness and capacity building is required at all levels, from public awareness, education in schools, international negotiations, research and learning amongst academics, scientists and researchers. However, technological limitations are inhibiting the flow of information; there is a need for a strengthened national focal point; and there is insufficient networking of key stakeholders particularly amongst the private sector and civil society.

Thailand

Issues in responding to climate change identified by Thailand include:

- Need more climate change scenarios that are appropriate to the sub-region
- Develop techniques for preparing socio-economic scenarios that are consistent with climate change

- Techniques for analysing impacts on major sectors and for prioritising adaptation options
- Introduce public health warning systems in critical areas
- Technologies required for: disaster warning systems; coping with coastal erosion; agricultural forecasting and warning systems; develop climate change resistant plant varieties
- Develop public health and disaster risk management systems in disaster-prone areas
- Promotion of climate scenarios in planning for different sectors especially agriculture, water resources and health

Thailand also refers to the need to enhance the capacity of climate change negotiators, as well as meteorologists, including through regional information exchange and communications.

These issues are taken into consideration through Thailand's National Climate Change Master Plan 2015-2050 which seeks to address:

- Institutional arrangements among government agencies
- Developing a financial supporting structure for domestic budget allocation and assessment to international funding sources
- Raising public awareness and stakeholder engagement
- Raising private sector involvement in financial support and implementation
- Constructing a central climate change database system
- Establishing a climate change adaptation knowledge and learning centre, and
- Developing a monitoring and evaluation system of national adaptation implementation.

Viet Nam

Viet Nam identified the following issues in responding to climate change:

- Need better resolution climate models to understand local impacts
- Database of impact assessments and adaptation measures is incomplete
- More in-depth analysis to distinguish between climate change and other impacts
- Adaptation impact assessment and response measure development models and tools are insufficient, in particular for cross-sector or inter-regional assessments
- Assessment of technological needs for adaptation lacks capacity, methodology and database
- Lack of technical experts
- Existing hydro-meteorological observational infrastructure and telecommunication systems are insufficient and lack uniformity
- Limited technical and human resource capacity
- Education curricula not well developed across all levels
- Broad lack of awareness of climate change
- Technology transfer needs
- Requirement to mobilise domestic and international funds and develop long-term financing plans

6.5 Summary of overall climate change patterns and response

The Member Countries recognise the Mekong will be affected by climate change and in response the MRC has undertaken a suite of basin-wide assessments on the potential impacts and vulnerabilities that may result. These assessments have informed the development and agreement by Member Countries of the Mekong Adaptation Strategy and Action Plan. Changes in rainfall and temperature may lead to greater variability in the hydrological regime of the Mekong, increasing the risk of both floods and droughts. In the delta, the most important factor related to flooding is expected to be sea level rise.

Greenhouse gas emissions the LMB area are still relatively low but emission rates are growing faster than the global average for fast-developing economies and considering population growth. Observed trends over the past show a small increase in temperature and for precipitation no clear changes have been observed so far. However, all climate models foresee a continuous increase in temperatures and either an increase or decrease in rainfall combined with more extremes. The impact of sea-level rise and changes in the hydrological regime has already led to an increase in flooding and it is expected that serious measures will be needed to counter-act this trend.

7. Cooperation Dimension

7.1 Introduction

The 1995 Mekong Agreement reaffirms and expands the globally acknowledged "Spirit of Mekong Cooperation" created in 1957. It adopts a set of mutually accepted and fair objectives and principles of cooperation for sustainable development and utilisation of the water and related resources and environment of the Mekong River Basin, and it provides for the upper two riparian countries - the People's Republic of China and the Union of Myanmar – to subsequently join in the cooperation.

The cooperation dimension of the MRC Indicator Framework reflects the MRC's intent set out in the 1995 Mekong Agreement to assist in the promotion of interdependent sub-regional growth and cooperation among the community of Mekong countries and to provide an adequate, efficient and functional joint organizational structure to implement this Agreement. It provides for enhancing joint efforts and partnerships in achieving sustainable development as called for by the 3rd Summit of the four Heads of Government in the Siem Reap Declaration of May 2018.

Four strategic indicators have been selected by which to judge whether the cooperation objectives of the Member Countries are being met. These three indicators are (i) equity of benefits from the Mekong River system, (ii) benefits derived from cooperation and (iii) self-finance of the MRC. These strategic indicators are supported by eight **assessment indicators** as follows:

Strategic indicators	Assessment indicators
Equity of benefits from the Mekong River system	❑ Overall social condition in each country
	❑ Overall environment condition in each country
	❑ Overall economic condition in each country
Benefits derived from cooperation	❑ Cross border engagement in projects of basin-wide significance
	❑ Cooperation between countries on joint projects
	❑ Notification and engagement on projects with potential trans-boundary impacts
	❑ Proportion of benefits derived from cooperation to total net economic value of all MRC water-related sectors
Self-finance of the MRC	❑ Proportion of MRC budget funded by national contributions during current period

Cooperation is achieved through a range of mechanisms both between Member Countries through the MRC and with other parties through regional cooperation mechanisms including ASEAN, the Greater Mekong Sub-region of the Asian Development Bank and the Mekong-Lancang Cooperation (MLC). Each of these mechanisms brings its own perspective and focus to cooperative development within the region and although complimentary, there is some overlap in areas of work. As advocated in Section 7.3.6, continued engagement and dialogue between all parties, particularly the upper riparian states, will be important to ensure outcomes are maximised and duplication of effort is minimised. In this, MRC has made efforts to engage with all key regional Mekong cooperation frameworks through formal partnership agreements and other joint work.

In 2010 an MoU was signed between the secretariats of the MRC and ASEAN for five years. The intent of the partnership has been to share information, knowledge and expertise in various fields. After two years of efforts, the MRC and ASEAN, in 2018, through their respective governing bodies and not only between their secretariats, have agreed to a new "Cooperation Framework" covering strategic cooperation, basin planning, environmental management, climate change, and flood and drought management. The MRC monitors closely developments under the GMS and continues to work with the ADB in two key areas – environment and energy, where the MRC's hydropower strategy updating process has engaged the GMS power trade coordination committee.

The MRC is also engaging with the Mekong Lancang Cooperation. The MLC states that it aims to bolster the economic and social development of the Sub-regional countries, enhancing the wellbeing of their people, narrowing the development gap among regional countries and supporting ASEAN Community building as well as promoting the implementation of the UN 2030 Agenda for Sustainable Development and advancing South-South cooperation. It seeks to achieve this through what it calls a 3+5 framework which consists of three cooperation pillars of political and security issues, economic and sustainable development, and social, cultural and people-to-people exchanges; and five key priority areas, namely, connectivity, production capacity, cross-border economic cooperation, water resources, agriculture and poverty reduction. The MRC and the Lancang Mekong Water Resources Cooperation Centre is working together on the Joint Assessment of the impacts of the Chinese dams on extreme events in the Mekong. China's Minister of Water Resources has welcomed the MRC and its Secretariat to engage with the MLC and has invited the MRCS and member countries to the Lancang Mekong Water Resources Cooperation Forum.

The MRC's exclusive focus on water and water-related resources of the Mekong puts it in a unique position to help foster the sustainable development of these resources as the concept of sustainability becomes ever more important with increasing investment in infrastructure and other means of economic expansion flowing into the region. The MRC's mandate as a unique and primary institution for Mekong sustainable water resources development and management was reaffirmed at the highest level by the Mekong Prime Ministers at the 3rd Summit in 2018.

Within the MRC five sets of procedures have been agreed between Member Countries manage the basin in a cooperative way. The intent of the Procedures and their supporting guidelines is to provide a systematic and uniform process for implementation of the 1995 Mekong Agreement by the MRC and Member Countries. As described by the MRC CEO (MRC, 2017):

> *"The Procedures for Data and Information Exchange and Sharing (PDIES) aim to operationalise the data and information exchange among MRC Member Countries; make data and information available for public access as determined by the National Mekong Committees; and promote understanding and cooperation among the Member Countries in a constructive and mutually beneficial manner. The PDIES underpins MRC's ability to develop a comprehensive knowledge base on parameters fundamental to Integrated Water Resources Management.*
>
> *The Procedures for Water Use Monitoring (PWUM) provides a comprehensive and adaptive framework and process to support effective implementation of the intra-basin water use monitoring and the monitoring of inter-basin diversions. The Procedures aim to promote better understanding and cooperation among the Member Countries through transparency and confidence in the water use monitoring system and the undergoing database provides valuable information to support future planning processes.*
>
> *Moreover, a permanent body of the MRC, the Technical Assistance and Coordination Team (TACT) was established in late-2003 to establish, maintain and improve the MRC Information System (MRC-IS) and Water Use Monitoring System (MRC-WUMS) under these first two procedures. Additional guidelines to facilitate implementation of these 1995 Mekong Agreement and Procedural Rules were prepared for approval of the Joint Committee and adoption by the MRC Council in early 2005.*
>
> *The Procedures for Notification, Prior Consultation and Agreement (PNPCA) provide the MRC Member Countries with a framework for proposed water utilisation and inter-basin diversions projects, which are considered with the MRC under Article 5 of the Mekong Agreement. They promote better understanding and cooperation among the MRC Member Countries to ensure the sustainable development, management and conservation of the water and related resources of the Mekong River Basin.*
>
> *Providing a framework for technical guidelines, institutional arrangements, directions and information to enable the MRC and its Member Countries to [monitor] flow regimes of the Mekong River mainstream at critical locations and times of the year, the Procedures for Maintenance of Flows on the Mainstream (PMFM) are considered during discussions on new development and provide early warning flow conditions that may fall outside agreed thresholds thereby necessitating investigations by MRC.*

Procedures for Water Quality (PWQ) establish a cooperative framework for the maintenance of acceptable/ good water quality to promote the sustainable development of the Mekong River Basin. The PWQ were approved by Council of the MRC in January 2011."

In addition to the formal procedures approved by the MRC Council under the authority of the 1995 Mekong Agreement, the Member Countries continually work together to prepare and implement guidelines and other relevant supporting material to facilitate the sustainable development of the Mekong River system. Important guidance documents that have been prepared by MRC in recent years and/or are close to finalisation include: (i) the fishery management strategy; (ii) the sustainable hydropower strategy; (iii) the updated Preliminary Design Guidance (PDG) on Mainstream Hydropower; (iv) the Transboundary Environmental Impact Assessment (TbEIA) guidelines; and (v) other studies such as the recent Council Study investigating development potential and trade-offs. Implementation of this guidance will help Member Countries to "*avoid, minimise and mitigate*" [33] the harmful effects that might occur to the environment from the development and use of the Mekong River Basin water resources.

7.2 Equity of benefits derived from the Mekong River system

7.2.1 Assessment methodology

Article 5 of the 1995 Mekong Agreement commits Member Countries to the reasonable and equitable utilisation of the waters of the Mekong river system. Member Countries each seek to achieve their share of equitable utilisation recognising that this may be achieved through different means appropriate to each country's national circumstances and interests. There are, however, often trade-offs between social, environment and economic conditions as a result of development, management and conservation decisions that countries take, and these trade-offs may be felt both within a country and between countries. The Strategic Indicator of equity of benefits derived from the Mekong River system seeks to enable an open and transparent dialogue between countries about the equitable utilisation of the common resource.

The **Strategic Indicator** "equity of benefits derived from the Mekong River system" is defined as "The extent to which the benefits of the Mekong River system are shared between member countries". The associated **assessment indicators** for this strategic indicator are:

- Overall environment condition in each country
- Overall social condition in each country
- Overall economic condition in each country

Each assessment indicator is evaluated based on the country-specific data obtained from each assessment indicator in the social, environment and economic dimensions.

7.2.2 Overall environment condition in each country

As illustrated in Chapter 3, the assessment indicators for environmental conditions across the Basin illustrate mixed results. Flow conditions are largely compliant with the procedures for monitoring flow in the mainstream and water quality is generally good. However, sediment transport has declined substantially, and much of the LMB's wetlands have been lost. Although fisheries catch data suggest relatively stable production levels, there are signs of heavy fishing pressure. A considerable increase in effort is being expended to catch the same amount of fish and smaller species make up a greater proportion of the catch. Following decades of decline, forest cover overall appears to be constant or even increasing, and more ecologically important areas than ever are under some form of protection.

33 In accordance with Article 7 of the 1995 Mekong Agreement relating to the Prevention and Cessation of Harmful Effects

The impact of changes to flow conditions in the upper Mekong Basin appear to be largely affecting Lao PDR and Thailand at this stage, with the increase in dry season flows evident at Chiang Saen, but less so at Kratie and not evident at all at Tan Chau. Reduced sediment flows are proportionally greater in the upper parts of the Lower Mekong Basin, but also substantial along the length of the mainstream, which is likely to be having deleterious effects in both Cambodia and Viet Nam. Sediments carried from upstream are critical to floodplain rejuvenation, carrying nutrients that support fisheries and agriculture. These sediments also help maintain the integrity of the Delta and buffer coastal erosion processes. No trend in salinity intrusion has been identified in the Delta to-date.

The area of wetland lost in each Member Country has been substantial, but by 2003 the loss was considerably higher in Thailand and Viet Nam than in Cambodia and Lao PDR. In 2010, as to be expected, the largest overall area of wetland still remains in the two downstream countries with the more expansive floodplain areas, Cambodia and Viet Nam. However, with grassland and mangrove wetlands seeing the greater proportional reduction in area between 2003 and 2010 (these wetland types being particularly prevalent around Tonle Sap and in the Delta region), wetlands in Cambodia and Viet Nam may be at the greatest ongoing risk. Updated wetland mapping will be important in assessing whether this is the case.

Catch-per-unit effort for fisheries appears to be declining at all capture fisheries where data exists. This is evident at locations in Cambodia, Lao PDR and Viet Nam. Viet Nam, however, is the only country where aquaculture fisheries production is growing strongly.

7.2.3 Overall social condition in each country

Based upon 2015 estimates there are approximately 65 million people living within the LMB. Thailand and Viet Nam each account for a little over a third of the population, Cambodia a fifth and Lao PDR the remainder. Social conditions of the population across the Lower Mekong Basin are difficult to ascertain with much confidence due to a lack of available data.

According to World Bank data (2014), overall poverty levels have significantly reduced in all LMB countries. In Viet Nam, the proportion of the population with income less than US$ 1.25 per day decreased from 50% in 1995 to 17% in 2010. The incidence of poverty also reduced in Cambodia (from 45% to 23%), Lao PDR (49% to 34%) and Thailand (2.5% to 0.4%). There are significant variations between provinces, but these percentages are generally greater in rural areas compared to urban areas.

Based on SIMVA surveys in 2011 and 2014, the number of people living in urban centres is increasing rapidly. Already a third live in towns and cities and, by 2060, this will reach around a half. Together with increasing industrialisation, this will create new demands upon government services, including improved flood protection, effective planning and management of urban sprawl on flood plains and strengthened measures to combat pollution risks.

The rural population in contrast is not expected to increase much above current levels in absolute terms before declining in the future following an established trend in Northeast Thailand. Combined with the changing age profile of the rural population, this will prompt changes in the way the rural occupations such as farming are undertaken and present new challenges and opportunities to maintain food security.

The evidence presented shows that livelihood conditions within the LMB are steadily improving with better access to public services and a reduction in poverty levels. This has brought about increased resilience in the rural population to withstand floods, drought and reductions in capture fisheries. However, there remains considerable variation in levels of resilience across the LMB, with the likelihood that some communities will continue to face for some years to come considerable difficulty in coping with changes in natural resources brought about by sector developments.

From the broader basin-scale data that is available in relation to the draft MRC Indicator Framework, the countries perform better or worse relative to each other on different indicators.

In relation to food security, infant malnutrition as indicated by wasting is a cause of some concern. Despite very substantial progress since the 1990s, it appears some measures of infant malnutrition have increased in recent years in both Cambodia and Thailand. On the other hand, both Lao PDR and Viet Nam have seen indicators of infant malnutrition continue to fall since the 1990s.

The adequacy of access to safe water supplies is considerably higher in Thailand and Viet Nam than Cambodia or Lao PDR. Thailand and Cambodia are more susceptible to drought, based on the proportion of population and drought susceptible area without access to irrigation. As expected, the population affected by flooding is much higher in Cambodia and Viet Nam.

Although access to electricity is generally good in Lao PDR, Thailand and Viet Nam, Cambodia lags behind by some distance. In all countries access is lower in rural than urban areas.

7.2.4 Overall economic condition in each country

Economic performance varies considerably between countries reflecting their differing development histories and economic contexts. Considering the four LMB countries as a whole, Thailand's economy accounts for around 68% of GDP, Viet Nam approximately 27%, with the remaining 5% divided between Cambodia (3%) and Lao PDR (2%).

The economic benefits derived from the Mekong River system are spread across water and water-related sectors, including from agriculture, fisheries, forestry, navigation, and wetlands. Of these sectors, fisheries including aquaculture, represents the largest economic sector in the LMB at present, followed by lowland agriculture, principally rice together with maize. Hydropower is currently only a relatively small contributor.

Viet Nam and Thailand, which have been extensively developing their parts of the Basin since the 1960's, are abstracting the greatest benefit. Viet Nam's intensive triple cropping of rice underpins their benefits, but fisheries, particularly aquaculture, are an important contributor. About 84 per cent of irrigated rice by value is grown in the Mekong Delta in Viet Nam. Viet Nam similarly dominates aquaculture production, with approximately 86 per cent of overall production value.

In the transport sector, Viet Nam dominates cargo transport with around 75 per cent of economic value. Passenger numbers both for domestic passengers and tourists is higher in Viet Nam than other countries.

For Thailand, fisheries are an important part of the benefit mix, as much of their agricultural land in the LMB is single cropped. Based on habitat yields more than 50 per cent of capture fisheries production value is in Thailand. Thailand also accounts for approximately 50 per cent of reservoir fisheries production although less than 10 per cent of overall capture fisheries production is from reservoirs. Thailand dominates international tourist receipts with approximately 81 per cent of all receipts across Member Countries, although these are based on total national figures not LMB-specific data. Across all countries there has been rapid growth in tourism receipt between 2006 and 2016 with the biggest increase in Lao PDR.

In Cambodia, fisheries and agriculture contribute in similar proportions to the rural economy at present, but lower productivity in the agricultural sector constrains their overall benefits from the natural resource system. Although figures on sand mining are difficult to come by, by some estimates Cambodia extracted around 60 per cent of all sand and gravel in 2011.

Lao PDR has limited opportunities for both agriculture and fisheries and hydropower already makes up a sizeable portion of their benefit mix. Between 2005 and 2015 Lao PDR overtook Viet Nam as the largest producer of hydropower, notwithstanding that Viet Nam more than doubled its own production during this period. Among all countries hydropower production more than trebled. More than half of all economic value from hydropower is in Lao PDR.

For further development, with export markets for aquaculture growing slowly and agriculture already highly productive, Viet Nam's challenge is to sustain its overall outputs in the face of threats from principally climate change, sea level rise and coastal erosion. Thailand can increase productivity if a greater proportion of its agricultural land is provided with irrigation whilst maintaining its highly productive fisheries. For Cambodia, a key challenge is to preserve its significant capture fisheries production, whilst addressing its rising energy demands and looking for growth in the agricultural sector through intensification on the back of expanded irrigation. For Lao PDR, the major opportunity for achieving more economic growth is through exploiting its abundant hydropower potential.

In 2015, the LMB fisheries sector (including capture fisheries, reservoir fisheries and aquaculture) represents almost 2.7% of the combined GDP of the four Lower Mekong countries (Cambodia: 16.6% of the country's total GDP; Lao PDR: 10.5% of total national GDP, Thailand: 1.7% and Viet Nam 3.0% of GDP). Although LMB fisheries values are higher in Thailand and Viet Nam, they represent smaller shares of overall activity in these economies, which are bigger and more developed than the Cambodian and Lao economies with considerable economic activity outside the basin.

7.2.5 Assessment of equity of benefits

The benefits derived from the Mekong River system cover social, economic and environmental dimensions. Due to their stage of economic development, it is apparent that some countries have gained more economically than others from the development and use of Mekong water resources to-date. Thailand and Viet Nam continue to draw the greatest economic benefits, particularly from fisheries including aquaculture and agriculture. However, Lao PDR is increasing its economic performance from Mekong resources through investment in hydropower and there is some evidence of greater irrigation abstractions in Cambodia.

The environmental benefits are shared across the four countries with increased dry season flows impacting Lao PDR and Thailand more than Cambodia and Viet Nam at this stage. Wetland areas across all countries have declined substantially but could be under greatest ongoing threat in Cambodia and Viet Nam. The decline in sediment transport will affect all countries with likely impacts on fish and agricultural productivity. The catch per unit effort of fish appears to be in decline in all countries, although more fish and other aquatic resources are being produced through aquaculture especially in Viet Nam.

Social conditions are generally higher in Thailand and Viet Nam due to their greater economic resources, although over recent decades all countries have made considerable progress on indicators of food, water and health security, as well as access to electricity.

During the last few years, the MRC has given greater attention to the issue of regional benefit sharing and has published a number of reports exploring the potential within the basin to obtain greater benefits for all Member Countries through cooperation than would otherwise be possible individually. Regional benefit sharing mechanisms have been identified which encompass the promotion of joint projects, involving two or more countries, as well as projects of basin-wide significance developed in one country but brining benefits to others. Section 7.3 below shows that significant steps are already being taken by all Member Countries in this regard.

The MRC has also recognised that to achieve optimal and equitable development of the basin, as envisaged in the 1995 Mekong Agreement, will require the consideration of trade-offs between alternative development pathways. Each Member Country has legitimate expectations of how the water and related-resources of the basin can bring benefits to their own countries and, increasingly, greater awareness that some developments can have negative impacts elsewhere within the basin. To this end, the MRC has so far undertaken two basin-wide assessments of potential future developments, the first in 2010 and the second (the Council Study) completed recently. These studies highlight the need for careful consideration of trade-offs in selecting projects within the basin in the future, pointing to the risks that some developments may bring to other countries and sectors.

These studies have identified that, on the one hand, water resource developments such as hydropower and irrigation can bring substantial benefit to national economies and rural communities. On the other hand, the studies have also highlighted risks that future developments potentially raise, including the consequences of streamflow disruption

and regulation caused by dam development on the migration of fish, sediment flows, riverine ecology and floodplain productivity and the related vulnerability of riverine communities to these changes. However, such risks also need to be seen within the wider changes occurring within the basin associated with climate change (including sea level rise), rapid urbanisation, increasing encroachment upon wetlands and continuing progress in reducing the incidence of poverty through greater access to education, transport, energy supply, health and social services. All of these changes, both from development of Mekong water resources as well as broader societal changes, have the potential to impact on the cultural values people associate with the Mekong River.

The challenge ahead remains to best manage these risks and to pursue optimal development of the water-related resources of the basin in each Member Country's interest. To this end, the MRC has recently undertaken a comprehensive revision of its five-yearly planning cycle to include, inter alia, a State of Basin Report to assess current conditions and development issues within the basin, to be followed by an assessment of alternative ways by which to address these issues and a consequent updating of the Basin Development Strategy steering towards optimal and equitable development of the basin.

7.3 Benefits derived from cooperation

As noted above, water and related resource development potentially can bring many benefits to Member Countries and to their peoples. These benefits encompass increased water, food and energy security as well as a consequent contribution to the nation's health, economic development, poverty reduction, community well-being and GHG reduction. The 1995 Mekong Agreement recognises that these benefits can best be realised through the Member Countries cooperating together. This section considers how well that cooperation is being realised through the MRC.

7.3.1 Assessment methodology

The benefits derived from cooperation among Member Countries are reflected in a range of processes and outcomes: in particular, through cooperation on joint projects, projects of basin-wide significance, and notifications and dialogue under the Procedures for Notification, Prior Consultation and Agreement (PNPCA). Cooperation also occurs through the sharing of information and knowledge, joint events with a range of stakeholders and partnership agreements with external parties.

The **Strategic Indicator** "benefits derived from cooperation" is defined as "the extent of cooperation between member countries and through partnerships with others, and the value of benefits derived from knowledge sharing, and joint projects with basin-wide significance or trans-boundary impacts". The associated **assessment indicators** for this strategic indicator are:

- Cross-border engagement in projects of basin-wide significance
- Cooperation between countries on joint projects
- Notification and engagement on projects with potential trans-boundary impacts
- Proportion of benefits derived from cooperation to total net economic value of MRC water-related sectors

Each assessment indicator is evaluated using relevant monitoring parameters to inform a judgement about the overall status of benefits derived from cooperation. Monitoring parameters are primarily obtained through the database of National Indicative Plans as submitted by Member Countries, although in the future "national projects of basin significance" and "joint projects" under ASEAN, GMS, MLC, etc may also be considered as well.

National Indicative Plans (NIPs) are prepared in each country under the coordination of the respective National Mekong Committee. These plans seek to incorporate the basin perspective of the MRC's Basin Development Strategy into national planning, decision-making and governance processes, integrating to the extent possible with five-year socio-economic and sector planning and annual work planning of relevant national agencies. In doing so, each NIP seeks to capture the benefits envisaged under the 1995 Mekong Agreement that will flow from regional cooperation and collaborative effort by optimising national and transboundary development opportunities and minimising harmful impacts.

7.3.2 Cross border engagement in projects of basin-wide significance

As illustrated in Table 7.1, as at June 2018 there were 78 projects with an estimated total value of US$827 million identified in the National Indicative Plans for all Member Countries.

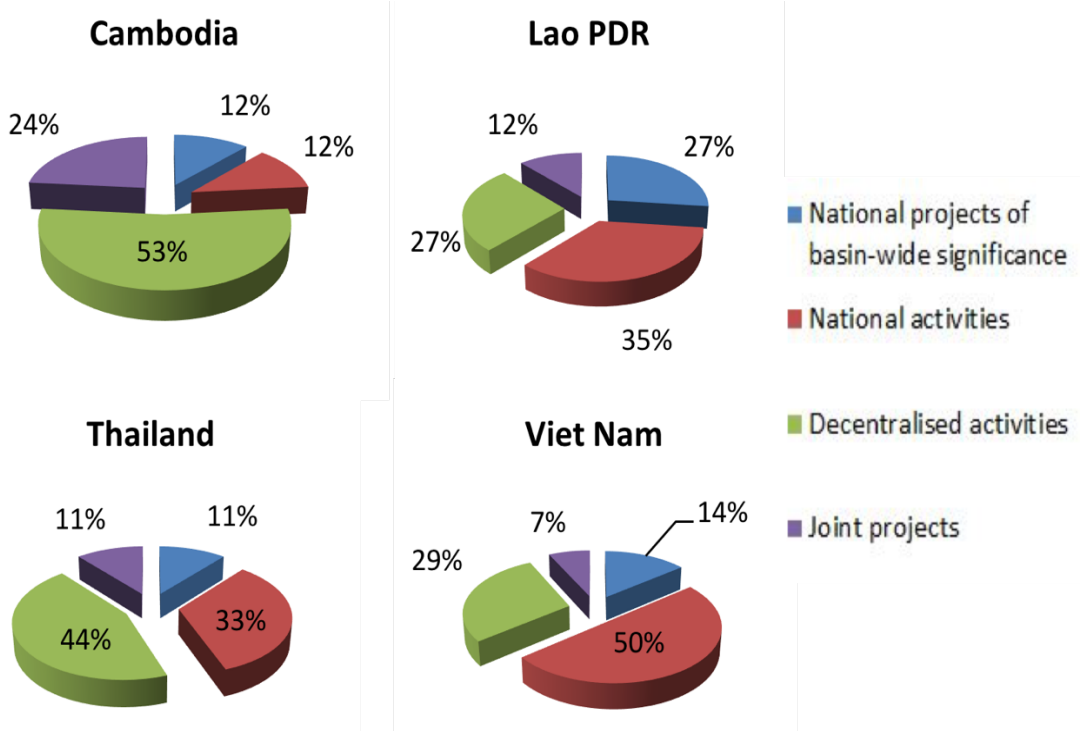
Table 7.1 Summary of NIP project numbers and values (US$ million) as at June 2018

Country	No. of projects	Total cost	Average cost
Cambodia	13	11.92	0.92
Lao PDR	23	462.14	20.09
Thailand	16	15.52	0.97
Viet Nam	26	336.95	12.96
Total	**78**	**826.53**	**10.60**

Source: MRC records

From an analysis of the 2016-20 NIPs (Figure 7.1), there are 15 national projects of basin-wide significance, 31 national activities contributing to the MRC Strategic Plan, and 32 decentralized activities. Projects of basin-wide significance are judged to be those directed at either investigating potential transboundary impacts or directed towards reducing knowledge gaps and better management of assets which may have transboundary impacts (e.g. improving catchment management, capture fisheries, hydropower planning, cost-benefit sharing, impacts of upstream developments, etc.)

Figure 7.1 Proportion of projects in NIPs that are of basin-wide significance, joint projects, or supporting national or decentralised activities in each country



To date, under the 2016-2020 Basin Development Strategy two projects of basin-wide significance have been funded, one in Cambodia and one in Lao PDR with a total value of US$328.5 million. Drawing on lessons learnt from the first set of NIPs and taking into account the streamlined planning process incorporated within the MRC's Strategic Plan for 2016 – 2020, the updated NIPs are focused on both promoting the implementation of development opportunities identified in the BDS, as well as contributing to common MRC outcomes and outputs identified in the MRC Strategic Plan.

7.3.3 Cooperation between countries on joint projects

Joint projects between Member Countries are intended to improve national water resources development plans in order to: (i) ensure long-term water and environmental security; and (ii) achieve sustainable development, as envisioned in the 1995 Mekong Agreement. The development of joint projects also increases transboundary cooperation and regional integration (MRC, 2017).

In line with its mandate, the MRC has prioritised the pursuit of joint projects through its refreshed strategic planning cycle. In response to the Basin Development Strategy for 2016-2020, the Lower Mekong Basin (LMB) countries identified and agreed five joint projects (Table 7.2). The characteristics of these joint projects are that they seek to facilitate one or more of (MRC, 2017):

- joint investments (sharing costs and benefits) in infrastructure and other facilities (for multiple purposes ranging from flood protection and navigation to energy and irrigation);
- coordinated national actions and investments of a non-structural nature (e.g. under a MoU, agreement or treaty as appropriate), such as navigation aids, monitoring and flood warning systems, or floodplain and watershed management;
- increased regional benefits or reduced regional costs, minimizing adverse impacts and providing water-related security.

These five joint projects have a total budget of US$11.03 million, of which US$ 755,000 has so far been made available either by Development Partners (specifically Germany) or through the MRC basket funding to enable preparatory work to commence.

Table 7.2 Joint projects prioritised by Member Countries in response to the Basin Development Strategy 2016-2020

Shared basin, delta, river, area	Countries	Title of joint project
Mekong Delta	Cambodia-Viet Nam	Flood management in the border area of Cambodia and Viet Nam in the Mekong Delta for water security and sustainable development
Sesan, Srepok and Sekong (3S) basin	Cambodia-Lao PDR-Viet Nam	Sustainable water resources development and management in the Sekong, Sesan and Srepok river basins (3S Basin)
Cambodia-Thai border area (Sub-area 9C-9T)	Cambodia-Thailand	Transboundary cooperation for flood and drought management in Cambodian-Thai border area – a part of 9C-9T Sub-area
Khone Falls area	Cambodia-Lao PDR	Cross border water resources development and management, including environmental impact monitoring of Don Sahong hydropower project
Mekong river	Lao PDR-Thailand	Lao-Thai safety regulations for navigation between Lao PDR and Thailand

Source: MRC (2017)

7.3.4 Notification and engagement on projects with potential trans-boundary impacts

The MRC's Procedures for Notification, Prior Consultation and Agreement (PNPCA) are a key instrument prescribed in the 1995 Mekong Agreement by which to "*promote better understanding and cooperation among the MRC member countries in a constructive and mutually beneficial manner to ensure the sustainable development, management and conservation of the water and related resources of the Mekong River Basin*".

The PNPCA requires Member Countries to notify other Member Countries of proposed uses in the case of (a) intra-basin use and inter-basin diversion on the tributaries, including Tonle Sap; and (b) intra-basin use during the wet season on the mainstream. Prior consultation between Member Countries is required to take into account Article 5 of the Mekong Agreement and is aimed at arriving at an agreement in the case of the following proposed uses: (a) inter-basin diversion from the mainstream during the wet season; (b) intra-basin use on the mainstream during the dry season; and (c) inter-basin diversion of the surplus quantity of water during the dry season.

The PNPCA also requires that Member Countries enter into a Specific Agreement should a Member Country wish to undertake any inter-basin diversion project from the mainstream during the dry season. The PNPCA sets out the processes required to be followed in each case above. Since 1998, there have been 49 notifications issued and four instances of prior consultation. These are summarised in Table 7.3 below. Notifications and prior consultations have been received most years by the MRCS, as illustrated in Figure 7.2. The spike in 2013 can be attributed to hydropower projects being notified by Lao PDR. Since 2012 Lao PDR is the only country to have notified any projects for Prior Consultation under PNPCA.

Table 7.3 Summary of numbers of notifications and prior consultations since 1998

	Bridge	Diversion	Hydropower	Irrigation	Multipurpose	Water management	Total
Notifications							
Cambodia	1		1	1			3
Lao PDR	1		31				32
Thailand							0
Viet Nam			11	2			13
Total	2	0	43	3	0	0	48
Prior consultation[34]							
Cambodia							0
Lao PDR			4				4
Thailand							0
Viet Nam							0
Total	0	0	4	0	0	0	4

Source: MRC records

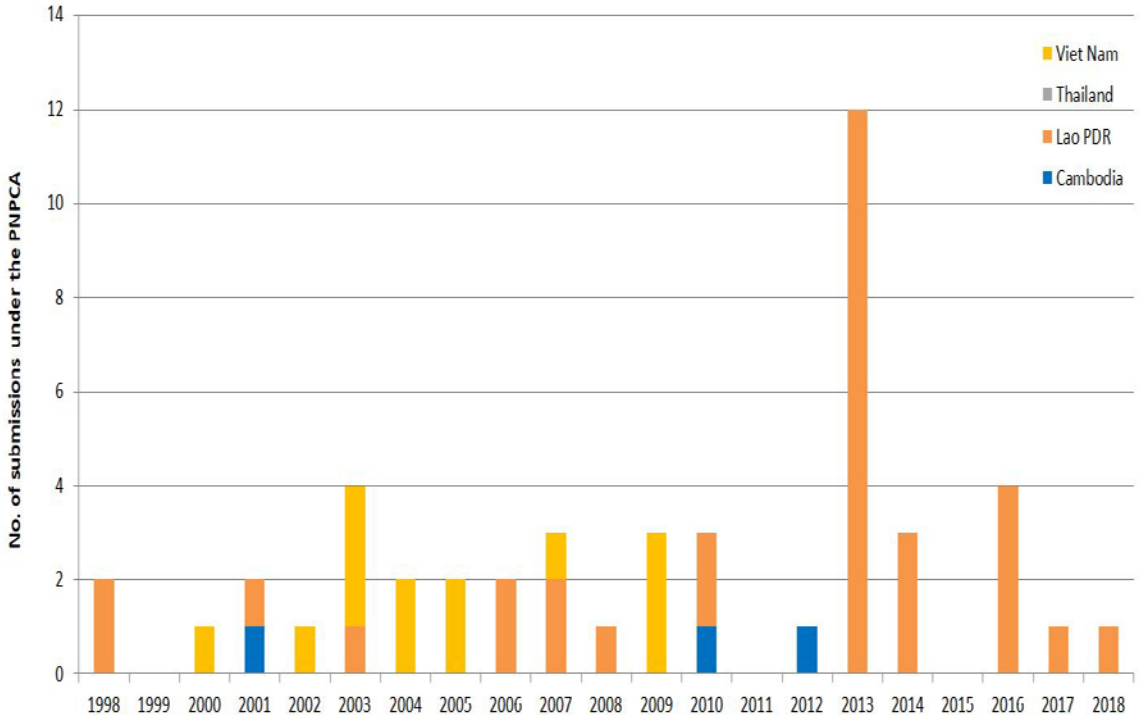
Implementation of the PNPCA has, in some instances, led to misunderstandings arising over its intent and the rights afforded to each Member Country during the process.

A 2015 report[35] on lessons learnt from the implementation of the procedures notes that with the increasing number of water development projects in the LMB, for mostly hydropower, there is a clear need to strengthen the PNPCA. The report goes to on say that the ambiguities in the text of the 1995 Mekong Agreement and the PNPCA need to be addressed to clarify interpretation of the implementation of the PNPCA, with clearer roles and responsibilities of the MRC Council, MRC Joint Committee and MRC Secretariat.

34 Note that the Prior consultation projects have also been notified and so are counted in the Notification project numbers as well as the Prior Consultation project numbers

35 Draft working paper on lessons learnt from implementation of the Procedures for Notification, Prior Consultation and Agreement (PNPCA), prepared for discussion at the JC Preparation Meeting, October 2015

Figure 7.2 Numbers of PNPCA notifications and prior consultations taken up each year since 1998



Source: MRC records

This need has been echoed by the Member Countries through the application of the Prior consultation process for the Xayaburi and Don Sarong Hydropower projects. The Xayaburi Prior Consultation process was not considered successful in fully reconciling the competing interests of the States concerned, notwithstanding that it led to substantial redesign of the project to minimise negative impacts, increasing the cost by US$400 million. No agreement was reached by the MRC Joint Committee and Council on the Xayaburi project, nor on Don Sahong, which was referred to Governments. On the third mainstream hydropower project, Pak Beng, the Joint Committee of the MRC issued an agreed statement calling for a range of additional measures and assurances from Lao PDR as well as the development of a Joint Action Plan.

7.3.5 Proportion of benefits derived from cooperation to total net economic value of all MRC water-related sectors

The total cost of projects listed in National Indicative Plans at June 2018 was US$ 826.53. On a rudimentary basis, relative to the overall annual economic value of MRC water-related sectors (see Section 5.2), this represents a proportion of about 3 per cent[36].

The total value of joint projects listed in National Indicative Plans as at June 2018 was US$ 11.03 million. Relative to the overall economic value of MRC water-related sectors, this represents a very small proportion.

36 This estimate is one that will need to be revised at a later stage. It compares upfront costs of new projects to annual value of existing ones (US$35 billion). The annual value of new projects is of course a much lower figure than the upfront investment cost. At the same time, the comparison is being made against the annual value of projects and activities in all water-related sectors implemented since the 1960's. At this stage, it wold be reasonable to conclude only that the new NIP projects are a relatively small proportion of cumulative investments to date, although when related to individual sectors, in some cases (eg hydropower) the proportion of new to existing would be far more significant.

7.3.6 Cooperation with MRC's dialogue partners

Cooperation between China, Myanmar and the Lower Mekong countries is increasingly taking place within several frameworks.

As dialogue partner, MRC and China share data and information, and conduct annual dialogue meeting, joint technical symposiums, exchange of visits, and joint studies. China and MRC are currently executing a joint research on hydrological impacts of the UMB hydropower cascade on downstream extreme events such as floods and droughts.

Myanmar, also a dialogue partner, has cooperated with MRC in a number of areas, such as improving the MRC's hydro-meteorological coverage by exchanging relevant monitoring and water-quality data and sharing technical expertise in flood prevention and management. A number of areas, such as navigation safety, strategic environmental assessment, and continued sharing of hydro-meteorological data with Myanmar, have been explored with potential for future technical cooperation. As with China, the government of Myanmar sends high-level participants to MRC summits and Council meetings.

Other forum where the MRC Member Countries cooperate with China and Myanmar include the Mekong Lancang Cooperation (MLC) mechanism and the establishment of the Lancang Mekong Water Resources Cooperation Center (LMWRCC). The LMWRCC aims to carry out joint research and analysis as well as capacity building related to Mekong water resources and influences of climate change, implement pilot projects and priority cooperation projects on sustainable water resources development, improve the water quality monitoring system and flood and drought disaster emergency management, and strengthen data and information sharing.

China and Myanmar are also both involved in the Greater Mekong Sub-region (GMS) initiative and the Joint Committee on Coordination of Commercial Navigation on the Mekong (JCCCN), which has developed the Development Plan of International Navigation on the Mekong-Lancang River (MLDP). In addition, Myanmar is engaged in the Association of South-East Asian Nations (ASEAN), the Ayeyarwady-Chao Phraya-Mekong Economic Cooperation Strategy (ACMECS), and the Cambodia-Laos-Myanmar-Vietnam cooperation initiative (CLMV).

7.3.7 Assessment of benefits derived from cooperation

The project data above illustrates a substantial level of cooperation among Member Countries towards the objectives of the 1995 Mekong Agreement. Joint projects cover a range of MRC water-related sectors including in relation to integrated flood plain management, strategic planning and strengthened coordination, and navigation. The PNPCA process is being used by countries to notify the other countries of projects with potential trans-boundary impacts, notwithstanding some misunderstanding of the rights afforded to Member Countries during the process, and the not always satisfactory reconciliation of issues identified even when substantial re-design occurs.

Furthermore, the MRC is increasingly proactive in engaging with both its wider stakeholder community and dialogue (Myanmar and PRC China) as well as its regional partners. This increased engagement not only raises the profile of MRC's mission but also opens up the prospect for broadening the potential trade-offs needed to drive basin development in line with the Member Countries' aims.

7.4 Self-finance of the MRC

7.4.1 Assessment methodology

The directions set by the Prime Ministers of the four Member Countries at the first MRC Summit in Hua Hin, April 2010, and reaffirmed at the Second Summit in HCMC, April 2014, include full member country financing of the MRC by 2030. This commitment to reform included a move to the full riparianisation of the MRC and to the decentralisation of the organisation's core functions to Member Countries, based on the principle of subsidiarity; and an associated shift in the MRC Secretariat to a leaner organisation focused on the MRC's core functions. This shift has led to a substantial downsizing of the size of the Secretariat since 2015 as Member Countries seek to cut costs and operate the Commission in a more efficient way. The **Strategic Indicator** "self-finance of the MRC" is defined as "the extent to which the activities of the MRC are self-financed through national contributions, in-line with the organisation's 2030 objective". The associated **assessment indicator** for this strategic indicator is [37]:

- ❑ Proportion of the MRC budget funded by national contributions during the current period

Each assessment indicator is evaluated using relevant monitoring parameters to inform a judgement about the overall status of self-financing of the MRC. Finance monitoring parameters are obtained from the MRC's annual reports and approved annual work-plans and from internal forecasts.

7.4.2 Proportion of MRC budget funded by national contributions during the current period

In 2017, the MRC's total annual budget, including both basket funding and earmarked funding, was US$12,429,272. The proportion of this funded by Member Countries was 23 per cent: up from 17 per cent in 2016 and 8 per cent in 2015 (Figure 7.3). During the current 2016-2020 period, total annual expenditures are forecast to decline to just under US$11 million by 2020, of which approximately 38 per cent is expected to be financed by Member Countries, putting the MRC well on track to be self-financed by 2030.

The projected growth in contributions from Member Countries out to 2030 is illustrated in Figure 7.4. This growth in Member Country contributions will see all countries each contribute 25 per cent of the budget of the MRC by 2030. The current 2018 budget is made up of proportional contributions of 30 per cent each from Thailand and Viet Nam and 20 per cent each from Cambodia and Lao PDR.

7.4.3 Assessment of status of self-finance of the MRC

The MRC appears to be on track to its 2030 objective of self-finance. In each of the past two years, the proportional contribution by Member Countries to the MRC budget has increased and is forecast to continue increasing through to 2020.

The ratio of earmarked to basket funding has declined and is forecast to continue declining to 2020 consistent with the MRC Strategic Plan's objective for a more flexible and agile financial management system.

37 In the light of comments received, the indicator "Ratio of Earmarked funding to basket funding during the current period" has been dropped as it is not relevant to wider audiences.

Figure 7.3 Total MRC budget and total and proportional contributions from Member Countries from 2015 to 2017 with forecast expenditures and contributions to 2020

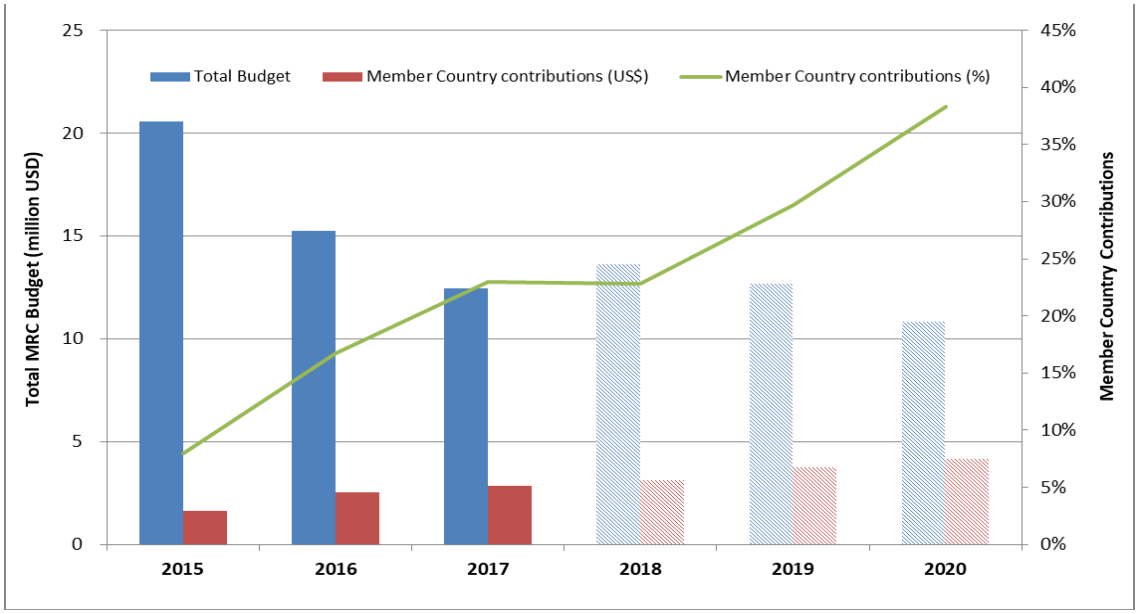
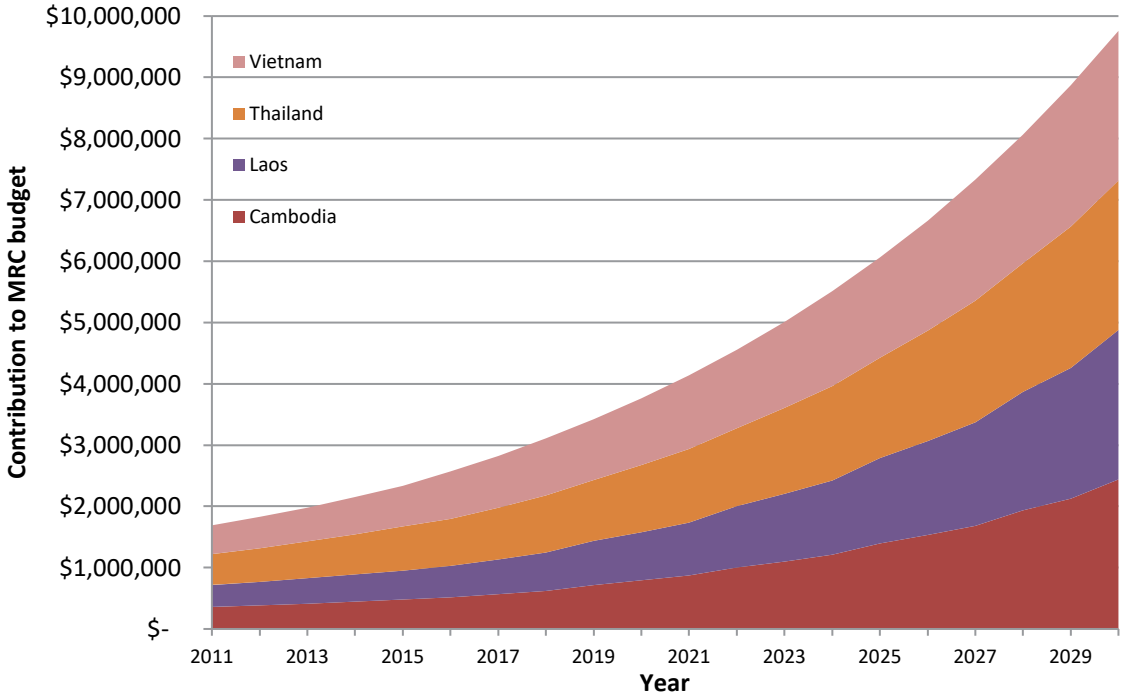


Figure 7.4 Projected growth in contributions from Member Countries to 2030



7.5 Summary of overall of status of cooperation within the basin

Overall cooperation with the Mekong Basin is positive. There is considerable engagement between Member Countries on joint projects and through common assessment studies and investigations. The Council Study completed in 2017 is one such example. Dialogue between countries on the range of MRC activities is frequent and focused on the important challenges facing the LMB communities. The PNPCA process is being used, even if some implementation issues concerning the rights of member countries and processes could be improved.

The countries agreed to a substantial reform agenda for the MRC, with an aim for progressive self-financing and equitable contributions from each country to be achieved by 2030. A new financial management system has been implemented aimed at increased agility and flexibility in expenditure, and work towards decentralisation of MRC activities from the Secretariat to the Member Countries well under way. Projected expenditure is forecast to decline under the current 2016-2020 period, requiring ongoing focus on key priorities relevant to the wellbeing of Basin communities.

Taking a "whole basin" approach cooperation with the upper riparian countries has also been enhanced. China and Myanmar have demonstrated an increasing commitment to cooperation, including sharing data and information and conducting joint activities.

In 2013, the MRC and China renewed their Memorandum of Understanding on provision of daily river flow and rainfall data from two monitoring stations in Yunnan Province during the wet season. and China extended the period for sharing data from four to five months (from the beginning of June to the end of October).

These data help improve the MRC's regional daily forecast of downstream water levels at key points on the Mekong River during the flood season. In turn, these forecasts can save lives and reduce damage to property and crops. China also agreed to increase the frequency of the data sent to the MRC from once to twice a day, and expressed its willingness to share the data during the dry season in case of drought emergencies. The extension of the agreement was a sign of continuous trust between the MRC and China.

In recent years, the MRC Secretariat has cooperated with Myanmar in a number of areas, such as improving the MRC's hydro-meteorological coverage by exchanging relevant monitoring and water-quality data and sharing technical expertise in flood prevention and management. A number of areas, such as navigation safety, strategic environmental assessment, and continued sharing of hydro-meteorological data with Myanmar, have been explored with potential for future technical cooperation.

Enhanced cooperation with China and Myanmar is crucial for the sustainable management of the Mekong Basin where flow conditions and sediment delivery downstream have already been modified by hydropower, sand mining and climate change. Building on the Dialogue Partner arrangement, future cooperation may include institutionalising a more extensive information sharing system on river flows and reservoir operations as well as joint technical studies and capacity-building in flood and drought management.

8. State of the Upper Mekong Basin

8.1 Introduction

The State of Basin report includes a description of the situation in the Upper Mekong Basin, where the river is known by China as the Lancang River. Reviews have been made of those parts of the basin within the territory of both Myanmar and PR China following, to the extent that data availability has allowed, a similar outline as that for the LMB as determined by the MRC Indicator Framework.

Information on this part of the basin has been prepared based on information and data shared by China to MRC (such as flood season hydrological data), the assessment by MRC (including joint studies), as well as additional publicly available information, including credible sources such as international organizations (UN, World Bank, etc) and universities and research centres in China and other countries.

8.2 Setting of the Upper Basin

The portion of the Mekong Basin located in China and Myanmar is regarded as the Upper Mekong Basin (UMB) in this State of the Basin Report. The UMB covers a total surface area of 186,356 km^2, which corresponds to 23.2% of the entire basin. The major part of the UMB (164,675 km^2, or 88.4%) is located in China with 21,681 km^2, or 11.6%, situated in Myanmar. These national sections are referred to as UMB-C and UMB-M respectively. Temperatures and rainfall amounts generally increase in a downstream direction.

Overall, the UMB comprises an area that is highly diverse in terms of landscape, climate and human pressures. The Mekong River rises from the Tibetan Plateau as the Za Qu River, running through alpine meadows at high elevations with a Tundra climate and limited agricultural and economic activity. As it enters Yunnan Province as one of the Three Parallel Rivers, it becomes associated with strongly incised river gorges, steep slopes and high flow velocities, draining a landscape with significant potential for erosion. This section of the basin in PR China has seen rapid economic development over the past years, in particular exemplified by the expansion of the hydropower and mining sectors.

There are four main sub-basins with limited hydropower development in Myanmar. The landscape is largely forested, with primary forests supporting severable threatened species. However, in some parts rapid deforestation is occurring due to slash-and-burn agriculture, mining and (rubber) plantations.

The total population of the UMB comprises a large number of ethnic groups and is estimated at a total of 7.1 million, of which 89% live in China.

Figure 8.1 Administrative map of the Chinese portion of the UMB, including locations of major towns and roads

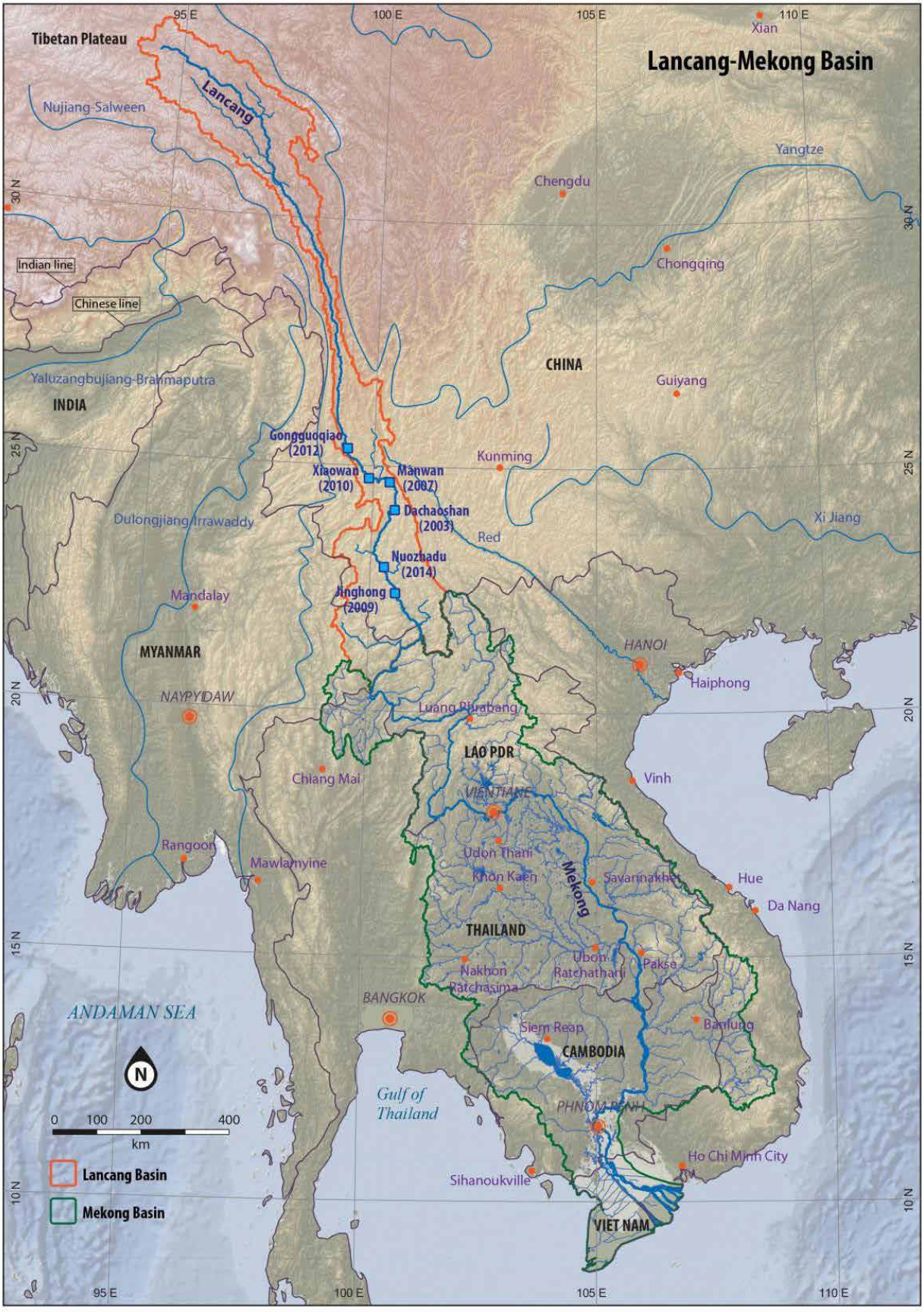
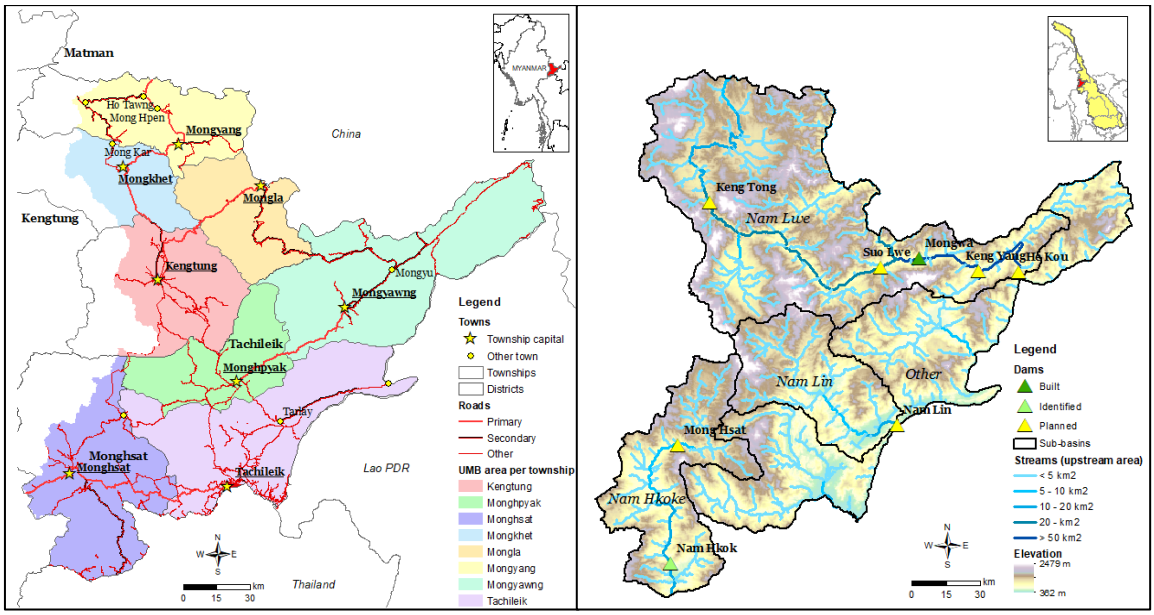


Figure 8.2 Administrative and sub-basin maps of the Myanmar portion of the UMB



8.3 Environmental status and trends

Land use changes, industrial activities and hydropower construction and operation in the UMB are all affecting its environmental status in various ways. Dam development in particular has changed seasonal flow dynamics. The UMB-C cascade of large reservoirs (see Figure 8.4) has so far led to significant increases in dry season flows as well as considerable reductions of wet season flows (Figure 8.3).

At Chiang Saen, average dry season flow in 2010-2017 was observed to have increased by 35% in comparison with 2000-2009, while flood season flows were reduced by 31%. The impact on the Lower Mekong flow regime becomes progressively less important downstream. On average, the UMB-C contributes approximately 18% of annual Mekong discharge, with an additional 1%-4% coming from Myanmar. Dam development in the UMB-M is currently taking off and may impact outflow patterns into the Mekong mainstream in the future.

Figure 8.3 Wet season flow volumes downstream of Jinghong dam in China

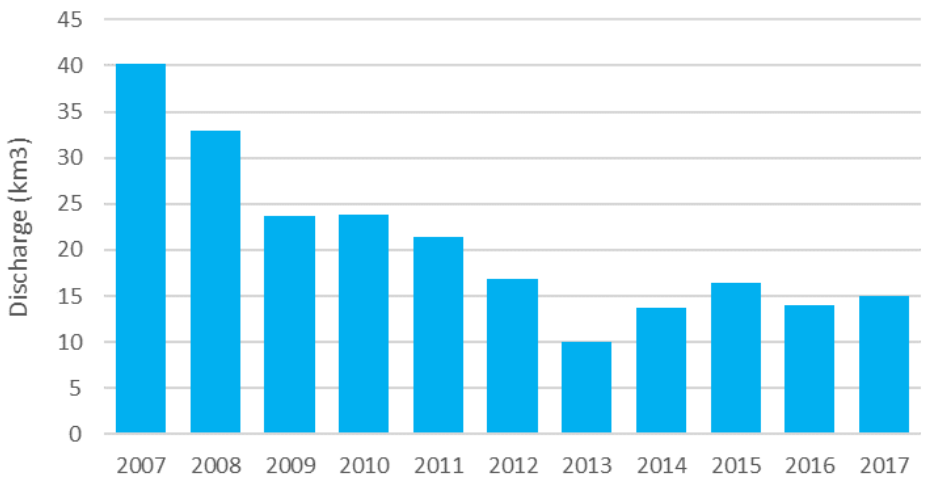
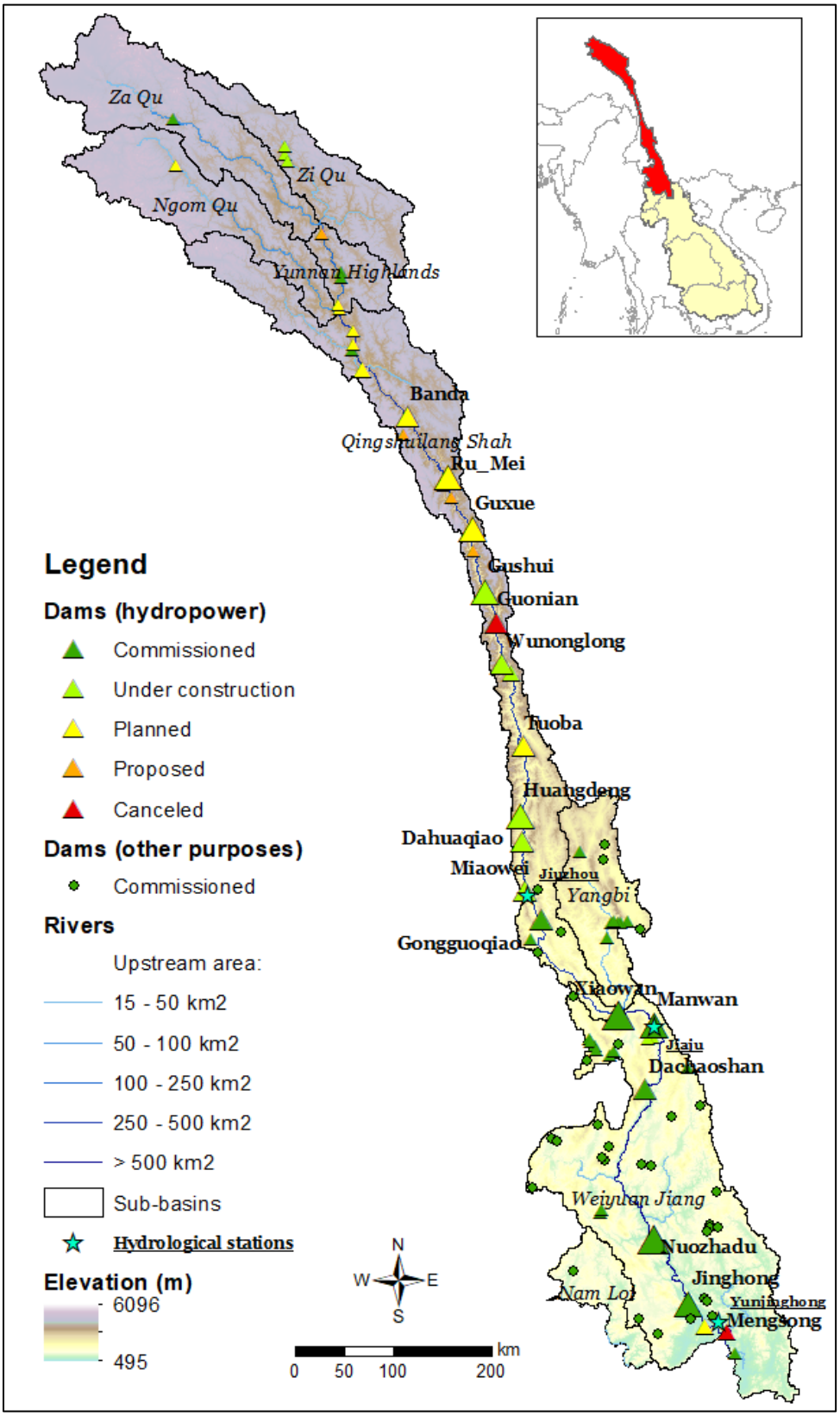


Figure 8.4 Sub-basins, major rivers and elevation of the UMB in China



Data source: WWF Hydro Basins. Locations and status of dam projects are indicated, with symbol size for hydropower dams proportional to installed capacity. Dams with an installed capacity of over 500 MW are labeled (dam data from CGIAR WLE Greater Mekong, 2018).

In addition to hydrological dynamics, the commissioning of the UMB-C reservoir cascade has also had a substantial impact on the sediment budget of the river, with clear reductions of 60-70% in sediment concentrations observed directly downstream of the main dams. This has its implications across the basin, with total sediment loads at Pakse having fallen by 55% in 2015 compared to baseline conditions. It should be noted that sand mining in both the Upper and Lower Mekong mainstream also plays a role in this reduction. The period of time to evaluate impacts of the full UMB-C cascade on hydrology and sediment loads is still relatively short, and the full picture is yet to be obtained.

Table 8.1 Average sediment concentration, transport rate and discharge at three hydrological stations in the Upper Mekong mainstream in China

Station	Annual sediment discharge (Mt)			
	1964-1977	*1978-1992*	*Post-1993*	*% in Jun-Sep*
Jiuzhou	21.96	26.94	27.061	95 (pre-2005)
Jiaju	38.74	54.34	19.382	95 (pre-1992)
Yunjinghong	73.05	108.45	26.663	96 (pre-2005)

Data source: From Lu et al., 2006, cited by Yu et al., 2018), locations are given in Figure 8.4. Note: 11993-2008, 21993-2008, 31993-2010

According to Chinese station measurements, water quality in the Upper Mekong mainstream is generally acceptable. Issues related to insufficient water quality in the UMB-C especially occur in tributaries and are caused by mining activities, increasing application of pesticides and fertilizers, as well as domestic and industrial wastewater. In the UMB-M, mining activities and pesticide use may impact on water quality, although very little data is available. A more comprehensive monitoring effort would be needed to evaluate potential water quality issues in Myanmar's part of the basin.

Several threatened fish species appear in the UMB-C and UMB-M. A combination of dam construction, overfishing, introduction of exotic species and water pollution has affected fish species richness in the UMB-C, with reported significant reductions of fish biodiversity. The cancellation of Mengsong Dam at the downstream end of the UMB-C cascade, which would have further impacted fish migration patterns, is a positive development in this light. In the UMB-M, several fish migration routes are present in the downstream areas which may be affected by recent dam development in the Nam Lwe sub-basin.

After rapid deforestation in the UMB-C during previous decades, logging has been reduced significantly due to introduction and enforcement of legislation and protected area (PA) management, with 29.3% of the basin holding a protected status. These PAs are however still challenged by industrialisation and associated land use changes. This is exemplified by the encroachment of Xishuangbanna forests by extensive monoculture rubber plantations, which has led to conversion of natural forests despite their protected status.

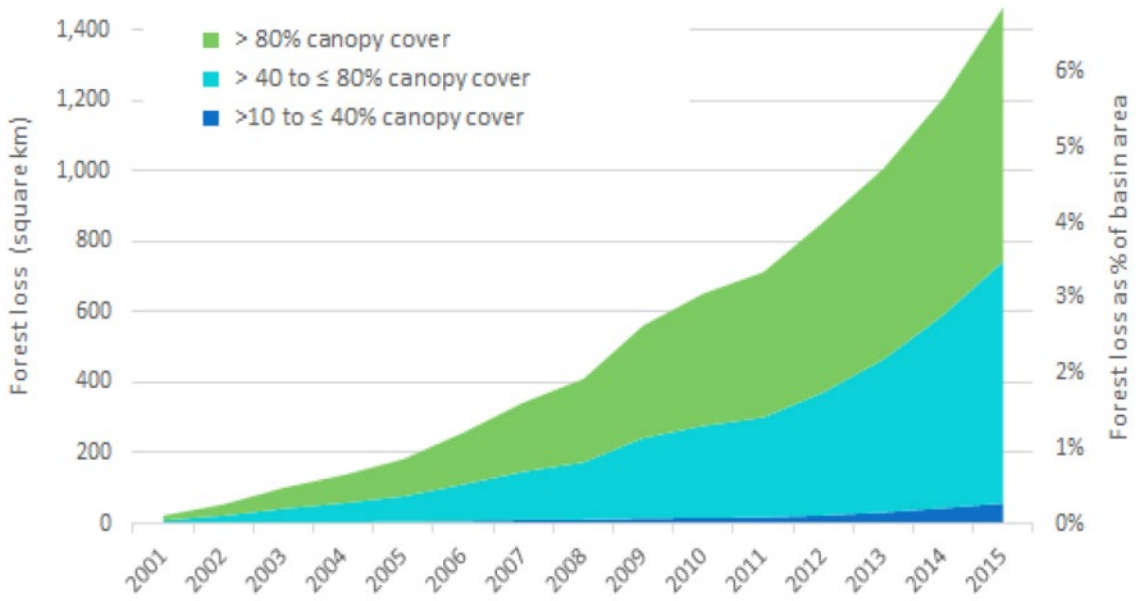
In the UMB-M, illegal logging, expansion of shifting cultivation, mining development and conversion to rubber monoculture continue to decimate its forests, with 10% of all primary forests having disappeared between 2000 and 2016. Only 0.7% of the basin is formally protected, although deforestation also occurs in these areas due to inadequate management and enforcement of conservation policies.

Table 8.2 Forest cover and loss per Protected Area (PA), disaggregated for different canopy cover densities (CC)

Protected area	Area		Forested cover in 2000		Forest cover loss			Total forest cover loss
	km²	*CC: 10-50%*	*CC:50-80%*	*CC:> 80%*	*CC: 10-50%*	*CC:50-80%*	*CC:> 80%*	*% of forest in 2000*
Three Parallel Rivers of Yunnan	3389.6	400.3	820.2	513.4	2.3	5.1	6.1	0.8%
Xishuangbanna	3778.3	213.6	1103.9	2081.2	21.6	46.7	47.4	3.4%
Other PAs in forest ecosystems	2788.3	267.2	632.1	481.9	7.0	24.8	9.1	3.0%
Total	9956.2	881.1	2556.1	3076.5	31.0	76.5	62.6	2.6%

Forest cover loss values indicate a conversion from forest to non-forest state in the period 2000 - 2016 (conversion from intact forest to degraded forest is not included). (Data from Hansen et al., 2013).

Figure 8.5 Deforestation trend in the UMB of Myanmar



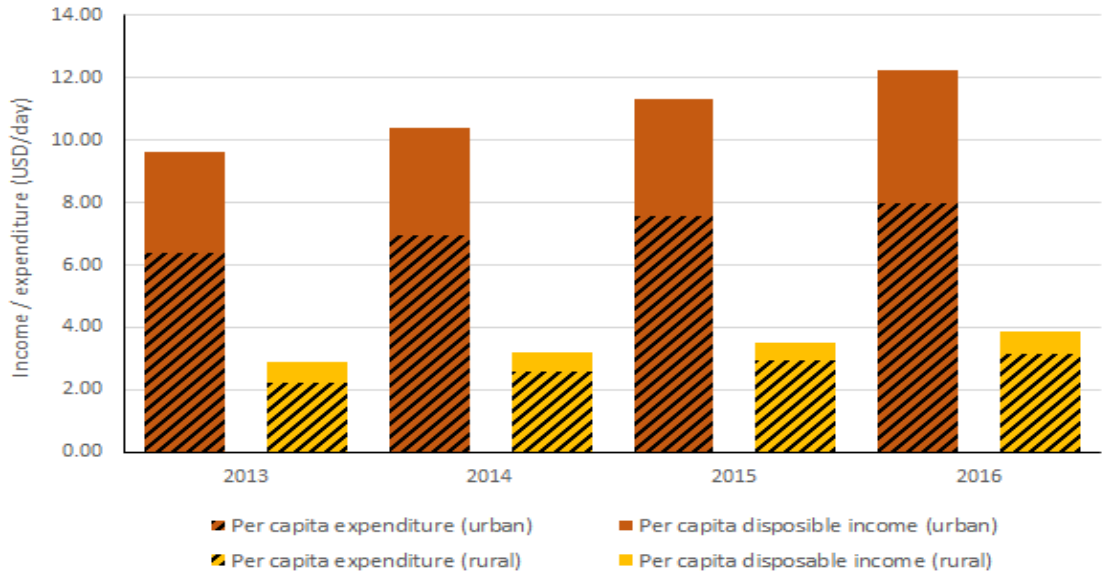
Adapted from IFC, 2017d

8.4 Social status and trends

Economic development and poverty alleviation efforts by China in the past years have led to an overall improvement of household living conditions in the UMB-C. This is illustrated by increased household incomes over 2013-2016 by 27% and 31% for urban and rural households respectively (Figure 8.6), as well as improved access to electricity (now at 100%) and access to medical facilities. However, in absolute terms, the gap between urban and rural household incomes and health security is still large and increasing.

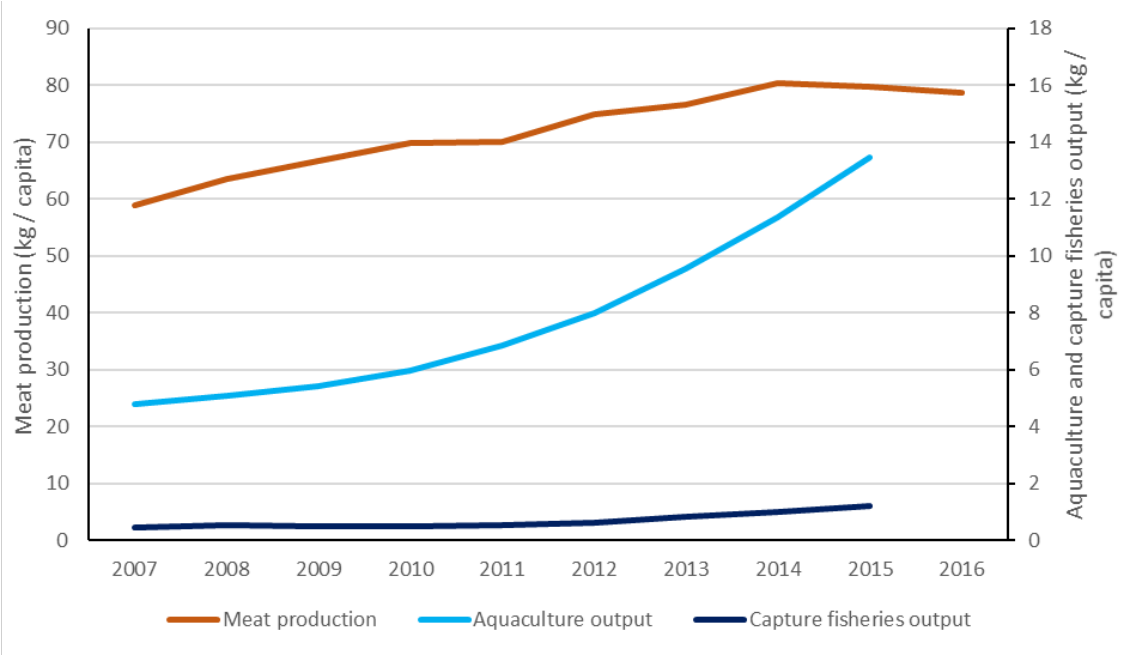
In terms of economic security and living conditions there is a sharp contrast with the UMB-M, one of the least developed areas of the Mekong Basin. Here, substantial parts of the population lack access to electricity (37.5%), safe water supplies (65.3%) or improved sanitation (64.5%). Almost half of the UMB-M population lives below the poverty line.

Figure 8.6 Per capita disposible income and expenditure of urban and rural households in Yunnan Province in 2013 – 2016



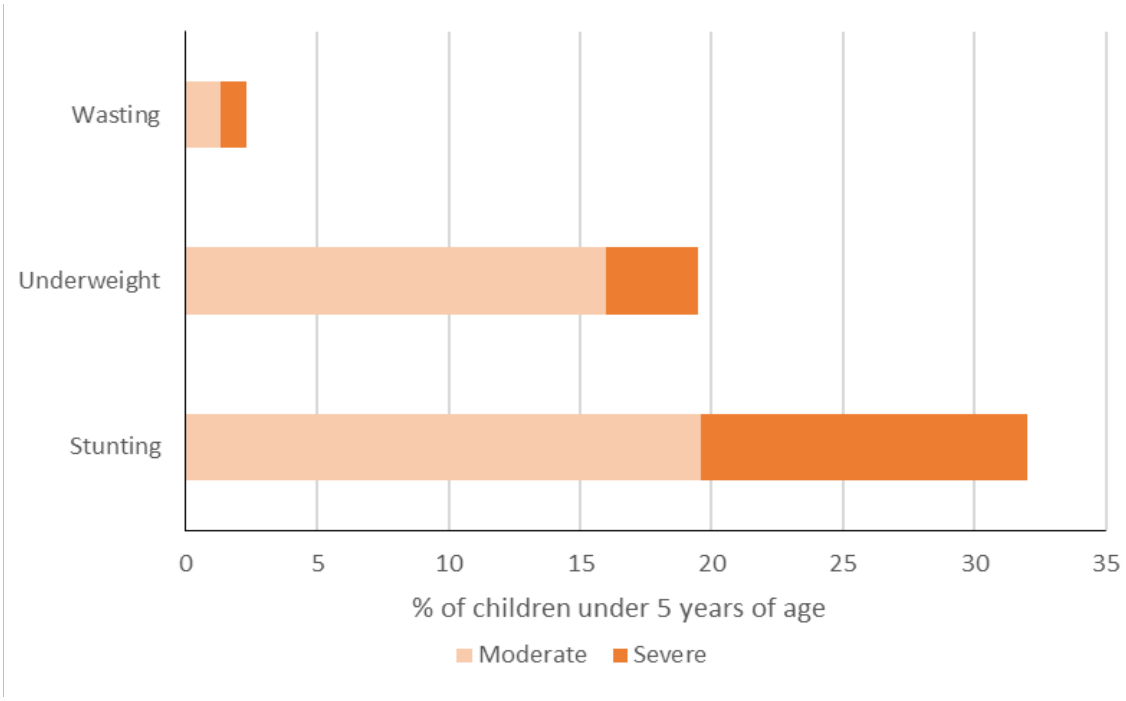
Food grain and protein production per capita in Yunnan Province have steadily increased over the past years. Based on these levels, lack of food security should not be a major issue for a large part of the UMB-C population, although recent statistics on nutrition have not been found. With 12% of the population having a per capita income below the poverty line in 2015, and often living in very remote areas, it is likely that a small part of the UMB-C population continues to be affected by food insecurity.

Figure 8.7 Protein production per capita in Yunnan Province, 2007 - 2016



The higher household poverty levels in the UMB-M are associated with lower food security, with 32% of all children under five reportedly suffering from either moderate or severe stunting in 2010.

Figure 8.8 Indicators of child malnutrition for Eastern Shan State, 2009-2010



Data from (MNPED et al., 2011)

With 46.3% of all employed persons being women in the UMB-C, gender engagement in employment can be considered as largely equal. There are, however, clear differences between sectors, with women comprising the majority of workers in livestock and tourism, and forestry and fisheries being male-dominated.

Table 8.3 Employment by gender and by sector in Yunnan province

Employment by sector	Total employed	Male		Female	
	no.	*no.*	*% of total*	*no.*	*% of total*
Agriculture	17,182,270	8,850,950	51.5%	8,331,320	48.5%
Forestry	140,930	101,040	71.7%	39,890	28.3%
Livestock	1,089,220	363,480	33.4%	725,740	66.6%
Fisheries	30,400	19,190	63.1%	11,210	36.9%
Tourism	185,190	63,010	34.0%	122,180	66.0%
Other	8,056,200	4,939,100	61.3%	3,117,100	38.7%
Total employed persons	**26,684,210**	**14,336,770**	**53.7%**	**12,347,440**	**46.3%**
Working age population	32,934,500	17,152,954	52.1%	15,781,546	47.9%

Data source: (NBS, 2011)

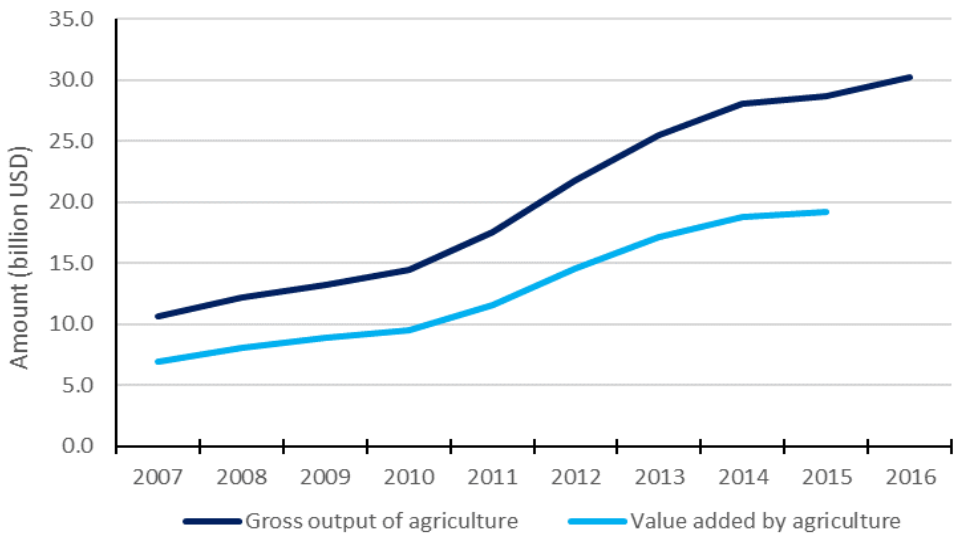
In the UMB-M, gender equality in employment is still some way off, with 55.0% of the female population of age 10 and over reported as economically active in 2014, as opposed to 77.4% of men.

8.5 Economic status and trends

8.5.1 Agriculture

The output and economic value of the UMB-C agricultural sector has rapidly risen over recent years, with the value added by agriculture having increased from US$ 6.9 to 19.2 billion for the entire Yunnan Province. Marked increases are especially observed with regards to production of vegetables, fruits, and tea.

Figure 8.9 Gross output and value added of the agricultural sector in Yunnan Province, 2007 - 2016



(Source: China's National Bureau of Statistics: China Statistical Yearbook 2017)

In Myanmar rice and maize are the most significant crops in terms of surface area, with tea, vegetables and fruits being important cash crops. Many UMB-M households are hardly able to make a living with the income obtained from selling their crop, often not lifting them above the poverty line per capita.

8.5.2 Hydropower

Extensive hydropower development has taken place in the UMB-C as part of China's national development strategy (see Figure 8.4 earlier). The existing dams (Table 8.4) with an installed capacity of over 100 MW had a total capacity of 19,285 MW in 2017 (mostly in Yunnan Province), with a further increase of 51.2% to 29,168 MW foreseen as the remaining planned infrastructure is commissioned over the coming years, including a cascade of reservoirs in Xizang Province (upper part of the UMB) (Table 8.5).

Total reservoir storage capacity could then arrive at over 54.6 BCM, most of which is on the mainstream. Part of the energy produced is transported across the country to fuel economic growth and industrial development in eastern China. The overall economic value of hydropower in the UMB-C is roughly estimated at US$ 3.7 billion per year, although this does not account for electricity losses across the distribution grid which are known to be substantial.

Although on a much smaller scale, hydropower is now also starting to be developed in the UMB-M, with the first dam commissioned in 2017 and construction of further dams by both Chinese and Myanmar developers expected (Table 8.6).

Table 8.4 Hydropower dams in the UMB of China with an installed capacity of over 100 MW

Project name	On mainstream (Y/N)	Commissioning year /status	Installed capacity	Mean annual energy	Total storage (FSL)	Estimated cost
			MW	*GW*	*MCM*	*Million USD*
Nuozhadu	Y	2012	5,850	23,912	23,703	3,681
Xiaowan	Y	2009	4,200	18,990	14,560	4,218
Huangdeng	Y	2018	1,900	8,578	1,613	2,631
Jinghong	Y	2008	1,750	5,570	1,140	1,121
Manwan	Y	1993	1,670	6,710	920	405
Miaowei	Y	2017	1,400	5,999	660	unknown
Dachaoshan	Y	2001	1,350	5,500	890	1,349
Gongguoqiao	Y	2011	900	4,041	316	1,369
GuoDuo	N	2015	160	823	83	618
Xi'er He 1	N	1979	105	440	unknown	unknown
Total			**19,285**	**80,563**	**43,885**	**15,392**

Data source: (CGIAR WLE Greater Mekong, 2018) as well as recent MRC studies.

Table 8.5 Planned hydropower dams in the UMB of China with an installed capacity of over 100 MW

Project name	On mainstream (Y/N)	Commissioning year /status	Installed capacity	Mean annual energy	Total storage (FSL)	Estimated cost
			MW	*GW*	*MCM*	*Million USD*
Gushui	Y	Under construction	2,600	8,337	3,912	unknown
Ru Mei	Y	Planned	2,100	10,582	3,602	6,297
Tuoba	Y	2023 (planned)	1,400	6,360	1,039	2,266
Banda	Y	Planned	1,000	5,234	938	3,620
Wunonglong	Y	2018 (planned)	990	4,116	284	1,139
Dahuaqiao	Y	2018 (planned)	920	4,070	293	11
Lidi	Y	2019 (planned)	420	1,753	75	830
Ganlanba	Y	Planned	195	1,177	577	669
Cege	Y	Planned	129	636	21	472
Yue Long	Y	Planned	129	644	unknown	502
Total			9,883	42,909	10,741	15,806

Data source: (CGIAR WLE Greater Mekong, 2018) as well as recent MRC studies. Cancelled projects are excluded.

Table 8.6 Key characteristics of hydropower projects in the UMB in Myanmar

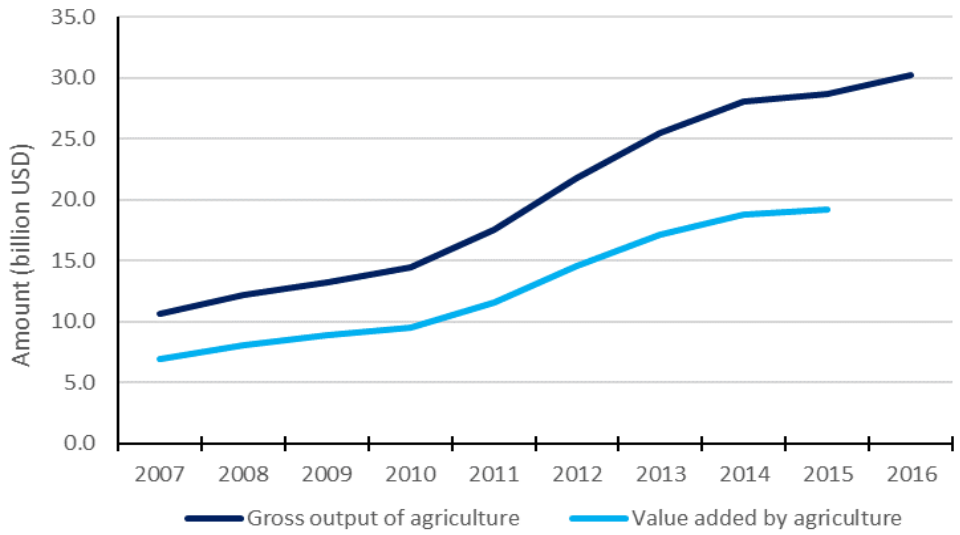
Project	Sub-basin	Type	Installed capacity (MW)	Annual generation (Gwh)	Implementation scheme	Commissioning year
Keng Tong	Nam Lwe	Storage	96	536.0	JV / BOT	Investigation stage
So Lue	Nam Lwe	Storage	165	742.0		
Keng Yang	Nam Lwe	Storage	28	155.0		
He Kou	Nam Lwe	Storage	88	483.0		
Mongwa	Nam Lwe	Storage	66	330.5	BOT with local entrepreneur	
Nam Lin	Nam Lin	Storage	36	156.0		
Mong Hsat	Nam Hkoke	-	-	-	BOT with local entrepreneur, managed by Regional Government	
Nam Hkoke	Nam Hkoke	-	-	-		

Source: Department of Electric Power Planning. Note: JV = Joint Venture, BOT = Build Operate Transfer.

8.5.3 Forestry

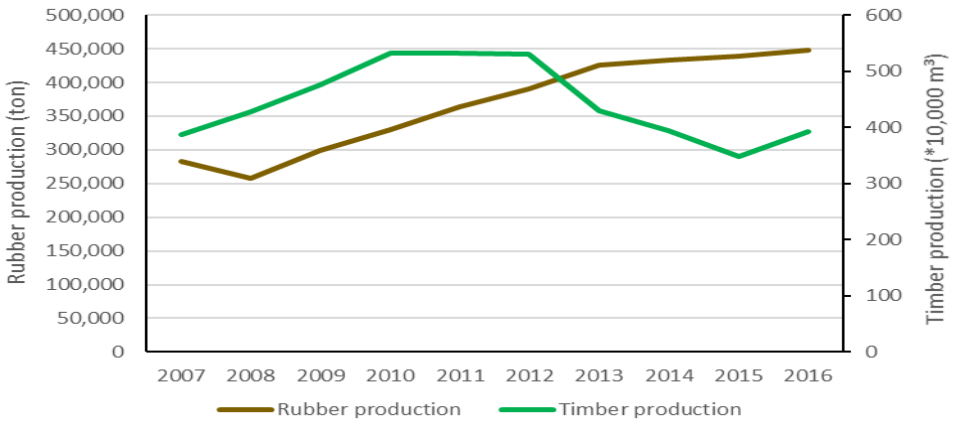
The overall value added of the forestry sector in Yunnan Province has increased steadily during 2007-2015 with approximately 9% per year (Figure 8.10). Timber production, however, has seen a decline over the period 2012-2016 of approximately 25%. This apparent discrepancy can be partly explained by the fact that rubber production in the southern UMB-C is still increasing, having risen with 59% between 2007 and 2016 (Figure 8.11).

Figure 8.10 Gross output and value added of the forestry sector in Yunnan Province, 2007 - 2016



Due to its attractiveness following government policies and rising market prices, former agricultural land and natural forests are being converted to monoculture plantations. Of the 450,000 tons of rubber production in Yunnan in 2016, the majority comes from Xishuangbanna Dai Prefecture in the UMB-C, with rubber plantations making up 30% of its total surface area in 2011.

Figure 8.11 Trends in output of timber and rubber in Yunnan Province, 2007 - 2016



Reduced timber production in the UMB-C is associated with substantial timber imports from Myanmar. These continue to make up an important part of the UMB-M economy, although now largely driven by illegal logging following the official ban on exports in 2014.

8.5.4 Mining

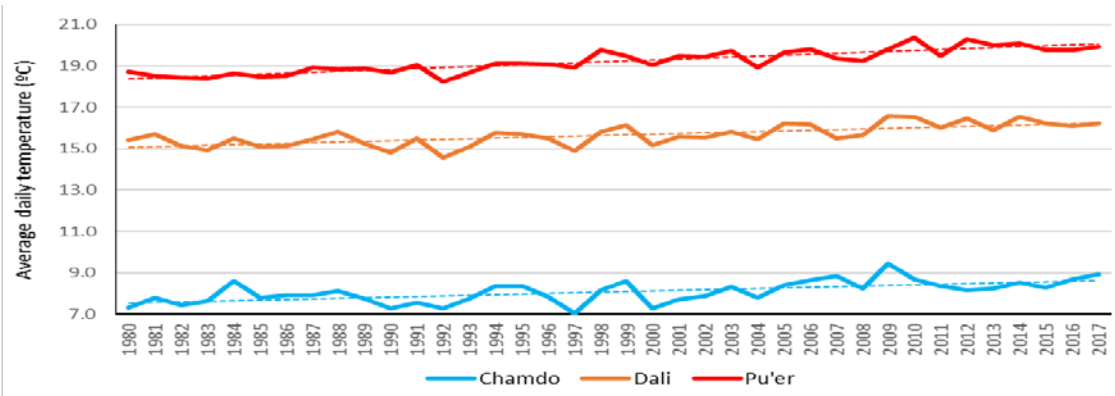
Mining of different resources, such as lead, zinc, tin and aluminium is another major contributor to UMB economy. Sand mining is a growing business in the UMB-C, driven by the extensive regional development of housing and infrastructure. However, very little quantitative information is available as to its economic value and impact.

8.6 Climate change status and trends

8.6.1 Changes in temperature and precipitation

Climate change studies are unambiguous with regards to a projected temperature increase in the UMB-C over the next decades. Analyses of station data at Chamdo, Dali and Pu'er over the period 1980-2015 paint a similar picture (Figure 8.12). In all three stations, each representing distinctive climate zones, statistically significant increasing trends are present in annual average daily temperature and lowest minimum temperature of the year.

Figure 8.12 Mean daily temperature per year for Chamdo, Dali, and Pu'er stations for 1980 - 2017



Note: Trend lines indicate statistically significant increasing trends ($p < 0.05$). Data were obtained from the GSOD station database (NOAA, 2018).

Precipitation patterns are more complex and show less clear trends, although results do suggest a reduction of extreme rainfall amounts. No significant long-term trends in rainfall-related indicators were observed for Kengtung station in the UMB-M.

Table 8.7 Significant trends (P < 0.05) identified for each of the precipitation metrics and stations

Indicator	Chamdo	Dali	Pu'er
Total precipitation per year / Annual SPI			
1-day maximum precipitation per year	Decreasing		Decreasing
No. of heavy precipitation days per year	Decreasing	Decreasing	
Maximum no. of consecutive dry days per year		Increasing	
Maximum no. of consecutive wet days per year			

Note: A blue colour indicates a significant decreasing trend, a red colour a significant increasing trend

8.6.2 Extent and severity of floods and drought

With regards to hydrological extremes, the most recent significant flood event of the Upper Mekong mainstream occurred in 2006 at Jinghong. Rising temperatures due to climate change are projected to cause a shift in snowmelt patterns, with melting of seasonal snow likely to contribute to streamflow in the months March to May rather than coinciding with the rainy season, as is currently the case. In conjunction with the extensive storage capacity that has been developed in the Upper Mekong mainstream, this implies that flooding of the mainstream is less likely to occur in the future. However, local flash flood events are an increasing problem particularly in the UMB-M, with their frequency increasing due to uphill deforestation, slash-and-burn agriculture and conversion to rubber monoculture.

Droughts are becoming an increasingly serious issue in the UMB-C. This trend is especially observed in its middle section which supports a significant part of the population, including Dali, one of the main urban centres. Drought events in recent years have impacted agriculture and household water security, among others. Climate change is expected to further exacerbate drought severity by enhanced evapotranspiration through higher temperatures.

8.7 Cooperation status and trends

Cooperation between China and the Lower Mekong countries is increasingly taking place within several frameworks.

The relationship between MRC and China, **a dialogue partner**, is long standing and continues to grow. As part of their collaboration, MRC and China share data and information, and conduct annual dialogue meeting, joint technical symposiums, exchange of visits, and joint studies. China and MRC are currently executing a joint research on hydrological impacts of the UMB hydropower cascade on downstream extreme events such as floods and droughts. As an important outcome of increased cooperation, China decided to implement its emergency water supplement during the 2016 drought by increasing discharge from Jinghong Reservoir, in order to alleviate drought impacts in the LMB.

A recent development is the setup of the **Mekong Lancang Cooperation** (MLC) mechanism involving all riparian countries including China and Myanmar, which includes the establishment of the Lancang Mekong Water Resources Cooperation Centre (LMWRCC). The LMWRCC aims to carry out joint research and analysis as well as capacity building related to Mekong-Lancang water resources and influences of climate change, implement pilot projects and priority cooperation projects on sustainable water resources development, improve the water quality monitoring system and flood and drought disaster emergency management, and strengthen data and information sharing.

Other notable joint projects in water-related sectors in the Mekong region such as fisheries, navigation, agriculture and environment are undertaken as part of several regional cooperation frameworks. China and Myanmar are both involved in the **Greater Mekong Sub-region** (GMS) initiative and the **Joint Committee on Coordination of Commercial Navigation** on the Mekong (JCCCN), which has developed the Development Plan of International Navigation on the Mekong-Lancang River (MLDP) that is currently being implemented.

Myanmar engages in several regional initiatives implementing activities with basin-wide impacts. As a **Dialogue Partner**, the government of Myanmar sends high-level participants to MRC summits and Council meetings. Myanmar and MRC cooperate on improving hydro-meteorological coverage, exchanging technical expertise in flood prevention and management, and navigation safety. Cooperation may be further extended as an outcome of the 3rd MRC Summit

As a member of **ASEAN**, Myanmar is involved in the development of a regional vision and implementation of development projects across a variety of sectors, including fisheries and navigation. In addition, Myanmar is engaged in the Ayeyarwady-Chao Phraya-Mekong Economic Cooperation Strategy (**ACMECS**), and the Cambodia-Laos-Myanmar-Viet Nam cooperation initiative (**CLMV**). ACMECS involves Myanmar and the four LMB countries and its current Plan of Action (2016-2018) covers eight areas, including agriculture and environmental cooperation, and specifically aims to strengthen its collaboration with MRC. During CLMV's 2018 summit, the member countries agreed to further deepen cooperation in several target areas, including infrastructure connectivity and agriculture.

The completed and planned development of storage capacity in the UMB has significantly altered river dynamics, but also provides an unprecedented opportunity to manage a substantial part of the overall Mekong flow volume and thereby affect all water-related sectors, particularly in the upper reaches of the LMB. This illustrates the importance of continuing and strengthening cooperation between the upper and lower riparian countries to ensure effective river basin management, in order to allow for sustainability of all benefits provided by the river.

9. Conclusions and recommendations

9.1 Summary of key conclusions on the State of the Basin

In its new format, this State of the Basin Report follows a structured approach to assessing the current status and past trends of conditions in the Mekong River basin. This approach, which is built on the foundation laid by the newly constructed MRC Indicator Framework, is intended to provide a comprehensive basin-level view of those conditions most relevant to the aims and intent of the MRC in fostering optimal and sustainable development and management of the basin's water-related resources.

The following sets out the main conclusions that can be drawn from the preceding chapters in terms of the development status, challenges and opportunities to achieve MRC's aims. These conclusions are structured around the 13 agreed strategic indicators [38] and the associated key questions (one for each indicator), intended to articulate the underlying issues that each strategic indicator is intended to address.

The overall conclusions are first summarised in Table 9.1 overleaf to provide the reader with a complete overview of the State of the Basin, based on the assessments made in the preceding chapters. These conclusions are then amplified in the following Section 9.2, which sets out for each indicator the development status and challenges to achieving MRC's aims. Section 9.2 also includes an assessment of conditions within the LMB with regard to the six UN Sustainable Development Goals considered most relevant to the MRC's mandate. Thereafter, Section 9.3 draws together the identified priority actions (including apparent development opportunities) for consideration in updating the Basin Development Strategy.

9.2 Development status and challenges to achieving MRC's aims

9.2.1 Environmental dimension

(i) **Water flow conditions in mainstream***: Are the conditions of water flow in the Mekong mainstream acceptable?*

Dry season water availability: Currently, dry season flows are generally conforming with PMFM requirements. At Chaeng Saen, the uppermost mainstream monitoring station in the LMB, dry season flows are now being significantly augmented by the new storage reservoirs in China, opening the potential for increased irrigation abstractions, but underscoring the need for effective monitoring of irrigation abstractions to ensure that the supply-demand balance is maintained within acceptable bounds in the future. Increased regulation within the basin is also causing significant fluctuations in daily flows in some instances, requiring more careful management of reservoir releases.

38 The current version of the MRC-IF has a total of 15 strategic indicators. Two of these (Overall Environment Condition and Overall Social Condition) represent the combined evidence of the other strategic indicators within the Environment and Social dimensions, respectively. As a result, specific conclusions and recommendations are not presented separately for these two strategic indicators.

Table 9.1 Summary of conclusions and challenges and recommended priority actions

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Insufficient data to form a view, requires action to address knowledge gaps*

Strategic indicators	Key strategic questions		Status /condition	Challenges	Recommended priority actions	BDS Recommendation
Environment						
Water flow conditions in mainstream	*Are the conditions of water flow in the Mekong mainstream acceptable?*	●	Generally compliant with PMFM, but induced changes in flow regime are of some concern	Managing the impacts of an apparent decrease of wet season flow during the recession period, the increase in dry season low flows and the increase in daily fluctuation in flows experienced in some reaches of the mainstream	Continue monitoring programmes and, in addition to PMFM reporting, monitor decreases in wet season flows and daily fluctuations and consider implications of impacts that may arise,	A
					Improve monitoring of water use for various sectors to ensure balance is maintained with increased development	B
Water quality and sediment conditions	*Are the conditions of water quality and sediment acceptable?*	●	Generally compliant with PWQ, but sediment concentrations much reduced	Identifying and implementing practical measures to mitigate the effects of reduced sediment concentrations and minimise further reductions	Continue the sediment and water quality monitoring programmes.	A
					Address the implications of reduced sediment concentrations through mechanisms to better manage sediment flows and mitigate transboundary impacts of reduced concentrations	B
Status of environmental assets	*Are key environmental assets in the Mekong basin being adequately preserved and protected?*	●	Loss of wetlands and riverine habitats continues, pressure on capture fisheries becoming evident	Taking urgent action to protect remaining assets and to better manage fisheries	Agree clear regional objectives, joint strategies and action plans for protecting and sustainably managing the remaining environmental assets and fisheries.	A
				Addressing the lack of sufficient data on wetland and riverine habits	Establish regular monitoring and data collection to address knowledge gaps and conservation activities for wetlands and other environmental assets including fisheries.	B
Social						
Living conditions and well-being	*What social benefits, direct and indirect, are being derived from water resource developments in the Mekong basin?*	●	Living conditions improving but water sector impacts unclear	Provincial and district levels data needed to better understand relationship with water-related sectors alongside greater consistency of data quality and accuracy.	Review and refinement of indicators and develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B
Employment in MRC water-related sectors	*How are the river-related livelihoods in each country being affected by land and water management decisions?*	○	*More information is needed to form a view*	*As above*	*As above*	B

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Insufficient data to form a view, requires action to address knowledge gaps*

Strategic indicators	Key strategic questions		Status /condition	Challenges	Recommended priority actions	BDS Recommendation
Economic						
Aggregate economic value of MRC water-related sectors	*What economic value does each Member Country derive from the use of the Mekong river system within the water-related sectors?*	○	*More information is needed to form a view*	Comprehensive data on all water-related sectors need to be assembled and analysed.	Review and refinement of indicators and develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B
				Promotion of economic development consistent with the aims of the 1995 Mekong Agreement.	Adoption of pro-active regional planning to promote optimal and equitable development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims	E
Contribution to basin economy	*How important is the economic value of the water-related sectors to the economy of the basin?*	○	*More information is needed to form a view*	*As above*	*As above*	B/E
Climate change						
Greenhouse gas emissions	*To what extent is the Mekong Basin contributing to global GHG emissions?*	●	LMB countries (as a whole) emission is about 1.5% of global total	Promote development practices within the basin that minimise GHG emissions consistent with each country's Nationally Determined Contribution under the Paris Agreement	Promotion of development practices that minimise GHG emission.	E
					Develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B
Climate change trends and extremes	*Is there evidence of climate change within the basin?*	●	Some evidence of rising temperatures and sea-levels. Flood damages are also higher. Other CC impacts are not seen.	Continued monitoring needed Continued assessment of potential future CC impacts based on latest available global and regional forecasts	Incorporate sea level rise as an indicator in future SOBR.	E
					Continue hydro-meteorological data collection programmes.	A
Adaptation to climate change	*How resilient are the current water infrastructure and plans to climate change?*	●	All countries have policies and strategies in place and 166 climate adaptation projects identified (2016)	To ensure that climate change is fully factored into development plans and that resilience is assured	Adoption of pro-active regional planning to address climate change and promote optimal and equitable development through increased cooperation	E

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Insufficient data to form a view, requires action to address knowledge gaps*

Strategic indicators	Key strategic questions		Status /condition	Challenges	Recommended priority actions	BDS Recommendation
Cooperation						
Equity of benefits from the Mekong River system	*How well is Mekong basin development moving towards optimal and sustainable development?*	○	Significant development in all countries, *but equity considerations need more data as above*	Adoption of pro-active regional planning to promote equitable use of basin's resources, together with establishment of a clear mechanism to define equity of benefit and trade-off arising from development in throughout the basin in water-related sectors	Adoption of pro-active regional planning to address climate change, promote optimal and equitable development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims	E
Benefits derived from cooperation	*What is the added value of cooperation under the 1995 Mekong Agreement facilitated by MRC?*	●	US$838m of projects supporting cooperation identified in National Indicative Plans	*As above*	*As above*	E
Self-finance of the MRC	*Is the MRC on-track to self-finance by 2030?*	●	MRC budgets in line with achieving self-finance by 2030, alongside renewed commitments to this end	Retain focus on core function activities and look to ways to improve efficiency in delivering these	Identify smart and cost-effective approaches to basin monitoring and information and knowledge sharing	B

Note: BDS recommendations A – E are elaborated in Section 9.3.2

Flood season flows: Whilst tropical storms and precipitation patterns are not showing any marked change to flood season flows, the value of the flood damages appears to be increasing, possibly due to the higher value of assets exposed to flood risk, a cause of concern together with the exacerbating effect of sea level rise in the coastal areas. Recent years have also shown some diminishment of flood flows during the flood recession period, the implications of which need to be considered carefully.

Overall, whilst the conditions of water flow in the Mekong mainstream remain generally in conformity the requirements of PMFM, increasing regulation within the basin is causing a progressive change in the natural flow regime in both the wet and dry seasons. Whilst peak floods may be reducing somewhat, the reduction in natural wetlands and the increasing value of assets exposed to flood damage presents real challenges to development planners. Increases in dry season flows open the opportunity for further abstractions, but this needs to be carefully monitored to ensure acceptable balances are maintained. Continued flow and water use monitoring is needed with attention paid to the impacts of wider flow regime change (beyond the strict bounds of PMFM) and to the requirements for an integrated approach to flood management.

(ii) **Water quality and sediment conditions***: Are the conditions of water quality and sediment conditions acceptable?*

Water quality and sediment flows: Although there are some points of local concern, water quality conditions within the basin generally show no reason for immediate concern, but continued monitoring is recommended.

Sediment flows: On the other hand, sediment concentrations in the mainstream have reduced dramatically since the construction of upstream storage reservoirs, signalling a substantial and seemingly permanent change in the river's morphology. Potential impacts include those on river bank and bed erosion, key environmental assets and on coastal building processes. Fewer nutrients will reach the remaining wetlands, impacting on wetland functionalities and procuctivity.

Thus, whilst continued monitoring and conducting comprehensive studies of water quality and sediment concentrations and nutrient flow throughout the basin remains important, understanding how the changes in sediment concentrations and nutrient flow will impact on the river, the environment and the socio-economic development is critical to determining coping strategies by which to better manage sediment flows and mitigate the transboundary impacts of reduced sediment concentrations.

(iii) **Status of environmental assets***: Are key environmental assets in the Mekong basin being adequately preserved and protected?*

Environmental assets: Environmental assets are widely under threat from development pressures. Wetlands are greatly diminished and at risk of disappearing altogether if no preventive action is taken. Riverine habitats are under threat from changed flow regime as a result of new storages in the basin re-regulating flows and backwater effects.

Capture fisheries: The basin's capture fisheries, which represent around a third of the annual economic value of the basin's resource utilisation, are showing increasing signs of pressure. Although overall wild fish production seemingly remains unchanged, it is under threat from both new mainstream and tributary dams disconnecting fish from their spawning grounds. Furthermore, the rise in fishing effort accompanied by the reduction in the size of fish caught is indicative of heavy fishing pressures.

Thus, the status of environmental assets in the Mekong basin should be seen as a source of major concern. Urgent action is needed to protect, preserve and enhance the remaining assets and fisheries through the active cooperation of Member Countries and other stakeholders. Clear and mutually agreed regional objectives are needed along with joint strategies and action plans for protecting and sustainably managing these remaining assets. In addition, it is important that basin-wide monitoring of wetlands and other environmental assets including fisheries is taken up as a core function on a regular basis.

9.2.2 Social dimension

(i) **Living conditions and well-being:** *What social benefits, direct and indirect, are being derived from water resource developments in the Mekong basin?*

Whilst the MRC does not undertake specific social improvement programmes, the intent is that water resource-related projects undertaken within the MRC mandate should have a significant and overall positive impact on socio-economic conditions. As reported here, overall living conditions and well-being in the LMB have improved significantly over the last fifteen years, together with improvements in food and water security, health status and access to electricity.

Drought susceptibility remains a problem in some areas, and there are some indications that damage due to flooding is increasing, although again this may be the result of greater investment in the region putting more expensive assets at risk. Health security indicators have also seen improvement in terms of improved access to basic sanitation and access to health services.

Nevertheless, there remains significant variation in performance between LMB countries largely reflecting their differing stages of development. There is also likely to be substantial sub-national variation in performance which is not picked up by these largely national level assessments.

Thus, whilst there are grounds to believe that living conditions and well-being within the basin are definitely improving, with the data currently available it is not possible to distinguish what social benefits are being derived from water resource developments within the basin. Given the problems faced with accessing spatially disaggregated information relevant to the LMB, MRC needs to reflect upon whether employing different and "smarter" social indicators would lead to an improved situation, which would enable MRC to better identify and support vulnerable communities. As with environmental data, social data collection needs to become a core function on a regular basis.

(ii) **Employment in MRC water-related sectors***: How are the river-related livelihoods in each country being affected by land and water management decisions?*

The main water related economic sectors in the LMB are agriculture, fisheries and navigation and to a lesser extent, hydropower, tourism and forestry. Whilst employment in water-related sectors in the LMB remains high, in agriculture it is somewhat declining as work opportunities elsewhere develop. Employment in capture fisheries remains important for livelihoods, but often only as a source of secondary employment. Employment in tourism and the navigation sectors is likely to grow rapidly.

The poverty rate has fallen dramatically across all LMB countries, approximately halving in the last decade and by around three-quarters since the turn of the century, most probably linked closely to changes in patterns of employment and improved productivity in the primary sectors.

Gender disaggregated data on employment in agriculture and related sectors points to small but persistent differences in male and female employment patterns. The GPI for primary school enrolment shows continuing gender disparities in the region, particularly in Lao PDR and Cambodia.

However, as with living conditions and well-being, more detailed data are needed from within the LMB for MRC to better understand the situation and formulate gender-balanced development strategies.

9.2.3 Economic dimension

(i) **Aggregate economic value of MRC water-related sectors:** *What economic value does each Member Country derive from the use of the Mekong river system within the water-related sectors?*

The annual economic value of the water-related sectors assessed in this report is just under US$ 35 billion per year, excluding tourism and forestry. The different sector values are listed below in order of descending value.

The economic value of the 2.3 million tonnes of annual **capture fish production** is estimated to be currently about US$ 11.2 billion, representing about 65% of the total value of all types of fisheries production. Of this Thailand is the largest producer with US$ 6.3 billion and Cambodia second at US$ 2.8 billion annually.

Irrigated agriculture has grown from virtually nil in the 1950's to over 5.7 Mha in 2013 (nearly 80% of which is in Viet Nam), with a total economic value of US$ 7.7 billion per year (although this may not capture fully the significant amounts of small-scale and informal irrigation).

The Mekong River has long been an important **inland waterway for cargo and passenger transport.** The IWT cargo in 2007 was worth US$ 6.8 billion annually and continues to increase, notwithstanding stiff competition from road transport. Between 2007 and 2014, total passenger numbers have risen from 37.6 million annual to 69.4 million, over 800,000 of whom were tourists.

Aquaculture has grown rapidly and was valued in 2015 at US$ 5.8 billion, up from US$4.6 billion in 2010 and US$0.7 billion in 2003. Viet Nam is by far the largest producer, accounting for 86% of the basin's production value. In addition, reservoir fisheries were worth US$1.2 billion in 2015, up from US$ 0.7 billion in 2010.

Tourism has developed rapidly in all the LMB countries brining in about US$65 billion annually to all four countries, but not necessarily within the basin. Nevertheless, national figures for Cambodia (US$3.5 billion in 2016) and Lao PDR (US$0.7 billion in 2016) may provide some guide to international tourism in the LMB in these two countries.

The annual value of **wetlands and the services they provide** is tentatively estimated to have been US$ 2.9 billion in 2010, down from US$ 3.6 billion in 2003, due to a 20% reduction in the extent of wetlands during that period.

By 2015, **59 hydropower projects** of between 1 MW and 4,200 MW had been developed in the LMB with a total installed capacity of 10,017 MW, representing some 35% of the total estimated technical hydropower potential for the LMB. The gross economic value of hydropower production has increased from US$ 0.55 billion per year in 2005 to over US$ 2 billion in 2015, over 50% of which accrues to Lao PDR.

Estimates made of **forestry output** value in the LMB suggest that the annual sustainable fuelwood production in the LMB was worth US$ 0.4 billion in 2010, rising to US$ 1.4 billion in 2016.

The economic value of **flood damages** during 2010-2014 shows that the annual cost varied between US$ 0.02 billion (2012) up to US$ 0.5 billion (2011), with an average during this 5-year period of US$ 0.2 billion per year, excluding those related to flash floods.

Sand mining in the LMB is extensive with rapidly increasing demand driven by infrastructure development in the delta, as well as for regional export. The sector is believed to be worth currently about US$ 175 million annually. Estimates of the annual cost of **river bank and coastal erosion** have not been possible to generate throughout the LMB, but over the last few years the value of land lost in Lao PDR is about US$ 100,000 per year.

Thus, as may be seen above, economic developments within the basin of the water-related sectors are important for each Member Country. However, some developments are known to impact on others, requiring trade-offs to be considered, in some cases between sectors and in others between countries as well. MRC can facilitate discussion of these trade-offs, which would be much enhanced if a process of pro-active regional planning is taken up by MRC to promote optimal and equitable development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims.

To achieve this, a comprehensive and up-to-date understanding of the rapidly evolving status of sectoral developments is essential for MRC to facilitate consideration of these trade-offs. As with the social indicators, there is an evident need to review and refine the indicators and data acquisition requirements and for economic data collection to be established as a core function within MRC on a regular basis.

(ii) **Contribution to basin economy**: *How important is the economic value of the water-related sectors to the economy of the basin?*

The LMB water-related economic sectors contribute to overall economic, food and energy security within the Basin and beyond as measured by their contribution to national and regional GDP, food grain supply, protein supply and power supply. As may be seen above, the LMB and water related sectors within it continue to contribute significantly to the broader national and regional economy. Their importance is particularly marked when considering the contribution of rice production in the Mekong delta to national rice production in Viet Nam. Similarly, the importance of hydropower production to domestic power supply is important across the basin but particularly in Cambodia and Lao PDR, as are power exports from Lao PDR to Thailand.

Nevertheless, a comprehensive view of the importance of the water-related sectors to the economy of the basin has not been possible to form because of data availability issues. As above, actions are needed to remedy this situation.

9.2.4 Climate change dimension

(i) **Greenhouse gas emissions**: *To what extent is the Mekong Basin contributing to global GHG emissions?*

Greenhouse gas emissions of the LMB countries as a whole contribute currently less than 2% of global emissions. Electricity generation, industry, transportation, and agriculture are the main sectors contributors. Data for emissions from the LMB only are not available, but seemingly the LMB may contribute well below 1% of total global emissions. However, emission rates appear to be growing faster than the global average.

Whilst the Mekong Basin is a relatively small contributor to global GHG emissions, it remains important that development practices are promoted that minimise GHG emission within the basin. Furthermore, continued monitoring through enhanced regional and national data collection programmes is needed.

(ii) **Climate change trends and extremes**: *Is there evidence of climate change within the basin?*

Climate change is apparent in terms of both temperature rise and sea level rise. However, in other respects (precipitation, storms, etc), there are no clear trends established.

Increasing temperatures will impact on snow melt, agricultural productivity, irrigation demands and some ecological functions. Sea level rise is a more direct threat for Viet Nam and one which warrants the active attention which Viet Nam is already devoting to it, as well as the wider joint projects to identify upstream transboundary flood management works.

Thus, there is already some evidence of climate change affecting the LMB and it seems important that sea level rise should be adopted as an indicator in the MRC-IF. Current and future projections of further climate change need to be monitored, studied and factored into future basin plans.

(iii) **Adaptation to climate change***: How resilient are the current water infrastructure and plans to climate change?*

All countries have policies and strategies to address climate in place with departments (or similar) set up to implement these. The United Nations Framework Convention on Climate Change (UNFCCC) has been ratified by all four Member Countries and each country has now submitted at least two National Communications to the Convention and committed to a Nationally Determined Contribution. In 2016, some 166 climate adaptation projects could be identified.

At the regional level, the Climate Change and Adaptation Initiative of MRC has developed a Mekong Adaptation Strategy and Action Plan (MASAP) which seeks to provide guidance on mainstreaming adaptation, particularly transboundary, measures across the LMB.

Thus, each Member Country and the MRC as a whole have made considerable commitment to addressing the need to adapt to climate change. The challenge ahead is to ensure that these positive steps are factored into basin planning at a regional level to address climate change as an input to promoting optimal and equitable development throughout the basin.

9.2.5 Cooperation dimension

(i) **Equity of benefits from the Mekong River system***: How well is Mekong basin development moving towards optimal and sustainable development?*

The benefits derived from the Mekong River system cover the environmental, social and economic dimensions. For the reasons given above, quantification of the relative benefits enjoyed by each Member Country is not possible until more data are assembled and assessed.

However, it may be observed that significant use is being made already of the water-related resources of the basin in all four countries. The challenge ahead is to build upon this through cooperative supra-national planning to continue to manage and develop these resources in an equitable manner towards optimal and sustainable development of the basin as envisaged in the 1995 Mekong Agreement.

(ii) **Benefits derived from cooperation***: What is the added value of cooperation under the 1995 Mekong Agreement facilitated by MRC?*

The assessments in this report demonstrate that, in many respects, the cooperation envisaged in the 1995 Mekong Agreement is happening and continuing to strengthen as a consequence of a greater shared understanding of development opportunities and transboundary issues within the basin. Cooperation with the upper riparian countries has also been enhanced, both China and Myanmar having demonstrated an increasing commitment to cooperation, including sharing data and information and conducting joint activities.

The refreshed 5-yearly planning cycle of the MRC provides an opportunity for Member Countries to work closely together to promote projects of basin-wide significance and joint project, both of which can contribute to moving towards optimal development of the basin. In the current National Indicative Plans, projects worth US$38 million have been identified in this regard.

Nevertheless, there remains the issue identified above of the sharing of information on current development facilities, water use and more broadly the socio-economy of the basin. In addition, this report highlights the need for Member Countries to formulate a collective response to the potential opportunities and current threats that prevail within the basin. Art. 24 of the Mekong Agreement empowers the MRC to adopt a more proactive stance to basin planning, including managing trade-offs between hydropower and fisheries more efficiently. As suggested also by the recent Council Study, there is a need for MRC to devise and agree regional policies with the objective of ensuring mutually shared benefits and costs to sustain water development in the region.

(iii) **Self-finance of the MRC***: Is the MRC on-track to self-finance by 2030?*

The Member Countries have reiterated their commitment to the 1995 Mekong Agreement at successive high-level summit meetings and are committed to a reform programme with an aim for progressive self-financing and equitable contributions from each country to be achieved by 2030. Annual budgets for the MRC are in line with these objectives.

However, as the MRC progressively takes up its defined core river basin management functions, so it is apparent that the cost of delivering these functions needs to be kept to a practical minimum. State of Basin monitoring represents a significant part of these costs and therefore it is incumbent upon the organisation to look to ways to undertake the necessary monitoring in as "smart" a way as possible.

9.2.6 State of the Lancang Basin

Inclusion in this report of Chapters on both Myanmar and China's activities within the river basin are intended to promote a greater understanding of the status of development issues within their parts of the basin. In both instances, continued dialogue and technical exchanges can only help to boost the mutual understanding of all riparian states of the issues and concerns each has. Whilst the impact of any likely developments in Myanmar on the LMB can be expected to be small, current developments in China have had already a substantial impact on LMB mainstream flow and sediment conditions. Three potential challenges for the LMB have been identified.

Firstly, China plans to develop eight further storages upstream of their current dams. Potentially, these dams may cause further changes to flow conditions in the LMB, although this is likely to be much less marked. Nevertheless, MRC needs to understand the long-term implications of these developments.

Secondly, the dams already developed in China are trapping significant quantities of sediments, greatly reducing sediment concentrations in the Mekong mainstream. Anecdotal reports suggest that the sediment trapped already represents a small but growing proportion of the storage currently available in China. The question that arises is what may happen if and when the trapping reaches levels that affect the overall operation of the cascade of dams in China? Whilst this may be many years ahead, MRC needs to have early warning of any actions planned by China in this regard.

Thirdly, at a day-to-day operational level, China has the capacity to cause substantial and sudden changes to LMB mainstream flows, either in emergency situations or during periods of unusual upstream inflows into the cascade. Sudden and large changes can have serious consequences for those downstream. The MRC has already entered into dialogue with China over such issues of flow management to minimise the risk of their occurring and this needs to continue.

9.2.7 Progress towards achieving SDG 6 in the Mekong-Lancang Basin

As noted in Section 1.4, the MRC's aims overlap many of the UN's Sustainable Development Goals (SDG). Whilst SDG 6 (Clean water and sanitation) is seen as the strongest connection, it has been recognised that MRC's policies, strategies and activities have relevance also to Goal 2: Zero hunger; Goal 7: Affordable and clean energy; Goal 13: Climate action; Goal 14: Life below water; and Goal 15: Life on land.

Each of the selected six Goals has associated with it a set of targets and indicators determined by the United Nations. Not all these targets and indicators are directly relevant to MRC. In some cases, data are currently not available either at all or specific to the LMB part of each Member Country, notwithstanding the relevance of the SDG. In some instances, the SDG indicators are simply not covered by the existing MRC-IF and this SOBR.

Nevertheless, a commentary on the current status of these indicators is provided in Table 9.2, based on the findings of this report. MRC will need to consider further how best support Member Countries in monitoring progress toward the SDG for future editions of the SOBR.

Table 9.2 Progress towards achieving selected SDG within the Mekong-Lancang Basin

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
SDG6	**Ensure availability and sustainable management of water and sanitation for all**				
6.1	By 2030, achieve universal and equitable access to safe and affordable drinking water for all	6.1.1	Proportion of population using safely managed drinking water services	●	*Nationally, by 2015, 70-97% of rural population have access to safe water supplies. LMB specific data not available.*
6.2	By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations	6.2.1	Proportion of population using safely managed sanitation services, including a hand-washing facility with soap and water	●	*Nationally, by 2015, Thailand had 95% of its population with access to at least basic improved sanitation facilities, Viet Nam 78%, Lao PDR 73% and Cambodia 49%. LMB specific data not available.*
6.3	By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally recycling and safe reuse globally	6.3.1	Proportion of wastewater safely treated	○	*Not reported on in SOBR*
		6.3.2	Proportion of bodies of water with good ambient water quality	●	*Mainstream and tributary water quality generally suitable for human and environmental purposes with only minor pockets of concern.*
6.4	By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1	Change in water-use efficiency over time	○	*Not reported on in SOBR*
		6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	●	*Water abstractions remain at levels that allow minimum acceptable flows in the mainstream in accordance with MRC agreed criteria*
6.5	By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1	Degree of integrated water resources management implementation (0-100)	●	*LMB countries committed to overall basin planning, have adopted Basin Development Strategy and are taking up joint projects*
		6.5.2	Proportion of transboundary basin area with an operational arrangement for water cooperation	●	*MRC policy, procedures and strategic guidelines in place covering entire LMB for equitable and sustainable use of Mekong water resources*
6.6	By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes	6.6.1	Change in the extent of water-related ecosystems over time	●	*The decline in wetlands continues and the quality of fisheries resources is reduced. Deforestation appears now to be being reversed in some areas. Mainstream flow regime changes induced by new storages threaten eco-systems*

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
6.A	By 2030, expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies	6.A.1	Amount of water- and sanitation-related official development assistance that is part of a government-coordinated spending plan	○	*Not reported on in SOBR*
6.B	Support and strengthen the participation of local communities in improving water and sanitation management	6.B.1	Proportion of local administrative units with established and operational policies and procedures for participation of local communities in water and sanitation management.	○	*Not reported on in SOBR*
SDG2	**End hunger, achieve food security and improved nutrition and promote sustainable agriculture**				
2.1	By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	2.1.1	Prevalence of undernourishment	●	*Undernourishment has declined in all LMB countries. Nationally in 2016, undernourishment was 15% in Cambodia, 17% in Lao PDR, 11% in Viet Nam and 10% in Thailand. No data available for LMB areas.*
		2.1.2	Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)	●	*Adequacy of Dietary Energy Supply nationally in 2016 was 122% in Viet Nam, 113% in Thailand, 112% in Cambodia and 106% in Lao PDR. No data available for LMB areas.*
2.2	By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons	2.2.1	Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age	○	*Not reported on in SOBR*
		2.2.2	Prevalence of malnutrition (weight for height >+2 or <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age, by type (wasting and overweight)	●	*Based on national data for wasting and severe wasting in children under 5: Cambodia (9.3% and 2.4% respectively in 2014) shows a downward trend, but a small increase in 2010 suggests some remaining vulnerability; Lao PDR (6.7% wasting and 1.9% respectively in 2012) shows a steady improvement since 1990s; in Thailand by contrast saw increases between 2006 and 2012 of 4.7% to 6.7% and 1.4% to 2.2% respectively; however, Viet Nam has seen rapid declines between 2008 and 2010 9.7% to 4.4% and 2.5% to 1.5% respectively.*
2.3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	2.3.1	Volume of production per labour unit by classes of farming/pastoral/forestry enterprise size	○	*Not reported on in SOBR*
		2.3.2	Average income of small-scale food producers, by sex and indigenous status	○	*Not reported on in SOBR*

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
2.4	By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	2.4.1	Proportion of agricultural area under productive and sustainable agriculture	●	*Across the LMB in 2010, paddy rice covered 22.5% of basin, annual crops 8.4% orchards 1.9% and shifting cultivation 1.6%.*
2.5	By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	2.5.1	Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities	○	*Not reported on in SOBR*
		2.5.2	Proportion of local breeds classified as being at risk, not-at-risk or at unknown level of risk of extinction	○	*Not reported on in SOBR*
2.A	Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries	2.A.1	The agriculture orientation index for government expenditures	○	*Not reported on in SOBR*
		2.A.2	Total official flows (official development assistance plus other official flows) to the agriculture sector	○	*Not reported on in SOBR*
2.B	Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round	2.B.1	Producer Support Estimate	○	*Not reported on in SOBR*
		2.B.2	Agricultural export subsidies	○	*Not reported on in SOBR*

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
SDG7	**Ensure access to affordable, reliable, sustainable and modern energy for all**				
7.1	By 2030, ensure universal access to affordable, reliable and modern energy services	7.1.1	Proportion of population with access to electricity	●	*In 2016 nationally, 100% of households in Viet Nam and Thailand had access to electricity and 87% of the total population and 80% of the rural population Lao PDR. Cambodia reports overall access at 58% in 2016 rising to 72% in 2018. No data available for LMB areas.*
		7.1.2	Proportion of population with primary reliance on clean fuels and technology	○	*Not reported on in SOBR*
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1	Renewable energy share in the total final energy consumption	○	*Not reported on in SOBR*
7.3	By 2030, double the global rate of improvement in energy efficiency	7.3.1	Energy intensity measured in terms of primary energy and GDP	○	*Not reported on in SOBR*
7.A	By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology	7.A.1	Mobilized amount of United States dollars per year starting in 2020 accountable towards the $100 billion commitment	○	*Investment flows in hydropower and other renewables not reported in the SOBR, but are thought significant relevant to 2020 target*
7.B	By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support	7.B.1	Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services	○	*Not reported on in SOBR*
SDG13	**Take urgent action to combat climate change and its impacts**				
13.1	Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	13.1.3	Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies	●	*All four Member Countries have ratified UN Framework Convention on Climate Change and Kyoto Protocol. All have relevant adaptation policies, strategies and institutional arrangements in place.*
		13.1.1	Number of deaths, missing persons and persons affected by disaster per 100,000 people	○	*Not reported on in SOBR*
		13.1.2	Number of countries with national and local disaster risk reduction strategies	○	*Not reported on in SOBR*

🟢 *No immediate concerns* 🟠 *Some significant concerns to address* 🔴 *Considerable concern, urgent action needed* ◯ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
13.2	Integrate climate change measures into national policies, strategies and planning	13.2.1	Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan, nationally determined contribution, national communication, biennial update report or other)	🟢	*All four Member Countries have ratified UN Framework Convention on Climate Change and Kyoto Protocol. All have relevant adaptation policies, strategies and institutional arrangements in place.*
13.3	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	13.3.1	Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into primary, secondary and tertiary curricula	◯	*Not reported on in SOBR*
		13.3.2	Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and technology transfer, and development actions	◯	*Not reported on in SOBR*
13.A	Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible	13.A.1	Mobilized amount of United States dollars per year starting in 2020 accountable towards the $100 billion commitment	🟠	*Current National Indicative Plans for 2016-20 identify US$ 827million of projects directed towards realising the sustainable potential of the LMB taking into account climate change.*
13.B	Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities (* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.	13.B.1	Number of least developed countries and small island developing States that are receiving specialized support, and amount of support, including finance, technology and capacity-building, for mechanisms for raising capacities for effective climate change-related planning and management, including focusing on women, youth and local and marginalized communities	◯	*Not reported on in SOBR*

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
SDG14	**Conserve and sustainably use the oceans, seas and marine resources for sustainable development**				
14.1	By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	14.1.1	Index of coastal eutrophication and floating plastic debris density	○	*Not reported on in SOBR*
14.2	By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	14.2.1	Proportion of national exclusive economic zones managed using ecosystem-based approaches	○	*Not reported on in SOBR* *However, potential threat to marine and coastal ecosystems including mangrove forests, from reduced sediment flows in Mekong mainstream highlighted as a priority action to address.*
14.3	Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	14.3.1	Average marine acidity (pH) measured at agreed suite of representative sampling stations	○	*Not reported on in SOBR*
14.4	By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	14.4.1	Proportion of fish stocks within biologically sustainable levels	○	*Marine fish stocks not reported on in SOBR* *However, inland fisheries production in the LMB is reported in the SOBR. There are no obvious trends in total tonnage of fish catch, but the quality of inland capture fisheries is declining.*
14.5	By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	14.5.1	Coverage of protected areas in relation to marine areas	○	*Not reported on in SOBR* *MRC report that mangrove areas in LMB fell from 1,839km^2 in 2003 to 1,303km^2 in 2010, a decline of 29%. WWF report that 10% of Indochina mangroves are protected*
14.6	By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation	14.6.1	Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing	○	*Not reported on in SOBR*
14.7	By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	14.7.1	Sustainable fisheries as a percentage of GDP in small island developing States, least developed countries and all countries	○	*Not reported on in SOBR*

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
14.A	Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	14.A.1	Proportion of total research budget allocated to research in the field of marine technology	○	*Not reported on in SOBR*
14.B	Provide access for small-scale artisanal fishers to marine resources and markets	14.B.1	Progress by countries in the degree of application of a legal/regulatory/policy/ institutional framework which recognizes and protects access rights for small-scale fisheries	○	*Not reported on in SOBR*
14.C	Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want	14.C.1	Number of countries making progress in ratifying, accepting and implementing through legal, policy and institutional frameworks, ocean-related instruments that implement international law, as reflected in the United Nation Convention on the Law of the Sea, for the conservation and sustainable use of the oceans and their resources	○	*Not reported on in SOBR*
SDG15	**Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss**				
15.1	By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1	Forest area as a proportion of total land area	●	*MRC report that total LMB forest area (broadleaved, bamboo, flooded, coniferous, plantation and mangrove) fell from 335,900km^2 in 2003 to 262,900km^2 in 2010, a decline of 28%. Subsequently some improvement has occurred in Lao PDR and Thailand.*
		15.1.2	Proportion of important sites for terrestrial and freshwater biodiversity that are covered by protected areas, by ecosystem type	○	*Not assessed in SOBR.* *However, overall LMB currently has 255 protected areas covering 173,939km^2.*

Targets		Indicators			Current status
15.2	By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally	15.2.1	Progress towards sustainable forest management	🔴	*MRC report that total LMB forest area (broadleaved, bamboo, flooded, coniferous, plantation and mangrove) fell from 335,900km² in 2003 to 262,900km² in 2010, a decline of 28%.* *Since 2010, Lao PDR report a 6% increase to 14,292km² in 2015 and Thailand has seen a 20% increase from a low in 1998. Cambodia, forest cover has remained steady across all provinces between 2010 and 2014, but in Viet Nam in the LMB forest cover declined from approximately 30% in 2011 to 27% in 2015. Viet Nam also reports that nationally during 2011-15, the quality of natural forest continues to decrease as much of the new forest cover is in plantations with low biodiversity values.*
15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1	Proportion of land that is degraded over total land area	◯	*Not reported on in SOBR*
15.4	By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	15.4.1	Coverage by protected areas of important sites for mountain biodiversity	◯	*Not assessed in SOBR*
		15.4.2	Mountain Green Cover Index	◯	*Not reported on in SOBR*
15.5	Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1	Red List Index	🔴	*Currently, 14 species listed as critically endangered (including the Irrawaddy dolphin and Mekong giant catfish), 21 species listed as endangered and a further 29 species are considered vulnerable.*
15.6	Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed	15.6.1	Number of countries that have adopted legislative, administrative and policy frameworks to ensure fair and equitable sharing of benefits	🔴	*All four Member Countries have committed, inter alia, under the 1995 Mekong Agreement, to "utilize the waters of the Mekong River system in a reasonable and equitable manner" and have established procedures and cooperative planning and monitoring systems to fulfil this commitment.*
15.7	Take urgent action to end poaching and trafficking of protected species of flora and fauna and address both demand and supply of illegal wildlife products	15.7.1	Proportion of traded wildlife that was poached or illicitly trafficked	🟢	*Not reported on in SOBR*

● *No immediate concerns* ● *Some significant concerns to address* ● *Considerable concern, urgent action needed* ○ *Not reported in SOBR, or insufficient data to form a view*

Targets		Indicators			Current status
15.8	By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species	15.8.1	Proportion of countries adopting relevant national legislation and adequately resourcing the prevention or control of invasive alien species	○	*Not reported on in SOBR*
15.9	By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts	15.9.1	Progress towards national targets established in accordance with Aichi Biodiversity Target 2 of the Strategic Plan for Biodiversity 2011-2020	○	*Not reported on in SOBR*
15.A	Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems	15.A.1	Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems	○	*Not reported on in SOBR*
15.B	Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation	15.B.1	Official development assistance and public expenditure on conservation and sustainable use of biodiversity and ecosystems	○	*Not reported on in SOBR*
15.C	Enhance global support for efforts to combat poaching and trafficking of protected species, including by increasing the capacity of local communities to pursue sustainable livelihood opportunities	15.C.1	Proportion of traded wildlife that was poached or illicitly trafficked	○	*Not reported on in SOBR*

9.3 Priority actions and recommendations for the Basin Development Strategy

9.3.1 Priority actions

The sections above have proposed a wide range of priority actions in response to the challenges identified in this report. Those actions are summarised in Table 9.3.

Table 9.3 Summary of proposed actions in each dimension

Dimension	Strategic indicators	Recommended priority actions	BDS Recommendation
Environment	Water flow conditions in mainstream	Continue monitoring programmes and, in addition to PMFM reporting, monitor decreases in wet season flows and daily fluctuations and consider implications of impacts that may arise.	A
		Improve monitoring of water use for various sectors to ensure balance is maintained with increased development	B
	Water quality and sediment conditions	Continue the sediment and water quality monitoring programmes.	A
		Address the implications of reduced sediment concentrations through mechanisms to better manage sediment flows and mitigate transboundary impacts of reduced concentrations	C
		Under a planned Basin Wide Environmental Strategy, agree clear regional objectives, joint strategies and action plans for protecting and sustainably managing the remaining environmental assets and fisheries.	D
		Establish regular monitoring and conservation activities for wetlands and other environmental assets including fisheries.	B
Social	Living conditions and well-being	Review and refinement of indicators and develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B
	Employment in MRC water-related sectors	As above	B
Economic	Aggregate economic value of MRC water-related sectors	Review and refinement of indicators and develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B
		Adoption of pro-active regional planning to promote optimal and equitable development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims	E
	Contribution to basin economy	*As above*	B/E
Climate change	Greenhouse gas emissions	Promotion of development practices that minimise GHG emission.	E
		Develop and implement a data acquisition, generation and requirements action plan to address knowledge gaps.	B
	Climate change trends and extremes	Determine whether to include sea level rise as an indicator in future SOBR.	B
		Continue hydro-meteorological data collection programmes.	A
	Adaptation to climate change	Adoption of pro-active regional planning to address climate change and promote optimal and equitable development through increased cooperation	E
Cooperation	Equity of benefits from the Mekong River system	Adoption of pro-active regional planning to address climate change, promote optimal and equitable development through increased cooperation and to identify opportunities for both socio-economic development and environmental protection consistent with these aims	E
	Benefits derived from cooperation	*As above*	E
	Self-finance of the MRC	Identify smart and cost-effective approaches to basin monitoring	B

9.3.2 Recommendations for the updating the Basin Development Strategy

In accordance with MRC's strategic 5-year planning cycle, the State of the Basin Report seeks to inform and help shape the updating of the MRC's Basin Development Strategy (BDS). The BDS is a high-level document which identifies the key issues faced in developing and managing the water and related resources of the LMB and sets out a strategy by which the Member Countries agree to address these issues and promote optimal and sustainable development of the basin in line with the aims and intent of the 1995 Mekong Agreement. The BDS provides the rationale for and is implemented primarily through the MRC's Strategic Plan at regional level and through four National Indicative Plans.

Based on the conclusions presented in this report and the priority actions summarised above in Table 9.3, the following six recommendations are made for consideration when updating the Basin Development Strategy:

(a) Continue and enhance monitoring of flow conditions and water quality

(b) Develop and implement a Data Acquisition and Generation Strategy and Action Plan

(c) Address the problem of reduced sediment concentrations

(d) Address the need to take urgent action to preserve and protect remaining environmental assets

(e) Adopt a more proactive approach to basin planning

(f) Maintain and strengthen cooperation with Dialogue Partners

These recommendations are elaborated below.

Recommendation (A): Continue and enhance monitoring of flow conditions and water quality

With increasing development in the basin and the onset of climate change impacts, the need for hydro-meteorological, flow, water quality and sediment monitoring is of ever more importance. These are designated as core functions of the MRC and it is recommended that they should remain so with sufficient budgets and resources allocated as needed.

However, this SOBR identifies that, in addition to mainstream flow monitoring in accordance with the agreed PMFM and related guidelines, recent developments within the basin appear to be decreasing mainstream flows during the flood recession period and also, in some instances, causing significant fluctuation in daily flows. Both circumstances might lead to undesirable impacts on both environmental assets and riverine communities and it is therefore important that a close watch is made to establish whether these circumstances represent a permanent change in river regime.

Recommendation (B): Develop and implement a Data Acquisition and Generation Strategy and Action Plan

The intent is that the MRC Indicator Framework (MRC-IF) defines the requirements for monitoring basin development conditions within the basin in line with the commitments made under the 1995 Mekong Agreement. Preparation of this State of Basin Report and the recent Council Study have been constrained by the availability of data prescribed by the MRC-IF. Whilst MRC has in place programmes to monitor hydrology, sediments, water quality, aquatic ecology and some development infrastructure, it lacks comprehensive programmes to monitor environmental assets (including fisheries), water use, land use, socio-economic and macro-economic aspects and some aspects of development infrastructure.

MRC has the Procedures by which to address these gaps (PWUM, PDIES, PNPCA). However, these need to be implemented in a more comprehensive manner, based on the MRC Indicator Framework. A Data Acquisition and Generation Strategy and Action Plan is needed to establish ways by which the data gaps are addressed. The strategy and action plans need to be realistically developed recognising that there will always be some limitations on the data

that can be assembled. There needs to be an ongoing inter-play between refining the MRC-IF and the practicalities of data acquisition to arrive at an effective and sustainable approach to basin-scale monitoring.

However, as the MRC move towards self-finance, it is essential that the cost of implementing the required monitoring programmes is kept to a reasonable minimum. As understanding of the basin's behaviour grows and as new technologies become available (eg. remote sensing), opportunities will arise to continue to simplify monitoring requirements with an increasing focus on those key issues which directly affect choices in strategic management of the basin.

The MRC needs to invest in continuing to look for ways to refine and reduce the cost of monitoring basin conditions by undertaking studies to leverage new technologies and to identify and verify a smaller number of smart monitoring parameters and indicators. In doing this, MRC may also ensure that gender issues are appropriately and realistically incorporated within the Indicator Framework and that, where needed, an adequate degree of spatial disaggregation is maintained.

Data acquisition and storage must be seen as a priority core river basin management function across all MRCS Divisions, with responsibilities at regional and national levels set out and appropriate investment included in annual budget plans.

Recommendation (C): Address the problem of reduced sediment concentrations

Sediment concentrations in the mainstream are observed to be much reduced largely (but not necessarily exclusively) as a consequence of upstream reservoir sediment trapping. it is evidently important that there a clear and shared understanding is established of the consequences in the short, medium and long term of diminished sediment concentrations on the river's morphology, bank stability, flood plain productivity, delta building processes and the productivity of coastal waters. This understanding should bring together the existing extensive body of knowledge and include the incremental impacts of run-of-river mainstream dams as well as further tributary dam development and sand mining.

Thereafter, the MRC needs to facilitate agreement on how best to deal with these issues through mechanisms to better manage sediments within the system and to mitigate the transboundary impacts of reduced concentrations.

Recommendation (D): Address the need to take urgent action to preserve and protect remaining environmental assets

This report has highlighted the threats that currently exist to many important environmental assets. Whilst the Council Study has sought to develop a greater understanding of the nature of these threats and how they may be affected by alternative future developments, the situation remains that the understandings are limited and lead to positions suggesting that certain developments should not be undertaken, as opposed to laying the foundation to what developments could be most beneficially taken up in the interests of optimal development of the basin. Whilst there are clearly many environmental issues potentially to deal with, this report highlights two key transboundary issues that are believed to be central to future plans for the LMB. These are:

- **Wetlands and key river habitats**: This report highlights the enormous historic loss of wetlands in the Mekong Basin, which is continuing today. The argument has been made many times that wetlands are critical to the long-term health of the basin's eco-system, and yet their degradation seemingly continues unabated. To arrest this decline, let alone reverse it, requires a clear understanding of the pressures on wetlands and river habitats from alternative land uses, changing flow regimes and climate change. Building an understanding of where and what these pressures are would be a first step towards identifying and prioritizing areas that may be brought under protection and the necessary trade-offs that this may involve. Thereafter the MRC should facilitate agreement on basin-wide objectives, joint strategies and action plans for protecting and sustainably managing the remaining environmental assets.

- **Fisheries productivity**: The perceived wisdom is that overall production of wild fisheries can be maintained as long as fish habitats remain accessible and unchanged, whereas the identified increase in effort to catch fish and the smaller size of fish being caught is down to increasing fishing pressure and changes in fish-catching technology. Hitherto, most attention has been given to monitoring fish production and less to building a comprehensive understanding of how fisheries may change in the future with and without further habitat changes, with and without regulation of capture fisheries practices and with future changes in consumption patterns in the light of socio-economic development. Building such an understanding is critical to developing strategies to support and maintain the sector in the future.

Recommendation (E): Adopt a more proactive approach to basin planning and the management of trade-offs between sectors and countries

Basin planning in the past has involved and been generally limited to assessing the acceptability of the transboundary impacts of national plans, formulated largely in isolation of those of the other riparian states. This State of Basin Report highlights the new opportunities and threats arising from changes in flow regime of the mainstream, sediment flows and climate change. The report also demonstrates the Member Countries' willingness to increase cooperation through joint projects and an increased focus on those of basin-wide significance.

Given the Member Countries' commitment to optimal and sustainable development, the new development challenges above and the complexity of the inter-play between different dimensions, it is strongly recommended that MRC adopts a more proactive stance to basin planning as mandated by Art. 24 of the Mekong Agreement. Such an approach would allow the MRC, working as it does with all Member Countries and significant stakeholders, to create platforms to discuss benefit sharing and trade-off between national development plans and thereby to determine the best ways by which to develop the basin given the current circumstances and the legitimate aims and concerns of each Member Country.

The results of this new approach would enable the "Development Opportunities" section of the BDS to proactively provide strategic guidance to national planning for the basin across all water-related sectors in line with the aims of the 1995 Mekong Agreement. This report has taken note that potentially there is considerable opportunity for further development as summarised in Table 9.4, notwithstanding the importance of the potential downsides of development opportunities, the need to carefully consider trade-offs and continue the efforts of assessing the potential impacts of climate change.

Table 9.4 Potential development opportunities

Category	Opportunities
Environmental management	To **preserve and leverage the remaining wetlands** and regionally significant environmental assets, including **riverine habitats**, for both ecological purposes and enhancing bio-diversity, including **fish** and **other aquatic organisms**, and to extend and promote greater tourism income.
	To continue to invest in **rehabilitation and improvement of forest areas** to better manage catchments, enhance the lifetime of storage reservoirs and contribute to reducing GHG.
	To implement measures for managing mainstream and tributary floods in a manner sensitive to environmental needs and climate change (including sea level rise), recognising the ecological benefits of floods as well as the rising cost of flood damage as a result of changing use and value of flood plains prompted by growing economies and expansion of urban and industrial centres..
Economic development	Further **develop hydropower** to promote regional energy security and cross-border trade and contribute to great security in dry season water availability.
	Increase abstractions for irrigation (whilst taking steps to improve irrigation efficiencies) to address and target drought protection, household food and water security needs and the economic value of the basin's resources.
	Improve inland water transport (navigation) by taking advantage of greater water depths in the dry season throughout the mainstream and in some tributaries.

Recommendation (F): Maintain and strengthen cooperation with Dialogue Partners

The MRC has long-recognised the importance of maintaining active dialogue with its upstream riparian neighbours. This importance is underscored by the substantial impacts that developments upstream have had on the flows in the LMB. It is also clear that, in looking forward, the changes brought about already offer a new set of opportunities and threats which the MRC has to manage as best as it can. This report highlights that further changes in river and sediment flows and in water quality entering the LMB could also arise in the future.

As with managing interplay of competing demands and development impacts within the LMB, so too must the MRC appreciate the development aspirations and challenges of its upstream neighbours in order to arrive at good outcomes that satisfy both upstream and downstream needs. By including chapters on the parts of the basin belonging to both Myanmar and China, this report represents a further step in building this appreciation.

However, it is recommended, given the short-term issues (principally day-to-day flow management of cross-border flows) and the long-term issues identified in this report (principally future water quality from Myanmar tributaries, future dam development in China and sediment filling of reservoirs), that cooperation with the Dialogue Partners is maintained and further strengthened through the exchange of data and technical ideas and resources.

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