CONTESTED WATERSCAPES in the Mekong Region

HYDROPOWER, LIVELIHOODS AND GOVERNANCE

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earthscan
publishing for a sustainable future

London • Sterling, VA

First published by Earthscan in the UK and USA in 2009

ISBN: 978-1-84407-707-6

Typeset by JS Typesetting Ltd, Porthcawl, Mid Glamorgan
Cover design by Susanne Harris

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Earthscan
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London, EC1N 8XA, UK
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22883 Quicksilver Drive, Sterling, VA 20166-2012, USA

Earthscan publishes in association with the International Institute for Environment and Development

A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data

Contested waterscapes in the Mekong Region : hydropower, livelihoods, and governance / edited by François Molle, Tira Foran, and Mira Käkönen.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-84407-707-6 (hardback)
1. Water resources development--Mekong River Watershed. 2. Water-supply--Mekong River Watershed. 3. Hydroelectric power plants--Political aspects--Mekong River Watershed. 4. Water rights--Mekong River Watershed. 5. Watershed management--Mekong River Watershed. I. Molle, François. II. Foran, Tira. III. Kakonen, Mira.
TC513.M45C67 2009
333.91'150959--dc22
2008051424

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This book was printed in the UK by Antony Rowe.
The paper used is FSC certified and the inks are vegetable based.

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Hydropower in the Mekong Region: What Are the Likely Impacts upon Fisheries?

Juha Sarkkula, Marko Keskinen, Jorma Koponen, Matti Kummu, Jeff E. Richey and Olli Varis

Introduction

The human impact upon water resources has increased dramatically all over the world during the last several decades (Vörösmarty, 2000). The Mekong River is one of the few large river basins yet to be irreversibly modified by large-scale infrastructure. While the first dams in a planned cascade have been built in the upper-middle reaches in China, flow regimes in the lower reaches of the mainstream are still, essentially, natural (MRC, 2005). These conditions may not last much longer. The Mekong River Basin is facing the prospects of a major growth in infrastructure projects as surrounding economies continue to expand. Huge hydropower dams as well as diversions for irrigation are planned throughout the basin, some on tributaries and others on the mainstream (e.g. King et al, 2007).

A body of recent research concludes that development in the river and the basin will alter flows and floods in the basin (Adamson, 2001; ADB, 2004; World Bank, 2004). The alterations to flow may have significant impacts upon the river ecosystem, wetlands, floodplains and well-being of people, especially those dependent upon natural resources in the Lower Mekong Basin (LMB).

Potential impacts upon fish form a particularly important issue: fish is a central social, economic and cultural resource in the basin, and forms, together with rice, the foundation of food security in practically all riparian countries. Mekong fisheries are also globally exceptional for their diversity and size, and the

Mekong Basin is considered to have the world's largest inland fisheries (Poulsen et al, 2004; Dugan 2008). Due to the diversity of fisheries and fishers in the region, it is difficult to estimate the actual amount and value of Mekong fisheries; the most recent estimates for the annual value range from US$2 billion up to US$3 billion, with catch estimates as high as 2.5 million tonnes a year (Dugan, 2008).

When discussing the potential impacts of hydropower development, fish is usually considered to be a resource particularly vulnerable to negative impacts. The impacts upon fisheries due to hydropower development can be divided into two main categories:

1 the so-called barrier effect of dams on fish migration; and
2 the impact that hydropower development has upon water quantity and quality, and, consequently, upon fish habitats, for example.

Overall, the fisheries of the Mekong are dependent upon migration over both long and short distances, with many of the commercial species having highly developed migratory patterns (Barlow, 2008). The migratory fish species generally move upstream to spawn, while juvenile fish then move back downstream to feed and grow on the floodplains and wetlands (Poulsen et al, 2002). Dams act as barriers for fish migrating upstream, while the fish migrating downstream must usually pass through hydropower turbines, resulting in mortalities with very low survival rates (Barlow, 2008). Dugan (2008) estimates that over 70 per cent of the total fish catch in the Lower Mekong Basin is dependent upon long-distance migrant species. Dugan (2008) also points out that existing fish passage facilities simply cannot cope with such a large fish migrations and high species diversity that is present in the Mekong, indicating that effective mitigation measures for the barrier effect are not easy – or cheap – to achieve in the Mekong context.

Hydropower dams also affect river flows, causing different kinds of changes in both water quantity and quality. These include, for example, changes in the extent, duration and timing of annual floods, as well as reduction in suspended sediment concentrations due to sediment trapping of the reservoirs (Kummu and Varis, 2007). Reduced floods with shorter duration reduce the available fish habitats in the floodplains, resulting in lower fish production (Barlow 2008; Halls et al, 2008). Changes in the timing of the floods can also disrupt the crucial spawning and migration cues of fishes (Baran, 2006). Overall, this chapter seeks to synthesize what is known about the magnitude and nature of the expected changes – particularly as a consequence of dam-building – to flow regimes, and their consequent potential impacts upon fish, fisheries and livelihoods. Related to this, the chapter discusses the challenges connected to models and impact assessments, as well as the problems in addressing the real value of diverse small-scale use of different water-related resources – most importantly, fish. The geographical focus of the chapter is on the Tonle Sap Lake in Cambodia that is one of the most productive freshwater ecosystems in the world.

MODELLERS AND MODELLING

The chapter draws largely on the findings of the Finnish component of the Water Utilization Programme (WUP-FIN) project, funded by the Ministry for Foreign Affairs of Finland and implemented during 2001 to 2006 as a complementary project to the MRC Water Utilization Programme (MRCS/WUP-FIN, 2007b). The focus of WUP-FIN was on hydrological and hydrodynamic modelling, scenario simulations, socio-economic and policy analyses, and integrated assessment of ecosystem and socio-economic impacts. Several case studies were carried out in different parts of the Lower Mekong Basin, with emphasis being on the Tonle Sap Lake and the Mekong floodplains in Cambodia.

Although essentially a modelling project, WUP-FIN also included strong socio-economic and policy analysis components. The socio-economic analyses carried out in WUP-FIN aimed to increase understanding of social, economic and political factors in water resources management at intermediate and local levels. This increased understanding was used to support other project components – in particular, model development, case study design and impact assessment, both locally and at the basin-wide scale. While the socio-economic and policy analyses ultimately aimed to also address regional basin-wide challenges, this was done by first studying the challenges at the local level, and then putting these into the larger regional context. As it turned out, many of the regional concerns emerged from impacts felt or foreseen at the local level.

The chapter is a follow-up to a review we made (Sarkkula et al, 2007) about the use of mathematical modelling in integrated management of water resources in a previous volume on improving water governance in the Mekong region (Lebel et al, 2007) that carried three important conclusions.

First, modelling projects must link better with the other dimensions of water management, most importantly with social dimensions where its linkages have traditionally been the weakest. This linkage should preferably be created from the very beginning of any modelling exercise, and enough time and resources should be allocated to this multiple and, essentially, interdisciplinary task.

Second, and related to the above, much deeper integration with social sciences is needed. Some progress in integration of research teams connecting natural and engineering sciences has been made, but integration with the social sciences is still only emerging. To date, the approach adopted by modellers to address these more multidisciplinary connections has typically been merely 'to add some social stuff' to their models (Nancarrow, 2005). This is clearly insufficient and can easily just increase the misunderstandings and even prejudice between modellers and non-modellers.

Third, modellers need to focus more on cooperation and communication. This will require more two-way dialogue with decision-makers, planners and other stakeholders on the models as well as on their results and uncertainties. The aim and outcome of these engagements should be increased transparency and intelligibility of the models and their results. In some instances, joint interpretation and assessment of the modelling and analysis results is also desirable and valuable.

The real change is therefore likely to come through the establishment of teams for integrated assessment and modelling with balanced and equal participation by modellers, social scientists, policy experts and other non-modellers. A spirit of mutual appreciation and respect has to be cultivated between the involved individuals, teams, stakeholders and interest groups, requiring good communication skills (Janssen and Goldsworthy, 1996) and genuine aspiration towards truly interdisciplinary work.

Modelled flow change and methodological development needs

Credible and accurate basin-wide hydrological and flow modelling is a task of primary importance in assessing the changes in flow caused by water resources developments in the basin. Relatively small flow alterations tend to have proportionally much greater impacts upon the river ecosystem and particularly upon the floodplains. Therefore, basin-wide hydrological modelling alone is not enough for proper flow assessment, but needs to be coupled with a sub-basin-scale floodplain model to understand the consequences of the flow alteration on the flood characteristics, and furthermore, on the ecosystem productivity in the river and its floodplains.

This chapter discusses some of the current challenges in basin-wide modelling in the Mekong Basin, and then provides an example from the WUP-FIN Project on simulated impacts of Mekong development upon the Tonle Sap floodplain system and its productivity, and consequently, upon fisheries.

Basin-wide modelling and its challenges

The Water Utilization Programme (WUP) was set up at the Mekong River Commission (MRC) to build up a knowledge and model base for the Mekong Basin.

The WUP *Project Implementation Plan* (PIP) states:

> *… The broad aim of Component A is to provide enhanced knowledge base and analytical tools to support the WUP, and the BDP [Basin Development Plan of the MRC], that are based on improved understanding of the interaction between the physical and biological features of the basin and their functions with respect to water resources, and the changes in these that may occur due to human activities.*

It is clear from this statement that a comprehensive basin-modelling package is necessary for the Mekong River Commission Secretariat (MRCS) core activities and implementation of the Mekong Agreement. It implies the need for primary data collection and ecosystem process studies, as well as an understanding of the socio-economic functions and impacts in the basin, on top of building an advanced model system to respond to the complexity of the Mekong Basin environment. This concept was included in the terms of reference (ToR) of the WUP-FIN phase 1 (Tonle Sap modelling project; see MRCS/WUP-FIN, 2003) and has been a guiding principle throughout the WUP-FIN work.

Furthermore, the specific objectives of the WUP modelling component were to:

- develop an integrated and comprehensive basin modelling package that provides analytical support needed by the MRC and the riparian countries to implement the Mekong Agreement, prepare the *Basin Development Plan*, and carry out basin and sub-basin planning for sustainable water resources development;
- develop additional model components to analyse and predict transboundary impacts of proposed actions on the aquatic ecosystem and other water uses and functions of social, economic, regional and global importance.

Although WUP plans set the objective of modelling and integrating water quantity and quality with biological, ecological and socio-economic issues, the actual WUP-A work, in practice, focused on water quantities only. The possibility of including water quality and the Tonle Sap lake and floodplain model in the Decision Support Framework (DSF) was lost when the original consultancy work for water quality and lake/floodplain modelling were eliminated during the project inception phase. Consequently, in the DSF there is only a limited 'set of impact analysis tools that enable the prediction of environmental and socio-economic impacts in response to changes in condition of the river system' (MRC, 2004). The set consists of flood properties and a rather schematic saline intrusion description. All of this has led to critical limitations in implementing the DSF and assessing the impacts of development scenarios.

The Model and Knowledge Base (i.e. Decision Support Framework of the MRC) was developed under an approximately US$5 million contract with Halcrow Group during the period of 2001 to 2003. The contract outputs consist of a basin knowledge base and hydrological/hydrodynamic models and impact assessment tools. Model components include catchment hydrology (SWAT), water use (IQQM) and 1D river hydrodynamics (ISIS). The ability of the DSF to simulate hydropower development impacts was critically studied by Adamson (2006), and reported at the Mekong Region Waters Dialogue meeting in Vientiane in July 2006. Adamson found the DSF hydrological model unsatisfactory for this purpose, stating the following:

> *The hydrological model IQQM selected for the DSF by the Halcrow Consultants was principally developed for the Murray Darling Basin in New South Wales in Australia, with major focus on identifying water allocations in a highly managed and regulated river system. The hydropower element had to be added to the Mekong version of IQQM in order to enable simulation of hydropower storage and power plants. However, this is fairly rudimentary and the DSF would not be the modelling system of choice on which to base an assessment of the consequences for the regional hydrological regimes of hydropower expansion in the Mekong Basin. Output would be coarsely indicative of the cumulative impacts of any regulatory storage. Meaningful hydropower simulation needs dedicated simulation models that are much more sophisticated than the relevant modules within the DSF.* (Adamson, 2006)

Consequently, it is clear that the current DSF system needs to be strengthened to meet the requirements set in the WUP *Project Implementation Plan*, most importantly to ensure that analytical tools are based on improved interaction between the physical and biological features of the basin; model components for analysis and prediction of transboundary impacts of proposed actions on the aquatic ecosystem are being developed and actively used; and modelling of water quantity and quality and its linkages with important environmental, social and economic issues, such as wetlands and fisheries, form the core of the system.

The recently established Information and Knowledge Management Programme (IKMP) of the MRC, which continues the work of the Water Utilization Programme, needs to address the existing gaps in the DSF – in particular, to focus on providing more comprehensive views on social and economic impacts that the changes in the flow and water quality of the Mekong system are likely to cause.

Improving the accuracy of change estimates

Plans for large-scale hydropower dams are mushrooming in the Mekong Basin; yet there are no appropriate and commonly agreed tools to make good estimates of their potential impacts. Credible, validated and transparent models are necessary for good decision-making and public acceptance of those decisions. Further work is needed, especially in improving the reliability of the estimates of hydrological, environmental, social and economic impacts, including:

- modelling the basin-wide hydrological impacts of the developments (e.g. by model studies comparative and complementary to the DSF in order to reduce the current uncertainties in the flow change estimates);[1]
- developing further the integrated indicator of the productivity of the Tonle Sap ecosystem (based on Junk, 1997; Lamberts, 2006), and the Lamberts and Koponen (2008) productivity model;

- continuing work on social impact assessment with particular focus on the inclusion of broader social issues, such as vulnerability and poverty; and
- continuing the work of defining the acceptable reverse flow to the Tonle Sap (as stated in the 1995 Mekong Agreement) as part of the national consultations and in dialogue with the stakeholders.

Changes in Tonle Sap flooding and productivity potential

Changes in the flow and water quality regime of the Mekong River have impacts upon flooding, erosion, sedimentation, navigation, fisheries and agriculture, as well as upon consequent social and economic issues. The objectives of the WUP-FIN phase 2 (MRCS/WUP-FIN, 2007b) were set to provide complementary tools and information to approach these questions. In addition to direct impacts upon the river system, Mekong developments have impacts upon the hydrology and ecosystems of the wetlands connected to the river as their behaviour is largely affected and controlled by the mainstream Mekong River. This is the case with some of the important tributaries' floodplains, the Tonle Sap system in Cambodia being the most highlighted example. The Tonle Sap River is, in some definitions, taken as part of the mainstream due to the dominant role that the river has in the functioning of the Tonle Sap Lake ecosystem. Around 60 per cent of the Tonle Sap flood water originates from the Mekong, and the water level in the lake is controlled by the water level in the Mekong mainstream (Kummu and Sarkkula, 2008). Therefore, the possible flow alterations in the Mekong mainstream will directly affect the flood pulse of the Tonle Sap Lake.

The Tonle Sap system and its remarkable levels of aquatic production are clearly of crucial importance for Cambodia and, indeed, for the entire Mekong Basin (e.g. Keskinen, 2006; Kummu and Sarkkula, 2008). The productivity of the Tonle Sap lake-and-floodplain system is driven by the flood pulse of the Mekong and by the rich floodplain biodiversity. The flood pulse transfers terrestrial primary products into the aquatic phase during flooding and creates an extremely rich ecosystem for aquatic life (Junk, 1997). Primary production (phytoplankton, periphyton and plants) fuels the food webs, resulting in one of the world's most productive fisheries grounds. The floodplain of the lake offers ample opportunities and conditions for fish to breed and grow (Lamberts, 2006; Lamberts and Koponen, 2008).

Hydropower development may change the natural flood pulse, directly undermining the productivity of the system by reducing the inundated habitats, delaying the onset of flooding, and shortening its duration (growth period for aquatic organisms). All of these changes are estimated to have a negative impact upon the fisheries productivity of the Tonle Sap system. Hydropower development would probably also reduce the supply of sediments and nutrients to the downstream ecosystems because of sediment trapping in the reservoirs. Fisheries productivity is further likely to be affected by worsening conditions for fish reproduction due to slowly rising flood waters and the associated poor water quality. Lower flow velocities will limit the drift of eggs, larvae and juveniles to the floodplain habitats, while dams will obstruct fish migrations.

A number of models have been used for flow regime simulations with the foreseen hydropower developments (e.g. the high development option with Chinese mainstream dams and Lower Mekong Basin tributaries dams). The DSF flow values were input into the WUP-FIN Tonle Sap model to simulate the flooding change of the Tonle Sap system, such as the change in the extent of the flooded habitat and the change in the dry season water level (two more simulations on the cumulative impact of the hydropower developments that were available in addition to the DSF are referred to below). The results from the different simulations are quite different, especially the dry season water levels. This is mainly due to the different development scenarios and assumptions, as well as the models themselves used in the analysis. An actual analysis and comparison of the models has not been possible due to their different contractual setting. The results require higher confidence levels and this question should be re-examined, with additional models brought into the ensemble (e.g. the Variable Infiltration Capacity (VIC) model and WUP-FIN).

The dry season water-level rise due to Mekong upstream development was, in different assessments, estimated as:

- 0.15m (by DSF, data prepared for IBFM);[2]
- 0.30m (by Henrik Garsdal of the Danish Hydraulic Institute (2004), based on Adamson's (2001) analysis on the mainstream Mekong Basin); and
- 0.60m (by ADB, 2004, using MIKE Basin).

The impact of the water-level rise upon the dry season lake area is presented in Figure 9.1. The 30-day minimum water level during the analysis period of 1997 to 2006 for May was 1.44m above mean sea level (amsl), which was used as a reference level. The bottom of the lake lies at 0.6m amsl; thus, during the low water level the average depth of the lake is only around 0.8m, with a lake area of around 2300km^2. The estimated rise of 0.60m in the dry season water level, as simulated by ADB (2004), would result in the flooding of an area of 3200 km^2, indicating that the permanent lake area would increase by nearly 1000 km^2 or 40 per cent (Kummu and Sarkkula, 2008).

The rise in the dry season water level of the lake would mean an extension of the permanent lake and significant destruction of the flooded gallery forest where it becomes permanently inundated and, consequently, loss of important habitats (Kummu and Sarkkula, 2008). The different cumulative impact assessments (CIAs) also predict that the peak water level would decrease and thus reduce the inundated area of the lake, as presented in Figure 9.2. Thus, the area of the floodplain would decrease, depending upon the CIA, by 7 to 16 per cent. For example, in the case of a CIA carried out by ADB (2004), the total floodplain area would decrease from

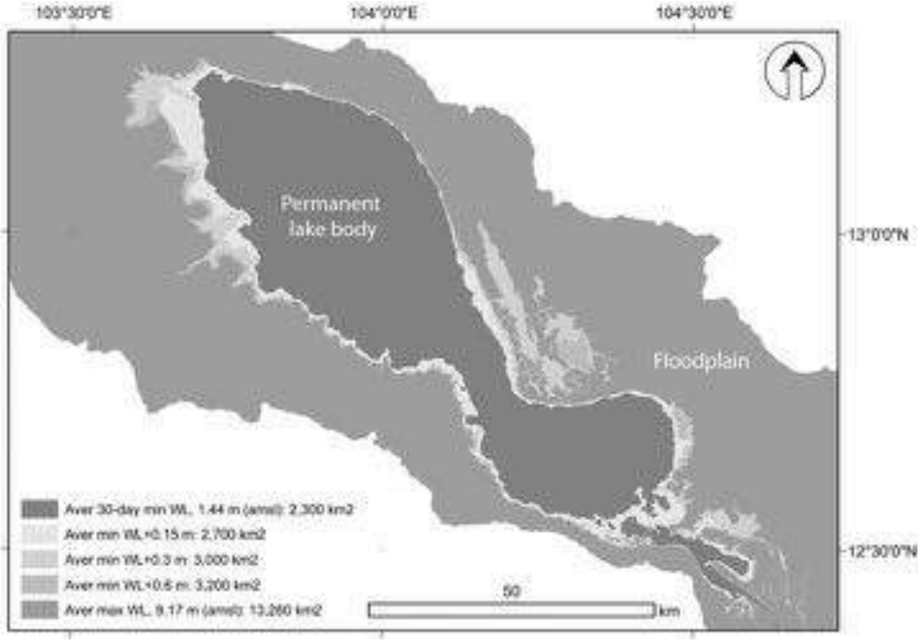

Figure 9.1 *Inundated areas due to the increased dry season water level*

Source: adapted from Kummu and Sarkkula (2008)

the current 10,750km^2 to 9060km^2 by the year 2025, resulting in around a 15 per cent decrease in both cumulative flooded area and volume.

Figure 9.3 shows the change in flood duration over the floodplain during 1997 conditions based on the EIA 3D model results and input of the MRC flow regimes developed for the IBFM project. The period of inundation decreases in most parts of the floodplain by one to two weeks (5 to 10 per cent), while in the lowest parts of the floodplain the inundation is prolonged due to the increase of the dry season lake level. Due to permanent inundation, these areas would be transferred from floodplain habitats to become part of the lake proper.

The tall gallery forest strips around the lake make an important physical barrier between the lake and the floodplain. The strips create favourable conditions for sedimentation within the forested zone where nutrients bound with the sediment, mainly from the Mekong, fuelling primary production. The lake extension would cause permanent submersion – in essence, destruction – of considerable strips of gallery forest surrounding the lake (Kummu and Sarkkula, 2008). The reduction of the flooded forest area could therefore have a significant impact upon the whole Tonle Sap ecosystem, and probably also upon floodplain dynamics. The evolution of the floodplain to its present state and biological functioning has taken several

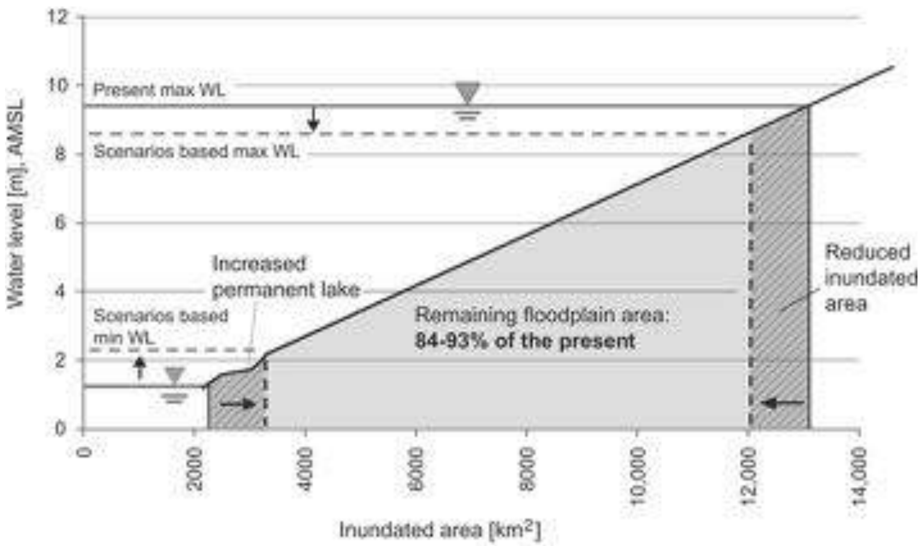

Figure 9.2 *Schematic presentation of the possible impacts on the floodplain extent due to changes in flow regime*

Source: adapted from Kummu and Sarkkula (2008)

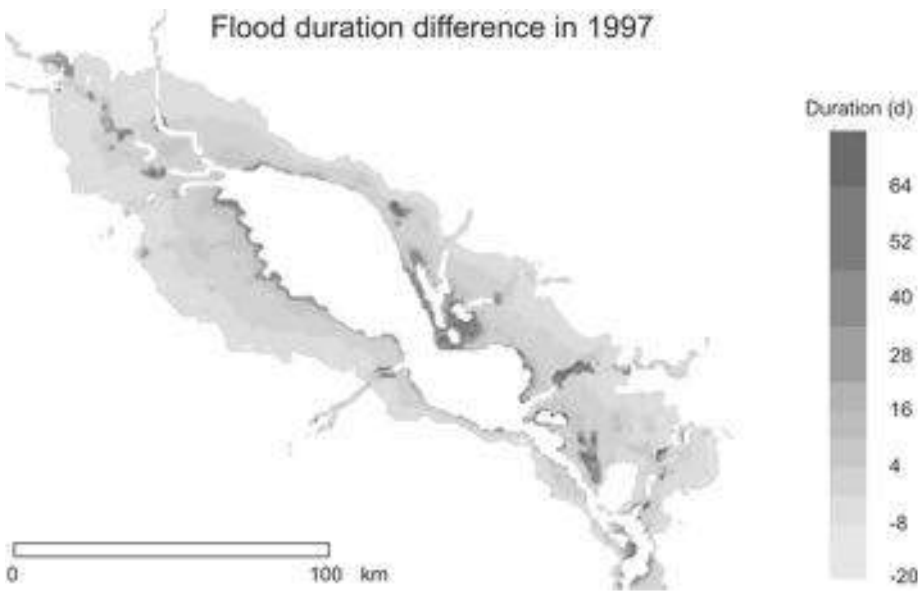

Figure 9.3 *Flood duration difference based on simulation results*

Source: adapted from MRCS/WUP-FIN (2007b)

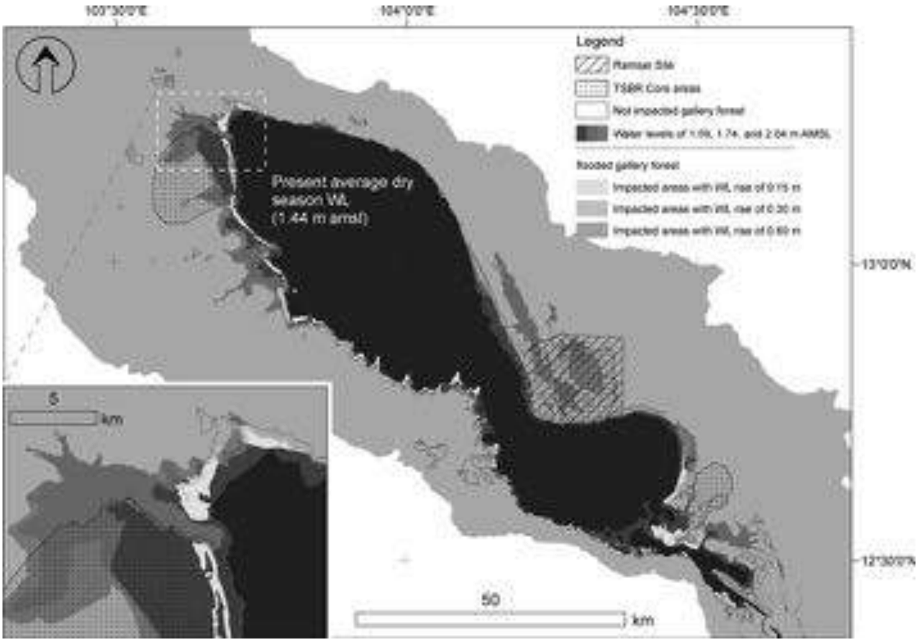

Figure 9.4 *Flooded and remaining tall gallery forest in the case of 0.6m dry season water-level rise*

Source: adapted from Kummu and Sarkkula (2008)

thousands of years (Tsukawaki, 1997), which means that what is lost in its structure and productivity can hardly be mitigated in any way.

Scenario work carried out under the WUP-FIN project, aiming to estimate the cumulative impact of the changing floodplain conditions in the Tonle Sap, focused on comparing the flow changes between Flow Regime FR3[3] (MRCS/IBFM, 2006a) and the baseline in 1997 and 1998 on a number of flood and water quality indicators of the lake and the floodplain. The comparison of the simulation results gave the following results:

- The inundated floodplain habitat would be reduced by 15 to 20 per cent.
- The period of inundation would be shortened by one to two weeks.
- The increased dry season water level would permanently inundate a major part of the flooded forest around the lake (extending the permanent lake).
- Dissolved oxygen conditions would worsen by extending the strongly hypoxic/anoxic period in the floodplain during early flooding due to slowly rising floods.

- Sediment and nutrient input to the lake with the flood waters would be reduced.

A first estimate of the impact of the changing floodplain conditions was made by introducing a cumulative indicator for floodplain productivity potential by giving an estimate for the minimum and maximum value for each individual indicator. The calculation of the cumulative impact of the physical and water quality factors gave a value in the order of 25 per cent reduction in the floodplain productivity potential, even with rather conservative estimates for individual indicator changes. This estimate is well in line with the assessment made by the expert panel within the IBFM phase 2, where it was estimated that Flow Regime 3 would result in an overall 20 to 30 per cent or more reduction in the productivity potential of the Tonle Sap Lake and its floodplain (MRCS/IBFM, 2006a).

Developing a Tonle Sap productivity model

The Tonle Sap flood pulse is largely (60 per cent) driven by the water that is pushed up into the lake by the reversed flow of the Tonle Sap River during the rise of the flooded Mekong River. The remainder is runoff from Tonle Sap's own catchment as well as direct open-water precipitation. The Mekong flood waters not only bring water and floods, but also nutrient-laden sediments that are largely deposited in the floodplain. The flood water integrates the terrestrial vegetation within the aquatic phase of the ecosystem, and this interaction between the terrestrial and aquatic phases is the driving force of ecosystem productivity. Knowledge of the relation between ecosystem productivity and the flood pulse, as ultimately determined by the flows in the Mekong River, is still very limited.

Lamberts and Koponen (2008) have developed a quantitative model of the ecosystem productivity of the Tonle Sap Lake and floodplain, with a particular focus on its response in the function of altered flow regimes in the Mekong River.

The underlying assumption is that the Tonle Sap secondary production (including fish production) is mostly endogenous (i.e. based on primary products generated within the ecosystem rather than imported with the flood waters). While there are no specific data to support this, the assumption is reasonable based on the low organic matter contents of the inflowing rain and Mekong waters and the known migration of fish between the Tonle Sap and the Mekong. This is believed to be largely a net export of fish biomass from the river, with mostly fish juveniles, larvae and eggs drifting into the Tonle Sap ecosystem with the flood waters. Furthermore, the assumption is made that most of the organic matter in the Tonle Sap ecosystem is produced locally by four categories of primary producers: periphyton, phytoplankton, rooted macrophytes and floating macrophytes.

The main result from this research is a spatially explicit model of Tonle Sap ecosystem primary production, which is the basis of the secondary food webs and determines, to a large extent, the overall productivity of the system. The modelled production is based on environmental factors, most of which are directly or indirectly dependent upon the hydrological cycle. The model allows quantitative assessments of the environmental impact (relative or absolute) upon ecosystem primary production. It uses the few data specific to the Tonle Sap and depends upon the hydrodynamic model for making the results spatially explicit. It has demonstrated where the main data and knowledge gaps are, and the model has been developed so that its accuracy can be improved by relatively few field measurements. In this way, it can be constantly refined while already providing the best available quantitative assessments of the impact of flow alterations in the Mekong River upon the primary production of the Tonle Sap ecosystem.

The link between primary production of the ecosystem, its fish production and the fish catches is very complex, and there is no specific information on these links, nor are there sufficient data on fish catches. However, with the reasonable assumption that most of the productivity of the Tonle Sap is located within the ecosystem rather than imported, taking into consideration the high fish production, and given the dynamic character of the ecosystem, it can be assumed that any loss of primary production will directly result in loss of secondary production and, hence, fish catches. The precise nature of this relationship is unclear and may be impossible to establish.

The ecosystem and economic values of resources

The Mekong and its floodplain are rich in natural resources, particularly in fish, supporting local livelihoods in a variety of ways. This was also evident in the socio-economic surveys carried out during the WUP-FIN Project in different parts of the basin (MRCS/WUP-FIN, 2007b). Although the study areas in the Lower Mekong Basin were diverse and, therefore, different in many ways, there were also findings – related, for example, to the value of and the dependency upon resources – that were similar in all studied areas; these are discussed next in more detail.

Estimating the real value

Measuring poverty and the value of resource use in the widely varied conditions present in the Mekong Basin is not simple. For example, the findings from the Tonle Sap, as well as from Nam Songkhram Basin in northeast Thailand, indicate that both of the areas are considered poor in monetary terms, but rich in natural resources. In both areas local people rely on diverse natural resources that provide both food and income, although not necessarily in cash. In Nam Songkhram, the area's wetlands are considered to be 'nature's supermarket' where you need no money to 'shop' for the large variety of different resources provided (MRCS/

WUP-FIN, 2007b). This coexistence of economic poverty and resource wealth raises questions about the validity of current poverty measures, and suggests that macro-economic analyses measuring poverty in pure monetary terms are not able to properly measure the wide and diverse use of natural resources. This leads to an underestimation of the real values of different natural resources for the people living in the Mekong Basin.

Consequently, the close linkage between the viability of river ecosystems and people's livelihoods is often not taken seriously into account in social and, particularly, economic analyses at national and regional levels (see Chapter 12). Everyone agrees that the health of the river ecosystem feeds directly back into supporting the welfare of the people in the basin, particularly those amongst the poorest sections of society. However, the importance of maintaining the river ecosystems – and, consequently, the diverse set of resources and services that they provide – is still neglected in most policy discussions about the development of the basin.

The dependence of poor people upon aquatic resources

The findings from the WUP-FIN case study areas indicate that the poorest villagers are those most directly dependent upon fisheries and related aquatic resources for their livelihoods. At the same time, the poorest have usually less capabilities and resources to adapt and make use of the changes that take place in the availability of these resources due to changes in water flows – for instance, irrigation development or dam construction. When coupled with prevalent governance challenges and problems of unequal access to different resources, this is likely to lead to growing disparities between villagers: while those who are better off are likely to gain, those who are already poorer will lose (e.g. Fox and Sneddon, 2005; Keskinen et al, 2007; Sneddon, 2007).

This finding was particularly evident from the results of the participatory village surveys in the Tonle Sap area (see Keskinen, 2006; MRCS/WUP-FIN, 2003), which concluded that the people living in the villages closest to the lake were in many ways most vulnerable to the changes in natural resources. They are generally poorer, less educated, have fewer livelihood options, do not own agricultural land, and depend strongly upon common-pool resources such as fish and flooded forests for their livelihood. Differences also seemed to emerge within the villages between the capabilities of the poor and the better-off to respond to the changes in natural resources.[4] Similar findings were also apparent in the Cambodian floodplains (MRCS/WUP-FIN, 2006a, 2006b), in Nam Songkhram (MRCS/WUP-FIN, 2007a; MWBP, 2005), as well as in the Mekong Delta (MRCS/WUP-FIN, 2006c), where livelihood developments focusing on intensive agriculture and aquaculture do not seem to take the poor's dependence upon, for example, wild-capture fisheries properly into account.

Small-scale utilization and distributing the benefits of development

Small-scale utilization of Mekong's water resources offers a more sustainable basis for poverty reduction than large-scale projects. As discussed above, we believe that many of the current economic assessments in the Mekong Basin are underestimating the actual value of natural resources for local people. Following on from this, the common justification for water development is the 'underutilization' and 'underdevelopment' of the basin's resources. However, the Mekong basin is – through small-scale fishing, farming, use of wetlands and floodplain resources – already extensively utilized in a variety of ways at the local level. Consequently, most future development options in the basin are focusing on the development of modern sectors such as irrigated agriculture, while a majority of the population in the basin actually depends upon more traditional livelihood sources (MRCS/IBFM, 2006b; Keskinen et al, 2008). As noted by Phillips et al (2006):

> *The key development paradox of the region is that economic growth is necessary to bring many of the populations out of poverty, but the 'classical' route involving the subsidized construction of massive infrastructure is most unlikely to provide the optimal result in this respect for the poorer sections of the populations.*

Indeed, we see that 'classic' large-scale development interventions such as irrigation and hydropower projects are, despite their objectives of poverty reduction, actually often undermining the foundations of the livelihoods of the poorest groups by impacting negatively upon the different common pool resources – most importantly, fisheries.

Consequently, the management and development of Mekong's water resources – if aiming at poverty reduction – should be based much more upon already existing 'decentralized' utilization of the Mekong's resources. In addition to the actual value of this diffuse utilization, its distributional benefits should also be considered. Compared, for example, with the distribution of the benefits from hydropower dams, small-scale utilization usually allows for more equal distribution of the benefits derived from the Mekong's resources, reaching the poorest more easily.[5] Hence, if, for example, the value of hydropower development and of sustaining river fisheries were of the same order of magnitude, in terms of poverty reduction, fisheries would provide a more favourable basis due to its more equitable – and already existing – distribution of benefits.

It is important to emphasize that our findings do not imply that infrastructure should not be built when it is needed for national economic development. What we are highlighting, however, is that in terms of poverty reduction, we believe that much more emphasis should be put on sustaining and developing existing small-scale and local livelihood resources. Overall, small-scale infrastructure reduces risks of unintended impact, better involves local stakeholders, and the distribution of benefits and costs from the project are much easier to monitor and address. This finding is also supported by the results from the ADB-funded Built Structures Project for the Tonle Sap Lake (CNMC and WorldFish Centre, 2007).

The recognition of the actual value of the traditional livelihood sources and their distributional benefits will most probably lead to more balanced discussion about the possible trade-offs required in developing the Mekong's resources. When considering the huge number of different plans for Mekong's development, it is worrying to notice a complete absence of well-informed and transparent discussion about the different trade-offs that are unavoidably required – both within and between the riparian countries – due to changes caused by water resources development. We see that there is an urgent need to acknowledge that water development requires trade-offs, and that the discussion about trade-offs is always highly political. Achieving the best compromises (where possible) on different trade-offs requires open and transparent discussion, access to relevant information by all concerned parties, as well as research focused on socio-economic and livelihood issues (such as small-scale fisheries) that are most likely to experience radical changes.

Peoples' well-being under threat

Up until 2006, only China was actively building and pursuing mainstream dams in the Mekong region. Since then, there has been a sudden surge in mainstream dam plans within the Lower Mekong Basin in Laos, Thailand and Cambodia (see Chapter 2). These intentions further increase the potential for destructive impacts upon fisheries in the Lower Mekong Basin. Apart from alteration of the flood pulse, changes in timing and duration of flooding and water levels, sedimentation in reservoirs, and other flow-related impacts such as changes in larvae and juvenile drift, the dams will block essential fish migration routes and disconnect spawning and living habitats. The impacts will very likely be significantly bigger than in the so-called high-development scenario (Chinese dams and Laos tributary dams) that was discussed in the section on 'Modelled flow change and methodological development needs'. The risk to people's well-being in the basin is consequently magnified.

This chapter has considered several issues related to living conditions in the Mekong region, often focusing on groups of rural poor who are particularly vulnerable to changes in floodplains. A critical question is about their life and future in relation to basin developments. The rural poor are defined as poor as a result of their low cash income, an indicator unable to describe their living circumstances and well-being. A much more important source of livelihood, however, originates from the rich natural resources in the basin, especially the enormously productive fisheries. Fisheries do not only benefit the people living next to the river or the floodplains, but all of the Lower Mekong Basin countries, providing their populations with the main portion of their animal protein needs.[6]

It is paradoxical to talk about the poverty of the population without properly taking into account this enormous natural resource. Basin developments are repeatedly and without critical views being justified by the statement that large-scale infrastructure construction is the solution to reducing poverty, although there is no evidence this will lead to the claimed result. The dams are expected to generate income; but how will the benefits and costs be shared?

Chapter 12 in this volume discusses the hydropower and fisheries trade-off and the storylines that are embedded within it. Friend et al identify the inherent assumption in the approach that society can afford to trade off fisheries for the economic benefits of hydropower. They claim that the notion that fisheries can be traded off rests on the highly questionable hypothesis that what is lost can be replaced. They conclude that an empirically based counter-narrative is required that can provide a counter-scenario where fisheries are not merely a resource of conservation value, but a resource whose management is central to meeting the development challenges of the basin.

The destructive effects of the dams at different timescales must be included in the development equations, as well. The lifetime of the dams is very short compared to the evolution needed for the ecosystem to develop its services. The richest ecosystem in the Mekong Basin, the Tonle Sap floodplain, was created about 6000 years ago when the Mekong and the Tonle Sap rivers were connected as a consequence of an elevated sea level (Tsukawaki, 1997). Since then, part of the Mekong flood waters have entered into the lake and the surrounding terrain through an annual reversal of the flow of the Tonle Sap River, resulting in the ecosystem's high biodiversity and productivity, particularly in the aquatic–terrestrial transition zone.

As discussed in this chapter, the modification of the Tonle Sap flood pulse due to construction of hydropower dams will negatively affect floodplain productivity. Already, the cumulative effects of the Chinese dams and the Lower Mekong Basin tributaries dams[7] have been estimated to have a significant negative effect upon the Tonle Sap ecosystem's productivity. It is important also to realize that permanent reduction in the flood extent and duration is not only likely to reduce fish catch and, thus, threaten livelihoods and food security, but can also threaten the long-term sustainability of the fish populations by reducing their reproductive potential (mean size) and by making fish more vulnerable to capture (Halls et al, 2008). In addition, while the latest plans of building a number of mainstream dams in the Lower Mekong Basin may have a limited impact upon the flood pulse, they will critically block fish migration routes and disconnect spawning grounds and living habitats. Most of the total fish catch in the Lower Mekong Basin is dependent upon long-distance migrant species (Dugan, 2008). There is little doubt that the impacts upon fisheries would be dramatically destructive.

In terms of trade-offs, the distribution of hydropower's benefits and costs is obviously between upstream and downstream, and between different social groups. It would be fair and reasonable to take these concerns as one elementary starting point in the development plans discussion, and to see whether the countries involved and their people are able to bear the consequences of losing an essential part of their ecosystem productivity and services. This also means taking social responsibility of the most affected, and being strict in assessing the impacts regarding general social conditions and food security risks in riparian countries.

The valuation of the fisheries resource has been largely pending and has often been excluded from the basin development equations. For example, Cowx et al (2004) state how poorly the true value of this sector is reflected in official statistics and discussions of food security and livelihoods; as a consequence, fisheries suffer in the face of relatively higher economical priorities such as hydropower. As highlighted by Sokhem and Sunada (2006), one of the key problems in the Mekong Basin is that the value of the fisheries resource is usually ill defined, severely undervalued and poorly represented from both an economic and social perspective.

Recent efforts to truly value the Mekong fisheries (e.g. by the MRC Fisheries Programme) are expected to give a more valid starting point to assess the well-being of people and give improved means to compare development impacts and prices.[8] It is necessary to try to estimate the real value of fish and fisheries: first, to highlight their importance for livelihoods, as well as to draw a more realistic picture of people's well-being and their vulnerability to change. There are many indicators and indices developed and available for assessing people's well-being and life quality that can be used as starting points to make such an evaluation in the Mekong (Henderson, 1996; Prescott-Allen, 2001).

Molle (2006) pointed out several risks in large water infrastructure projects. The challenges, he argues, are how to ensure that:

- projects are not primarily moved by bureaucracies seeking to perpetuate themselves or by the financial and political interests of decision-makers;
- displaced people are fairly compensated (the lack of a voice from poor rural people in many countries suggests that attention to their fate will remain limited);
- benefits are not captured by, and concentrated upon, a few well-off elites, and costs and risks are not borne by poorer people; and
- development alternatives are fairly assessed.

In the case of the Mekong region, the worst scenario – made more likely with the recent boom of dam projects – is that hydropower development will be given priority, with nil or insufficient consideration of, or compensation to, the diverse groups of people undergoing the negative impacts of that development. It is hard to see how the costs and benefits of this development will be fairly balanced – both within and between the riparian countries. Unfortunately, the MRC has so far, despite its mandate and constitution (the 1995 Mekong Agreement), done very little to ensure that a worst-case scenario does not unfold (see Chapter 14).

The conventional economic development path currently pursued in the Mekong is fraught with risks. It is necessary to step back to properly see and assess the plausible alternatives and their implications. We propose a radical strengthening of development dialogues that places emphasis on broad multi-stakeholder participation. We anticipate that this would bring to the fore the uneven sharing of burdens, costs, benefits and risks between upstream and downstream, as well as between different social groups. This kind of finding will most probably draw more attention to the potential of alternative, smaller-scale, development options. In addition, it will demand vastly improved dissemination of information relating to development projects with the result that the public will be better engaged in scrutinizing proposals, promises and potential impacts.

This radical change needs to be supported by research and continuing improvement of the methods for assessing development project impacts, improving their accuracy, transparency and credibility. In this process, the MRC still has an unfulfilled potential. Through credible and comprehensive assessment tools and constructive dialogue with different partners, it can still become a key organization in helping to find an appropriate balance between acceptable levels of hydropower development and the maintenance of fisheries as a vital environmental and social resource in the basin.

NOTES

1 The Mekong basin-wide distributed hydrological Variable Infiltration Capacity (VIC) model provides an existing tool and opportunity to improve the hydrological basin development simulations (Costa-Cabral et al, 2007). Connected with the WUP-FIN Lower Mekong Basin river and floodplain model (MRCS/WUP-FIN, 2007b), the coupled system largely responds to the needs and complexity of the Mekong Basin and its ecosystem. Both the VIC and WUP-FIN models have water quality and ecosystem productivity simulation capability.

2 This refers to the integrated basin flow management process of the MRC.

3 FR3 represents the potential high developments in the basin, as foreseen in 2003 (including the Chinese mainstream and Laos tributaries hydropower dams).

4 This conclusion is also supported by the findings of the ADB-supported Built Structures Project (CNMC and WorldFish Centre, 2007)

5 Distribution of the benefits from different common pool resources (such as fisheries) is naturally not without problems either: the poorest groups, in particular, often have problems getting equal access to these resources.

6 Hortle (2007) summarizes the available information on consumption and yields of inland fish and other aquatic animals (OAA) in the Lower Mekong Basin, reaching an estimate of the total consumption of fish and OAA at about 2.1 million tonnes per year and 0.5 million tonnes per year, respectively. Annual consumption of inland

fish plus OAAs as country averages is in the range of 40kg to 50kg per capita, and its portion of all animal protein consumption values is high across the LMB (as high as 82 per cent in Cambodia).

7 So-called high-development scenario, designed during BDP phase 1.

8 The current estimates for the economic values (first-sale value) of freshwater fish and aquatic products range between US$1 billion and US$1.5 billion (Ahmed et al, 1998; MRC, 2002; Baran, 2005; MRCS/IBFM, 2006a). Including all multiplier effects, the fishery is worth several times more than this figure and its replacement value is far higher (Baran, 2005).

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