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INFLUENCE OF BUILT STRUCTURES ON THE FISHERIES OF THE TONLE SAP: A MULTIDISCIPLINARY APPROACH

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ABSTRACT

The fishery resources of Cambodia, originating mainly from the Tonle Sap Lake, rank first in the world for their productivity and fourth for their total catch. However the natural productivity of the Tonle Sap might be threatened if the flood pulse, the seasonally submerged habitats, and the fish migration routes are significantly altered. “Built Structures” consist of a diversity of constructions (e.g., dams, embankments, roads).that contribute to changing the hydrology and functioning of a natural system. In this paper we present a research project that started in May 2006 and whose objective is to assess the influence of Built Structures on the Tonle Sap fisheries. The approach is multidisciplinary and includes 6 interconnected components: database, hydrological modelling, environmental impact, fisheries, livelihoods and policy outreach.

KEYWORDS Cambodia, fisheries, infrastructures

INTRODUCTION

The fishery resources of Cambodia, originating mainly from the Tonle Sap Lake, rank first in the world for their productivity and fourth for their total catch, despite the small size of the country. The floodplains’ contribution to income, employment, and food security through fisheries is higher than in any other country. However the natural productivity of the Tonle Sap's floodplains is threatened if the flood pulse, the seasonally submerged habitats, and the fish migration routes of the Tonle Sap are not understood and addressed [Baran 2005].

One such threat to the natural productivity of the floodplains comes from the creation of man-made structures on the floodplain or on connected rivers. These built structures consist of a diversity of constructions or items set up by man that contribute to changing the hydrology of a natural system, and include: i) structures that oppose water outflow (e.g., dams, irrigation schemes, dykes); ii) structures that prevent water inflow (e.g. embankments, polders, levees); and iii) structures altering water inflow or outflow (e.g., roads, railways, canals). Structures that iv) degrade water quality (e.g. factories, sewers) can be also considered as built structures.

Built structures primarily influence hydrology, but they also influence, directly and indirectly, the environment, fisheries and the livelihoods of people who depend on aquatic resources [Kummu *et al.* 2005]. Thus, as **Figure 1** illustrates, a given built structure implies some form of floodplain modification, that has direct effects, for example on hydrology and fish and that can also catalyse changes in the way that people use resources, for example through increased or reduced access to fisheries or opportunities to develop other livelihood aspects. Some of these changes may involve further modifications to the floodplain, for example further embankments or the development of paddy fields. These changes will then produce their own impacts that represent the indirect impacts of the original built structure.

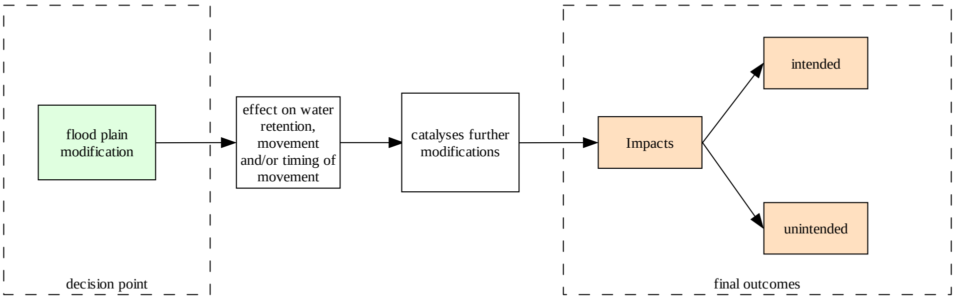

Figure 1: Process by which built structures achieve impacts

The combination of technical, bio-physical and social interactions that result from the introduction of a built structure require a multidisciplinary approach if the impacts, cumulative effects and trade-offs of the new constructions are to be understood. We present in this paper an on-going multidisciplinary study of the influence of built structures on the fisheries of the Tonle Sap, from hydrology to livelihoods. The Cambodian National Mekong Committee (CNMC) is the executing agency of this 10-months study that started in May 2006; the WorldFish Center is the implementer, together with a consortium of Finnish scientists from EIA Ltd., HUT and Biota BD.

METHOD

This scientific project is aimed at generating knowledge and informing decision-makers. It is intended to help answer the development question "How to maximise returns and minimise negative impacts of built structures on the Tonle Sap resources and communities?". Our approach to answer this question is three-fold, i.e. exploratory, multi-scale and multidisciplinary. It is exploratory as tropical built structures and their impact on environment and aquatic resources have been little studied and quantified [Kruskopf, in press], so limited background information is available. The multi-scale approach results from the fact that Tonle Sap fisheries depend on the presence of extensive local floodplains, fed by sub-basin tributaries and a major input from the Mekong mainstream. Last, our approach is multidisciplinary to reflect the fact that hydrological modifications influence the environment and aquatic resources, which influences in turn socio-economic patterns and the livelihoods of rural people. Integrating these different perspectives implies a particular focus on trade-offs.

The exploratory approach requires a balance between comprehensiveness and feasibility. This resulted in the selection of few types of different structures, all having an impact on fisheries. Four main types of structures have thus been selected: dams, irrigation schemes, floodplain roads/dykes and large fishing gear. Dams are a type of construction whose negative impacts on the environment and fisheries are well known [WCD 2000], although they primarily respond to a demand for hydropower or irrigation. Irrigation schemes combine water retention and land use changes, with subsequent modification of environmental and socioeconomic patterns. Roads in floodplains are almost always associated with dykes; they result in floodplain fragmentation and loss of habitat for fish, although they also facilitate social exchanges and trade. Lastly, large scale fishing gear is specific to Cambodia, where bamboo and net fences are set up in the floodplain before flood water recedes to catch fish; fenced fishing lots now cover 3140 km^2 [Keskinen 2003] and each of the current 81 lots uses on average 20 to 40 km of fence [Nao Thuok and Sam Nuov 1996]. In addition to their obvious role on fish stock, it is hypothesized in this project that these large scale fishing structures significantly influence the lake's hydrodynamics.

Three scales are addressed in the study: i) Tonle Sap floodplains; ii) Tonle Sap tributaries, and iii) Lower Mekong Basin. Tonle Sap floodplains were selected because of their crucial role in sustaining Cambodia's fisheries productivity [Baran 2005]. It was decided to also integrate to the study the Tonle Sap tributaries as they provide 40% of the Tonle Sap water [DHI 2004]. Last, the Lower Mekong was also encompassed because of its major contribution to the lake's hydrology, ecological functioning and fisheries [Van Zalinge *et al.* 2004].

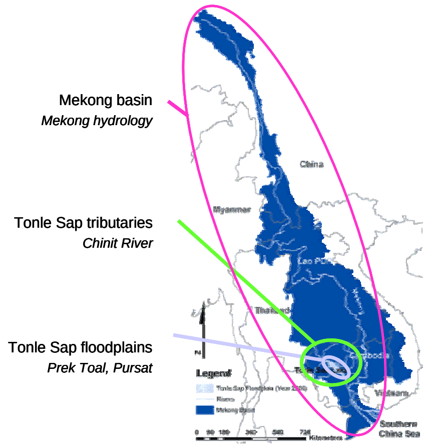

Figure2: Scales addressed by the Built Structures project

This project comprises six components, reflecting the disciplines that the study of built structures requires and the dissemination of results:

- *Database component*, to characterize and map major built structures in the Tonle Sap floodplain and study sites;
- *Hydrology component*, to model the influence of built structures on hydrology, hydrodynamics and water quality;
- *Environment component*, to analyze information on the influence of built structures on the environment;
- *Fishery component*, to assess the influence of built structures on fishery resources;
- *Livelihoods component* to evaluate the influence of built structures on socioeconomic patterns and on livelihoods, as well as their perception by stakeholders; and
- *Policy outreach component*, to package the information generated and actively disseminate it as a priority to decision-makers but also to other relevant audiences.

Table 1 below indicates the scale at which each component operates.

Table 1: Scale at which study components operate.

Component	**Scale**		
	Local	**Sub-basin**	**Basin**
Database	Yes	Yes	
Hydrology	Yes	Yes	Yes
Environment	Yes	Yes	Yes
Fisheries	Yes	Yes	
Livelihoods	Yes		
Policy outreach	Yes	Yes	Yes

Field work

Location and number of study sites

The study concentrates on three sites that illustrate the major types of structures in the Tonle Sap sub-basin: an irrigation scheme along the Chinit River (Kampong Thom province), fishing gear in Prek Toal (Battambang province), and floodplain roads in Pursat province (**Figure 3**).

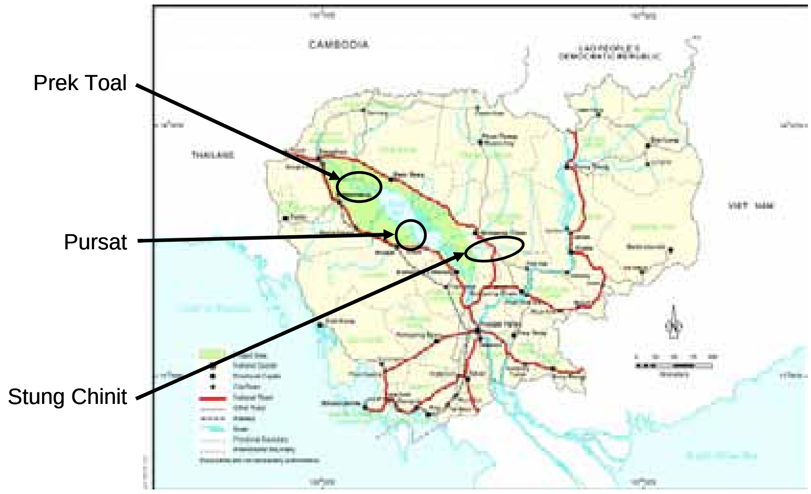

Figure 3: Project study sites in the Tonle Sap sub-basin

Stung Chinit

Stung Chinit is one of the major tributaries of the Tonle Sap Basin. This is also a site where, since 2001, an irrigation scheme has been developed. The scheme is located in Kompong Thom province, about 100 km upstream from the Tonle Sap Lake. It is located along the Chinit River that flows southwards to the lake. A large weir has been built across the river, fish migrations are likely to be impacted but a fish pass has been built as a mitigation measure. Information is available on the socioeconomic and ecological features of these sites. The site illustrates the influence of a structure built for irrigation purposes, and the balance between possible fisheries losses and agricultural gains.

Pursat

The study site in Pursat illustrates the influence of roads on the floodplain ecology and subsequent socioeconomic consequences. The site selected is in Krakor District, east of Pursat city. It consists of two track roads within the floodplain, about 8 km from the national road. Both roads were built across the direction of flooding, one in 2005 for communication purposes while the other was built a decade ago primarily as an embankment to protect rice crops from the flood (although farmers acknowledge the trade-off between flooding, loss of rice and bigger fish catches). Both roads allow an analysis of the influence of such roads and dykes on fisheries and livelihoods, either from a spatial perspective (inside/outside the area protected from flooding) or from a temporal perspective (before/after the recent construction of a road).

Prek Toal

Prek Toal is located at the Southwest corner of the lake, at the mouth of the Sangkae River in Battambang province. The Prek Toal area is on paper one of the three core protected areas of the UNESCO Tonle Sap Biosphere Reserve, and in practice one of the most intensive fishing zones of the Tonle Sap. The area is bordered on the west and south-west sides by flooded forest, and corresponds almost entirely to the surface of fishing lot #2. This privately owned and restricted access fishing lot, of a surface area of about 500 km^2 (the biggest in Cambodia), is fenced from approximately November to April by dozens of kilometers of dense bamboo fences that concentrate fish leaving the floodplain to the lake when the flood recedes. The site is bordered by four multi-ethnic villages whose villagers are primarily fishermen and the site constitutes a patchwork of social groups and situations in an intensive fishery context. A study of the hydrological and ecological influence of fishing gears as well as their impact on the social fabric and on the fisheries-related economic networks in one of the most productive floodplains worldwide is of crucial interest to inform fishery management and secure the sustainable exploitation of the resource. Although the extent of fences is probably unique in the world, similar fishing methods are used on a large scale in Bangladesh and Africa, and the knowledge generated in Cambodia will be of interest to many other countries.

Approach

Database component

The specific objective of this component is to make updated information on Tonle Sap built structures available to technicians, managers and decision makers. This component has conducted a scoping study on built structures, aimed at defining structures of relevance for cataloguing. The review is primarily focused on Tonle Sap floodplains, but also encompasses specific structures in the provinces of the three site studies, and major structures of concern in the Tonle Sap sub-basin. As a number of projects have recently contributed to the identification and characterization of built structures in the Tonle Sap Basin [e.g. Fujii *et al.* 2003, Cross 2005], the component initially focused on collating the information from these sources. Key sources of information also include high-resolution aerial photomaps and digital terrain model prepared in 2005 by FINNMAP under the ADB funded Tonle Sap Environmental Management Project, and comprehensive data on road embankments and main bridges from ongoing ADB-funded Tonle Sap Infrastructure Improvement Project. The database component will ground-truth the information gathered in selected locations (in particular the three study sites); and will ultimately produce a database of the Tonle Sap built structures, their location and their specifications. The database will be compatible with the databases of the MRC Secretariat and Tonle Sap Biosphere Reserve Environment Information Database (TSBR-ED; www.tsbr-ed.org).

Hydrology component

The approach of this component relies on the Tonle Sap three dimensional hydrodynamic and water quality model developed by WUP-FIN in 2001-2003 [Sarkkula *et al.* 2003], supplemented by the Mekong model subsequently developed [Sarkkula *et al.* 2004, 2005]. The component is thus developing an integrated model encompassing topography, land use/vegetation, water bodies (river channels, lake proper), meteorology, hydrology and water quality data. Built structures, which were not part of the previous versions of the WUP-FIN Tonle Sap model, are also integrated. Field surveys and measurements are being conducted in the selected study areas to update the model. This model will provide output data on a range of variables including flow and flooding characteristics, sedimentation, water quality, fish larvae drift (particles representing larvae) and habitat conditions. Using the model, not only the local Tonle Sap built structures impacts but also the influence of upstream developments, such as upstream irrigation and dam development, will be studied and these will be compared to the local impacts [Kummu *et al.* 2004]. The changes in the flow regimes are based on MRCS development scenario simulation outputs [e.g. Podger *et al.* 2004, Beecham and Cross, 2006]. In this way a perspective will be gained on the relative importance of local and regional developments. The results of the modeling exercises will be summarized into simple maps and illustrative animations that are designed to help communicate the complex mechanisms to a non-technical audience.

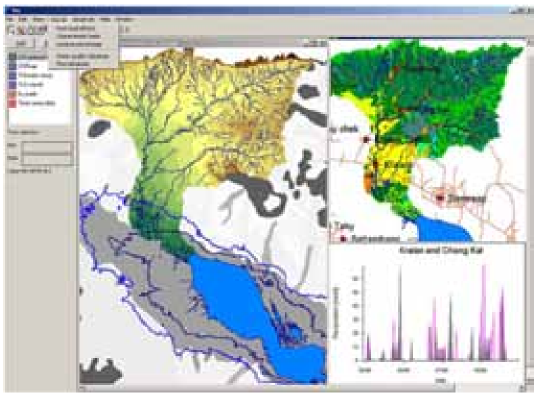

Figure 4: Example of a GIS contribution to the WUPFIN Tonle Sap updated hydrodynamic model

Environment component

This component aims at assessing the state of global and local knowledge on the impacts of built structures on the floodplain environment and aquatic resources. The study is structured as a dual review of scientific literature on the impacts of built structures on tropical floodplains worldwide, and of scientific and grey literature on Tonle Sap Environmental Impact Assessments (EIA). The objective of the global review is to draw key lessons from scientific publications and to assess the possibility for transferring and applying the main recommendations to the Tonle Sap ecosystem. The local review assesses the state of knowledge in EIAs (including initial assessments) of existing and planned construction projects in the Tonle Sap area. The objective of the local review is to identify strengths and weaknesses in local environmental assessment processes in order to improve their implementation and outputs, especially their capacity to support the decision-making of built structure projects. Recommendations for effective integration of irrigation impacts on fisheries in existing EIA processes are available and emphasise the need for improved integrated and participatory impact assessments [Nguyen Khoa *et al.* 2005]. Both worldwide and local reviews consider potential cumulative impacts of built structures implemented in the same catchment and sub-basin and possible avenues to overcome their absence.

Fishery component

The fishery component applies a diversity of methods to assess the consequences of built structures on local fishery resources, and their weight in relation to other environmental factors. The study is three-fold: one sub-component will identify the main ecological fish groups and the changes in fish composition and abundance between sites under the influence of built structures or outside their influence. Given a time constraint that does not allow biological monitoring over a full annual cycle, the approach will involve surveys of traditional knowledge gathered from key informants, experienced fishers in particular, through semi-open questionnaires [Poizat and Baran 1997, Bao *et al.* 2001, Baird 2003]. The second sub-component will compare changes in the fishery resources highlighted by the first sub-component and changes in hydrological regime, as characterized by the hydrology component. In a third sub-component, the conclusions of the previous studies will be integrated into BayFish, a probabilistic Bayesian model of the Tonle Sap fish production [Baran and Jantunen 2005]. Recent work has demonstrated that in the Mekong Basin fish production is not influenced by hydrology alone but by multiple factors including habitat quality, migrations and fishing [Baran *et al.* 2001, Kurien *et al.* 2006; Figure 5]. Therefore the results will be integrated to a broader framework encompassing other environmental and fishery parameters, so that the influence of hydrological changes on fishery resources that result from built structures can be quantified and compared to that of other environmental parameters.

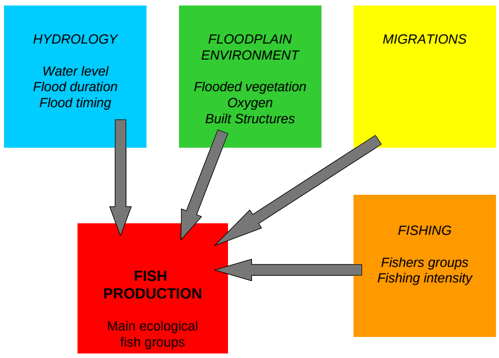

Figure 5: Main factors contributing to Tonle Sap fish production

Livelihoods component

The importance of Tonle Sap aquatic resources to rural communities is well recognized [Hap *et al.* 2006] and it is therefore crucial to examine the influence of activities that may cause ecosystem changes on people's livelihoods, their food security and their overall vulnerability. The study under this component is two-fold: i) assessing the influence of Built Structures on the livelihoods of Tonle Sap communities and ii) examining the availability of alternative livelihoods for aquatic resource-dependent communities. The first will assess, from questionnaires and participatory village surveys, possible changes in the people's livelihood in terms of changes in activity patterns, vulnerability, resource access, diet and food security, and income. It will also capture people's perception of the interconnectivity between hydrology, built structures, environment, fisheries and livelihoods, as well as their viewpoints on best practices for built structures. In the second sub-component, alternatives livelihood options and strategies as well as constraints will be explored to provide recommendations on enhancing other elements of livelihood assets, such as human, physical, and financial capitals, and relevant transforming structures and processes that enable such enhancements. Outputs from this component will contribute directly to increasing knowledge and raising awareness about the dependency of the 1.2 million Tonle Sap dwellers on "natural capital" -fisheries and water- and will highlight their vulnerability to changes in the access to the natural capital, as possibly caused by built structures. On the other hand, built structures themselves can be considered a type of "physical capital" which contributes to generating livelihoods. This component will therefore provide insights into possible constraints and opportunities for the communities in sustaining their livelihoods.

Policy outreach component

Generation of new knowledge does not contribute to informing decision-makers if information is not appropriately packaged and actively disseminated [Serrat 2005]. The latter two elements are embedded within this project, with i) the definition of a dissemination strategy identifying communication targets, and ii) the transformation of scientific reports into communication products. The communication strategy characterizes the different stakeholders and more specifically the decision makers at the state level (legislative and executive branches), but also at the provincial and private levels. Products appropriate for each component are proposed, costed, and the practicalities of their dissemination are detailed. Such products include an integrative synthesis report, a policy brief, guidelines, as well as journal articles and ready-made clips and interviews for broadcasting. The Cambodia National Mekong Committee, given its mandate and as a coordinating body whose members include many of the relevant agencies, is pivotal in this communication strategy and the dissemination of results and recommendations to decision makers.

CONCLUSIONS

This project has started four months ago, and will produce its final conclusions and reports within next six months. At the moment results are preliminary and concern mainly the Environment component.
In terms of ecosystem services, floodplains are ranked amongst the highest valued landscapes of the world. Their natural productivity is due to the flood pulse itself, and to the connectivity of river and floodplains. In these landscapes, the influences of built structures are not well documented, although the impact of structures in terms of losses of fish catches and biodiversity, as well as changes in fish species composition, is largely reported. As highlighted in the introduction, changes and effects are due to built structures themselves but also to associated developments. Most management recommendations for tropical floodplains (e.g. in Australia) are relevant for the Tonle Sap floodplain, e.g. preventing flood pulse disruption, avoiding the loss of hydrological connectivity, averting high increase in nutrient inputs, and warding off dramatic changes in species composition. Regarding dams, indicators of potential impacts and management procedures have been developed to facilitate sound management of fish biodiversity, fish stocks and fisheries at all stages of dam construction. Lastly, all studies show that rehabilitation efforts can only partly recover the ecosystem services lost due to built structures, but once lost, it is hard to restore the entire variety of floodplain ecosystem services.
Regarding Environmental Impact Assessments of Tonle Sap built structures, in the few accessible EIAs the effects on fisheries are usually addressed but potential changes in rural livelihoods and socio-economic patterns and less covered and not systematically assessed. Similarly, integration across disciplines and with relevant key sectors is usually weak. Future improvements would include increased and optimized use of available knowledge, encompassing both stakeholder and international scientific knowledge. The participation of stakeholders in the assessment as well as during public consultation should also be enhanced. Finally, the development of approaches and methods dealing with scarce data and uncertainty, as well as methods for valuation of tradeoffs between costs and benefits of built structures are required to improve the outputs of environmental assessments, especially their capacity to support the decision-making in relation to built structures projects implemented in the Tonle Sap ecosystem.

As the results of the Environment component indicate, there has been very few multi-disciplinary studies like this project anywhere in the world, particularly in tropical countries, with an objective to assess not only the negative impacts of built structures but also to address trade-offs involved in the development of infrastructure projects that affect floodplains. Our initial interactions with stakeholders clearly show that there is high demand for such studies, especially in the Mekong River Basin where development pressure on water resources is rapidly increasing. It is our hope that this study will produce much needed information to further the debates on the hydrological development strategy for the region, and also will serve as an assessment framework that can be tested elsewhere in the world.

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