THE UNIVERSITY OF HULL

Adapting fisheries-based livelihoods to hydrological changes in the Lower Mekong River Basin: a case study of Lao PDR

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by

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ACRONYMS

ADB	Asian Development Bank
CPUE	Catch Per Unit Effort
DFID	Department for International Development, UK
DLF	Department of Livestock and Fisheries
DoF	Department of Forestry
EIA	Environmental Impacts Assessment
EGAT	Electricity Generating Authority of Thailand
EDL	Electricite Du Laos
FAO	Food and Agriculture Organization of the United Nations
FCZ	Fishery Conservation Zone
FIVIMS	Food Insecurity and Vulnerability Information and Mapping System
GDP	Gross Domestic Product
GoL	Government of Laos
IUCN	International Union for Conservation of Nature
ICEM	International Centre for Environmental Management
IHA	Indicator of Hydrologic Alteration
IPCC	Intergovernmental Panel on Climate Change
LARReC	Living Aquatic Resources Research Center
LECS	Lao Expenditure and Consumption Survey
LMB	Lower Mekong Basin
MDG	Millennium Development Goals
MDS	Non-metric Multi-Dimensional Scaling
MoU	Memorandum of Understanding
MW	Megawatt
MRC	Mekong River Commission
NAFRI	National Agriculture and Forestry Research Institute
NTFPs	Non Timber Forest Products
NBCA	National Biodiversity Conservation Areas
NTPC	Nam Theun 2 Power Company
NAPA	National Adaptation Plan of Action
NSCCC	National Steering Committee on Climate Change
OAAs	Other Aquatic Animals
ODOP	One District One Product
PRA	Participatory Rural Appraisal
RAFMS	Rapid Appraisal of Fisheries Management Systems
RFA	Reservoir Fisheries Association
RVA	Range of Variability Approach

SIA	Social Impacts Assessment
STEA	Science Technology and Environmental Agencies
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VFGs	Village Fishery Groups
WTO	World Trade Organization
WCD	World Commission on Dams
WB	World Bank
WREA	Water Resources and Environment Administration

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ABSTRACT

Nam Theun 2 hydropower dam was selected for this study to assess how local communities respond to hydrological changes and examine the impacts of these changes to ecology and livelihoods of people around the Nakai reservoir and downstream in the Xe Bang Fai River. The results confirmed that fish and Other Aquatic Animals (OAAs) are essential sources of food and income generation of both reservoir and downstream Xe Bang Fai River households. People living around the reservoir and river consume fish and OAAs almost every meal. Fish and OAAs account for 62% (54% in reservoir and 70% in river) of animal protein intake. Reservoir households, which have limited land and poor soil for rice cultivation, rely on the reservoir fishery not just for subsistence but also for generating income to buy rice for consumption. By contrast, the households living further downstream along the Xe Bang Fai River are likely to own more land and fertile soil for agriculture, and the artisanal fisheries are mainly for consumption, but they also sell part of their catch when they have excess or during the high fishing season at the start of the wet season.

The results from the study indicate that the impacts of trans-basin hydropower dams on the ecological functioning and livelihoods of people are significant. The impacts from climate change in the study areas and elsewhere are minor in comparison with the impacts from mainstream and tributary dams. Nam Theun 2 dam has changed the hydrological regime of the Xe Bang Fai River, destroyed the riverbed and disrupted dry season refuge habitats. Many high value species that initially resided in the reservoir have disappeared and are replaced by small and carnivorous species such as *Channa striata* , as well as alien species such as *Oreochromis niloticus* and *Cyprinus carpio*. However, it is unclear whether the species composition in downstream areas has changed because fishers are still learning to adapt to high and strong flows or many fishers have shifted to fish in small streams and swamps as they are concerned about safety issues.

Fishers in the reservoir have adapted to the new environment and lifestyle by diversifying their income sources, by opening small village shops, trading and labouring to supplement their income from reservoir fishing. The downstream fishers have more opportunities and more diverse livelihood activities to cope with the hydrological changes and adverse weather. Although rice farming is the most important activity for the downstream villages, most of their immediate cash comes from livestock, in particular large ruminants that provide their main sources of income. However, they also sell some of their daily catch to help purchase foods and maintain food security. The study highlights the need to provide financial and technical assistance for the affected households; to assist them starting new alternative livelihood activities aiming to supplement the declining fish catches in the reservoir and river. These livelihood activities include ecotourism and services, cultivating organic vegetable, working in clothes and agricultural processing factories, promoting One District One Product, and aquaculture.

The promotion of reservoir fisheries as an alternative livelihood may be good in the short term, but for the long term and sustainable use of fishery resources, there is a need to look for other options outside fisheries and balance between the need for food security and protection of fisheries resources for future generations. Although the reservoir fishery can support production it requires more investment, thus it is necessary to protect habitat in small streams and rivers in the headwaters of the reservoir to ensure fish can use these habitats for spawning. In the river, critical habitats, such as deep pools and floodplains vital to the Mekong fisheries need protection. Maintaining connectivity between the mainstream and floodplains is also necessary, allowing fish free access to spawning, nursery, feeding and refuge habitats to complete their lifecycles. These protections can be instigated at different scales, such as local, national and regional levels, with participation from local communities and institutions concerned with the fisheries. At the regional level, it could be achieved through the trans-boundary fisheries management framework being developed by the Mekong River Commission.

CHAPTER 1: INTRODUCTION

1. BACKGROUND

1.1 The Mekong River

The Mekong River is a trans-boundary water resource in South East Asia. It is the world's 10th longest river in terms of length (MRC 2003) and second largest river in terms of fish diversity (Froese & Pauly 2010). The Mekong River originates in the Tibetan Plateau of China, and flows through six countries before reaching the South China Sea via the Mekong Delta in southern Vietnam (Figure 1.1). The Mekong River with its important tributaries (at least 30) and the Tonle Sap or Great Lake (the largest lake in Southeast Asia) have formed a variety of ecosystems that serve as spawning, nursery, feeding and refuge habitats for aquatic flora and fauna. The important spawning habitats are in the middle of the Mekong, including the Songkhram river basin and Mun-Chi river in Northeast Thailand, the Xe Bang Fai, Xebanghiang, Theun and Hiboun rivers in central Laos as well as the 3S river system (Sesan, Sekong and Srepok) and inundated forests around the Great Lake in the lower part of the basin in Cambodia. These provide critical habitat for the reproduction of the Mekong species. Many deep pools are recorded in the mainstream and tributaries channels. For instance, in Laos deep pools range from 4 to 40 m deep, while they are up to 80 m deep in Cambodia (Halls *et al.* 2013c). These deep pools are believed to be used by many Mekong fish species as dry season refuges when other habitats are not available. The floodplain around the Great Lake also expands from just 3,000 km^2 in the dry season up to 13,000 km^2 during the wet season (MRC 2003), forming a highly productive habitat for fish and other aquatic animals during the reproductive period.

It has been said that the Mekong River functions as one ecological system, providing corridors for fish movement, linking spawning habitats in the upstream with downstream nursery and feeding habitats, as well as connecting dry season refuge habitats in the mainstream with feeding habitats on closed water bodies, swamps and the floodplains. Many Mekong species are trans-boundary resources, in particular long distance migratory species, including the iconic Mekong Giant catfish (*Pangasianodon gigas* Chevey, 1931) that migrates across many countries to complete its lifecycle. As a consequence of the complexity of the ecosystem, the high variability between the wet and dry seasons, and because many areas are inaccessible by road, it is difficult to assess the exact number of aquatic organisms, in particular fish species. Nevertheless, at least 898 freshwater fish species have been documented and more species have yet to be discovered, particularly in the remote mountainous areas or underwater caves in Laos (Kottelat 2011). It has been estimated that some 830 mammals, 2,800 bird, 250 amphibians and 650 reptiles species inhabit the Lower Mekong Basin (MRC 2003).

Fish and other aquatic animals play a very important role in the livelihoods of the people in the Lower Mekong Basin (LMB). They provide a major cheap source of animal protein, additional income and job opportunities for people, especially the rural poor in remote areas. Capture fisheries in Laos can be characterized as small-scale fisheries which contribute directly to food security and livelihoods, balanced nutrition, poverty reduction, wealth creation and rural development (FAO 2009). The inland capture fisheries in Laos are based mainly on rivers, hydropower and irrigation reservoirs, floodplains and rice fields. Total aquatic resources available for capture fisheries in Laos amount to 1,288,508 ha (Phonvisay 2013). The average annual yield from Laos fisheries, aquaculture and other aquatic animals is estimated at 208,503 tonnes, indicating consumption of about 43 kg per capita (Hortle, 2007).

1.2 Pressures and threats on the Mekong

In the last two decades the economies of the riparian countries in the LMB have grown rapidly due to the improvement of livelihoods, healthcare, infrastructure, trade and investment. In order to provide adequate foods, including fishes, and energy to support the market demands and rapid industrialisation, the farming has shifted from subsistence to market-oriented agriculture. Changing land use and farming systems from self-sufficient to cash crops have expanded rapidly in the LMB, as has the expansion of teak and rubber plantations leading to degraded secondary and community forests, which has resulted in landslides and soil erosion. The water demand for agriculture is also increasing; many irrigation systems, water diversions, weirs and pumping stations have been constructed along the river banks to supply water for the crops. Rice farming has increased from one to four crops per year (MRC 2010a). The mining industry, in particular gold and copper, is also using considerable amounts of water and leaves behind environmental degradation and pollution of the river system. Although there is no evidence to support the impact from agriculture and industries on water volume and discharge of the Mekong River, recent falls in water level in the Mekong in the dry season in early 2014 (field observation) and pollution from agriculture and mining (MRC 2010a) may be a warning sign of the pressures building in the Mekong from these developments.

Another significant change in the LMB is expansion of the hydropower industry. Hydropower represents a substantial component of national development plans among the LMB countries. In Laos, it forms a major part of the national poverty alleviation

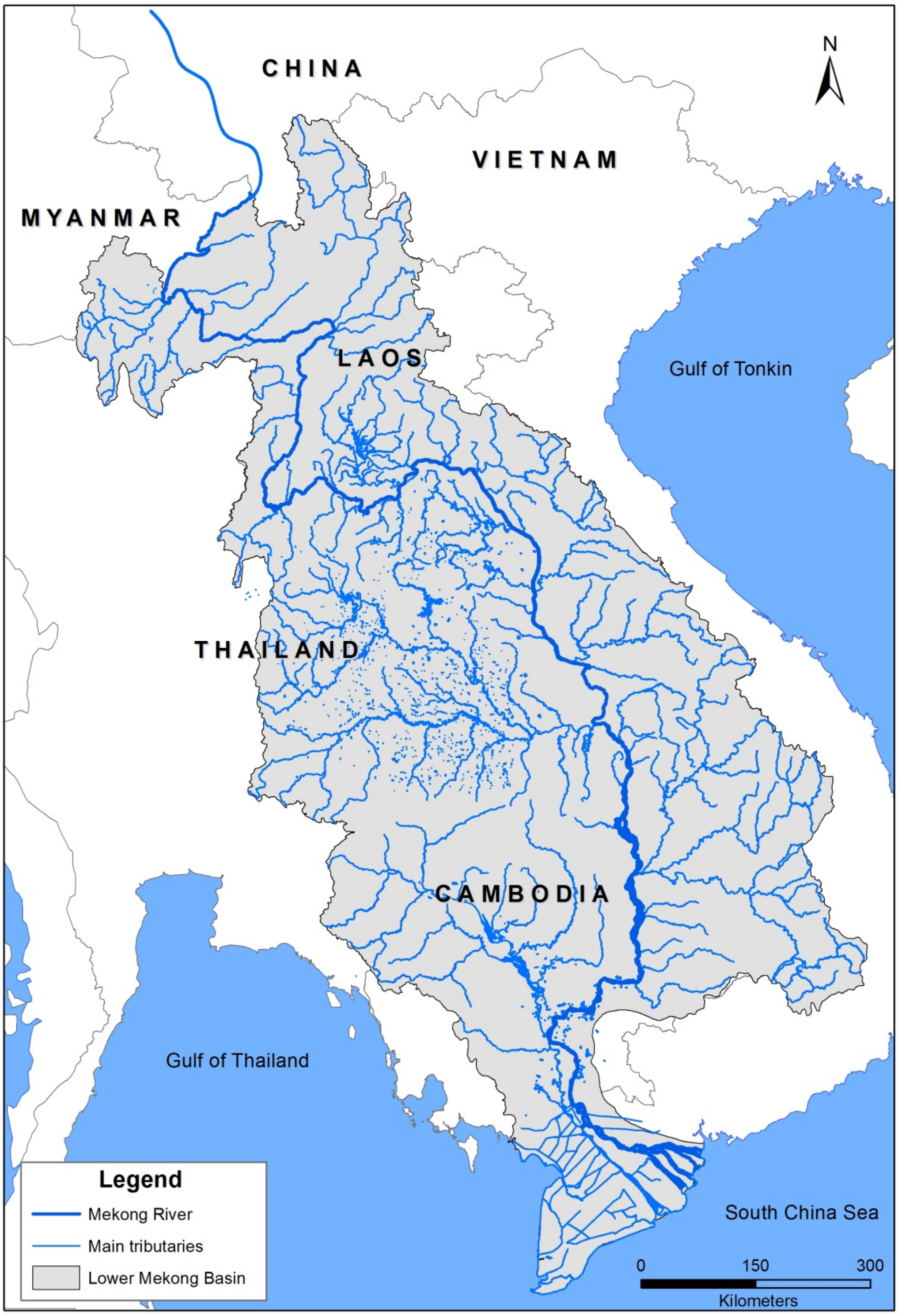


Figure 1.1. River and water bodies in the LMB.

strategy (MRC 2007). The estimated potential of hydropower development in Laos is 20,906 MW (MRC 2010a). In 2010, a total of 1,732 MW was installed on the Mekong tributaries and projects with a further capacity of 1,488 MW already under construction. Large hydropower reservoirs (Nam Ngum, Nam Theun 2 and others) cover an estimated 96,030 ha (Phonvisay 2013). Interest in hydropower development in the LMB has recently increased, particularly in Laos where seven dams have been proposed across the Mekong River mainstream (MRC 2010a). Many other hydropower dams in the Mekong tributaries are already operating, under construction or planned. In addition, there are 10,993 temporary irrigation weirs, 1,160 permanent diversion weirs and 108 gates and dykes operated in Laos (Phonvisay 2013). The Lao government is promoting sustainable practices for improved food security and environmental sustainability with the goal of eliminating poverty. Poverty has declined steadily from 46% in 2005 to 26.9% in 2010, and the country is on the way to achieve the Millennium Development Goals target of halving poverty by 2015 (UNDP 2010). Hydropower dams are expected to generate revenue to support social and economic development plans, food security and poverty alleviation of the country.

Hydropower dams provide flood-control protection, electricity, water supply and storage, transportation and irrigation in the dry season (WCD 2000). However, hydropower dams also have negative impacts on the environment by changing water flows and volumes in the dry season, for example, and reducing flooded areas in the wet season (Ferguson *et al.* 2010). Dams are also a barrier to fish migration (Dugan *et al.* 2010), disconnecting rivers from floodplains that act as nursing and feeding habitats for larvae and juveniles (Cowx *et al.* 2012).

The emerging issue of climate change is also putting pressure on the Mekong River flows and affecting many sectors, in particular fisheries that have already been affected by developments from other sectors, notably water development projects (irrigations and hydropower development). The impact of climate change on freshwater fisheries is already recognised globally and will continue into the future (Palmer *et al.* 2009, Badjeck *et al.* 2010, IPCC 2014), and environmental changes such as extreme floods and severe storms are likely to heighten due to climate change (Keskinen *et al.* 2010). In Laos, information and tools to predict future climate change trends are limited, but there is evidence that extreme floods are already taking place (MRC 2009a). For example, tropical storm Kammuri in August 2008, typhoon Ketsana in September 2009 and typhoon Nock-Ten in August 2011 caused flooding in many villages and agriculture lands, affecting livelihoods, food security and well-being of the Lao people.

The Mekong River is very important to the livelihoods of the people in the LMB, not only in terms of food security and income generation but also job creation and traditional culture values. Any changes to this river will affect its ecosystem, diversity and production of aquatic animal that serve as the main sources of animal protein of millions of people, in particular the poor, who rely on fisheries resources for their living. This includes the numerous hydropower development projects, especially those on the Mekong tributaries, notably Theun-Hinboun, Nam Theun 2, Pak Mun and Yale dams. The hydrological changes caused by these dams will likely impact on the livelihoods of the fishing communities (Roberts 2011; Wyatt & Baird 2007). To address this issue the Mekong River Commission released the Strategic Environmental Assessment to provide broad scenarios and strategic concerns which need to be taken into account before specific project decisions are made (ICEM 2010).

Despite these concerns, there is no evidence that current proposals to build hydropower dams will be dropped (Dugan *et al.* 2010). The impacts of water development and climate change to river fisheries and on people are expected to evolve in coming decades. Unfortunately, at present, baseline data and knowledge on status and trends of the Mekong fisheries are limited, and the data on impact of trans-basin dams on the ecology of the rivers and fisheries in particular, on the livelihoods of local people is poor. In addition, information on how local communities respond to these changes, as well as the options for mitigation, are also limited.

As a consequence there is an urgent need to fill these gaps in knowledge and to assess the status and trends in the Mekong fisheries before mainstream dams are constructed. This will be achieved through a series of studies such as analysis of fish catch monitoring data, conducting fish consumption monitoring and field survey of the affected areas. The outcome of such research could be used to supplement existing information to support planning and decision making of new projects, especially with regards the conflicts between water development projects and the fisheries sector.

2. OBJECTIVE OF THE STUDY

The overall aim of the thesis was to address some of the knowledge gaps indentified and determine the impacts of hydrological (dam development) and climate changes on the Mekong environment and fisheries and on the livelihoods of people, focusing on ecological loss, food security, and wellbeing of local communities in the reservoir and downstream areas. The study also aims to examine how affected communities respond to the changes and investigate the options to minimize the impacts of these changes.
The specific aims of the research were:

1. To analyse the current status and trends of fisheries in the Mekong River to provide baseline information against which to assess any changes to the fisheries sector as a result of dam development;
2. To assess the impacts of flow modification on the ecosystem integrity and livelihoods of local people affected by reservoir development; and to examine the opportunities and challenges for minimising these impacts;
3. To assess the impacts of environmental and hydrological changes around existing dams on food security through consumption monitoring in local

communities and to examine the contribution of fish and OAAs to household dietary composition and protein intake at different times of the year;

4. To assess likely climate change impacts on fisheries, forestry, and agriculture production; and examine adaptation mechanisms, responses to the changes at both the national and community levels.

3. STRUCTURE

The study was divided into key topics that are addressed in Chapters 2 to 7. Specific objectives are provided separately in each chapter. The outline of the thesis is summarised as follows:

Chapter 2 provides an introduction to the Mekong River and developments in the LMB countries, such as agriculture and hydropower development. Fish biodiversity and migration systems are also included in this chapter. The knowledge systems such as the methods for assessment of food security, livelihood approach, the Indicators of Hydrological Alteration and relationship between hydrological regime and fish communities are reviewed.

Chapter 3 provides an overview of fishery resources in the Mekong River before any mainstream dams are constructed. Data from gill net and lee trap fisheries monitoring in Laos have been used as a case study. This chapter attempts to assess fish composition, species diversity and richness, and relationships between water level and fish movement. Inter- and intra-variation in fish catches at different times of the year and the possible causes of this change are discussed.

Chapter 4 examines the impact of Nam Theun 2 dam on the hydrology and ecosystem, and on the livelihoods of people living in villages around the reservoir and downstream. Social and environment issues are discussed in relation to environmental protection, food security and poverty alleviation. This chapter also focuses on the impact of hydrological changes on fish population ecology and yield, and reproductive processes in the Nakai reservoir and the Xe Bang Fai River. Impacts on livelihoods such as resettlement, alternative agricultural practices and food security are also addressed. The alternative livelihoods options for minimising the impacts of the hydrological changes caused by dams and climate changes are also outlined.

Chapter 5 provides an assessment of food security issues around Xe Bang Fai River and the Nakai reservoir. This chapter examines how local people obtain their food at the household level, by assessing the availability and accessibility to food sources in different seasons, daily intake of fish and other aquatic animals in the wet and dry seasons and investigates the contribution of fishes and other food sources (e.g. beef, pork, chicken) to daily animal protein intake. This chapter also discusses food security in terms of food availability, food access, food utilisation and food stability.

Chapter 6 provides an historical overview of data on climate and hydrological change in the Lower Mekong Basin. The chapter attempts to synthesize the projection of future climate and hydrological changes, and discuss the potential impacts on the environment and livelihoods of vulnerable communities. It also addresses the existing mechanisms and capacity to adapt and minimise the impact of climate change, and thus prepare for future climate change impacts at the national and communities.

Chapter 7 this chapter summarises the research with a general discussion and recommendations for further research.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

The Mekong River Basin is an important strategic resource supporting diverse livelihoods and food security for millions of people. This chapter reviews the current status and importance of the river to the riparian countries as a backdrop to understanding the impact of changing hydrological and climate conditions on the ecosystem functioning and services. It is divided in two sections: section one aims to provide background information on the development of the LMB, including population and economic development, capture and aquaculture fisheries resources, land use and agriculture development, and current and proposed hydropower development in the Lower Mekong Basin. Section two reviews topics that will be applied to this research such as the methods used to assess food security, the livelihoods approach, and the Indicators of Hydrological Alteration as well as the importance of the hydrological regime to aquatic plants and animals.

2.2 THE LOWER MEKONG BASIN AND ITS DEVELOPMENT

2.2.1 Population and economic development

The human population in the LMB is estimated at 60 million (2007): 13 million in Cambodia (90% of the total population), 5.9 million in Laos (97% of the population), 23 million in Thailand (39% of the population) and 20 million in Viet Nam (20% of the population) (MRC 2010a). Population growth in the LMB is under 2% in Thailand, Viet Nam and Cambodia, but up to 3% in Laos. The livelihoods of the people in the basin are highly dependent on the river system, with over 60% of the people engaged in water-related activities (MRC 2011a). Millions of poor people depend on wild fish for maintaining their food and income. The LMB has a stable economic development that has grown very fast since the early 2000s. Thailand is the largest economy, while the Vietnamese economy is the fastest growing (MRC 2010b); economic development in Cambodia and Laos is also growing rapidly. Poverty in the region has decreased significantly, but the income gap between urban and rural areas is very high and remains the main challenge for economic development in the LMB (RIS 2007).

Cambodia’s economy grew rapidly from the early 2000s with a rate of 11.1% from 2004 to 2007 (MRC 2010b). In 2013, the economic growth was 7.2% (ADB 2014). The services sector, such as retail, real estate and tourism, were the largest growth areas, estimated at 8.4% in 2013. Rice milling also contributed to industrial growth, with exports doubling to 366,000 t, valued at $262 million.

The Laos economic performance has improved since the country joined the World Trade Organization in 2010. During 2004-2008, GDP grew by 7.3% (MRC 2010b), which included rapid growth in the energy sector through hydropower and mining. Over the past in 20 years, agriculture accounted more than 50% of GDP, while the industrial and service sectors have contributed comparatively little. In 2013, GDP grew by 7.6%, slightly less than 2012 (7.9%) (ADB 2014). The service sector expanded by 9.0%, with a 12% increase in the number of tourists, reaching 3.7 million in 2013. Copper, gold and silver production increased by 3.5%, 6.6% and 54.9% respectively. Despite impacts from floods in 2013, agriculture still grew by 2.7%.

Thailand's economy experienced an average GDP growth rate of 5% from 2000 to 2007 (MRC 2010b). The service sector has contributed 50% of GDP since the early 1960s, and remains strong over time. Industry has expanded steadily and contributed about 45% of GDP in 2007. In 2013, the economy slowed sharply due to a decrease in domestic demand, slowing down of export markets and political disruptions leading to a GDP growth rate of 2.9% (ADB 2014). While the service industry increased, the contribution of agriculture sector was less. Agriculture and fisheries grew by 1.4%, but shrimp production declined because of disease problems, rice harvest fell slightly, as did cassava output.

Vietnam's economic growth rate was 7.6% annually from 2000 to 2007 (MRC 2010b) influenced by the continued expansion of investment in infrastructure, manufacturing and the service sector. GDP growth fell to about 6% in 2008 and 4.5% in 2009 due to the global financial crisis. In 2013, economic growth was 5.4% (ADB 2014). The service sector was the largest with its contribution to GDP growth increasing to 6.6%. Hotels and restaurants increased by 9.9%, there was an 11% increase in tourist numbers, and banking and finance extended by 6.9%. Agriculture and fisheries maintained a growth at 2.7%. Fisheries accounted for 20% and doubled their share of 10 years ago.

2.2.2 Fisheries resources in the Lower Mekong Basin

Capture fisheries in the LMB

FAO estimated capture production in the LMB countries to be about 900,000 tonnes (Figure 2.1). These data underestimate the true catch because they do not include small scale subsistence fisheries that account for more than 50% of the total catch of the Mekong fisheries. The Mekong River Commission estimated fisheries production in the LMB at 3.7-4.4 million tonnes (Hortle 2007, MRC 2010a), of which 1.8-2.5 million tonnes is from aquaculture. The MRC estimate considered is reasonable as it is based on compiling information from different studies as well as from household fish consumption monitoring (Hortle 2007).

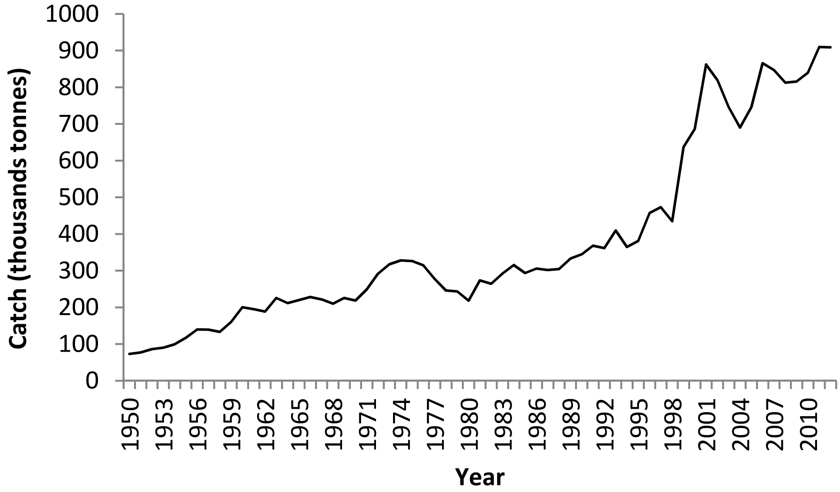


Figure 2.1. Capture fisheries production in the LMB (Source: FAO-FishStat).

The results from fish catch monitoring at 15 stations in the Mekong across the four riparian countries during 2003 and 2005 indicated that catches at seven stations were declining, six were increasing and two observed stable (MRC 2010a). The top four families in terms of the contribution of weight to total fish catch were Cyprinidae (48% of total weight), follow by Pangasiidae and Siluridae (12% each) and Bagridae (9%). In terms of size, the catch was dominated by large (60-99 cm total length) and very large fish (>90 cm) accounting for 50% of the catch followed by small (<25 cm) and medium (26-59 cm) sized fish, contributing 30 and 20% respectively. The results also highlighted that endangered species that include in the IUCN Red List of Threatened Species, such as Mekong stingray (*Dasyatis laosensis* Roberts & Karnasuta, 1987) were recorded in all countries and Julien's golden carp (*Probarbus jullieni* Sauvage, 1880) was found in Cambodia, Laos and Thailand. The contribution of endangered species is large and suggests the populations are viable if the catches from 15 monitoring stations are considered in relation to the total catch of the Mekong fishery. The data also do not fully support the claim that there is a general decline in catches but it requires long term data to validate this trend (MRC 2010a).

Recent results from an integrated analysis of MRC fisheries monitoring programme data from 40 sites (Figure 2.2) across the LMB between 2003 and 2010 indicated that 339 species of fish and OAAs are caught in the four riparian countries (Halls *et al.* 2013a). Dominant species in terms of the percentage contribution to total catch weight were *Labeo chrysophekadion* (Bleeker, 1850), *Cirrhinus lobatus, Pangasius conchophilus* Robert & Vidthayanon 1991, *Phalacronotus apogon*, *Puntioplites falcifer*

Smith 1929*, Poropuntius malcolmi, Wallago attu* Schneider, 1801 and *Barbonymus gonionotus* Bleeker, 1850 *.* As expected, species richness was lower at the upstream sites in Laos than those in the floodplains of Cambodia (Halls *et al.* 2013a). The relative biomass of medium and large cyprinids was relatively higher in 2004 and 2005 than the following years. *L. chrysophekadion* was recorded at all the monitoring sites and was most abundant in northern Cambodia and northern Laos*.*

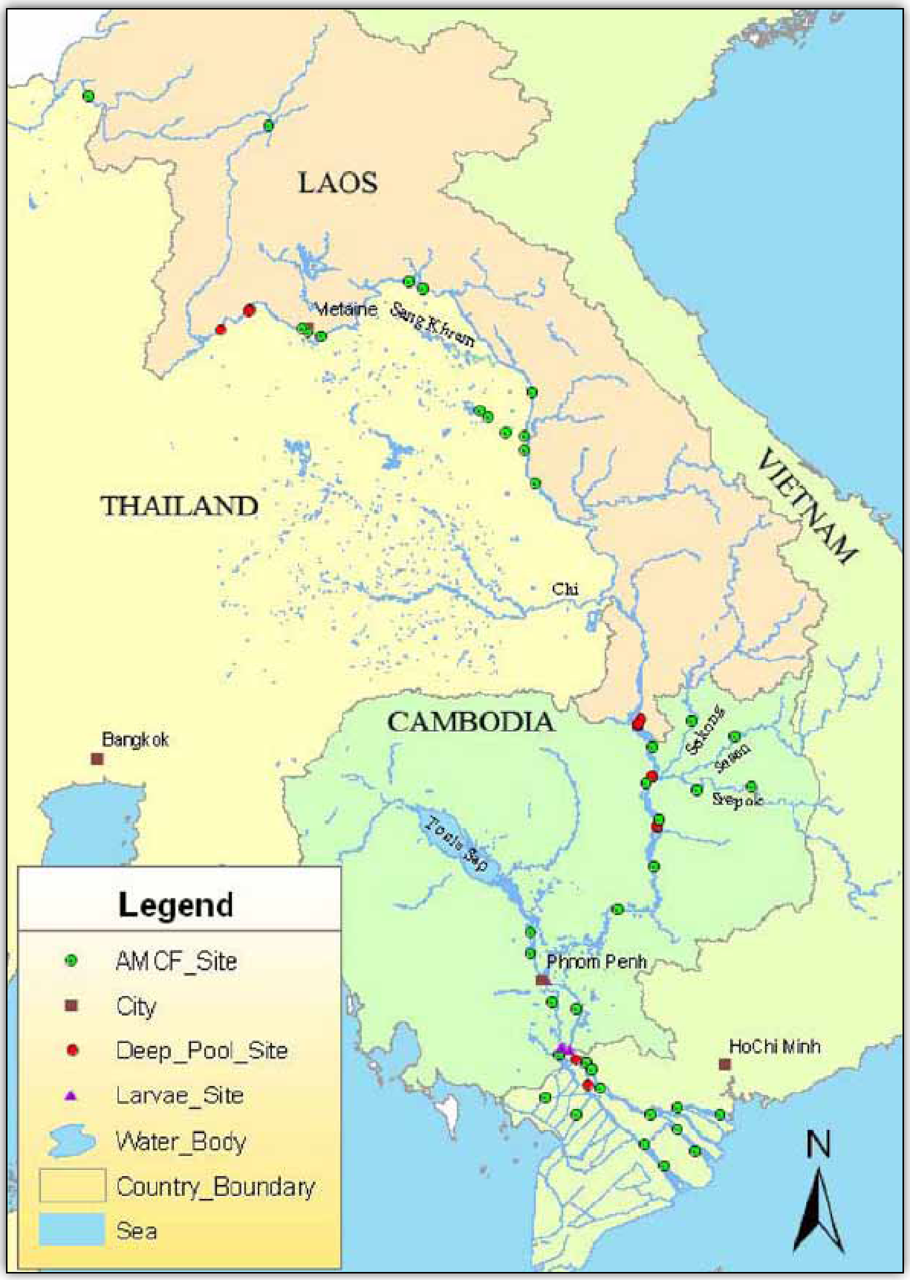


Figure 2.2. Locations of the MRC catch monitoring programme (Source: Halls *et al.* 2013a).

P. conchophilus was reported to be abundant in northern Cambodia and central Laos (Figure 2.3). The relative biomass of this species showed no decline during the monitoring period but the biomass *i* was higher in 2004 and 2005 than other monitoring years.

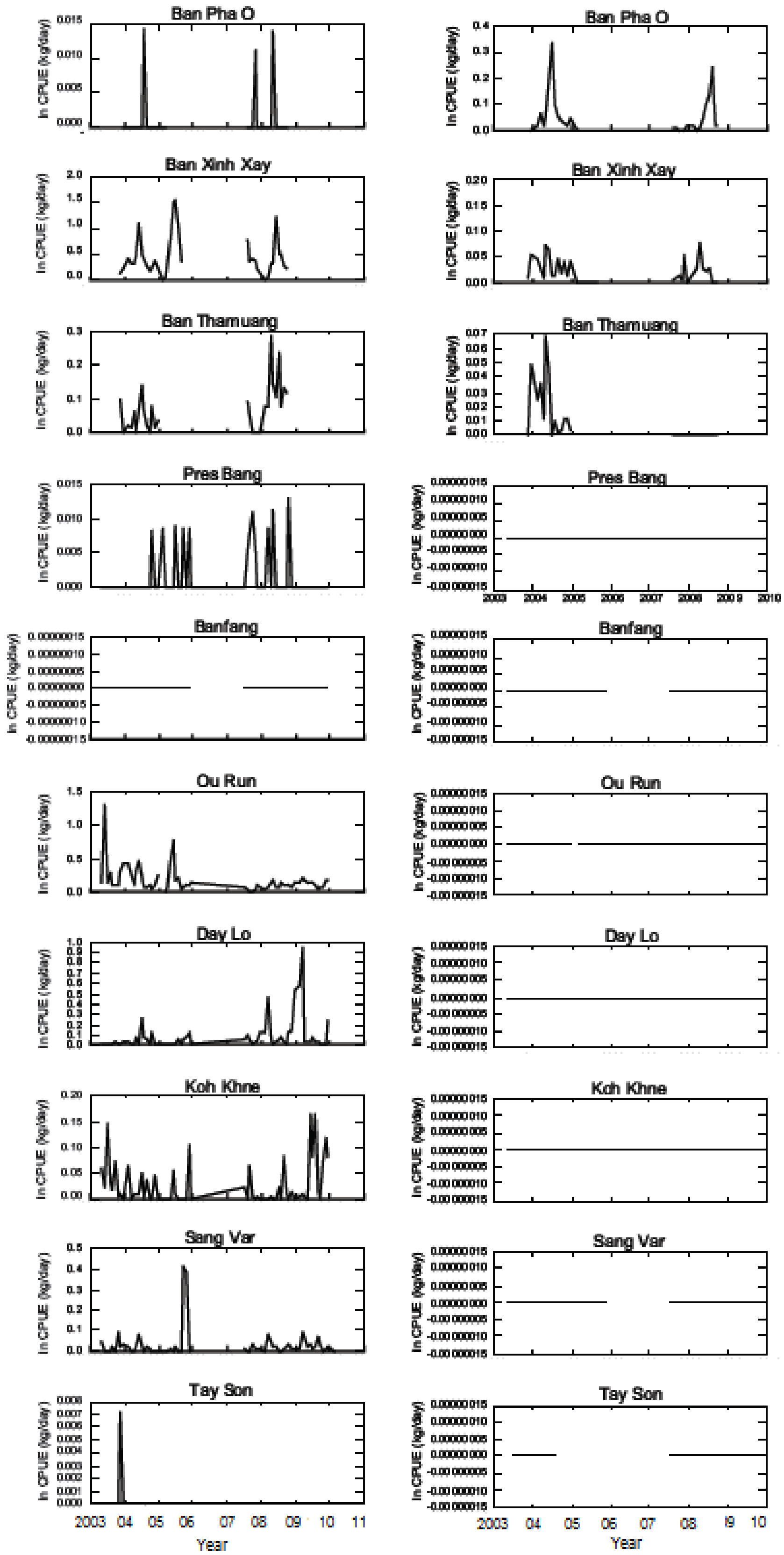


Figure 2.3. Log-transformed average monthly fisher catch rates by site for *P. conchophilus* (left) and *Hemibagrus nemurus* (right) (Source: Halls *et al.* 2013a).

The stationary trawl (Dai) fishery of the Tonle Sap-Great Lake System is the largest industrial fishery in Cambodia. It has been operating since the 1930s, landing about 14% of the annual catch of the Tonle Sap-Great Lake System. Several studies indicate that the species dominating the catch of the Cambodian Dai fishery have remained unchanged since the 1930s (Baran *et al.* 2001; Halls *et al*. 2007; Halls & Paxton 2012). Thirteen years of Dai fishery monitoring data (1997-2010) revealed that total catch varies between years ranging from 9,000 to 35,000 tonnes, with a mean 17,000 tonnes. High catches were recorded in 2000-2001 (25,000 tonnes), 2004-2005 (25,000 tonnes) and 2005-2006 was highest catch recorded (35,000 tonnes) since 1997 (Figure 2.4). During 2011-2012, when Cambodia experienced extraordinary floods that rose 10.9 metres, fish catch was the highest over the past two decades at 46,007 tonnes (Chheng *et al.* 2014). The catch is highest during the dry season (December-January) and lowest in wet season (October). In addition, fish catches are strongly correlated with the lunar cycle, with fish landing peaking during the second quarter of the lunar cycle that coincides with the end of the flood season (Halls *et al.* 2013a).

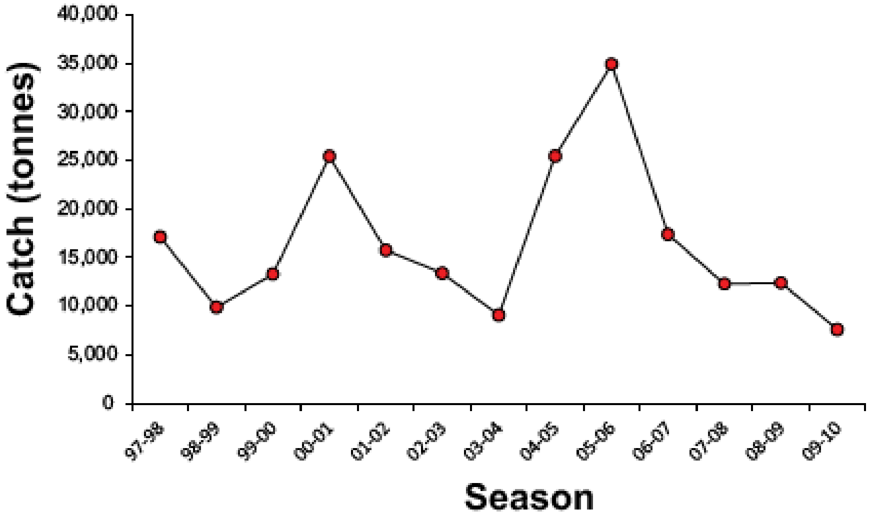


Figure 2.4. Dai fishery production (1997-2010) (Source: Halls *et al.* 2013a).

Several authors concluded that fish catches in the LMB have remained fairly stable and still in relatively good condition (MRC 2003; Baird & Flaherty 2004; MRC 2010a; Halls *et al.* 2013a). In general, evaluation of the Mekong fishery based on gill net catches confirms this position. There is no evidence to suggest a decline in species abundance and biomass, or mean weight among all the sampling locations over the gill net monitoring period (Figure 2.5). However, high market demand for fish, changing hydrological regimes as a consequence of climate changes and water development projects, in particular Mekong mainstream dams, will likely affect fish community dynamics, fish catches and production of the Mekong fishery if no measures or strategies are put in place to ameliorate the problems.

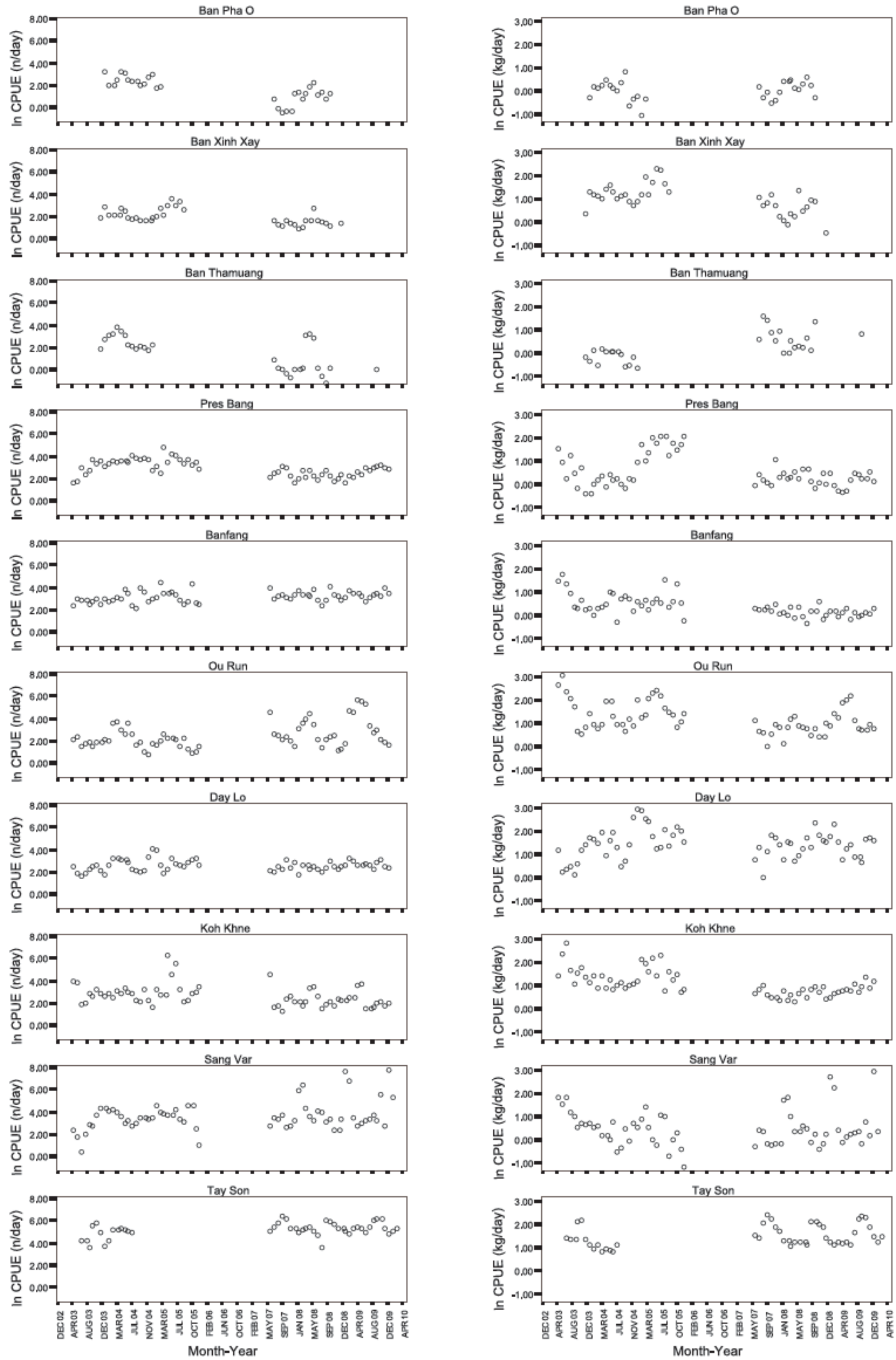


Figure 2.5. Monthly estimates of the relative fish abundance (left) and biomass (right) indicated by log-transformed average fisher catch rates per day at those sites monitored under MRC gillnet monitoring programmes (Source: Halls *et al.* 2013a).

Capture fisheries in Laos

Capture fisheries in Laos are based on artisanal fisheries and most of the catches are for subsistence. These catches are usually missing from national statistics for various reasons, including a lack of capacity and resources, difficult access to remote villages and dispersed nature of the fisheries. For these reasons the catch production is calculated based on yield per unit area of the water bodies or through fish consumption studies. The following is a summary of fish production in Laos from available sources.

The fisheries sector is poorly represented in government priorities and interests in Laos. Other aquatic animals are not represented in national statistics, and inland fisheries catch statistics are much disputed (Phonvisay 2013). Most of the catch statistics are based on total water resource area, for instance in 1996, the Department of Livestock and Fisheries (DLF) estimated a total water resource area of 791,720 ha for capture and culture fisheries and fish production was estimated at 38,000 tonnes, of which aquaculture accounted for 12,000 tonnes (DLF 1996). In 2000, fish production was estimated at about 60,000 tonnes and aquaculture contributed 26% (Guttman & Funge-Smith 2000). Further revision of production was made by DLF in 2004 to 90,000 tonnes and then new estimates of area were carried out in 2006 and fish production was estimated up to 143,847 tonnes, of which 89,097 tonnes was from capture fisheries and 54,750 tonnes (38% of total production) from aquaculture (DLF 2007). Hortle (2007), however, estimated production at 208,503 tonnes, including 167,922 tonnes of fish (85,076 tonnes of fresh fish and 82,846 tonnes of preserved fish), and 40,581 tonnes of other aquatic animals. This estimation was based on a consumption study. The only time series data on capture fisheries in Laos is the FAO-FishStat database. Although these data are considered to underestimate the catch, they provide a general upward trend (Figure 2.6) which is considered indicative of the change in the fishery, although caution must be taken as this could also be improved sampling methods not any actual growth in yield or the effect of increased effort.

Fish species assemblages in Laos are well documented, particularly in the hydropower project areas or other water development projects that require EIAs and surveys of aquatic animals including fisheries. At least 481 species have been documented in Laos including 22 exotic species (Kottelat 2001). Several ichthyological surveys have been carried out in the Mekong tributaries including the Xe Bang Fai (130 species), Nam Theun (66 species), Xekong (175 species), Nam Ou (84 species) (Kottelat 1998, 2001, 2009,). New species are still waiting for identification and many have been documented when intensive ichthyological explorations have been undertaken (Kottelat 2011).

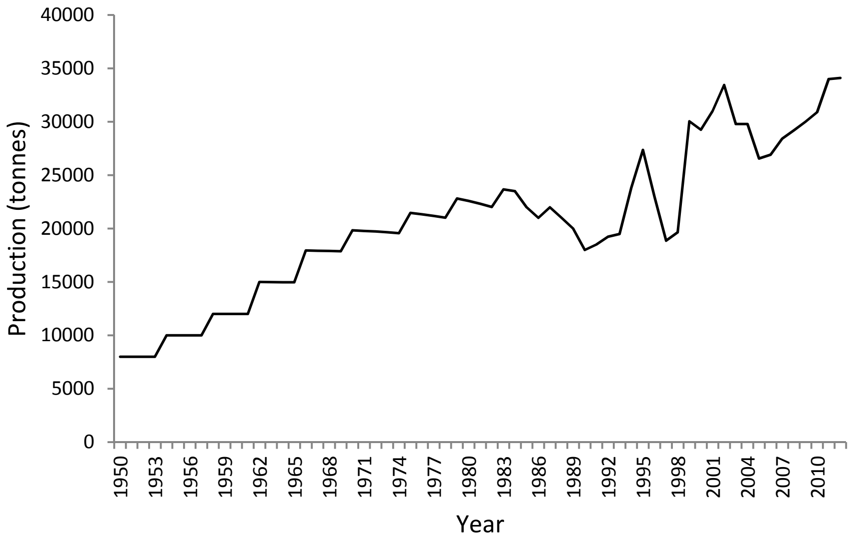


Figure 2.6. Capture fisheries production in Laos (Source: FAO-FishStat).

There is no information on change in abundance, biomass and species composition in the main Mekong River in Laos. The large fish species, including the endangered *Probarbus jullieni*, are caught in central and south parts of the country (MRC 2010a; Cacot 2008). Many mature individuals of economically important fish species, such as *Pangasius krempfi* Chaux & Fang, 1949*, Hemibagrus wyckioides* Chaux & Fang, 1949, and *Cirrhinus microlepis,* Sauvage 1878, are captured in Champassack province for artificial breeding and domestic purposes (Cacot 2007). In Louangprabang province, the annual catch per fisher reported in 2000 was 110.4 kg (Sjorslev 2000), ten years later the catch has changed little at 111.6 kg/fisher/year (Cacot 2010). In addition, the medium and large fish (100-1000 g) accounted for 53% of total catch and endangered species, such as Mekong stingray, are observed in many areas. However, the catch of individual fishers is declining in some areas, because of increasing numbers of fishers but overall catch is stable. Fishery resources are under pressure from increasing fishing effort as a result of high market demand of wild fish. The fisheries are also likely to be at risk when the mainstream dams in the LMB are constructed and operational at the end of this decade. Therefore, it is necessary to incorporate the fisheries sector into water development projects, to ensure fisheries resources are taken into account when formulating new projects, and mitigation measures are in place to minimize the negative impacts on the aquatic resources.

Importance of fisheries in the Lower Mekong Basin

As described above the total yield of the Mekong fishery is estimated at between 3.7 and 4.4 million tonnes per year, of which capture fisheries contribute about 1.9 million tonnes. At a price of US$ 1-1.8 per kg (based on 2008 prices) the total value of the

Mekong fishery is US$ 3.7-7.0 billion per year (MRC 2010a). Capture fisheries in the LMB play a very important role in rural livelihoods, not only providing food for subsistence but also income and employment, in particular for rural poor, who have limited assets and income generation opportunities. People living along the river bank rely heavily on long distance migratory species for their food security. This trans-boundary, long-distance fish migration accounts for 40-70% of the total catch (Barlow *et al.* 2008). Fish related activities, such as marketing, processing, fishing gear, boat making and repairing, provide job opportunities and contribute to the rural economy. For example, *Pangasius* farming in the Mekong Delta of Vietnam employs two million people in the production line starting from culture of the fish to the final product (package of fish fillet).

Fishes are important sources of animal protein that contribute 49-82% of animal protein consumed in the LMB. Average fish consumption in the LMB is 45.4 kg/capita/year (Hortle 2007), Cambodia and Vietnam consume high levels at 52.4 and 49.5 kg/capita/year respectively, follow by Thailand (46.9 kg/capita/year) and Laos (43 kg/capita/year). About one-third of fish consumed in Thailand and Vietnam is preserved fish, about one-quarter in Cambodia and less than one-tenth in Laos.

People in the LMB consume fish and OAAs almost every meal. Fermented fish and fish sauce are commonly use in recipes or eaten directly with rice and other foods. Milk and dairy products, rich sources of important minerals in particular calcium, are not traditional foods for people in the LMB and are not available in rural areas. The main sources of essential minerals and vitamins for the people in the LMB come from fish, fish products and OAAs. Small fish have a rich mineral content, in particular calcium and vitamin A, which is much greater than found in larger fish (Roos 2003), so they are very important to rural poor and disadvantaged people who commonly consume small fish and sell larger ones. These small fish are especially important for children to ensure good bone growth and neuromuscular function as well as prevention of diseases such as rickets (Pettifor 2004).

Fishers engage in fishing in different habitats, notably the Mekong mainstream and its tributaries, floodplains, reservoirs, lakes, swamps and rice fields. A variety of traditional fishing gears is employed: in Cambodia, 150 gear types are documented (Deap *et al.* 2003) while at least 63 fishing methods are recorded in Laos (Claridge *et al.* 1997). The common fishing methods used in the main river are gillnets, cast nets, hooks and lines while scoop nets, scoop baskets and lift nets are used to target small cyprinids in the rice fields, flooded forest and channels. People fish all year but fishing is also traditionally linked with the fish migration periods. The main fishing seasons are at the beginning of wet season (June–July), when fishers target migratory species that move from the mainstream to breeding habitats, and at the end of flooding period (November-December), when fish return to the mainstream, dry-season refuges. The dry season movement is also important, as many species migrate to deep pools in the mainstream for food and reproduction; fishers also catch these species for subsistence and income.

Although there is limited information on sport fishing in the LMB, this activity has recently become popular in the cities and urban areas, where anglers target fish not only in the Mekong and its tributaries but also in the channels, swamps, reservoirs and communes. Catches are mainly for consumption or the sale of larger fish for cash. Fish also play an important role in culture, traditions and religions. People in rural areas give fishes to their relatives as gifts when they catch a lot. Many people believe that releasing fish in the New Year will bring good luck and good health in the coming year. Fish also represent symbols of religion; many drawings of fish are found on the walls of temples. The catching large Giant Mekong Catfish is seen as very lucky for fishers in Laos and Thailand, as they sell for a high price. Conversely, fishers in Cambodia do not want to catch this fish; when this species is accidentally caught in the Dai fishery, this means a very bad day for them as they believe that catfish is a ghost and will bring bad luck to their family. If it is still alive it will be released immediately, but if not a religious ceremony to ask for forgiveness for the death of the fish will be organised.

Fish species and migration system

Fish species in the LMB can be grouped into white, black and grey fishes (Poulsen *et al.* 2002; Welcomme *et al.* 2006b). White fishes reside in the river channels for the main part of the year and make long distance migrations between floodplains and the main channels. Black fishes are species that live most of the time in floodplains, lakes and swamps, and undertake limited lateral migrations between permanent and seasonal water bodies while grey fishes live most of the time in tributaries and do not undertake longitudinal migrations. They migrate to the floodplains in the wet season and move back to tributaries when the flood recedes.

Fish migration in the LMB can be classified into three migration systems (Poulsen *et al.* 2002). The Lower migration system covers downstream from the Khone Falls, to the Tonle Sap river and lake system in Cambodia and the Mekong Delta in Viet Nam (Figure 2.7). Migration is thought to take place at the beginning of the flood season when the water level rises, stimulating fish to move from deep pools (dry season habitats) to floodplain habitats in the Tonle Sap/Great Lake system and the Mekong Delta in Vietnam. This is, however, not accurate as fish migrate at all times of the year (Figure 2.8). The fishes feed in the flooded forest and on vegetation in the floodplains.

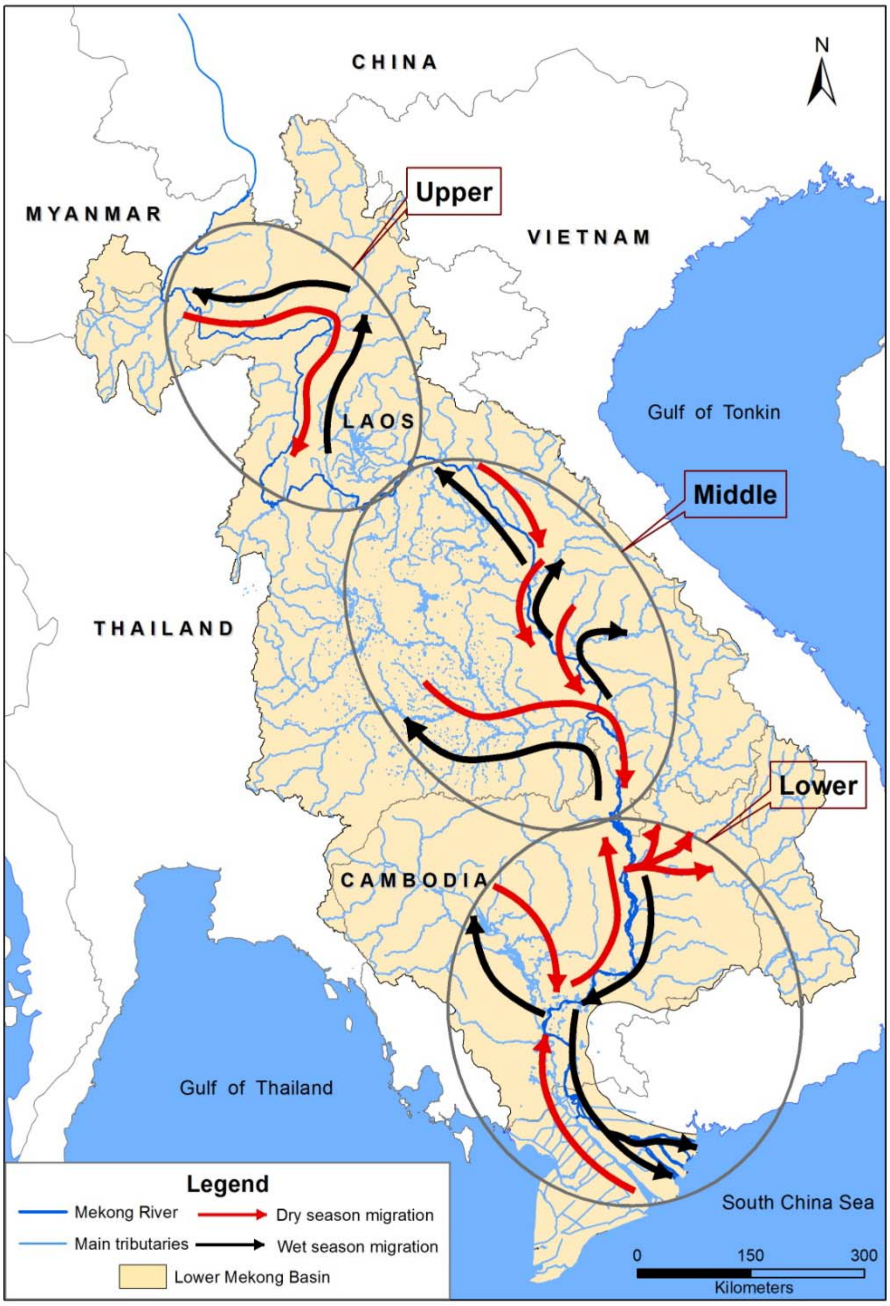


Figure 2.7. Map of migration systems in the Lower Mekong Basin (Source: Poulsen *et al.* 2002).

Several species also spawn in deep pools while others spawn far upstream and depend on the flow to bring eggs and larvae back downstream to the floodplain nursery and feeding areas (Poulsen *et al.* 2002). The Tonle Sap/Great Lake system plays a very important role in enabling the drift of larvae onto its floodplain. When water discharge in the Mekong River increases at the beginning of the flood season, the flow of the Tonle Sap River changes direction, flowing from the Mekong into the Tonle Sap and towards the Great Lake, carrying drifting larvae and juveniles into the floodplain in Tonle Sap from the Mekong. An important group of migratory species in this system is the genus *Henicorhynchus* that accounts for 40 % of the total catch (Lieng *et al.* 1995).

Others species, including *Catlocarpio siamensis* Broulenger, 1898, *C. microlepis*, *Cyclocheilichthys enoplos* Bleeker, 1850 and *P. jullieni*, as well as Mekong catfish (Pangasiidae family), also take part in this Lower migration system. The 3S tributary system (Sekong, Sesan and Srepok) are the most important tributaries linked with the Lower Mekong Migration System (Ziv *et al.* 2012). Many species also move from the Mekong River to the 3S system to complete their lifecycles, for example *Henicorhynchus* species and *P. jullieni*.

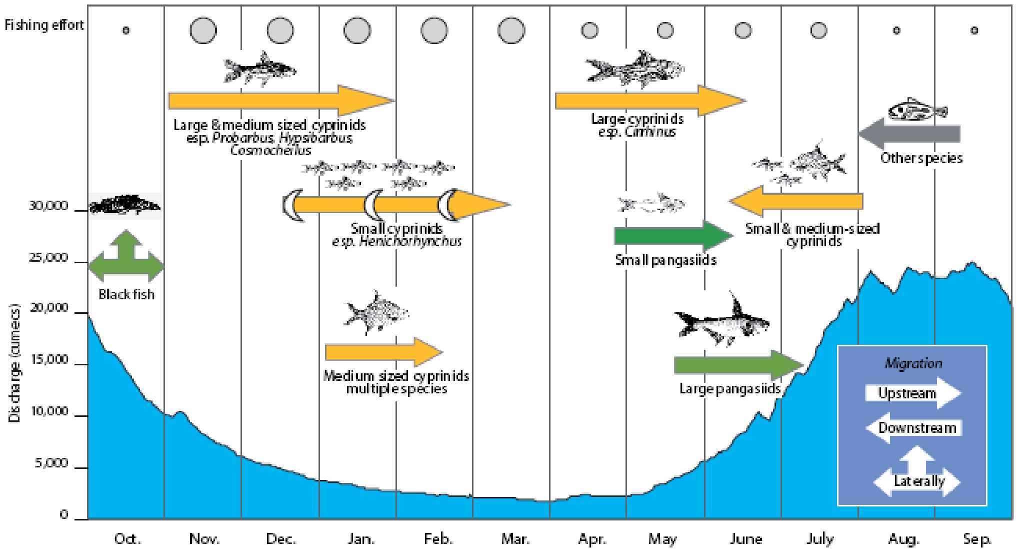


Figure 2.8. Fish migration patterns in Khone Falls Areas, the Mekong River (Baird *et al.* 2001).

The middle migration system extends from above Khone Falls to above Vientiane. This system consists of many floodplain habitats connecting with the major tributaries of the Mekong (the Kading River, San River, Xe Bang Fai River, Hinboun River, Mun River, Songkhram River and other tributaries). Fish move between their dry season refuge habitats in the deep pools to floodplain feeding and spawning habitats in the tributaries. At the beginning of the flood season, fish migrate upstream through the tributaries into floodplain habitats and move back at the end of wet season to seek dry season refuge habitats in deep pools in the mainstream. The Lower and Middle systems are interconnected. Several species are documented to move over the Khone Falls, during the migration period (beginning of flood season and during the dry season). Some species, including the same species that contribute to the lower migration system when juveniles, also take part of the middle migration system once they reach maturity. For example, *C. enoplos* and *C. microlepis* are mainly reported to be found as juveniles and sub-adults in the Lower Migration System but as mature adults in the Middle Mekong Migration System (Poulsen *et al.* 2002).

The Upper Mekong System starts from above Vientiane to the border with China. This stretch is a comparatively narrow, rapid and fast flowing channel with numerous small streams and tributaries with limited floodplain. The fish migration system is characterised by upstream movements at the beginning of flood season, when fish migrate from dry season refuge habitats in the mainstream to spawning habitats further upstream. The well known fish species of this migration system is the Giant Mekong Catfish that moves upstream for spawning in the dry season during April and May. *Henicorhynchus* spp. are also important for the upper Mekong fishery system; up to 200 kg per day can be caught by individual fishers during the migration period in October (Poulsen *et al.* 2002)

These three migration systems are interconnected and many species migrate across many countries. Several species migrate at the onset of the flood season from the Mekong mainstream to tributaries and floodplains for breeding and then move back to mainstream again for dry season refuge when water levels recede at the end of the flooding period. Several species undertake long distance movement for reproduction, including the giant Mekong catfish, which spawns in the dry season during April-May. Many species use more than one habitat to complete their lifecycles. For instance, Pangasiidae spawn in rapids, use the floodplains as nursery and feeding habitats and deep pools in the main river for refuge in the dry season (Figure 2.9). In general, floodplains act as nursery and feeding habitats for the Mekong species. When breeding takes place in upstream areas, eggs and larvae drift downstream with the current to flooded forests and floodplains from where fish will grow before migrating back to the main channel at the end of wet season.

There is limited information on the spawning requirements and spawning grounds of many of the Mekong fishes, but it is believed they are associated with the rapids and deep pools in the mainstream and tributaries, and in the floodplains. The species using deep pools in the mainstream for spawning include *Boesemania microlepis* Bleeker, 1859*, C. microlepis* and *Mekongina erythrospila* Fowler, 1937. The spawning grounds of the first two species have been identified in the Mekong mainstream in Champasack Province, southern Laos (Poulsen *et al.* 2004).

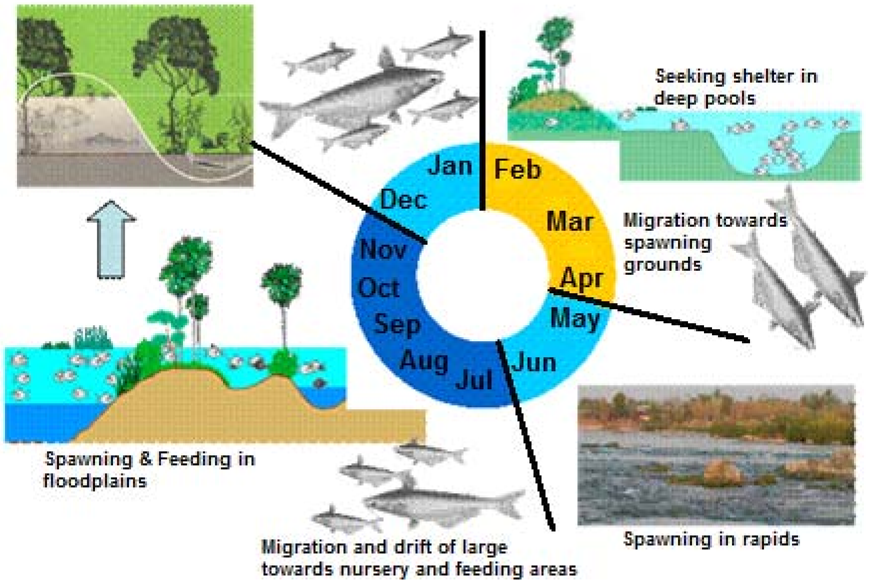


Figure 2.9. Generalized life cycle of the Mekong fish species (Source: Sverdrup-Jensen 2002).

Aquaculture development

Over the past two decades governments in the LMB countries have invested in aquaculture research, infrastructure and extension programmes. Thailand and Viet Nam have increased investment in capacity building directed at aquaculture techniques and extension packages and now aquaculture systems are well developed in these two countries. With assistance from various donor organisations, aquaculture in Laos has also improved both in terms of infrastructure and capacity of the staff; in 2012 there were 31 state hatcheries and more than 32 private hatcheries (Phonvisay 2013).

Aquaculture in the Mekong region is important for food security and income generation in rural areas. The common aquaculture systems are cages, earthen ponds and paddy fields (Pawaputanon 2007). The species used for aquaculture include exotic species (e.g. *O. niloticus*, *C. carpio*, *Labeo rohita F. Hamilton 1822, Clarias gariepinus* (Burchell, 1822), *Ctenopharyngodon idella* (Valenciennes in Cuvier & Valenciennes, 1844), *Hypophthalmichthys nobilis* (J. Richardson, 1845) (Welcomme & Vidthayanom 2003) and indigenous species (e.g. *C. striata*, *Anabas testudineus* (Bloch, 1792), *B. gonionotus*, *C. microlepis*, *H. wyckioides*, *Osphronemus goramy Lacepède*, 1801, *Pangasianodon hypophthalmus* (Sauvage, 1878), *Pangasius larnaudii* Bocourt, 1866 and *Leptobarbus hoevenii* Bleeker, 1851) (Phillips 2002). However, the alien species, such as *O. niloticus*, *C. carpio*, and *C. gariepinus* are common for aquaculture as they grow quickly and require less technical input.

The aquaculture sector in the LMB has grown rapidly in the last decade. The main production area is the Mekong Delta in Viet Nam and the Korat Plateau in Northeast Thailand, with much less production from Cambodia and Laos (Phillips 2002). The boom of *Pangasius* farming in the Mekong Delta in the early 2000s was driven by an expanding export market in the United States of America, one that has had significant impacts on the US catfish farming industry. Since that time the market has expanded into Europe, Australia and other countries. *Pangasius* production has increased significantly and reached more than 1.25 million tonnes in 2013 (Dzung 2012). The recent growth in *Pangasius* production has dominated aquaculture production in the LMB. Total fish production in 2001 estimated at about only 730,000 tonnes, increase sharply more than 2.7 million tonnes in 2012 (Figure 2.10) of which nearly half came from *Pangasius* farming in the Mekong Delta of Vietnam.

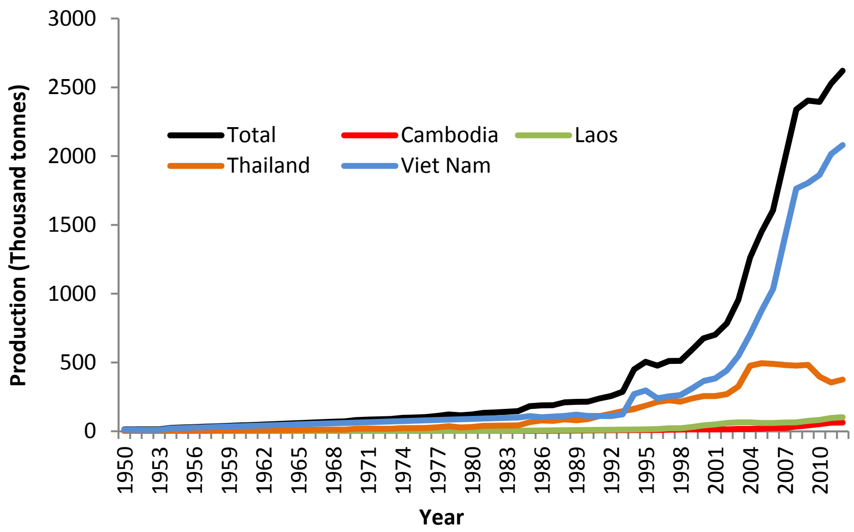


Figure 2.10.   Aquaculture productions in the LMB (Source: FAO FISHSTAT 2014).

The aquaculture sector contributes to the livelihoods of people in the LBM in various ways, not only providing fish for food and income for small scale household farmers and private enterprises but also creating job opportunities for local people. In the Mekong Delta, *Pangasius* exports were valued at over $US 1.8 billion in 2011 and employed more than two million people (Dzung 2012). However, the rapid growth of *Pangasius* aquaculture in the Mekong Delta has created concern over pollution and water quality caused by the intense farming methods used. Food waste and anti-biotics used in aquaculture may affect the ecosystem and diseases may be spread to wild fishes. In addition, the rural poor have little benefit from the Pangasius industry in terms of food security because most of products are exported.

The limitation and challenges of aquaculture development in the LMB is related to the high investment cost and availability of land and water. Aquaculture is only suitable for households who have sufficient assets and access to credit.

Despite the importance of capture fisheries and aquaculture to food security and rural economy in the LMB, this has largely been overlooked and priorities have been given to other sectors such as agriculture, hydropower, and mining (Welcomme *et al.* 2010). As a result, the fisheries sector has received little attention, limited support and it is difficult to mainstream fisheries activities into national agendas (Cowx & Portocarrero 2011). Fisheries have been seen as a resource of last resort for the rural poor, which contributes to food security in the affected communities in the Nakai reservoir area (NTPC 2012).

2.2.3 Land use and agriculture development

Agriculture is the backbone of food systems in the LMB countries, in particular rice production that provides food security and foreign exchange revenue for the region. Agricultural development in the LMB can be broadly classified into three different agro-ecological zones namely upper, middle and lower (Figure 2.7). The upper zone covers northern Laos and north Thailand. This area is characterised by mountainous and high slopes land, with limited land for paddy rice. In the upper zone, people practice swidden agriculture, raising livestock and collecting NTFPs for their subsistence. In some lowland area, farmers also practice rainfed rice and other cash crops for subsistence and income. In the north of Laos, rubber plantations, cassava and teak forestry is expanding in the upland forest (Vongvisouk *et al.* 2014). The middle zone covers lowland and plateau areas, the soils are more fertile than the upper zone (ICEM 2014). Rainfed rice dominates production in this zone; followed by the cassava, sugarcane, soybean and maize farming particularly in northeast Thailand. These crops are well developed to produce high yields (ICEM 2013). Coffee plantations are found in the plateau areas such as the Bolaven plateau in Laos and Central highlands in Vietnam. In lowland areas in central and southern Laos commercial forestry is practiced (e.g. Teak, Aquilaria, Eucalyptus) (IISD 2009). Recently, rubber tree plantations have expanded and are replacing the natural forest in the central and southern provinces of Laos. The lower zone is flat and can be divided in two sub zones, the Cambodian floodplain and Mekong delta (Vietnam). Rainfed and irrigated rice is prominent in the Cambodian floodplain. The Mekong Delta has the largest number of irrigated canals in the LMB and rainfed rice farming is very intensive, with up to three crops per year (MRC 2010b).

Agriculture in the upper zone is typically less intensified than in the middle and lower zones, where most crop production takes place. Lowland rice farming systems include rainfed rice, dry season irrigated rice, floating rice, flood recession rice, and multi-crop production systems are prominent in the Cambodia floodplain and Mekong Delta (MRC 2005a). The main harvest is the rainfed rice season crop. Most of the rural farmers use rainfed rice for household consumption and to sell for cash. The main rice producers in the LMB are Thailand and Vietnam (Table 2.1), the farmers in middle and lower zone have progressively shifted from subsistence to commercial rice farming.

More than 24 million hectares of the LMB's total cultivated land is used to produce rice (FAOSTAT 2014). Rice is a key staple food in the LMB region, and it plays a very important role in food security (Eliste 2012). Rice consumption varies between the countries of the LMB, for instance, on average annual rice consumption in Laos is 162 kg/person/year, Cambodia and Vietnam is 159 and 145 kg respectively, while in Thailand it is around 112 kg (FAOSTAT 2014).

Table 2.1. Rice production in the LMB (2012).

	Cambodia	Laos	Thailand	Vietnam
Area harvested (ha)	3,007,545	933,767	12,600,000	7,753,163
Production (t)	9,290,940	3,489,210	37,800,000	43,661,570
Yield (Hg/ha)	30,892	37,367	30,000	56,315

Source: FAOSTAT: http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E

Rice is a common crop for Cambodian farmers, with more than 80% of farmers growing rice (CSES 2004 & 2007). Rice is one of the main contributors to agricultural growth, accounting for nearly half of total production between 1994 and 2006. Rice has become the most important agricultural export commodity contributing to more than 10% of the total export value in 2007 (Yu & Diao 2011). According to MRC (2010b), rice culture in Cambodia has increased in area and yield between 2000 and 2005; the total wet season area increased from 1.93 million ha to 2.08 million ha while the dry season area expanded from 233,000 ha to 321,000 ha. Average yields also increased from less than 2 t/ha to 2.48 t/ha, with distinct differences between wet and dry season yields. In 2012, the cultivation area had increased to 3 million ha with the yield estimated at 9.3 million tonnes (Table 2.1).

Rice is also the dominant crop in Laos, with a total area of 736,000 ha in 2005 (MRC 2010b). Rice production in the country can be divided into three categories: rainfed lowland, irrigated lowland, and upland (Linquist *et al.* 2006). Over the last two decades, Lao rice production has more than doubled from 1.7 million tonnes (Eliste 2012) to around 3.5 million tonnes in 2012 (FAOSTAT 2014). This represents an average of

5.1% annual growth, which is one of the highest in the region (Eliste 2012). The increase in rice production is due to improvements in yields and the expansion of rice cultivated areas.

Thailand is the largest rice exporter country in the LMB. There is a total land area of 51.31 million ha of which about 40% is agricultural land (ODI 2011). The main agriculture crops are rice (60% of the cultivated area), maize, cassava, sugar cane and palm oil. Rice production was estimated at more than 37 million tonnes in 2012 (FAOSTAT 2014). The main cultivated areas are in the northeast region, where paddy rice accounts for more than 80% of the total cultivated area (MRC 2005a). The rice cropping systems can be classified into three system (MRC 2010b): (1) lower paddy land which is wet season rice that is vulnerable to flooding and temporary water logging; (2) middle paddy land with better water management and control systems is the most productive area; and (3) upper paddy land mostly for drought-resistant plantation and short-duration rice varieties.

Rice is very important to the Vietnamese economy and food security, not only in terms of foreign exchange earning but also providing rice for consumption by the local people. Rice became the second largest foreign exchange revenue, contributing 10% of total export value and accounting for 40% of the agricultural export value in 2007 (Que & Que 2000). Rice production in Vietnam is the highest in the LMB and reached nearly 44 million tonnes in 2012 (Table 2.1). The main rice growing area is the Mekong Delta region which covers nearly half the total farm land in the whole country and about 60% of the area is irrigated. Yields are much higher than the other LMB countries (MRC 2010b). Up to four crops are produced per year. Farm production is diversifying: rice and shrimp or fish farming (Preston & Clayton 2003) and integrated rice cum duck systems (VSF-CICDA 2006) are common in this area.

2.2.4 Hydropower development in the Lower Mekong River Basin

Potential of hydropower development in the LMB

Damming plays an important role in providing energy resources for people around the world; it provides water and electricity services, as well as flood protection and recreational activities. According to World Commission on Dams Report 2000, there were more than 45 000 large dams worldwide of which about 22,000 are in China. Dams supply water for agriculture (40% of dams) and contribute 19% of world electricity. Whilst dams support economic development they also bring social and environmental risks (MRC 2010a). It has been estimated that 40-80 million people have been displaced by dams and 60% of the world’s rivers have been affected by dams and diversions (WCD 2000).

The development of hydro power dams in the Mekong mainstream is not new; they have been planned since the 1950s by the Mekong Committee (Mekong Secretariat 1994) but the Cold War put development on hold in the 1960s through to the 1980s (Hirsch 2011). Interest in hydropower development on the mainstream of the Mekong River returned to the agenda when the increase in international crude oil, gas prices and climate change concerns renewed interest in hydropower as a clean energy source (Barlow 2008). In 2010, eleven dams were proposed for construction on the Mekong mainstream (ICEM 2010): two dams (Xayabury and Don Sahong) are being constructed in Laos at present and others are in the planning phases (Figure 2.11).

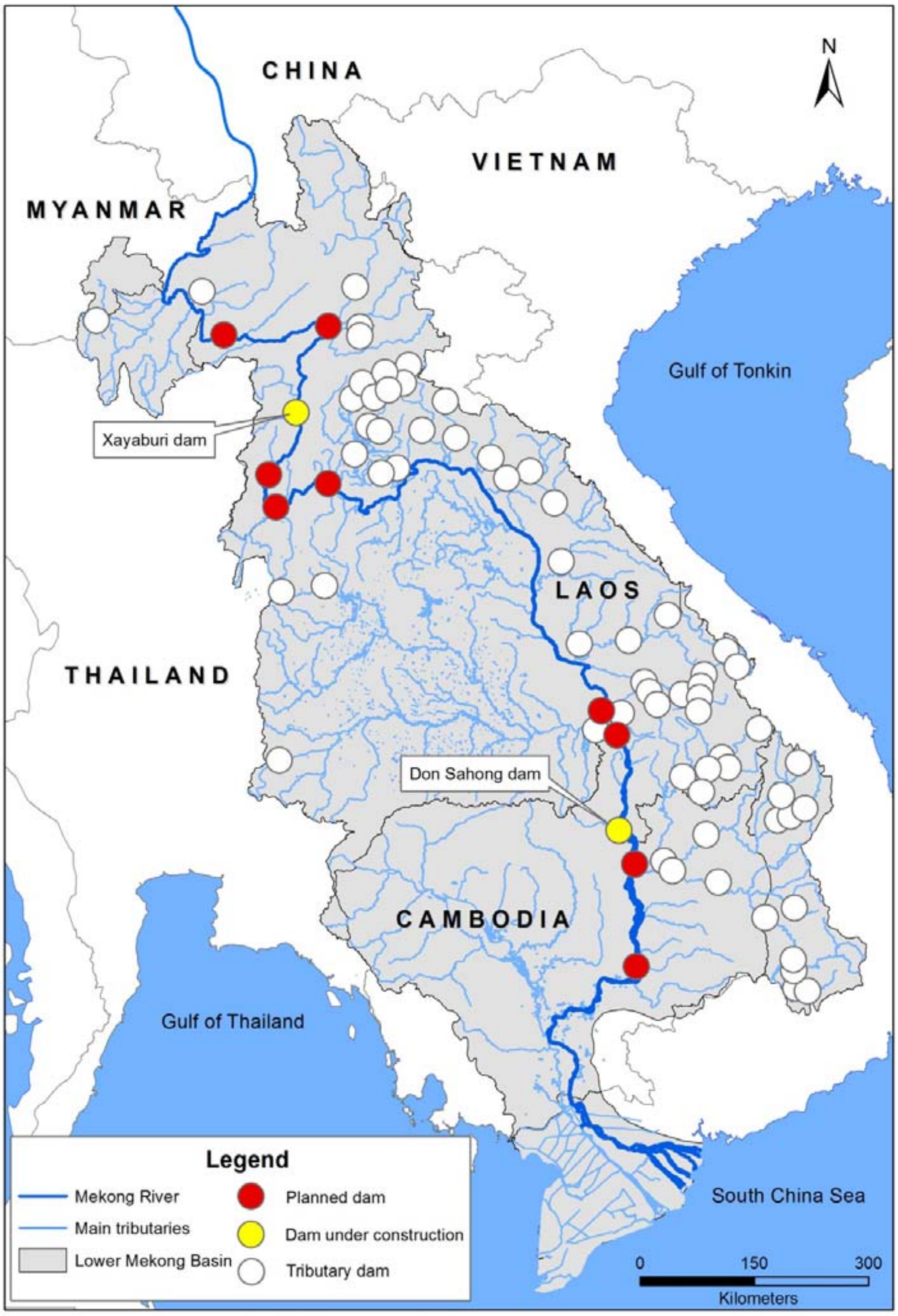


Figure 2.11. Proposed Mekong mainstream and tributary dams (ICEM 2010).

The Lower Mekong River Basin Countries have considerable potential for hydropower development. Hydropower will boost national socio economic development and earn foreign exchange. The policies of the LMB governments on hydropower development is to promote the use of water resources to generate electricity for national needs and support cross-border power trade within the wider framework of regional energy trade and economic integration (MRC 2010b). The potential of hydropower development in the LMB has been estimated at more than 30,000 MW (Table 2.2) of which 22% (6683 MW) has been developed. The number of hydropower projects is going to increase because of growing interests from investment companies and demand for electricity is high (MRC 2010b). Most dams in the LMB have been constructed in the Mekong tributaries of Laos. Currently, there are 29 dams with total installed capacity of 10611 MW in the Mekong River Basin (Table 2.3) and more dams are planned on the Mekong and its tributaries. Since 2007, the governments of the LMB countries have proposed eleven mainstream dams with total installed capacity of 13,377 MW (Table 2.4).

Table 2.2. Hydropower development in the LMB (Source: MRC State of the Basin Report 2010; *Power Project in Lao PDR 2011).

Country	Existing		Under construction		Planned		Total (MW)
	No. Dams	MW	No. Dams	MW	No. Dams	MW	
Cambodia	1	1	0	0	6	5589	5590
Laos	14	2549*	8	1168*	60	17686	21403
Thailand	7	745	0	0	0	0	745
Vietnam	4	1204	7	1016	4	299	2519
Total	**26**	**4499**	**15**	**2184**	**70**	**23574**	**30257**

Energy demands and trade

In the past decade industrial development has increased significantly in the LMB, in particular in Thailand and Vietnam. As a result there is a need to have sufficient energy to meet demand. The predicted power demands in the LMB countries are high, from 67,307 MW in 2015 to 96,182 MW in 2020 (Table 2.5). While Thailand and Vietnam have already developed or have exploited their hydro power resources, attention has focussed on Cambodia and Laos where potential for hydropower development is extensive. Laos has massive potential for hydropower development but few sites have been developed and currently only 41% of households in Laos have access to electricity; the government plans to increase it to 90% by 2020 (EDP 2004). The power development policy in Laos has focused on two national priorities; providing energy to meet its domestic electrification needs and exporting electricity to neighbouring countries (STEA 2006).

Recognising the importance of the hydropower sector to economic growth and poverty alleviation, the Government of Laos in 1993 signed the first Memorandum Of Understanding with the Government of Thailand to supply 1,500 MW and in 2007 it agreed to supply up to 7,000 MW of electric power to Thailand by 2020 (EPD 2008). An MOU was also signed with Vietnam in 1998 to provide 2000 MW and the amount was increased to 3000 MW by 2015; the last agreement in 2008 was 5000 MW by 2020.

Table 2.3. Commissioned dams in the Mekong River Basin (more than 20 MW) (Source: MRC hydropower database 2008; *International Rivers 2013).

No	Dam name	Country	River	Commis -sioned	Installed capacity (MW)	Height (m)
1	Manwan*	China	Mekong	2007	1,550	126
2	Dachaoshan*	China	Mekong	2003	1,350	118
3	Gongguoqiao*	China	Mekong	2012	900	130
4	Jinghong*	China	Mekong	2009	1,750	118
5	Xiaowan*	China	Mekong	2010	4,200	292
6	Nuozhadu*	China	Mekong	2012	5,850	262
7	Nam Ngum 1	Laos	Nam Ngum	1971	148.7	75
8	Nam Ngum 2	Laos	Nam Ngum	2011	615	181
9	Theun-Hinboun	Laos	Theun/Hinboun	1998	220	38
10	Xeset 1	Laos	Xeset	1994	45	16
11	Xeset 2	Laos	Xeset	2009	76	16
12	Nam Mang 3	Laos	Nam Mang	2004	40	28
13	Houay Ho	Laos	Houayho/Xekong	1999	150	76.5
14	Nam Leuk	Laos	Leuk/Nam Ngum	2000	60	45
15	Nam Lik 2	Laos	Lik	2010	103	328
16	Nam Theun 2	Laos	Theun/Xe Bang Fai	2010	1,075	48
17	Ubol Ratana	Thailand	Nam Pong	1966	25.2	35.1
18	Sirindhorn	Thailand	Lam Dom Noi	1971	36	42
19	Chulabhorn	Thailand	Nam Phrom	1972	40	70
20	Pak Mun	Thailand	Mun	1994	136	17
21	Lam Ta Khong	Thailand	Lam Ta Khong	2002	500	40.3
22	Yali Falls	Vietnam	Sesan	2001	720	65
23	Sesan 3	Vietnam	Sesan	2006	79	79
24	Sesan 3A	Vietnam	Sesan	2007	96	35
25	Plei Krong	Vietnam	Se San/Kroong Po Ko	2008	100	65
26	Buon Kuop	Vietnam	Sre Pok	2009	280	34
27	Buon Tua Sra	Vietnam	Se San/Kroong Po Ko	2009	86	83
28	Sesan 4	Vietnam	Sesan	2009	360	60
29	Sre Pok 3	Vietnam	Sre Pok	2009	220	52.5
	Total				**10,611**	

Table 2.4. Proposed dams on the Lower Mekong River Basin (Source: ICEM 2010).

No.	Project name	Country	Installed capacity (MW)	Dam Height (m)
1	Pak Beng	Laos	1,230	76
2	Luang Prabang	Laos	1,410	68
3	Xayaburi	Laos	1,260	32
4	Pak Lay	Laos	1,320	35
5	Sanakham	Laos	700	38
6	Pak Chom	Laos	1,079	1,200
7	Ban Koum	Laos	1,872	53
8	Lat Sua	Laos	686	27
9	Don Sahong	Laos	240	10.6
10	Stung Treng	Cambodia	980	22
11	Sambor	Cambodia	2,600	56
	Total		**13,377**	

Table 2.5. LMB power demands (MW) (Source: MRC State of Basin Report 2010).

	2005	2010	2015	2020
Cambodia	302	407	699	NA
Laos	291	648	1,216	1,487
Thailand	20,538	25,612	33,897	44,695
Vietnam	9,255	20,000	31,495	50,000
Total	30,386	46,667	67,307	96,182

Benefits and Loss

Apart from electricity, dams also supply water for agriculture in the dry season and hold water to prevent flooding in the wet season (WDC 2000). Dams also create reservoir fisheries, provide potential for aquaculture and create job opportunities for local people living near the reservoir (Sverdrup-Jensen 2002, Barlow 2008). Fish marketing and processing in Nam Ngum Reservoir, Laos, provided new jobs for women. In addition, fish production both from capture and aquaculture in the reservoir supported more than 50% of fish supplied to the Vientiane municipality and some also to Luangprabang province (Phonvisay 2006).

The development of hydropower plants in the LMB is faced with many challenges over the social and environmental impacts. The Nam Theun 2 dam in Laos displaced more than 6,200 indigenous people from the reservoir area and affected more than 100,000 people downstream of the dam who lost access to paddy fields, river bank gardening, forests and grazing lands (WCD 2010). Dams are barriers to fish migration, changing the river ecosystem and fish habitats (Barlow 2008; Dugan *et al.* 2010; Halls *et al.* 2009).

The physical barrier created by a dam not only prevents longitudinal migration to spawning grounds of many fish species but also blocks the downstream movement of fish eggs and larvae to nursery and feeding habitats (Petts 1984; Cowx and Welcomme 1998; Lucas *et. al.* 2001; Agostinho *et al.* 2008). To date there is no technology in place to mitigate this impact, in fact existing fish pass technology used in Europe and America does not necessarily apply in the Mekong river due to the species diversity and complexity of the ecosystem (Dugan 2008).

Future direction

Effort has been made through regional cooperation to ensure the hydropower developments meet regional and international standards on sustainable development of water resources[1]. The MRC is the intergovernmental body responsible for cooperation on the sustainable management of the Mekong Basin whose members include Cambodia, Laos, Thailand and Viet Nam. Its mission is to promote and coordinate sustainable management and development of water and related resources for the countries' mutual benefit and the people's well-being. MRC plays an important role in coordinating and facilitating the process of water development in the Mekong River. An example of MRC's role in hydropower development on the Mekong Mainstream is the Xayabouri dam project, as it tried to make an agreement among the four countries and ensure that the development has less negative impacts on people and the environment and benefits all.

The debate on Mekong Mainstream dams is ongoing, but guidance and assessment tools for sustainable hydropower development have been developed (MRC 2009c, MRC 2010a). Nevertheless, at the same time many tributary dams are under construction or planned. The demands of electricity to meet economic development are high and will continue to increase over the next two decades (MRC 2010a). In Laos, hydropower development has become a significant sector to support national policy on food security and poverty alleviation (NTPC 2005). The government has set a goal to

[1] In April 1995, Cambodia, Lao PDR, Thailand and Viet Nam signed an "*Agreement on the Cooperation for the **Sustainable Development** of the Mekong River Basin*" (the 1995 Mekong Agreement). This agreement provides a framework for the sustainable development, utilisation, management and conservation of the water related resources of the Mekong River Basin, optimising multiple-use and mutual benefits and minimising harmful effects (Article 1). Beyond this the Member Countries agreed to protect the environment and ecological balance of the Basin (Article 3), and to make every effort to avoid minimise and mitigate harmful effects on the environment and water quality (Article 7)

be the "Battery of Asia" so hydropower development will continue to serve the growing demand for electricity in the region.

2.3 KNOWLEDGE SYSTEMS

2.3.1 Methods for assessing food security

This section is based on literature from FIVIMS & FAO (2002) on measurement and assessment of food deprivation and poor nutrition. This report summarised worldwide experiences on the use of methods to assess food security and provides the strengths and weaknesses of each method that need to be considered when applying to specific research.

The FAO measure of food deprivation

The FAO measure of food insufficiency refers to the occurrence of undernourishment based on a comparison of dietary energy intake (kcal) to meet certain energy requirements. Household food consumption below the energy requirement standard is called undernourished. The focus on dietary energy in assessing food deprivation is necessary as a minimum amount of daily energy intake is crucial for physical work performance and maintenance of body weight.

The FAO method provides a broad view for evaluating the worldwide picture of food insecurity and can be applied for identifying long-term trends in malnutrition. However, the disadvantages of this method include an inaccuracy in the basic food balance sheet data arising from inconsistent production data (e.g. fish production data); overstated prevalence of undernourishment due to too much focus on mean energy intake and inadequate on energy distribution; and consideration of energy intakes only and ignoring other aspects such as micronutrient intake.

Household Expenditure Surveys

The household expenditure survey is mainly used to assess the consumption and wellbeing of nationwide populations. Most surveys are intended to cover the full distribution across a population of various measures of welfare, including total income, total expenditure, consumption of food and non-food items. Food consumption data are normally classified according to three sources, namely (1) food purchased; (2) food given to a household member; and (3) food consumed from own production.

The advantages of the household expenditure survey is that it is a source of multiple, policy-relevant and valid measures including household food energy insufficiency;

dietary diversity; and the percent of expenditures on food. The second advantage is that they allow multilevel monitoring and targeting. The household expenditure survey can be employed to calculate national and regional prevalence of food insecurity in developing counties and to monitor how these changes over time, and also to identify food insecure groups. The third advantage is that it provides an analysis for identifying actions to combat food insecurity. Finally, as the data on expenditures are collected directly from the household level, they may be more reliable than those data from other sources. The main disadvantages of household expenditure surveys for measuring food insecurity are: (1) they are currently not undertaken on a regular basis; (2) they need considerable resources, skills and funding for data collection and analysis; (3) data are not included on the access to food by individual household members; and (4) estimates of food insecurity may be biased due to various systematic and non-sampling errors.

Individual Food Intake Surveys

Individual food intake surveys can be classified into questionnaire-based and current intake methods. Each method consists of several sub methods. Questionnaire-based methods are divided into dietary history methods, food frequency questionnaires, and 24-hour recall methods. Current intake methods cover weighed dietary records and chemical analysis of diets.

1. Dietary history method is one of the oldest approaches for assessing individual diets and is rarely used today. The dietary history consists of three steps. The first step is to identify eating patterns and to find out which foods are regularly eaten at which meal including the frequency and quantity of consumption. The second step is to cross check during the interview using a completed list of foods and fill in gaps of the interviewee. The final step is to record all foods consumed over the next three days. The time interval covered by the dietary history can vary from a few weeks to a season or to a year. The interview is carried out at the individual level and may last between 30 and 45 minutes, and more time is required to record all foods eaten over the next three days.

2. Food frequency questionnaires have many similarities with the dietary history method. It is applied for very large population samples, where time and budgets are limited. This method is used to determine food intake and most often used in epidemiological research. The questionnaires are designed for rating or grading food items into four or five categories of consumption to identify differences between consumers and non-consumers of particular foods and to test for links with disease.

The questions relate to the frequency of foods' consumption (daily, weekly or seasonally) or food groups over a given period of time. The surveys can be conducted in face-to-face interviews or by telephone, and also may be self-administered through postal surveys.

3. 24-hour recall method is commonly used to obtain information on food consumption by the individual or household over the previous 24 hours. The interview may take from 30 to 45 minutes. The interviewer may use appropriate memory aids, such as photographs of prepared dishes with diverse and calibrated servings, food models, and standardized household measures. The 24-hour recall method relies on memory capacity of what has been consumed. The recall usually retrieves information only on the previous day's consumption. Multiple 24-hour recalls may be better for estimating food consumption over a longer period.

4. Weighed dietary records involve recording the weights of all foods prior to consumption. A weighing scale of the appropriate capacity (e.g. 2 to 5 kg), and a logbook are provided to record the weight of all foods and beverages consumed and of any leftover food. For meals consumed away from home, estimates of the weights are recorded and later checked by the dieticians with the help of household measures, models, photographs. In some dietary surveys, all ingredients of the cooked dishes are weighed. If foods are prepared for the entire family, this approach requires that the entire prepared food be measured and then the individual consumption portion weighed as well as any leftovers. The number of days of food weighing and recording usually varies between one and seven days. The length of the survey depends on the purpose of the research, the sample size, individual or group. The dietary record method is considered to be the most accurate if compare to other methods. This method is often used as the reference method for validating more expedient methods.

5. Chemical analysis of diets requires the individual to provide a duplicate of all foods consumed (a sample of consumed food), including beverages, over the stipulated number of days. The duplicates are collected and stored in refrigerated wide-neck container. There are different ways of collecting dietary duplicates: one modality is to collect the exact weighed replica of all consumed foods; a second modality is to collect an aliquot of each of the servings, and a third is to reconstruct *a posteriori,* on the basis of the records of a dietary survey, aliquots of all raw food ingredients that have been eaten by the individual. At the end of the survey, the container is brought to the laboratory for chemical analysis of the nutrients.

None of the methods used to assess daily food intakes is completely free from inherent errors, and provide a fully accurate measure. This weakness applies to both individual and household surveys of dietary intake. In the individual surveys, much work has been done to minimise the errors by developing statistical techniques for adjusting with these errors.

Anthropometric surveys

An anthropometric survey is a survey to record the weights, heights and ages of a sample of children. The survey measures children using weighing scales and height-measuring boards and uses written documents to determine their ages. The data are then analysed to compare each child's measurements with a reference group. The findings of the surveys usually consist of values such as low height for age, low weight for age and low weight for height.

Anthropometric data do not necessarily reflect food consumption as they are influenced by other factor determinants of nutritional status, such as infections. These analyses show a lack of connection between the estimates of malnutrition in children and adults when comparing anthropometric data with measures of adequacy of dietary energy supply. The anthropometric indicators are used more widely in national surveys for projection of trends and long-term forecasts of food needs.

Qualitative surveys

Qualitative surveys involve participant observation, in-depth interviews and focus groups. Techniques such as Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) attempt to build simpler tools for assessing communities; both RRA and PRA rely heavily on focus groups and in-depth interviews of a limited number of individuals. These approaches, however, are unable to provide the basic understanding of food security to construct a valid and reliable qualitative measure. The Food Security Measurement Project in the United States attempted to create a model that could be taken to produce a country-specific measurement of food insecurity. The advantages of qualitative measures are that they have been well developed; can be quickly analysed; can be integrated into other surveys to reduce costs and logistics; and can incorporate as essential elements the perceptions of food insecurity and hunger by the people most affected. The disadvantages include the time and costs for the development of modules and it is unclear whether only one food security scale will measure the complexity of hunger in any given locale.

2.3.2. Livelihoods concept and analysis

The concept of livelihoods has been widely used in the survey of rural development and poverty in the past decade. The concept of sustainable livelihoods was put forward in the report of an Advisory Panel of the World Commission on Environment and Development that proposed sustainable livelihood security as an integrating concept and defined livelihood as "adequate stocks and flows of food and cash to meet basic needs, while security is referred to secure ownership of access to resources and income earning activities" (WCED 1987). Chambers & Conway (1992) provided the concept of sustainable rural livelihoods and defined sustainable livelihoods as a livelihood that comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living. The important feature of this livelihood definition is to draw attention to the link between assets and the options people have to practice alternative activities that can generate the income level required for their living. A revised definition of sustainable livelihoods and approach is provided by the Institute for Development Studies and the British Department for International Development, defining a livelihood as comprising the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, and maintain or enhance its capability and assets while not undermining the natural base (DFID 1999).

Ellis (2000) and Scoones (2009) provided a framework for the analysis of rural livelihoods (Table 2.6). The framework illustrates the main factors that influence livelihoods of people and the linkage between these. It focuses on people-centred analysis that begins with assessment of household assets, the livelihood outcomes and a livelihood strategy that they adapt to achieve these outcome (DFID 1999). The livelihood framework can be applied for both planning new development activities and assessing the contribution to sustainable livelihood made by existing projects.

The livelihood framework identifies household assets owned as livelihood platforms consisting of five main asset categories, namely: natural capital (fish stock, NTFPs, trees, land); physical capital (roads, irrigation, buildings, and machines); human capital (education, health); financial capital (credit, savings) and social capital (networks, associations). The household's access to these assets is modified by social relations, institutions and organisation. It is also influenced by external factors including trend (population growth, technology changes, migration, relative prices, national economic trends, world economic trends) and shocks (droughts and floods, fisheries collapses diseases, civil war) that are outside the control of the family. Under these stresses and shocks, households pursue diverse livelihood strategies composed of various activities including natural resources-based activities (e.g. fishing, livestock, collecting NTFPs) and non-natural resources-based activities, namely off-farm work, trade or remittances. The outcome of livelihood strategies is reflected in livelihood security effects (food supply, income, seasonality, degree of risk) and environmental sustainability effects (fish stock, water quality, biodiversity, forests).

In the context of small-scale fisheries, the household assets are fishing equipment (boats, fishing gears) and agriculture land where households pursue both fishing and farming for subsistence (Allison & Ellis 2001). The institutional context of small-scale fisheries include regulation and community rules that control access to resources to conserve and ensure sustainable exploitation of natural resources.

The livelihood framework has been employed in various disciplines including fisheries, livestock, forestry, agriculture, health, and urban development. The approach has become central to development programming in rural development and poverty reduction (Scoones 1998; Ellis 2000, Bene & Neiland 2003), monitoring and evaluation (Adato & Dick 2002), fisheries development policy and practice (Smith *et al.* 2005; Allison & Horemans 2006,), management of small-scale fisheries (Allison & Ellis 2001), understanding ecosystem and floodplain exploitation (Shoemaker *et al.* 2001; Mollot *et al.* 2003), access to aquatic resources and its role in food security (Vannaara 2003) .

Livelihood approaches provide a complete understanding, capturing the range of views held by all those who have an interest in the fishery. It is also helps outsiders to understand the complexity of aquatic resources (e.g. fish and OAAs, aquatic plants, and habitats) and reflects the diverse role of these resources in rural livelihoods. The livelihood approach recognises that people manage aquatic resources as a whole rather than just fisheries or aquaculture; livelihood approaches often require coordinated, multi-agency activity and, as a result, take both government's and people's objectives into account (TAB 2006).

Smith *et al.* (2005) used livelihood approaches to produce a framework in which to analyse and categorise fishing-related livelihoods. They identified four livelihood scenarios (Table 2.7) including (i) survival; (ii) semi-subsistence diversification; (iii) specialist occupation and (iv) diversification for accumulation. In the first scenario the households are in extreme poverty, landless and disadvantaged. Fishing is mainly for subsistence. The policy priority should be to provide alternative employment and micro enterprise opportunity in the rural economy (Table 2.8). For the second scenario the priority is to maintain the benefits from fisheries and diversified livelihood strategies, focusing on the vulnerable groups with limited assets to take advantage of new opportunities provided by rural economic growth. The third scenario represents inland fishing as a specialised occupation. In this scenario the fishery enhancement, modernisation and economies have been fully utilised, and further improvement of income for fishers can only come from adding value through fish processing and fish marketing or livelihood diversification. The last scenario focuses on an interest in fishing to increase income but the livelihood activities tend to decline and the policy priority should be focused on fisheries conservation. This analysis has important consequences for policymaking as it provides a need for more diverse and flexible management measures, focusing on local priorities and conditions, ensuring poor households can access the benefits of inland fisheries and at the same time meet conservation objectives.

Table 2.6. A framework for the analysis of rural livelihood (Source: Ellis (2000) and Scoones (2009).

Livelihood platform	Access modified by	In context of	Resulting in	Composed of	With effects on
Assets Natural capital Physical capital Human capital Financial capital Social capital	***Social relations*** Gender Class Age Ethnicity ***Institutions*** Rules Costoms land tenure Markets ***Organisations*** Local administration State agencies NGOs	***Trends*** Population Migration Technology Relative prices National econ. trends World econ. trends ***Shocks*** Drought and Floods Pests Diseases collapse Civil war	***Livelihood strategies***	***Natural resource based activities*** Fishing Collection of NTFPs Cash crop Livestock ***Non Natural resource based activities*** Non farm work Trade Remittances Other services	***Livelihood security*** Food supply Income Seasonality Degrees of risk ***Enviromental sustainability*** Soils quality Water Fish stocks Forests Biodiversity

Livelihood approaches provide an analytical method for studying rural livelihoods that not only can be used to provide a framework for drafting and implementing policies for the sustainable management of the Mekong's fisheries but also can be applied for assessment of the impacts of water development and climate changes on the ecology and livelihood of local communities. As the framework provides the vulnerability context that fishers face and the livelihood strategies that they apply to cope with the changes, it will provide a broad view of the resilience and adaptation of local communities at the critical period. However, livelihood approaches have yet to be used by policymakers and fishery managers. This is largely because this approach is not widely disseminated or accepted. Therefore, there is a need to promote and disseminate this framework through training and participatory workshops.

Table 2.7. Fisheries livelihood functions and strategy (after Smith *et al.* 2005).

Livelihood strategy	**Fishery Characteristics**	**Livelihood functions of fishery**
Survival	• Open access, likely to be overexploited	• Subsistence • Full-time or significant part-time • Particularly important to women, and children
Semi-subsistence diversification	• Open access, but self-regulating depending on population • Pressure on land and other natural resources	• Food security • Buffering, coping, smoothing; • Source for cash • Exchange; • Important to women and children
Specialist occupation	• Restricted access and effective management • Measures to sustain incomes • May be subject to 'monopolisation' of access rights by individuals	• Income and saving; • Male dominated
Diversification for accumulation	• Open access and probably self regulating given 'light' regulation by community or state	• Some residual buffering function, but of declining importance; • Own-consumption and recreation

This study will use various techniques and methods mentioned above including the weighed dietary records method to understand the importance of fish and OAAs on food security of the affected households; the qualitative survey methods with PAR and other techniques (livelihoods approach) to assess the general situation in the study areas as well as to identify the current issues and potential impacts of hydrological change in the environment and on the livelihoods of the impacted households, and to propose the potential livelihood options for minimizing the current impacts of hydrological changes.

Table 2.8. The main policy objectives and instruments in different livelihood strategy (from Smith *et al.* 2005).

Livelihood strategy	Main policy objectives	Policy instruments
Survival	• Reduce number of fishers • Resource conservation	• Alternative employment in the rural economy • Welfare 'safety nets' • Maintain of the fishery as a 'safety net'
Semi-subsistence diversification	• Sustainability of traditional livelihoods • Resource conservation and enhancement	• 'Light' regulation • Maintain access for the poor through enabling institutions and 'permeable barriers to entry' • Fishery enhancements
Specialist occupation	• Sustainable commercial fishery	• Strengthen community management, or regulate exclusive private access rights • Fishery enhancements • Modernization of methods • Credit and market access • Processing and marketing • Effective access restrictions
Diversification for accumulation	• Ecological conservation	• 'Light' regulation • Ecological protection measures

2.3.3 Hydrological regime and fisheries

Natural flows depend on rainfall and geographical area of the river basin for their seasonal precipitation and discharge. Flow variations may be very rapid in small basins because they respond to only local rainfall, but in large basins where many tributaries flow into the mainstream, the flood curve becomes smoother. In general, natural flow regimes consist of two components, namely base flows and floods (Welcomme *et al.* 2006). Base flows are when flow is confined to the main channel and floodplain water bodies remain isolated, while floods are defined as when high flows overbank and flood surrounding flooded forest or seasonal floodplains and reconnect isolated wetlands to the main channel. This section aims to review the effects of changes in characteristics of flow regimes (the timing, continuity, smoothness, rapidity of change, amplitude and duration of flow events (Figure 2.12) on fish species; the relationship of amplitude to duration will also be discussed. This section is based on literature by Dyson *et al*. (2003); Arthington *et al.* (2004); Welcomme & Halls (2004) and Welcomme *et al.* (2006a), to understand and describe the effects and relationship between flood curves and fish communities in tropical rivers.

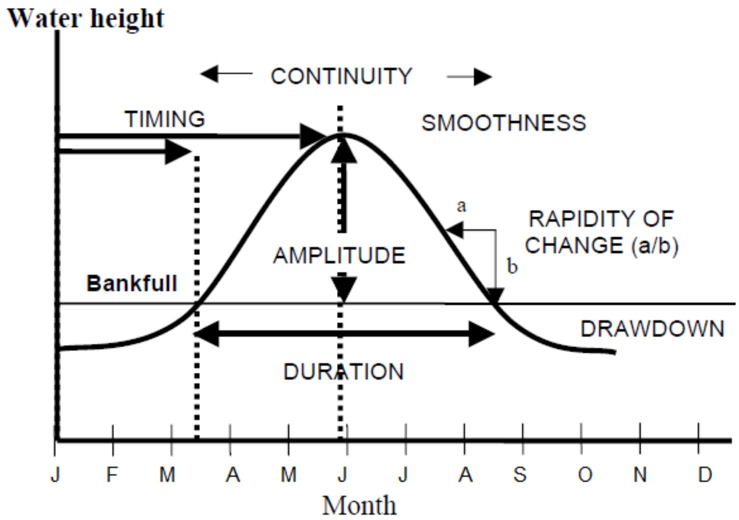


Figure 2.12. Important parameters of a flood curve having biological significance (Source: Welcomme *et al.* 2004).

Timing

The timing of the period of flood plays an important role for many riverine fish species, as their life cycles (e.g. migration, reproduction, larvae drift, survival and growth) are often associated with the increase of water discharge at certain times of the year (Singhanouvong *et al.* 1996b; Baran *et al.* 2005; Halls *et al.* 2013a). The breeding seasons of most of the Mekong species, in particular migratory white fish species, occur in the wet season when water level is rising (Warren & Singhanouvong 2005). A recent study of the Dai fishery in the Tonle Sap-Great Lake System, Cambodia, indicated that the migration and reproduction of many small cyprinid species is closely associated with the lunar cycle (Halls *et al.* 2013c) but are also linked to the flood cycle. Rises in water levels and discharge during certain periods are migration cues or trigger fish migrations. For example, analysis of daily catches of *P. krempfi* in southern Laos showed a close relationship between the migration of this species and rising water levels (Baran *et al*. 2005). Many upstream spawners also rely on rising water levels to transport their eggs and larvae to suitable nursery and feeding habitats in the floodplain (Poulsen *et al.* 2002). Any change or modification to the hydrology of the Mekong River will affect the behaviour, migration, breeding and reproduction of the Mekong fish species.

Continuity

Continuity of floods may be interrupted by human activities or occur naturally. Drought periods can take place between flood periods due to natural hydrological cycles or climate change. Discontinuities are also induced in regulated systems when the user places demands on the water, leading to interruption of the smooth progression of flooding. Such discontinuities are likely to be damaging to catfish (white fish) and some grey fish that spawn during the beginning of the wet season (Welcomme & Halls 2004) because eggs and larvae may die or drift onto unsuitable habitats due to temporary recession of the waters. Black and grey fish may also lose breeding opportunities due to the floodplain drying during low flow periods.

Smoothness

The smoothness of the flood is defined as a measure of the steadiness of the rise and fall of water level. The smoothness is the contrary of flashiness, which is the rapidity with which the river responds to local flood events. Fish species living in higher order systems are normally better adapted to smoother flood curves than species of smaller river and low order streams. In the Mekong River, the smoothness of the flood curve is very important for the spawning of white fish, because temporary recessions can delay larval drift in the same way as discontinuity of flooding. Severe fluctuations in water level will also affect marginal spawners and nest builder species, where the littoral zone can be flooded and then expose nests, leaving the eggs and fry to dry out.

Rapidity of change

The rate of increase and decrease in the water level is potentially important for many Mekong species. A rapid change in flow may affect many fish species directly as rapid flooding can submerge nests of bottom breeding species to too great a depth; when water is too deep and turbid, low light levels may affect the breeding activities. The rapid flows associated with transitions in water discharge can flush away the eggs and larvae of phytophilous species that lay their eggs in the marginal areas of floodplains and pelagic and semi-pelagic larvae in the main river past their appropriate nursery and feeding habitats. In addition, overly rapid retreat of the flood during declines in water level may increase the risks of fish living in temporary pools in swamps and floodplains, resulting in high mortality during this critical period.

Amplitude

The amplitude of the hydrograph reflects the difference between the low water level and the maximum level reached during flood events. In the Mekong River, in particular the tributaries, where the river is overbank, the amplitude of the flood will create more nursery and feeding habitats for fish. The higher the flood the greater the area of floodplain submerged. The flooded forest and floodplains in the Mekong River serve as spawning, nursery, feeding and refuge habitats for many fish species (Welcomme 1985; Poulsen *et al.* 2002). Therefore, the higher the amplitude, the larger the area available for fish to explore, which may increase recruitment and productivity.

Duration

Duration of flooding is measured from bankfull as the flood increases to bankfull during drawdown. The duration of flows is essential for reproduction and growth of fish because the longer the duration of flooding extends, the greater the amount of time available for feeding and growth, leading to a greater potential to survive and improved recruitment success (Welcomme 1985). Duration of flooding also influences the floodplain vegetation. In the Mekong system, floodplain vegetation is adapted to the natural flood cycle, but longer floods may cause die out and decomposition of vegetation. This may contribute to de-oxygenated conditions in the river and affect organisms in the river systems.

Relationship of amplitude to duration

The amplitude and duration of floods can influence fish population dynamics. The optimal flood for many species lies in a compromise between the amplitude and duration. In river systems, greater floods create a larger area, which increases feeding habitat to support fish populations. The variability of flooding in a system can also influence the relative abundance of the species in a fish assemblage.

Different species respond differently to different types of flood regime, in some cases flooding is needed to maintain the habitat and survival of fish communities, and the relationship between the amplitude and duration of flood is important. In these cases a long flood of low amplitude will provide a smaller flooded area for a greater duration, leading to reducing reproductive success and survival of fish, but growth may be enhanced. By contrast, if the flood is of high amplitude but of too short a duration, reproductive success may be higher but the young fish may not have sufficient time to grow. As a result, smaller fish will be more vulnerable and mortality rate may increase through the dry season because of low energy reserves.

In the Mekong River, the amplitude may be more important than duration (Baran *et al.* 2001) mainly because of the improved influx of nutrient rich silt brought in by big floods, for instance the growth of floodplain spawning *Henicorhynchus spp.* However, Halls *et al.* (2001) suggested that duration may be more important in terms of improved growth of the fish stock. Unfortunately, there are limited data on the relationship of floodplain fishery and hydrological regime to answer this question.

Types of flow

The effects of modification of flow regimes on ecology and aquatic animals are summarised in Table 2.9. Bunn and Arthington (2002), Cowx *et al*. (2004), Welcomme and Halls (2004) classified flow into four types based on the way they operate on fish communities:

- *Population flows* influence the biomass of the fish community through density dependent interactions. They control the volume of flooded area in a system. They also change the accessibility of different types of habitat in the channel and access to floodplains and backwaters. The main criteria are volume, depth, connectivity and flooded areas.
- *Trigger flows* cue events such as migration and reproduction. The main features of this are timing, flow velocity, temperature and lunar phase.
- *Extreme flows* put fish in danger due to the excessive velocity at high water or drought at low water. These are expressed as extreme flows occurring when floods or droughts and typically have a very long return period. The main criteria are flow velocities at peak or extreme low flows.
- *Habitat flows* maintain the habitat and environmental quality (e.g. temperature, dissolved oxygen levels, sediment transport) and environmental support systems (e.g. vegetation and food organisms). The key features are water volume, flow velocity, connectivity, and flooded area in a system.

Considering the importance of flow to fauna and flora, there is a need to protect river flows for preservation of species diversity and management of river ecosystems (Welcomme *et al.* 2006a). In large river systems that have great diversity of fish species, it is difficult to manage the flow requirements for individual species. Management practices to conserve selected species are normally based on their importance in terms of size, value or biological contribution to fisheries or conservation. Grouping fish into guilds according to their flow requirements is an alternative approach to managing the flow for multi species assemblages (Welcomme *et al*. 2006b). Each guild reacts differently to hydrological changes, black and grey guilds are more tolerant to changes in the hydrograph than white-fish guilds. A summary of the behavioural guilds their likely responses to flow changes is given in Table 2.10.

General indicators of change in fish populations communities

Fish communities respond to anthropogenic stress by undergoing a series of changes in size, species composition and abundance (Table 2.11). Fishing pressure, pollution from industry and agriculture, environmental degradation due to changing land use and alterations to the hydrological regime (e.g. water abstraction, irrigation, hydropower dam) all tend to elicit varied responses to different perturbations (Welcomme 1995). Biodiversity loss and a decline in the mean size of fish in populations are common indicators of changes that are linked with externally-induced stress (Cowx *et al.* 2004).

Table 2.9. Effects of modifications of flow regime on aquatic animals (after Welcomme *et al*. 2006a).

Flow characteristic	Change	Effect on fauna and flora
Timing	Delay of arrival of peak flows	Influences physiological readiness of fish to mature, migrate and spawn; Synchronises maturation of drifting larvae and movement to floodplains and backwaters; Influences thermal coupling between flood and temperature of the water
Continuity	Interruption to flood	Stranding of fish in temporary pools; Failure of eggs and larvae to colonize floodplain; Exposure of spawning substrates with stranding and desiccation of eggs.
Smoothness	Increased flashiness	Exposure of nests and spawning substrates with stranding and desiccation of eggs or larvae.
Rapidity of change	Overly rapid rise in level	Failure of floodplain vegetation; Submergence of nests and spawn in too great a depth.
	Excessive flow in main channel	Can sweep drifting larvae past suitable habitat.
Amplitude	Decreased depth of flooding	Less space for reproduction, refuge and feeding of young and adult fish during flood; Fewer floodplain water bodies connected to main system.
	Decreased level in main channel during dry season	Smaller refuges for fish; Increased risk of anoxia; Greater mortality in main channel through competition and predation
Duration	Reduced time when floodplain submerged	Less time for growth of fish; Less time for fish to remain in floodplain refuges. Greater exposure of fish to negative condition in main channel;
	Increased time when dry phase in main channel	Greater risk of desiccation of main channel, backwaters and floodplain water bodies; Greater exposure to fishermen and predators.

Table 2.10. Behavioural guilds reactions to changes in hydrograph (after Welcomme *et al.* 2006a, b).

Guild	Behaviour: General	Behaviour: Specific	Response to changes in flow regimes
White fish rheophilic species	Long-distance migrants; One breeding season a year; Intolerant of low oxygen.	A: Main channel residents not migrating to floodplain; Predominantly psammophils, lithophils or pelagophils; Often have drifting eggs and larvae.	Tend to disappear when damming in a river that blocking migration route; When timing of high flow inconsistent with their breeding season; If flow excessive or too slow for the needs of drifting eggs larvae.
		B: Use floodplain for reproduction (breeding, nursery), and feeding; Mainly phytophils; Spawning at floodplain; sometimes have drifting eggs and larvae.	Tend to disappear when damming in a river that blocking migration route; Damaged when river disconnect to floodplain (fry and juveniles passed to inappropriate nursing ground).
Black fish limnophilic species	Floodplain residents move short distance between floodplain, swamps, and flooded forest; Repeat breeders with specialized reproductive behaviour; Predominantly polyphils, nest builders, parental carers; Resistant to low dissolved oxygen or anoxia (auxiliary breathing adaptations).	A: Resistant to low dissolved oxygen tensions only	Tend to disappear when floodplain disconnected; May increase in population in shallow water, isolated wetlands and rice-fields.
		B: Tolerant of complete anoxia	Live in floodplain water bodies; Colony in rice field and ditch faunas
Grey fish eurytopic species	Resistant to low dissolved oxygen; Repeat breeders; Predominantly phytophils but some nesters or parental carers; Short-distance migrants often with local populations.	A: Inhabit in main channel generally benthic	Be able to adapt to altered flow regime; Usually increase in population while other species decline; At risks when flows altered the sediment transport process and change the river bed.
		B: Reside in riparian vegetation	Be able to adapt to altered flow regime; Usually increase in population while other species decline; Impacted negatively by flows and management that changes riparian structure.
		C: Live in larger and healthier oxygen in floodplain water bodies	Susceptible to isolation of floodplain but can live in river if flow slowed adequately; Often form in reservoirs.

Table 2.11. Indicators of fish population changes in response to pressure from fishing and environmental changes (after Cowx *et al.* 2004).

Indicator	Trend
Level of catch	**1.** Dropping of total catch of single species, but catch levels can be maintained through a wide range of effort and can only be interpreted relative to the catch composition.
Mean length	**2.** Disappearance of larger fish and falling mean size within species **3.** Disappearance of larger species and falling mean size of population as a whole
Number of species	**4.** Declining number of species diversity
Biomass	**5.** Declining biomass in induced mortality is prevalent or reproductive processes compromised. **6.** Increased mortality where primary and secondary production of water body increased, e.g. eutrophication
Type of species	**7.** Decline and disappearance of anadromous and long distance migratory species **8.** Decline and eliminated of native species and replace by alliance species where exotics have introduced **9.** Decline and eradicated of higher trophic levels (predators) and replacement by lower food chain species **10.** Decline and disappearance of high oxygen requirements species and replacement by tolerant of low oxygen species.
Population demography	**11.** Reduction in the proportion of juveniles in population due to compromised recruitment processes.
Response time	**12.** In rivers, lakes and reservoirs shortened time between flood events and response by population
Other indicators:	**13.** Production/Biomass (P/B) ratios rise **14.** Mortality rates (z and f) increase **15.** Longevity of species declines **16.** Drop in condition of individual fish **17.** Higher incidence of diseased and deformed individuals

Species that cannot adapt to or are not tolerant of changing environments will be eliminated and often replaced by smaller species. The worst scenario is where larger species that are unable to accommodate fishing pressure and hydrological change disappear from the system. The shift to smaller fishes also involves a change from long-lived species to short-lived ones and is a recognized response to pressure on animal communities in general (Barrett *et al.* 1976). Some species are capable of adapting by reducing their breeding size and adjusting maturation time.

2.3.4 Indicators of Hydrologic Alteration

The natural flow regime plays an important role in providing different habitats for aquatic animals to complete their lifecycle and maintain ecosystem functions. Variation of the natural discharge of a river differs in terms of time scales (e.g. hours, days, seasons, years) (Poff *et al.* 1997). The components of a natural flow regime can be categorized using time series and probability analysis of extremely high or low flows or of the entire range of flows expressed as average daily discharge (Dunne and Leopold 1978). Richter *et al.* (1996) classified five critical components of the flow regime that control the ecological function of river ecosystems, namely the magnitude, frequency, duration, timing and rate of change of hydrological conditions. They argued that these components can be applied to characterise the entire range of flows and certain hydrological phenomena, such as high or low flows, that are important to the integrity of river systems. They also proposed the Indicators of Hydrologic Alteration (IHA) methodology for assessing hydrological alteration within an ecosystem. The IHA method is based on 33 biologically relevant hydrologic parameters divided into five groups to statically characterize within annual hydrologic variation (Table 2.12).

Richter *et al.* (1998) suggested that the range of natural variability in 33 different ecologically relevant flow parameters should be used as the basis for setting management targets. They called this method 'the Range of Variability Approach' (RVA). The RVA sets hydrological data into (pre-impact) and alteration (post-impact) flow regime periods, and then compares them to determine the changes of flow that occurred between the two periods. This approach can be used in planning water management activities and measuring the conservation and restoration of river systems.

IHA methodology is very useful and will be applied in this study as it covers important hydrologic alteration parameters that allow comparisons of flow regime before and after dam operation. The outcome of this method provides regime characteristic and hydrological parameters that influence ecosystems and important habitats for fishes.

Table 2.12. Hydrologic alteration parameters and their characteristics (after Richter *et al.* 1998).

IHA general group	**Regime characteristic**	**Hydrological parameters**	**Example of ecosystem influence**
Group 1: magnitude of monthly water conditions	Magnitude Timing	Mean value for each calendar month	Habitat availability for aquatic organisms Soil moisture availability for plants Availability of water for terrestrial animals Reliability of water supplies for terrestrial animals Access by predators to nesting sites Influences water temperature, oxygen levels, photosynthesis in water column
Group 2: magnitude and duration of annual extreme water conditions	Magnitude Duration	Annual minima 1-day means Annual maxima 1-day means Annual minima 3-day means Annual maxima 3-day means Annual minima 7-day means Annual maxima 7-day means Annual minima 30 -day means Annual maxima 30 -day means Annual minima 90 -day means Annual maxima 90-day means Number of zero-flow days 7-day minimum flow divided by mean flow for year ('base flow')	Balance of competitive, ruderal, and stress-tolerant organisms Structuring of river channel morphology and physical habitat conditions Soil moisture stress in plants Dehydration in animals Anaerobic stress in plants Volume of nutrient exchanges between rivers and floodplains Duration of high flows for waste disposal, aeration of spawning beds in channel sediments
Group 3: Timing of annual extreme water conditions	Timing	Julian date of each annual one-day maximum Julian date of each annual one-day minimum	Compatibility with life cycles of organisms Predictability/avoidability of stress for organisms Access to special habitats during reproduction Spawning cues for fish migration Evolution of life history strategies, behavioural mechanisms
Group 4: Frequency and duration of high and low pulses	Magnitude Frequency Duration	No. of high pulses each year No. of low pulses each year Mean duration of high pulses within each year Mean duration of low pulses within each year	Availability of floodplain habitats for aquatic organisms Nutrient and organic matter exchanges between river and floodplain Soil mineral availability Influences bedload transport, channel sediment textures, and duration of substrate disturbance (high pulses)
Group 5: Rate and frequency of water condition changes	Frequency Rate of change	Means of all positive differences between consecutive daily values Means of all negative differences between consecutive daily values No. of flow reversals	Drought stress on plants (falling levels) Entrapment of organisms on islands, floodplains (rising levels) Desiccation stress on low-mobility stream edge (varial zone) organisms

CHAPTER 3: STATUS AND TRENDS OF THE MEKONG FISHERY IN LAOS

3.1 INTRODUCTION

The Mekong River is one of largest rivers in the world in terms of biodiversity and production. It provides water for agriculture, transportation and human consumption. People have been fishing in the Mekong River for many millennia. People living along the river banks are dependent on the river for their livelihoods and food security. Fishes and OAAs are crucial components of the daily food intake, and provide cheap sources of animal protein and micronutrients for the rural poor. The Mekong fishery has changed in recent decades due to population growth and infrastructural development in the LMB. There is now a greater demand for fish to meet the food demand and consequently increased exploitation of the fishery coupled with risk of degradation from the water development projects, especially to support agriculture and energy demands. It should be recognised that fishes are not just for household consumption but also for trade and exchange for other goods (e.g. rice, fishing equipment).

In the last two decades, interest in hydropower development in the Mekong River has become highly visible as the price of crude oil has soared and concerns have been raised over environmental pollution and security of energy sources from lignite and nuclear power (Barlow 2008). In the late 2000s, it was proposed to construct eleven hydropower dams on the Mekong mainstream of the LMB; this has already begun with the decision to construct Xayaburi dam in 2012. Concerns have been raised over the potential negative impacts of these proposed Mekong mainstream dams on the Mekong fisheries, which are already under pressure from the many dams constructed or being built on the tributaries or upper Mekong River dams in China, coupled with other economic developments (e.g. mining and deforestation).

In the last three decades, several projects have attempted to study the biology and migration of fishes in the Mekong River (Singhanouvong *et al.* 1996a,b; Poulsen *et al.* 2002; Baran 2005; Cowx *et al.* 2012; Halls *et al.* 2013a). With assistance from the Mekong River Commission (MRC), Fish Catch Monitoring Programmes were established in Cambodia, Laos, Thailand and Vietnam (Halls *et al.* 2013a). These monitoring programmes included the Dai fishery monitoring in Tonle Sap, Cambodia, Lee trap monitoring in southern Laos, the Fish Abundance and Diversity Monitoring Programme in the four LMB countries, and Fish Larvae Density Monitoring in Cambodia and Viet Nam. The expectation of these studies is that data from the fish catch monitoring will provide a better understanding of the biology and life cycles of fish species in the Mekong River, including migration behaviours and relationships between hydrology and migration patterns.

While more Mekong mainstream and tributary dams will be constructed in the coming years, it is necessary to review and analyse the existing fish catch monitoring data to improve understanding of the status and trends in the fisheries, including species composition, diversity and biomass caught. This information will provide baseline data before the mainstream dams are commissioned to assess their impact on the fisheries sector and support decision making over other water development projects.

As the MRC supported programmes have explored the data from a regional basin-wide perspective (Halls *et al.* 2013a), this study focuses on two data sets specific to Laos: the Fish Abundance and Diversity Monitoring Programme (2008-2012) and the wet season Lee trap monitoring (1997-2012).

3.2 OBJECTIVE

The overall objective was to analyse the current status and trends in fisheries catches in the Mekong River in Laos to provide baseline information against which to assess any changes to the fisheries sector as a result of dam development. The specific objectives were:

(1) to assess fish catch composition and species diversity in southern, middle and northern parts of the Mekong River in Laos;
(2) to investigate seasonal and annual changes in fish catches and abundance;
(3) to determine any relationship between water level and fish migration patterns.

3.3 METHODS

3.3.1 Data sets and site descriptions

This study used two time-series data sets from the catch monitoring database collected by the Living Aquatic Resources Research Centre in Laos with the financial support from Mekong River Commission, Fisheries Programme. The monitoring stations are indicated in Figure 3.1.

1. Lee trap fish monitoring was conducted in Khong District, Champasack Province (Southern Laos where the Mekong River continues to flow to Cambodia). Fish catch monitoring started in 1997 to assess fish migration through Hou Som Yai Channel in southern Laos, between May and September, the main fishing season during the flood period. Between 1997 and 2007, fourteen species were monitored for 14 days between the end of May and the end of June (Singhanouvong *et al.* 1996b). From 2008 to 2012, the monitoring was expanded to cover all species and the sampling period was extended to the end of Lee trap fishing season in September (Halls *et al.* 2011a) when the traps were mostly destroyed by the strong water current in the flood season.

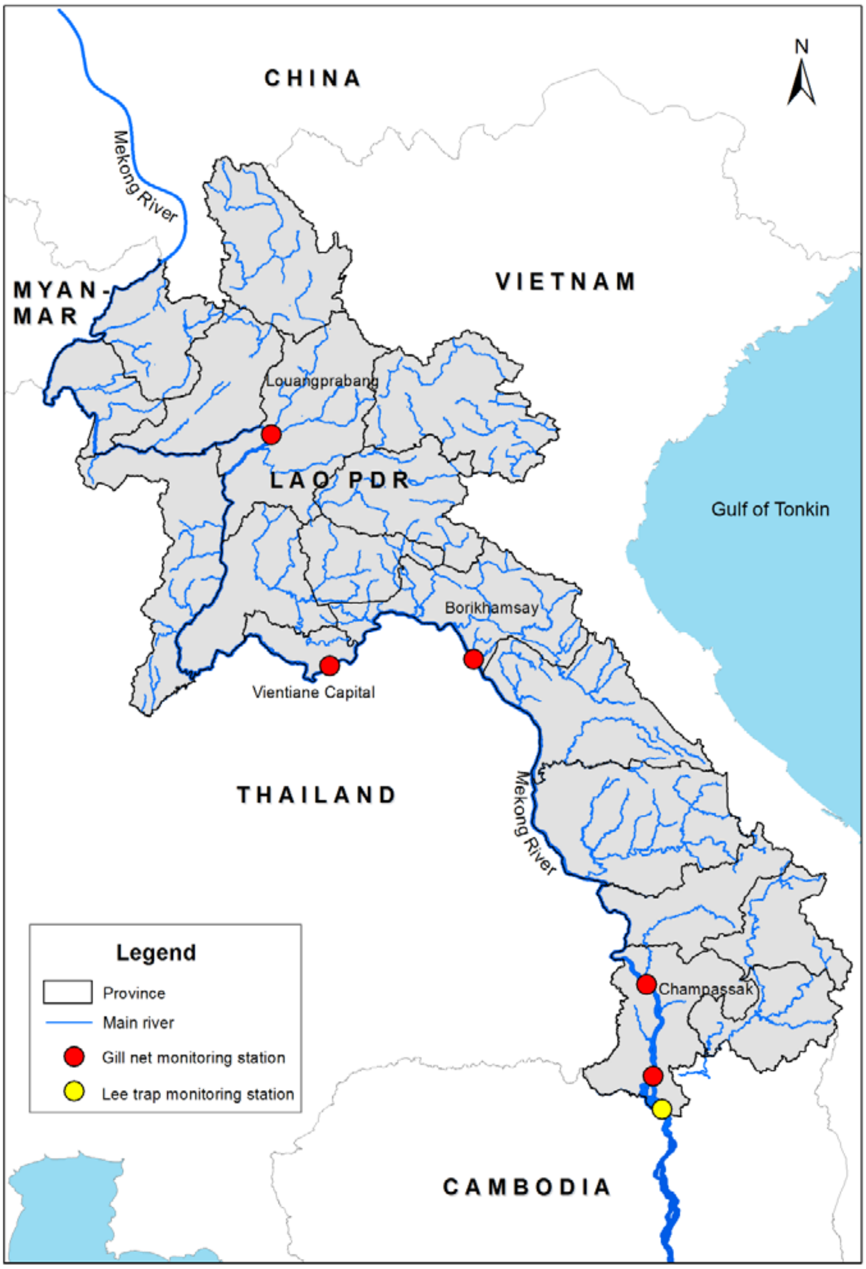


Figure 3.1. Map of Laos showing location of gill net and Lee trap monitoring stations.

Lee traps *or Bamboo-wing traps* are commonly used to target wet season migratory species in the Khong district, Champasack province. Lee traps are made from bamboo and are 8-10 m long and 1.5 m wide (Figure 3.2). Lee traps are set directly in the current with half of the trap in the water. These traps catch mainly catfish (Pangasiidae and Siluridae) that move upstream but fall back into the trap when fish tire whilst swimming against the strong current: only strong fish can pass and weak fish drop down with the current into the Lee trap and where they are collected by fishers (Warren *et al.* 2005). Cacot (2007) reported that some 600 Lee traps operated in 18 major channels around the great fault line, Khong district, southern Laos, in 2004. The Lee trap fishery operates in the flood season during late May-September but are either destroyed by strong currents or flooded out after this period (Warren *et al.* 2005).

The Hoo Som Yai, located close to the village of the same name, was selected for the monitoring programme (Warren *et al.* 2005). Hoo Som Yai is a rocky channel located closed to Khonephapeng waterfalls with a length of 1200 m, channel width of 10-20 m and the depth between 3.5 and 4 m in the wet season and on average of 0.5 m in the dry season (Singhanouvong *et al.* 1996b). The channel is more accessible than the other 18 channels, although the Hoo Sahong channel to the west of Hoo Som Yai (Figure 3.3) is considered to be the most important migratory route because of the flow in the Hoo Sahong channel is deeper and wider in both the wet and dry seasons (Baird 2006). Some 24 to 40 traps operate in the Hoo Som Yai channel depending on fisher's ability to build them (Singhanouvong *et al.* 2013), and the monitoring covered all Lee traps operating in Hoo Som Yai channel in each year.

2. Fish abundance and diversity monitoring (gill net monitoring). Gill net monitoring data were collected between 2008 and 2012. Four provinces were selected to represent the northern-upland (Louangprabang), central-lowland (Vientiane Capital), Central-floodplains (Borikhamsay) and Southern-floodplains (Champasack). Three fishers from each province were selected to monitor their daily fish catch throughout the year. Logbooks were used to record the catch of surface and drift gill nets, including the species name, species number, total weight and the maximum length.

3.3.2 Data analysis

A sum of total catch of each species during sampling period was calculated to estimate percentage of fish species composition and mean CPUE were determined to estimate percentage contribution of each species to total CPUE. Lee trap CPUE unit was kilogram per trap per day (kg/trap/day), but kilogram per fisher per day (kg/fisher/day) was used for CPUE estimates for gill nets, because of missing data on the number of gill nets operating in some provinces.

Comparison of mean CUPE between years and locations was carried out using Primer (Plymouth Routines in Multivariate Ecological Research) software. All CPUE data were log (x+1) transformed before analysis because of variability in the data (CPUE was varies). Mean CPUE were tested for similarity using Bray-Curtis similarity index followed by cluster analysis and MDS (Non-metric multi-dimensional scaling) was used to identify similarity of CPUE between sampling years.

SIMPER (Similarity Percentages) was used to look at dissimilarity between and within groups of mean CPUE in each monitoring site and fishing year.

(A)

(B)

Figure 3.2. Lee trap fishery: (A) Lee trap at the beginning of fishing season and (B) Fisher collecting fish from Lee trap.

Figure 3.3. Map of Khong district showing location of Hoo Som Yai and Hoo Sahong channels.

Species richness and species diversity were explored by a variety of indices (Clarke & Gorley 2006), including the Shannon diversity index and Margalef index.

Margalef index (d) was calculated as:

$$d = (S-1) / \log N$$

where S is total number of species and N is total number of individuals.

The Shannon diversity index was estimated from:

$$H' = -SUM (Pi * Log (Pi))$$

where P_i is the proportion of total count arising from i species.

Annual mean CPUE of all species combine were used to determine species richness and species diversity.

Regression analysis was used to examine the correlation between CPUE and water level. In addition, to examine the relationship of fish migration and water level, the mean CPUE of multispecies from Lee trap and gillnet were plotted against water level measured at the station in each province. For Lee trap and gillnets in Khong district, water level data from Pakse were used.

To test whether other flow characteristics influence catch, the CPUE of the 14 species monitored was correlated against peak and intensity of flooding in the year using Canoco software-Canonical Correspondence Analysis (ter Braak & Smilauer 2002).

Intensity of flooding was defined as the sum of the difference in daily water level over a 5-m baseline level measured at Pakse and actual water level for all days in each year.

3.4 RESULTS

3.4.1 Lee trap monitoring

Catch composition 2008-2012

Between 2008 and 2012, 72 species were recorded from the Lee trap fishery, with a minimum of 31 species in 2011-2012 and a maximum of 72 species in 2010. *P. larnaudiei* accounted for 31% of the total catch (biomass) followed by *Bangarius yarrelli* Sykes,1839 (14%), *L. chrysophekadion* (14%), *P. conchophilus* (10%) and *Hemisilurus mekongsensis* Bornbusch & Lundburg, 1989 (7%) (Figure 3.4). However, considerable variation was found in species composition between sampling years (Figure 3.5). *B. yarrelli* contributed 36% in 2008 but dropped to 12% in 2010 and rose to 41% in 2011. The percentage of catch composition of *P. larnaudiei* also fluctuated throughout sampling period with a very low contribution in 2008 but dominating in 2009 and 2012.

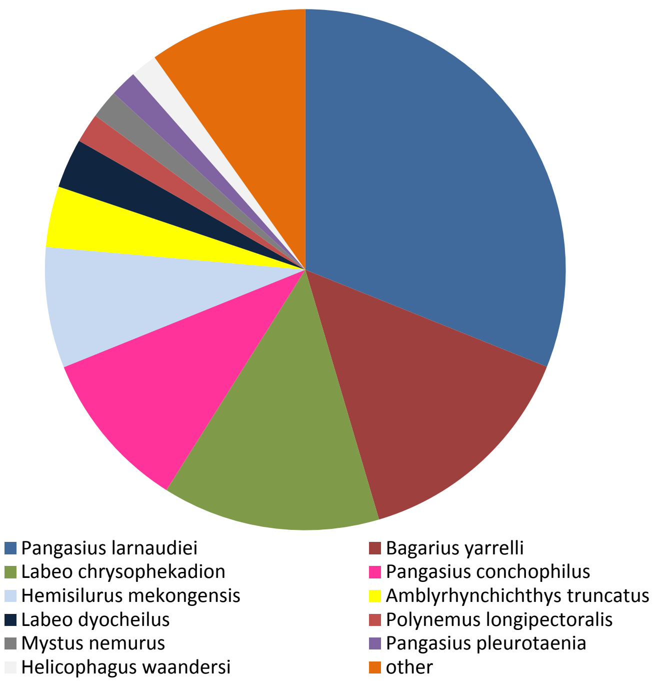


Figure 3.4. Fish species composition of catch from Lee traps in Hoo Som Yai Channel. 2008-2012.

A similar pattern was also observed for other species, with fluctuating catch weights between years. It is unclear what factors influence the variability in contribution of different species to fish landings between years, but it may be associated with the changing river conditions (e.g. water discharge, temperature, turbidity) that stimulate fish movement. This is explored further below in relation to CPUE.

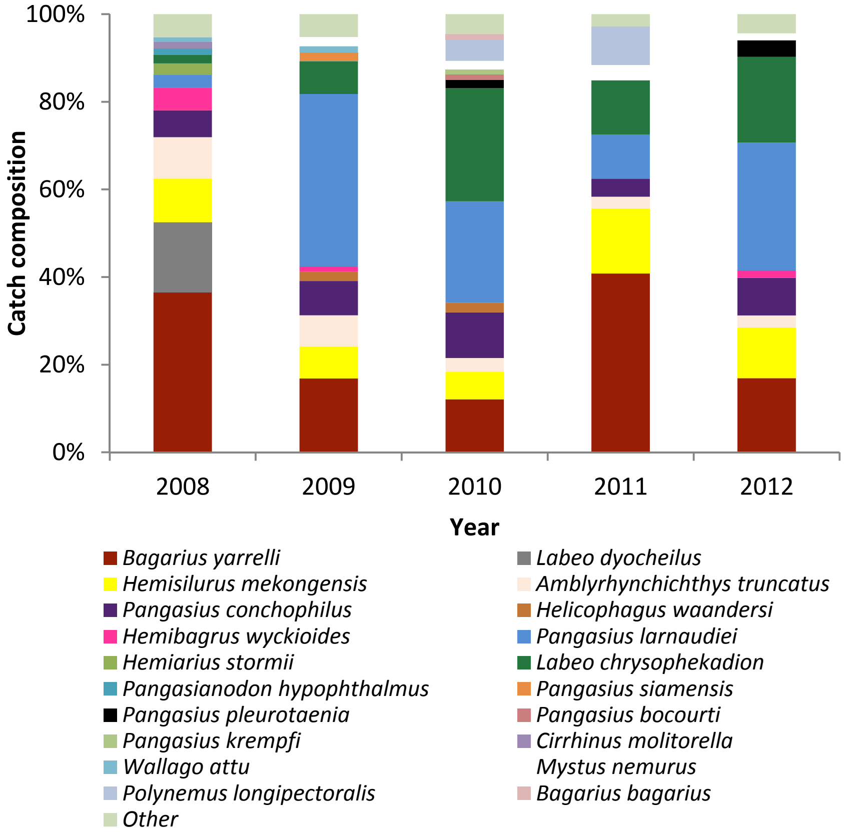


Figure 3.5. Percentage of mean CPUE of Lee traps in Hoo Yom Yai channel, 2008-2012. (only those species which comprised 95% by weight of total catch are shown)

Inter annual variability in catch 2008-2012

The CPUE of species caught varied between years. The absence of *Micronema apogon* Bleeker, 1851 and *H. wyckioides* in 2011 (Figure 3.6) may be because of the big flood in 2011 that destroyed Lee traps at the time these two species migrate through Hoo Som Yai channel. *B. yarrelli* Sykes,1839 and *W. attu* shared similar patterns, with CPUE peaking in 2008 and 2011 and being lower in the other years. *Amblyrhynchichthys truncates* Bleeker, 1851 was relatively stable throughout except for a major declined in 2010, while *L. chrysophekadion* peaked in 2008, decline in 2009-2010 and then increased in 2011-2012.

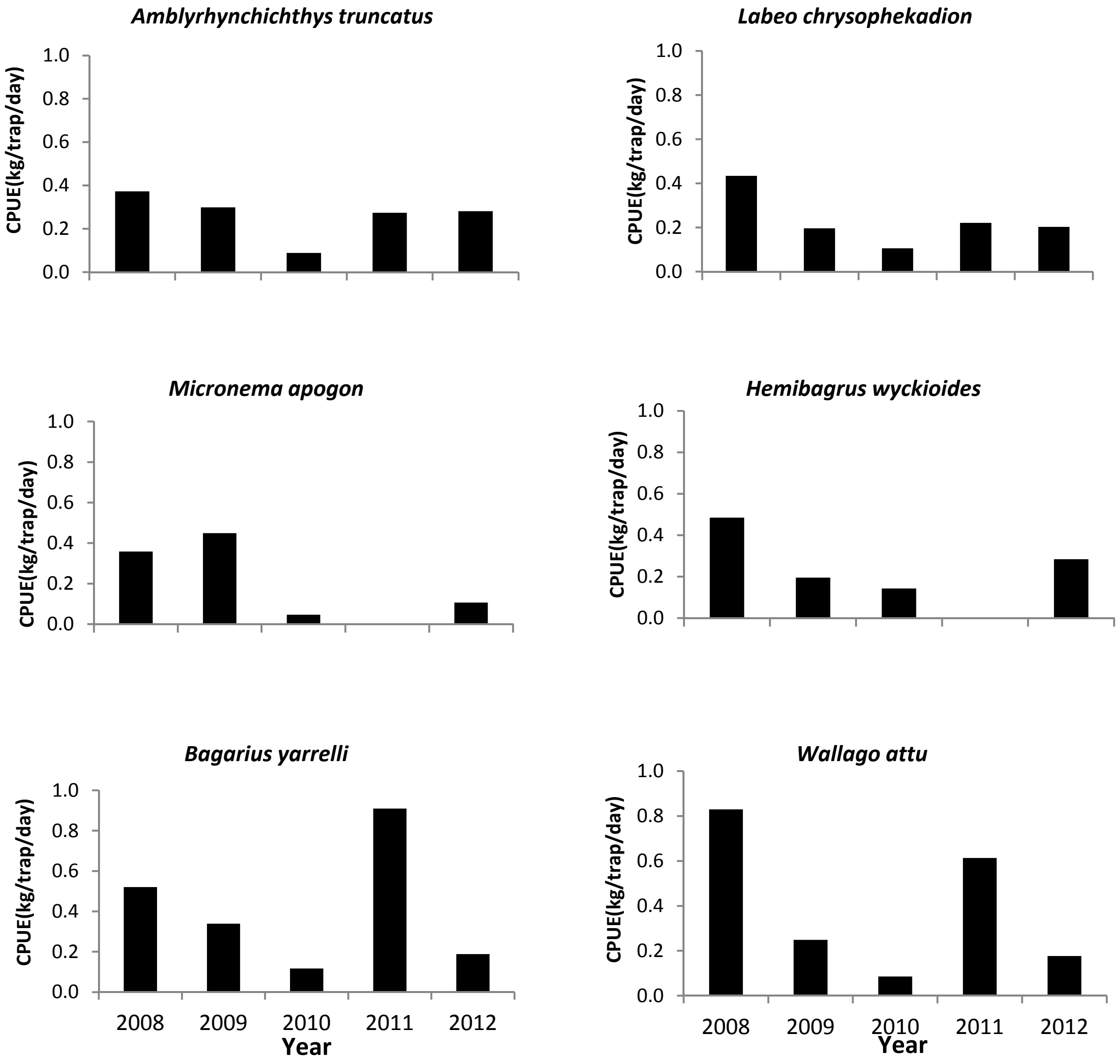
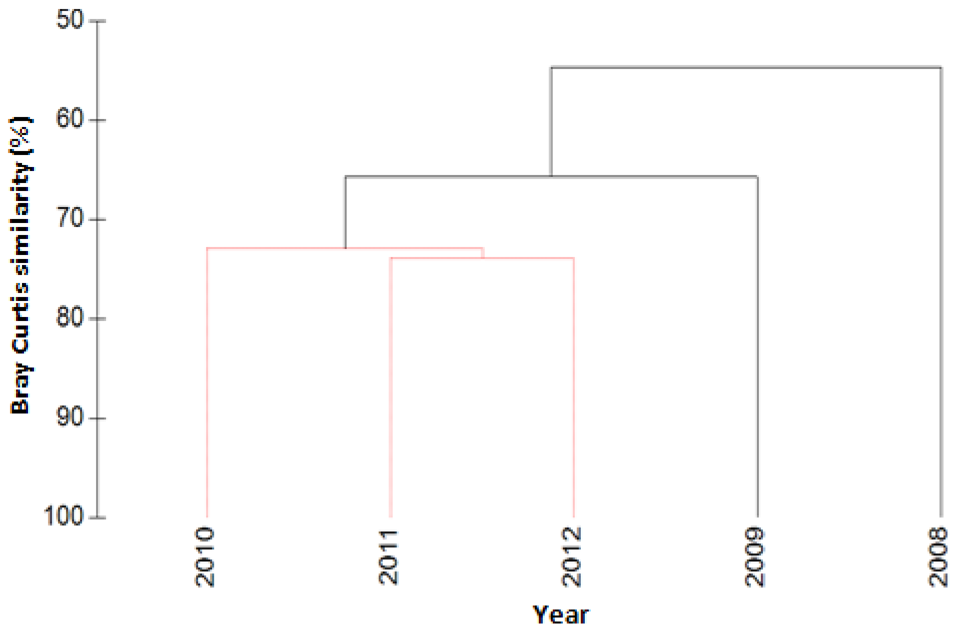


Figure 3.6. Mean CPUE of key fish species monitored from Lee traps in Hoo Som Yai, 2008-2012.

Cluster analysis highlighted the similarity in contribution of CPUE of different species between years (Figure 3.7 A). Three clusters were identified: 2008 and 2009 were significantly different from a cluster grouping 2010-2012. MDS conformed this grouping but 2008 differed from other groups (Figure 3.7 B).

(A)



(B)

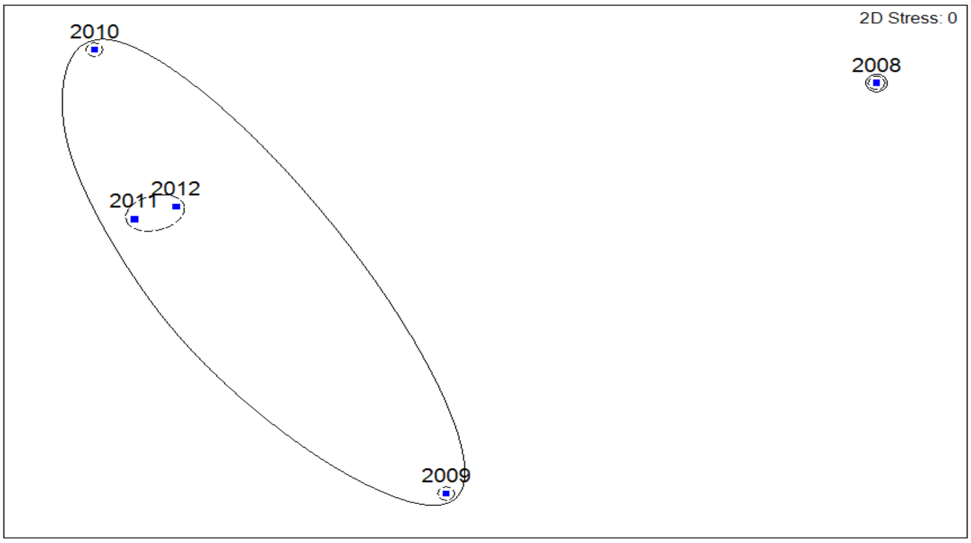


Figure 3.7. Cluster (A) and MDS (B) analyses of mean CPUE in Hoo Som Yai channel, using group average clustering from Bray Curtis similarity on transformed data Log(X+1). 2008 was differed from the other years due to the flooding was coming late.

SIMPER analysis was used to explain the differences in species CPUE contributions between years and accounted for between 26.1 and 47.5% in dissimilarity. Details of species contributing to the dissimilarity of each group are summarized in Table 3.1

Table 3.1. SIMPER analysis of mean CPUE indicating top five species contributing to dissimilarity between years.

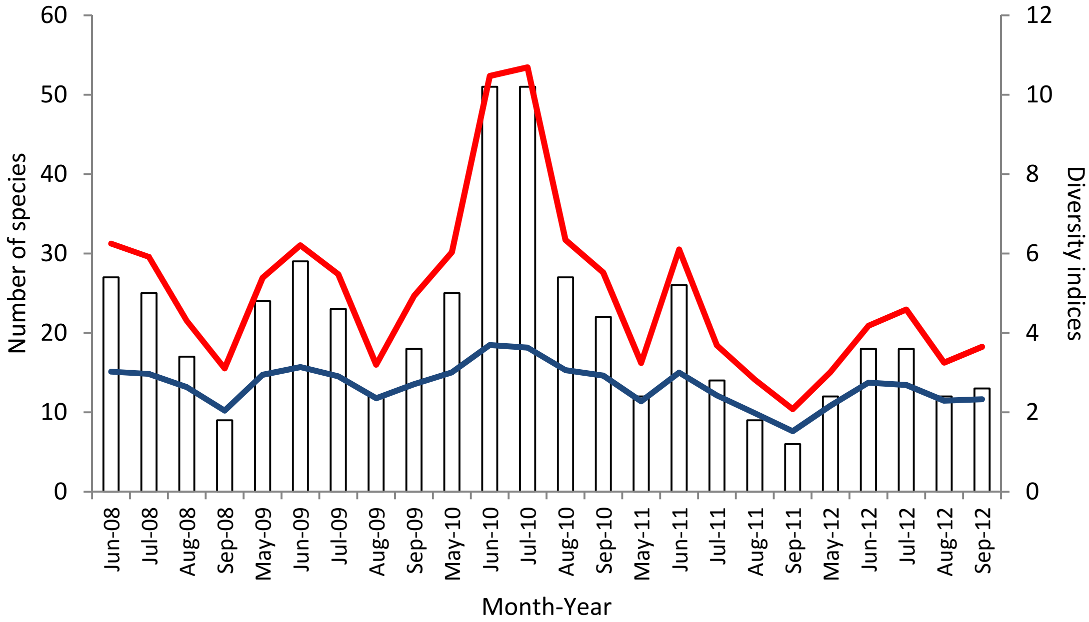
Year	Overall dissimilarity (%)	Species name	Contribution to Dissimilarity (%)
2008-2009	41.9		
		Labeo dyocheilus	10.9
		P. larnaudiei	6.5
		Hemiarius stormii Bleeker, 1858	6.3
		Helicophagus waandersi Robert & Vidthayanon, 1991	5.7
		P. siamensis	5.4
2008-2010	47.4		
		L. dyocheilus	9.4
		H. wyckioides	6.8
		H. stormii	6.0
		B. yarrelli	4.9
		C. molitorella	4.7
2008-2011	46.7		
		L. dyocheilus	11.8
		H. wyckioides	8.7
		H. stormii	6.8
		P. hypophthalmus	5.3
		C. molitorella	5.3
2008-2012	45.1		
		L. dyocheilus	11.8
		H. stormii	6.9
		Pangasius pleurotaenia Sauvage , 1878	6.0
		C. molitorella	5.4
		P. hypophthalmus	5.2
2009-2010	37.3		
		Polynemus longipectoralis Weber & de Beaufort, 1922	7.2
		P. siamensis	5.1
		W. attu	5.0
		A. truncatus	4.9
		P. pleurotaenia	4.7
2009-2011	35.7		
		P. longipectoralis	11.6
		P. siamensis	7.9
		P. larnaudiei	7.1
		H. waandersi	6.5
		H. wyckioides	6.2
2009-2012	29.6		
		P. pleurotaenia	9.5
		P. siamensis	9.4
		H. waandersi	6.7
		A. truncatus	6.6
		W. attu	6.3

Table 3.1 continued

2010-2011	27.7		
		B. yarrelli	8.2
		P. pleurotaenia	7.1
		H. mekongensis	6.0
		H. waandersi	5.7
		P. krempfi	5.4
2010-2012	26.3		
		P. longipectoralis	7.6
		Bagarius bagarius (Hamilton, 1822)	6.3
		H. wyckioides	6.1
		P. krempfi	5.6
		Bangana behri (Fowler, 1937)	5.0
2011-2012	26		
		P. longipectoralis	14.1
		P. pleurotaenia	12.8
		H. wyckioides	9.4
		B. yarrelli	6.5
		P. larnaudiei	6.0

Species abundance and diversity 2008-2012

The number of species caught during each sampling year ranged from 31 in 2012 to 72 in 2010. It is not clear why the number of species caught in 2010 increased, while the number of species caught in the other years ranged from 31 to 40 species. The number of species increased in June-July and declined in August-September each year (Figure 3.8), suggesting that the period of migration of many species was in June-July prior to the onset of flooding, although care must be taken as the fishery was not sampled in the main flood period. In particular it appears that species of the Pangasiidae and Siluridae families use this channel, presumably to connect with upstream spawning and breeding habitats. The species diversity index ranged from 1.48-2.8, but the trends mirrored those of species richness (Figure 3.8).



Number of fish species; — Margalef diversity index; — Shannon Weiner diversity index of fish composition.

Figure 3.8. Number of fish species, richness and diversity of Lee trap fishery in Hoo Som Yai Channel from June to September, 2008-2012.

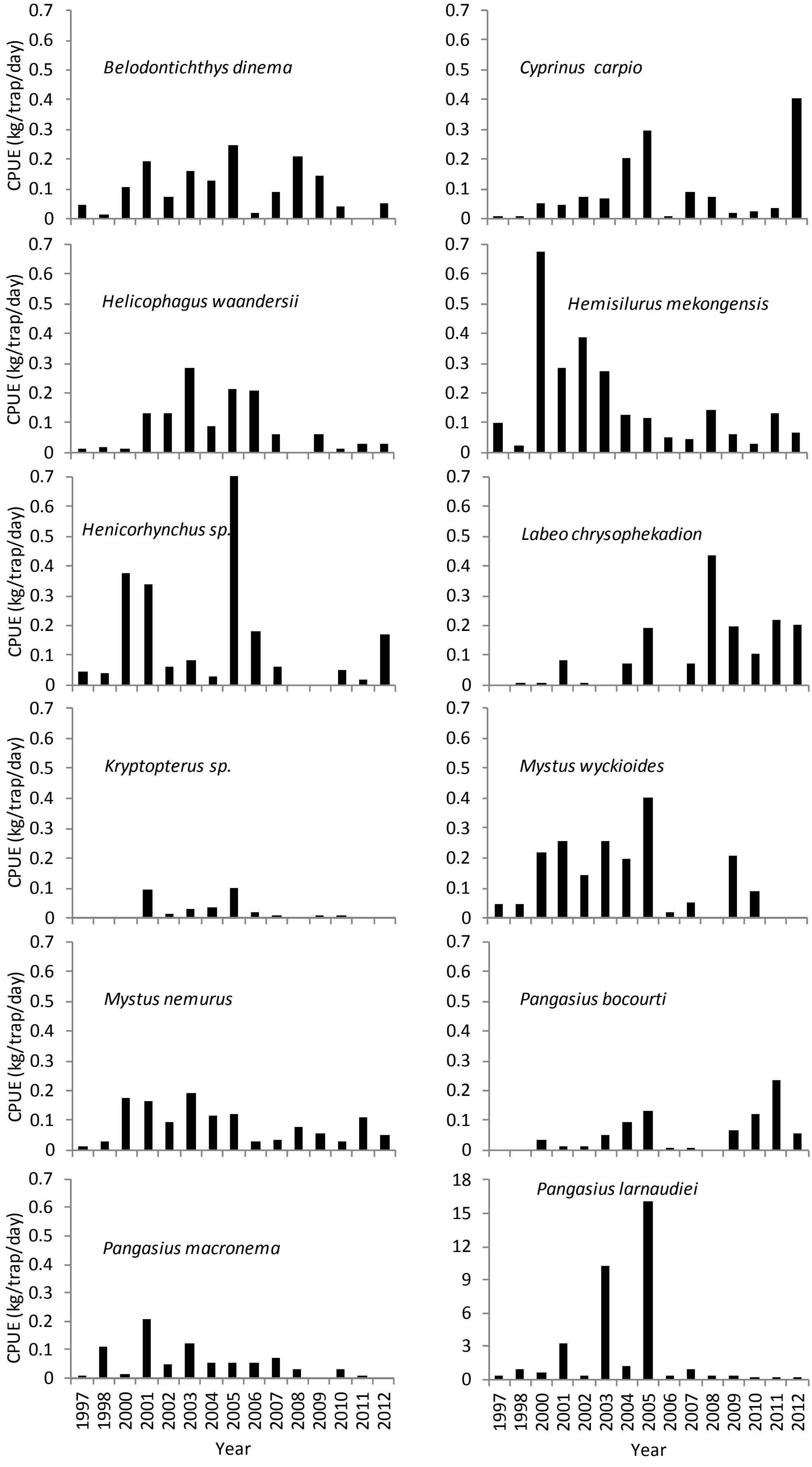
Annual variability in catch of common species 1997-2012

Considerable variability in the CPUE of the 14 predominant species monitored between 1997 and 2012 was found (Figure 3.9). CPUE of individual species fluctuated between years, but the mean CPUE of most species monitored decreased with time except *P. bocourti* (peaked in 2011), *C. carpio* (peaked in 2012) and *L. chrysophekadion* (peaked in 2008).

Two species (*P. conchophilus, P. larnaudiei)* contributed more than 85% of CPUE in 2001 and 2003; one species (*P. conchophilus)* accounted for more than 90% in 2002 and 2006. Three species (*P. conchophilus, P. larnaudiei,* and *P. pleurotaenia)* contributed 95% of CPUE in 2005 when the highest CPUE (51 kg/trap/day) since the monitoring started in 1997 was recorded (Figures 3.10).

The overall CPUE of 14 species shows no obvious trend between 1997 and 2012 except that CPUE was higher in the 2001-2006 period, excluding 2005 (Figure 3.10). It is unclear what factors caused this peak in CPUE but it may be flow related, however, there was no linear relationship between mean daily CPUE of multispecies and daily water level measured in Pakse $r^2<0.001$ .Rising water level appears to stimulate peak migration of fish as CPUE increases as water level rises (Figure 3.11). Peak migration started at the beginning of the flooding season when water started to rise. In 2009, 2010 and 2012, fish migration was highest in June and July and declined in late August-September, but in big flood years (2008 and 2011) secondary fish movement occurred into August.

Canonical Correspondence Analysis of the CPUE of the 14 species plotted against environmental factors (peak and intensity) indicated that flood intensity and peak flow influenced CPUE of some species (Figure 3.12). At least one species (*P. pleurotaenia*) is influenced by the amplitude (peak) of the flooding and two species (*P. bocourti and C. carpio*) are influenced by flood intensity (duration and flood level).



The scale unit of *P. larnaudiei, P. conchophilus* and *P. pleurotaenia* are different from the other.

Figure 3.9. Inter annual variation of mean CPUE of 14 species of Lee trap fishery in Hoo Som Yai Channel,1997-2012.

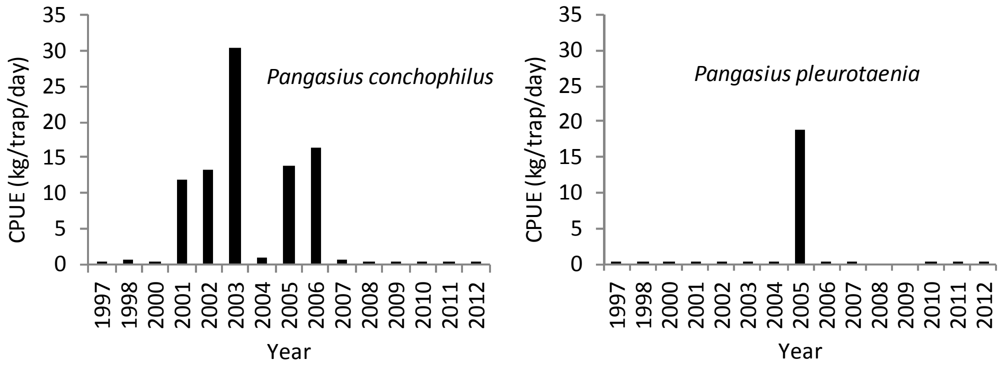


Figure 3.9. Continued

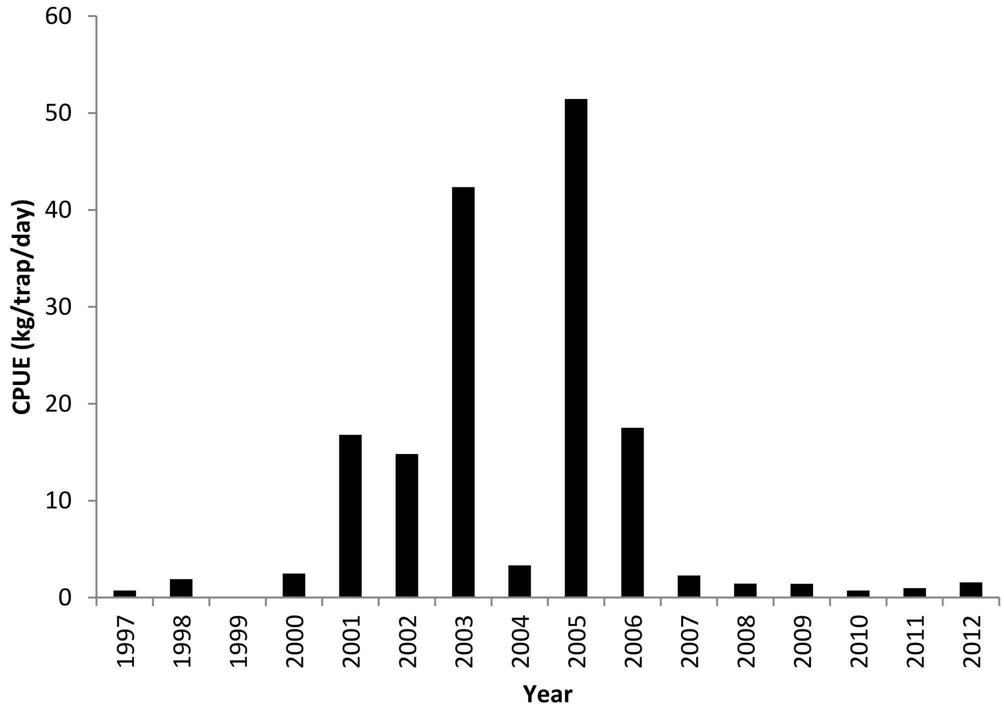


Figure 3.10. Mean CPUE of 14 species monitored at Ho Som Yai channel during 1997-2012. No data in 1999.

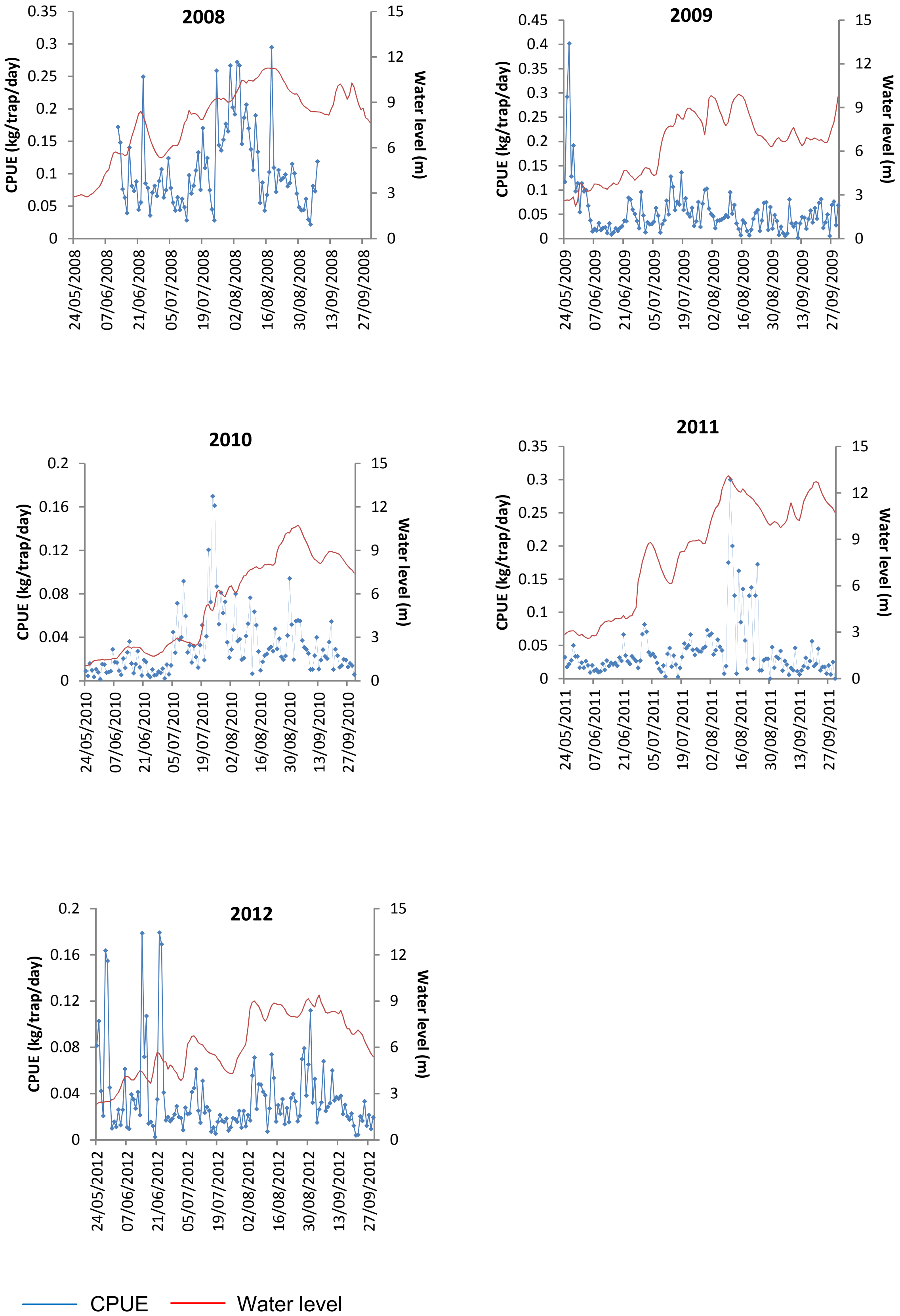


Figure 3.11. Relationship between mean CPUE of 14 species monitored at Hoo Som Yai channel and water level measured in Pakse, 2008-2012.

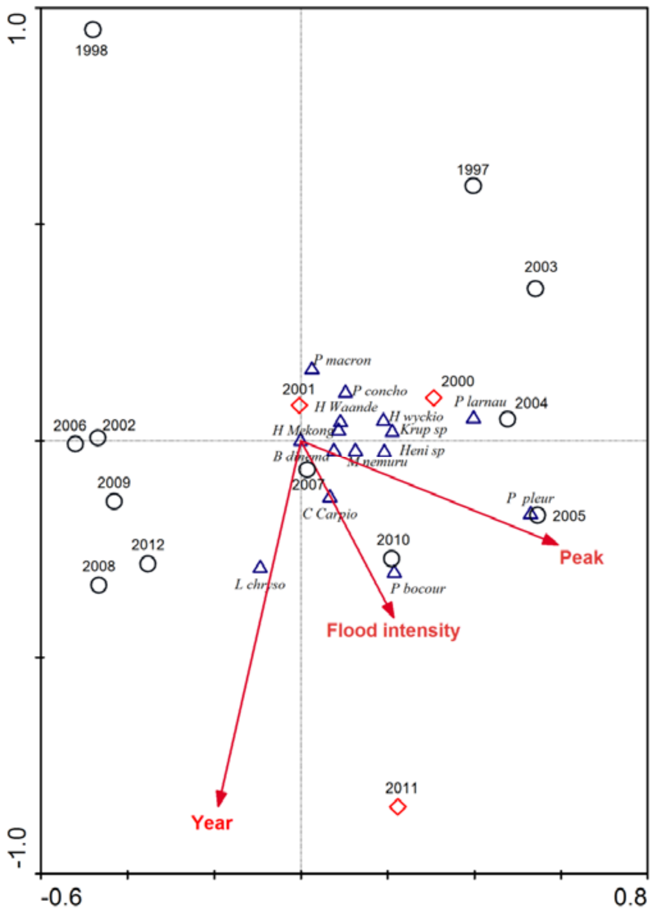


Figure 3.12. Canonical Correspondence Analysis of mean CPUE of 14 fish species monitored at Hoo Som Yai Channel and environmental factors (peak and flood intensity).

3.4.2 Gill netting monitoring

Catch composition

In total 157 fish species were recorded between 2008 and 2012. *P. conchophilus* contributed 11% of the total catch landed, followed by *L. chrysophekadion* and *Cosmochilus harmandi* Sauvage, 1878 accounting for 10 and 9%, respectively (Figure 3.13).

Inter-annual change

Species composition differed between the south (CHS1 and CHS2), central (BKS and VTE) and northern (LPB) monitoring sites. While *L. chrysophekadion* formed more than 21% of the catch in the south, *P. conchophilus* and *C. harmandi* predominated in BKS, accounting for 24% and 13% of the catch, respectively (Figure 3.14). Five species (*B. bagarius, C. harmandi, H. waandersii, P. djambal* and *P. jullieni*) contributed between 8 and 11% of the catch at the VTE station. *C. carpio* accounted for 22% of the catch at

LPB, followed by *Hypsibarbus vernayi* Norman ,1925 (18%) and *Hypsibarbus malcolmi* Smith, 1945 (16%).

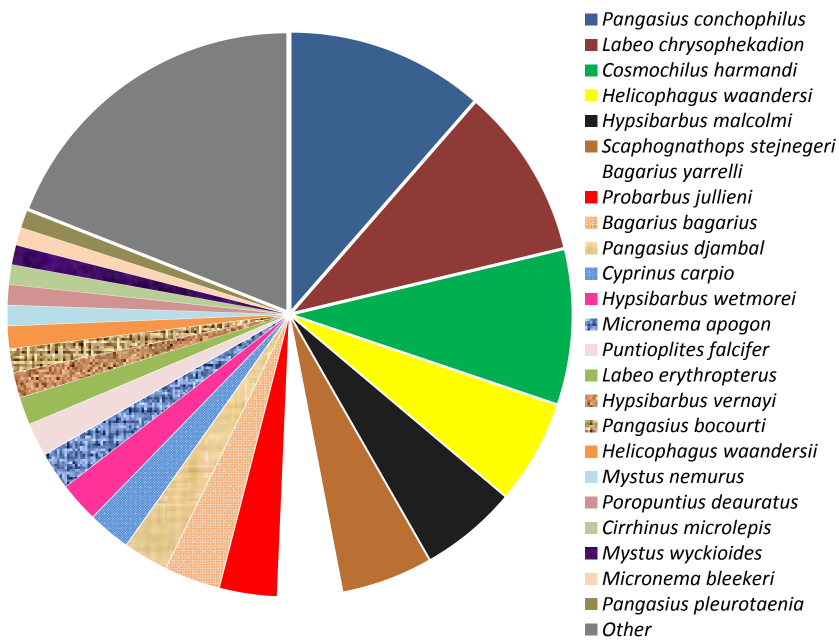


Figure 3.13. Fish species composition of the catch from gill nets fishery at five stations, 2008-2012.

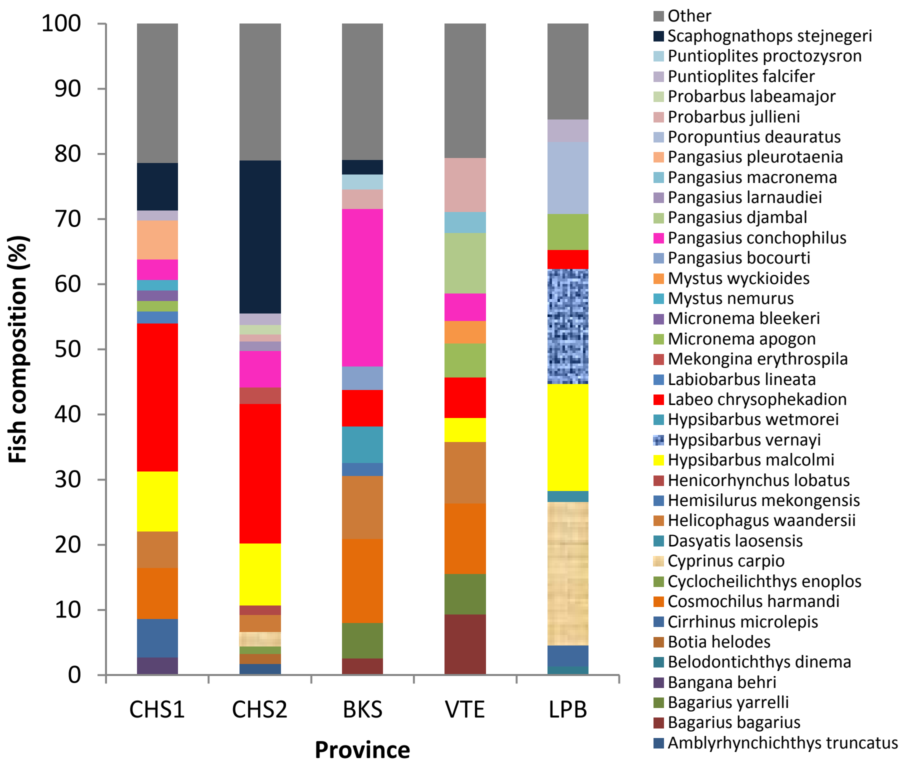
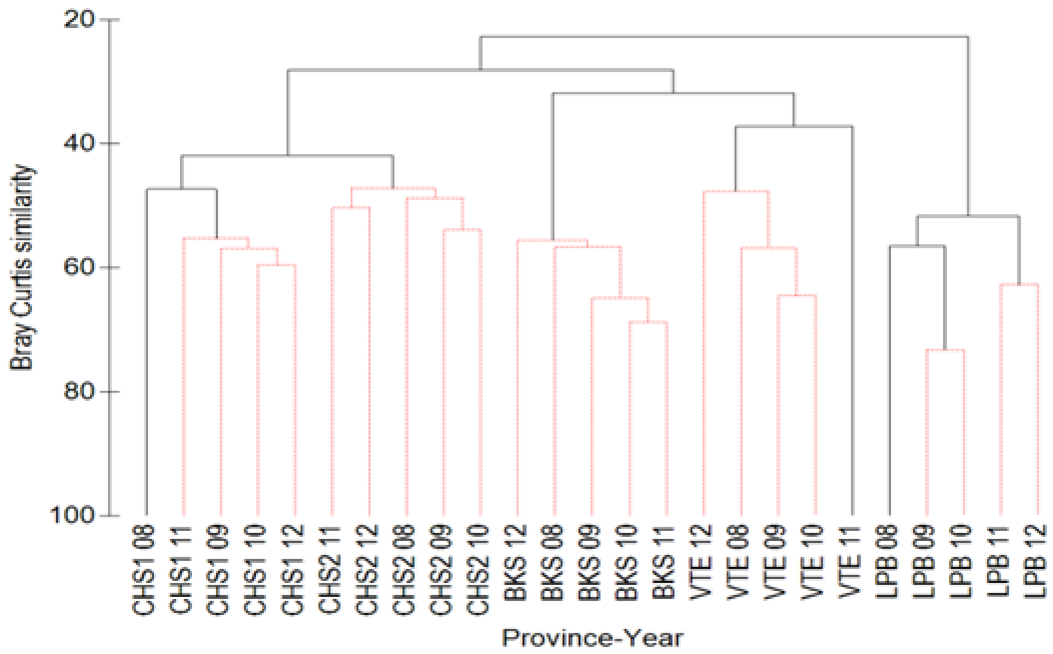


Figure 3.14. Percentage of mean CPUE from gill nets at five stations, 2008-2012. Only those species which comprised 80% by weight of total catch are shown)

Cluster analysis confirmed the differences between the five monitoring stations (Figure 3.15 A). As expected, the two stations in Champasack province (CHS1 and CHS2) grouped closely, whilst other sites were well separated, but each was mostly similar between years (Figure 3.15 B).

SIMPER analysis was used to explain the differences in species CPUE contributions between stations and accounted for between 62 and 82% in dissimilarity. The distance between stations influenced the level of dissimilarity; the two stations in Champasack province (CHS1 and CHS2) were most similar (dissimilarity = 59.8%). whilst the degree of dissimilarity increased to a maximum between the most downstream station (CHS1) and upstream station (LPB) (72.0%), although the highest dissimilarity was between LPB-VTE (81.5%) (Table 3.2) presumably because of the lower species diversity at these more upstream sites.

A



CHS1 and CHS2- Champasack province; BKS- Borikhamsay provice; VTE-Vientiane Capital and LPB- Louangprabang province.

Figure 3.15. (A) Cluster analysis of mean CPUE at five stations. Using group average clustering from Bray Curtis similarity on transformed data Log(X+1). 2008-2012.

B

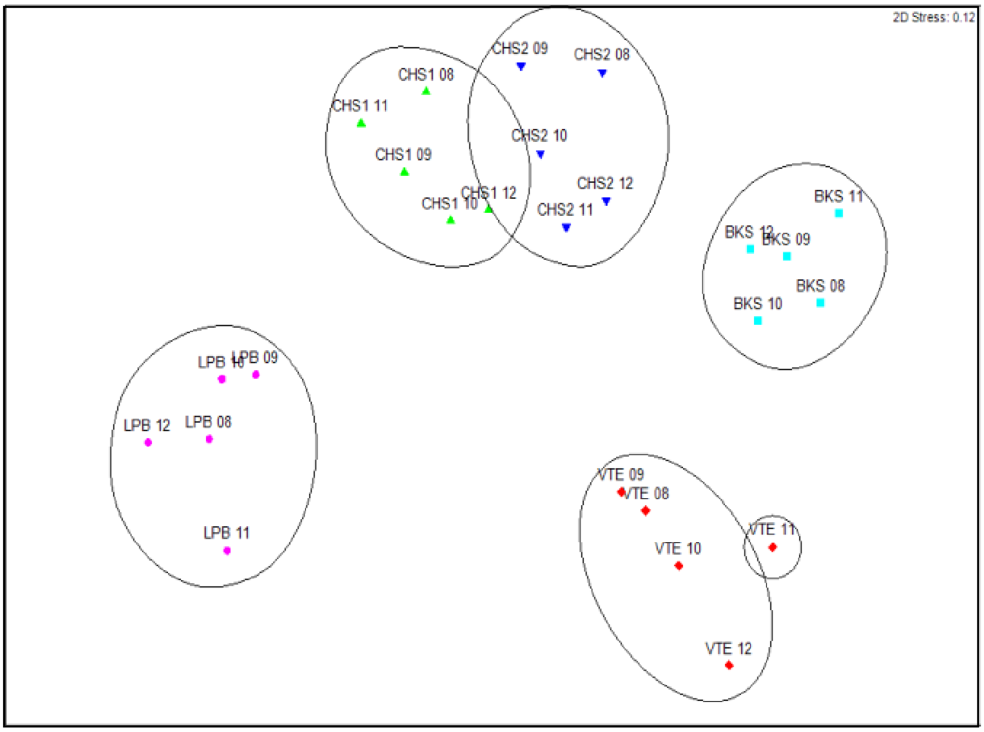


Figure 3.15. (B) MDS analysis of mean CPUE at five stations, showing the similarity levels of mean CPUE between year of 45%.

Table 3.2. SIMPER analysis of Mean CPUE of gill nets fishery indicating top five species contributing to the dissimilarity between five stations.

Station	Overall dissimilarity (%)	Species name	Contribution to Dissimilarity (%)
CHS2-CHS1	59.8		
		C. microlepis,	2.5
		P. labeamajor	2.5
		P. longipectoralis	2.3
		P. larnaudiei	2.1
		B. behri	2.0
CHS2-BKS	61.8		
		C. harmandi	3.5
		P. labeamajor	3.1
		P. bocourti	3.0
		P. krempfi	3.0
		P. jullien	2.8
CHS2-VTE	75.6		
		P. jullieni	4.1
		M. wyckioides	3.9
		L. erythropterus	3.7
		P. labeamajor	3.4
		C. harmandi	3.2

Table 3.2. continued

CHS2-LPB	73.4		
		D. laosensis	3.1
		P. conchophilus	2.9
		P. labeamajor	2.7
		C. carpio	2.4
		C. microlepis	2.3
CHS1-BKS	63.9		
		C. harmandi	3.6
		P. labeamajor	3.4
		C. carpio	2.8
		P. krempfi	2.7
		C. enoplos	2.6
CHS1-VTE	75.4		
		P. jullieni	4.2
		M. wyckioides	3.7
		L. erythropterus	3.5
		C. microlepis	3.6
		C. harmandi	3.3
CHS1- LPB	72.6		
		C. microlepis	3.8
		D laosensis	3.7
		C. carpio	3.6
		C. enoplos	2.7
		P. longipectoralis	2.4
BKS-VTE	62.4		
		P. labeamajor	4.5
		M. wyckioides	4.1
		L. erythropterus	3.8
		P. jullieni	3.7
		P. bocourti	3.6
LPB-BKS	72.0		
		P. labeamajor	4.1
		C. harmandi	3.9
		P. jullieni	3.8
		P bocourti	3.5
		D. laosensis	3.2
LPB-VTE	81.5		
		P. jullieni	5.6
		M. wyckioides	5.1
		L. erythropterus	4.2
		C. harmandi	4.0
		C. carpio	3.7

It should be noted that the dissimilarity of the species and catches between the stations is influenced by many factors including fishing skills, fishing ground topography, gear used and target species. Fishers in Vientiane (VTE) are likely to target only large fish and use large mesh size of gillnets to catch fish to sell, while fishers in Champasack (CHS1 and CHS2) use both small and large mesh sizes to catch fish following the changes in fish migration patterns throughout the year: the catches are both for subsistence and income. The Mekong freshwater stringray (*D. laosensis),* which is included in the IUCN Red List of Threatened Species under the endangered category, is known to inhabit the Mekong mainstream and its tributaries including floodplains, and is also abundant in the northern province (LPB). This species was also found in others provinces (stations) but rarely caught in gillnet fisheries and is more commonly caught by hook. Only one exotic species, *C. carpio*, was found in the catch monitoring record, this species is well adapted to the Mekong system and widespread throughout the tributaries and floodplains. The catch of this species was high in LPB.

Species abundance and diversity

The number of species was highest in the south (between 67 and 70 species), and was considerably lower in the central (25-45 species) and northern station (35 species) (Figure 3.16). A similar trend was found in species richness, where the lowland stations had the highest species richness. It should be noted that the differences in the number of species caught were associated with the fishing areas and the effectiveness of the gear type, including different mesh sizes that fishers use. Larger mesh sizes were used in the central and north stations to catch medium and large fish for trade.

At all stations, the number of species was higher in the dry season than the flooding season (Figure 3.17). This may related to the breeding cycle: the decline in the number of fish species in the wet season may be associated with their migration to the spawning grounds in tributary, streams and floodplain areas away from the mainstream river and associated sampling areas. In addition, the rise in water level may decrease the effectiveness of fishing gears.

Figure 3.18 shows the distinguished group of similarity between dry and flooding season in each station from 2008 to 2012. Again it confirms the differences in CPUE during dry and wet seasons. The overall similarity of the groups was 25%. The top five species contributing to the differences between dry and flooding season at each station are summarised in the Table 3.3.

Table 3.3. SIMPER analysis of gill net fishery indicating top five species at five stations contributing to the dissimilarity between seasons.

Station	Overall dissimilarity (%)	Species name	Contribution to dissimilarity (%)
CHS1	53.9		
		B. behri	3.3
		W. attu	3.0
		P. longipectoralis	2.8
		D. laosensis	2.6
		C. molitorella	2.4
CHS2	60.8		
		P. labeamajor	3.8
		C. microlepis	2.6
		P. larnaudiei	2.5
		Osteochilus melanopleura	2.4
		C. harmandi	2.4
BKS	44.2		
		P. krempfi	7.4
		C. carpio	5.9
		P. gigas	5.1
		P. labeamajor	4.7
		L.erythropterus	4.4
VTE	51.0		
		P. labeamajor	7.0
		P. jullieni	4.8
		P. micronemus	4.5
		B. yarrelli	4.4
		M. wyckioides	4.1
LPB	58.4		
		D. laosensis	4.7
		C. harmandi	4.5
		C. carpio	4.1
		C. ornate	3.9
		H. wetmorei	3.4

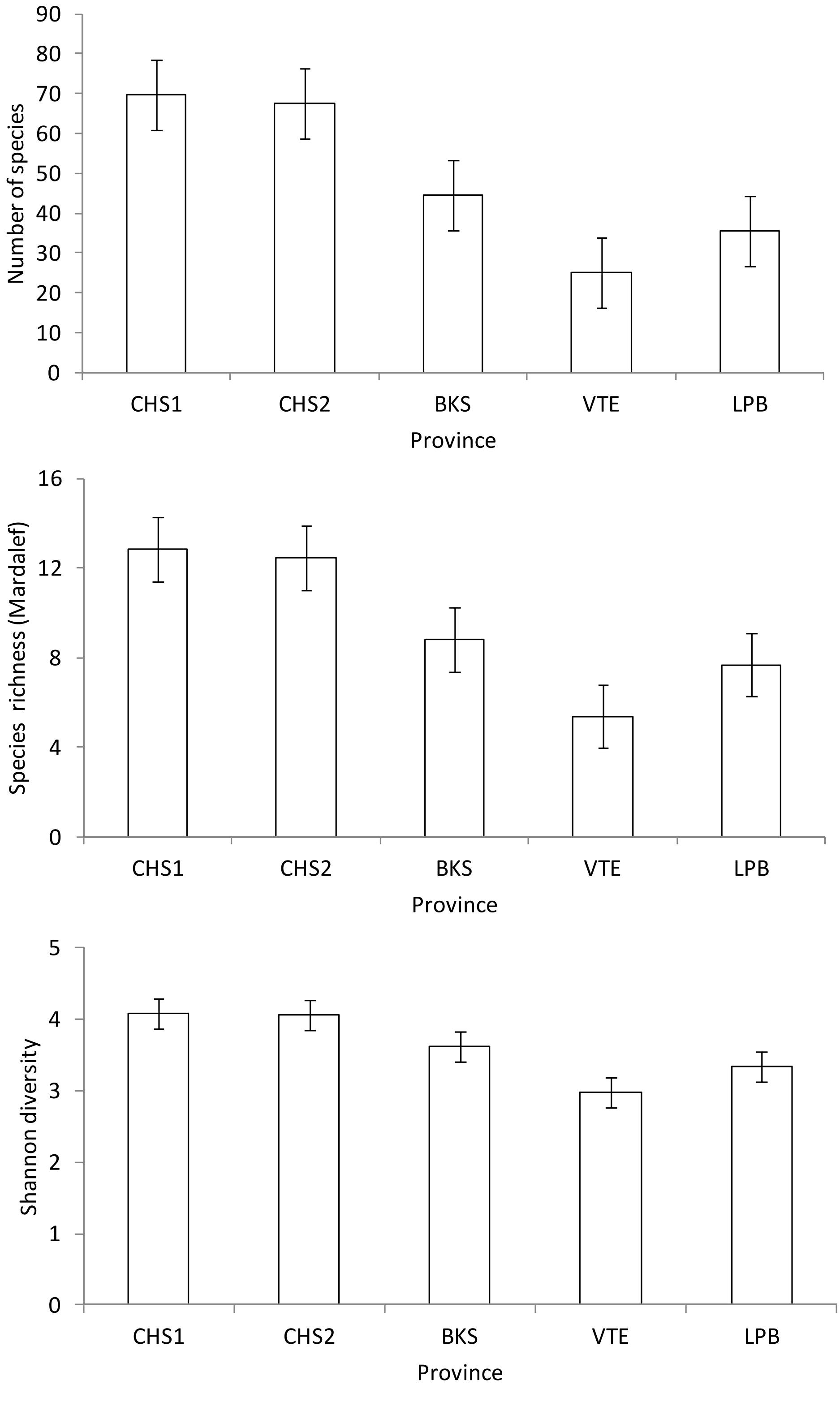
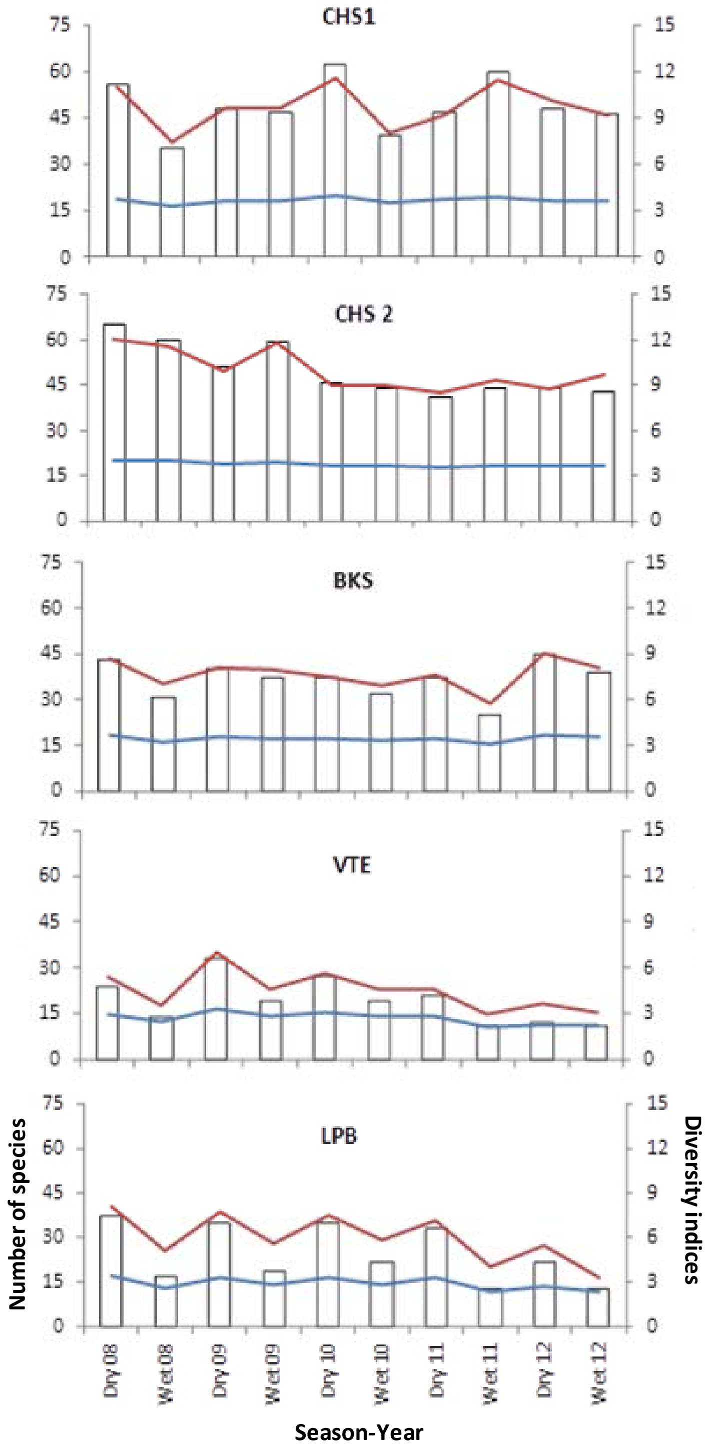
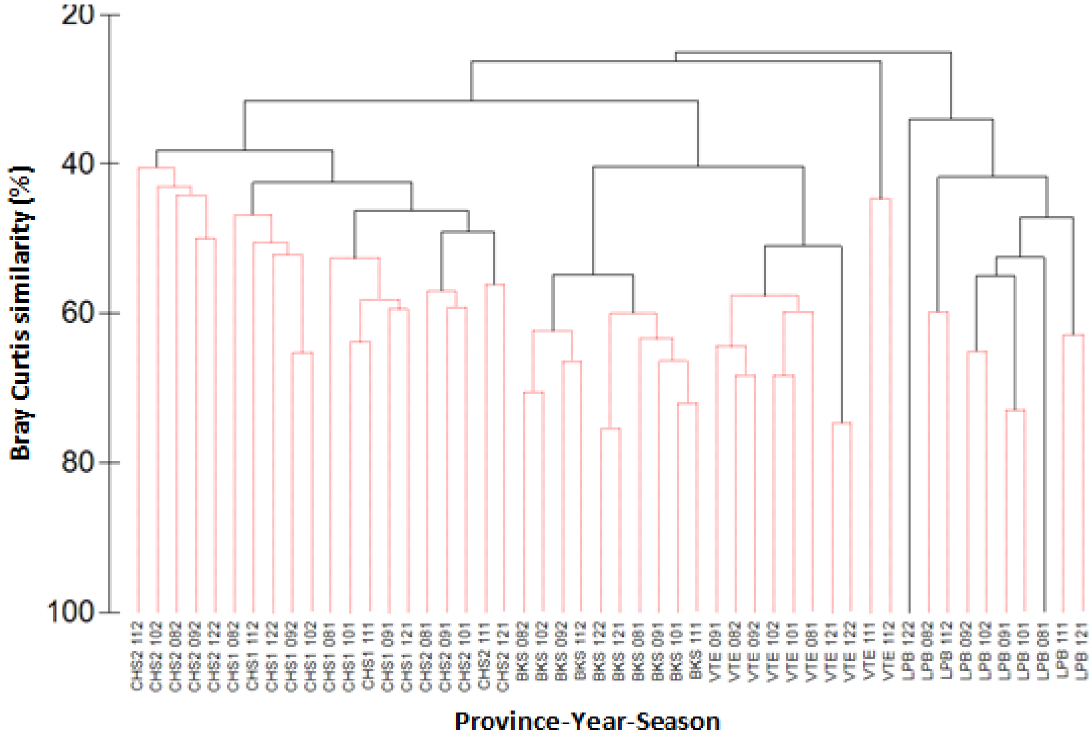


Figure 3.16. Mean species abundance, species richness, species diversity and error bars of gill nets fishery at five stations, 2008-2012.



▭ Number of fish species; ─── Margalef diversity index; ─── Shannon Weiner diversity index.

Figure 3.17. Seasonal variation in fish species diversity of gill nets fishery at five stations, 2008-2012.



First two numbers is year, follow by season: 1 is wet season; 2 is dry season.

Figure 3.18. Cluster analysis of the mean CPUE of gill nets fishery at five stations. Using group average clustering from Bray Curtis similarity on transformed data Log(X+1). The Similarity between groups was 25%.

Annual variation of the common species

Inter-annual variability of species was found in the catches at each station (Figure 3.19). In Champasack province (CHS1), the contribution of *B. behri, C. microlepis* and *L. chrysophekadion* varied little during the monitoring year, while other species fluctuated slightly. The increase in CPUE at CHS2 station in 2009 was influenced by peaks in abundance of *P. jullieni* and *P. labeamajor.* In Borikhamsay province (BKS), the dominant species (*C. harmandi, P. jullieni* and *L. chrysophekadion)* were relatively constant in their contribution to catches. The contribution of *P. jullieni, C. harmandi, L. chrysophekadion* and *M. wyckioides* fluctuated in Vientiane (VTE). It is important to note that the decline in fish catches in VTE in 2011 (Figure 3.19) was mainly due to missing records rather than changing size and weight. In Luangprabang province (LPB), *H. malcolmi, D. laosensis, C. carpio* and *B. dinema* increased their contribution to the weight of fish caught.

There is no linear relationship between mean number of fish and mean water level of four stations r^2 <0.1 (Figure 3.20). However, there was a strong linear relationship between mean weight of multispecies and water level in VTE station (Figure 3.21 B) (r^2 = 0.59; P<0.0001). For the other stations (CHS1 and CHS2) the mean weight increased as the water level rose, suggesting that water level possibly stimulated the migration trigger.

The mean number of fish caught in Champasack stations (CHS1 and CHS2) in the dry season was highest in February-April whilst the mean weight was highest in June-July (Figure 3.20) during the wet season migration of many fish species. A similar migration pattern was also observed in Borikhamsay province (BKS). In Vientiane Capital (VTE), the biomass rose in the period July to December when fishers mainly targetted large fish (brood stock), including *P. jullieni*, *C. harmandi*, *B. yarrelli, H. mekongensis, M. wyckioides.* Further upstream in Luangprabang (LPB) the number of fish peaked in the dry season (November-December) associated with dry season movements from the streams to the Mekong River. The increase in biomass found in the dry season (March) was mainly influenced by the peak in abundance of large fish (*D. laosensis*).

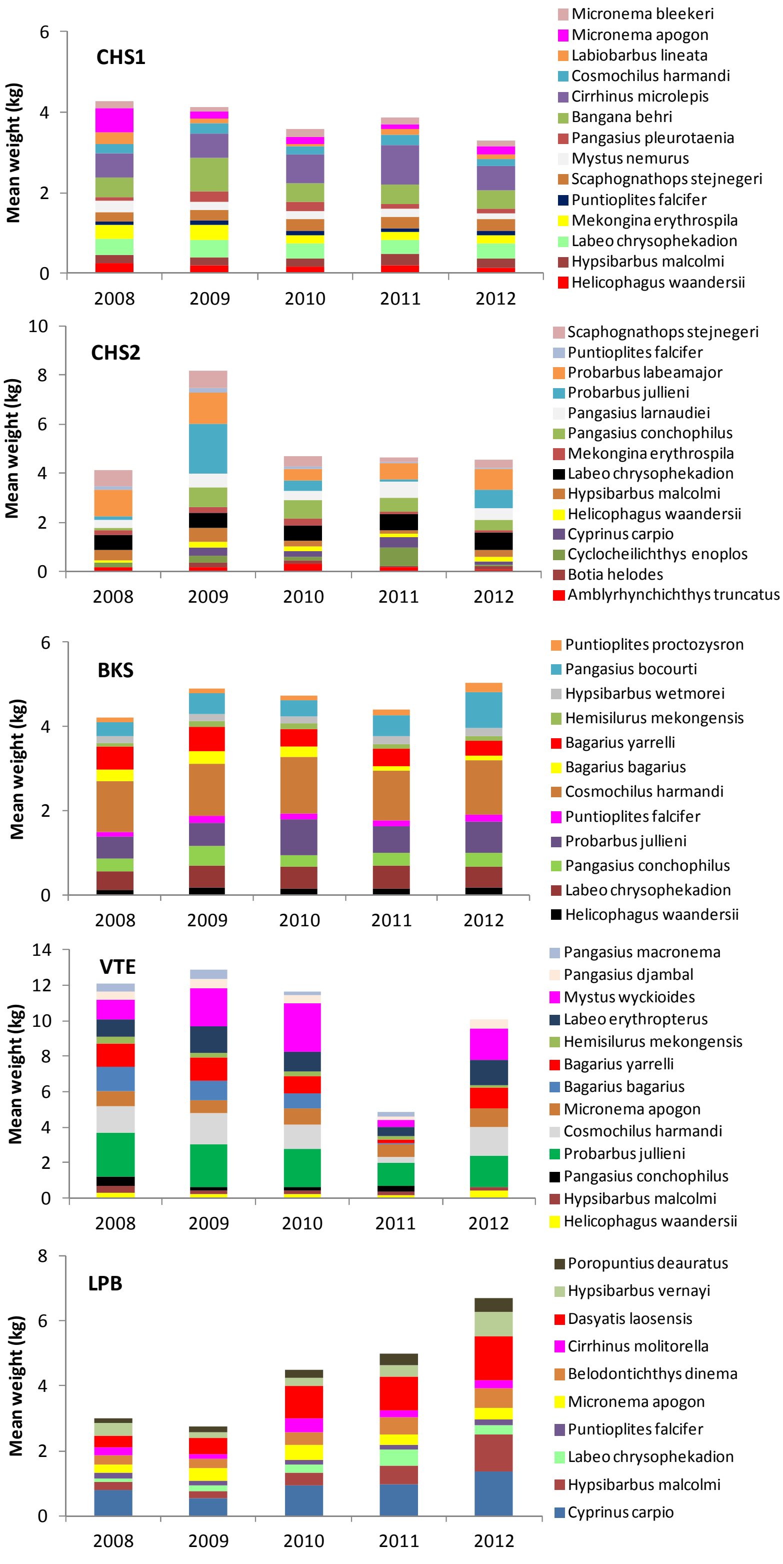


Figure 3.19. Inter annual variation of mean CPUE of common species of gill nets fishery at five stations, 2008-2012. (BKS no data September 2011-February 2012; VTE no data June 2011-March 2012).

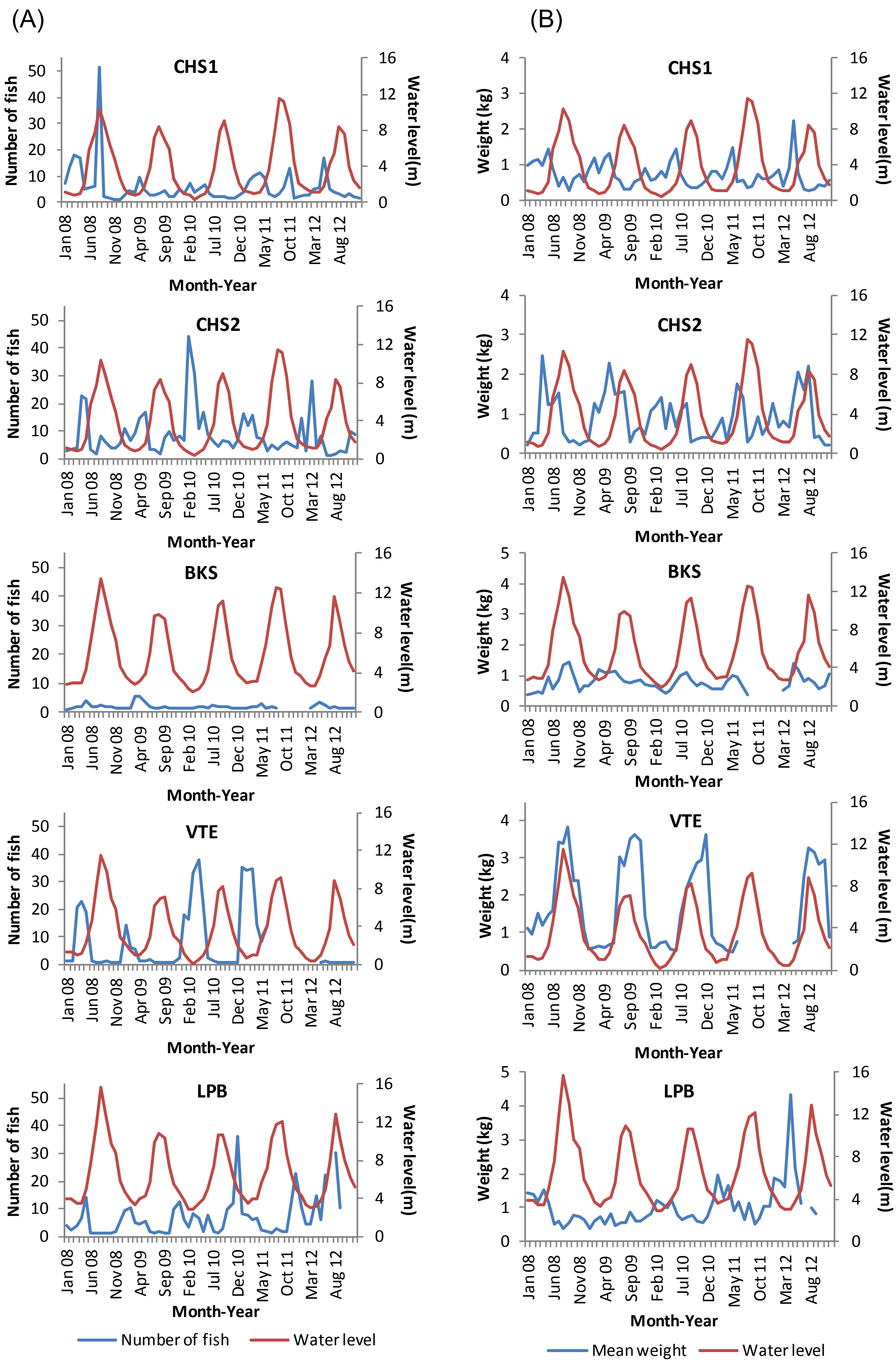


Figure 3.20. Relationship between (A) mean number of fishes and (B) mean weight of gill nets fishery at five stations and water level, 2008-2012. BKS-no data September 2011- February 2012; VTE-no data June 2011-March 2012).

3.5 DISCUSSION

3.5.1 Status and trends

The study monitored the daily catch of fishers in the most productive fishery in Champasack province and other key areas in Borikhamsay, Vientiane Capital and Luangprabang provinces. The Lee trap fishery targets the wet season migratory species in southern Laos. These areas represent the most important migration pathways of catfish (Pangasiidae and Siluridae), Sisoridae, Bagridae and Cyprinidae (Singhanouvong *et al.* 1996b). *P. conchophilus* and *P. larnaudiei* were the dominant species in the Hoo Som Yai Lee trap fishery (Warren *et al*. 2005). The variability in annual catch rates was mainly caused by fluctuations in the catches of three species, *P. conchophilus, P. larnaudiei, P. pleurotaenia,* with a peak catch of 51 kg/trap/day in 2005. This peak coincided with the highest catch recorded in the Cambodian Dai fishery (Halls *et al.* 2013a). Other abundant species in the Lee trap fishery but rarely found in the Hoo Som Yai channel traps were *P. krempfi* and *H. wyckioides* the females of these two species are caught in full reproductive condition in Hoo Sa Hong and Don Nokasoum channels in July-August, located on the west of Hoo Som Yai Channel (Cacot 2007), suggesting they are on their spawning runs. *B. yarrelli, L. chrysophekadion* and *H. mekongensis* were also dominant in the catches from the Lee trap fishery.

As expected, there was more number of species were caught by gill net (157 species) than Lee traps (72 species). The differences in species numbers between these two gears were partly because of the fishing period, the effectiveness of the gear and the fishing locations. In terms of fishing efficiency, gill nets catch a greater variety of sizes (depending on mesh size) and species. Considerable differences were also found between the five monitoring stations in terms of species abundance and biomass; the dissimilarity of species and catches between the stations ranged from 60 to 82%. There were considerable differences between the stations in the lower floodplain reaches around VTE and the upper reaches LPB; it confirmed previous findings that indicated that the upper reaches of the LMB had lower species diversity and abundance than the lower reaches and floodplain areas (Barlow 2008, Halls *et al.* 2013a). The gill net fisheries in the two stations in Champasack, southern province, targeted dry season movements of the Cyprinidae family (as reported by Singhanouvong *et al.* 1996a); the dominant species were *S. stejnegeri*, *L. chrysophekadion*, and *H. malcolmi.* Phonekhampheng (2010) estimated that 102 species migrated through Hoo Sahong, Sadam and Xangpeuak (the large channel in the Siphandone area), of which 88 were recorded using Hoo Sahong as a migration route.

The study was unable to determine any relationship between multispecies catch and water level in most stations for either the Lee trap or gill net fisheries, except the gill net fishery in VTE. However, water level, as a surrogate for discharge, seemed to stimulate fish movement; catches were higher when the water level rose and declined when the water level dropped. The reasons for the lack of a direct relationship between fish movement and water level may be due to differential migration behaviours of the individual species that takes place at different times of the year. For instance, the peak migrations of *P. larnaudii* and *P. krempfi* were in the wet season June-September, but *P. jullieni* migrated for reproduction during the dry season from December to February. Many authors have reported that fish migration is associated with the flooding cycle, as demonstrated by peak catches at the start of the flooding period (Singhanouvong *et al.* 1996; Poulsen *et al.* 2002; Warren *et al.* 2005). Baran *et al.* (2006) indicated that migration of at least 30 species in the Mekong River was triggered by changing water level and discharge. They concluded that there were at least four environmental factors triggering fish migration: change in discharge and water level; first rainfalls at the beginning of the wet season; change in water colour; and the occurrence of insects. This supported earlier research describing a relationship between peak migration of *P. krempfi* and rising water levels (Baran *et al.* 2005) and at least six species depend on the rising of water level (Halls *et al.* 2013a). Flow peak and flood intensity were likely key determinants triggering migration of some fish species (*P. pleurotaenia, P. bocourti and C. carpio)* found in the present study.

The cumulative of impacts water resource (agriculture and hydropower) and other developments (deforestation, mining and navigation) are likely to threaten the Mekong fisheries (Baran *et al.* 2005 Halls & Kshatriya 2009). Logging, clearing the flooded forest around Great Lake and Tonle Sap, are damaging spawning and breeding habitats in the floodplain areas (Nao & van Zalinge 2001). Blasting and dredging rapids to improve dry season navigation in the north of Laos (Banran *et al.* 2007) has destroyed the diversity of habitats including shallow rapids and deep pools that are believed to act as dry season refuge habitats for many fish species. Dam operations in China have affected the flow regime downstream in northeast Thailand and disrupted fish migration resulting in falling fish catches (Sretthachau & Deetes 2004). Fishing pressure from the use of illegal fishing gears such as dynamite, poisoning and electrofishing in Cambodia and Vietnam, have seriously diminished fish populations and diversity (Deap *et al.* 2003, Dieu 2010). Climate change impacts, in particular rising temperature, severe drought and more frequent floods, are also likely to disrupt migration patterns and cues (see Chapter 6). Others factor threatening the fisheries include human population growth, urbanisation and high market demand for wild fishes.

Poulsen *et al.* 2012 reported that many species migrated during the dry season from December to April. At least 60 species migrated from the Khone Falls area to Hat village (CHS1) during the dry season (Singhanouvong *et al.* 1996b). These movements were for reproductive, trophic or basic dispersion purposes. This study (Lee trap monitoring) also highlighted the importance of the wet season to fish migration in the Mekong River, when combining the Lee trap and gill net monitoring outputs, it provides a better picture of species diversity and migration patterns in the system. However, the Hoo Som Yai is just one of the many channels in the Khone Falls, and Lee trap catches from these may not be representative of the overall migration patterns. It only covers wet season movements of the target species, and many species are not caught. It is recommended that the monitoring programme is extended in other channels (e.g. Hoo Sadam, Hoo Sahong, Hoo Xangpheuk) to get a better understanding of the migration patterns and behaviours of the multispecies fish assemblage in the region. The gill net monitoring programme should also continue and be expanded to the important tributaries (e.g. Ou river, Xebangfai, Sekong).

3.5.2 Implications of hydropower developments

There is major concern about the construction of 11 mainstream dams in the LMB which was precipitated by the start of construction of the first at Xayaburi in Laos in 2012. The concerns orientate around the dams intercepting huge amounts of sediment, which will reduce sediment loading to the Cambodian floodplains and Mekong delta and act as physical barriers disrupting longitudinal migration along the mainstream and lateral movement between the mainstream and floodplains for reproduction and feeding (Dugan *et al.* 2010). The impacts of the tributary dams on fish production and people's livelihoods have largely been ignored, yet there are 41 dams constructed on major tributaries and another 77 planned (ICEM 2010). The impacts of these tributary dams can be as great as, if not greater than, the mainstream dams, especially if the cumulative effects are considered. For example, Yali dam in Vietnam has impacted the fisheries, flooded agricultural land and destroyed houses of people living along the Se San River in Cambodia (IRN 2012). Other issues are associated with the alteration of natural flows and discharge, which disrupt fish habitat and migration, leading to reduction of fish populations and yield. These issues are discussed further in Chapter 4 where a case study on Nakai Reservoir is examined.

As mentioned in Chapter 2, fish migration systems in the Mekong River are inter-connected with the tributaries, particularly in the Lower and Middle Systems-here people depend on migratory fish for their food security and income generation. Building dams on the mainstream will likely impact on fish populations, in particular the long-distance migratory species. As a consequence, the livelihood of the people living along the river banks will be seriously affected. The construction of Hoo Sahong, Sambor and Strung Treng dams will not only block key migration corridors, but also will likely create trans-boundary impacts on the downstream environment, including bank erosion and reduction of sediment load to downstream floodplains and delta leading to a reduction in agriculture productivity and an food insecurity of the people around the Great Lake and in the Mekong Delta (ICEM 2010). According to Cowx *et al.* (2012), the impacts of dams can be grouped into downstream and upstream impacts. The overall impacts are associated with blocking of fish migration to breeding habitats, which will likely reduce fish diversity and yield. In addition, the changing flood pulse and fluctuations in water level and discharge as a result of dam operations will disrupt reproductive processes, destroy habitats, alter migration systems and disrupt migration cues. Also the newly created reservoirs will result in a change from a riverine to a lacustrine environment. Fish species that favour standing water conditions are likely to take over and dominate the new impoundments. In this context, it is often alien invasive species such as common carp and tilapia that proliferate in these new conditions. Dam operation and the mere presence of a large impoundment also disrupts larvae and juvenile drift; normally these fishes will drift downstream to the floodplain for feeding but are likely to be killed when passing through turbines or spillways or simply drop out in the reservoir because of the reduction in flows (Barlow *et al.* 2008). Fly can also be accelerated past suitable floodplains if the flow is too heavy or not reach them in the main channel if flow is too slow.

In general, fish passes across dams <6 m high are more effective than those across higher dams. For example, a fish passage for a small irrigation reservoir (less than a 6 m high) in Paksan province, Laos, can provide a pass way for more than 125 species from the Mekong River to the floodplain areas (Starr 2013). However, the existing technology of fish passage facilities cannot mitigate the barrier effects of the mainstream dams that are more than 100 m high due to the complexity of the ecology and species diversity (Dugan *et al.* 2011). The size of Mekong fish, which have total lengths ranging from just 1.3 cm (*Boraras micros*) to more than 300 cm (*P. gigas*) makes it even more difficult and more time and resources to develop new technology to mitigate the barrier effects is needed.

A potential decline in the species diversity and yield of the Mekong fisheries caused by dam development will ultimately have significant impacts on the fishing communities in the LMB, especially the rural poor who depend upon fisheries resources. Any development projects should include the fisheries sectors in their planning process and examine the impacts of the development on fisheries to ensure that sufficient mitigation measures are in place. This is rarely the case because fisheries are a common property resource and largely ignored in development projects, and given only limited attention in the Mekong dam developments. Consequently, before making any decisions on the construction of hydropower dams, there is a need to determine the economic value of fisheries to the communities, including food security. Social and cultural benefits should also be indentified and measured against the benefits from the proposed dams development project (Cowx *et al.* 2012). Key to this is ensuring the local fishing communities are correctly compensated for the loss of the fisheries and alternative livelihoods are provided that are not dependent on fisheries that will ultimately change (see Chapter 4).

Alternative energy sources such as solar power, biogas and wind power should be explored to supplement or replace hydropower dams. If the mainstream dams are to be built, the Mekong River Commission should act as the focal point to facilitate and coordinate among the member countries to ensure the water development schemes are in line with the Mekong 1995 agreement on the Cooperation for the Sustainable Development of the Mekong River Basin. By promoting regional cooperation, it will help to minimise the impacts and strengthen the collaboration for environmental protection, including aquatic resources, as well as ecological balance from pollution or other harmful effects caused by developments and the use of water resources in the LMB.

CHAPTER 4: ECOLOGICAL AND LIVELIHOODS IMPACTS OF NAM THEUN 2 DAM

4.1 INTRODUCTION

Hydroelectricity is seen as a green energy source compared with the other energies (e.g. lignite and nuclear power) in terms of environmental pollution and safety. In Laos, hydropower was first developed in the late 1960s, when the capacity of installations was very small, ranging from 50 KW to 5 MW (Phannalangsi 2011). These units supplied electricity for domestic use only. Since 2000, the government of Laos has been set a goal to promote sustainable hydropower development for supporting the implementation of the MDG on food security and poverty alleviation. In 2008, the electricity sector was the third largest export revenue earner for the country (MEM 2008). There are mainly two types of hydropower in Laos, namely run of the river (Theun-Hinboun dam) and reservoir hydroelectric power plants. The latter are commonly found but recently a trans-basin diversion hydropower scheme has been developed (Nam Theun 2 dam).

In the United Kingdom, water resources developments including hydropower schemes, water extraction, weirs and irrigation, are strictly monitored and regulations, guidelines and measures to minimize the negative impacts of projects on the environment are in place (Robson 2013). In 2013, the United States of America removed 51 dams from rivers because they did not meet their intended purposes or concerns over safety and environmental issues (American River 2014). By contrast, in South East Asia, the demands for electricity are high due to rapid economic growth and dramatic expansion of the industrial sectors, leading more private sector companies investing in hydropower plant projects (Barlow 2008). As a result, several dams are being constructed or planned, in particular in Laos, where the potential to develop hydropower plants is greater than the other countries in the LMB.

Hydropower dam developments are known to impact on the social, economic, ecological and environmental dimensions of rivers (Petts 1984, Cowx & Welcomme 1998, WCD 2000). Blocking fish migration, reduction of sediment load, environmental degradation and social depression are the main concerns over the impacts of hydropower development in the Lower Mekong Basin (Robert 2001, Dugan *et al*. 2008, ICEM 2010). In addition, impoundment of rivers creates social and economic problems for resettled households (ADB 2004), affecting the livelihoods and food security of people living around and downstream of the reservoir (Pearse-Smith 2012). Although Environmental Impact and Social Impact Assessments are required by the government and the development banks before approval and providing loans (STEA 2006), many

EIA and SIA reports are very poor, overlooking potential impacts and are rarely shared or consulted upon with the general public. Details about hydrological changes and their impacts on the environment and livelihoods of people in Laos are limited, especially changes in river flows as a result of trans-basin diversion dams. This study was intended to investigate the hydrological change caused by Nam Theun 2 dam in the Xebang Fai River (XBF) and assess the associated impacts of these changes on the fisheries resources and livelihoods of local people living around Nakai dam and along the river downstream.

4.2 OBJECTIVES

The objectives were to assess the impacts of flow modification on ecosystem integrity and the livelihoods of local people affected by reservoir development; and to examine opportunities and challenges to minimise these impacts.

4.3 METHODS

4.3.1 General description of the study areas

Nakai reservoir

The Nam Theun 2 Power Company (NTPC) received a 25-year Concession Agreement (2009-2034) to build Nam Theun 2 Hydro electric dam on the Nam Theun River, in the Nakai plateau (Figure 4.1). After the Concession Agreement period ends this dam will be handed over to the Government of Laos (GOL). This project is expected to generate 1,070 MW of electricity, of which 93% will be exported to the Electricity Generating Authority of Thailand (EGAT) and the rest supplies to ELECTRICITE DU LAOS (EDL) (ADB 2004). The project is expected to generate US$1.9 billion in revenue for the GOL over the project concession period (ADB 2004). Nam Theun 2 dam has been operated in March 2010.

Nam Theun 2 hydropower dam is a trans-basin diversion project, diverting water from Theun River to the Xe Bang Fai River (Figure 4.1). Nakai reservoir is located on the Nakai plateau, in Nakai district, Khammoune Province. The reservoir is surrounded by Nakai Nam Theun National Biodiversity Conservation Area (NBCA) to the west and north, Phou Hin Poun to the east, and Hin Nam Nor NBCA to the south (Figure 4.2). The area includes 3,445 km^2 of the Nakai Nam Theun National Protected Area lying in the Annamite Mountains along the border with Vietnam. According to ADB (2004), the Nakai plateau is characterised by poor soil and covered by pine forest. Shrub and bamboo forest is found in the lower attitudes less than 600 m, whereas higher attitude (600-1000 m) in mountainous areas are dominated by dry evergreen forest, which covers a large proportion of the protected area. Wet evergreen forest is found in the upper mountainous areas (over 1800 m) along the border with Vietnam.

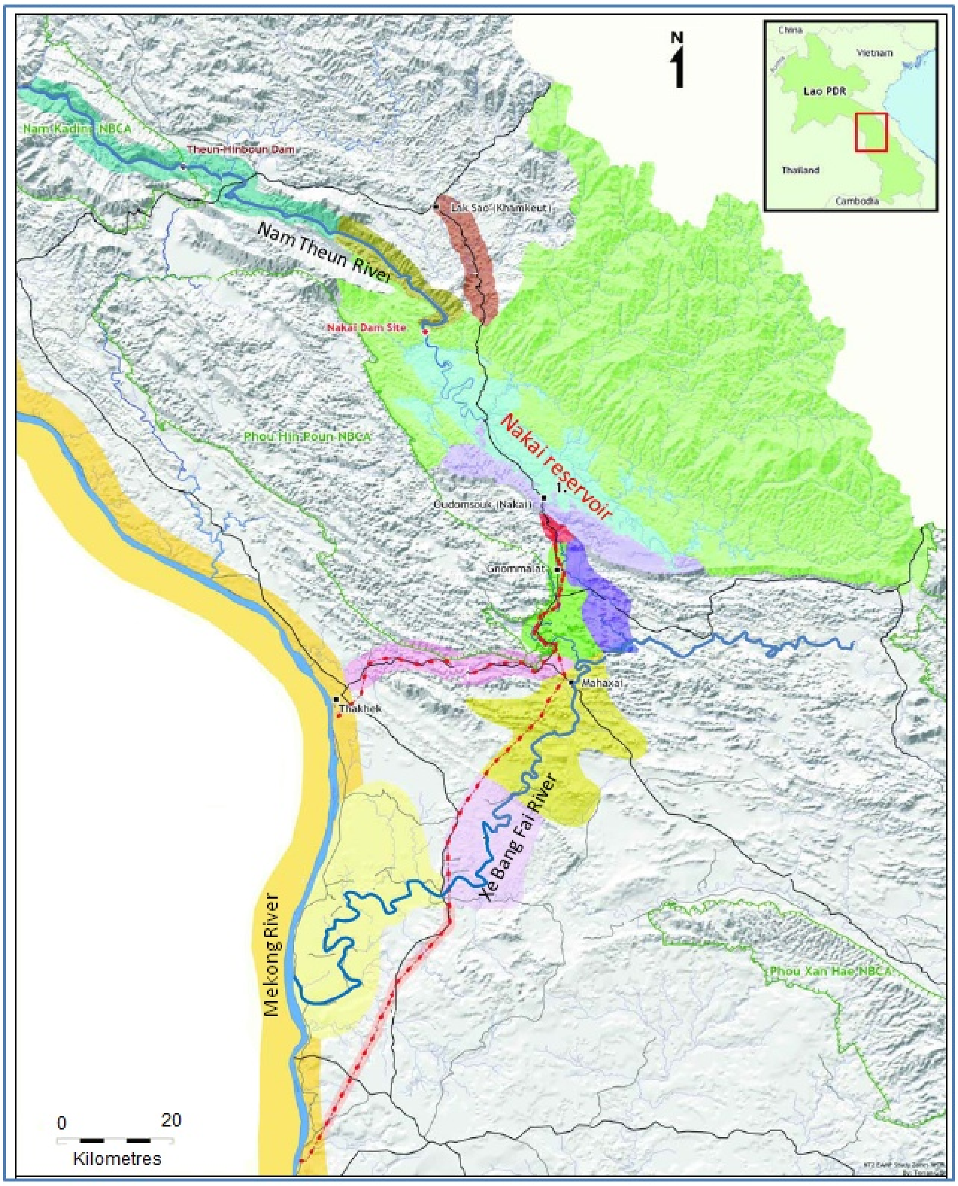


Figure 4.1. Map of the Nakai reservoir (Source: ADB 2004).

Nakai reservoir receives most of its water from the Nam Theun River that has inundated approximately 40% of Nakai plateau, including the Nakai Nam Theun NBCA. The Nam Theun River originates in the Annamite Mountains with an elevation of 2,286 m and has a length of 138 km. Theun River has four tributaries, the On, Noy, Xot and Pao rivers. The first three join Theun River on the Nakai Plateau and the latter joins downstream near the head of the Theun Hinboun Hydroelectric Project. There are no villages situated along the Theun River downstream of Nakai dam for at least 50 km; this area is covered by forest and is mountainous.

The reservoir has a total of surface area of 450 km^2 when full (538 m) and 108 km^2 at the minimum dry season level (325 m). The reservoir has a carry capacity of 3.5 billion m^3, with an average depth of 7 m (Table 4.1). Water from the reservoir falls 350 m through a tunnel to a power generation house before it is released to a regulating dam that can store up to 8 million m^3 of water, from where it flows a further 27 km in a channel before being released to XBF at Na Kew village (Figure 4.3).

Table 4.1. Nam Theun 2 dam installed capacity and its hydrological characteristics (Source: NTCP 2012).

Descriptions	Hydrology and catchment
Installed capacity	1075 MW
Generate electricity per year	6000 GWh
Catchment area	4013 km^2
Dam height	39 m
Dam with a crest length	325 m
Annual average flow	240 m^3/s
Maximum depth	47 m
Average depth	7 m
Peak flow of a 5000 year flood	7,425 m^3/s
Peak flow of a PMF (Probable Maximum Flood) 24 hours flood	16,000 m^3/s
Extreme Water Level	540.00 m ASL
Full Supply Level	538.00 m ASL
Live capacity	3,530 Mm^3

NTCP (2005) reported about 5684 persons, 1030 households and 17 villages existed in the inundated area of Nakai reservoir. There are five main ethnic groups: Brou, Tai Bo, Upland Tai, Vietic and Sek. The people practiced upland shifting cultivation, gardening, collecting NTFPs, fishing, hunting and livestock for their living.

Before the dam was commissioned, infrastructure in Nakai plateau was poorly developed. Only Oudomsouk village, located at the district centre, had electricity. The dirt roads were in poor condition. Schools existed in the larger villages but attendance was poor; more than 60% of the population do not attend school. There is only one hospital located at Oudomsouk village; the average distance to the village was 11 km and was only accessible on foot. Most villages have a village health volunteer but they have very limited skills or the necessary medicines.

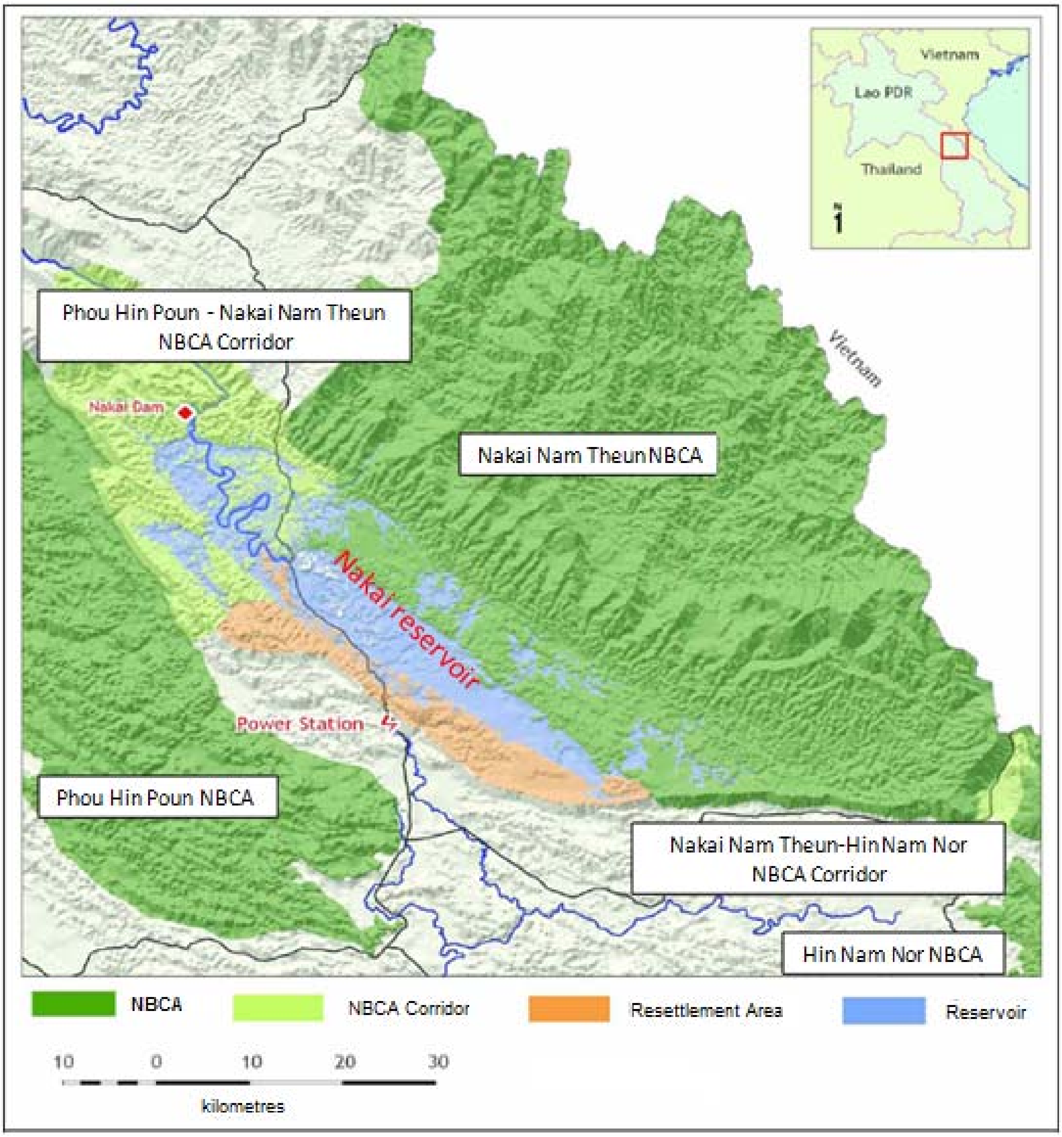


Figure 4.2. Map of Nakai reservoir showing National Biodiversity Conservation Areas (Source: ADB 2004).

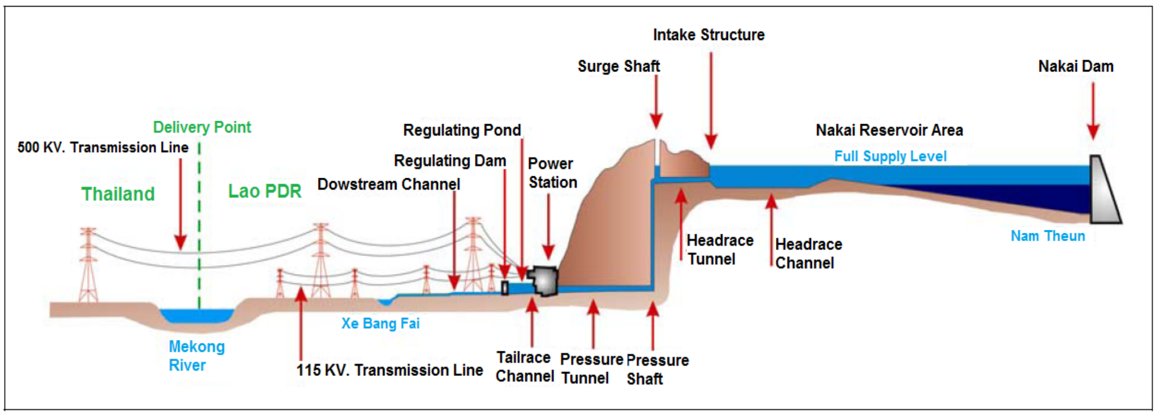


Figure 4.3. Nam Theun 2 hydropower project scheme (Source: ADB 2004).

NTPC relocated 16 villages, 6,200 people, living along the Nam Theun River bank to new resettled areas on the Nakai plateau (Figure 4.1 and 4.2 above). The resettlement villages are located on the east bank of Nakai reservoir along Road No 8 B to Laksao city, Khamkeut District, Borikhamsay Province. The resettled households receive newly built houses with toilets, water tanks and electricity from the project. The project also built primary schools and improved infrastructure such as road and electricity networks (Table 4.2).

Table 4.2. House and infrastructure supported by NTPC (Source: The World Bank 2013).

Description	Unit
New houses	1,330
Community building	104
Water pumps	330
Primary schools	16
Nursery schools	16
Health centre	2
Road (km)	120

Xe Bang Fai River

XBF is found in the central provinces of Laos. It has a total length of 386 km, a catchment area of 10,345 km² and flows through Khammouane and Savannakhet provinces (IUCN 2007). The main tributaries of XBF are the Nam Ngo, Nam Gnom, Nam Phit, Nam Phanang, Nam Oula, Nam Piat and Nam Xe Noy. The headwaters (the Laos-Vietnam border) are characterised by steep ridges and deeply incised valleys where the major rivers have moderate slopes with frequent pools, rock bars and rapids. The floodplains of the lower XBF flood on an almost annual basis in the rainy season. According to the 36 year gauge history at XBF (bridge on route No. 13), the XBF spilled over bank in 31 of the years under natural conditions (SMEC 1996). The flow of the XBF basin combined with backwater from the Mekong River causes flooding in the surrounding districts along the river bank, notably Thakek, Nongbok, Xe Bang Fai and Mahaxai. This flooding occurs between July and mid-October and lasts several months (MRC 2009a). The flood levels in the Lower XBF area depend on three factors, namely the XBF discharge, the water levels in the Mekong River, and runoff of local rainfall (MRC 2008).

During the dry season, the XBF carries little water, most of the discharge (90%) occurs during the rainy season (MRC 2007). Since 2010, when the Nam Theun 2 dam (NT2) became operating, the hydrological regime has changed, as downstream releases from NT2 dam are diverted into the XBF basin (NTCP 2012).

According to NTCP (2005), at least 537 households live in 12 villages along the river in the Upper XBF. The main two ethnic groups present in this area are the Kaleung and Brou. There are 852 households in 12 villages in the upper, of which 75% are Tailao and 10% Brou. Another 20 villages are found in the middle XBF, with a total of 668 households, comprising 56% Phou Thai, 37% Tai Lao and 5% Brou. The Lower XBF was characterised by floodplain and rice field areas with a total of 5,003 households living in 53 villages. Ethnic groups presented in this area were 52% Lowland Lao, 42% Phu Thai, 2% Upland Tai and 4% Khamu.

4.3.2 Data collection

Villages along the XBF, Theun, Kading, Hai and Hinboun rivers and around Nakai reservoir were selected as study areas (Figure 4.4). The study area covered seven districts; five in Khammouan Province (Xebangfai, Mahaxai, Nakai, Hinboun and Khounkham districts) and two in Borikhamsay Province (Pakkading and Khamkeut districts). Ten households from each of 20 villages (a total of 200 households) were selected for interview. The field surveys were conducted in both the wet and dry seasons to observe seasonal changes in the fisheries and livelihoods of the fishing communities in the study area. The households were randomly selected from the list of households provided by the village heads.

A semi-structure open-ended interview method was used for the surveys. This method requires only a checklist covering specific subtopics or issues that need to be discussed during the interviews (Appendix 1). The checklist provides a guide to specific questions and to broader selection, thus allowing researchers to gain a better understanding of local variations. Participatory Rural Appraisal (PRA) and Rapid Appraisal of Fisheries Management Systems (RAFMS) (Pido *et al.* 1996) were also used. PRA was employed to gather general information on livelihood systems and other background conditions of the villages while RAFMS was employed to identify specific information related to fisheries issues, fisheries management systems, exploitation, conservation and protection of aquatic resources (Appendix 2). The interviews were divided into two groups, viz. village head men and elderly people, and individual household interviews.

A Livelihood Approach was used to examine livelihood assets, livelihood strategies and livelihood outcomes (Carney 1998). Where possible, the interviewing team stayed overnight in the villages to familiarise themselves with the fisheries systems and trust-building with communities while providing opportunities to observe lifestyle and culture.

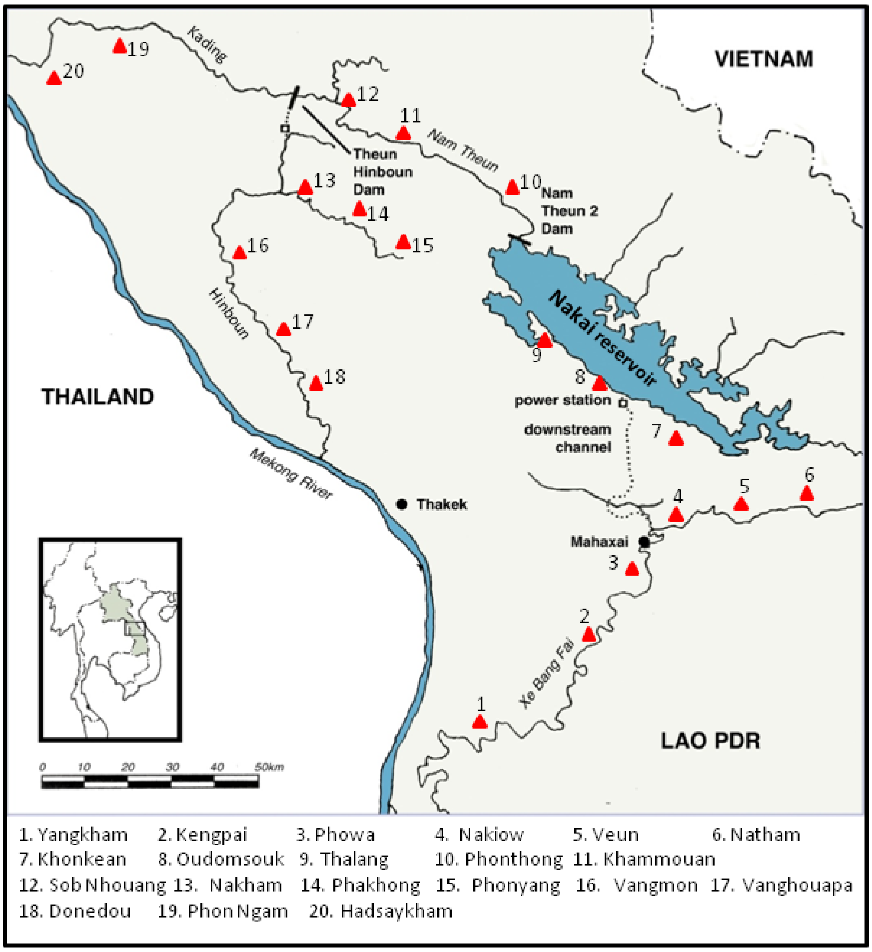


Figure 4.4. Map of study villages. Village numbers 1-3 are downstream of Xe Bang Fai (XBF), 4-6 are upstream XBF, 7-9 are Nakai reservoir, 10-12 are downstream Nam Theun (NT), 13-15 are upstream Hinboun river (HB), 16-18 are downstream HB, 19-20 are downstream Kading river (KD).
Source: The International River http://www.internationalrivers.org/campaigns/nam-theun-2-dam

4.3.3 Data analysis

Daily discharge data from the MRC for the periods 2000-2009 and 2010-2013 were used to illustrate differences in flow patterns before and after dam construction.

Flow Duration Curves

Flow duration curves were used to illustrate changes in the percentage of time, or probability, that flow can be equal to or exceed a particular value. In general, low flows are exceeded most of the time, while high flows, such as those resulting in floods, are exceeded infrequently.

According to EPA (2011), a basic flow duration curve measures high flows to low flows along the X-axis. The X-axis is the percentage of time (duration or frequency of occurrence) that a particular flow value is equaled or exceeded. The Y-axis is the quantity of flow at a given time step (cubic metre per second), associated with the duration. Flow duration intervals are indicated as percentage of exceedance, with zero representing the highest stream discharge in the record (flood conditions) and 100 is the lowest (drought conditions).

The following procedure was used to calculate the flow duration curve.

Step 1: Arrange the average daily flow in descending order.
Step 2: Assign each discharge value a rank (R), starting with 1 for the largest daily discharge value.
Step 3: Calculate exceedance probability (P) as follows:

$$\mathrm{P} = 100 \times \frac{R}{N+1}$$

Where P is the probability that a given flow will be equaled or exceeded (% of time)
R is rank
N is number of observations
Output is probability of exceedance of a flow band, which can be displayed graphically.

An Indicator of Hydrologic Alteration (IHA)

The Indicator of Hydrologic Alteration (IHA) software (Richter *et al.* 1997) was applied to assess hydrological alteration. IHA software was used to analyse the differences in hydrology pre and post dam construction based on mean daily flow data. These IHA changes were categorised into five Environmental Flow Components (Table 4.3) with 34 IHAs. The Environmental Flow Components algorithm within the IHA 7.1 defines high flows as all flows that exceed the 75^{th} percentile of all flows, low flows as all flows that are below the 50^{th} percentile, extreme low flows as an initial low flow below the 10^{th} percentile, and small and large floods as flows with return intervals of 2 and 10 years, respectively.

Paired *t*-test analysis was used to determine the differences of reservoir fish production, as well as the daily mean flow in the pre and post-dam periods.

Table 4.3. Environmental flow components and their indicators of hydrological alteration (after Richter *et al.* 1997).

Environmental Flow Component	Hydrologic Parameters
1. Monthly low flows	Mean or median values of low flows during each calendar month 12 parameters
2. Extreme low flows	Frequency of extreme low flows during each water year or season Mean or median values of extreme low flow event: · Duration (days) · Peak flow (minimum flow during event) · Timing (Julian date of peak flow) 4 parameters
3. High flow pulses	Frequency of high flow pulses during each water year or season Mean or median values of high flow pulse event: · Duration (days) · Peak flow (maximum flow during event) · Timing (Julian date of peak flow) · Rise and fall rates 6 parameters
4. Small floods	Frequency of small floods during each water year or season Mean or median values of small flood event: · Duration (days) · Peak flow (maximum flow during event) · Timing (Julian date of peak flow) · Rise and fall rates 6 parameters
5. Large floods	Frequency of large floods during each water year or season Mean or median values of large flood event: · Duration (days) · Peak flow (maximum flow during event) · Timing (Julian date of peak flow) · Rise and fall rates 6 parameters

4.4. RESULTS

4.4.1 Downstream impacts

Increased dry and wet season discharge

Nam Theun 2 dam started operation in early 2010, resulting in a reduction of discharge in the downstream reach of Nam Theun River caused by the diversion of water out of the system, and XBF receiving a huge amount of water that changed its hydrological regime, river structure and ecosystem functioning.

The natural flow regime in XBF is mainly driven by the monsoon seasonal rains and tropical storms. The flow regime falls into two distinct seasons, namely the dry and wet seasons. The differences between the wet and dry seasons create a diversity of habitats, including spawning, nursery and feeding grounds for aquatic fauna that inhabit in XBF system. It also influences the aquatic flora, especially in the flooded areas and on in-channel islands and berms. Since dam operation started in March 2010, the discharge of XBF has dramatically increased in both dry and wet seasons. Under the natural flow conditions the high flood period appears predominantly during August and September (Figure 4.5). After dam construction, flooding occurred earlier in June and July during 2011-2013, but was late in October 2010 and of a bimodal nature. In addition, in the wet season, under natural flow conditions, the lower part of XBF experienced bankfull flows (small floods) almost every year, while extreme floods also occured, e.g. in August 2005 and August 2011 (Figure 4.5).

Before dam operation, the discharge (average discharge between 2000 and 2009) of XBF in the dry season (January-April), without additional discharge from the Nakai dam, ranged from 14 to 21 m^3/s, and in the wet season (June-September) ranged from 304 to 974 m^3/s (Table 4.4). In addition, IHA analysis indicated a mean 1-day minimum flow of 10 m^3/s, but a 1-day maximum flow upto 1968 m^3/s, indicating high seasonal variation between the dry and wet seasons.

After the dam was commissioned the dry season mean daily flow was 12 times higher than the pre-dam period, ranging from 16 to 185 m^3/s. In the wet season, the mean flow rose 1.2 times and ranged from 652 to 810 m^3/s. There was also a sharp decrease in the number of low-flow days from over 124 to 30 days (Table 4.4), demonstrating the change in extreme flows in terms of both timing and duration.

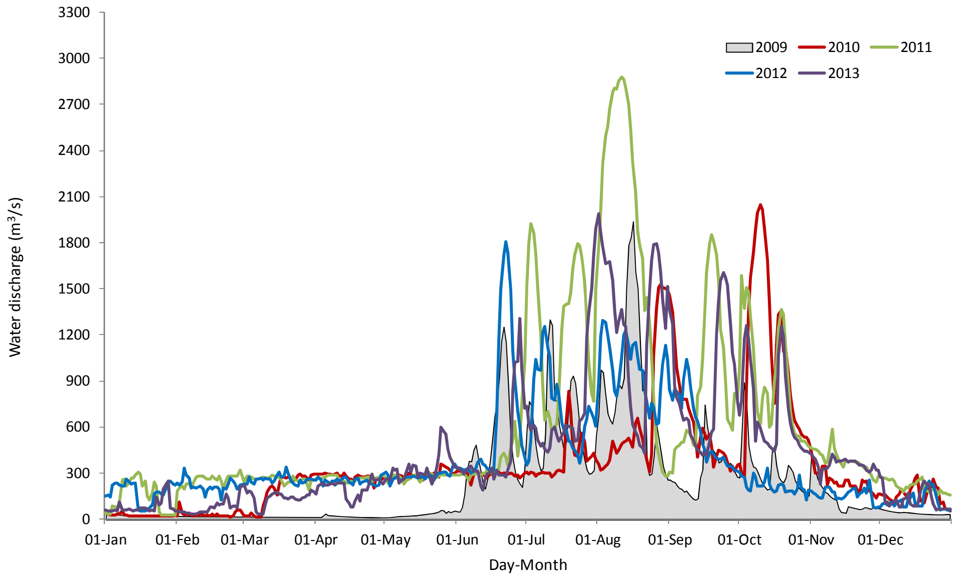


Figure 4.5. Modification of natural flow regimes due to dam operation, Xe Bang Fai river at Mahaxai station. 2009 represents the natural flow regime. (Dam started operation in March 2010; 2011 was big flood). Data course: Department of Meteorology and Hydrology.

Table 4.4. Means of IHA parameters for the Xe Bang Fai. Data used for analysis were daily mean flow, reported here as cubic meters per second.

Parameters	Pre-dam 2000-2009	Post-dam 2010-2013
Parameter Group 1		
January	20.5	116.2
February	15.5	150.2
March	13.7	222.9
April	14.1	250.8
May	44.2	303.1
June	303.6	538.2
July	670.9	872.0
August	973.7	1097.0
September	659.1	732.2
October	270.6	641.5
November	68.5	257.7
December	36.3	140.1
Parameter Group 2		
1-day minimum	9.9	31.4
3-day minimum	10.1	32.8
7-day minimum	10.3	35.4
30-day minimum	11.7	92.1
90-day minimum	13.7	146
1-day maximum	1968	2181
3-day maximum	1939	2137

Table 4.4. Continued.

7-day maximum	1839	2004
30-day maximum	1204	1376
90-day maximum	818	1014
Parameter Group 3		
Date of minimum	124.2	30.3
Date of maximum	234.7	218.5
Parameter Group 4		
Low pulse count	3.1	0.3
Low pulse duration	38.5	3.0
High pulse count	5.3	5.3
High pulse duration	9.6	11.9
Parameter Group 5		
Rise rate	78.0	58.5
Fall rate	-31.3	-48.7

This variation in the flow regime is also illustrated by comparison of the flow duration curve from the post dam commission period (2010 to 2013) and the natural flow (pre-dam) (Figure 4.6). A paired-samples *t*-test indicated that the daily mean flow in the pre and post-dam periods were significantly different ($P<0.001$). High flow events were more common in the wet season and mid-range flows (Q40-Q80) were lost due to additional discharge received from the dam. At the same time, extreme low flows (Q95) also increased dramatically between 2011 and 2013.

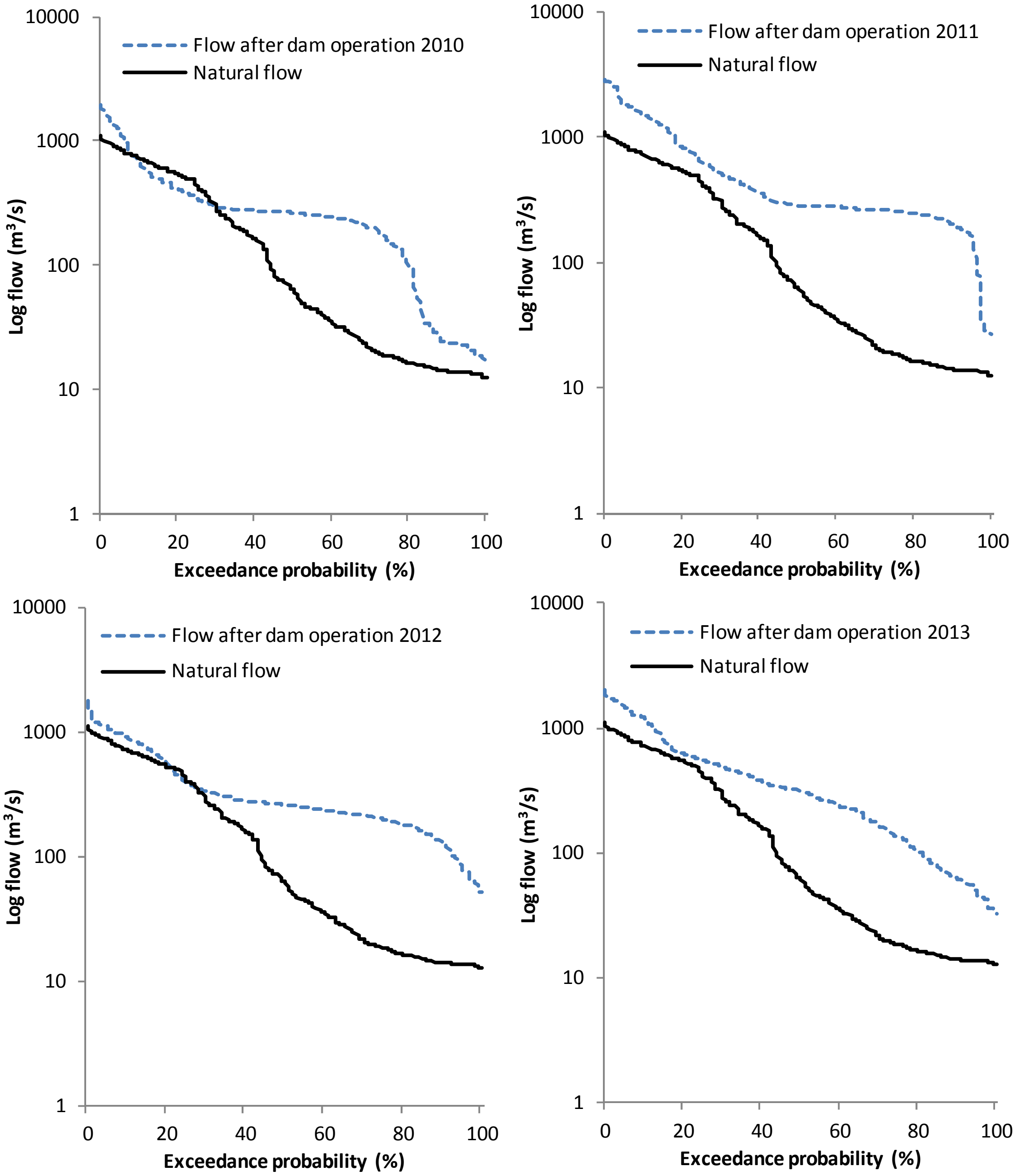


Figure 4.6. Flow duration curves of the XBF, 2010-2013 (2011 was an extreme flood; 2012-13 normal years).

Deconstruction of the hydrograph (Figure 4.7) illustrates the distribution of flow components from 2000-2013. Under natural flow conditions (2000-2009), there was variation in flows (extreme, low and high flows) in each year that maintained the ecological functioning of the river system (erosion and deposition processes), while small and large floods also occurred in the natural flow cycle that support the lifecycles of flora and fauna and flush sediments to downstream reaches. Since 2010 when the dam started operating, low and extreme low flows have been lost from the system. Small floods have also disappeared and been replaced by high flow pulses (Figure 4.7).

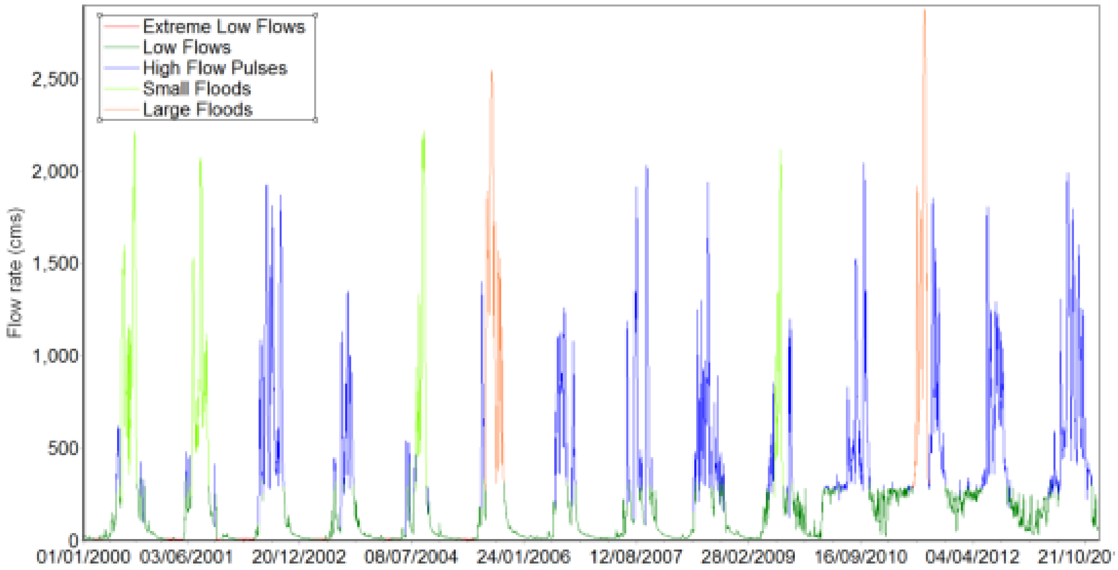


Figure 4.7. Hydrographs of natural (2000-2009) and modified flow (2010-2013) of the XBF (2005 and 2011 were extreme floods, 2010-2012-2013 were normal years).

Altered dry and wet season flow patterns

Natural flow conditions are very important because they maintain the riverine ecosystem functioning to which the biota has adapted (Arthington *et al.* 2006). The altered flow regime in XBF, especially the increased flow in the dry season and elimination of low and medium flows (Q60 – Q95) is likely to have severe impacts on the biota. The low flow period in the dry season is very important for aquatic fauna and flora in XBF, not only as a refuge from larger predators but also to provide specific feeding and breeding habitats. The disappearance of the mid-flows could also affect the life cycle of many fish species, in particular the migration and reproduction processes. As fish used different natural flow conditions as cues for migrations, changing water volumes and timings could interfere with fish migration patterns in XBF, particularly lateral migrations from the mainstream channel onto the floodplains that serve as spawning and feeding habitats for many Mekong species. Ultimately, altered dry and wet season flow regimes coul directly decrease fish populations and production of the Mekong fisheries as a whole.

Fishers in Phowa and Kengpai villages reported that many aquatic animals, such as shrimps, crabs and snails, that used to reside in the shallow water of the XBF in the dry season had already disappeared. They believed that many fish species had also moved away either to small streams or further down into the Mekong River. However, there are insufficient data to confirm these claims.

Changes in catch and species composition

During the field survey it was difficult to get information on fish population and species composition changes in XBF for several reasons. Firstly, fishers were still adapting to the new environment (strong current). Secondly, many fishers had moved to fish in wetlands and swamps (Phowa village) and only experienced fishers were still fishing in XBF; and finally there were no records of small or non-economic species catches that comprised more than half of the total number of species caught in XBF. However, a dramatic change in water level could likely impact on some of these species, as fishes have different behaviours and favour different hydrological conditions. In this case, species that can adapt to the new environment will likely survive or thrive or new species may become dominant, while species that cannot tolerate the strong currents will be eliminated or move to other streams. The species rarely reported or caught in XBF after dam construction were the high value and marketable species, such as *H. wyckioides*, *B. yarrelli,* and *W. attu* (Table 4.5). The common species caught in XBF after dam operations were mainly low value species including *P. laoensis, M. marginatus, L. leptocheilus* (Table 4.6). These changes suggest that fishes moved to the tributaries of the XBF or the Mekong River where natural hydrology regimes and favoured habitats for refuge and reproduction persist.

Table 4.5. Top ten fish species caught in the XBF before dam construction but rarely thereafter (Source: Field survey. * Data from FishBase).

Scientific name	Max length SL (cm)*	Lao name
H. wyckioides	130 TL	Pa Kheung
B. yarrelli	200	Pa Khae
Datnioides undecimradiatus (Roberts & Kottelat, 1994)	40	Pa Seua
P. jullieni	150	Pa Eaun
B. microlepis	100	Pa Kouang
Osphronemus goramy Lacepède,1801	70	Pa Maieun
C. microlepis Sauvage, 1870	65	Pa Porn
W. attu	240 TL	Pa Khao
W. leerii	150 TL	Pa Khoune
Oxyeleotris marmorata (Bleeker,1852)	65	Pa Bou

Apart from the decline in catches of high value species, fishers in Kengpai and Yangkham village (the middle and lower XBF) believed that there were many fish in the river that they could not catch because of the strong currents. For example, between 25 and 31 January 2011, when no water was released to XBF due to inspection and maintenance of the turbines, the fishers in Kengpai village reported they caught a lot of fish during the outage when the water discharge was back to natural conditions. A similar report was also found in Vanghouapa village when Theun Hin Boun dam stopped releasing water to the Hinboun River during maintenance and New Year holiday in early 2012 (field interview). The water discharge at that time dramatically reduced, allowing fishers to take advantage to catch fish. Many fishers were fishing for one species, *Phalacronotus micronemus*, for just two days, and one fisher earned enough money to buy a new motorbike at a cost of 400 US$. However, it was unclear whether the fish were still inhabiting the mainstream or returned from the tributaries to seek refuge when water levels were back to near natural during the dry season period.

Apart from fishes, fishers in Phowa, Kengpai and Yangkham villages reported that they used to collect snails, mussels, shrimps and green algae during the dry season in the rapid and shallow water. Since dam operation started fishers cannot catch or collect these aquatic animals and plants; they believed that they had been flushed away by the strong currents.

Table 4.6. Common fish species caught in the XBF after dam construction (Source: Field survey;* Data from FishBase).

Scientific name	Max. length SL (cm)*	Lao name
Poropuntius laoensis (Günther, 1868)	32 TL	Pa chat
Mystus atrifasciatus Fowler, 1937	15	Pa kahnyeng
Mystacoleucus marginatus (Valenciennes,1842)	20	Pa lang nam
Barbodes altus (Günther,1868)	20	Pa wein fai
Cyclocheilichthys armatus (Valenciennes,1842)	23	Pa dok ngieu
Puntius orphoides (Valenciennes,1842)	25	Pa pok
Cyclocheilichthys apogon (Valenciennes,1842)	25	Pa dok ngiew
Labiobarbus leptocheilus (Valenciennes,1842)	30	Pa khoui lam
Macrognathus siamensis (Günther, 1861)	30	Pa lot
Osteochilus hasselti (Valenciennes, 1842)	32	Pa E thai
Barbonymus gonionotus	40	Pa pak
Mastacembelus armatus (Lacepède,1800)	90	Pa lat
L. chrysophekadion	90	Pa phia
Hemibagrus nemurus (Valenciennes,1840)	65	Pa kot

4.4.2 Upstream impoundment impacts

Hydrological changes

Nakai reservoir has changed the Theun River from a natural lotic environment to a lentic habitat. This has resulted in changes in the fish fauna from riverine fishes that are dependent on flowing water for completion of their life cycle, to species that are able to tolerate lacustrine conditions. River species have declined in abundance because they are unable to complete their life cycle, and have been replaced by species that are tolerant of the static water environment. The fishers in Nakai reservoir reported that the species that disappeared from the reservoir were the larger, commercially important species such as *Hemibagrus wyckioides*, and *Bagarius yarrelli,* and were replaced by low value, smaller species (*C. apogon*, *P. laoensis*) or alien invasive species *(O. niloticus, C. carpio)* (Table 4.7).

The reservoir also experiences water fluctuations related to dam operation that could disrupt aquatic organisms in the reservoir including riparian vegetation. As mentioned above fishes are sensitive to fluctuations in water level, in particular in the spawning season. Frequent changes in water level, as is typically found with hydropower reservoirs to meet daily demand, could also disrupt natural spawning processes and increase the risk of being attached by predators.

In the Nakai reservoir, it appears that the species that have benefited from this changing environment are alien invasive species (e.g. *O. niloticus, C. carpio*). Although *O. niloticus* was not expected to be abundant in the reservoir because the fluctuating water levels disrupt reproductive processes, production was still high in the first and second years of impoundment. It is believed that these *O. niloticus* move up to the tributaries for spawning and inhabit shallow areas of the reservoir. Apart from alien species, black fish species such as snakehead now also dominate the catch from the Nakai reservoir fishery, which is possibly indicative of their ability to exploit diverse habitat conditions.

Flooding of spawning and nursery areas

Transforming the Theun River to the Nakai reservoir has destroyed the spawning and nursery habitats of many fish species. Although there is limited information on spawning grounds in the Theun River, many species are known to migrate from the Mekong River to tributaries for breeding and feeding during the wet season. Flooding of spawning and nursery habitats could impact on the recruitment of fish populations, thus production of some species is expected to decline and some species could become extinct. Anecdotal evidence suggests that many species have moved further upstream to Theun River tributaries (Nam On, Nam Noy and Nam Xot) for spawning and feeding.

Based on field observations and fisher interviews, the fisheries in Nakai reservoir have changed in terms of both species composition and production. Many river species that inhabited the area before the impoundment have disappeared, in particular *Tor* spp. (*Tor tambroides*, *Tor laterivittatus, Tor ater* and *Tor cf. tambra*). These species were abundant in the upper Theun River and now are mainly found in the Nam On, Nam Noy and Nam Xot upstream of the reservoir.

Table 4.7. Common species caught pre-dam and post-dam in Nakai reservoir (Source: Field survey; * Data from fish base, ** Dominant species).

Scientific name	Max. length SL (cm)*	Pre-dam	Post-dam
Bangana elegans Kottelat,1998	34	Yes	
C. molitorella	55 TL	Yes	Yes
Cyclocheilichthys repasson (Bleeker,1853)	25	Yes	
Hampala macrolepidota Kuhl Van Hasselt,1823	70	Yes	Yes**
Hypsibarbus vernayi (Norman,1925)	21.6	Yes	
Mystacoleucus marginatus (Valenciennes,1842)	20TL	Yes	
Poropuntius carinatus (Wu & Lin,1977)	23	Yes	
Scaphiodonichthys acanthopterus (Fowler,1934)	31	Yes	
Scaphognathops theunensis Kottelat,1998	30	Yes	
Tor ater Roberts,1999	33.2	Yes	
Tor cf. tambra (Velenciennes,1842)	17.8	Yes	
Tor laterivittatus Zhu & Cui,1996	58	Yes	
Tor tambroides (Bleeker, 1854)	53	Yes	
H. wyckioides	130 TL	Yes	
Mastacembelus armatus (Lacepède,1800)	90	Yes	Yes
Cyclocheilichthys apogon (Valenciennes,1842)	25	Yes	Yes**
Cyclocheilichthys armatus (Valenciennes,1842)	23	Yes	Yes**
Poropuntius laoensis (Günther,1868)	32	Yes	Yes**
Channa marulius (Hamilton,1822)	183 TL	Yes	Yes
C. striata	100	Yes	Yes**
B. yarrelli	200	Yes	Yes
Systomus orphoides (Valenciennes,1842)	25	Yes	Yes
O. niloticus	60	Yes	Yes
C. carpio	110	Yes	Yes
Cyprinus rubrofuscus Lacepède,1803	28	Yes	Yes
Clarias batrachus (Linnaeus,1758)	47	Yes	Yes

Disruption to migration and reproduction

One of the major negative impacts of dams to the Mekong fisheries is the creation of physical barriers to fish migration. As more than 70% of Mekong fish species are migratory, Nakai dam will likely block longitudinal movement of fish from the main river to tributaries and floodplains. The dam has no fish passage facilities and there is no opportunity for fish to migrate through this barrier to their upstream breeding grounds.

In addition, larvae and juveniles, which drift passively downstream from upstream spawning grounds, are either drawn over the dam spillways or into the generating turbines. Fish entering the turbines are exposed to physical stresses that can cause injury or death (Jacobson 2011). As the water from the reservoir drops about 350 m through a channel to the turbines, fish have little chance of survival and mortality rates are likely very high. A similar situation occurs when larvae and juvenile fishes pass over the spillway, and can be potentially cause death. Another problem occurs with downstream drifting larvae being trapped in the reservoir because the flow is too slow and the impoundment acts as a sink.

Disruption of these upstream and downstream migration patterns means that fish cannot complete their life cycles. If fishes cannot pass the dam to reproduce or the eggs and larvae of fish spawning upstream are blocked by the dam, it could impact on the whole fish productivity in the river system, as natural recruitment would decline and the production would likely drop both downstream of the dam and in the impoundment.

Changes in yield and species catch composition

Fish catches in Nakai reservoir after impoundment were high in 2009, the first year after dam closure, reaching 1500 t, but this dropped to 680 t in 2010 (Figure 4.8). The catches continued to decline and only reached just above 400 t in the years 2011-2013. The decline in fish production between 2009 and 2013 was significant ($t = 0.025$, $P<0.05$) and reflects typical changes in reservoirs following impoundment, because fishes take advantage of abundant food resources in the reservoir following flooding, although production usually takes 5-7 years to decline. It should be note that the dam was not fully operational in 2009; the water level was more or less constant and did not appear to affect the fish populations. In early 2010, the dam became operational and as a result the catch declined sharply.

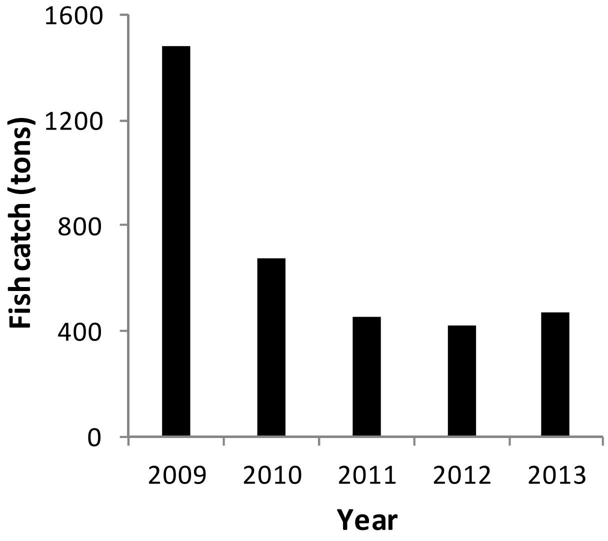


Figure 4.8. Fish production in Nakai reservoir (Source: Nam Theun 2 Reservoir Management Committee).

After the reservoir had filled (post 2008-2009), the catch was dominated by *C. carpio*, *O. niloticus*, *C. striata*, *H. macrolepidota*, Puntuis sp. and *C. apogon* (Table 4.7). It is premature to conclude which species have become extirpated or abundant in Nakai reservoir, but information from interviews suggests species composition has changed and fewer species were caught after dam operation (Table 4.7).

4.4.3 Livelihood assets

Livelihood activities before and after dam construction

Before dam construction

Before dam construction the Nakai plateau was considered as one of the most remote and least developed areas of Khammoune province. People in the Nakai plateau resided along the Theun River and engaged in upland shifting cultivation, gardening, hunting, collecting NTFPs, fishing and raising livestock for their subsistence. People were heavily dependent on the forest for food security and income generation. Upland rice was insufficient to meet domestic demand. People sold NTFPs, poultry and fishes to buy or exchange for rice. Cattle and buffalo were the main asset; people sold these animals when they needed immediate cash to spend on weddings, funerals or health services, while chickens and ducks were consumed when they were busy with upland rice planting and harvesting when farmers had no time to acquire other foods.

People practiced integrated shifting cultivation and small holder livestock keeping for food security. The average upland agriculture area (mainly for rice planting) per household was at least 1.2 ha and 0.5 ha of garden for growing vegetables including maize, banana and other crops. Buffalo and cattle were raised by traditional methods with a minimum input. There was no housing for the animals - they feed and live in the forest; the owners checked their animals on a monthly basis. Each household kept an average of 4.7 buffalo and cattle, 2-3 pigs and 25-30 chickens and ducks.

Infrastructure in this area was poorly developed: most of the transportation during both the wet and dry seasons was by boat. The dirt road normally used for transporting wood out from forest to the city was only useable in the dry season. The villages did not have access to electricity or water sanitation for drinking. People used the Theun River for household consumption and cleaning. There was no healthcare or hospital in the villages, the district hospital was located relatively far from the villages and it took almost a day's travelling. The common diseases were fever, malaria, dengue and diarrhea. People suffered with micronutrient deficiencies and occurrences of anemia, vitamin A and iodine deficiencies were high.

After dam construction

All villages located along the Theun River were relocated to the east and the south of Nakai reservoir. New houses for the resettlers were provided with 0.66 ha of land for agriculture. Four livelihood programmes were developed for the affected households in the reservoir area, namely agriculture, livestock, reservoir fishing, and community forestry. Based on the geography and soil conditions and access to natural resources (forest and fisheries) the resettlement areas were divided into three zones. In the northern zone, characterized with the best soils, livelihood activities were focused on rice cultivation including cash crops, fisheries and community forestry. The central zone, situated around the district centre with trade and service opportunities, orientated around selling vegetables, animals, NTFPs, fish and OAAs. Integrated farming systems of cash crops and fruit trees with rice in rotation with legumes were the main focus of this area. The southern zone is characterized by poor soils and livelihood activities were centered on the reservoir fishery, livestock, community forest activities and the use of the drawdown area for keeping ruminants.

Household assets

Households assets of the communities around Nakai reservoir were less than before dam construction and other typical households in different areas. The Nakai households had limited land for agriculture - an average of 0.66 ha per household - while other households in XBF, NT, KD and HB owned at least 1 ha (downstream NT) of rainfed paddy (Table 4.8).

Other assets, such as animal keeping were also different; reservoir households owned an average of 1.5 cattle and 10 poultry compared with 3.2-6.5 cattle and more than 20 chickens and ducks kept by river households (Table 4.9). The reasons for reducing the number of animals in the reservoir area were due to limited grazing land and areas for animal huts for small animals.

Table 4.8. Average household land holding and other assets (Source: Field survey).

Study areas	Rainfed paddy	Irrigated paddy	Swidden paddy	Garden	Industrial tree
	ha	Ha	ha	ha	ha
Nakai reservoir	0	0	0.66	0	0.1
Upstream XBF	1.4	2.3	0.1	0.1	0.1
Downstream XBF	2.2	1.3	0.2	0.1	0.4
Downstream NT	1.0	0	0.5	0.6	0.5
Downstream KD	1.6	0	0	0.2	0.1
Downstream HB	0.7	3.6	0	0.0	0.6
Upstream HB	1.9	0	0	0.4	0.1

It is important to note that in terms of fishing gears owned, households around Nakai reservoir owned more gears (average of 21 sets of gillnets, 191 hooks and line) than the river households (4-9 sets of gillnets, 11-116 hooks and line) (Table 4.10). However, the river households employed more diverse gears than reservoir households. Investment in more fishing gears by the reservoir households reflected their livelihood strategies that focused on fishing as their main source of income and food, while river households were mainly part time fishing to supplement food and income.

Table 4.9. Average household livestock owning (Source: Field survey).

Study areas	Cattle/buffalo	Pig	Poultry	Goat
Nakai reservoir	1.5	0.4	10.0	0.3
Upstream XBF	3.2	0.6	27.0	0
Downstream XBF	6.5	1.1	24.9	0
Downstream NT	4.6	2.2	23.2	0.6
Downstream KD	4.1	0.9	20.2	0.4
Downstream HB	3.4	0.7	23.5	0.4
Upstream HB	4.0	0.8	25.1	0

With respect to the number of people fishing, on average fewer persons from reservoir households went fishing (1.6) than from river households (2.8). This could be explained because reservoir fishing needed more skilled fishers than river fishing, as the water in reservoir was very deep and rough (big waves) during the rainy season, so mostly men and adults fish in the reservoir. By contrast, the river households had greater access to the river, streams, flooded forest, swamps and rice fields; almost every household member went fishing, including women and children, who sometimes would join the adults fishing in the river or they would fish in rice fields and the flooded forest.

Table 4.10. Average household fishing assets and number of people fishing (Source: Field survey).

Study areas	Motor boat	Paddle boat	Gill net	Cast net	Lift net	Hook and line	Trap	No. of person fish
Nakai reservoir	1.1	0.2	20.8	0.5	0.4	191	0	1.6
Upstream XBF	0	1.0	6.5	0.7	0.4	11	0	2.7
Downstream XBF	0.5	1.0	6.4	1.5	0.8	70	0.9	2.8
Downstream NT	0.4	0.4	9.3	0.7	0.4	81	0	2.4
Downstream KD	0.5	0.7	5.7	0.2	0.6	76	1.8	2.5
Downstream HB	0.1	1.0	6.3	0.5	0.5	116	1.3	2.7
Upstream HB	0.2	1.1	4.4	0.7	1.4	84	2.3	2.6

The Nam Theun 2 project provided boats and fishing gears to the resettled as part of the agreement to subsidize the affected households towards developing new livelihood activities. A total of 1310 sets of fishing gear were provided to those resettled. Each resettled household received one set of fishing equipment, the gear sets included hooks and line, one gill net fleet, one lift net and one cast net. The gill nets had various mesh size ranging from 14-20 cm width and a length of 100-200 m. The resettled households were registered with a commercial license or a subsistence license. The license fee for commercial fishing is approximately 4 US$ and 3,2 US$ per year for the subsistence fishing.

Livelihoods activities

In general, households living along Nam Theun 2 and Xe Ban Fai engaged in more than one livelihood activity for their food security and income generation. Integrated rice farming with livestock, gardening, fishing, hunting and collecting NTFPs were commonly found in all villages surveyed and were the important livelihood activities of the rural poor. In addition, off-farm activities such as labouring, small village shops, trade and other services were observed in urban areas (downstream KD and HB), where infrastructure was more developed and competition to exploit the natural resources was high.

In the reservoir areas, apart from the four livelihoods promoted by the NTPC, the households also practiced various labouring activities (e.g. drivers, house building, and furniture factory), fish marketing and services (car and boat transport) (Table 4.11). Most household members engaged in livelihoods activities, for instance, in Khonekean village fishing was the primary activity for the head of household (man), while the wife was responsible for gardening and collecting NTFPs and children looked after livestock before and after finishing school. In terms of time spent, fishing and collecting OAAs were ranked fourth because the average fishing time was 2-3 hours per day (setting in late afternoon and collecting in early morning) while the rest of the time was spent on trade, paid labouring and NTFPs.

Table 4.11. Main livelihood activities calendar of reservoir households (Source: Field survey).

Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Fishing and collecting OAAs	◄	—	—	—	—	—	—	—	—	—	—	►
2. Wage labour	◄	—	—	—	—	—	—	—	—	—	—	►
3. Communities forest	◄	—	—	—	—	—	—	—	—	—	—	►
4. Trade and services	◄	—	—	—	—	—	—	—	—	—	—	►
5. Collecting NTFPs and hunting	◄	—	—	—	—	—	—	—	—	—	—	►
6. Upland rice			◄	—	—	—	—	—	—	—	►	
7. Gardening	◄	—	—	►						◄	—	►
8. Livestock rearing	◄	—	—	—	—	—	—	—	—	—	—	►

The livelihoods of river households represented the lifestyle of the rural and ethnic minorities of Laos. The people depended heavily on natural resources for their living, although they were among the group most vulnerable to food insecurity if resources change due to the climate change effects or natural disasters. They respond to these changes differently according to the resources and assets they hold. For example, during drought years that damaged their crops they sold animals or exchanged them for rice, and collected NTFPs to supplement their food and income. During extreme floods that destroyed rice production, many people moved to urban areas for paid labour and went fishing to maintain their food security. As in reservoir households, all river household members were involved in different livelihood activities. Men were responsible for manual work, such as ploughing land for rice planting, while women were involved in rice planting and harvesting, and children took part in others activities (e.g. looking after animals, collecting NTFPs and fishing). River households would switch between livelihoods activities (Table 4.12) when faced with problems such as droughts and floods.

Most river households consider rice farming as their primary occupation based on time spent and labour required for this activity, while other activities such as livestock raising, collecting NTFPs, gardening and fishing were second, third, fourth and fifth activities, respectively. These activities supplemented the primary activity to obtain food and income revenue for the household.

Table 4.12. Main livelihood activities calendar of river household. Source: data from interviewed (Source: Field survey).

Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Wet rice cultivation					↔	↔	↔	↔	↔	↔	↔	
2. Upland rice cultivation			↔	↔	↔	↔	↔	↔	↔	↔	↔	
3. Gardening	↔	↔	↔	↔							↔	↔
4. Cash crop	↔	↔	↔	↔	↔					↔	↔	↔
5. Weeding industrial tree				↔	↔						↔	↔
6. Livestock rearing	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔
7. Fishing and collecting OAAs	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔
8. Collecting NTFPs and hunting	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔	↔
9.Weaving/handicraft	↔	↔	↔	↔							↔	↔
10. Wage labour	↔	↔	↔	↔	↔					↔	↔	↔

Household income and expenditure

As mentioned earlier, in terms of assets, reservoir households had less agricultural land, limited access to natural resources, including NTFPs, rivers, stream and wetland. In the pre-resettlement period, the households relied on selling NTFPs and livestock to buy rice, when they could not produce enough rice for consumption. After dam closure in 2009, most of the forest and NTFPs were inundated. Resettled households had to go long distances to collect NTFPs and these products were mainly used for subsistence. Selling fish, paid labour and trade, including small village shops, were the main income for the reservoir households. Revenue from fishes accounted for 60% of income, followed by paid labour and trade, contributing 17 and 15%, respectively (Figure 4.9).

The income of river households was diverse as they practiced more varied activities than reservoir households. Livestock was the main income for the downstream XBF households, accounting for 35% of total household income, followed by NTFPs (20%) and paid labour (14%). In downstream HB and NT, paid labour accounted for 61% and 31% respectively (Figure 4.9). Many households engaged in off-farm jobs to earn money for 3-5 months per year. They worked in other jobs after finishing rice planting and returned when the harvest season began in November and went again until the planting season started in June.

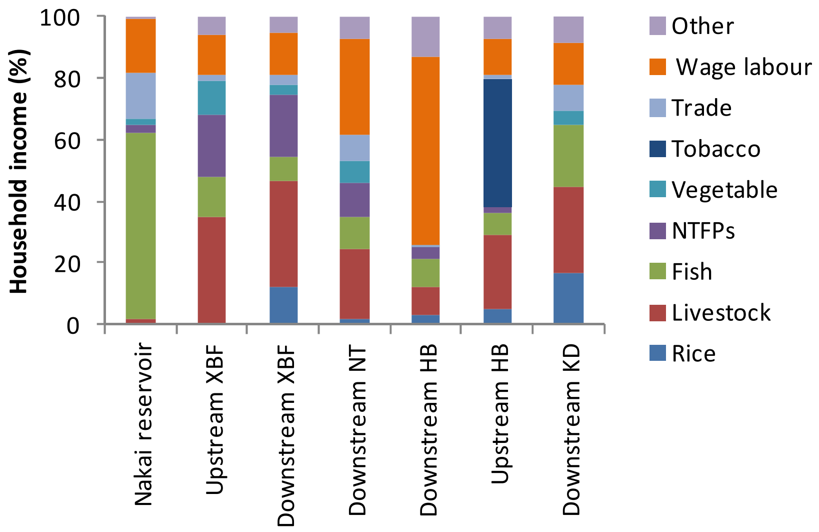


Figure 4.9. Percentage of household income in the study areas.

Little information on income from wild animals and NTFPs was acquired during the interviews, due to a campaign on the protection of wild animals and law enforcement on illegal hunting of protected wildlife. Persons selling meat and parts of protected wild animals such as barking deer, bear and elephant, will be prosecuted. Some rattan species were also on the list of protected species and could only be collected for consumption. For these reasons, the contribution of wild animals and NTFPs to household incomes and consumption in the villages surveyed was low compared with other studies conducted in upland areas where NTFPs and wild animal accounted for more than 50% of household income. However, some wild animals and many NTFPs were observed in the markets or along the road where villagers sold their products, indicating that the household income from NTFPs and wild animals could be higher than determined in this study.

Much of the expenditure of reservoir households was on food and equipment, accounting for 39 and 33% respectively (Figure 4.10). It should be noted that more than 80% of the total expenditure on equipment of reservoir households was on buying gill nets and gasoline for the motor boat for fishing, as fishing was the main source of their income, and the rest was spent on agriculture and animal husbandry. The expenditure by river households differed depending on the location of the villages and accessibility to the markets. Expenditure on food was less in the villages without local markets (XBF) and more for the villages located in urban areas (HB and KD) or along the road in relatively close proximity to the market. Expenditure on food by HB and KD households ranged between 43 and 48% of total household expenditure (Figure 4.10). However, the expenses for equipment in river households were for rice farming inputs and livestock (80%) and fishing equipment (20%). It can be concluded that rice farming and livestock were important parts of the livelihoods of river households that not only provided food for subsistence but also supported income generation and saving.

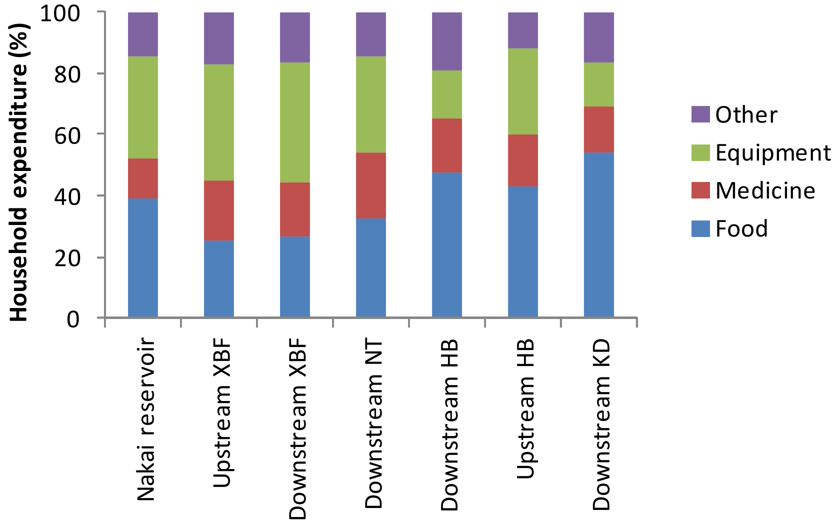


Figure 4.10. Percentage of household expenses in the study areas.

Expenditure in medicines by reservoir households (13%) was lower than river households (15-20%). There were two reasons for this difference, firstly the reservoir households received subsidised treatment from the NTPC or they could buy cheaper medicines at the healthcare centre as part of a healthcare revolving fund. Secondly, the improvement of living condition and sanitation of reservoir villages reduced prevalence to infection or illness.

4.4.4 Fishery exploitation and management

Fishing season and gear uses

In Laos, natural resources, including forests, rivers, streams and wetlands, are common property; people can access and use these resources in a sustainable manner in accordance with the laws and regulations of the host community. Fishery resources are classified as open access and everyone has a right to use, manage and protect these resources for future generations. Fisheries have been seen as resources of last resort for the local communities, in particular for the poor when their crops are damaged as a consequence of natural disasters; fishes are the only free resources that require low investment and provide cheap animal protein to sustain the livelihoods and well-being of the poorest people.

The fishing season in XBF and Theun River can be classified as wet and dry season fishing. The fishers follow the seasonal changes and fish migration to catch fishes for subsistence and income. In the river villages (Phowa, Keangpai and Yangkham) fishing intensified in the wet season when fishers targeted migratory species that move from the main channel to small streams and the floodplains for spawning. This fishing season starts at the beginning of rainy season in June and lasts until September, and is known as the high fishing season in Laos. During this period fishers fish in the flooded forest and floodplains because of the high flows and strong current in the main river, making it too dangerous to fish in the main channel. A considerable amount of fish is caught during this season, the size of which varies and includes medium and large fishes (brood stock). Fishes were sold and preserved for long term use. Fermentation salting and drying were common practices for fish processing. On average, a river household could produce at least one or two jars of fermented fish (one jar equal 12 kg). This fermented fish is used in the dry season when they catch less fish; some fermented fish was also sold or exchanged for other goods.

Dry season fishing started when the water level receded in late October, during this time fishers tended to catch fish that migrate from small streams and floodplains to deep pools in the main river for dry season refuge. Dry season fishing continued until May, fishers mostly fished at deep pools in the main channel and also targeted dry season migratory species. The catches were poorer than in the wet season, but fishers still managed to sell their catch or used it for subsistence.

More than 20 fishing methods were employed in the study areas. The commonly used fishing gears in the wet and dry season were gillnets, cast nets, lift nets, scoop nets, hooks and lines. In the wet season, fishers also employed various traps to target large fish, namely *lop, xa, chan,* but the main fishing methods were gill nets, and hooks and lines. In addition, scoop nets and lift nets were used to catch fishes in the flooded forest and in the rice fields. Gill nets were also used to catch fishes in deep pools in the dry season while cast nets were used to catch fishes in shallow water near the river bank or in swamps.

In the reservoir, gill nets, hooks and line were used the whole year round and the catch did not differ much between the wet and dry seasons. Wet season fishing in the reservoir was considered dangerous, because of strong winds and high water levels in the monsoon season, and the depth of the reservoir prevented fishers reach suitable fishing grounds or they could only fish in areas close to villages. Processed fish, such as fermented (Pa Deek) fish was less commonly consumed by reservoir households as many indigenous minorities did not like this product. Instead, dried and soured fish were the main fish processing methods used to preserve fish for long term use.

Production and exploitation

The Nakai reservoir fishery is one of the important resources for the people living around the reservoir. Most of the households engaged in fishing (Table 4.13); out of a total of 236 households surveyed in the villages only 33 households (8%) did not fish. Most of the households surveyed reported that fish catches were declining. The extent of the fall in fish catches reported varied depending on the location and distance of the village to the dam site or access to small stream and tributaries. For example, fishers in upstream XBF reported their catches declined 5-10%, while in the downstream XBF area fishers claimed that the catch dropped 10-20%. Similar declines were found in downstream NT, downstream HB, upstream HB and downstream KD where fishers reported fish catches declining between 10-30%. The reasons for the decreased fish catches were: the dam changing flows (50%), deforestation (20%), illegal fishing (10%), fishing pressure (10%) and other (10%).

Table 4.13. Number of fishing households and number of boats provided by the project (Source: Field survey).

Description	Thalang	Oudomsouk	Khonkene
Commercial fishers	55	72	20
Subsistence fishers	15	18	23
Non fishing	8	17	8
Total household	78	107	51
Fibreglass boat	8	54	0
Wood boat	31	0	25
Total boats	38	54	25

The use of catch was different between reservoir and river households. As expected in the reservoir where there was a good opportunity to catch fish, fishers use their catch for income generation. Fishers in Nakai reservoir sold approximately 72% of their catch (Figure 4.11), the rest was for consumption and processing, accounting for 20 and 8% respectively. By contrast, river households mostly used their catch for consumption ranging from 62 to 70%; they sold the fishes (20-25%) when the catch was high or they caught large fish at the beginning of the wet season. The small or less valuable fishes (5-16%) were either fermented, dried or salted for consumption in the dry season or to be sold in local markets.

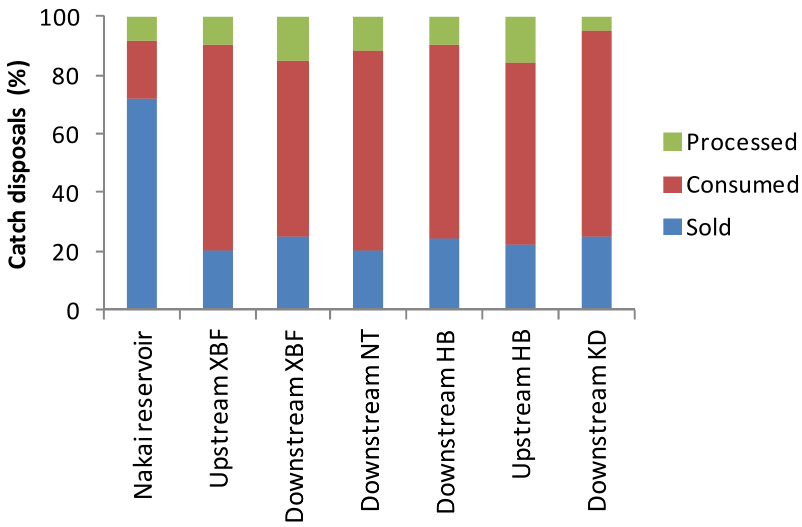


Figure 4.11. Percentage of fish catch utilisation in the study areas.

Management

Fisheries resources in the study areas were considered to be well managed. Out of 20 villages surveyed, 16 had Fishery Conservation Zones (FCZ). In total, 19 FCZs, including six FCZs in the reservoir area, prohibited fishing the whole year round or during the spawning and dry season. The size of the protected areas varied, ranging from 400 m^2 to 10,000 m^2. Fishing communities set up their village regulations to manage fisheries resources in accordance with the Fishery Law. The common rules were: no fishing during the breeding season, restrictions on gear mesh sizes, banning the use of destructive fishing methods, including electro fishing, dynamite and poisoning, and prohibiting fishing in fish conservation areas. However, law enforcement was not effective and illegal fishing was prevalent in some areas, particularly using explosives and toxins that destroy all living organisms in the river systems. It is believed that these illegal fishing methods were one of many reasons causing the decline in fish productivity. Illegal fishing also took place in the fish conservation zones located relatively far from the villages; effective management of fish conservation zones was usually associated with proximity to the villages or linked with religion (in front of the temples).

Fisheries management in the reservoir was slightly different from the villages along the river. Reservoir villages had more support in terms of the financial and technical assistance from the NTPC to implement and monitor Nakai reservoir fisheries. At least ten decrees and regulations were issued to support fisheries management and development in Nakai reservoir. A management policy and initial arrangements were developed prior to the closure of the dam. The policy focused on preserving the resources of the reservoir for the resettled households as an important asset for their new livelihood opportunities. It also aimed to engage the beneficiaries in the management of the fisheries in a form of co-management. Fishery co-management in Nakai Reservoir aimed to develop the existing management structure into an effective and engaging co-management arrangement, capacity building, awareness raising, consensus and trust building.

A Reservoir Fisheries Association (RFA) was established to facilitate fisheries development and management. The general objectives of the RFA were to protect, manage and sustainably use the fisheries resources in the reservoir for the benefit of village fishery groups (VFGs) members. The roles and responsibility of RFA were to develop and implement a fisheries management plan, to issue fishing licenses, develop a system for patrolling and enforcement of reservoir fisheries regulations, identify and demarcate fish conservation zones. The organisational structure of the RFA (Figure 4.12) had four units to support the implementation plan. The fishery management unit was responsible for undertaking fish catch monitoring, research into the status of the reservoir fisheries and technical support for conservation and sustainable resource management. The marketing unit was under the supervision of a Fisheries Manger, to assist VFGs in fisheries marketing operations and monitoring as well as providing technical support for fisheries market development. The patrolling unit was responsible for co-ordinating VFGs activities in co-operation with RMC, District Agriculture and Forestry Office and the District Police for the enforcement of reservoir fisheries rules and regulations. This also included establishing information campaigns to educate resettlers and visitors about fishing rules and regulations as well as reporting infringements that may be occurring and developing required action plans. Finally the Admin and Finance unit was responsible for accounting and financial management, purchasing goods and services, issuing licenses and maintaining full and accountable records.

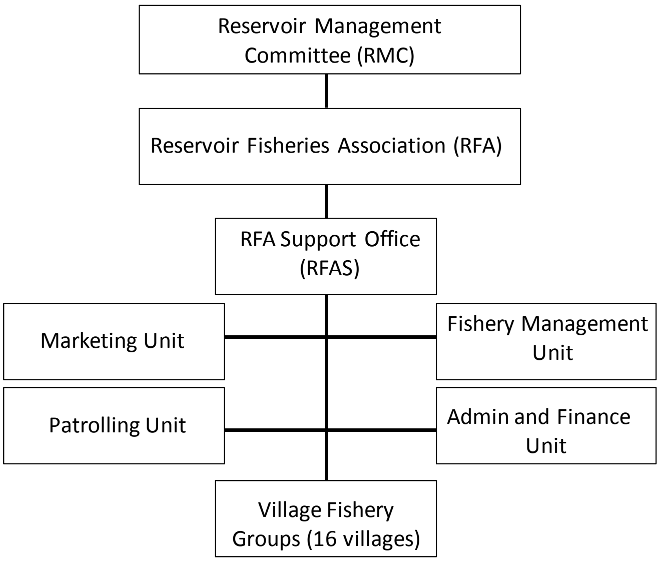


Figure: 4.12. Reservoir Fisheries Association Organisation Chart (Source: Lamberts 2010).

4.4.5 Livelihoods impacts

Social and culture impact

As mentioned earlier, the NTPC relocated 16 villages from the inundated areas to new locations along the east bank of Nakai reservoir. The communities lost 560 ha of rice fields, 139 ha of other crops and vegetables, forest land and fishing grounds. Each resettled household received a 0.66 ha plot of land with a new timber house and surrounding garden. The new location was far from the river and forest where they usually fished and collected NTFP for subsistence. In addition, the resettlers were faced with unfamiliar locations, poor soil and clear land without any trees or forest nearby and were stressed by changes in their lifestyles and livelihoods. The resettlers suffered many problems associated with the resettlement process, delays in payment for compensation of agricultural and garden land, conflicts between villages over access to resources, and difficulties in adapting to new alternative livelihoods (reservoir fishing, cash crops, and community forestry).

Downstream of the dam at the XBF fishers used to follow the pattern of flooding and catch migratory fish from June to September or fish the mainstream in the dry season, but, due to the increased discharges in both the dry and wet seasons, fishers have had to develop new fishing techniques or fish elsewhere. Phowa village was the most affected village due to its located close to the diversion channel where the dam releases water to the XBF. Fishing in the XBF is now almost impossible because of strong currents, and many fishers had to move to fish in natural ponds, swamps, small streams, and in under water caves located far from their village. The number of days fishing and fish catch also declined depending on the water level and current.

The river bank gardens were flooded and people could not cultivate vegetables for their own daily consumption. In addition, transportation by boat became difficult and dangerous as strong water currents and could cause the boats to sink and have increased fuel consumption when travelling upstream against the current.

The river villages in downstream areas were also subject to a potentially high risk from flooding in the wet season as a result of water released from the reservoir when the storage capacity was exceeded because of severe storms or tropical typhoons. This occurred in 2011 when about one thousand households downstream of the Xe Bang Fai and Theun River were affected. Many households stopped cultivating wet rice in 2012 fearing the floods would again destroy their crops and agricultural land. They had to find other activities to obtain rice for consumption, e.g. labouring and irrigated rice cultivation in the dry season.

In the reservoir, many household found it difficult to adapt to their new life style and start new activities. In the past, their livelihoods depended on agriculture and natural resources. All household members were involved in upland rice farming and gardening; they went to work in the fields in the early morning and came back in the evening. Now they do not have that work due to the limited land and changing crop system. Women were more stressed because they could not do agricultural work but also experienced difficulties collecting NTFPs due to the long distances and most of the forest was now only accessible by boat. Changing livelihood activities in the reservoir resulted in most of the work being done by the men, whilst women and children were less involved and mostly responsible for household tasks.

Apart from social impacts, the construction of Nakai reservoir also affected traditions and the culture of the ethnic minorities. Many important religious structures (temples, historic lime kilns), spiritual sites and cemeteries were flooded. These assets are part of the cultural traditions and belief. According to religious traditions these spiritual sites should not be disturbed or relocated, in particular the guardian spirit that is believed to guard and protect the communities from bad things and provide food, good harvests and good health for the communities.

Agriculture impacts

Many households complained that the agricultural land provided by the NTPC was not enough for rice cultivation, even for subsistence. The quality of land was poor and most land was located at high altitude (plateau) without water resources or irrigation systems, making gardening impossible. In the past, they owned more land but only 17% of households produced sufficient rice for the full year. In regards to the promotion of agriculture (rice and cash crop) activity, many households report that they could not produce enough rice for consumption or cash crop for sale due to the limited land. They have had to find other ways to obtain food through paid labour, fishing or trading.

The new alternative livelihoods provided by NTPC also required new skills, techniques and investment to support their implementation. Many activities were delayed for many reasons, including the extension packages, which needed more time to test and the selection of suitable seed for particular soil types. Delays in providing irrigation systems for crops and vegetables made it difficult to get enough cash to buy rice. Other alternative livelihoods (community forestry, livestock farming and services) required more time and resources, and thus many resettled households turned to reservoir fishing so they could catch fish every day and sell their catches to buy rice.

Another issue that resettlers faced was related to the marketing of the crops and vegetables that they produced. The concern was that supply would exceed demand, because the resettled population in Nakai district accounted for more than 70% of total population and the local market is very small. New marketing networks are needed to guarantee prices and distribution of the products to neighbouring districts and provinces. Uncertainty over markets, price and crops caused resettlers difficulty in deciding which new livelihood activities to invest their time and resources. Many households in Konekean village were confused and relied on support from the NTPC and were afraid of starting unfamiliar livelihood programmes.

Food and income impacts

Many households faced difficulties getting foods. In the past villagers depended on the forest, river and agriculture for food security; the food chain was also linked with seasonal patterns. There was more food available in the wet season when people could collect NTFPs (including bamboo shoots, mushroom, edible tree leaves), aquatic animals (frogs, shrimps, crabs, snails) and fish. In the dry season they relied on hunting wild animals, collecting some NTFPs and fishing. Most of the daily meals were either from the wild or their own produce.

Nowadays the resettlers have limited resources to support their living. Not only do they not have enough food for consumption, because the reservoir inundated the forest and the possibility to produce food has also been restricted. Households have had to rely on markets to acquire food. When no other sources were available, people have turned to fish in the reservoir, putting pressure on reservoir fish stocks. More than 80% of households relied on fishing and fish marketing for food and income. Full time fishers had to sell their catch to buy rice and other staple foods. Now their livelihoods depend on the markets, so they are vulnerable and at risk from the rising costs of food due to shortages in supply as a consequence of floods or droughts.

Household consumption monitoring (Chapter 5) suggested that, apart from fish, most resettled households acquired their food from the markets rather than their own produce or the forest compared with typical remote households. In addition, the reservoir households tended to consume more meat than the river households, as it is easy to access and affordable.

In the past, the main income of the fishers came from livestock and NTFPs. Large animals (cattle, buffalo and pigs) were the main household assets. Fishers would sell these animals when they needed immediate cash for repairing or constructing new houses, wedding ceremonies or a medical treatment. Many resettlers lost their animals or were forced to sell them due to the loss of land caused by inundation of the forest and previously available grassland. After relocation to the new villages, many households did not have any savings left, and several households turned to fishing or fishery related activities for their living.

Failure in planning of the equipment provided for reservoir fisheries also affected food security of many households. For example, in Oudomsouk village, the NTPC subsidised only one fibreglass boat for every two households. This meant fishers had to go fishing together every day, and many fishers argue that it is difficult and inconvenient for them to agree a suitable time to go fishing as their fishing skills and selection of the fishing grounds are different. Maintenance of the fibreglass boats are also a problem as they do not have the skills to fix and maintain them and as a result the lifespan of fibreglass boats is shorter than it should be.

4.5 DISCUSSION

4.5.1 Hydrological regime and fish life cycle

Significant changes in water discharge in the river downstream due to diversion of water from Nakai dam to XBF was evident. These changes dramatically increased water discharge in both the dry and wet seasons. Although there has been little research on the impacts of hydrological changes on Mekong fish species, the results from this study suggest that increased water levels in the dry season have completely changed the ecosystem and living aquatic organisms of the XBF basin. In particular, the extreme and medium flows that maintain river functioning and are important cues for fish migration have been disrupted. The relationship between the fish life cycle and the natural flow regimes in the Mekong River is illustrated in Figure 4.13 to highlight the potential disruption.

Many fish species are sensitive to changes in discharge, including time and duration of the flood pulse, thus any changes and disturbance to this natural process may directly impact on fish reproduction, species diversity and production (Cowx *et al.* 2004; Welcomme *et al.* 2006). This study indicated that many fish species, as well as OAAs and aquatic plants, will likely disappear from XBF or decrease in abundance, due to increased water volume and current. Many authors have reported that rapid fluctuations in water level in the wet season due to water abstraction or diversion have disrupted the migration, spawning, reproduction, growth and survival of fish eggs and larvae (Petts 1984; Lucas *et al.* 2001; Marmulla 2001). It could also affect riparian vegetation and trees that fish use as indirect sources of food e.g. periphyton (Cowx & Welcomme 1998). In addition, short term fluctuations in water level can lead to a decline in the abundance and diversity of fauna and flora (Poff *et al.* 1997). This study indicated that hydrology has likely affected access to and suitability of spawning habitats of fish species, not only in the wet season but also in the dry season when reproduction of some species takes place. This study confirmed the results of Warren (1999) who concluded that the large cyprinid species *L. striolatus,* which spawns during the dry season in the Theun River, and possibly also existed in XBF, was affected by changing dry season discharge from Theun-Hinboun dam and had moved to tributaries where water discharge was under natural flow conditions.

Fish communities require a combination of volume, rate, and different flow patterns in various habitats to complete their life cycle (Cowx *et al.* 2012*).* The flows that influence fish communities and fauna are population flows, critical flows, stress flows and habitat flows (Cowx *et al*. 2004; Welcomme & Halls 2004). As described in Chapter 2, population flows are very important for fishes as they allow fish to connect to different habitats, including floodplains and isolated swamps. Critical flows provide a cue for fish to migrate and reproduce, while stress flows putt fish in danger because of excessive velocities at high water or drought at low water. Finally, habitat flows are needed for maintenance of ecosystem services, including environmental quality and habitat for fish. This suggests that species diversity and production may potentially decline in the XBF as a result of changing water flow and discharge. These changes are not yet fully evident in the present study because the flow regime only existed for two years prior to when this study was carried out, and many fish species were still adapting to the new environment while new species have yet to utilize the habitat. Thus, it is too early to draw any conclusions on how many species may be affected by the changing flow and discharge in the XBF. However, anecdotal information indicates that at least ten species were declining in abundance and difficult to catch and most of the catch was dominant by small and low value species.

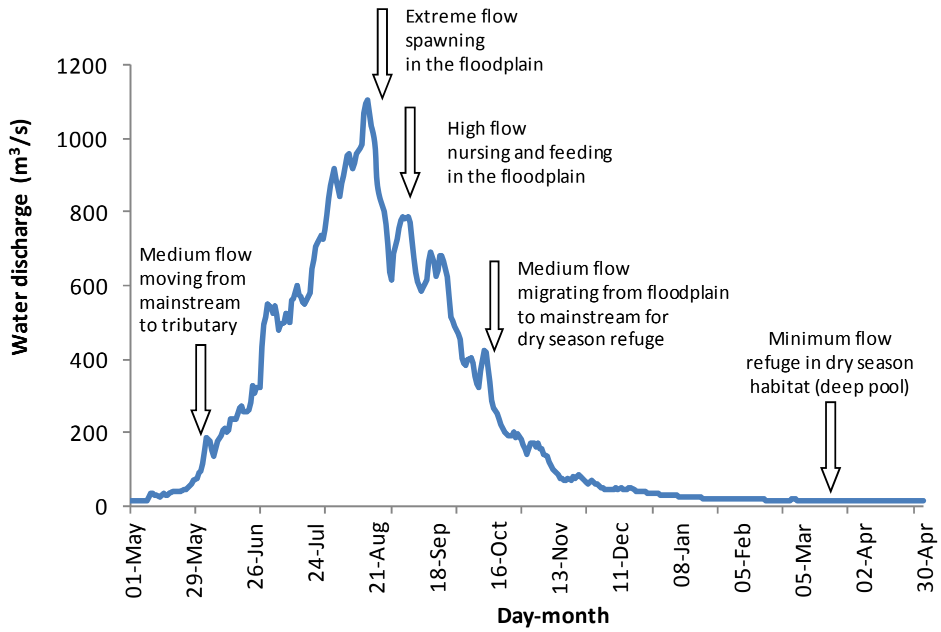


Figure 4.13: Natural flow and fish movement in the Mekong River system (Modified from Poulsen *et al.* 2002).

The impact of the impoundment of Nakai reservoir on fisheries was significant. A fishery survey after impoundment in 2009 indicated that out of 66 species previously inhabiting the Theun River, only 20 were found in the reservoir (Vattanathum 2010). Similarly, out of 265 species that existed in the Mun River in Thailand, prior to commissioning of Pak Mun dam, only 96 species were found upstream several years later (WCD 2000); in the Se San river at least 21 species have disappeared since Yali dam in Vietnam became operational in 2000 (Baird & Meach 2005). This study found that both catches and species in Nakai reservoir have declined. The catch is now dominated by a few species, including exotic species such as tilapia and common carp.

4.5.2 Habitat destruction

XBF, like most rivers, comprises different habitats types (Kottelat 1998). The headwater XBF channels are characteristic of limestone mountain rivers consisting of rocky areas, riffles, pools and karts, while the middle XBF consists of many deep pools, rapids and the substrate varies from sand to rocks. The lower XBF is characterised as a lowland floodplain, the substrate is muddy or sandy bottom, with rocks and areas of rapids. The river floods forest areas and is connected to wetlands during the wet season. The river depth in this section is variable, ranging from several metres to a few centimetres on some sand bars. Under normal natural flow conditions, fishes use these habitats for spawning, feeding and refuge.

The increased water flow in the dry season has completely changed the river morphology and ecology. High water levels in the middle (Phowa and Kengpai) and lower parts (Yangkham) of the XBF have eliminated the dry season refuge and spawning habitats, increasing mortality of eggs and larvae. Although there is limited information on species using deep pools as dry season habitat in the dry season in XBF, in the Mekong main stream several species use deep pools at some stage of their life cycle (Viravong *et al.* 2006). Fishers in Kengpai village reported that they caught many deep pool species in the XBF, including *L. chrysophekadion*, *H. malcolmi, H. waandersi* and *M. armatus*. The rapid increase in depth and velocity of the river has destroyed both the deep pool and shallow habitats that are home to more than 100 fish species in XBF (Kottelat 2006). Dry season spawning species are affected by the higher volumes of water in the dry season that compromise their spawning and nursery habitats. These species include small cyprinids such as *Sikukia gudgeri*, which spawns in February and the endangered IUCN Red Listed species *P. jullieni* that spawns between December and February and which was also found in the lower and middle XBF. The spawning grounds of *P. jullieni,* which well known in the Mekong River, Champasack province, southern Laos and in Ou river (tributary of the Mekong), Luangprabang province, northern Laos, but until the fisher surveys their spawning habitat in XBF was unknown. The fishers usually captured this species in XBF deep pool during the dry season, which they believed many fish species use for refuge.

Increased water volume, flow and discharge in the dry season not only destroys the dry season and spawning habitats of fish but also changes species composition and production as shallow habitat species are displaced by deep-water and strong-current resistant species. In addition, inundation of rocks, riffles and rapids also resulted reduced habitat diversity for fish, in particular the sandy-rock and rapids that young fish used as feeding and nursery habitats in the dry season.

4.5.3 Disruption of migration and spawning dynamics

Fishes are very sensitive to water level and discharge changes, particularly during the migration and reproductive periods (Welcomme & Halls 2004). Fishes rely on different flow conditions to complete their life cycles (Cowx & Welcomme 1998). Young fishes and juveniles can benefit from low flows over the rearing and nursery habitats, but the middle flows often stimulate migration of adult fish from the mainstream to spawning grounds in the floodplain (Poulsen *et al.* 2012). In the Mekong River, more than 160 species undergo longitudinal migrations. Many species also move into tributaries, including XBF, for spawning and feeding in the flood season. Changes in flows, timing, duration and frequency will impact on these migrations. Fish are often encouraged to migrate upstream by rising flows, although some movement occurs when discharge is low; peak migrations occur at times coincident with increasing discharge (Baran 2006). There is, for example, a strong relationship between the migration of *H. siamensis* and discharge (Halls *et al.* 2013c); fish start to migrate when the water is rising, but movement is also linked with lunar cycle. This pattern is confirmed by catches in the Lee traps, which tend to rise as water level starts to rise (Chapter 3).

Fluctuations in discharge, loss of seasonal flow variability and loss of the middle flow conditions due to dam operation could have serious implications for the fisheries. Migration cues could be lost, leading to disruption of reproduction processes and loss of recruitment. Furthermore, changes in water depth, timing and duration of flooding are likely to disrupt lateral migration of fish from the Mekong River to the XBF. For example, if the peak flood is early fish may not be ready to spawn but if the flood is late (October 2010) the inundation period may not be sufficient for eggs and larvae to hatch and develop or the fish may have sought sub-optimal spawning habitat. As a result, these scenarios could lead to increased mortality or poor growth of fishes. Many white fish species (*C. microlepis, Hampala dispar, L. chrysophekadion, H. wyckioides, H. leptorhynchus* and *P. larnaudii*) that inhabit the Mekong River were also found in XBF during the wet season. Fishers believed that these species migrate to the lower and possibly middle and upstream reaches of the XBF and its tributaries to spawn. There is no doubt that hydrological changes will impact on the migration and reproduction of fishes in the XBF, which could also affect Mekong fishes moving downstream to the mainstream to complete their life cycles.

4.5.4 Rural livelihoods and resilience

Most rural people in Laos engage in rice-based agriculture combined with livestock raising, collecting NTFP, and fishing for subsistence and income generation (MAF 2010). The livelihood activities are different depending on the agro-ecological zone. For example, households in north (upland regions) mainly cultivate upland rice combined with industrial tree plantations (rubbers, teaks), livestock farming and hunting (Phonvisay 2013; Vongvisouk *et al.* 2014), while households in the south associated with more lowland areas and rivers, practiced wet rice farming, cultivation of cash crops, livestock rearing, fishing and trade (Meusch *et al.* 2003; Mollot *et al.* 2003). This study found that the livelihoods of people along the XBF were similar to households in the southern provinces, with most people in the XBF engaged in wet rice plantation, raising livestock, collecting NTFPs, growing vegetation and fishing as the main occupations. However, in terms of cash earnings livestock was the main activity, followed by NTFPs and rice farming (Table 4.14). In addition, other livelihood activities such as weaving, paid labour and trading were also commonly practiced by the households living along the XBF River. The main occupations of those settled around Nakai reservoir differed because resettlers have limited assets and less productive land for rice cultivation, thus reservoir fishing represented their primary activity in terms of income generation followed by paid labour and trade (Table 4.14). By contrast, in terms of spent time each day, fishing was ranked fourth, while paid labour, trade and NTFPs were ranked one, two and three respectively. It should be noticed that the capture fisheries in Nakai reservoir were not only used for subsistence but also for income generation and buying rice and fishing equipment. In Nam Ngum reservoir where people had access to fertile soils, fishing was ranked as a second economic activity after rice farming, and livestock rearing was third (Mattson *et al.* 2000).

The resilience and adaptation strategies of the rural communities to natural events (floods and droughts) or human interventions (dams, deforestation) varies depending on the location and access to livelihood assets (natural, physical, human, financial and social capital). In most cases when people faced natural phenomena that destroy their rice fields or gardens, they turn to their savings, not only in cash but also in the form of animals (chicken, pig, cattle) to cope with the shortage of food (Meusch *et al.* 2003). In addition, income diversification by doing off-farm work (paid labour) was also found in urban areas where infrastructure was well developed (WFP 2007). In this study, households in the XBF who could not go fishing or grow vegetables in river bank gardens, still relied on fishing but changed their fishing techniques or moved to fish in streams and wetlands; other fishers switched between handicrafts, paid labour and fishing. In the reservoir, most households tried to adapt to the reservoir fishery by changing gear types, mesh sizes and fishing techniques. Some people shifted to services and trade to achieve livelihood security, e.g. village shops selling foods, tools for gardening and fishing gear were also found in the reservoir villages.

The success in adaptation and livelihood diversification is dependent on the capital, skills and assets of the households. This study found that the households in villages located close to the centre or market (Oudomsouk village) have more opportunities and diverse activities to obtain their food and income than villages relatively distant from the market (Kengpai and Thalang villages). In this case infrastructural development (e.g. road, market) becomes an important part of livelihood diversification of the reservoir villages.

Table 4.14. Top five Livelihood activates ranged by economic importance and time spent.

Description	Economic importance		Time spent	
	Reservoir	XBF	Reservoir	XBF
First activity	Fishing*	Livestock	Wage labour	Rice farming
Second activity	Wage labour	NTFPs	Trade	Livestock
Third activity	Trade	Rice farming	NTFPs	NTFPs
Fourth activity	NTFPs	Fishing*	Fishing*	Gardening
Fifth activity	Livestock/gardening	Gardening	Livestock/gardening	Fishing*

* Gill net, hook and line were main fishing methods and classified as passive fishing (set in the evening and collect in the next morning)

4.5.5 Opportunity and challenges

Nakai Reservoir

Fish processing and marketing

Most of the catch from the Nakai reservoir is sold as fresh or live fishes at a low price compared with the price of processed fish such as dried or fermented (soured or salted) fishes sold in city markets. For example, one kilogram of fresh snakehead is bought by middle men in the villages for only US$1.5 but the price of dried snakehead in the city or provincial markets is almost five times higher.

Although the NTPC tried to promote fish processing in the reservoir villages, it failed due to various reasons. Many fishers had to sell their catch quickly to get money to buy food, including rice, and pay for household utilities. There was no secure market to guarantee that their products could be sold at a reasonable price and they had limited fish processing skills, marketing and business knowledge to handle this activity. Many fishers feel that they still need more support and training, especially with fish processing. Micro finance or low interest loans are needed to allow fishers to have enough money for buying foods initially before they can sell their product. More training on fish processing, hygiene and packing is also needed to increase the value and safety of the foods for consumers.

Improving marketing networks can also increase the fishers' income and improve their living conditions. In the cities, demand for fishes is very high because many people are shifting to eat healthy foods and reduce the consumption of animal meat and fats. Fishes and vegetables are amongst the most frequent foods consumed by people in the city and the price of many Mekong fish species is higher than the price of beef and pork. There are still big differences in the price of fresh fish around the reservoir and in the cities, for instance, the price of fresh fish in Khammouan market, located about 120 km from the reservoir was US$5/kg. Value added to fresh fish by improving post harvest, transportation and marketing network will also increase and strengthen the income of the resettlers.

Ecotourism

Nakai reservoir is a distinctive environment compared with other reservoirs in the country, because it is located close to the Nakai NBCA, one of the largest protected areas in Laos. Whilst the reservoir itself can attract tourism, linking it with the wild animals, including birds, butterflies and plants (wild orchids), in the NBCA, will provide opportunities through ecotourism. Such activities include trekking, camping, staying in the homes of ethnic minorities, fishing and watching wildlife.

Setting up ecotourism opportunities requires support and guidance from the government or the NTPC, in particular for the selection of suitable sites, tourism skills and the formulation of laws or regulations for sustainable ecotourism to ensure that these activities do not interrupt traditional and cultural values of the indigenous peoples, as well as to protect the ecosystem and its inhabitants.

Promotion of ecotourism will create job opportunities and supplement income for the local people, potentially reducing poverty and food insecurity and increasing environmental protection. At the same time, it will create an awareness of the importance of the natural resources to the livelihoods of the indigenous peoples and the need to protect these resources for future generations.

Transportation and other services

Since there are limited public transportation services between reservoir villages and the nearest towns and cities, local transportation both on the land and river, is another potential service opportunity that could be exploited by local fishers, in particular river transportation that can serve not only local people but also outsiders or tourists who want to visit for short stays. Other services include village shops and restaurants to sell food to visitors and local residents. These services will provide additional earnings to supplement household incomes, especially when fishers cannot catch enough fish to sell or when they have limited cash to buy food.

Credit and financial support

Many fishers lack funds and assets to start new livelihood activities. In the past household savings in the form of large animals such as cattle and buffalo, were used. They could sell these animals when they needed immediate cash to spend in emergencies (e.g. funeral or wedding). Lack of grassland and limited forest land due to the impoundment, has forced many households to sell their animals, thus they have no assets.

As the main income of households comes from the reservoir fishery and this income is just enough to buy food and fishing equipment, fishers faced difficulty to find funds to start new activities including on-farm and off-farm activities. Assisting the resettler households to access credit or create a village revolving fund would improve their livelihood opportunities, enabling them to diversify activities and income. This can be done through awareness raising campaigns and through training programmes on marketing, business management and saving schemes.

Aquaculture

Aquaculture is an option for the resettled households to supplement food security and income generation. Like other reservoirs, Nakai reservoir is suitable for cage culture, which can increase fish production. However, cage culture requires high capital cost for setup including materials to build cages and feeds, as well as skills and techniques to operate. There is a need to provide financial resources and training for the resettled households before they can carry out this activity. Exchange visits to other reservoirs such as Nam Houm and Nam Ngum, where cage culture is well develop, may be a good opportunity for the affected households to learn and explore the advantages and issues of cage culture in other places.

Downstream: XBF

Some of potential activities proposed for Nakai reservoir may also apply downstream of the dam along the XBF. For example, the credit and financial support initiative would assist impacted households to have sufficient funds to set up new activities to supplement food and income opportunities that they lose from capture fisheries. Ecotourism is another potential activity for the XBF households, as many places along the XBF have beautiful under water caves surrounded by limestone mountains that could attract local and foreign visitors.

Others potential opportunities are the promotion of One District One Product (ODOP), promotion of organic farming (rice and cash crops), small holder livestock fattening farming (including native chickens), off-farm activities (working at agricultural processing and clothing factories), and promotion of aquaculture (pond and culture-based fisheries)

Promotion of One District One Product

One District One Product (ODOP) has been successfully promoted in the urban areas around the capital Vientiane. The aim of this concept is to upgrade existing products by improving quantities and sanitation including packaging and storage. ODOP could be any products ranging from foods to traditional cloths, handicrafts and souvenirs. The Phowa, Kengpai and Yangkham villages may be suitable for making baskets to store cooked steamed sticky rice or making traditional tables and chairs from bamboo. These products are in high demand in the city and have potential for export to neighbouring countries and elsewhere. Since the fishers used to produce these products for household use only, there is a need to increase the quantity and quality needed by the market, thus training is necessary to improve skills and techniques including selection of the right bamboo for specific parts of the product, plus identifying markets to sell the products.

Promotion of organic farming

Recently the consumption of organic products has increased, due to awareness campaigns on the impact of chemical toxicants in foods and vegetables on human health and well-being. Consequently high and middle income classes in the cities and urban areas have shifted to consume more organic vegetables. Fishers could earn more money from organic products, as the price of organic vegetables is three times that of non-organic vegetables. Although many areas faced water shortages in the dry season in the past, there is now more water available for agriculture in the dry season since Nam Theun 2 dam has started to operate. To start this activity, farmers need assistance and resources, in particular irrigation networks and training on organic farm management.

Promotion of off-farm activities

Off-farm activities are important for farmers who cannot fish for their daily meal because of strong river flows. In the past, this activity was used by many farmers who sent their family members to the city to engage in paid labour. Recently there are many factories, including agricultural processers, distilling of water for drinking and clothing, opening business in Khammouan Province. These factories could provide alternative off-farm jobs for farmers who do not want to invest time on alternative farm work, when they finish rice planting and harvesting. They could choose to work in these factories.

Promotion of smallholder livestock fattening farming

This activity may be suitable for farmers who already have their own livestock or for those who want to start. Traditionally, farmers have raised animals as a form of savings and for subsistence. Ruminants feed in the forests or on rice fields after rice is harvested with little input of feeds or vaccinations. As a result, it takes a long time (3-5 years) before the animals can be sold to the market. By improving feeds and raising techniques, it should be possible to cut the time to market and increase the value of live cattle or beef, as the quality of fattened meats should be better than that raises by traditional methods. Raising native chickens and pig farms are another option for farmers who have limited land or funds for ruminants. These activities need financial and technical support, in particular animal husbandry, animal health care and vaccinations. In most of the study villages, the percentage of vaccinated animals was very low, especially for poultry, and as a result disease outbreaks are common in the study areas. Apart from improving feeds, priority should be given to vaccination programmes.

Aquaculture and culture-based fisheries

As mentioned above, both cage and pond culture requires high investment costs to implement but may be suitable for some households. Many researchers argue that aquaculture can complement the Mekong capture fisheries sector but cannot replace it in terms of food security. This is particularly true for the XBF where fishers depend on wild fishes for their subsistence.

Culture-based fishery is another option for the villages that have community ponds or swamps that can be used for stocking fish. Lessons learned from the region show that the catch from culture-based fisheries cannot only help shield fishes from the declining capture fisheries but also provide funds that can be used to maintain roads, temples and schools. This activity is well developed in Sri Lanka and Vietnam (De Silva *et al.* 2006). The natural swamp in Phowa village may be appropriated for this activity and a good starting point to explore and use as a demonstration site.

4.5.6 Trans-boundary impacts

This study highlights the impact of Nam Theun 2 dam on environmental issues and livelihoods of the local people at the local scale. However, there are concerns about trans-boundary impacts of the dams on the social economic dimensions, livelihoods and the environment of other countries in the LMB. These impacts are not covered in this study. The issue of trans-boundary impacts was raised when the 11 dams on the mainstream of the Mekong River were proposed, but the impacts of tributary dams have received little attention despite an agreement on sustainable development of the Mekong River Basin, endorsed by the countries in the LMB (Cambodia, Laos, Thailand and Vietnam) in 1995 (Mekong 1995 Agreement). Any water development in the mainstream of the Mekong River should follow the procedures of the Mekong 1995 Agreement. For instance, a prior consultation process under the Procedures for

Notification, Prior Consultation and Agreement is an obligation of the 1995 Mekong Agreement for countries to review any proposed mainstream projects, aimed at reaching a consensus to minimize any impacts in a mutually beneficial manner for sustainable development and management of the Mekong River Basin (MRC 1995). However, the Mekong 1995 Agreement does not include development projects on the mainstream in the upper Mekong River (Lancang River) in Chinese territory nor does it include tributary dams.

Although this study highlighted only localized impacts on the livelihoods of people in terms of food security and income generation, the Mekong could be impacted by the physical barrier to fish migration and reduced sediment loading from the Theun River. As a consequence it could affect the livelihoods of people living in the Cambodia floodplain or the Mekong Delta of Vietnam. An example of the trans-boundary impact of tributary dams in the LMB is the Yali Falls dam, constructed on a tributary of the Sesan River in Vietnam. In 2000, when the dam commissioned, it caused not only environmental, social and economic impacts to the livelihood of people living along the Sesan River in Vietnam, but also affected 55,000 people in 90 villages in Ratanakiri and Stung Treng province of Cambodia (Wyatt & Baird 2007). The impacts included unpredicted and rapid water discharge and level leading to 39 people being drowned (Lerner 2003), and loss of houses, agricultural lands, livestock and crops (Fisheries Office 2000). In this case, the trans-boundary impacts were not incorporated into the Environmental Impact Assessment (EIA) of Yali Falls dam and no trans-boundary EIA was conducted (Wyatt & Baird 2007).

During the past few years, the prediction of trans-boundary impacts of main stream dams in the LMB has been initiated. The MRC Strategic Environmental Assessment of hydropower on the Mekong mainstream used three scenarios to analyse four hydro-ecological zones, namely (1) Lancang River; (2) Chiang Saen to Vientiane; (3) Vientiane to Pakse and Pakse to Kratie; and (4) Kratie to Phnom Penh (ICEM 2010). The SEA highlighted that in 2000, 16 dams blocked 20.6% of the LMB, disconnecting upstream fish migration to other habitats; if all dams are built, 81% of the basin will be blocked to fish movement, and 76% of rapids and 48% of deep pools will be lost. In Cambodia, most fishers will likely suffer from declining fish production in the same way as those in this study, while the reduction of sediment load to the lower part of the Mekong River in the delta could affect the soil quality, leading to declining rice yields, impacting local livelihoods and the national economy. In Thailand, water resources, including irrigation weirs and dams, have been heavily developed in the tributaries and these have had significant impacts on fish migration and production, as well as the livelihood of fishers (Roberts 2001). The impacts from tributary dams in Thailand will likely be similar to the XBF in terms of declining fish catches and flooding of river gardens.

The potential trans-boundary impacts of the mainstream and tributary dams are huge and need to be considered in the early stage of the planning process. As the existing dams on tributaries already impact the ecosystem and the livelihoods of people, many tributary and mainstream dams are planned, for instance, the proposed dams on 3S Rivers and Sambor dam (mainstream dam) could destroy the ecology of the river system and add more pressure on livelihoods of the poor that are already heavily affected by existing dams. Measures and mitigations should be in place to minimise the potential trans-boundary impacts of dams to the environment and food security of the peoples. This process could be done through an existing mechanism and use the MRC Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin as a starting point.

CHAPTER 5: FOOD CONSUMPTION AND NUTRITION

5.1 INTRODUCTION

Food security is an important indicator of both economic growth and poverty in a country. FAO (2012) estimated about 870 million people equivalent to 12.5% of the world population, were malnourished, of which approximately 852 million were in the developing counties. In Laos, many people still live in poverty, in particular the indigenous minority living in the remote mountainous areas in the east. In response to the Millennium Development Goals, the government of Laos has targeted halving poverty and hunger by 2015. In the past, it always focused on ensuring an adequate quantity of rice as an indicator to achieving food security but recently the concept of food security covers not only quantity of food but also nutritional value (Vathana 2011). Malnutrition in Laos is high, causing chronic food insecurity among children (MOH and LSB 2012). This chronic malnutrition is associated with long term inadequate nutritional intake and health status.

People in the remote areas of Laos acquire their food from forests, rivers, natural ponds and rice fields. Fish and other aquatic animals provide major sources of animal protein (Phonvisay 2013). Any attempt to alter these natural resources would directly affect rural livelihoods (Meusch *et al*. 2003; Mollot *et al*. 2003; Garaway *et al.* 2013). In recent years, the construction of hydropower dams, development of mining and privatisation of land for rubber plantations have increased dramatically. These developments have created concern regarding their potential impacts on natural resources that provide major food sources for local communities.

In order to assess the impacts of the developments and climate change on the livelihoods of people, it is necessary to understand the social, economic and livelihoods dimensions of the people likely to be affected, including risks to their food security. This requires a wide range of information at the household level on family characteristics, food sources, health and sanitation; at the same time food consumption, health and nutrition status at the individual level also needs to be indentified (FAO 2002). Many development projects overlook food security issues when formulating projects. The focus of Environmental Impact Assessments and Social Impact Assessments are usually limited about information on food security and mostly relate to ensuring the local populace have sufficient rice rather than about nutrition and other key issues (Meusch *et al.* 2003; WFP 2007; LSB 2012). Food consumption data at the household level are also limited or out of date, in particular in the affected areas where many people suffer from water resources development schemes and climate change. To understand food security, it is important to include four components, namely food availability, food accessibility, stability of food sources and food utilization (FIVIMS 2002).

This study aims to determine the impacts of reservoir development on food security through shifts in household food consumption and daily food intake both in the wet and dry seasons. It is anticipated that monitoring daily food intake at different times of the year will provide input about food security issues across the year and changes caused by the water resource development projects and climate change. This information can be used for planning new development projects, as well as contributing to assessment of food security issues and poverty alleviation in Laos.

5.2 OBJECTIVES

The general aims were to assess the impacts of environmental and hydrological changes around existing dams on food security through consumption monitoring in local communities and to examine the contribution of fish and OAAs to household dietary composition and protein intake at different times of the year. The specific objectives were to:

1. assess the food sources and seasonal availability of different food types;
2. determine animal protein intake from fish and other animals sources;
3. analyse food resources patterns in relation to seasonal and climate changes.

5.3 METHODS

5.3.1 General description of the study areas

These studies were conducted around Nakai reservoir in Khammoune Province and downstream of the reservoir along the XBF. The location of the study villages and description of Nakai reservoir are described in Chapter 4. The infrastructure around the reservoir areas was more developed than in the remote downstream XBF villages. Thalang and Khonekean villages are new resettlement villages constructed by the Nam Theun 2 Power Company (Figure 4.4; Chapter 4): they have new houses, electricity, underground water supply and healthcare centre facilities for the communities. The least-developed village in terms of roads and access was Kengpai where road access is only possible in the dry season; in the wet season some roads (earth road) are flooded and the main transportation to other villages or towns in this period is by boat. By contrast, the villages in XBF benefit from greater access to natural resources (rivers, forest, natural pond, swamp) and land for agriculture than the villages around the reservoir that had limited land and are far from these natural resources. These resources served not only as a “food bank” but also saved expenditure for both villages around the reservoir and XBF. The distance from the study villages to the district centres ranges from 6 to 27 km (Table 5.1).

Table 5.1. List of study villages (Source: Data from field survey).

Village	District	Distance to district centre (km)
1. Yangkham	Xebangfai	25
2. Kengpai	Xebaingfai	20
3. Phowa	Mahaxai	10
4. Khonekean	Nakai	25
5. Oudomsouk	Nakai	0
6. Thalang	Nakai	27

5.3.2 Household selection

Twenty households from six villages in three districts in Khammoune Province were selected for household consumption monitoring. Ten households were situated in Nakai reservoir area, and another 10 were located along the XBF. The distance from a village to the district centre and the geographical location (north, centre and south) were considered when selecting the villages. Households were randomly selected from the list of people willing to participate in this research. Monitoring was carried out three times: starting in August 2012 (wet season), December 2012 (dry season) and May 2013 (transitional season). Each monitoring period lasted 14 days, giving a total of 42 days of monitoring.

All food items, weight of food consumed and the number of people (including the visitors) consuming meals each day (breakfast, lunch and dinner) were recorded in a logbook (Appendix 3). The logbook categorised the different types of food eaten, for instance, self cooked food, bought foods, other foods (e.g. noodle, fried rice, fried noodle), fruits, drinks and outgoing food (mainly food given to relatives or monks). The project provided one weighing scale up to 5 kg maximum to monitor the household foods consumed.

Before starting the monitoring programme, training was provided to the representative of the household who was responsible for measuring food and filling in the logbook. Interviews were also conducted to get general information on the household status, food preferences and food sources. Provincial officers in each district visited the household three times during each monitoring period (at the beginning, in the middle and end) to monitor and assist in filling in the form or to answer any questions regarding measurement of the food items.

5.3.3 Methods

Many methods can be used to assess food security and availability, including household income and expenditure surveys, individual dietary survey methods, anthropometric surveys and qualitative household studies (FAO 2002, 2005; LECS 4 2009). This research used the household dietary monitoring method to monitor actual daily food consumption at the household level and record the amount of foods consumed at different times of the year. The advantage of this method is that it provides actual intake of particular foods, exposing food composition and giving an approximate estimate of micronutrient intakes (FIVIMS 2002; Mason 2002). The disadvantages concern cultural refusal to allow strangers to hold the foods or tradition and cultural rules that cause discomfort and unwillingness to collaborate (Kigutha 1997). In addition, small quantities of food consumed including fish, preserved fish and other non-staple foods may be excluded in the records, causing biases in the estimation of micronutrient intake (Mason 2002).

Monitoring also may not include the food consumed by people elsewhere (e.g. wedding or traditional festival), which happens a lot in the dry season. A problem of duplicate recording of food may occur with leftover food consumed. These problems were checked for accuracy, especially when the observer noted the same food being eaten for consecutive meals. Another issue of leftover foods is some households feed leftovers (mostly rice) to animals (cats, dogs, chickens and pigs) and this may lead to overestimation of the amount of rice consumed.

Another potential bias that was checked was that some fishers recorded the weight of food bought not the quantities cooked; this was particularly the case for meats. This was double checked when abnormal quantities of food intake were found and the data were adjusted.

Some problems with consumption monitoring were encountered when fishers consumed small quantities of fish, preserved fish and OAAs that weighed less than 50 g. This may have been excluded from the logbook records because it was difficult to measure small amounts on the scales provided.

Preserved fish, particularly in the form of liquid (fish sauce, fermented fish) fish paste, were excluded from the monitoring due to difficulties in measurement and time required for the household to record such contributions. However, this kind of food was estimated indirectly by calculating the numbers of jars (used to store fermented products) that are produced each year for consumption and sale. In addition, it can be estimated from the cooked food. For instance, a medium cooking pot of mushroom or bamboo shoot soup contains around 50-150 ml of fermented fish liquid or *lappa* (a traditional food mix of filleted fish with vegetables) uses 20-50 ml of fermented fish liquid.

For NTFPs, bamboo shoots and rattan were grouped into “bamboo shoots”.

5.3.4 Conversion factor

Conversion factors used to convert actual weight of food consumed to protein were based on different sources: all meats (beef, pork, chicken) were from FAO (2007), and fresh fish and OAAs from Nurhasan *et al.* (2010) and Mogensen (2001). The factors were used to account for the current situation to minimize any error of over or under estimation (Table 5.2). There are no data on protein content in wild animals so the protein content of beef was applied in this case. The edible portion of fish was estimated at 60% because fishers eat more large fish than small fish. Calorie conversion for rice was based on the US National Nutrient Database for Standard Reference (USDA, 2013).

Table 5.2. Conversion factors from actual weight to edible protein (Source: Nurhasan *et al.* (2010); Mogensen 2001; *FAO (2007); ** US Department of Agriculture, Agricultural Research Service (2013).

Animal	Edible portions (%)	Protein edible portions (%)	Calories per 100 g
Fish	60	21	113
Dried and sour fish	80	50	290
Frog	60	19	73
Snail	22	12.1	90
Shrimp	50	15.6	79
Crab	38	10.7	79
Beef		19.4*	182*
Pork		17*	348*
chicken		20*	105*
Wild animal		19.4*	182*
Glutinous rice			370**

5.3.6 Data analysis

Primer v6 software (Clarke & Gorley 2006) was used to determine the similarities in the diet between locations and seasons and thus changes of food consumption during the study period. Similarity percentages (SIMPER) analysis was used to identify the main animal source food contributing to overall food intake in different seasons. The top five animal source foods identified by SIMPER analysis were compared between seasons at each monitoring site (reservoir and river).

Permutational Manova (PERMANOVA) analysis using Bray-Curtis similarity, 9999 permutations and unrestricted permutation of raw data was used to examine the effects of seasonality on food intake from different animal sources between reservoir and river households.

5.4. RESULTS

5.4.1 Food acquisition practices

Food sources

The people living around Nakai reservoir and along the river bank of XBF depended on natural resources for their food and income. Forests, rivers and wetlands were the most important open access sources for them. Food acquired can be categorized into three groups: food collected from the wild (Non Timber Forest Products - NTFPs), food from their own production (farming and gardening products) and food purchased.

Non Timber Forest Products

At least 306 species of NTFPs have been documented on the Nakai plateau and XBF, of which 247 were edible and can be used as food. NTFPs were available in both the wet and dry seasons but were more abundant in the wet season. Rattan and bamboo shoots were commonly exploited in the study area. The common species of rattan were *Daemonorops schmidtiana* and *Raphis* sp. and there were more than 10 species of bamboos (Table 5.3); the most commonly used as food were mai kasen (*Neuhouzea mekkhongensis*), mai phai (*Bambusa blumeana*), mai bong (*Bambusa tulda*), mai sod (*Oxythenanthera parvifolia*) and mai hia (*Cephalostachyum virgatum*). Various products from the forest are used in the daily diet; around 40 types of leaves from trees, shrubs and herbs were edible. Wild mushrooms locally call *het* are a crucial food source in the rainy season (Table 5.3). The widely used species are *Lentinus polyporaceae, Termitomyces amanitaceae, Astraeus sclerodermataceae* and *Amanita amanitaceae*.

According to DOF (1997), some 31 mammals, 24 birds and 13 reptile species were recorded as regularly eaten in Nakai plateau. Many lizards, rats, snakes and birds were also observed on the market. Fish and OAAs were a readily available and cheap source of protein for people living around the reservoir and XBF river. Many fish and OAAs species inhabit the study areas: 66 fish species are found in the Theun River and 146 species have been recorded in XBF. Fish were available all year round but were most abundant in the wet season. Fish species caught in Nakai reservoir were dominated by tilapia and snakehead. Fishes from aquaculture were rarely found around Nakai reservoir as it was still in an initial stage of the development. Although some farmers in the Xebangfai villages had started fish culture in earth ponds or concrete tanks, the products were used only for subsistence.

Dried fish, sour fish and fermented fish were commonly consumed in the study areas. Many fishers produced fermented fish themselves, but some fishers who caught just enough fish to eat had to buy this product from the market.

Frogs, snails, shrimps and crabs were a frequent food and some products were available all year round (snails, crabs). The frog species *Hoplobatrachus chinensis* (*Kob*) *Rana lateralis* and *Fejervarya limnocharis (Kiet)* were most abundant at the beginning of the rainy season (late May-August), although *Rana lateralis* and *Fejervarya limnocharis* were also available in the dry season from swamp areas and rice fields (where they take refuge in paddy fields). There were three shrimp species (Caridina sp., *Macrobrachium lanchesteri*, *Macrobrachium pilimanus*) and at least seven crabs species (*Chulathelphusa aff. brandti*, *Chulathelphusa aff. neisi, Esanthelphusa nimoafi, Hainanpotamon* sp., *Esanthelphusa* sp., *Potamon aff. kimboiense* and *Potamon* sp.) found in the Nam Theun watershed. Giant water bug (*lethocerus indicus*) was also found in the study areas.

Farming and gardening products

In general, people living in rural areas mostly consumed rice and vegetables they produced. Villages located near district centres had limited access to land and forest resources and relied on the market to purchase vegetables and other foods. People living along the river usually had their own garden on the river bank and cultivated many types of vegetables, including lettuce, morning glory, string beans, cucumber, pumpkin, green onions, leafy garlic and chillies. Many people grow green onion, coriander, chilli, mint, dill and lemon grass near the house for consumption. Papaya and banana were also cultivated in gardens close to the house. Coconut, mango, tamarind and jackfruit are sometimes planted at the front of the house, and the fruits were mainly for consumption.

Sticky rice (glutinous rice) and fish are the staple food of the Lao people. Glutinous rice is the most important food of the people in remote areas. Most of the people living along the XBF riverside practiced rice cultivation; rice paddies were used not just for rice production but also for capturing fish and OAAs. Apart from rice, people also consumed instant noodles, noodle soup, and fried noodles, which were available in the local market or local shops in the villages, as a supplement for rice in the morning and lunch time.

Table 5.3. The list of edible NTFPs in the study areas (Sources: *NAFRI *et al.* (2007), ** DOF 1997)

No.	Lao name	Scientific name	Edible part
	Bamboo and rattan*		
1	Mai hia	*Cephalostachyum virgatum*	shoots
2	Mai sod	*Oxythenanthera parvifolia*	shoots
3	Mai bong	*Bambusa tulda*	shoots
4	Mai phai	*Bambusa blumeana*	shoots
5	Mai kasen	*Neuhouzea mekkhongensis*	shoots
6	Mai Lai	*Gigantochloa albociliata*	shoots
7	Mai hea	*Schizostachyum blumei*	shoots
8	Mai phang	*Dendrocalamus lonoifimbriatus*	shoots
9	Mai sanphai	*Dendrocalamus brandisii*	shoots
10	Mai hok	*Dendrocalamus hamiltonii*	shoots
11	Vai boun	*Daemonorops schmidtiana*	shoots
12	Vai hang nou	*Calamus javanensis*	shoots
13	Vai thoun	*Calamus sp*	shoots
	Mushroom*		
1	Het bot	*Lentinus polyporaceae*	Whole
2	Het pouak	*Termitomyces amanitaceae*	Whole
3	Het poh	*Astraeus sclerodermataceae*	Whole
4	Het la ngok	*Amanita amanitaceae*	Whole
5	Het hounou	*Auricularia auriculariaceae*	Whole
6	Het din	*Russula russulaceae*	Whole
7	Het Pheung	*Boletus boletaceae*	Whole
8	Het Pheung leuang	*Boletus chrysenteroides*	Whole
9	Het la ngok leaung	*Amanita hemibapha*	Whole
10	Het daeng	*Russula lepida*	Whole
	Leafs and flowers**		
1	Phak tew	*Cratoxylum formosum*	leaf
2	Phak samek	*Syzygium gratum*	leaf
3	Phak kadao	*Azadirachta siamensis*	flower
4	Dok kai	*Markhamia stipulata*	flower
5	Phak kout	*Diplazium esculentum*	branch
6	Phak wanh	*Melientha suavis*	branch
7	Phak khayeng	*Limnophila geoffrayi* Bonati.	Whole
8	Phak Kha	*Mimosa pennata*	branch
9	Khi lek	*Senna siamea* Lam	leaf
10	Kha	*Alpinia sp.*	Root
11	Mak linmai	*Oroxylum indicum*	Flower and fruit

Domestic animals played a crucial role in providing food and a ‘safety net’ for the rural people. The national average number of domestic animals kept per household in rural areas was 3.3 cattle, 1.9 buffalo, 2.5 pigs and 13.3 chickens, but for Khammoune Province it was 2.9 cattle, 2.4 buffalo, 1.4 pigs and 9.4 chickens. The number of large animals (cattle and buffalo) has declined over the last decade due to limited grass land, and many farmers have sold their buffalo to buy hand tractors. Farmers also keep chickens and ducks near to their house or near the rice fields and used them as an alternative to fish and meat. Cattle, buffalo and pig act as a ‘safety net’; farmers sell these animals when they need money for social and traditional events (e.g. when people die, get married, house renovation).

Food purchased

Farmers living far from district centres seldom buy food from the market - many only buy beef, buffalo meat or pork a few times a month or even less frequently purchases. Most agricultural products (rice, vegetables and small animals) and NTFPs, including fish, OAAs and wild animals are available in the market. These products are usually sold in the early morning and late afternoon (5 am to 6 pm). These activities are also associated with the livelihoods of rural people who sell the products they gathered/collected the previous day (when selling in the morning) or collected in the afternoon for sale in the evening or the next morning.

Villages located far from district centres that have limited access to the markets organize their own markets called *talat nat* (markets that open on a specific date in the month) to sell their products. In the past, these markets sold only foods (NTFPs, agriculture products) but more recently they have sold clothes, agriculture equipment and others goods.

The families living in villages near the reservoir consumed a high percentage of food bought from the market (e.g. chickens, processed fish and wild animals) compared to the river households (Figure 5.1). It can be noted that reservoir households had limited land to raise chickens, inadequate catches for fish processing and limited access to the forests. With the exception of beef and pork, river households mostly consumed food from their own produce, including chickens, processed fish and OAAs.

Apart from agriculture products and NTFPs, marine products were also available in the district markets. These products are imported from Vietnam and Thailand, and include tuna, dried squid and canned tuna. Normally, the people in the district centre have an advantage in acquiring food from the market. Consequently, they consumed more meat and other products than people living far from the centre. Occasionally, those better-off also consumed marine products, in addition to fresh fish and meat.

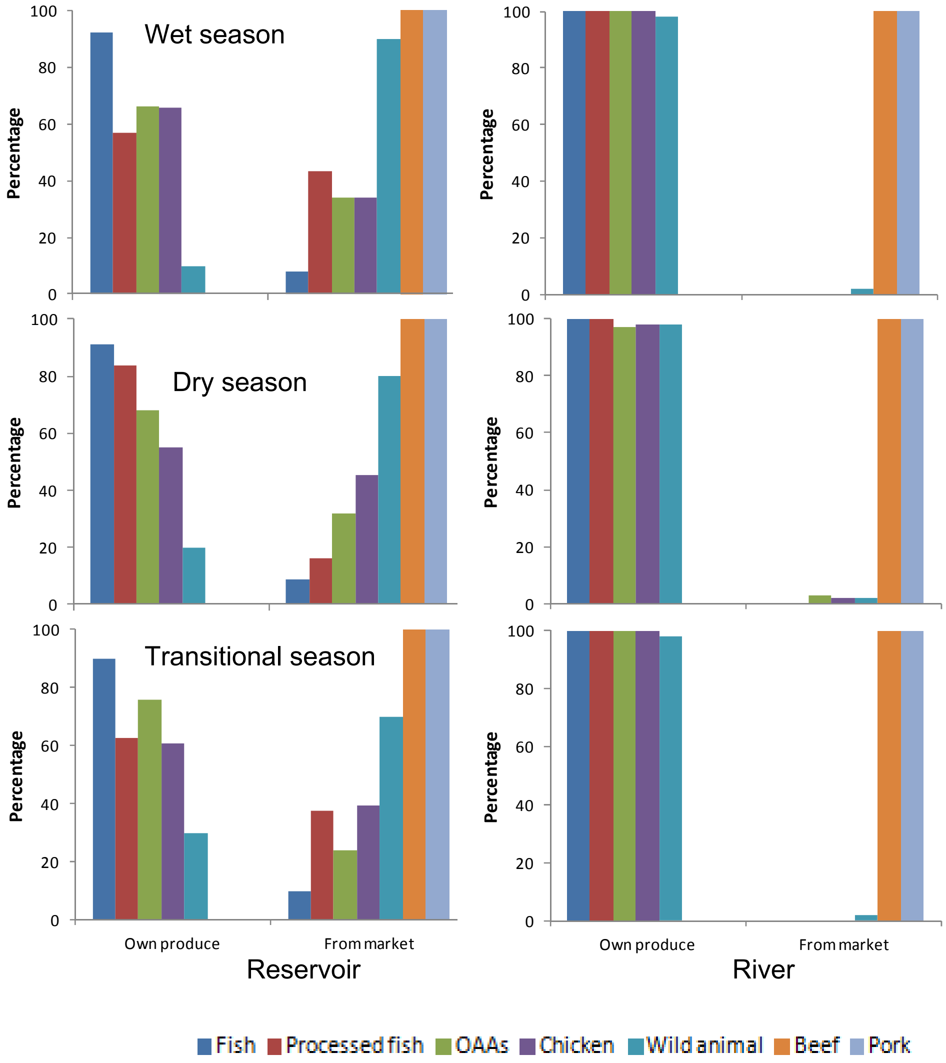


Figure 5.1. Percentage of home produced and food purchased from the market consumed by river and reservoir households .

Food preference and eating habits

In general, Lao people eat three meals a day. Breakfast is in the early morning (06:00-07:00), lunch around noon (11:30-12:00) and dinner in the evening (19:00-20:00). Breakfast is very important to farmers as it provides energy for farm work. The farmers start working before sunrise, and in some cases they do the farm work first and then take a break for breakfast between 08:00 and 09:00 am. Sticky rice is steamed in the morning and evening for breakfast and dinner. For lunch, they eat leftover rice from breakfast.

A typical Lao meal was sticky rice, a meat dish (meat or fish), chilli paste, soup, and a vegetable dish (including mushroom and bamboo shoots). In some cases, when food is short they eat sticky rice mixed with salt or chilli with fish sauce for breakfast.

Rural people prefer to eat fish for every meal, i.e. fish served at breakfast, lunch and dinner. The cooking methods used vary depending on eating habits. The common cooking methods are to boil, grill, stream or fry. Fish was the most frequently consumed food in all seasons (Figure 5.2). The number of days fish was eaten, during one month period each season was, on average, 22 days for households in reservoir villages and 27 days for the river villages. The number of days OAAs were consumed during the transitional season was high in both reservoir and river households due to the abundance of frogs at the beginning of wet season.

The type of meat consumed differed between households living around the reservoir and the households living alongside the XBF. Reservoir households prefer to eat more beef, buffalo and pork than the XBF households. One reason is that the reservoir households have better access to the market in the district centre while XBF villages have limited access or are far from the markets. In addition, it may also reflect the household income as the better-off can afford the expensive food, while the poor rural people rely on their own produce. The increase in consumption of pork, chicken and duck in the transitional season in reservoir village households was because the price of beef soared due to a shortage in supply and many fishers shifted to cheaper meats.

Vegetables and fruits were consumed by all monitored households. Households living along the XBF consumed their own cultivated vegetables, while the reservoir households depended on the market to buy their vegetables due to the lack of land for gardening. Fruits were also consumed widely by both reservoir and XBF households. People usually consumed tropical fruits, e.g. mango, tamarind, custard apple (sugar apple), coconut, banana, papaya, and jackfruit, while imported fruits (apples, grapes, strawberries and others) were rarely eaten because they are more expensive than local fruits.

On average fish and OAAs accounted for more than 30% of all kinds of food (excluding rice). The contribution of fish and OAAs to the food intake of households from XBF was slightly greater (36%) than those around the reservoir (34%) (Figure 5.3). In contrast, the proportion of meat consumed by reservoir households was greater (17%) than those from the river (11%). However, the use of vegetables and other foods was similar.

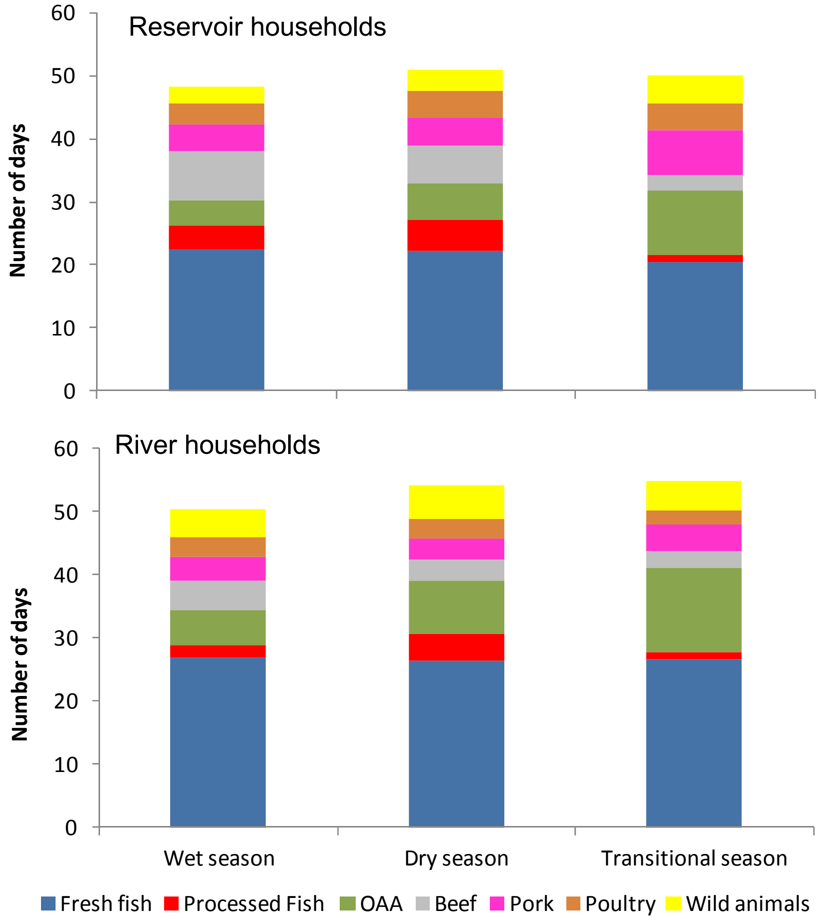


Figure 5.2. Frequency of eating fish, OAAs and animal meats during one month period in different seasons.

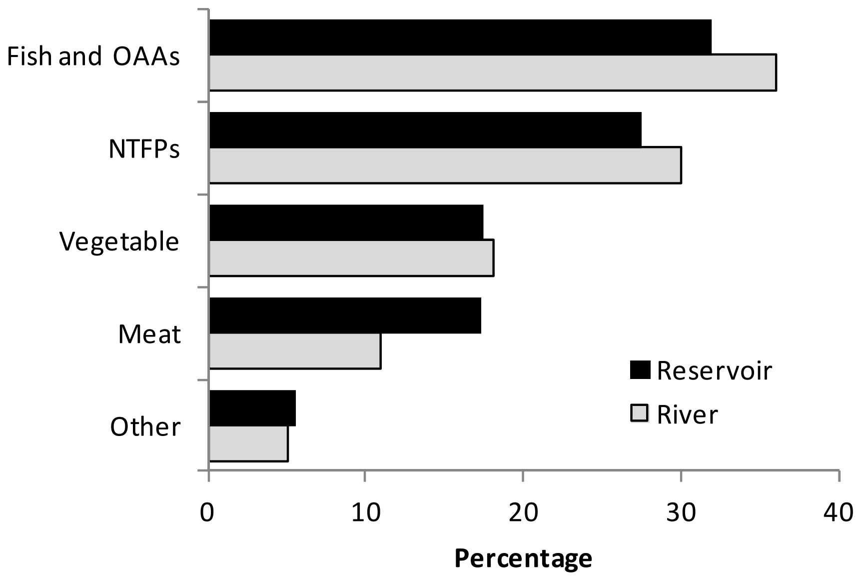


Figure 5.3. Percentage daily food intake by weight in reservoir and river households.

5.4.2 Seasonal variation in food consumption

Animal food sources

Household consumption of food from animal sources in the study areas in different seasons is illustrated in Figure 5.4. Fresh fishes were the main animal food consumed in both the reservoir and river households, contributing more than 60% in all seasons to river households and slightly less to reservoir households, although there was a notable decline in consumption of fish in reservoir households in the transitional season (May). Frogs were consumed in all seasons but were most important to both reservoir and river households in the transitional season, contributing approximately 17% of the animal sources. The contribution of beef declined dramatically in the transitional season due to the increased price and people shifted to pork and frogs to supplement beef.

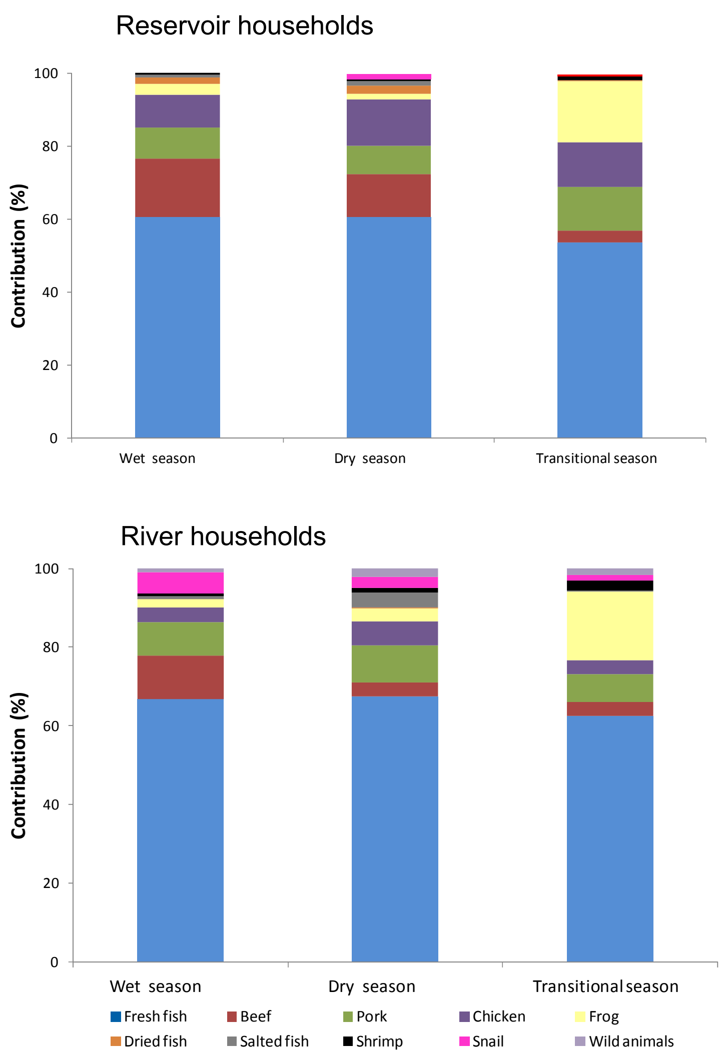


Figure 5.4. Variation in contribution of different animal sources to the foods consumed in different seasons in the reservoir and the river households.

Seasonal change of animal sources food consumption

SIMPER analysis found considerable variation in consumption of food from different animal sources in different seasons. The main foods contributing to the dissimilarity are summarised as follows:

- Reservoir wet and dry seasons: average dissimilarity between these seasons was 34.8%. The top five animal food sources contributing to the dissimilarity were beef (25.8%), chicken (15.8%), pork (14.0%), fresh fish (9.7%) and snails (9.3%).
- Reservoir wet and transitional seasons: average dissimilarity between these seasons was 38.1%. The top five animal food sources contributing to the dissimilarity were beef (22.0%), pork (16.9%), chicken (15.7%), frog (15.4%) and fresh fish (8.4%).
- Reservoir dry and transitional seasons: average dissimilarity between these seasons was 38.5%. The top five animal food sources contributing to the dissimilarity were beef (17.4%), pork (16.6%), frog (16.1%), chicken (13.0%) and snails (10.8%).
- River wet and dry seasons: average dissimilarity between these seasons was 31.1%. The top five animal food sources contributing to the dissimilarity were snails (23.3%), chicken (15.4%), beef (12.4%), wild animals (12.0%) and pork (10.0%).
- River wet and transitional seasons: average dissimilarity between these seasons was 31.9%. The top five animal food sources contributing to the dissimilarity were frog (21.1%), snail (17.4%), chicken (12.7%), beef (12.3%) and pork (10.9%).
- River dry and transitional seasons: average dissimilarity between these seasons was 30.6%. The top five animal food sources contributing to the dissimilarity were snail (20.8%), frog (19.5%), chicken (14.4%), beef (9.5%) and wild animal (8.2%).

The variation in animal proteins consumed in different seasons in the reservoir households was mainly caused by shifts in the contribution of beef. This shift was not influenced by the seasonal change but influenced by the increase in beef price in late 2012; many households shifted to cheaper and affordable meats such as pork and chicken instead of beef. The main seasonal differences in animal protein consumed by river households were shifts in the contribution of OAAs, with frogs and snails contributing more than 20% of average dissimilarity.

Differences in animal food sources consumed by reservoir and river households

There were significant differences between the animal food sources consumed by reservoir and river households in different seasons (P = 0.001). The average dissimilarity between seasons ranged from 33 to 38% (Table 5.4). The difference in the wet season was 37.6%, contributed in descending order by beef, chicken, snails, pork

Table 5.4. SIMPER analysis indicating the differences in animal food sources consumed by reservoir and river households.

Descriptions	Reservoir Mean (kg/person/14 days)	River Mean (kg/person/14 days)	Contribution (%)	Cumulative (%)
Wet season: Reservoir vs. River (37.6% dissimilarity), P=0.018				
Beef	0.49	0.26	19.73	19.73
Chicken	0.3	0.18	15.06	34.78
Snail	0	0.27	14.2	48.98
Pork	0.26	0.23	12.59	61.57
Fresh fish	1.17	1.54	11.46	73.04
Frog	0.08	0.15	8.19	81.23
Wild animal	0.03	0.14	8.08	89.31
Salted fish	0.05	0.05	4.39	93.71
Dried fish	0.05	0.01	3.72	97.43
Shrimp	0.02	0.03	2.57	100
Dry season: Reservoir vs. River (37.4% dissimilarity), P=0.007				
Snail	0.17	0.3	17.91	17.91
Beef	0.43	0.15	17.58	35.5
Fresh fish	1.13	1.59	14.18	49.67
Chicken	0.24	0.25	11.8	61.47
Pork	0.23	0.18	8.92	70.39
Frog	0.06	0.1	6.59	76.98
Salted fish	0.06	0.09	6.54	83.52
Wild animal	0.008	0.1	6.51	90.03
Dried fish	0.08	0.02	5.21	95.24
Shrimp	0.03	0.06	4.76	100
Transitional season: Reservoir vs. River (32.7% dissimilarity), P=0.045				
Pork	0.4	0.18	18.79	18.79
Chicken	0.36	0.15	17.04	35.83
Fresh fish	1.18	1.55	14.41	50.24
Snail	0.09	0.15	11.82	62.06
Frog	0.3	0.4	10.44	72.5
Beef	0.15	0.09	8.99	81.5
Shrimp	0.07	0.11	7.58	89.08
Wild animal	0.04	0.06	6.16	95.24
Dried fish	0.04	0.004	2.84	98.09
Salted fish	0.01	0.02	1.91	100

and fresh fish. In the dry season, snails, beef, fresh fish and chicken were the main contributors to the difference, while in the transitional season pork, chicken, fresh fish, snails and frogs were the major groups contributing to the dissimilarity.

The multivariate nested permanova indicated that there was a significant difference in the consumption of animal food sources by season *P(perm)*=0.001 (Table 5.5). This indicates the seasonal variation in food sources consumed by both reservoir and river households.

Table 5.5. PERMANOVA model examining the effect of season on consumption of animal foods.

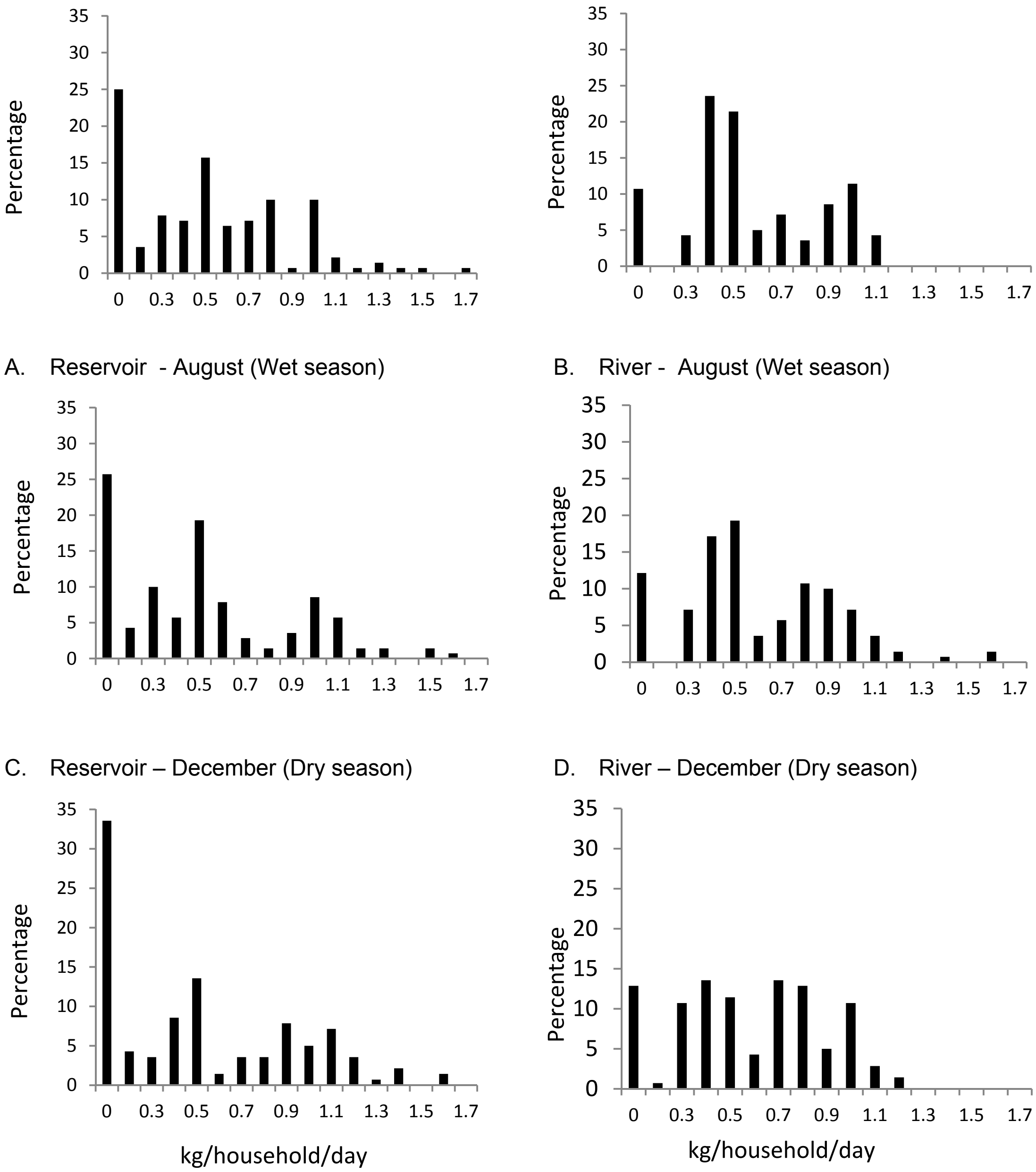
Source	df	SS	MS	Pseudo-F	*P (*perm)
Season	5	10054	2010.8	3.5583	0.001
Residual	54	30515	565.09		
Total	59	40569			

5.4.3 Food consumption rates in reservoir and XBF households

Fish and OAAs

The weight of fish consumed by households was very small, ranging from 0.25 to 1.7 kg/household/day with a mean of 0.53 kg/household/day (Figure 5.5). The average consumption per person in reservoir households was 83.92 g/person/day and 112.57 g/person/day for river households (Table 5.6). It is important to note how little fish people eat per household member (average 5.6 persons/household). This is because of the cooking methods used; traditional cooking uses mostly vegetables to prepare food, e.g. *ponpa* (a mixture of fish fillet with eggplants and liquid of fermented fish). One bowl of *ponpa* with vegetables can feed 5-7 persons. The main cooking method is boiling or making fish soups and accounts for 60% of fish cooked, followed by grilling (20%) and steaming (10%).

Tilapia and snakehead account for more than 70% of the total fish weight consumed by reservoir households, while XBF households consumed a more diverse range of species, between 10 and 20 species annually (Table 5.7). Fish species consumed by XBF households were associated with the migration patterns of the fish species. In the wet season the fishers targeted the migratory species (e.g. *L. chrysophekadion*, *H. nemurus, B. gonionotus, M. armatus*) moving from the Mekong River and into the tributaries to spawning and feeding on the floodplains of XBF. In this period fishers can catch large brood fish.



A. Reservoir - August (Wet season)
B. River - August (Wet season)
C. Reservoir – December (Dry season)
D. River – December (Dry season)
E. Reservoir – May (Transitional season)
F. River – May (Transitional season)

Figure 5.5. Distribution of weight of fish consumed per day in reservoir and river households in different seasons.

The catch is usually divided into three parts: large fish for sale, medium fish used for consumption and small species for preservation (dried, salted or fermented) and stored for eating in the dry season. In the dry season, fishers catch fish from natural ponds or deep pools in the XBF.

OAAs are an extremely important part of the diet of rural people. People from households around the reservoir consumed on average 11.49 g of frogs per person per day and slightly greater in river households (15.27 g/person/day) (Table 5.6). They consumed more at the beginning of wet season in May - 22.56 g/person/day in reservoir households and 28.57 g/person/day in the river households than in the dry season - 5.14 g and 7.14 g for the reservoir and river households, respectively.

Consumption of snails was also important in the dry season (December) in both reservoir and river households, 6.27 and 18.33 g/day for the reservoir and river households, respectively (Table 5.6). OAAs include shrimps and crabs - 2.84 and 5.23 g/day for the reservoir and river households respectively. Other aquatic insects, the frog species *Fejervarya limnocharis* and tadpoles were not registered during the monitoring studies, but they were sold in the market. The reason fishers did not include these insects on the record forms may be related to tradition, culture and their eating habits; fishers may feel umbrage recording that they eat these types of insects as some ethnic minorities do not eat them.

Processed fish is an important component of the Lao diet; it can be consumed directly as main food (dried and sour fish) or used in recipes (fish sauce, fish paste, fermented fish) in traditional cooking. Dried and sour fish are consumed by both reservoir and river households. Consumption of dried and sour fish is high in the dry season when other resources were limited. Reservoir households consumed more processed fish in the dry season than river households: 10.34 g/day compare with 7.42 g/day for the river households (Table 5.6). This may arise because there was more processed fish available on the market for reservoir households or people along the XBF have access to a greater variety of food resources.

Table 5.6. A proximate daily fish, OAAs and animal meat consumption (Source: Data from consumption monitoring).

Description	Wet season g/person	Transitional season g/person	Dry season g/person	Average g/person
Reservoir (n=10)				
Fish	85.72	83.10	82.96	83.92
Frog	6.77	22.56	5.14	11.49
Snail	0	8	11	6.27
Other	1.75	4.01	2.76	2.84
Dried fish	3.76	2.88	5.26	3.97
Sour fish	3.76	0.13	5.08	2.99
Beef	35.24	10.71	31.18	25.71
Pork	18.24	29.29	15.52	21.01
Chicken	21.55	25.45	19.54	22.18
Wild animal	1.79	1.79	0.63	1.40
Total meat	73.82	67.24	66.87	70.3
River (n=10)				
Fish	110.84	111.91	114.96	112.57
Frog	10.08	28.57	7.14	15.27
Snail	17	12	26	18.33
Other	2.66	7.70	5.32	5.23
Dried fish	0.98	0.42	1.26	0.89
Sour fish	3.36	1.54	6.16	3.69
Beef	18.52	6.90	10.98	11.90
Pork	15.87	13.48	8.67	12.44
Chicken	13.19	10.88	18.31	14.13
Wild animal	8.81	4.97	7.36	7.05
Total meat	56.39	36.23	45.32	45.52

Animal meat

People were found to purchase beef and buffalo meat from the market for their daily consumption, but rural people also consumed beef, buffalo and pork at traditional ceremonial events (weddings, funerals, new born cerebrations). It was not surprising that households for villages around the reservoir located near district centres or markets consumed more meat than people living further away. The monitoring data highlighted that the average consumption of beef was 25.71 g/day and the highest contribution of animal meats consumed in the reservoir areas (Table 5.6 above), followed by chicken and pork. By contrast, consumption of beef in XBF was quite low, 11.90 g/day, and chicken (14 g/day) contributed the most to animal meat intake for XBF river households. All beef, buffalo and pork was purchased from the market, while 30-40% of chickens consumed by reservoir households (Figure 5.2 above) was also bought from the market but only 2% of chicken consumed by XBF households came from the market - the rest came from their own production. Consumption of wild animals was very low in both the reservoir and XBF households, on average 1.4 and 7.05 g/person/day. The wild animal meats consumed were birds, rats and lizards.

Table 5.7. Fish species consumed by monitored household (Source: Data from consumption monitoring).

No.	Species name	Reservoir		River	
		Wet	Dry	Wet	Dry
1	*O. nilotica*	√	√		
2	*C. carpio*	√	√		
3	*C. striata*	√	√	√	√
4	*C. batrachus*	√	√	√	√
5	*B. gonionotus*			√	√
6	*P. siamenesis*			√	√
7	*P. jacobusboehlkei*	√	√	√	√
8	*H. nemurus*	√	√	√	√
9	*C. heteronema*			√	√
10	*P. falcifer*			√	√
11	*L. chrysophekadion*			√	√
12	*C. harmandi*			√	√
13	*C. undecemradiatus*			√	√
14	*O. enneaporos*	√		√	
15	*W. attu*			√	
16	*M. armatus*	√		√	
17	*H. macrolepidota*			√	
18	*Micronema sp*			√	
19	*A. testudineus*			√	
20	*L. leptocheilos*	√	√	√	
21	*O. hasselti*			√	
22	*O. siluroides*			√	
23	*H. wyckioides*	√	√	√	√

Rice and NTFPs

As mentioned earlier, rice is a very important component of Lao food and people consumed rice at almost every meal. In general, people in urban areas consumed less rice than rural people; on average rice consumption in the reservoir was 595 g/day and 605 g/day for river (Table 5.8).

People in the reservoir and river households consumed vegetables in almost every meal: on average reservoir people consumed 49 g/person/day and river people 58 g/person/day (Table 5.8). It is important to note that NTFPs also play an important role in diet of rural people. Bamboo shoots and mushroom were consumed both by reservoir and river households, especially in the early rainy season. The people in XBF consumed up to 103 g of bamboo shoots per day compared with 82 g/day for the reservoir people.

Most of the fruit consumed was from the households own production but some also came from the wild. The fruit produced by the households were mango, banana, tamarind and jackfruit. Imported fruit was rarely consumed and only two households around the reservoir ate apples. On average fruit consumption in reservoir and river households was 63 and 82 g/person/day, respectively (Table 5.8).

Table 5.8. A proximate daily rice, vegetable and fruit consumption (Source: Data from consumption monitoring).

	August g/person	December g/person	May g/person	Average g/person
Reservoir (n=10)				
Rice	596.62	593.61	593.48	594.57
Vegetable	53.26	43.61	51.00	49.29
Others	19.55	10.40	11.40	13.78
Bamboo shoot	112.16	59.27	73.68	81.70
Mushroom	13.16	6.89	32.08	17.38
Papaya	17.04	28.20	15.54	20.26
Fruit	70.18	57.64	60.15	62.66
River (n=10)				
Rice	607.28	605.32	603.50	605.37
Vegetable	64.29	52.10	57.98	58.12
Others	21.29	13.38	11.13	15.27
Bamboo	140.06	79.27	89.92	103.08
Mushroom	23.25	11.90	46.08	27.08
Papaya	17.23	31.23	21.01	23.16
Fruit	89.64	77.03	79.83	82.17

5.4.4 Animal protein intake

Animal protein consumption can be classified into two groups. i) fish and OAAs and ii) other animals namely cattle, buffalo, pig, chicken and wild animals. Animal protein consumption in reservoir households (28.72 g/person) was slightly higher than in river households (26.95 g/person). Protein from meat intake in reservoir households was also higher than in river households, 13.19 g/person and 8.2 g/person, respectively (Table 5.8). By contrast, consumption of animal protein from fish and OAAs in river households (18.75 g/person) was greater than in reservoir households (15.53 g/person). Overall, protein consumption met the standard required; daily protein intake in reservoir households was 70.37 g/person and 69.3 g/person in river households (Table 5.9).

It is important to note that the differences in protein sources for reservoir and river households were from fish, OAAs, and animal meat. The reservoir households obtained more protein from meat and less from fish, while the river households received more protein from fish and less from meat. Again this was associated with the availability and accessibility of animal meats and reservoir households had the advantage of better accessibility to the market than river households.

Table 5.9. A proximate daily animal protein consumption (Source: Data from consumption monitoring).

	Protein g/person	Calories kcal /person/day	Percentage of animal protein
Reservoir			
Fresh and process fish	14.10	77.08	
OAAs	1.43	7.67	
Sub total	15.53	84.75	54.07
Meat	13.19	137.99	45.93
Total	28.72	222.74	
Rice	41.65	2202	
Grand total	70.37	2424.74	
River			
Fresh and process fish	16.50	89.60	
OAAs	2.25	13.26	
Sub total	18.75	102.86	69.57
Meat	8.2	93.85	30.43
Total	26.95	196.71	
Rice	42.35	2239	
Grand total	69.3	2435.71	

5.5. DISCUSSION

5.5.1 Food consumption pattern

People living around the reservoir and XBF obtained their foods from the forest, river and markets. Fish, OAAs, vegetables and NTFPs were available all year round. Most of the people engaged in fishing, collecting OAAs and NTFPs for subsistence. Fish and OAAs accounted for 35% of all foods by weight, and on an average of 62% (54% in reservoir and 70% in river) of animal protein intake. OAAs, in particular snails and frogs, were a crucial source of animal protein, not only in the wet season but also in the dry season when other foods were limited or not available. The estimation of fish consumption in this study was 36 kg/person/year (reservoir village 31 kg, river 41 kg). The results of fish consumption from this study is comparable with other studies. Singhanouvong & Phouthavong (2003), using a one-year-recall interview method in the most productive fishery in the Mekong River in the Champasack Province, southern Laos, estimated fish consumption at 45.1 kg/person/year. The national average fish and OAAs consumption determined by the Mekong River Commission, based on a literature review of different data sources, was 43.5 kg/person/year (Hortle 2007). LECS4 (2009) estimated fish consumption in central Laos, based on household expenditure, was 28.26 kg/person/year. Garaway *et al.* (2013) found annual fish consumption per Adult Equivalent Units in a household survey in the rice field ecosystems in three provinces of Laos to be 25.2 kg/person/year. The differences found between studies were due to the methods used and environment (the Mekong River vs. tributaries, rice fields vs. reservoirs). In addition, fish consumption in the reservoir was lower than the river, due partly to the reservoir being newly built (only 16 months when monitoring started); and the fishers still adapting to the new environment (from flowing to standing and deep water) and new fishing methods. They also needed to balance the catches for consumption against selling to buy rice.

The consumption of animal meat was different in the reservoir and river. The people living in the reservoir close to the district centre and market consumed more meat than people living relatively far from the city. It was likely that the urban fishers had to work hard to earn money to buy food; they had to put more effort and time to compete and get more fish for subsistence and income. The people living far from the district centre, had least access to good roads and infrastructure, but had greater access to natural resources, this group of people heavily depended on the wild, they could live with a minimum income and gather fish for subsistence and exchange for goods.

Meat consumption declined during the monitoring period; it was a good example of how people cope with the situation when beef prices soar due to a shortage of supply, people shifted to cheaper and affordable meat (e.g. pork, chicken) and fish to supplement the beef. Fishers apply a similar strategy when they cannot catch fish; they rely on preserved fish, OAAs or meat. Consumption of meat in the reservoir and river villages was different in both wet and dry season. The daily meat consumption in the reservoir was 70.30 and 45.52 g/person/day in the river, or an average of 21 kg/person/year (25.65 kg for reservoir households and 16.61 kg for river households). This finding was consistent with the LECS4 (2009) report, the average meat consumption for the rural with road access was 20 kg/person/year.

The consumption of preserved fish is low (3-6% of total weight of aquatic animals) compared with other studies (Table 5.10). The national average of processed fish accounts for 39% of aquatic animals consumed; and about 42% in Nam Ngum reservoir. This is because the results cannot be directly compared due to the different methods used; this study did not directly account for fermented fish (liquid) that was more frequently eaten by rural people. In addition, the national average and the estimate for Nam Ngum reservoir were based on recall methods from the individual interviews.

Wild animals were found to play a crucial role in the food security of the poor by Fenton *et al*. (2010), accounting for over 30% of animal meat consumed, but some researchers (Mollot *et al.* 2003; Meusch *et al.* 2003) including this research could not confirm these data. Meusch *et al.* (2003) stated that the reason why the contribution of wild meats was low was partly because of the introduction of regulations to protect wild animals since 1997. A campaign on the dangers of eating wild meat due to diseases and health problems caused by the chemicals used to preserve the meat for longer use, may also have contributed to a change in eating habits of many people in the rural areas. In addition, hunting and poaching wild animals during the breeding season (July to October) is prohibited and subject to prosecution (National Assemble 2007).

Table 5.10. Comparison of contribution of aquatic animal foods consumed with other studies.

Descriptions	Fresh fish (%)	Preserved (%)	OAAs(%)
Mattson *et al.* 2000: Nam Ngum reservoir	58	42	NA
Singhanouvong *et al* 2003: Mekong river (Khong Island)	63	20	18
Hortle 2006: National average	43	39	19
Garaway *et al.* 2013: Rice field ecosystem	50	NA	50
This study			
Nakai reservoir	75	6	18
Xebangfai river	72	3	25

Apart from animal food sources, NTFPs also play a very important role in food supply; most people in the river areas collected NTFPs from the forest and wetlands for food security and income generation. The consumption of NTFPs, including OAAs, was associated with seasonal changes - people consumed more NTFPs in the wet and transitional seasons than in the dry season (Section 5.4.1 and 5.4.3). This illustrates the natural cycle of food availability that allows local people to exploit seasonal changes. Access to natural resources and distance to the market also influence consumption patterns of the reservoir and river households. The people who have greater access to forest and river resources (river households) consumed more NTFPs and OAAs than people that have limited access to these resources(reservoir households). By contrast, the households with easier access to the markets consume more meat than households living far from the markets.

As expected, rice consumption was higher than other foods. Rice is a very important food for the farmers who practice agriculture and most of their energy came from rice. This study estimated average rice consumption is 600 g/day. This finding was similar to the result from the LECS4 study that found rice consumption in rural areas of Khammouane province was 592 g/day and 534 g/day for urban areas (LECS4 2009).

This study suggests that people who live around the reservoir and along the XBF bank are highly dependent on natural resources (e.g. forest and river) for their food security and income. At the same time they are highly vulnerable to climate and hydrological changes. Any changes to natural resources as a consequence of climate change or human development will affect the food chain of people who depend on it for their daily meals. It will be worse for the people who still live in poverty and have limited capacity and assets to adapt to these changes. Forming new reservoirs and changing flow downstream can destroy aquatic animal resources that serve as food for the people. Fishers had to take more time and effort to get enough fish and other food for their daily meals. Some households also engaged in off-farm activities as alternative income sources to ensure their food security.

5.5.2 Energy supply

In general, food supply and consumption in Laos has increased over the last decade. This was associated with socio-economic development and improvements of infrastructure that give people better access to markets and food supply. Rice consumption decreased from 72% of the food intake in 1990-92 to 64.2% in 2006-08 (Table 5.11). It has been suggested that when the livelihoods and well being of people improves their eating habits also change. Better-off people seem to consume less rice but more meat. Meat consumption rose from 2.5% in 1990-92 to 3.1% in 2006-2008; a similar trend was also observed in fat consumption. LECS4 (2009) reported a similar food consumption pattern, with rice consumption declining 4.1% (from 43% in 1993 to 39% in 2008) but other food items, such as meat, cereals and bread, milk, cheese and eggs, rising by 3.5%, 0.8% and 0.3%, respectively.

In accordance with FAO (2000) the basic daily energy requirements of a person varies between 2000 and 2350 kcal/person, depending on sex, age and level of physical activity. In addition, protein intake should be at least 10-12% of energy intake and fats 15-30%. For farmers during rice planting and harvesting, energy requirements may increase to up to 3000 kcal/person/day.

This research found that the people in the reservoir and river villages consumed a variety of foods and in considerable quantities to meet their energy requirements. There was no concern about daily energy consumption, but there is a concern over vitamin and micronutrient deficiencies due to eating small quantities of food from animal sources. There are many alternative approaches to combat micronutrient insufficiencies, but the main way is to diversify food intake and increase the consumption of animal food sources, including fish and eggs that contain amino-acids as well as micronutrients (FAO *et al.* 2012).

Table 5.11. Food consumption indicators (Source: FAO Food security: Laos country profile).

	1990-92	1995-97	2000-02	2006-08
Major food commodities consumed (percent)				
Rice, milled	72	71.2	66.5	64.2
Flour of maize	5.6	4.9	6.2	5.4
Pig meat	2.5	2.9	2.6	3.1
Vegetables	0.4	0.5	3.3	2.8
Food Supply for Human Consumption				
Dietary energy supply (DES) *(cal/person/day)*	2010	2040	2120	2240
Total protein consumption (g/person/day)	49.0	50.7	57.1	60.7
Animal protein consumption (g/person/day)	6.6	8.7	10.9	13.1
Fat consumption (g/person/day)	22.1	25.4	26.8	31.8

5.5.3 Micronutrient requirements

Micronutrient deficiencies still occur and affect more than 30% of the world's population (FAO *et al*. 2012). The impacts include reduction of working capability and loss of human potential. Moreover, Vitamin A, B, D, iron, zinc and calcium deficiencies still persist in developing countries, as a result of consuming only certain foods with a limited amount of important micronutrients (FAO *et al.* 2012). Low intakes of these micronutrients will affect bone health and neuromuscular function in children, especially vitamin D deficiency and inadequate calcium in the diet will lead to childhood diseases such as rickets. Daily micronutrients required for females and males are presented in Table 5.12.

In remote areas where many people still living in poverty, most of their micronutrients come from traditional food products from the river and forest. This study confirmed that fish, OAAs and NTFPs are the main sources of protein and nutrients. Many scholars acknowledged that small and by-catch fish contain high sources of micronutrients such as vitamin A, calcium, iron and iodine (Roos *et al.* 2003; Nurhasan *et al*. 2010; Kabahenda *et al.* 2011). In addition, traditional processing of products, namely dried, salted, fermented fish and OAAs, are high in calcium content (Sverdrup-Jensen 2002; Udomthawee *et al.* 2012).

Many studies have proved that when people eat small fish (whole fish), they receive a great amount of calcium. Roos *et al.* (2007) studied the content of vitamin A in fresh water fish of selected Cambodian fish species and found that *P. siamensis* and *Rasbora tornieri* had the highest vitamin A content (more than 1500 g), followed by

Barbodes sp. and *P. proctozysron* (500-1500 g), *C. micropeltes* and *C. apogon* (100-500 g).

Table 5.12. Nutrient requirements for adults (Source: FAO 2000 Status of Food Insecurity in the World 2000).

Nutrient	Female *per day*	Male *per day*	Female *per 1000 kcal*	Male *per 1000 kcal*
Calcium (mg)	1000	1000	500	350
Iron (mg)	24	11	12	4
Vitamin A (µg)	500	600	250	210
Vitamin C (mg)	45	45	23	16
Vitamin E (mg)	7.5	10	3.6	3.6
Niacin (mg)	14	16	7	6
Protein (g)	50	63	25	22.5

Nurhasan *et al.* (2010) studied micronutrients in fish and OAAs in rice field ecosystems in Laos and found crabs, snails and frogs contained considerable amounts of calcium ranging from 525 mg to 6800 mg (Table 5.13). By contrast, crabs, snails and fermented fish have low protein content (7.8-16.3 g).

The consumption monitoring did not cover the intake of oils and fats as it is used in very small amounts and seldom used in preparation of food. However, when cooking methods were assessed the main foods were boiled, streamed and grilled, and fried foods only made a low contribution to diets. It can thus be assumed that the consumption of oils and fats in the study households was low. This supports previous studies in southern Laos that found the rural people rarely intake food rich in oil and traditional foods did not use much oil and fats (Meusch *et al.* 2003). This is despite the recommendation of a daily caloric intake of 60% carbohydrate, 10% protein and 30% fat (Guthrie and Picciano 1997, cited by Meusch *et al.* 2003).

Table 5.13. Micronutrient contents of fish, OAAs and fermented fish (Source: Nurhasan *et al.* 2010).

Common name	Ca mg/100 g	Fe mg/100 g	Zn mg/100 g	Fat g/100 g	Ash g/100 g	Protein g/100 g
Swamp eel	525	1.1	1.4	0.8	2.4	19.7
Walking catfish	299	0.6	0.9	3.0	1.4	19.0
Snake head	71	0.3	0.7	0.4	1.3	18.0
Crab	6800	10	3.1	0.4	17.4	16.3
Small apple snail	1200	4.3	8.1	0.4	4.0	13.0
Golden apple snail	444	48	6.9	0.1	0.3	11.6
Big apple snail	812	102	12	0.4	3.4	11.8
Chinese frog	1300	0.9	1.7	0.8	3.9	17.3
Fermented fish	235	8.5	0.9	0.4	8.1	7.8

5.5.4 Food and nutrition security

The World Food Summit 1996 defined food security as "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO 2006). This definition of food security reflects four dimensions, viz. food availability, food access, food utilisation and food stability.

1. Food availability refers to adequate qualities and quantities of food that households can obtain from markets and local shops (FAO 2006). The result from this study indicated that reservoir village households had more opportunity to obtain foods than river village households, because almost every type of food was available in the market, in particular beef and other animal meats. The river village households faced difficulty in getting animal meat from the market and relied on local shops or mobile markets to acquire some foods. However, not all households in the reservoirs benefit from the availability of foods in the market as they could not afford to buy some food types or some ethnic minorities were reluctant to eat some animal meats. This is in line with the link between food availability, domestic food supply and the ability to purchase food from external sources described by Barrett & Lentz (2009). More available food does not necessary mean people will get enough food to eat; it also depends on financial capabilities, and cultural and eating behaviours of individual households.

In the current study, availability of particular meats (beef and pork), seafood and processed foods was associated with infrastructural development (roads and markets). There was more food available where infrastructure had been developed; by contrast, limited food availability occurred in isolated villages with poor roads and no markets. The villages along the river were self-sufficient in food, relying on their own food production (rice, vegetation and poultries), while the reservoir villages depended both their own production and purchased foods.

2. Food access can be defined as households gaining access to adequate resources for acquiring suitable foods (FAO 2006). In Laos, natural resources, including forests, and water resources, are common properties - all people have a right to access in accordance with the rules and regulations of the host community. However, in some cases access rights have been given to specific communities, for instance in Nakai reservoir where the fishery has been allocated only to the villages affected (relocated).

Both reservoir and river households depend on forests and rivers for their living. Collecting NTFPs, fishing and hunting were the main sources of food for the river households. Agriculture products, such as rice, vegetables and poultry, were also important sources of food, in particular rice that is considered the main staple and consumed at almost every meal. In terms of accessibility to food, especially NTFPs, reservoir households had limited access to forests because they had been inundated by the reservoir. People had to go long distances to collect NTFPs from the NBCA. Household resources, food prices and food preferences were the main drivers of food access (Pieters *et al.* 2013). Household resources covered labour, human capital, assets and natural resources. In the study villages, woman played a very important role in acquiring food from the wild and contributed to agricultural production, including gardening and raising animals. Other studies also found that woman contributed to the food and income generation of families through their labour (Hopkins *et al.* 1994; Hoddinott & Haddad 1995, cited by Pieters *et al.* 2013).

According to Pieters *et al.* (2013) food availability and food access may overlap where local markets do not exist. In the river villages where local markets were not available, households depended heavily upon their own food production as a means to access food, thus food access and food availability are from the same sources.

3. Food utilization can be described as individual daily food intake with sufficient diet, not only in terms of quantity and quality of food but also the calories, micronutrients and sanitation to meet energy needs for physical activities (FAO 2006). Both reservoir and river households consumed various foods but most of the protein and calories came from rice. As mentioned earlier, rice is a staple food of the Lao people, contributing nearly 60% of daily protein intake and up to 90% of calories were from rice (Section 5.4.3). In terms of protein and energy requirements to meet the needs of daily physical activities, both reservoir and river households had adequate protein and calories with an average protein intake of 70 g/person/day and 2431 kcal/person/day.

The main concern of food utilization in the study areas was insufficient intake of micronutrients and poor sanitation. As most of the important micronutrients (iron, zinc, vitamins A, D and E, calcium) come from animal food sources, mainly from meat and fish, the small quantities of meat (average of 58 g/person) and fish (98 g/person) consumed by the reservoir and river households was considered low (Section 5.4.3). In addition, the consumption of oils was also low because of the traditional cooking methods, which tend to use little oil and fats. According to FAO (2013), insufficient micronutrient intake could weaken the immune system and increase vulnerability to infection and disease. There are several other important factors contributing to the wellbeing of the households, notably lack of availability and access to food; inadequate health services and poor water and sanitation; and poor food selection, poor child-care practices and inadequate nutritious supplement feeding. This study did not cover hygiene aspects of food and drinking water but information from field observations showed that sanitation also created health and safety issues. Diarrhoea and liver fluke were commonly found amongst people in rural areas; these symptoms and disease were caused by either consuming foods not cooked properly or poor sanitation in cooking and living conditions.

It is important to note that fishes and OAAs are rich of protein and micronutrients in particular vitamin A, calcium, iron and iodine (Roos *et al.* 2003; Nurhasan *et al.* 2010). There is now considerable evidence linking the consumption of adequate fish to improved brain development and enhanced vision and eye health of children (FAO 2013). To overcome the micronutrient deficiencies requires more support, funding and resources to encourage people to eat more meats as supplementary foods and supplements are impractical, because rural people cannot afford to buy these expensive foods. Instead awareness raising about the importance of micronutrients to individual health and encouraging people to eat more fishes and OAAs may be the starting point for eradication of micronutrient deficiencies.

4. Food stability is a very important measurement of food and nutrition security. According to the FAO (2006), the concept of food stability covers the availability and access dimensions of food security, meaning households have to have access to sufficient foods at all times. In the study villages, people were vulnerable to stability of food due to uncertainty in stressor events (e.g. severe floods and droughts) and hydrological changes caused by dam operations. The reservoir households were asset poor, had little land for planting rice or vegetables and usually relied on capture fisheries to maintain food security, while the river households, which had more land for rice fields and were generally self-sufficient for rice, also depended on wild fishes for food and income saving.

The severe floods in 2008 and 2011 in the XBF affected hundreds of households which lost their properties, rice fields, crops and livestock. At that time people relied on aid from the government and international organisations that provided some goods for living and seeds for agriculture. The indirect impact of the severe weather also disturbed the livelihoods of people; many households were unable to plant rice in the following year fearing that floods would damage their crops again. The changing water flow in the dry season due to Nakai dam, which started to operate in 2010, has also affected to the livelihoods of people who live along the XBF bank. People could not fish as in the past, and aquatic animals, such as snails and shrimp that could normally be found on the riverbed or in shallow water also disappeared. Fishers had to go further afield to small streams or wetlands to capture fish and OAAs for their food.

Many factors contribute to household food security, not only in terms of the food dimension but also socio-economic, culture, education, health and infrastructure development of the village or communities. The reservoir and river households meet their minimum daily requirements of protein and energy supply. However, there is a need to increase micronutrient intake and sanitation of the households in the rural areas where people are still living in poverty and infrastructural development is poor. Recent reports indicate that improved health care, sanitation and raising awareness about the importance of micro nutrients to child growth will lead to a more healthy population (MOH & LSB 2012), and these issues are equally important, as the need to maintain fish and OAAs in the diet.

CHAPTER 6: CLIMATE CHANGE AND ADAPTATION

6.1 INDRODUCTION

Global climate change has been observed for some decades. This change involves an increase in average air and ocean temperatures, and rising average sea level (IPPC 2007). The causes of change are mainly increases in greenhouse gases, changing land use and solar radiation (IPPC 2000). According to the IPPC (2007) climate change projections global average temperatures will increase as will extreme periods of drought and intense precipitation, and the intensity of tropical cyclones and storms. The changes will bring significant negative impacts to the environment and the livelihoods of people if there are no mitigation plans in place to minimise these impacts (Ficke 2007). People in developing countries whose livelihoods are dependent on natural resources for subsistence are likely to be the most vulnerable to severe weather pattern changes (Allison 2006).

Climate change and its impacts on the environment and the people of the LMB are not new. Historical evidence has shown that floods and droughts have destroyed agricultural production and property affecting millions of people (World Bank 2011). It is very difficult to predict climate change in the LMB (Allison 2006) because of poor tools for assessment, limited baseline and historical data, and limited funds and capacity (MRC 2009b). However, several studies have attempted to predict climate change in the LMB, but the results vary in terms of predictions about increasing temperatures and flows depending on the method used and prediction zones. Adaptation to and mitigation of climate changes differ from place to place; successful mitigation options depend on the socio-economic conditions, capacity and availability of potential livelihood options to cope with the changes. In addition, there is no single tool or sector that can eliminate the impact of climate change (IPPC 2014), it requires integration of climate change impacts into the planning of all sectors to ensure that every project has sufficient measures to cope and minimise the impacts of climate change in their sectors. This study reviews the impacts of climate change in the LMB, focusing on current climate and hydrology. It summarises climate projections and impacts in the LMB and downscales to assess potential adaptations and responses to climate change at the national and community levels in Laos.

6.2. CLIMATE CHANGE, IMPACTS AND CLIMATE PROJECTION

6.2.1 Overview of climate and hydrology

Mekong catchment

The Mekong River is the longest river in Southeast Asia, with a total length of 4,800 km from its source in the Upper Mekong Basin in Tibet, China, to the Mekong Delta in Vietnam. The Mekong River has a total catchment area of 795,000 km^2, covering six countries (China, Myanmar, Laos, Thailand, Cambodia and Vietnam). The Upper Basin covers 24% of the total catchment area and contributes 18% of the flow to the Mekong River, while Laos contributes a large proportion of both catchment area and flow, accounted for 25 and 35%, respectively (Table 6.1).

Table 6.1. The countries contributed to the Mekong River Basin catchment areas (after MRC 2005b).

Description	China	Myanmar	Laos	Thailand	Cambodia	Vietnam	Total
Area (km^2)	155,000	24,000	202,000	184,000	155,000	65,000	795,000
Catchment as % of MRB	21	3	25	23	20	8	100
Flow as % of MRB	16	2	35	18	18	11	100

According to the MRC (2005b), the Mekong River can be classified into six hydrological reaches (Figure 6.1) based on hydrological characteristics, physiography, land use, and resource development (existing, proposed and planned).

Hydrological Reach 1: China-Upper Mekong River (Lancang Jiang). The main source of flow in this section comes from melting ice on the Tibetan Plateau. This flow is very important as it maintains the low flows of the LMB. The Lancang Jiang flow contributes up to 30% of the average dry season flow in Kratie, in Northern Cambodia.

Hydrological Reach 2: Chiang Saen to Vientiane and Nogkhai. This section consists of mountainous areas with natural forest and upland swidden agriculture areas (areas cleared for temporary cultivation by cutting and burning the vegetation). Before 2010, there were no plans for mainstream dams and the hydrological regime was the most natural and undisturbed in the entire LMB. The development of tributary dams in Laos, the diversion water from the Mekong Basin to south-flowing basins in Thailand and the recent construction of the first mainstream dam in the LMB - Xayabury dam - will have significant effects on the hydrology of the LMB.

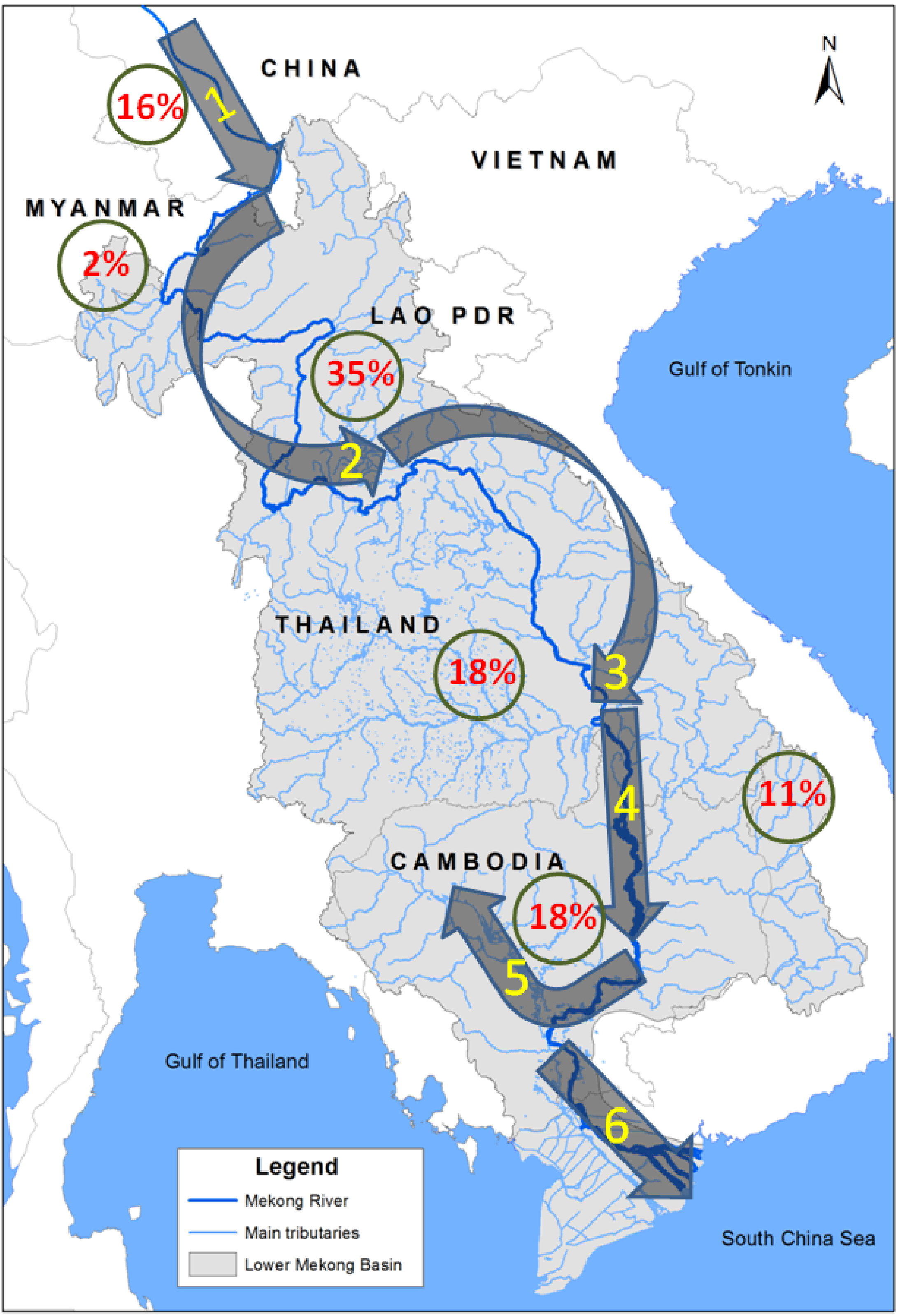


Figure 6.1. Hydrological reach of the Mekong River. Modified from MRC 2005b (Number in arrow is hydrological reach zone, the percentage value in the circle represents the flow contribution to the Mekong from different country).

Hydrological Reach 3: Vientiane and Nogkhai to Pakse. The flow in this section is influenced by the large tributaries in Laos, such as Nam Ngum, Nam Theun, Nam Hinboun, Se Bang Fai, Se Bang Hieng and Se Done, and the Mun-Chi river system on the right bank in Thailand is also connected to the Mekong River in this reach. The hydrology of this section is different between the left and right banks of the Mekong. The Mun and Chi rivers (right bank) are highly developed with reservoirs for dry season irrigation while the left bank Lao tributaries are increasingly being developed for hydropower and irrigation for expansion of dry season rice production.

Hydrological Reach 4: Pakse to Kratie. The main flow input to this section comes from the 3S rivers (Se Kong, Se San and Sre Pok), accounting for more than 25% of the mean annual flow of the Mekong in Kratie. In addition to the 3S flow, the Tonle Sap reversal flow in the dry season also contributes a significant flow to the mainstream river. The 3S catchment forms the largest hydrological subcomponent of the Lower Basin. The main issue in this section is the impacts on flow regimes from the hydropower operation of Yali dam on the upper Se San in Vietnam but the whole system will potentially be impacted by the Lower Se San 2 dam at the confluence of the Se San and Sre Pok rivers, as well as many other dams proposed for the 3Ss system.

Hydrological Reach 5: Kratie to Phnom Penh. This section consists of the Cambodia floodplain, the Tonle Sap and the Great Lake system. More than 95% of the total flow from these systems enters the Mekong mainstream. This reach is potentially going to be impacted by the proposed dams at Sambor and Strung Treng.

Hydrological Reach 6: Phnom Penh to the South China Sea. In this reach, the Mekong divides into many branches and canals that form the delta. The important flow regime is influenced by the tide, which also regulates salt water intrusion. Between 35 and 50% of this area is inundated annually during the rainy season.

Temperature

The mean monthly temperature in the Mekong basin varies between the upper and lower Mekong Basins. In the upper Mekong (Jinhong) where the altitude is above 500 m asl, the mean monthly temperatures are lower than in the LMB, where the altitude ranges between 10 (Phnom Penh) and 282 m asl (Chiang Ria).

Mean monthly temperature in the LMB varies little between the dry and wet seasons (Table 6.2). Temperatures in the wet season - from May to September - are similar throughout the LMB from Chiang Rai (Thailand) in the north to Pakse (Laos) and Phnom Penh (Cambodia) in the south. However, dry season mean monthly temperatures decline from south to north, from 26-27 °C in Phnom Penh to 21-23 °C in Luangprabang and Chiang Rai.

Table 6.2. Mean monthly temperature (degree Celsius) at selected sites (Source: MRC 2005b).

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jinhong	15	18	21	24	26	26	25	25	24	23	18	16
Chiang Rai	21	22	26	30	29	27	28	27	27	27	23	21
Luangprabang	22	23	26	28	28	28	28	28	27	27	24	21
Vientiane	24	25	28	29	29	29	28	28	28	28	25	23
Khonkaen	24	25	28	29	28	28	27	27	26	26	25	23
Pakse	26	27	30	30	29	29	28	28	28	28	26	25
Phnom Penh	27	28	30	31	30	29	28	28	28	28	27	26

Rainfall

The climate of the LMB is influenced by the Southwest Monsoon, which can be divided into wet and dry seasons. The wet season runs from May to September or early October while the dry season lasts from November until March. However, there are transitional periods between these two in April and May when the weather is hot and dry (MRC 2005b). In the northern Central and Highland regions, the seasonal rainfall patterns peak in August, while the Korat Plateau and Cambodia floodplain have a single peak rainfall month in September. The peak rainfall month in the Vietnam Delta is in October. The annual average rainfalls in the Korat plateau, Cambodia floodplain and the Vietnam Delta are low (1210-1320 mm), compared with the Central Highlands and Central Region in Pakse that have high annual rainfalls (2050-2200 mm).

Hydrology

The mean monthly discharges of the Mekong River at different sites differ between the wet and dry seasons, and seasonal flows also vary from year to year. The peak flows occur during August - September whereas the low flows appear in between March and April (Table 6.3). At Pakse, the flows are more than 14 times higher in the wet season (26,300 m^3/s) than the low season (1,800 m^3/s) illustrating high between season variation. In addition, the flows at Pakse during August exceed 20,000 m^3/s in 9 out of 10 years, but exceed 34,000 m^3/s only one year in 10 (MRC 2005b).

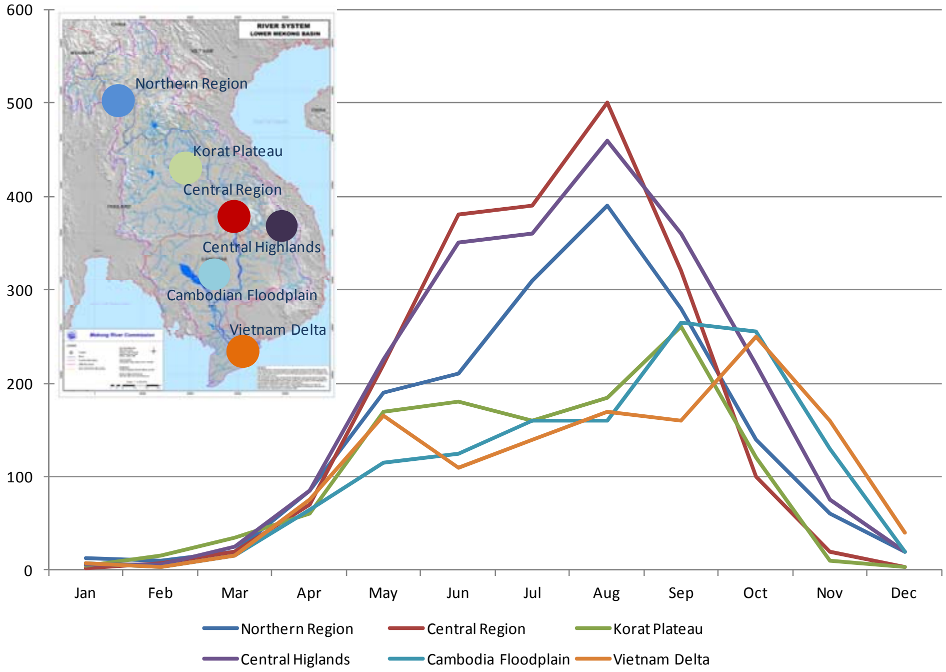


Figure 6.2. Seasonal average rainfall in the LMB (mm) (Source: ICEM 2013).

Table 6.3. Mean monthly discharge 1960-2004 (m^3/s) (Source: MRC 2005b).

Month	Mainstream site						
	Chiang Saen	Luang Prabang	Vientiane	Nakhon Phanom	Mukdahan	Pakse	Kratie
Jan	1,150	1,690	1,760	2,380	2,370	2,800	3,620
Feb	930	1,280	1,370	1,860	1,880	2,170	2,730
Mar	830	1,060	1,170	1,560	1,600	1,840	2,290
Apr	910	1,110	1,190	1,530	1,560	1,800	2,220
May	1,300	1,570	1,720	2,410	2,430	2,920	3,640
Jun	2,460	3,110	3,410	6,610	7,090	8,810	11,200
Jul	4,720	6,400	6,920	12,800	13,600	16,600	22,200
Aug	6,480	9,920	11,000	19,100	20,600	26,200	35,500
Sep	5,510	8,990	10,800	18,500	19,800	26,300	36,700
Oct	3,840	5,750	6,800	10,200	10,900	15,400	22,000
Nov	2,510	3,790	4,230	5,410	5,710	7,780	10,900
Dec	1,590	2,400	2,560	3,340	3,410	4,190	5,710

6.2.2 Climate and hydrological projections

The Intergovernmental Panel on Climate Change (IPCC) reported that the global average temperature has increased between 0.15 and 0.3 °C per decade between 1990 and 2005 (IPCC 2007). Based on future scenarios of change in global emission levels, global temperatures are projected to rise by 1.1 - 6.4 °C by the end of the 21st Century, if no actions are put in place to prevent temperatures rising. The future climate change IPCC predictions for South East Asia are similar to the global change patterns, such as an increase in temperatures, increase in annual rainfall by about 7%, and increased intensity and frequency of temperature and precipitation extremes.

As a result of these changes, it is likely that climate change will pose the following impacts on the Mekong ecosystem and its productivity (IPCC 2007):

- Water resources: Water will decrease by 10–30% in mid-latitudes and in the dry tropics. Drought areas will likely increase in size, while extreme floods are expected to increase in frequency.
- Ecosystems: Increased global average temperatures over 1.5-2.5 °C would damage ecosystem structure and functioning, in particular the ecological interactions between species and their habitats, mainly with negative effects for biodiversity and ecosystem goods and services;
- Crop production at lower latitudes will decline as a consequence of temperature rises of only 1-2 °C.

It is believed that developing countries and poor communities are likely to suffer the most from climate change hazards due to their geographical location, limited finances and weak capacity to adapt, especially as their livelihoods depend on rivers, forestry and agriculture. These resources are highly sensitive to climate change.

In the last decade several studies have been conducted on global warming and climate change impacts. These studies used different scenarios and models to predict the trends in climate change in the LMB (Snidvongs *et al.* 2003; Eastham *et al.* 2008; MRC 2009b; Hoanh *et al.* 2010; Schipper *et al*. 2010). The forecasted changes vary to some degree depending on the methods, models and sites. However, the results of all the studies indicate that over the next decade temperature will rise and rainfall patterns will change in the wet and dry seasons. The dry season rainfall will decrease in some areas but there will be an increase in severe and extreme weather events. Water flow is projected to increase in the wet season and bring extreme floods, while increases in water level in the dry season will alter the environment and affect agriculture productivity.

Temperature

Hoanh *et al.* (2010) projected that by 2050, mean annual average temperature in the LMB will increase between 0.7 and 0.8 °C with larger increases expected in the southern parts where temperature will increase by more than 1 °C (Figure 6.3). ICEM (2013) used climate threat modelling to project temperature changes in the LMB, and concluded that the annual average daily maximum temperatures will increase by 1.6 - 4.1 °C. The northern region will experience minor increases compared with the south and south-eastern region (Figure 6.4). In northern Thailand and Laos the increase in temperature is projected to be relatively low, below 2 °C, while in Korat Plateau (Thailand) the projected temperature will increase 1-2 °C. Dramatic changes in temperature are predicted in the southeast of the basin throughout the 3S river basins with an increase of greater than 4 °C. Increases in temperature will generally vary between seasons, with temperature changes in the historically cooler wet season, rising between 5 and 20% or 1.7 to 5.3 °C compared with rises of from 4.5 to 13% or 1.5 to 3.5 °C during the dry season.

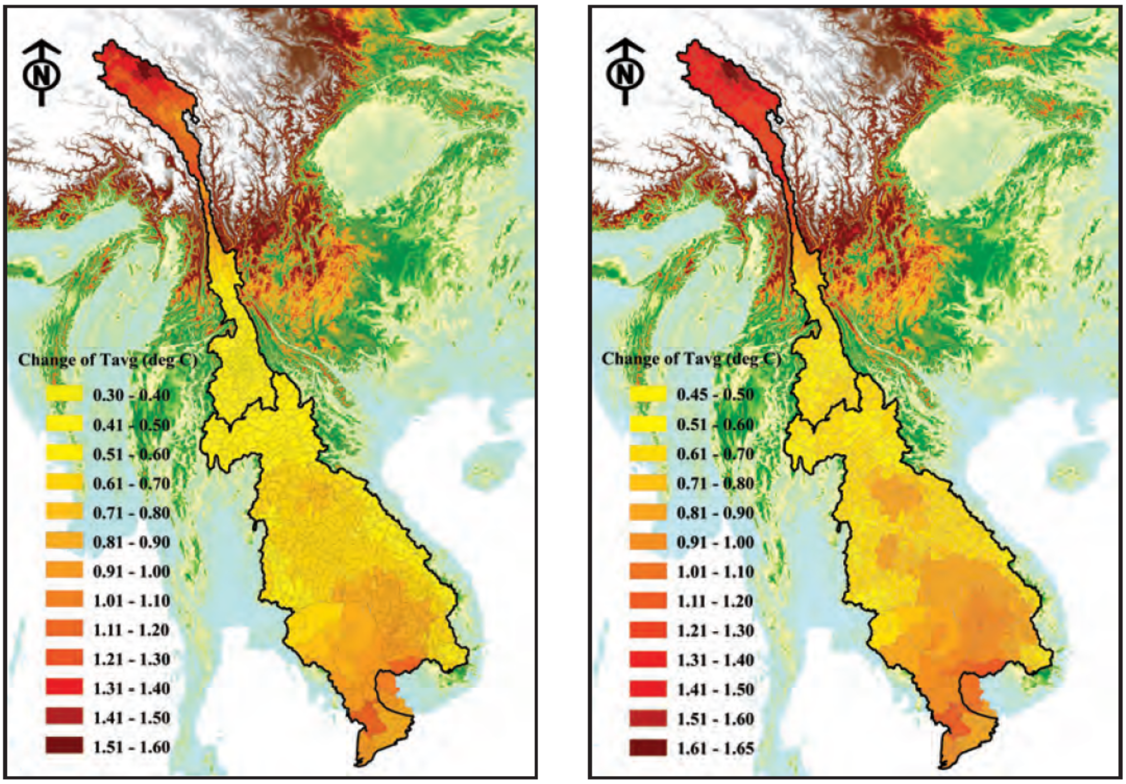


Figure 6.3. Projection of annual average temperature during 2010-2050 compared with 1985-2000. Scenario A2 (left) assumes high population growth with slower per capita economic growth and technological change, and B2 (right) assumes moderate population growth and economic development with less rapid and more diverse technological change. (Source: Hoanh *et al.* 2010).

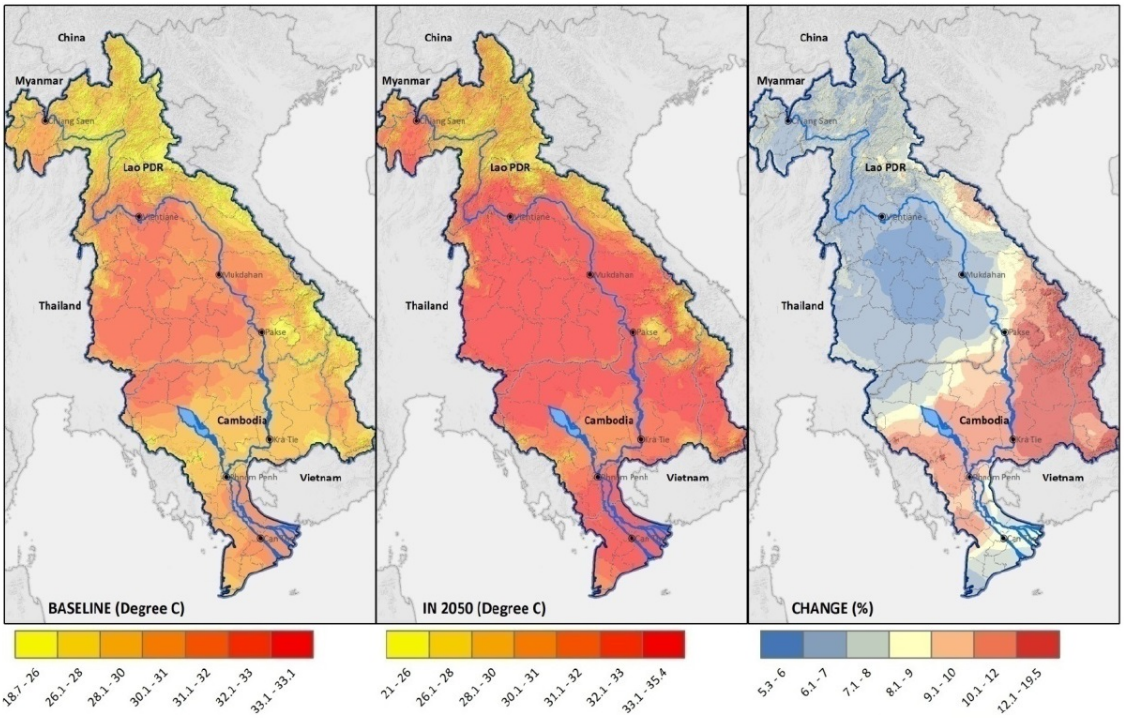


Figure: 6.4. Average maximum daily temperature in wet season (Source: ICEM 2013).

Hydrology and precipitation

ICEM (2013) projected the hydrology of the Mekong River will change with respect to timing and duration of flow in the wet and dry seasons due to changing patterns of rainfall and temperature. These changes include:

- Wet season will start 1-2 weeks earlier and last 2-4 weeks longer;
- Dry season will start 1-3 weeks later and last 1-3 weeks shorter;
- Transitional season will start 1 week earlier and will last 1-2 weeks shorter;
- Upper sections of the river will experience the largest delay and largest increase in flood season duration;
- Lower reaches will experience the least delay and the smallest increase in flood season duration.

In the wet season, total flow volumes are expected to increase approximately 54,000 MCM at Kratie while the dry season flows will decline at all stations as the seasons shorten. The peak flood pulse will intensify during August-September and the size of the flood peak is expected to increase at all stations. Chiang Saen will experience the smallest flood increase (1,200 m^3/s), while the flood size is projected to increase by 6,200 m^3/s in the downstream station in Kratie (ICEM 2013).

The annual Mekong flood pulse will increase with climate change (Figure 6.5). Annual minimum daily flows will rise up to 100 m^3/s, while annual maximum daily flows will increase to 10,000 m^3/s (ICEM 2013).

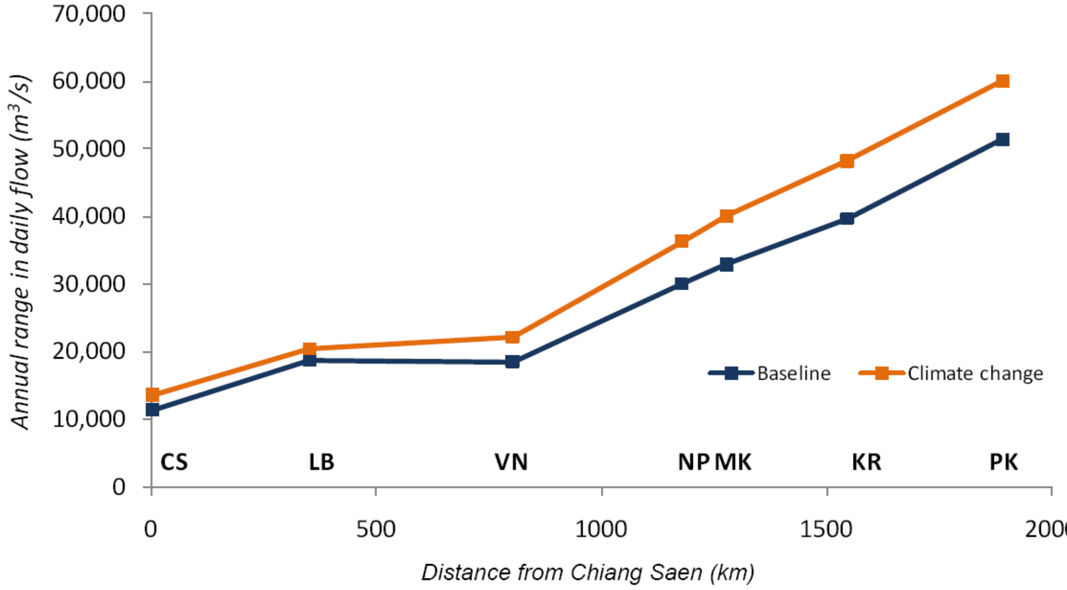


Figure 6.5. Average annual flood of the Mekong under baseline and climate change conditions. CS-Chiang Saen, LB-Laungprabang, VN-Vientiane, NP-Nakhon Pranom, KR-Kratie, PK- Piek Kdam (Source: ICEM 2013).

Annual precipitation in most of the LMB is expected to increase by 1-10%, except in some parts in northern Laos and central Vietnam (Hoanh *et al.* 2010). Precipitation is expected to decrease by up to 8% in some southern areas (e.g. Vietnamese Delta), (Figure 6.6). The predicted changes in precipitation are expected to increase both wet (2-6%) and dry season flows (11-13%) in the Vietnamese Delta (from the MRC's baseline scenario), equivalent to an annual increase in discharge from 4 to 8% (Hoanh *et al.* 2010).

Tropical cyclones and storms

The LMB is influenced by two cyclone systems namely the Pacific Ocean east of the Philippines and the South China Sea. A cyclone occurs at least once every two years with high winds and a large volume of rainfall that causes flooding and damages property. Based on global climate changes projections, the average cyclone strength will increase by 10% and the proportion of Category 4-5 cyclones will also increase (ICEM 2013).

Estimated increases in precipitation in the LMB will also be influenced by cyclone intensities. It is anticipated that the peak daily precipitation of the LMB will increase over 5%. In the 3S system and central Cambodian floodplain, the peak precipitation will increase greater than 16%.

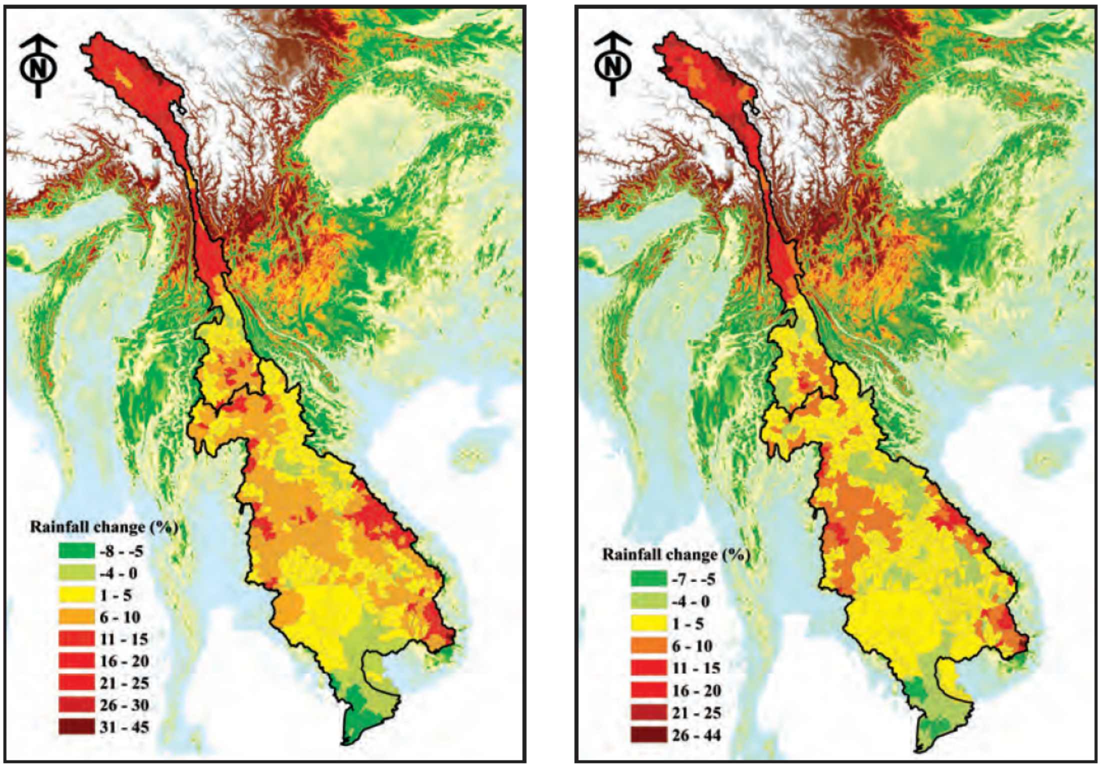


Figure 6.6. Projection of mean annual precipitation during 2010-2050 compared with 1985-2000. Scenario A2 (left) assumes high population growth with slower per capita economic growth and technological change, and B2 (right) assumes moderate population growth and economic development with less rapid and more diverse technological change. (Source: Hoanh *et al.* 2010).

Flooding

It is projected that sea level will rise and the depth and duration of average floods in the Vietnamese Delta and Cambodia floodplain will increase. Maximum flood depths along the South China Sea coastline are projected to increase by 1.0 m. It is estimated that 19% of the total delta area (600,000 ha) that historically never flooded will be flooded and the flood duration will increase by four or more days during an average flood year. In the floodplains, 5% of the total area (210,000 ha) that historically rarely flooded will experience floods of over 0.5 m for four or more days a year.

6.2.3 Impacts of climate change in the LMB

Fisheries and Aquaculture

Information on the impacts of climate change on natural resources including fisheries in the LMB is limited. It is difficult to predict the direct adverse impacts likely to be caused by climate change on fisheries due to the complexities of the ecology, high species diversity and inadequate biological information. However, the cumulative impacts that will likely threaten fisheries will probably be evident through alteration of fish population dynamics and declining production. This will likely be similar to many of the impacts likely to arise from hydropower and agricultural development and indeed it may be difficult to discriminate climate change impacts from water resource development impacts.

Fishery resources in the LMB are already stressed from other anthropogenic changes (e.g. dams, mining, deforestation), population growth and high market demand for aquatic products. Climate change will add more pressure to these cumulative impacts that will affect fish populations, recruitment and species biodiversity. In general, the potential impacts of climate change on inland fisheries will likely be an increase in water temperatures and changing hydrological regimes (Ficke *et al.* 2007, Halls 2009). Fish are very sensitive to water temperatures, and rising temperatures will decrease dissolved oxygen levels in water, but this is coupled with increasing metabolic rate of fish that will require more oxygen and food intake (Halls 2009). As fish are poikilothermic, metabolism, growth and reproduction are likely to be influenced, possibly negatively, by the altered temperature regime (Franklin *et al.* 1995). Increasing water temperature may alter reproduction processes, slow growth rates of some species and increase mortality rates of both wild and cultured fishes (Ficke *et al.* 2007). In addition, higher temperatures are associated with increased occurrence of some diseases (Karvonen *et al.* 2010) leading to reduced fish survival and declines in production.

Increased precipitation in the wet season due to climate change may provide more floodplain habitats and feeding and breeding areas for fish, which will likely increase fish production (Welcomme *et al.* 2010). However, alterations in the timing and duration of the floods will potentially disturb spawning processes (Welcomme & Halls 2001). Decreased flows in the dry season have the potential to alter dry season habitats and limit food resources for fish, as many fish species use deep pools for shelter in the dry season. If these areas dry out or hold insufficient water for fish to survive, this will directly impact on broodstocks that are vulnerable to predators or being caught by fishers. Fish life cycles are associated with, and depend on, natural flow regimes and temperature cycles for migration and reproduction. Changes in these characteristics will affect fish production and diversity. However, not all species will be negatively affected by climate change; species that can adapt to the changing conditions, may benefit and maintain productivity, while other less adaptable species may be lost from the system (ICEM 2013). It is important to recognise that alien invasive species introduced for aquaculture, such as common carp and tilapia species, are likely to benefit from climate change effects and potentially explode in the communities and their contribution to catches.

As mentioned in Chapter 2, fish species in the LMB can be classified into white, black and grey fishes. The potential impacts of climate change on these fishes are different depending on their biological characteristics and tolerance to specific climate conditions.

White fishes include *C. microlepis* and Pangasiidae catfishes that are usually commercially valuable, and account for 37% of the Mekong species. These white fishes are intolerant of low oxygen (Welcomme *et al.* 2006a), and likely to decline in production when the time of flooding is changed or in the face of extreme floods and droughts caused by climate changes that will potentially disrupt their seasonal breeding and prevent drifting larvae reaching the floodplains.

Black fishes are well adapted to adverse environmental conditions and can survive in low oxygen levels (Welcomme *et al.* 2006a), which allows them to live in swamps or lakes with low water levels during the dry season. However, black fish are negatively affected by drying or modification of the floodplain. These species include *C. striata, C. batrachus* and *A. Testudineus*. This guild contributes 13% of the total species catch.

Some grey fishes species are also tolerant of low dissolved oxygen (Welcomme *et al.* 2006a). This group accounts for 50% of Mekong species and includes *Mystu*s catfishes (e.g. *M. mysticetus, H. filamentus*), *W. attu,* and *C. ornate*.

The group most vulnerable to climate change is the white fishes that require high oxygen levels and undergo long-distance movements, while black and grey fishes are more tolerant of low dissolved oxygen levels and with only limited movements are potentially less vulnerable to extreme weather conditions. A small temperature increase of 1-2 °C will potentially affect reproduction of fishes when it is combined with other stressor effects associated with the disrupted flow regime (Ficke *et al.* 2007). Barlow *et al.* (2008), based on an analysis of different fish guild group, concluded that the migratory fish species were most at risk from the mainstream dam developments in the Mekong River. They found at least 58 species (38.5% of the total catch of 233 species) were vulnerable to dams; these belong to the main channel resident, main channel spawner, semi-anadromous and catadromous guilds. They estimated that between 0.7 and 1.6 million tonnes of fish would be lost annually because of problems created by the dam developments. It is likely the same species are vulnerable to climate change effects with the same outcome. Assessment of the impacts of climate change on fisheries in six selected provinces in the LMB indicated that upland fish species and long distance migratory fishes will be most vulnerable to climate change in Chiang Rai, Gia Lai, and Mondulkiri (ICEM 2013). In addition vulnerability assessments of fish guild structure concluded that upland fish will be the most vulnerable, migratory white fish will be vulnerable, black fish will be low or not vulnerable and alien species will benefit and spread as a result of climate change.

Increased temperatures, storm intensity and changes in rainfall will directly affect fish biodiversity and productivity. Some of these effects, such as reduced dry season rainfall and increased temperatures, will form adverse conditions for some species that use deep pools for refuge or undertake dry season migrations (ICEM 2013). The species potentially at risk include the Mekong Irrawaddy dolphin (*Orcaella brevirostris*), which currently has a population size of between 78 and 91 individuals, and inhabits deep pool habitats during the low-flow season (Thompson *et al.* 2014). *P. gigas),* which undergo long distance upstream migrations in the dry season, between the border of Chiang Rai and Houaxay province Northern Thailand and Laos, will also be affected by changing temperatures and flows during the dry season. Other species include the dry season spawner *Probarbus jullieni,* which will likely also be at risk from extreme droughts and increased temperatures.

Sea level rise will enable saline water to move upstream in the river during the dry season and threaten freshwater aquaculture, mainly for Pangasid catfishes and shrimps in the delta (IPCC, 2007). Reduction of wild fish stocks as a consequence of climate change will also affect small-scale, rice-fish systems (Das 2002; Halwart & Gupta 2004). Rice cum fish aquaculture systems are common in north east Thailand, Central Laos and Cambodia where farmers depend on wild fish entering the rice fields and use these catches for food and income. These wild stocks are very important resources for small-scale aquaculture, where farmers depend on them for seed and food (FAO, 2008c).

Agriculture and Livestock

The agriculture sector is likely to be extremely vulnerable to climate change, in particular rice farming that relies on sufficient rainfall to maintain production. Climate change will affect yield and crops of agriculture systems at the local and regional scales (Johnston *et al.* 2009). These threats are caused by changes in temperature, precipitation and sea level rise.

The various climate change projections indicated that by 2050 the number of droughts per year would increase dramatically in large areas in the south and east of the LMB (ICEM 2013). The Cambodian floodplain, Vietnamese Central Highlands, southern Lao PDR, and the delta area the number of drought month is predicted to increase with a change of one drought month increase per year. Whereas, in the north of the LMB (Chiang Rai and Houasay), the drought months are projected decline by up to 25%

with a decrease of two weeks of drought per year. The crop yield modelling indicated that rice and maize yield will decrease by 3-12%. Gia Lai in Vietnam is projected to decline in both rainfed rice and maize yields of 12.6% and 12.1% respectively (ICEM 2013).

Livestock is also vulnerable to climate change in particular temperature rises and droughts, although flooding also can cause problems. The threats vary considerably between each animal and husbandry system. While higher temperatures will have less impact on individual animals in small-holder subsistence systems, the small and medium-scale commercial farms are most vulnerable because they have limited capacity to adapt (ICEM 2013). Increased temperatures above the upper critical level will impact on productivity in intensely stocked systems. This threat will mostly affect to commercial poultry and pig systems that have high stocking densities. Animals will reduce their feed intake, compromising weight gain and increasing the time to slaughter weight.

Forestry and NTFPs

The impacts of climate change on forestry in the LMB and elsewhere remain unclear (Staudinger *et al.* 2012). Increased precipitation may lead to rapid growth and or droughts to less rapid growth of some trees and NTFPs species. Increased temperatures in the dry season may stimulate pest outbreaks, leading to high mortality rates and vulnerability to extensive fires. Key drivers affecting NTFPs are deforestation (e.g. logging and rubber plantations), habitat loss due to hydropower development, expansion of agricultural lands, forest fires and over-exploitation.

The result from a vulnerability assessment of selected NTFPs in four hotspots (Mondulkiri-Cambodia, Gia Lai-Vietnam, Chiang Rai-Thailand and Khammouan-Laos) of the LMB conducted by ICEM (2014) indicated that future average temperatures in the LMB will still benefit wild mushrooms whose availability and abundance would be boosted by increased precipitation during the wet season. Mondulkiri would be vulnerable to drought in the dry season and greater rainfall during the wet season which would likely increase the production of wild mushrooms (*Russula virescens*). By contrast, areas less vulnerable of drought (Chiang Rai) or to slight changes in drought patterns (Khammouan and Gia Lai) would be favourable to growth of this species. Increased rainfall in the wet season coupled with intense storms and high winds will affect young seedling of bamboos and rattans that are not tolerant to large floods. The important characteristics of future climate change that may reduce the habitats and production of NTFPs include increased temperatures and more intense dry seasons, increased precipitation and extended wet seasons, high risk of wild fires and more frequent severe storms. In all four hotspots, NTFPs have moderate vulnerability to future climate change.

6.3 CLIMATE CHANGE IMPACTS IN LAOS

Laos is a mountainous, landlocked country with more than 70% of the total land with a slope over 20%. Laos's climate can be classified into two distinct seasons: a dry season from mid-October to April, and a rainy season, between May and mid-October influenced by the southwest monsoon, with high rainfall, high humidity and high temperatures. The average annual rainfall ranges between 1,300-3,000 mm. Temperatures during December and January can drop as low as 15°C, while during the dry season' s hot months of March and May, temperatures can reach above 30°C (MRC 2003). Based on the latitude, Laos can be classified into three climatic zones:

- The northern mountains, with elevations above 1,000 m, have average rainfall of 1,500-2,000 mm and average temperatures under 25°C.
- The central region areas with highest temperatures and average rainfall from 2,500-3,500 mm. These areas are very vulnerable to droughts during the driest months, from January to March.
- The tropical lowland plains and floodplains in the south that predominantly paddy rice areas. Average rainfall is 1,500-2,000 mm. These areas are highly vulnerable to floods and droughts.

According to the World Bank (2011) report on vulnerability, risk reduction and adaptation to climate change, recent climate trends in Laos are: (1) increases in temperatures, with an average increase of 0.1-0.3°C per decade from 1951 to 2000 (1988 was the hottest year in the past two decades with the average temperature of 30°C and also the driest year with average rainfall 800 mm); (2) rainfall fell between 1961 and 1998; (3) the number of drought and flood events over the last three decades has risen.

Historically, Laos has frequent extreme floods and droughts. In 1977 and 1978, severe droughts followed by floods led to a food crisis, and severe droughts during 1988 and 1989 caused a reduction in rice production by about a third (MAF & FAO 2012). In the 37-year period between 1966 and 2002, at least part of the country was affected by either flood or drought, or a mixture of both, in every year (Schiller *et al.* 2006). Over the past 40 years, Laos has been affected by five extreme droughts, with the most severe in 1977 affecting 3.5 million people. A later drought occurred in 1998 affecting 750,000 people (World Bank 2011). The Prevention Web of the United Nations International Strategy for Disaster Reduction for the period 1980‑2010 (MAF & FAO 2012) found that droughts, floods and storms accounted more than 70 percent of the 30 natural disasters in Laos, of which floods were the most common. The most vulnerable areas to flooding are the areas along the Mekong River (central and southern parts). There were 50 floods between 1970 and 2010, with a large flood in 1992 causing economic loss over US$ 21 million (World Bank 2011). The impacts of floods and drought on agriculture are significant and illustrated by the area of rain-fed rice fields damaged by floods and drought between 1995 and 2011 (Figure 6.7).

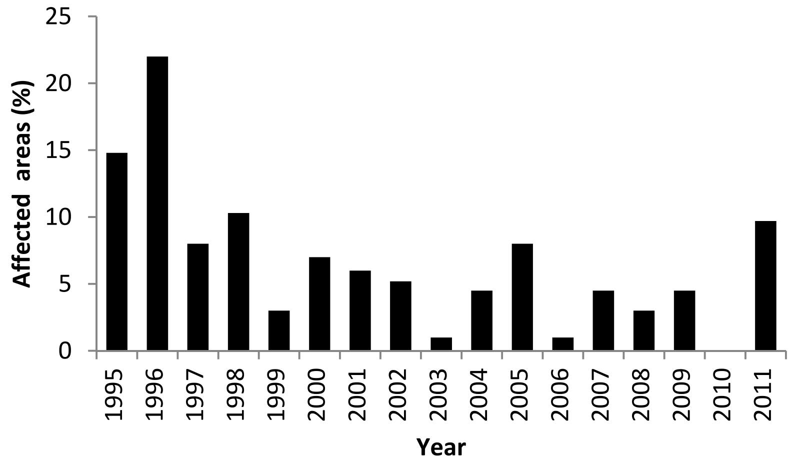


Figure 6.7. Impact of extreme climate changes on agricultural land. After MAF and FAO 2012 (affected area as % of total cultivated area, no data for 2010).

According to the World Bank (2011) projected climate changes in Laos are as follows:

- Mean annual temperatures are predicted to rise by 1.4-4.3 °C by 2100, the northern and central zones will experience less warming than the southern zone;
- Mean annual rainfall will increase significantly in the wet season;
- Annual precipitation will increase 4.2% by 2080-2099, in particular in the northern province;
- Number of wet days will increase with wetter in the southern province along the Mekong River;
- The magnitudes and frequency of extreme events will increase across the country.

Laos already suffers under extreme weather conditions and the further climate change is likely to make the situation worse. Agricultural production will decrease, in particular rice yield caused by increasing temperatures and changes in rainfall, flow and soil moisture (World Bank 2011). It has been estimated that about 188,000 households in Laos are at risk of food insecurity caused by drought, and with climate change, droughts are projected to become more severe and longer. The households that reside in the central and southern provinces will be the most vulnerable group. Agricultural lands in central and southern provinces that support 80% of the rice production in the country (MAF & FAO 2012), have already been affected by flooding in recent years and are predicted to be hit by extreme floods. The risk of epidemics is likely to increase. In the past four decades, eight epidemics have occurred in Laos, including a cholera outbreak in 1994 that killed 500 people and affected 8,000 (EcoLao 2012). These epidemics are associated with floods and droughts.

6. 4 ADAPTATION AND RESPONSE TO CLIMATE CHANGE

6.4.1 National level

Laos has recognised the importance of natural resources to its people and the country's economy. The sustainable use of natural resources both for food security and revenue has been promoted and included as the first priority of the national development policy. In order to prevent or minimise the impacts of climate change and improve communication among keys sectors, the government established the Water Resources and Environment Administration (WREA) in 2007, to coordinate and provide guidance on sustainable development. The Climate Change Office was also established in 2008. Since that time various decrees and regulatory frameworks have been endorsed, for instance, the Decree on Environmental Impact Assessment, the Decree on Establishment and Implementation of the National Environment Committees, the Decree on Compensation and Resettlement of People Affected by Development of Projects, and the Policy on the Environmental and Social Sustainability of the Hydropower Sector (WREA 2010).

In 1995 the Government endorsed the United Nations Framework Convention on Climate Change (UNFCCC) followed by the Kyoto Protocol in 2003. In 2009 the National Adaptation Plan of Action (NAPA) was finalised. NAPA covers 45 priority projects, with four sectors for priority for climate change adaptation identified, namely agriculture, forestry, water and water resources, and health (WREA 2009).

The institutional arrangements for climate change are illustrated in Figure 6.8. A National Steering Committee on Climate Change (NSCCC), chaired by a Deputy Prime Minister and Chairman of the National Environment Committee, has been established. The committee advise on policy and guidance for the implementation of climate change adaptation and mitigation programmes. Eight Technical Working Groups were also established to assess the impacts and prioritising action plans for mitigation and adaptation.

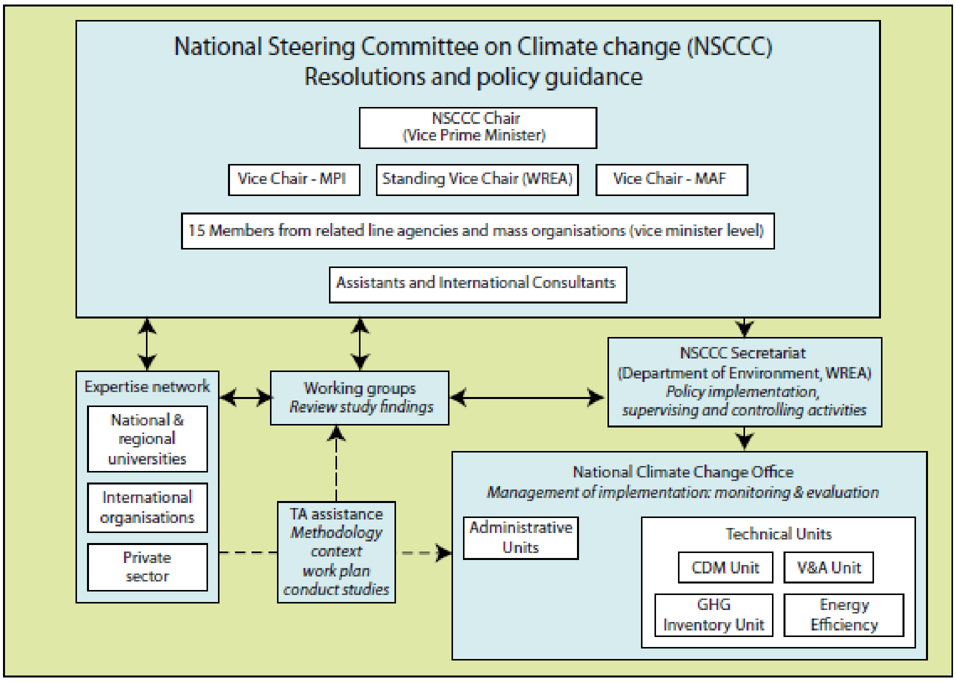


Figure 6.8. Institutional arrangement for climate changes (Source: after MRC 2009b).

As mentioned above, Laos is one of the countries most susceptible to severe climate impacts, not only because the country relies on natural resources for food security and economic development but also limits to funds and capacity to cope with climate hazards. For these reasons, the government has given high priority to adaptation and mitigation strategies to ensure sustainable development and minimise climate change impacts. At the international level, the government has focused on priority actions to mitigate carbon growth, while at the national level priority has been given to the establishment of a reliable national early warning system, sustainable forestry management and conservation, sustainable energy efficiency and sustainable transport (WREA 2010) to ensure vulnerable groups are well informed and prepared before disasters occur.

According to NAPA, approved by government in 2009, the main actions should focus on strengthening capacity building and mainstreaming climate change into development and planning projects from grassroots to high ranking decision levels. The priority actions to respond to projected climate change fall into four sectors.

Agriculture

- Promote secondary professions to improve the livelihoods of affected farmers.
- Land use planning in hazard prone and affected areas.
- Improve and develop crop varieties and animal species that are better adapted to natural hazard prone areas.

- Promote integrated pest management and use of herbal medicines in pest management and livestock treatment.

Forestry

- Continue the slash and burn eradication programme and the permanent job creation programme.
- Develop and promote plant species tolerant to pests and climate change.
- Strengthen the capacity of village forestry volunteers in forest management and use of village forests.
- Raise awareness of wildlife conservation and forest-fire prevention.

Water Resources

- Establish an early warning system for flood-prone areas, improve and expand meteorological and hydrological networks and weather monitoring systems.
- Survey underground water sources in drought prone areas.
- Study, design and build multi-use reservoirs in drought prone areas.
- Mapping of flood-prone areas.

Public Health

- Improve systems for the sustainable use of drinking water and sanitation with community participation in flood and drought prone areas.
- Increase prevention and treatment of epidemics and water borne diseases.

6.4.2 Community level

Several studies have suggested that poor people, who live in remote areas, in particular the 160,592 households in 72 districts in Laos that are classified as poor, are highly vulnerable to climate change (National Assemble 2004, WFP 2007, MAF 2010, LSB 2012). These people mostly live in the upland areas in the North and East of the country, where infrastructure, including roads, electricity and water sanitation, are less well developed. People are heavily dependent on upland rice farming (slash and burn or shifting cultivation), harvesting NTFPs and raising livestock for subsistence. In a normal year, these people do not have sufficient rice for consumption. They are living in poor conditions and experience high mortality rates and suffer from water-borne diseases such as diarrhea and malaria (WFP 2007). They are mostly unskilled people with relatively high levels of illiteracy and have less opportunity to diversify livelihood activities.

As described in Chapter 4, rural households in Laos practice a range of livelihood activities to secure their food and income. These activities include agriculture, livestock, fisheries, and collecting of NTFPs. In response to climate changes and other stressors caused by human activities, the farmers may shift their primary occupation around these four components, for instance, from rice planting to fisheries or harvesting NTFPs, although, the shift from one sector to another may lead to a decline in production of the new sector that many people pursue to diversify their portfolios (ICEM 2014b). In addition to the four activities, off-farm work (both skilled and unskilled labour), trade and services, are also common activities that farmers employ to cope with uncertainty and climate hazards.

In many cases, the responses to climate change differ from place to place, depending on the assets and capacity that farmers have. In the reservoir areas, many households engage in reservoir fishing as the main source of food and income, instead of rice farming (see Chapter 4). In the lowland areas where farmers have greater access to water or irrigation systems, they shift from irrigated rice planting to cash crops, to avoid water shortage in the dry season and disease that may occur in monoculture species (Gansberghe & Soulimon 2005). In upland areas, farmers use the integrated farming system approach to improving soil quality and protect farm land from landslide or erosion cause by extreme weather. These techniques include: planting multi-trees species, including fodder trees and legumes that can improve soil quality and at the same time can be used as feed for ruminants and pigs (Phengsavanh *et al.* 2005); planting vetiver grass (*Chrysopogon zizanioides*) in the steep sloping land to prevent soil erosion; increasing fallow periods of shifting cultivation to improve soil quality and increase productivity (Pravongviengkham 1998); integrated livestock in teak or rubber farms to supplement income before the primary product can be harvested (Phimphachanhvongsod & Horne 2005). In Louangprabang province, many households culture frogs as an alternative livelihood to ensure food security and earn supplementary income for the household (LARReC 2005), especially when their crops are damaged by drought or flood. Many households in the lower XBF and Theun River engage in aquaculture of African catfish in earth ponds for consumption and to sell to get extra income for buying other foods. On-farm labour jobs (e.g. planting, weeding and harvesting) are also common in most areas where affected households seek additional income to compensate for loss of crop yields due to floods and droughts. Off-farm activities or paid labour are also found in most rural areas (see Chapter 4).

6.5. KEY ISSUES AND CHALLENGES TO MINIMISE IMPACTS

6.5.1 Key drivers of climate changes and impact

Historical climate data on temperatures and precipitation show that the climate has changed in the past two decades and the future climate projection is expected to see increases in temperatures, precipitation and the magnitude of storms. Recent evidence of climate changes caused by global warming in the region include tropical storm Kammuri (2008), typhoon Ketsana (2009), typhoon Nock-Ten (2011) and typhoon Haiyan (2013) which devastated the LMB countries and the Philippines, causing more than one thousand deaths and affecting millions of people. These events are symptomatic of what is likely to occur in the future. Mitigation and adaptation strategies are needed to minimise the impacts of climate change on the Mekong ecosystem and livelihoods of people.

The impacts of climate change on river ecology and tropical fisheries are relatively marginal (IPCC 2001), but when they interact with impacts from other anthropogenic stressors, such as water diversion, overexploitation and pollution, it will likely create significantly pressure on the ecology and fisheries productivity (Verchuren *et al.* 2002; Parmesan & Yohe 2003; Ficke *et al.* 2007). The potential risks associated with future climate changes events are: the risk of food insecurity of people living in poverty due to droughts and floods; the risk of death and illness of people in lowland areas associated with extreme floods that disrupt livelihoods, damaging infrastructure and agriculture; risk of loss of ecosystem functioning and services that contribute to livelihoods of people (IPCC 2014).

The predicted future climate change impacts and risks will influence many sectors. It will slow down economic growth, increase health problems and delay the implementation of MDGs such as food security and poverty reduction. The poor will be poorer as they have insufficient foods for subsistence and households that cannot adapt to the changes will likely drop into the poverty group. Malnutrition will continue to create more problems with heath and will lead to increased deaths, ill health, and reduce physical fitness of family members who are usually the main labour force carrying out on-farm and off-farm activities for food and income.

6.5.1 Challenge on minimise the impacts of climate change

Adaptation and mitigation measures to minimise the impacts of climate change are complex and should include all sectors. As the impacts of climate change on the environment and livelihoods of people are the same or similar to the impacts from other developments (dam, deforestation, agriculture) there is a need to incorporate all cumulative impacts of all sectors into planning and development projects. Adaptation and mitigation of the impacts of climate change is a dynamic process and differs from place to place (IPCC 2014). Successful reduction of the impact will depend on the capacity and capital resources to support implementation.

The current mitigation and adaptation to the impacts of climate change in Laos are focused around four sectors that provide food security and maintain the wellbeing and health of people. Details of the priority actions are mostly concerned with development of new crop varieties and tree species that are tolerant to climate changes. However, environmental management is rarely seen in the adaptation plan, in particular fisheries in the context of ecosystem services. Fisheries provide resources when other resources are under pressure or are used as alternative mechanisms to secure food and income for impacted communities (e.g. resettled households in reservoir village). However, they are largely overlooked compared with economically important sectors such as agriculture, hydropower and mining when considering new projects related to water resources development. Apart from the challenges of limited funds and capacity to cope with the impacts of climate change, management and conservation of water resources and associated flora and fauna are also necessary as these resources play an important role in food security and income generation of the rural people (see Chapters 4 and 5). Management actions, such as enhancing genetic diversity, reducing anthropogenic stressors (IPCC 2014) and maintaining habitats, will decrease the risks of climate change impacts on fisheries and ecosystems functioning.

Adaptation and mitigation projects to reduce the impacts of climate change should be integrated into the existing programmes concerning food security and poverty elimination. Integrated agriculture farming systems with livestock and fisheries, diversified livelihood activities along with the provision of technical and financial support for vulnerable communities will assist them to prepare and cope with current and predicted severe climate-related problems. Improving infrastructure and providing access to markets and credit will increase product values and provide an opportunity to explore new alternative livelihoods (e.g. trade and services) to secure food and income of the vulnerable households (see Chapter 4). Providing basic healthcare such as clean water and sanitation, maintaining essential vaccination programmes for children (IPCC 2014), and ensuring micronutrient intake will reduce the risk of disease outbreaks and improve health and well-being of people, making them more able to respond and adapt to future climate change problems.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 GENERAL DISCUSSION

Freshwater fisheries are an important part of the national economy and crucial to the livelihoods of people in Laos where many people still live in poverty and depend on natural resource for food security and income generation. Improvements in livelihoods due to rapid economic growth and an expansion of water resource development projects, especially hydropower and for agriculture, and climate change are threatening the very fisheries resources that many depend on. Fisheries resources are also at risk from intense fishing pressure caused by improvements in fishing efficiency of gears that can catch all fish sizes, and the use of illegal fishing gears (e.g. dynamite, electro fishing, poisoning) that destroy fish habitat and brood stock. Nevertheless, the Mekong fishery is still considered in good shape (Sverdrup-Jensen 2002), despite the fact that there is a slight decrease in large fish and the fish catch is dominated by medium and small fishes (Halls *et al*. 2013c). In some areas the catch of endangered species such as *P. jullieni* has actually increased (Halls *et al.* 2013a). The factors driving the fluctuations and changes in fish production in the LMB are unclear, partly due to limitations of knowledge on fish biology, including spawning areas and lifecycles of the important species, species diversity and the complexity of the river ecosystem. In addition, most fishing operates in remote areas and is artisanal fishing for household consumption. These data are usually excluded from the national statistics, leading to under estimation of fish production, or fish production data are inaccurate and not reliable (Coates 2002). Anecdotal evidence suggests that factors likely to cause decline in fish yields in the Mekong River are the impacts of hydropower development projects that block migration of breeding fish to spawning habitats and movement of juvenile fish to nursery habitats in the floodplains. Other factors include deforestation, pollution from industry and agriculture, and climate change that causes soil erosion, changing water quality and quantity, changing fish habitat, affecting fish population and yield.

Fish landings at monitoring sites have fluctuated in recent years but there is no significant change in both biomass and species composition (Chapter 3). Despite difficulties in catching fish in the reservoir and downstream areas because of changing water conditions in the reservoir and strong currents downstream, fish and OAAs remain the main source of animal protein and income of the rural poor, in particular the people living along the riverbanks and close to the reservoirs (Chapters 4 and 5). The impacts of hydrological changes on the ecology and the livelihoods of people both in downstream and reservoir areas are significant and include altered ecological functions, loss of dry season habitats, disruptions to fish migration, and limited access to natural resources, resulting in changes in livelihood activities and difficulty adapting to the new environment (Chapter 4). Minimising these impacts on the livelihoods of people in the reservoir and downstream villages can be achieved through livelihoods diversification. Worldwide experiences indicate that promotion of alternative livelihoods (on-farm and off-farm activities) cannot replace fishing because it provides supplementary food and income for artisanal fishers (Martin *et al.* 2013). This study found that fishers in downstream areas, who already have many livelihood activities, still fish or comeback to fishing where it is possible. Thus, as most of fishers engage in agriculture and off-farm activities, these alternative activities may give other opportunities and ultimately are likely to reduce fishing pressure. Livelihood diversification can be categorized into three groups, viz: intensifying agricultural production; modernizing and trading certain products, and promoting new off-farm activities (Bouahom *et al.* 2004). Intensification of agricultural production requires high capital cost to develop new technologies and inputs and is thus not considered an option for rural poor people. This study suggests promoting the latter two livelihood diversification activities (Chapter 4). Apart from the impacts of human activities, the potential impacts of climate change are an additional pressure on the environment to which the local people have to adapt. Having said that, the impact of climate change alone on fisheries appear less harmful (IPPC 2007), but when this threat interacts with other anthropogenic impacts, namely habitat destruction, changing land cover and dams, fisheries become highly vulnerable (Chapter 6).

7. 2 CONCLUSIONS AND RECOMMENDATIONS

7.2.1 Fisheries management

Mekong fish depend on several habitats to complete their lifecycles. Many habitats are seasonally connected to the main river (e.g. swamp, floodplain), providing rich food sources for juveniles and young-of-the-year fishes. Many white fish species migrate from the mainstream to floodplain habitats for spawning during the wet season and return to the main channel at the end of flood period for refuge in deep pools in the tributaries or mainstream. The reproductive process is highly dependent on connectivity of the main river and floodplains, therefore, **it is recommended that connectivity between the main river and major tributaries and floodplain is maintained, to ensure fish can access these habitats for spawning, and eggs and larvae can freely drift to suitable nursery habitats in the flooded forests and swamps, without any barriers or disruption. This needs to be done at the local and regional level.** Improvement of fish production in the reservoir is difficult and requires more investment. Therefore, **protection of habitats in small streams and upstream of reservoirs is very important**, to ensure that fish can use these habitats for spawning. Proposed implementing agencies are LARReC, DLF, IUCN and WWF.

Currently, there is no evidence that hydropower development projects in the LMB, in particular in Laos will be suspended. While not all tributaries are dammed, **it is recommended that an inventory of the tributaries that have no dams is assessed, in particular in the northern provinces of Laos, and "green protected zones of river" where no water development projects can take place are established.** These areas could be declared as National Biodiversity Conservation Parks. These areas will not only serve as safe habitats for fish and OAAs but also provide opportunities for field study sites for education or use as ecotourism. Proposed implementing agencies are LARReC, DLF and MRC.

Several species undertake longitudinal migrations across the border of many countries from the Mekong Delta in Vietnam to Central Laos around Vientiane and possibly up to Northern Laos and further to China. A trans-boundary fisheries management project has been initiated between Laos-Thailand, Laos-Cambodia, and Cambodia-Vietnam. This MRC supported project mainly focuses on exchange of information on local fisheries management and strengthening cooperation among the bordering provinces. **There is a need to improve trans-boundary fisheries management and conservation planning at the national and regional levels. Management plans should include target conservation species and guilds, to make sure that protected species are treated the same way in different parts of the river.** In doing so, regional agreements or regulations are needed to facilitate the implementation of the project. As most fishers living along the river bank rely on fish for subsistence, the management plan should balance between local needs and biological conservation. To implement this project, there is a need for support from all stakeholders including participation of local communities and government. At the community level they need both technical and financial support from the government and international organisations. In additional to protected species, **fisheries protected areas also needed to be established**. These areas can serve as regional biological protected areas to provide refuge habitats for fish and to promote the diversity and richness of the Mekong fisheries. The selection of sites has to link with watershed management and national forest protected areas to ensure that the conservation areas are surrounded by less polluted or untouched environments. For trans-boundary fisheries and regional fisheries management these protected areas could be established through a trans-boundary fisheries management framework under the Mekong River Commission programmes. Proposed implementing agencies are LARReC, DLF and MRC.

Trans-boundary impacts of dams cover other parameters apart from the barrier effect to fish migration and include livelihood impacts and reduction of sediment loading, river bank erosion, flooding of agricultural lands, and transmission of diseases. These impacts are often only looked at in local areas and large-scale impacts on downstream countries are largely overlooked. As trans-boundary impacts of tributary dams are visible and already happening in the 3S areas, **trans-boundary impact assessments of the mainstream and tributary dams should be included in any EIA at the planning stage to minimize the impacts and to ensure that mitigation measures are in place**. At the same time monitoring of trans-boundary impacts should be conducted before and after dam construction to identify and mitigate the impacts as well as protect the environment and improve the livelihoods and wellbeing of the impacted communities in downstream countries. Proposed implementing agencies are WREA, LARReC, DLF and developers.

Fishery resources are seen as a profit-oriented choice when people fail to achieve their food or income from other activities. However, when compared with other sectors such as rice, electricity and mining, only direct value (first sale value of catch) has been used to evaluate the importance of fisheries to the national economy and livelihoods. The same value is used for decision making of new water development projects when dealing with the fisheries sector. In order to highlight the importance of fisheries and to compete with other sectors, **it is recommended that the total value of the Mekong fisheries in the context of freshwater ecosystem services is derived.** In general, only the provision of food is acknowledged when evaluating the importance of fisheries to food security. However, fisheries contribute to the livelihoods of people in many ways. For example, job creation in related fishing activities (e.g. fish processing and marketing, and marketing and sale of fishing gears); providing cheap and rich sources of micronutrients and vitamins (calcium and vitamin A); maintaining aquatic ecosystems (control of eutrophication processes and unwanted species) and provision of recreation and leisure services, such as sport fishing and fisheries for ornamented species or provision of religious and traditional medicine services (e.g. releasing fish for good luck and good heath). Proposed implementing agencies are LARReC, DLF and MRC.

Historical data suggest that climate change impacts occur globally and will be more intense in frequency and scale in the coming decades. Potential losses could be prevented or minimized if people are aware and well prepared for these changes. The lack of warning and communication systems in the past has caused many deaths and loss of property, because people were not aware of or did not realise the magnitude of storm events or intensity of droughts. **Therefore, it is important to raise awareness of the impacts of climate change and provide reliable warning systems in**

vulnerable areas. In addition, building trust and providing accurate information are also important. Since most villages have mobile phone network coverage, the warning system could be integrated into this network or alternatively local radio is an option. Proposed implementing agencies are WREA and DLF.

7.2.2 Livelihood options

Most of the fish in Nakai reservoir are sold fresh. As a result fishers get low prices compared with processed fish. Experiences from Nam Ngum and Nam Houm reservoirs suggest that fishers could increase their income from fish by adding value through post harvest and fish processing. **Therefore, in the short-term, it is recommended that fish processing is promoted and marketing networks in the reservoir areas to provide additional income for the resettle households are improved.** Dried and fermented fish (sour fish) are high value products and in high demand in the cities. As fishers need to sell their catch to buy rice, it is necessary to provide loans or revolving funds to the fishers so they can have sufficient money to purchase rice before they can sell their products. A training course on fish processing, packing and marketing is also needed to ensure fishers have adequate skills to implement this activity. Theoretically, reservoir fish production will decline if fish cannot find suitable habitats for reproduction in the rivers upstream of the reservoir, as a result it will reduce recruitment and fisheries are likely to collapse. Thus the promotion of fishery related activities are unlikely to be good options for livelihood diversification. **In this case, off-farm activities including ecotourism, trading, paid labour and other services activities should be promoted**.

In the XBF area, farmers have engaged in diverse activities such as farming, including rice and cash crops, livestock raising, fishing, collecting NTFPs and off-farm paid labour. Fishing is seen as a hobby for some fishers, they like to go fishing even though they catch only a few fish. For most fishers, fishing is for food and income to supplement daily meals, viz. animal meats and NTFPs. Reducing fish catch means fishers have to rely on other foods (e.g. OAAs and NTFPs) to replace fish or to find alternative income to buy fish. Therefore, **it is recommended that alternative off-farm jobs (paid labour in the agricultural or clothing factories), One District One Product activities, ecotourism, and aquaculture including culture-based fisheries are promoted.**

Livelihood diversification is widely used to secure foods and income for impacted and vulnerable households. Recently, most of these alternative options have been heavily linked with the utilization of natural resources such as fishing and collecting of NTFPs that are already vulnerable from over exploitation and climate change. Therefore,

diversifying alternative livelihoods should be carefully planned to provide an opportunity to reduce dependency on natural resources rather than promoting existing activities that will add more pressure on the natural resources. Balancing between the need for human uses and maintaining ecosystem services is likely key for sustainable use of natural resources. It will not only ensure food security for the people who depend on it, but will also protect fisheries resources and enhance the productivity for the benefit of the rural poor.

7.2.3 Further research

Fish catch monitoring in the Mekong River provides important data sources and gives time series baseline data on the status and trends of the fisheries before the main stream dams are commissioned. However, information on the biology and ecology of the Mekong fishes remains limited; existing information on migration and spawning is based on local knowledge and anecdotal field observations. For these reasons, it is difficult to evaluate and assess the impacts of development and climate change on the fisheries. For the management and sustainable use of the Mekong fisheries, **it is recommended that research on the lifecycles/life histories of commercially important migratory species, in particular white fishes, spawning habitats, and growth performance at different of life stages is conducted.** This information can be used to validate the existing knowledge and used for management planning and development of the Mekong fisheries.

This study highlighted that households acquire food from the rivers and forests. They consume considerable amounts of protein to meet minimum requirements for physical work. The main protein source of typical households in Laos comes from rice. Most of animal protein comes from fish and OAAs, followed by animal meats. The consumption of fish, OAAs and meats is in very small quantities and does not meet the daily requirement of micronutrient intake. As a result, it has caused slow growth and high mortality rates of children, as well as disease outbreaks due to lack of basic healthcare and illnesses because of consumption of cooked food that has not been prepared properly. Ultimately this has resulted in higher death rates in remote areas. Fish and OAAs contain rich sources of micronutrients (e.g. calcium, vitamins A, D and zinc), that the body needs to maintain growth. Information on Mekong fish species that have high micronutrient content is limited; most information is about aquaculture fish (e.g. tilapia, *Pangasius*). Therefore, **future studies on food consumption should include nutrient intake analysis of local food stuffs, including fish, OAAs and NTFPs. In addition, sanitation is also needed to promote drinking boiled water and cooking meat and fish properly.**

Worldwide evidence suggests that hydro power dams create more social and environmental problems than the benefits received from selling electricity, particularly in developing countries, where most of the benefits are to the investors, ignoring social and environmental issues related to the local poor. In developed countries, such as the United States of America, dams are being removed to restore rivers and connectivity for aquatic animals. The number of hydropower dams in Laos has increased dramatically in the last decade due to rapid economic development and the need for foreign revenue to support the implementation of food security and poverty reduction programmes. The impacts of dams on the livelihoods of people are unaccounted for in terms of food security, poverty and social issues. From the fisheries view point, dams disrupt migration, spawning and recruitment dynamics, flooding spawning and nursery habitats, disconnecting floodplain habitats and disrupting lateral connectivity. In order to protect the water resources that provide food, income and job opportunities for millions of people, **it is necessary to investigate alternative power sources to supplement or replace hydropower, for instance, wind power, solar power, and biogas.** The last two may be suitable in the northern province where technology is already in place and requires low investment costs (biogas) compared with other sources.

The methods used in this research can be applied for other regions or areas where water development projects are planned. The consumption monitoring provides information on food security including food sources, animal protein intake and shifts in the seasonal food intake patterns of impacted and vulnerable households. The field surveys and hydrological analysis using IHA, provide vital information on the potential impacts of hydrological changes in the environment and on livelihoods of people. IHA parameters and flow duration curves compare water discharge and flows before and after dam construction, indicating a dramatic increase in water discharge both during the wet and dry seasons after dams were commissioned. The field surveys provide details on the livelihoods of impacted households, including the assets and activities that households engage in for food security and income earning. When collating consumption monitoring, field surveys and IHA analysis information, it creates a greater knowledge of the potential impacts, fisheries trends, the current situation coped with resilience and adaptation strategies as well as potential measures to minimize the impact of hydrological changes on the livelihoods of local people. This information is important and can be used to highlight the value of fish and OAAs to the food security and incomes of the indigenous minority groups and, ultimately can support the decision making process when it is needed to value fisheries against other water development projects.

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Appendix 1: Checklist topics for the village headmen interview

1. General information

- Village identification: Location, distance to the centre, road, market, access to health care centre, access to electricity, access to safe drinking water, school, temple, irrigation.....
- Population: number of inhabitants, number of household, ethnic groups....
- Agricultural/ farmland/cultivated area: paddy rice, irrigation rice, upland rice, vegetable garden, cash crop, river, swamp, reservoir, flooding forest, forest/scrub, grassland/grazing, aquaculture pond...
- Access to farmlands: number of HH own each type of the farmlands, agriculture production
- Drawing a map of village

2. Occupations, farming calendar and income

- Occupation and time spending in the activities: rice farming, vegetation garden, collecting non-timber forest product, looking after livestock, fishing, raising livestock, off-farm activities.
- List of all existed livelihood activities
- Income and expenditure...

3. Natural resources use

- Food security, income earning, recreation, culture.....

4. Fisheries exploitation and management

- Number of full time and part time fishers, number of boat, species caught, and fishing gear use.
- Changing in fisheries: new fishing gear, stock decline, species at risk, species abundance
- Fish species and Other Aquatic Animals caught in different season....
- Disposal of catch
- Price and marketing
- Management measurement: local regulation, fish sanctuary, traditional management system.

5. Environmental change (water resources and others)

- When the changes start
- Water fluctuation
- Water quality, colour, level and flows
- Agriculture land, flooded forest, river bank garden

6. Impact and issues

- What are the impacts, risks, shock associated
- Number of HH/persons injured, death
- Number of HH lost land, opportunities access to resources
- Impact to social and culture activities

7. Adaptation and response

- List of livelihood activities, income from these alternative livelihoods

8. Internal and external assistance

- Assistance project from government, international, non international organization

Appendix 2: Individual/Household questionnaire

Village name:……………………. District :……………Province…………………………….
Respondent interviewed name …………………………………
Age……………………………..

I. Household profile and assets:

HH member:………… Female………………, main labour:………… secondary labour……….. Education:…………………….…
Land uses area: Paddy rice ………..irrigated rice………..Upland rice…………River bank garden …………cash crop…………….. Fish pond………………………………..other ……………………
Production: paddy rice ………..irrigated rice………..Upland rice…………River bank garden …………cash crop…………….. Other …………………………………………
Asset:
bicycle…………motorcycle…………car……….tractor…………other……………………
Livestock: Cattle………Buffalo…………Pig………..
Goat…………poultry………………………..
Other……………………………………………………………………………………

II. Household activities

No.	Activities	Year											
		1	2	3	4	5	6	7	8	9	10	11	12
1													
2													
3													
4													
5													
6													

III. Fisheries and other activities

Fishing: ❑ full time; ❑ part time; number of fishers……… Boat: ❑Motor…….
❑ Paddle
Fishing areas ………………..……………………………………………………….…
Fishing gear uses: Dry season …………………………………… …………………… …
Wet season ……………………………………………………………
Fisheries trend compare to last five years: ❑ increase ❑ decrease
Reasons for increase or decrease ………………………………………………….……
Species difficult to catch ……………………………………………………………………..
Species abundance in the past but very rare now…………………………………………
Top ten species caught:

-Dry season:…………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

-Wet season
……………………………………………………………………….......…………..
…..………………………………………………………………………….……………
……………………………………………………………………………………………

- Estimated fish catch:…………….kg. Disposal of catch: consumed………. kg or percent, sold……..kg, processing….……..kg, Given to relative……… kg, other…… kg
- Most recent catch:…………kg, species name……………………………..……………
- OAAs catch…......................………………………………………………………….

- Disposal of catch: consumed………. kg or percent, sold……..kg processing…. ……..kg, given to relative……… kg, other………… kg

- Useful Aquatic Plants (UAPs)……………………………………………………………..
  - Disposal of UAPs : consumed………. kg or percent, sold……..kg processing…. ……..kg, given to relative……… kg, other………… kg
- Non-Timber Forest Product (NTFP):……………………………………………………..
  - Disposal of UAPs: consumed………. kg or percent, sold……..kg processing…. ……..kg, given to relative……… kg, other………… kg
- Aquaculture: Species……………………………………….., Production………………
  - Disposal of Aquaculture fish: consumed………. kg or percent, sold……..kg processing…. ……..kg, given to relative……… kg, other………… kg
- Consumption: ranking the most important 1,2,3,4 (1 is very importance)

Beef……../ pork………./ chicken………./ wildlife ………./ fish……./ OAAs……./ egg ……./ other…..……

- How much did you eat fish yesterday

…………………………………………………………………………………………………

IV. Water resources changes

Changing water resources in last five years

+ Dry season:**…………………………………………………………………………………………**

…………………………………………………………………………………………………

+ Wet season:……………………………………………………………………………………………

…………………………………………………………………………………………………

Impact from the changes (HH member injured, death…)

…………………………………………………………………………………………………

Vulnerability, risks/shocks**……………………………………………………………………… .**

…………………………………………………………………………………………………

V. The main activities (resilience) undertake when cannot catch fish, extreme flood, drought, water fluctuation

No	Activities	Time (Month)	Food or income received	Remarks
1				
2				
3				
4				
5				

VI. Household economy

Income: percentage

Rice:………/ Livestock: ………/ Fish: ………/ Vegetable………/ Handicraft………/ Trade: ………/ Remittance: ………/ Labour: ………/ Other:………………………………………….…………

Expenditure: percentage

Food………/, Clothes………/, Agriculture input………/, Health care………/, Social activities……/, Education………/

Other:…………………………………………………………………………..…………

Appendix 3: Consumption monitoring form

Household code:		Village:	
Family name:		District:	
Date:		Province:	

Source: Purchase, *caught/gathered, cultured or grown by household, gift)*

No	Food types	Source	Quantity	Units	Number of people eaten	Remarks
I. Cooks food						
1. Breakfast						
2. Lunch						

3. Dinner						
II. Buys food						
III. Other food *(noodle, fry rice, bread, etc.)*						

IV.	**Fruits** *(banana, mango, pineapple, dragon fruit and others)*					
V.	**Drinks** *(coffee, tea, coke, Pepsi, alcohol, beer)*					
VI.	**Outgoing food** *(given to relative, given to monks and other)*					

No	Food item	Given to whom	Quantity	Units	Remarks