PUBLIC PARTICIPATORY GIS APPROACH FOR FISHERIES MANAGEMENT ON THE MEKONG RIVER

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2014

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M.A. (Geography)

A THESIS SUBMITTED FOR THE DEGREE

OF

DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOGRAPHY

NATIONAL UNIVERSITY OF SINGAPORE

2014

DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Wisa Wisesjindawat Fink

AKNOWLEDGEMENTS

"My mom tries to save the river, then fish will have food

and place to live for a long time."

Barnet Tawan Fink, 5 year old son.

The researcher was overwhelmed by her five year old son when someone asked him about his mom's work on the Mekong River. At the end of the day, his passionate answer encouraged and motivated me to continue my research journey. The research process is like casting a cast net (*hae*) to catch fish, it is a long process that takes many casts, but eventually you will catch a fish. Similarly, the Ph.D. research process is a complicated progression that takes many attempts. Intellect and talent, are a starting point, but one must also allow for changes in mindset along the path of an arduous Ph.D. dissertation.

Much in research and writing are governed by people and places. Several persons and institutions deserve gratitude for the tremendous support given to me during the challenging times of this PhD program. I would like to express the deepest appreciation to my most exciting critic, Professor David Higgitt, an advisor of my research, and Professor Alan Zeigler, willingly advise me of my research. They have the attitude and substance of a genius: they continually and convincingly conveyed a spirit of adventure in regard to research and scholarship, and excitement in regards to advising. Without their guidance and persistent help this dissertation would not have been possible.

I would like to thank my committee members, Dr. Carl Grundy-Warr and Associate Professor Chen-Chieh Feng**,** whose work demonstrated to me that concern for global affairs, supported by an "engagement" in human geography and geotechnologies, are worthy areas to pursue. Their advice was a useful guide for my research process.

Research cannot move forward with the proper instruments. I was fortunate to receive support and expertise in this area from Professor Alan Zeigler (NUS), Associate Professor Watcharapong Wattanakul and Associate Professor Kanjana Payooha, Assistant Professor Tounthong Jutagate from the Department of Fisheries at Ubon Ratchathani University, Thailand.

Thank you very much for all those interesting discussions to the lecturers at the Geography Department at NUS, Associate Professor Mathious Roth, Lu Xi Xi and many more who I have not mentioned here. Furthermore, thank you for their kind guidance to Associate Professor Kanokwan Manorom, the Dean of the Faculty of Arts and Social Science at Ubon Ratchathani University, Thailand, and Dr Lilao Bouapao, the coordinator of the Mekong Program on Water Environment and Resilience (M-POWER).

My special thanks for their generous and compassionate support for the research, goes to the Fisheries Department in Bangkok and Ubon Ratchathani, Thailand, Udon Thani and Ubon Ratchathani Inland Fisheries Research and Development Center, and the chief of Sub-district Administrative Authority of Nawang. Furthermore, the research would not have been possible without funds. A major part of the research funding came from a NUS research grant for conducting the field survey and a M-POWER grant that allowed the researcher to conduct the public participatory GIS workshop and further field survey work.

Thanks are also warmly extended to the friendly fishermen neighbourhoods at Nawang, Ubon Ratchathani, Thailand and Thapae village, Salavan, Lao PDR for their warm welcome, information, time, and local knowledge. Their patience while teaching me to cast a cast net (*hae*) on the Mekong River was a most valuable experience as a researcher.

My deep thanks Ms. Pauline Lee, for kind administrative support and advice through the years of this research regarding the bureaucratic dimension of the Ph.D. process.

Friendly thanks for guides and friends for taking that impulsive trip to Nawang, Ubon Ratchathani, Thailand for Nick Jachowski who assisted me at the start of the river field survey and Chutchai Kongmont for video recording during the PPGIS workshop. A particular thanks for energy, friendship and encouragement to Pisit Phomikong, Amornrat Rangsiwiwat, Julie Van Den Berg, Peerayot Sidonrusmee, Sirisak Chaiyasook, Xiengkun Yang, Matti Kammu, Lim Han She, Yikang, Seo Young, and many more friends who I cannot names them all.

To Scott and David Fink, my household research editors, for being the kind of proof readers that writers dream about. They kept my spirits up and in working order. In addition, special thanks go to Mick Atha, who read, edited and critically reviewed through this research. Without them, it would be impossible for me to research and write this dissertation.

And finally but immensely, my lovely family. For their love and support.

Thank you very much.

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SUMMARY

This thesis is based upon research carried out within five fishing communities in Na Waeng, Ubon Ratchathani Province, Thailand, which explored the potential effects of developments on the Mekong River, in the hope that it would foster increasing awareness of environmental issues in the area. Before this research, little was known about the potential impacts of basin development activities, such as hydropower dams, on the riverbed phenomenon of deep pools, or their role in terms of fish habitats. This study shows that deep pools act as important refuges for many fish species and as associated spawning areas for some species during the dry season.

An analysis of the topography and geomorphological structures of seven deep pools, located in bedrock constrictions and with depths ranging from 10.5 to 171 m, reveals two main reason why the deep pools around Na Waeng are generally deeper than elsewhere along the Mekong's course. First, they are structurally controlled due to regional and local fracture patterns. Second, hydrological control on deep pools is associated with hydraulic conditions, meaning there is a greater potential for bed erosion (scour), leading to the occurrence and maintenance of deeper and bigger pools.

The results of a CART analysis confirmed the deep pools' ecological function and the implications for fisheries of future development by projecting the spatio-temporal predicted correlation between the presence/characteristics of deep pools and fish abundance/fish species richness levels along the river. The CART analysis revealed that predictions made by the fish abundance model correspond closely with the geomorphological variables of water depth and river channel width, and also with the physio-chemical variables of DO concentrations, pH levels, and zooplankton densities during dry season. The species richness model developed by the study confirms the relationship between the physical variables and the density of zooplankton and phytoplankton, DO levels, and water turbidity levels.

The LEK of local *chaopramong* was gathered in order to help provide validation for, and thereby strengthen, the scientific models regarding fish species and behaviour. The results from a 30-day catch monitoring survey informed explanations of deep pools' function as a key habitat for migratory fish, indeed 98% of the total catch can be classified as migratory fish. The LEK of *chaopramong* was also shown to have the potential to offer valuable support to fisheries management and should be given equal consideration to scientific knowledge.

The use of a PPGIS approach provides a unique tactic for engaging the *chaopramong* in decision making, through its goal of incorporating their LEK into a contextualized and complex GIS platform, thereby stimulating the participation and empowerment of distant voices within the decision-making process. The outcomes of this research present an opportunity for the creation of fisheries conservation zones in the study area; for example, in fishing grounds, deep pools, and beside temples. Future implementation should focus on: the development of programs to increase environmental awareness, the establishment of fisheries management mechanisms, and the development of bilateral fisheries management regimes between Laos and Thailand.

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GLOSSARY OF THAI WORDS

Thai Term (Phonetics)	Thai Script	Description
Archan	อาจารย์	teacher
baan	หมู่บ้าน	village
bang fai phya nak	บั้งไฟพญานาค	fire balls
bet	เบ็ด	fishing rod made from bamboo
bung	บุ่ง	fishing ground area
cha-moueng	ฉมวก	harpoon
chaobaan	ชาวบ้าน	villagers
chaopho	เจ้าพ่อ	Guardian spirit
chaopramong	ชาวประมง	Fishermen
don	ดอน	An island
fon loung	ฝนหลวง	artificial rains or cloud seeding
haadsai	หาดทราย	sandbar
hae	แห	cast net
heu or re˥˩x	เรือ หรือ เฮือ	A boat in Isan and Thai language, respectively
Isan	อีสาน	The Northeast of Thailand, a language
Isan Khiew	อีสานเขียว	Greening Isan Project or Green Isan Project
jaew	แจ่ว	spicy sauce
kamnan	กำนัน	Na Waeng sub-district headman
kan	คัน	submerged rocky area that aligns across the river channel
keang or klâeng	แก่ง หรือ แก้ง	rapid
lai rue fai	ไหลเรือไฟ	decorated boat with lanterns and flowers
lau-do-nam-daeng	ฤดูน้ำแดง	rainny season
loung	ลวง	*de facto* rights over fishing grounds
mae nam khong	แม่น้ำโขง	The Mekong River
namphrathai chak nai luang	น้ำพระทัยจากในหลวง	kindness of the king
ngan wiijai tai baan	งานวิจัยไทบ้าน	Tai or Thai Baan Research

Thai Term (Phonetics)	Thai Script	Description
pha	ผา	river rock cliff
Phak Khom Vang Mai	พรรคความหวังใหม่	New Aspiration Party
phew or phewnamluk	แปว หรือ แปวน้ำลึก	thalweg
phom	ป๊อม	stone maker
phuyaibaan	ผู้ใหญ่บ้าน	village chief
pla	ปลา	fish
sala klang baan	ศาลากลางบ้าน	Meeting hall of the village
sa-wing	สวิง	scoop net
sin	ซิ่น	Laos skirts
tambon	ตำบล	Sub-district
tham	ถ้ำ	cave
vern, vang nam louek	เวิน, วังน้ำลึก	deep water area or a term of deep pool in this research

CHAPTER 1

Setting the Scene

1.1 Introduction

The Mekong River is the largest river in Southeast Asia and the twelfth largest in the world, with a length of approximately 4,400 km (Pantalu, 1986). From its source in the Tibetan Himalayas, it flows through six countries: China, Myanmar, Thailand, Laos, Cambodia, and Vietnam (Figure 1.1), and its most abundant natural resources are fish and fresh water. The Mekong watershed is also home to significant levels of biodiversity, with new species still being discovered on a regular basis. Estimates of the fish species richness of the Mekong system varies between different scientific studies but all such studies affirm the magnificence of the Mekong River as a region of rich biodiversity. FishBase (2009) analysed data on freshwater fish species richness for various rivers of the world, and the Mekong River is ranked as the second richest river (781 species) in the world after the Amazon River (1,217 species). In a recent article, Kottelat *et al.* (2012) listed 500 freshwater species from the Mekong River. If the possible brackish and marine visitors are included, the probable total number of species has been variously estimated to be 1,100 (Hortle, 2009), 1,200 (Rainboth, 1996) or even 1,300 species (Zalinge *et al*., 2004). The total fish production in the Lower Mekong Basin contributes one-quarter of the world's freshwater fish catch, or approximately 2.64 million tons (Zalinge *et al*., 2004) out of a global total of 10 million tons (Baran *et al*., 2007). The vast majority of fish caught are consumed locally; indeed 80% of animal protein consumed in Cambodia comes from fish caught in the Mekong (MRC, 2004).

The Mekong is dominated by a monsoon climate, which maintains the dynamic river system, and is characterized by a wet season (May to October) and a dry season (November to April). During the dry season, fish retreat to deeper parts of

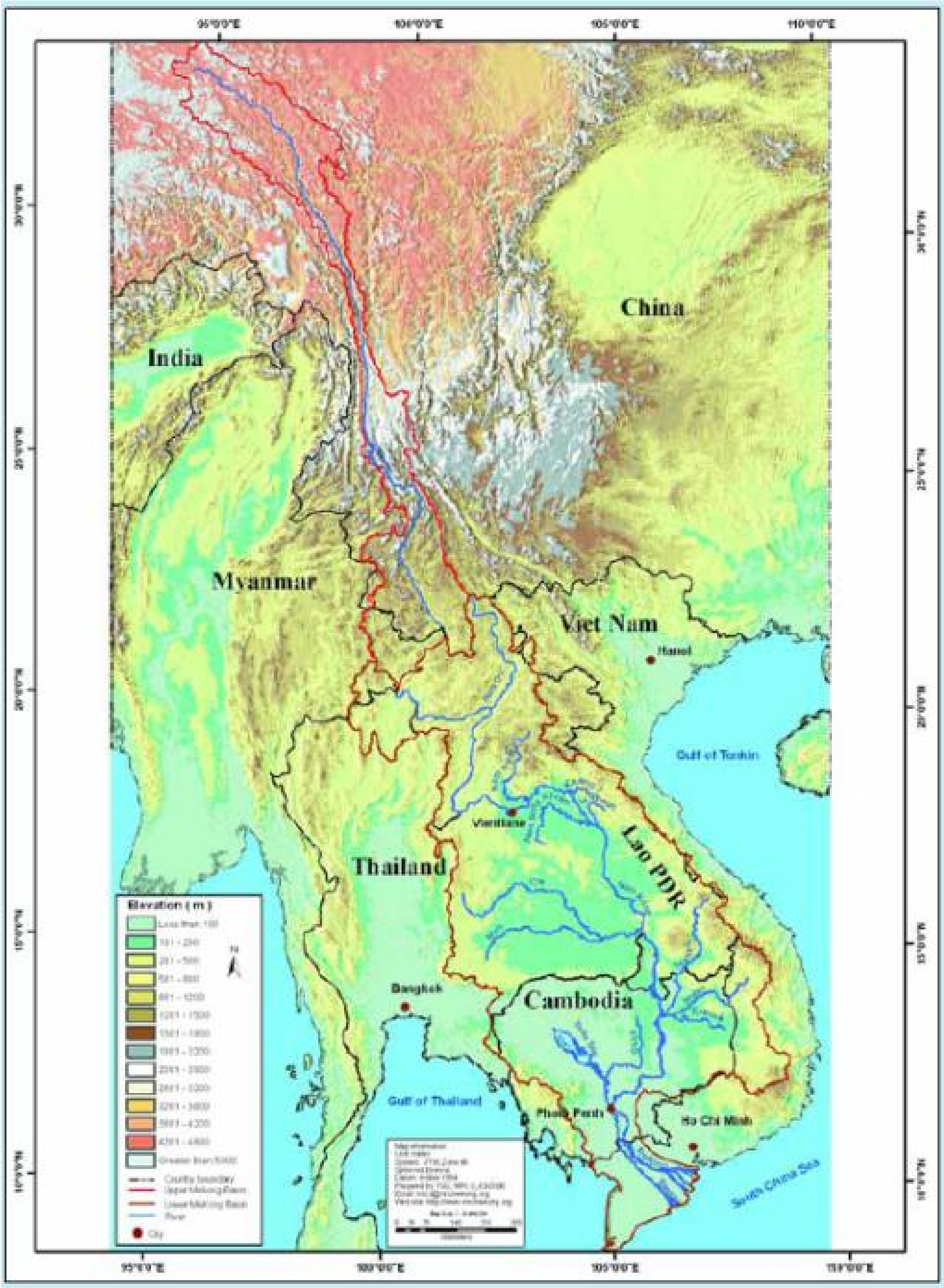

Figure 1.1: Geography of the Mekong basin (source: Map of MRC, 2011b)

the river or deep pools, schooling there until the next wet season arrives. This means deep pools provide critical refuges and spawning habitats for many species of fish during the dry season (Welcomme, 1985; Bayley, 1989; Roberts and Baird, 1995; Hoggarth *et al.,* 1999; Baird *et al.,* 2001; Poulsen *et al.,* 2002; Baird and Flaherty, 2005). For example, there is anecdotal evidence provided from around the world by fishermen [*chaopramong* in Thailand and Laos] that catfish stay in deep pools, especially during times of low water volume and in diverse river environments such as the Parana River, the Amazon and Orinoco rivers, and the Niger River (Welcomme, 2001). Furthermore, endangered species such as the giant Mekong catfish and the Irrawaddydolphin make use of deep pools along the Mekong's course (Poulsen and Valbo-Jorgensen, 2001). Interestingly, it seems likely that deep pools also provide fish with shelter from predators and act as refuges (Baird, 2006).

Many scientists have highlighted the importance of fish resources in the Lower Mekong Basin as being significant from a global perspective (Zalinge *et al*., 2004; Baran *et al*., 2007; Hortle, 2007), and deep pools, if studied and understood properly, could function in the future as a reliable monitor of the health of the Mekong's environment, as well as the state of its fisheries. In spite of the vital role they play in fisheries and livelihoods, information concerning the ecological function and geomorphological processes of deep pools remains sparse, meaning there is a need to carry out research in order to fill the knowledge gap that currently exists and contribute to the existing literature.

While the prospective effects of Mekong basin development activities have been explored elsewhere, and there is an increasing awareness of environmental issues in the watershed, little is known about the potential impacts of basin development on the riverbed phenomena of deep pools and their relationship with fish habitats. For example, hydropower dam construction activities may impact upon water flows and sediment transportation, and so deny fish access to deep pools (MRC, 2008a). The impacts of the Yali Falls hydropower dam in Vietnam on deep pools along the Sesan River have already been observed. As a result of this dam's construction, in Voen Say district, Cambodia – which is approximately 100 kilometres downstream from the dam – siltation has reduced the depth of the deep pools there by nearly 90 percent, and dramatically decreased the number of fish species present (Fisheries Office of Ratanakiri Province, Cambodia, 2000). A similar impact has been observed along the Hinboun River in central Laos, as a result of construction of the Theun-Hinboun Dam in Khammouane province (Poulsen *et al*., 2002a).

The development and implementation of the fisheries management activities needed to address those problems have in general not yet taken place, and in most cases where they have they are ineffective due to the poor enforcement of state regulations, which can lead to such initiatives having only a short term effect. For instance, in the mid-1990s, the Sekong provincial government in Laos established a number of fish sanctuaries along the Sekong River in southern Laos, which is a tributary of the Mekong. However, there was little consultation carried out with local people, and as a result the project failed (Baird, 2006). Similarly negative results were produced in Khammouane province on the Hinboun River in central Laos (Baird, 2006) and at Champasak on the Sedone River in southern Laos (Hirsch, 2000).

In contrast, a community-based fisheries co-management system called 'Fishery Conservation Zones' (FCZs) was established by villagers and the local government in Champasak province and downstream to Strung Treng in Cambodia, with the aim of protecting deep pools (Baird, 1999). The local villagers in this area have a very good understanding of their local environment, and so were able to prioritize deep pool conservation activities without the need for scientific analysis and evidence. As a result of the co-management system, the conservation zones were initially a success, with studies by Warren and Meusch (1997 as cited in Baird, 2006) and Cunningham (1998) both reporting positive results for the FCZs in the province, which were found to benefit fish stocks and the local communities. Though the program was eventually discontinued, Baird (2006) contends that the inclusion of local fishers in such a scheme has the potential to improve fisheries management activities, but only when they are allowed to participate fully in the monitoring and management processes. Hence, it would in future be interesting to carry out a study investigating this issue along the Mekong, and especially using an approach such as a public participatory geographic information system (PPGIS).

It has been established that villagers tend to have a greater knowledge of their local environment than government officials or other outsiders; however, they often do not use their knowledge in a systematic or quantitative way, and their knowledge generally tends to be excluded from decision-making processes (Elwood, 2009a; Minang and McCall, 2005). A PPGIS approach uses geographic information system (GIS) technologies in tandem with local knowledge; the aim being to empower marginalized populations through the practices of Participatory Learning and Action (PLA) and Participatory Rural Appraisal (PRA). As a consequence of such an approach, local level or community groups are encouraged to help define and participate in research, planning, and decision making processes. Alongside these aspects, PPGIS methods can be used without having to have GIS technology in place to elicit local knowledge, and so are increasingly being adopted in community-based projects, which are those that help to link people and natural resources together in a more sustainable manner (Christie *et al.,* 2002; McCall, 2004; Poole, 1995; Shepherd *et al.,* 2004).

In light of this, researchers should primarily consider using the PPGIS approach for natural resources and environmental management activities. This study intends to examine the PPGIS approach as a means to elicit local ecological knowledge (LEK) regarding water resources, and then systematically transform this into a scientific GIS platform, the aim being to support fisheries management activities on the Mekong River. In addition, the PPGIS approach used here will initially investigate the freshwater fisheries management process in this region, while taking into account the conservation of ecological functions supported by deep pools, the geomorphic processes involved, and the livelihoods of local *chaopramong*.

1.2 Statement of the problem

Deep pools act as important refuges and spawning habitats for many species of fish in the Mekong River during the dry season, which means they could function in the future as a barometer of the health of the Mekong River's environment and the state of its fisheries, both of which have been under growing pressure due to developments taking place in the basin. There have been reports that over-fishing has occurred in some fishing communities on the Mekong River; however, the development and implementation of the fisheries management activities needed to address these problems has not been forthcoming and, in most cases, such initiatives have not been effective due to the lack of enforcement of state regulations. Moreover, such regulations often fail to fully understand the physical characteristics of deep pools and their uses by fish, or their influence on the livelihoods of *chaopramong*.

Some fishing villages along the Mekong River have set up fisheries management programs in their communities, which take into account the importance of deep pools. Villagers may have greater knowledge with regard to their local environment than government officials or other outsiders; however, they tend not to fully utilize their knowledge in a systematic manner or using quantitative data, so their knowledge tends to be ignored by government officials and researchers, who believe their approaches lack accuracy and do not provide precise information.

The key advantage of the PPGIS approach is that it can help address this concern regarding accuracy, and combine the qualitative information drawn from local people, including *chaopramong*, with spatial, quantitative information using participatory mapping. The results can then be fed into a scientific platform, namely GIS. In addition, the very nature of the public participation process empowers local communities, meaning they become more involved in the research and management processes, and this helps link local people and natural resources together in a more sustainable manner.

Along with these aspects, a PPGIS approach may be used to integrate local ecological knowledge with a GIS, and so help it to support fisheries management activities along the Mekong River.

- The research problem is: Can the PPGIS approach integrate local ecological knowledge (qualitative information) with a scientific platform such as GIS (quantitative information), in order to help it support fisheries management activities?

1.3 Research goals and objectives

The key goal of this study is to explore the use of PPGIS as an approach to integrate local ecological knowledge with the scientific platform of GIS, in order to facilitate and support fisheries management activities. Based on this goal, five objectives were used to develop the research questions, though many other questions were likely to arise during the course of the research itself. The objectives are as follows:

1. To investigate the key characteristics of deep pools found in the riverbed rock channels of the Mekong River in the study area, and to understand their role with regard to fish habitats and the potential consequences of their disappearance.
    - What are the deep pools' characteristics in terms of location, length, width, depth, substrate, temperature, and fish biomass?
2. To study the local ecological knowledge (LEK) of *chaopramong*, and how this knowledge is related to their understanding and use of deep pools.
    - What spatial knowledge do local *chaopramong* possess regarding the river's ecology and how do they use it? Here the focus will be on

their 'sense' of the river, its water currents, their fishing practices, the fish species and fish migration patterns found, and their perception of endangered fish species and of the deep pools.

3. To study the role that deep pools could play in fisheries management activities.

    - To what extent do *chaopramong* interact with deep pools?
    - What size are the fish catches made in the study area and how does this influence the livelihoods of the study *chaopramong*?

4. To develop a number of fisheries management strategies that use a PPGIS approach and GIS spatial analysis.

    - Can the PPGIS approach incorporate LEK within a GIS platform? If so, how?
    - Can LEK contribute to the development of fisheries management activities? If so, how?

5. To assess current outcomes of fisheries management activities and their development using PPGIS.

    - Can LEK effectively contribute to the development of fisheries management activities?
    - Can PPGIS processes effectively assist the actors involved in fisheries management activities, and enable them to have a greater understanding of the state of the environment?
    - What is the potential for PPGIS to be developed with the participation of *chaopramong*, allowing them to assist and become stakeholders in the maintenance of the fisheries ecosystem?

- What is the potential of PPGIS in terms of helping to articulate local communities fisheries management activities among provincial managers?

1.4 The research conceptual framework and approach

This research design constitutes a triangulation of methods within PPGIS approach and with political ecology framework as the conceptual framework. The PPGIS provides the framework to include socially differentiated LEK of *chaopramong* without the barriers created by GIS technology, and the plan is to link people and natural resources in a more sustainable manner. Moreover, this framework represents the starting point for promoting the use of LEK of *chaopramong* and facilitating LEK as a negotiating framework, which would encourage the democratization of community management processes. More importantly, the results of LEK sketch mapping can be cross validated by scientific research and provide some hidden issues of politics of water resources and commons. The attention is drawn to the political ecology about the discourse of water resources management and the vital roll it plays on the Mekong River. The insight of political ecology establishes a critical understanding about the politics that plays on spaces, scales, power and relations among stakeholders and politics of knowledge that impacting the use of water resources in the Mekong River. Furthermore, the political ecology hatches to undertake in-depth study of the politics of commons that share and create conflicts over the Mekong River from local to regional scale.

The research employs a mixed method of data collection and analysis in qualitative and quantitative research approach. The concept of methodological approach (Figure 1.2) used in this study is comprised of three core elements, including survey of *chaopramong,* river survey and PPGIS workshop. This methodology is defining the mixed methods to unpack this interdisciplinary research, including the implementation of participatory approach, key informant interviews, field observation, GIS technology, integrating LEK into a GIS using the PPGIS approach and the analysis of PPGIS approach and political ecology framework (see Chapter 3).

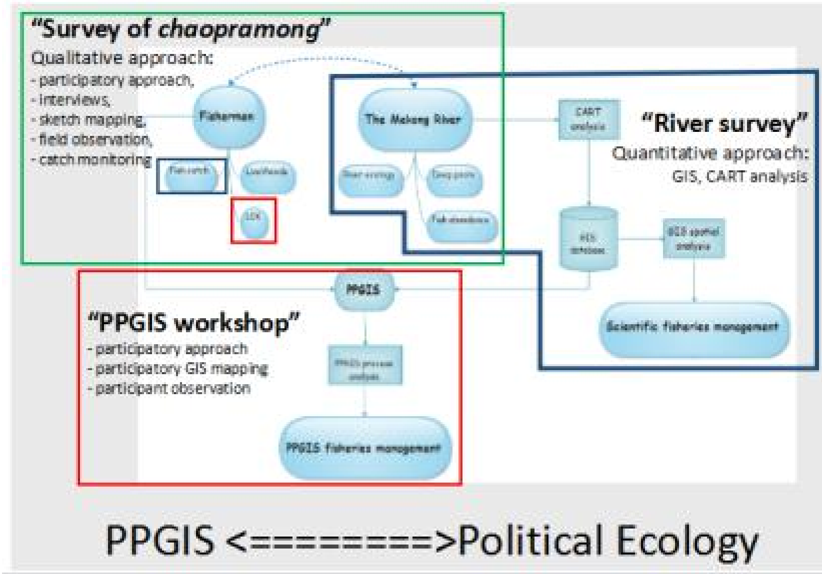

Figure 1.2: Conceptual framework of the research
(Source: Author)

The term 'local ecological knowledge' (LEK) is used throughout this dissertation to refer to local and ecological knowledge of *chaopramong* who live in five fishing communities in Na Waeng, Ubon Ratchathani in Thailand. The use of LEK here is intended to underline a 'situated' knowledge that links to prolonged contact with a geographic place or locale. In other words, local people here are historically linked by genealogy to a geographical place. The term does not imply that they are a minority or marginalized group. Instead it includes the broader concept of 'local' which is generally more inclusive.

The perspective of ecological knowledge in this dissertation refers to a transient knowledge system that is gained through the perspective of epistemology, not as a represented category of information that is gathered by local communities or people: for instance, this may include knowledge of fish species names, riverbed characteristics, how to control a boat, and supernatural beliefs.

The participatory approach in this research means to give credence to key informants as experts on their own community environment (Jung and Elwood, 2010). This research used LEK sketch mapping as one of participatory tools (Lynch, 1960; Niem Tu and Doherty, 2007) and a PPGIS mapping based on satellite images as a PPGIS tool to facilitate key informants' spatial knowledge of water resources on the Mekong River.

1.5 Strategies – Sites and selection reasons

The reason for choosing the research site was due to the cluster of seven deep pools that can be found in the Mekong River at Na Waeng, Ubon Ratchathani in Thailand (Figure 1.3). The significance of this site is that it contains the deepest known pool on the Mekong River, at 90.5 metres. This area is located in a heavily constricted bedrock reach between the provincial city of Mukdahan and the confluence of the Mun River with the Mekong, in the Thai province of Ubon Ratchathani. The hydrology of this zone is influenced by tributary systems in both Laos and Thailand. The deepest study pool was first identified by the Mekong River Commission (MRC) through the use of geomorphic statistical analysis. In addition to the extreme depth of the pool at his site, it is my hypothesis that deep pools such as these, unlike most, tend to be controlled by both geological and hydrological processes.

Upon conducting a preliminary study of the sites and talking to local *chaopramong*, I found that Na Waeng had used neither a community-based fisheries management system nor the PPGIS approach, and that over fishing had occurred in some fishing communities in the area, in villages such as Bong Khew in Khamarat district.

Other factors leading to the selection of this study site were the possibility of collaboration taking place among villagers, and also the presence of other researchers and the Thai Fisheries Department. There was also a possibility that the Thai

Fisheries Department and the Fisheries Department of Ubon Ratchathani University would collaborate with me at this site, due to its significance with regard to deep pools. These organizations showed great interest in my research, offering me the use of an echo-sounder and their expertise with regard to its use. In addition, they also

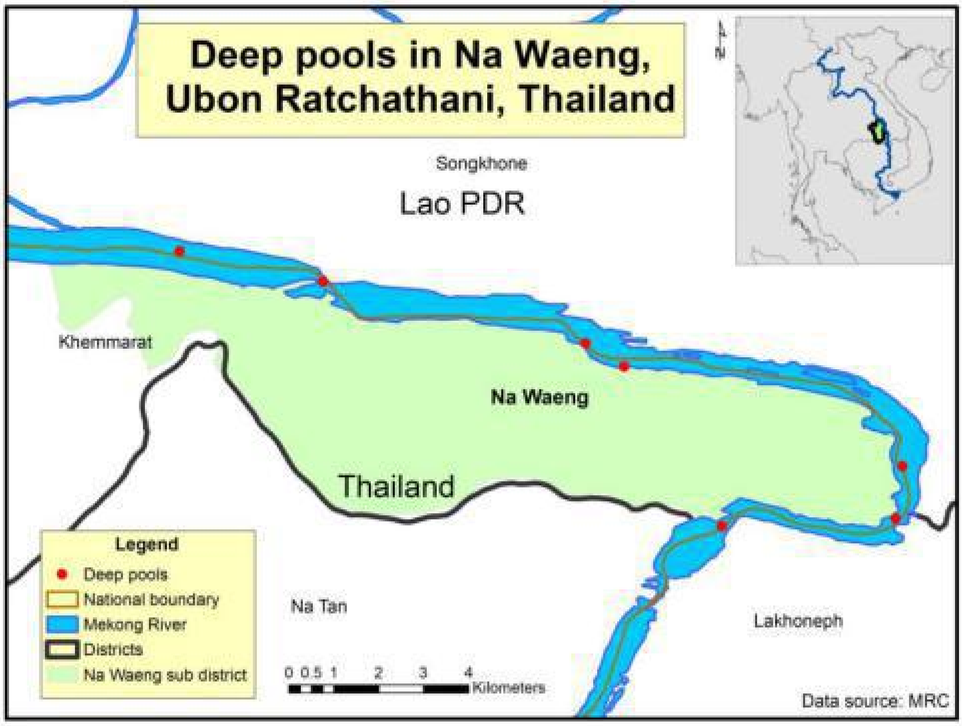

Figure 1.3: Deep pools around Na Waeng, Ubon Ratchathani in Thailand
(Source: Author)

provided support in the form of other PhD scholars, who worked at the site and will hopefully form part of a formal, collaborative project in the future.

1.6 Contribution and applicability of the study

This research study will contribute to the development of GIScience, which helps to provide a better understanding of the methodology behind empirical and theoretical studies, and so contributes to 'GIScience and Society' literature. This is especially the case with regard to broad concerns about how people, space, and the environment are represented in GIS when using the PPGIS approach. This study represents one of the first occasions in which ecological functions, the geomorphic processes within and around deep pools, and the PPGIS approach have been explored to investigate the freshwater fisheries management processes practiced along the Mekong River. Therefore, there were two key inspirations for this study, these being to contribute to the interdisciplinary study of deep pools, and to enhance local ecological knowledge (LEK) through the use of the PPGIS approach.

Firstly, the research work for this study made use of interdisciplinary studies, those which cross traditional boundaries and combine both physical and human geography through the use of GIScience, for problem solving purposes. This approach was then combined with those of other disciplines, such as fisheries, fish ecology, and anthropology. A comprehensive understanding of the special phenomenon of deep pools on the Mekong River does not exist, and when it comes to understanding fish behaviours, and their relationship with the deep pools' geomorphology, plus the influence of these two aspects on the livelihoods of *chaopramong*, fish biologists, traditional geographers, and anthropologists must sometimes take a back seat. This is hardly surprising, as little effort has been made by scientists and researchers to investigate these intertwined consequences.

Aside from this, deep pools represent a complex phenomenon on the Mekong River, and still need to be integrated with a range of perspectives in order to provide a more comprehensive understanding. Even the definitions, ecological functions, and geomorphological processes related to deep pools are still in flux; therefore, this thesis seeks to provide a greater level of understanding on the formation processes and characteristics of deep pools along bedrock channels, whilst also aiming to improve the general level of understanding of the vital role deep pools play for fish and *chaopramong*'s livelihoods.

Lastly, during my research I elicited local ecological knowledge (LEK), which comprised spatial and environmental knowledge regarding the river, and transformed it into a systematic and scientific GIS platform, using the PPGIS approach to develop a fisheries management regime. Through the use of PPGIS practices and approaches, it is hoped to further empower *chaopramong* within the fisheries management decision-making process. By incorporating *chaopramong* into part of the research and management process, it is hoped to link people and natural resources together in a more sustainable way, utilizing their LEK, spatial knowledge, and access to data for use by all stakeholders, thereby helping to build environmental awareness, and leading to the effective and local co-management of natural resources.

1.7 Organization of this thesis

This thesis consists of eight chapters. In the first chapter I provide a brief background and introduction to the research, after which Chapter 2 provides the theoretical background to the research, reviewing the existing literature on the concept of PPGIS with regard to freshwater fisheries management and deep pools on the Mekong River. This chapter first describes and discusses the core concepts of PPGIS and then relates the application of PPGIS to the Mekong River Basin, which means that the literature pertaining to the Mekong region and deep pools, fish migration, the hydrological and geomorphological zones, climate and livelihoods will all be articulated.

Chapter 3 describes the research design and methods employed to collect data on the river, plus the fish catch monitoring techniques used and the *chaopramong*'s livelihoods in the study area, Na Waeng. In addition, the methodological framework is described in detail, as it relates to the different phases of the PPGIS process. Chapter 4 sets the scene regarding the study area, and seeks to examine the socio-economic and physiological characteristics of Na Waeng.

Chapter 5 describes the geomorphology of deep pools on the Mekong River, followed by the key characteristics and controls used during their study. The chapter then goes on to explore the historical background and geomorphological structure of the area, using regression analysis as a measuring tool. Chapter 6 discusses the significance of deep pools as a refuge for fish species during the dry season, and also gives guidelines on some aspects of the spatial conservation techniques to be applied in fisheries management.

Chapter 7 explores the potential for employing a Participatory Geographic Information System approach to fisheries management activities in the study area. The chapter also describes the development of the *chaopramong*'s local ecological knowledge and how this facilitated the development of a GIS platform, which was designed to provide the local fishing community with the ability to visualize information; thus offering them a basis upon which participatory fisheries management decisions could be made. Finally, Chapter 8 concludes and presents the main findings of the study, and makes recommendations for future research into this topic.

CHAPTER 2

Literature Review

2.1 Introduction

This chapter reviews the literature relevant to the key concepts behind my research study. As this is the first study to attempt to apply the Public Participatory Geographic Information System (PPGIS) to freshwater fisheries management activities related to deep pools on the Mekong River, my literature review will address a number of topics. First, this chapter will describe and discuss the core concepts of PPGIS. The application of PPGIS as used here is grounded in the Mekong River Basin, and so literature pertaining to the Mekong region, and particularly that related to deep pools and fish migration, the hydrological and geomorphological zones, plus the climate and the livelihoods of people in the study area, will be articulated. As the study focuses on fisheries management along the Mekong River, one section will focus on the fisheries management challenges faced in the area and also some examples of community-based fisheries management activities there. The chapter aims to introduce the key themes and concepts used in the research, plus the information upon which it is based. As the research embraces many different fields it is not straightforward to present all of the relevant literature in a single chapter. The aim of this chapter is therefore to outline the main features of previous work and current knowledge in each area, but in subsequent chapters further elaboration of relevant literature will be provided.

2.2 Geographic Information System (GIS)

2.2.1 An overview of GIS and evolution of GIS technology

Geographic Information Systems (GIS) are computer systems capable of capturing, storing, analysing, and displaying geographically referenced information;

that is, data identified according to location (USGS, 2007). Interestingly, GIS supports science-based research and problem solving activities, using both quantitative and qualitative knowledge relating to geographic references.

The evolution of GIS technology has taken place over four eras: (i) computer mapping in the 1970s (Beginning Years), (ii) Spatial Database Management in the 1980s (Adolescent Years), (iii) map analysis/modelling in the 1990s and since (Maturing Years) and (iv) multimedia mapping (2010s, Full Cycle) (Berry, 2007; 2013). GIS were first developed in the mid-1960s, with the term 'GIS' initially introduced as the Canada Geographic Information System (CGIS), a computerized map measuring system (Longley*,* 2005). As the versatility of GIS has grown, so have the number of definitions, based on the use contexts and applications across various sectors and by various stakeholders. The second period was the era of commercialization in the 1980s, when the use of GIS expanded rapidly, from governmental and academic institutions into commercial enterprises, and as the price of computer hardware dropped to an affordable level. The third era of GIS continued its evolution into spatial analysis applications and modelling. The result of this evolution was GIS functionality that changed from mimicking the manual procedures in users' daily activities into computer automating repetitive operations. This numeric-based mapping process moves forward the GIS systems and decision-making models into effective decision support systems.

In addition, Berry (2007; 2013) proposed that the evolution of GIS has been more cyclical than linear, so that nowadays GIS represent 'multimedia mapping' (2010s, Full Cycle) tools or the last era of GIS, which are focused on the original usage of the technology. However, these days GIS utilize 3D-4D visualization, Google Earth, GPS and i-phone applications, meaning GIS innovations in the 2020s, are likely to focus on 'data/structure and analysis'.

"*It (GIS) has moved mapping from a historical role of provider of input, to an active and vital ingredient in the "thruput" process of decision-making. Today's professional is challenged to understand this new environment and formulate innovative applications that meet the complexity and accelerating needs of the twenty-first century*" (Berry, 2008, 8).

Throughout the decades, GIS has seen a rapid development of theories, technologies and organizations influencing their taxonomy in terms of research and its applications. Drummond and French (2008) described significant factors for the development of GIS technology based on its own technology base, however this change is shaped by social demand for particular users or professional affiliation. In the early years of GIS, applications and research focused on the underlying concepts, structures and tools supporting modern geospatial information technologies (GIT) (Maguire, 1991) with a wide range of applications diffused in relation to GIScience or GIT, including GIS, remote-sensing image analysis and global positioning systems (GPS). Later on, GIS were integrated into other fields, to support management decision-making; for instance, on natural resources, facilities management, city planning, public health, business, agriculture, the environment, fisheries, and of course geography, to name but a few (Maguire, 1991; Berry, 2007; 2013).

The future of GIS is pushing beyond mapping, into modelling, 'spatial reasoning, and dialogue' (Future, Communicating Perceptions), which means GIS have implications for society through their use in decision making, and as a tool of public participation (Berry, 2007; 2013). Additionally, the inclusion of public participatory applications helps overcome some 'critical issues of GIS' (Future Challenges) and can further articulate an expanding notion of GIS applications and technologies, in order to produce knowledge and meaning for not only GIS users, but also non-GIS users and societies.

2.2.2 Critical GIS

"*Questions about the social and political impacts of GIS were evident from the earliest development of automated and digital systems for the representation and analysis of spatial data*" (Dobson, 1983; Chrisman, 1987 in Elwood, 2006a, 695), while some issues related to the politics of knowledge and the social impacts of use (Pickles, 1991, 1995; Lake, 1993; Sui, 1994; Miller, 1995; Sheppard, 1995). The mainstream of GIS critique grew out of thoughts that apparently had been developing among human geographers for a few years, and the 'kick-off' was sparked by the 'new imperialist geography' as termed by Peter Taylor. In the beginning, and as a recurring, unresolved theme ever since, has been the issue of epistemology and the effects of GIS knowledge, especially with regard to positivism (Taylor, 1990; Taylor and Overton, 1991; Smith, 1992; Lake, 1993). Shuurman (2000, 577) summarized the gist of the critique as "*Human geography critics felt that GIS failed to accommodate less rational, more intuitive analyses of geographical issues, and that its methodology, by definition, excluded a range of inquiry*". In similar vein, as noted by Elwood (2006a, 695) "*questions gave rise to a critical GIScience research agenda which were around epistemology, ontology, uneven access to GIS technologies and digital data, and the implications of its techniques for representing people and place*". Beside those issues, there are some fundamental barriers to use GIS in general, such as the time consuming nature of GIS database production, high cost of database and software, and GIS skill level required to operate a GIS system (*ibid*).

The foci of the GIS debate shifted over time with the main development of critiques on GIS, as reflected in Schuurman's (2006) review of the more than sixty published critiques of GIS during the 1990s (Table 2.1). Additionally, she described the critiques of GIS and main arguments in three distinct waves (Schuurman, 2000; 2006). In overview, she noted that, "*critical GIS had also moved from an antagonistic* *activity to a means of positively affecting a technology that was being widely adopted in other disciplines and in the commercial sphere"* (Schuurman, 2006, 364).

Table 2.1: Content of critiques of GIS from 1990-2001

Source of critique	**Complaint about GIS**
Pre 1993 papers (e.g., Taylor, 1990; Taylor&Overton, 1991; Smith, 1992; Lake, 1993; Pickles, 1993)	Based on data rather than information; subject to naïve empiricism; a positivist technology that assumes the possibility of objectivity; complicit in warfare; based on a Cartesian framework incapable of describing human geography or natural phenomena.
1995 publications: Ground Truth (Pickles, ed.), Special issue of Cartography and GIS (Sheppard, ed.)	A masculine technology; part of a cybermetric grid of control; a marketing tool; epistemological inertia; limitations of visualization; Cartesian perspectivalism and rationalism; need to make the technology accessible.
1995-1999 (e.g., Curry, 1997; Pickles, 1997; Katz, 2001)	Lack of attention to epistemologies and ontologies; failure to accommodate marginalized voices; a means of greater surveillance.

(Source: Schuurman, 2006)

The theory-laden body of Critical GIS literature has augmented awareness of the complex relationship between technology and epistemology in general, and GIS and positivism in particular (Leszczynski, 2009, 584). In the latter half of the 1990s these issues developed into the GIS and Society research agenda in seven prime themes: (1) the relevance of GIS to communities, (2) GIS and gender, (3) GIS and ethics, (4) GIS and political ecology, (5) GIS and global change, (6) alternate forms of GIS, and (7) the social history of GIS (Sheppard, 2005). Consequently, these themes became established within their own complex research agendas. In the late 1990s, many geographers were willing to engage in a substantive dialogue that would acknowledge social-theoretical and GIS-related interests (see Schuurman, 2000, 578–579, on 'Friday Harbor' meetings). Intellectual discussions emerged, which included those grouped under participatory (see Elwood, 2006a), feminist (see Kwan, 2002), and qualitative GIS (see Kwan and Ding, 2008; Cope and Elwood, 2009). At the beginning of the 2000s, those themes developed further under the banner of Critical GIS; for example, the first theme developed into the community-oriented PPGIS and the second developed into Feminist and Queer GIS. Just as these research agendas started to amalgamate, technology shifted toward Web-based mapping, and geographers began a new round of research under banners including the geospatial web (Geoweb), volunteer geographic information (VGI), neogeography, new spatial media, crowdsourcing, and more (Goodchild, 2007; Sui, 2008; Elwood, 2010). However, the critique of GIS still surrounds the same questions of democracy and exclusion, activism and inequality, privacy and surveillance, and more (Elwood, 2009b).

Recently, in the meeting "Revisiting GIS critical" (see Thatcher *et al.,* 2015), at the University of Washington's Friday Harbour Laboratories, discussion tended to approach questions both emerging and enduring around the intersection of the spatial and the digital in terms of four topics: (1) Social justice and GIS; (2) Two hybrid strategies, among others: critical quantifications and digital humanities; (3) A political economy of GIS; and (4) Repetition with difference: future directions, present entanglements. The meeting concluded that (see Thatcher *et al.,* 2015, 2) "*both 'critical' and 'GIS' evolve in unresolved tension"*, but rather as recurrences with modifications. Both 'critical' and 'GIS' should be allowed to grow and change under stress and strain as geospatial technologies and information become more commonplace in daily life, and as new fields of study broaden and expand spatial inquiry and visualization, and the academy itself also struggles with its role in a quickly shifting world. Critical GIS offers a path which leads to, a "*constant dialectical process of critique and renewal*" (*ibid*).

2.3 Local knowledge, and epistemology, ontology in GIS

2.3.1 Local knowledge

"Local knowledge" (LK) is defined as the knowledge developed over time due to living in a community (Warburton & Martin, 1999). The type of knowledge people acquire is associated with their age, gender, occupation, family and community structure, their socio-economic status, their experience, environment, history and location. Several writers (Berkes, 1999; Huntington *et al.*, 2005;

Chambers *et al*., 2004) have considered the nature of "indigenous knowledge" (IK), which is characterised as a holistic approach to ways of knowing and understanding the world. This is of particular relevance to survival, valued and refined over countless generations, as individual experience builds upon lessons from the older generation in communities.

There have been debates over the terminology surrounding local knowledge, with some researchers holding that terms such as "traditional", "indigenous", "folk", and "native" are ambiguous at best, and culturally loaded at worst (see for example, the discussions on terminology in Ellen and Harris, 2000). The most regularly used terms and their acronyms are "indigenous environmental knowledge" (IEK or IK), "local environmental (or ecological) knowledge" (LEK), and "traditional environmental knowledge" (TEK). Here I choose to use local ecological knowledge (LEK), as it seems to me the most neutral term, and is related to the connotations of the research, especially the *chaopramong* [fishermen]'s knowledge of river ecology.

The concept of LEK complements people's every day spatial thinking conception and is used for everyday activities. It includes a sense of locations and where to find things around us (Piaget and Inhelder, 1967). In terms of the geosciences, *"Spatial thinking is thinking that finds meaning in the shape, size, orientation, location, direction or trajectory, of objects, processes or phenomena, or the relative positions in space of multiple objects, processes or phenomena. Spatial thinking uses the properties of space as a vehicle for structuring problems, for finding answers, and for expressing solutions"* (Downs, R., & DeSouza, A., 2006, 83).

Spatial thinking is based on a constructive amalgam of three elements: concepts of space, tools of representation, and processes of reasoning (Downs, R., & DeSouza, A., 2006).

1 **Concepts of space:** The conceptual and analytical framework within which data can be integrated, related and structured into a whole. For example, space, time, objects, shapes, boundaries, sizes, textures, distances, directions, and distribution.

2 **Tools of representation:** The forms within which structured information can be stored, analysed comprehended, and communicated to others. For example, prototypes, mental maps, maps, diagrams, graphs, words, geometry, and 3D-models.

3 **Processes of reasoning:** The means of manipulating, interpreting, and explaining structured information. For example, statistical and spatial measures or analysis, distribution, data generalization, interpolation, and extraction.

2.3.2 Epistemology and ontology in GIS

"Epistemology involves the study of theories of knowledge, the questions we ask about how we know, whereas ontology involves the study of theories of being, the questions we ask about what can really exist" (Smith, 1998, 279).

Epistemology (knowledge) and ontology (reality or existence) are closely intertwined with the study of theories of knowledge as ontology is grounded in epistemology. In other words "..ontology attempts to account for what is in the world, epistemology asks how it is possible to *know* [emphasis original] the world" (Gregory *et al.* , 2011, 206). Schuurman (2004, 26) offered a way of understanding epistemologies in GIS as "*methods we use to study the world, and the lenses that they entail*", or as ways of knowing the world (Schuurman, 2006). "*Every epistemological perspective imbues the observation with different meaning, and different ontologies come into view depending on the epistemology of the GIS user*" (*ibid*, 26).

The meaning of ontology is multifaceted and variously defined within different fields of study. Ontology is signified in the social sciences and philosophy as "*a foundational reality, the essence of an object or phenomena*" (Schuurman 2006, 731), whereas within the computer sciences, ontology is seen as "*a formally defined* *set of objects in which all the potential relationships between objects are well defined*" (i.e. a data model) (*ibid*, 31). Alternatively, ontologies are a response to the question: What must the world be like for knowledge of any object or phenomenon to be possible? (Gregory, 2000). "*Both field and object models rely ultimately on a view of the world in which neutral and absolute space is assumed. Nor does either allow the characterization of complex, interrelated geographic entities*" (Schuurman, 2004, 38).

The ontological data model in GIS is not only there to define its relationship with other objects, but also to encode digitally representation as either discrete objects (points, lines, polygon) or continuous fields (elevation) (Schuurman, 2004). An example of rules from Schuurman (2004) is that a road can cross a bridge, but a river must run under it. "*Data models reflect different ways of seeing the world. They are ways of imagining space – in order to render it in a computational environment*" (Schuurman, 2004, 32).

Each data model in GIS representation is fundamentally limited due to the complex nature of reality, however "*GIS can be made to represent multiple perspectives in its present guise*" (Schuurman, 2006, 736). Indeed PPGIS has flourished to fit the current representational limits of GIS and critical GIS in terms of it being articulated to work with local communities, and political claims (*ibid*). Additionally, "*representation of the spatial realm must take the next step of representing social concerns including power relations, gender inequities, social control through numerical representation, and social marginalization*" (*ibid*, 736).

2.3.3 Engaging local knowledge in the epistemology, ontology of GIS

"*..most scholars have now come to accept that there are no simple or universal criteria that can be deployed to separate indigenous from western or scientific knowledge*" (Ellen *et al.*, 2000 as cited in Agrawal, 2002, 293).

Agrawal (1995) stated that in order to effectively engage IK in development, researchers should understand beyond the dichotomy of indigenous and scientific and work towards greater autonomy for indigenous peoples. Agrawal clarifies the differences of these two opposite poles of knowledge into three themes which are: 1) substantive differences: the subject matter and characteristics; 2) methodological and epistemological differences: in knowledge employment to investigate reality and world-view; 3) contextuality: IK is deeply rooted in its context and makes unlikely scientific knowledge. Hviding (1996) states that the ontology of Western science represents the dualistic conception of humans as separate from nature, hence the IK of subsistence societies is largely incommensurable with it. Additionally, Hviding recommends that attempt by scientists to appraise IK with reference to scientific knowledge (via 'ethnobiology'), always grants 'epistemological privilege' to the latter. Researchers and development planners fail to place the information they are receiving from indigenous informants within the proper context (Foale, 1998). Furthermore, Foale (1998) contends that it is rational to assume a complex of ontological and epistemological paradigms for IK and that sustainable resource yields would benefit if supplemented with the expert knowledge of related fields of work.

There are commonalities between GIS and LEK epistemologies. GIS as a scientific and cartographic tool is associated with knowledge production of the real world and the storage and coding of data in a computer system. LEK includes all of the ways of knowing from the environment and experience of the real world, which attaches to spatial knowledge or spatial thinking, but the specific manifestations are stored in human conceptualization of reality as a brain function or cognitive impression of reality. Human spatial ability plays a fundamental role in human cognition, and consciousness (Jaynes 1976; Mach, 1886; 1959; Edelman, 1987; 1989; Gentry and Wakefield, 1991). "..[*S*]*patial cognition is determined by the (human) brain's mechanisms that form categories using widely distributed and massively* *parallel neural networks that precludes any localization of memory or fixed cognitive maps of the world*". (Gentry and Wakefield, 1991, 207).

In order to integrate LEK into GIS platforms, researchers should comprehend not only the differences of knowledge between GIS and LEK, as Agrawal suggested, but also understand the concept of "*the boundary between conceptualization and formalization*" in ontological research in GIScience (Figure 2.1). "*A mechanism for moving between spatial cognitive impressions of reality and database representations of reality is required*" (Schuurman, 2006, page 731), in other words the ontology of human spatial conceptualization of reality is stepping from descriptive concepts toward digital form in GIS or mapping (Brodeur *et al*., 2003). This is the basis of this thesis: an attempt to implement a PPGIS approach together with LEK of *chaopramong*, which will be heard and consequently can be utilized for the purpose of development of fisheries management on the Mekong River.

There is a broad range of literature addressing the incorporation of LK and indigenous knowledge into a GIS in the fields of international development and environmental management. GIS is capable of combining statistical analysis with geographic location to create meaningful maps that can be applied to development needs (USAID, 2002), and natural resources management (Stouffle *et al*.,1994; Johannes, 1998; Roberts, 2000; Balram *et al*., 2004). For example, the spatio-temporal mapping of indigenous ecological knowledge can foster biodiversity conservation (Rundstrom, 1995; Balram *et al*., 2004), while fishers' indigenous ecological knowledge in the Western Solomon Islands was incorporated when designing a marine protected area in Oceania (Aswani and Lauer, 2006). The increased appreciation of LK and indigenous knowledge is particularly notable because GIS can facilitate the inclusion of such knowledge and peoples in decision-making processes locally and globally (Harris *et al*., 1995; Weiner *et al*., 1995;

Carver, 2001; Ghose, 2001; Warren, 2004). Indeed PPGIS has been an important development within participatory processes.

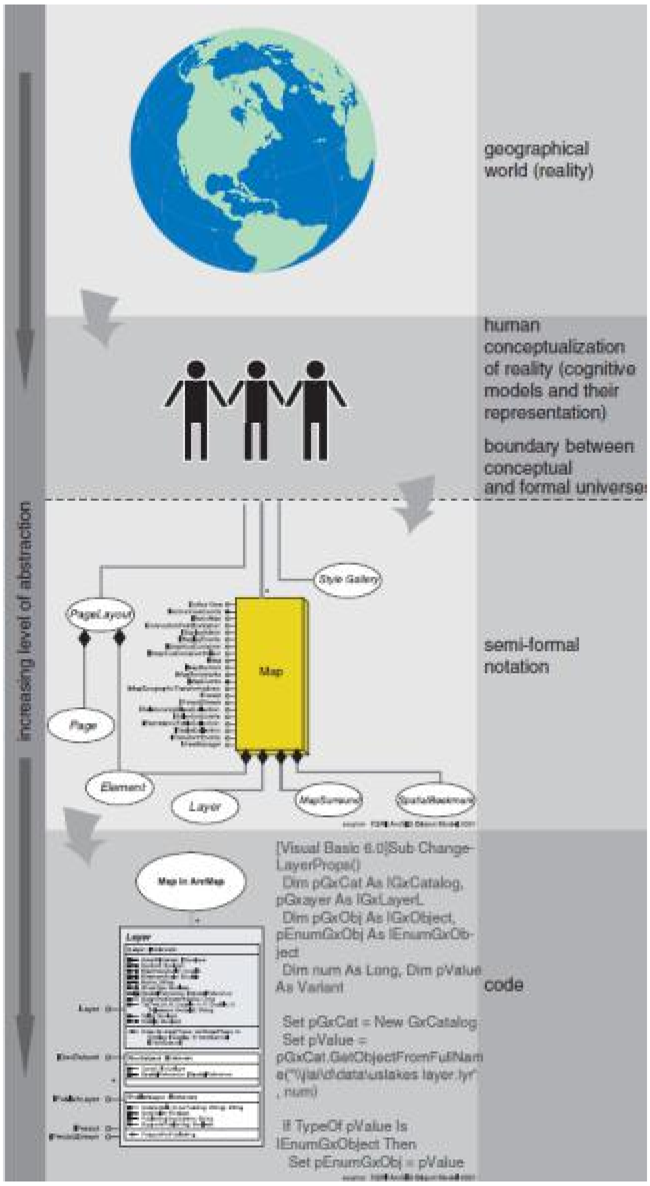

Figure 2.1: The process of human spatial conceptualization rendered into digital form in GIS (ESRI, 2001 in Schuurman, 2006).

On the other hand, some commentators are in profound opposition to the use of GIS for LK and mapping initiatives. Rundstrom (1995, 45) stated that "…*GIS as potentially toxic to human diversity, notably the diversity of systems for knowing about the world…destroy indigenous cultures*". Additionally, he indicated that modern GIS technology is based upon contemporary epistemologies, and is incompatible with indigenous epistemologies and ways of knowing. Similar aspects of indigenous incompatibilities occurred with the Zuni culture (an American Indian tribe from the southwestern United States). Their culture uses a seven-dimensional spatial schematization (North, South, East, West, Zenith, Nadir, and Centre), which is not represented by modern GIS/mapping technologies that include only the four cardinal directions (Fox, 1998). Chambers *et al*. (2004) summarised the main issues of the GIS/indigenous knowledge debate as follows: (1) GIS may not be compatible with indigenous ways of knowing; and (2) GIS may be unsuitable because of the cost of the technology and data, the need for specialized training, concerns over rights of information, access and use, as well as the fundamental difficulties in Cartesian methods of spatial representation. However, Chambers *et al*. (2004) still remained optimistic of the significant benefits of inclusion of indigenous people and/or local communities, not only for the sake of decision-making processes, but also for revealing the potential for use within communities for further development and planning. Schuurman (2006) commented that despite the number of issues raised by early critics of GIS, research into GIS epistemologies and ontologies has taken the debate to a more foundational level.

This section has highlighted how GIS critiques have helped to deconstruct GIS and reconstruct PPGIS. Most PPGIS practices have focused on empowering underprivileged groups within decision-making processes, promoting bottom-up management, encouraging equitable access to GIS data among relevant stakeholders, re-designing its use for non-traditional GIS users, and facilitating the transformation of indigenous knowledge into a scientific platform, so broadening public participation and helping to co-investigate the challenges faced by GIScience and other, diverse disciplines.

2.4 The Public Participatory Geographic Information System (PPGIS): Practice and implementation

2.4.1 The Public Participation Geographic Information System (PPGIS)

The concept of a Public Participation Geographic Information System (PPGIS) arose out of the widening discussions on GIS and society in the 1990s. Such critiques of GIS led to the Specialist Meeting of the National Centre for Geographic Information and Analysis (NCGIA) taking place in the United States in 1998, at which participants reported on the rapid spread of PPGIS practices, as a reasonably new field in the GISciences (Tulloch and Shapiro, 2003). The mixing of participatory research and GIS technology has been applied prominently in development studies and other, various fields, especially as a system used to collect and analyse data for local communities, natural resources management, and conservation and over the web (Weiner, *et al.* 1995; Harris *et al.*, 1998; Carver *et al.*, 2001; Ghose, 2001; Ball, 2002; Craig *et al.,* 2002*;* Sawicki and Peterman, 2002; Warren, 2004; Sieber, 2006; 2007; Brown and Reed, 2009; Hall *et al.*, 2010; Brown *et al.*, 2012; Brown and Kytta, 2014). Numerous PPGIS conference papers and articles deal with issues of representation and ontologies (Rundstrom, 1995; Barndt, 1998; Sieber, 2000; Elwood and Leitner, 2003; Kyem, 2004).

PPGIS has been defined in various ways over time. Originally, it was defined as "*a variety of approaches to make GIS and other spatial decision-making tools available and accessible to all those with a stake in official decisions"* (Schroeder, 1996, 28). Interestingly, PPGIS is a practice that has emerged out of participatory approaches to planning, spatial information, and communication management (Rambaldi and Weiner, 2004). According to Tulloch and Shapiro (2003), PPGIS has to be defined in accordance with the process or activity it is being applied to. Some research studies have focused on participation in terms of mapping and data collection, while others have focused more on participation in public agency decisions. Therefore, it is impossible to describe PPGIS using a singular definition.

Further to this, the term 'PPGIS' has increasingly been shortened to Participatory GIS (PGIS), because the latter term acknowledges the wider involvement of governmental organizations, non-governmental organizations, and the private sector when using the platform. Initiatives to develop participation at the grass roots level typically go beyond the public sector. However, PPGIS and PGIS can be used interchangeably. Some researchers prefer the term PGIS because it places significant emphasis on the participatory methods used in the production of GIS data, but the PPGIS term seems to be most widely used, even where there is an argument over whether 'the haves' and 'the have-nots' in communities have been consulted (Sieber, 2006).

Each acronym conveys its own context, methods and actors, such as those who co-operate in research through the practice of Participatory Learning and Action (PLA) using GIS and through Participatory Rural Appraisal (PRA). PLA and PRA are approaches and methods used for learning about and engaging with communities (Bie, 1998). Actually, the participatory creation of maps began in the late 1980s, with the use of PRA methods such as sketch mapping (Dent *et al.,* 2013), rather than complex GIScience and GIS tools. Sketch mapping combines a range of geo-spatial information management tools and methods to represent people's spatial knowledge in the forms of visual representations; with maps used as interactive vehicles for spatial learning, discussion, analysis, decision making, and advocacy (Rambaldi *et al.,* 2006a). GIS, three dimensional modelling, photo maps, satellite images, ephemeral mapping, and sketch mapping are all examples of PPGIS tools, and these tools can be attributed to one type of PRA tool: space-related tools, of those which examine local perceptions of resources and space within communities (Kumar and Kumar, 2002). Space-related PRA methods include social maps, resource maps, participatory modelling methods, mobility maps, services and opportunities maps, transects, and participatory census methods.

However, where communities cannot access technology-based maps and there is a limited knowledge base, it is likely that the use of PPGIS tools such as sketch maps and mental maps should be used to elicit local knowledge and spatial knowledge, and to allow for community participation in planning, without facing the constraint of requiring GIS knowledge, using GIS software, and needing cartographic accuracy. People's mental maps are symbolic and visionary, and normally related to the land and its resources. Unlike GIScience applications, they tend to provide qualitative information; for example, in connection with ethnographic studies of low income urban households and for crime information (Matthews *et al.,* 2005), plus evaluating landscape values for forest planning purposes (Brown and Reed, 2009), as well as land tenure and community-based natural resources information (Poole, 1995; McCall, 2004). Harris and Weiner (2002) agreed that mental maps are useful in helping communities to express their perceptions of the local landscape and when collecting socially and historically differentiated community local knowledge that can be digitized and analysed as GIS data. This practice represents a big move, from the involvement of inherently techno-centric to non-traditional GIS users, and also reduces the barriers created by the need for GIS expertise, the ontology of GIS data, and empowerment within decision-making processes. Furthermore, this practice shifts the social and technological contexts of GIS, to an engagement with mixed research methods, particularly with the recent emergence of qualitative GIS (Elwood, 2006a).

One of the concerns researchers have with local knowledge is its accuracy, which may be qualitatively different from scientific knowledge. However, this type of knowledge has cognitive structures, even though the units and references may be different and difficult to translate (McCall and Minang, 2005). For instance, fishing communities along the Mekong River use a measurement called a *lar* (similar to a yard) to represent 90 cm, but generally researchers use metric measurements. Therefore, researchers need to have a better understanding of local practices and knowledge, and be able to translate it to fit the systems they use. According to McCall and Minang (2005), indigenous technical knowledge is more reliable, and tends to be more accurate, because it embodies generations of practical knowledge and frames interactive and holistic systems. Therefore, PPGIS often involves both indigenous knowledge and modern scientific knowledge using applications that can potentially empower local communities. In other words, PPGIS combines low- and high-end technology, and so addresses questions of accuracy trade-offs, reliability, and acceptability (McCall and Minang, 2005).

2.4.2 Participation in PPGIS approaches

Participation is a fundamental requirement of participatory approaches, and the process of participation in PPGIS can be categorised into three degrees or intensities: appropriateness of work, competencies, and relationships between actors (McCall, 2003; 2004). Along with these aspects, participation should be used to characterise those three intensities, from the least to the most participatory level (McCall, 2003; 2004; Water-Bayer and Bayer, 1994; Selener, 1997), in line with the following points:

1. **Information Sharing:** One- or two-way communication between external and local actors, e.g. eliciting local people's knowledge and sharing project information.
2. **Consultation:** The external actors discuss curtain issues with local actors, for further refinement, detail and to prioritise issues. The external actors, however, get to control all of the processes.
3. **Involvement in decision-making by all actors:** To engage in all project processes from the start, including from development of the agenda, to project implementation and decision-making processes.

4. **Initiating Actions:** Independent initiatives coming from and 'owned' by local actors who are empowered to perform community activities.
5. **Sharing of Benefits:** A form of participation which involves receiving income, food or political power.

Participation intensities can be divided into three based on the reasons for promoting participation in PPGIS; from the lowest to the highest promotion level, such as the approaches used in spatial planning and environmental management (McCall, 1998), as shown below:

- **Facilitation:** Means to introduce, facilitate and lubricate external interventions, projects and policies into local communities
- **Mediation:** Means to bridge gaps between external and local communities; to promote support or re-direct higher level interventions from local communities, those which reflect local needs, aspirations and resource constraints.
- **Empowerment:** Means to encourage and reinforce local decisions and local responsibilities within decision-making processes. Such empowerment can increase participation and public empowerment levels from zero to much greater (Carver, 2003).

2.4.3 Practice and implementation

Over the past two decades, PPGIS applications have been applied in a variety of fields to elicit local knowledge and transform it in a systematically scientific way; to determine planning processes and manage resources (Dunn, 2007) such as natural resources, landscape values, community forests, land, watersheds, and fisheries (e.g. See Morain, 1999). PPGIS has also been applied extensively by a range of users including researchers, conservation managers, and practitioners e.g. Elwood and Ghose, 2004; Kyem, 2004; Brown, 2005; 2006; Dunn, 2007; Brown and Donovan; 2013.

PPGIS has increasingly been used for a greater variety of purposes, including: park planning (Brown, 2006); regional planning for tourism, conservation, and development (Brown, 2006; Brown and Raymond, 2007; Raymond and Brown, 2007; Brown and Weber, 2012); national forest planning (Brown and Reed, 2000; 2009; Brown and Donovan, 2013); marine conservation (Brown *et al*., 2001; Hall and Close, 2007), in Hawaii (Calamia, 1996), the Philippines (Burke *et al.,* 2006), and in Scotland, UK (Green, 2010); and, lastly, to integrate traditional and scientific knowledge into supporting fisheries management in southern Brazil (De Freitas and Tagliani, 2009) and in the Solomon Islands, Oceania (Aswani and Lauer, 2006).

PPGIS approaches have also been applied in community-based research projects helping to link people and natural resources in a more sustainable manner (Christie *et al.,* 2002; McConchie and McKinnon, 2002; Poole, 1995; Shepherd *et al*., 2004), as well as those empowering marginalized local communities and non-traditional GIS users within planning processes (McCall and Minang, 2005, Kyem, 2002a; 2004). Such use by community members is at odds with the fact that GIS information is mostly use for policy making purposes by policy makers (Sieber, 2006). It is because GIS is an elitist tool and system with technocratic foundations in which it can exert power to the holders. Such view might be connected to the critiques of maps as a form of power-knowledge in which the power in mapping practices is context-dependent and expressed by unequal power relations (see Wood, 1992; Crampton, 2001; Kitchen and Dodge, 2007).

However, maps have its own power to convey messages very clearly, in a way that is easy to understand by all those involved. Therefore, maps are a key component of efforts to bring about grassroots change (Elwood and Leitner, 1998; Talen, 2000; English *et al*., 2003), and can be an important component of the work of human services organizations (Hoefer *et al.,* 1994; Queralt and Witte, 1998; Kellogg, 1999), as well as being able facilitate and highlight issues of equity and community condition (Harris, 1998; Schlossberg, 1998; O'Looney, 2000; Elwood, 2002; Williams and Dunn, 2003). Furthermore, these applications have also been included in community-based planning and neighbourhood revitalization (Al-Kodmany, 2001; Ghose and Huxhold, 2001; Elwood, 2002; Sawicki and Peterman, 2002; Hall *et al.*, 2009; Bugs *et al.*, 2010; Lowery and Morse, 2013).

There are also some examples of involving local people in decision-making processes, in order to make subsequent management interventions more acceptable. For example, Alcorn (2000) underlines the uses and potential of PPGIS for grassroots-based advocacy, helping to assist changes in policy and management at all levels. The outcomes of this study helped promote good governance and have continued to spur-on communities, NGOs, and governments to apply PPGIS in natural resources management activities. This project in part contributed to the adoption of PPGIS among community forest development projects in Cameroon. Kyem (2004) used GIS to manage a conflict between a logging group and a forest preservation group regarding natural resources allocation in a rural community in southern Ghana, Africa. Even though GIS applications themselves are not able to resolve value-based conflicts, they are helpful in defining spatial and natural resource conflicts. During the PPGIS process in Kyem's study, the tool was able to serve the demands of each group involved, by creating a single objective, multiple-criteria problem, and as a consequence manage areas of conflicting claims and come up with a compromise solution. In another case, PPGIS was applied with land use planning in Dane County, Wisconsin, where the County Executive agreed that PPGIS tools improved and supported its proposed land use goals (Ventura *et al.*, 2002). Some integrated PPGIS with Volunteered Geographic Information (VGI) systems for engaging multiple stakeholders in an internet-based PPGIS to identify national forest values and use preferences in the United States (Brown *et al.*, 2014) and in an assessment of PPGIS and Web 2.0 technologies in urban planning practice in Canela, Brazil (Bugs *et al.,* 2010).

Likewise, McKinnon (2005) used a Mobile Interactive Geographic Information System (MIGIS) to support local farmers' interests in local institutional arrangements in South-east Asia. He noticed that local farmers had mapping skills; for instance, the reading and drawing of maps, and they understood aerial photographs. In addition, local farmers were able to justify the criteria they used for the distribution of wealth, and discuss their situation in an informed and intelligent manner. Even though the project had minimal support from traditional local leaders and lacked funding, the MIGIS approach was warmly received by the local farmers.

In the Mekong region, Anuchiracheeva *et al.* (2003) applied PRA and GIS among local *chaopramong*, in order to establish rights-based fisheries and co-management activities in Bang Saphan Bay, Prachuap Khiri Khan Province, Thailand. The integration of local knowledge among *chaopramong* was systematized in GIS and the succinct results used to guide fisheries management and co-management. The most valuable aspect of using the *chaopramong*'s local knowledge was the support it provided to in-depth scientific research, reducing the time and cost of the operation, such as identifying the locations of fishing grounds for certain species. However, so far there have been only a few studies of co-management activities for freshwater fisheries management activities, these being conducted in the Lower Songkhram River basin in Thailand (Khumsri, 2010) and along the Mekong River in support of Fishery Conservation Zones used to protect deep pools (Baird, 1999). Far too little attention has been paid to PPGIS for fisheries management in the Mekong River region, and especially with respect to the special ecological functions and geomorphic processes of deep pools.

These examples show the application of PPGIS across a wide range of disciplines, plus provide enough support with respect to the attitudes and participation of local communities regarding natural resources conservation, to be noteworthy for sustainable management purposes. In the next section, I will describe other studies relevant to fisheries management activities on the Mekong River.

2.5 An overview of Political Ecology

Political ecology is an interdisciplinary study that involves the combination of several schools of thought into the study of the relationships of politics, economics, geography, anthropology, sociology, environmental history, and ecological economics and social factors with environmental issues (Stonich, 2001). Many studies reveal that the political ecology arena studies the roots of social conflicts over access, and use of the environment from the lens of social, distribution, and knowledge conflicts. The focus is on the power structures that determine resource access.

The origin of the term “political ecology” was first published by Frank Thone (1935), under the title, "Nature Rambling: We Fight for Grass,", and has been broadly applied in human geography and human ecology. The field of Third World political ecology originated in the early 1970s at a time when human-environment interactions were under increasing public and scholarly scrutiny (Bryant and Bailey, 1997). The well-known anthropologist Eric Wolf was among those who used the term ‘political ecology’ in his criticism of cultural ecological and ecological anthropological approaches to the study of Alpine ecology, and he highlighted the theoretical need to place local ecological realities within the broader political economy (Wolf, 1972). There are multiple antecedents and streams of thought which coalesced and evolved to form political ecology during the 1970-1980s:

- Political economists: Neo-Marxists gradually raised the awareness of growing environmental problems in the 1960-1970s and re-analysed the way ‘nature’ was framed within political economy (Redclift, 1984).

- Human ecologists: The focus of human ecologists on the study of the society and environment relationship conceived an understanding of politically nuanced processes of social and environmental change. For instance, Rambo and Sajise (1984) mentioned the neglect in human ecology studies of the issues of competition, conflict, exploitation, and human misery.
- Geographers: Radical geographers reflected a critical perspective and concern for human emancipation and global inequalities to political economy and human ecology, which showed in the works of Peet (1978) and Watts (1983). While Blaikie and Brookfield's (1987) study "Land Degradation and Society" is considered as a landmark of contemporary political ecology by many studies.

In the late 1990s and early 2000s, political ecology fragmented into several parts that have since developed into the following vigorous research areas: as a framework for analysing human-environmental relations (Grossman, 1984); a historical out-growth of the central questions asked by the social sciences about the relations between human society, viewed in its bio–cultural–political complexity, and significantly humanized nature (Greenberg and Park, 1994); and a reaction to certain features of human ecology or ecological anthropology or cultural ecology (Vayda and Walters, 1999). Some researchers such as Escobar (1996) and Baghel and Nusser (2010) argued that political ecology applied to post–structural approaches because they examined unequal relations and how they established themselves on environmental change across multiple scales. Until 2000, much of political ecology's approach to Third World development has revealed that the crucial issue underlying environmental demolition and human poverty is obvious inequality in access to resources within a socially institutionalized context (Painter, 1995). Bryant and Bailey (1997) summarized five main approaches adopted by political ecologists and explained their relations to the field of geography, which are related to socio-economic approach, actor-oriented approach, concepts, regional political ecology, and environmental problems.

Currently, the broad concept of political ecology encompasses a much wider range of research scholarship. Stonich (2001) highlighted trends and debates of political ecology in two broad areas. The first important trend involves an understanding of the social construction of the environment and the increased integration of various cultural and discursive approaches. For instance, Escobar (1999) underlined that perceptions and discourses about environmental problems are social constructions that reflect specific backgrounds, values, and positions of power rather than absolute truths. Blaikie (1985) researched the linkages between environmental changes and their associated social and political processes, which links into the political economy of environmental problems.

The second trend is the 'serious treatment of politics in political ecology', or in other words, the study of nuances of political action into questions of resource access and control in various scales of study from local to global level (Peet and Watts, 1996). For example, Peluso (1993), who showed how state power and forestry institutions in Indonesia are disputed by Indonesian peasants in the context of coercive conservation measures. Similarity, Stonich (1993) stressed the role of local level influence interacting with broader structures of power. In other words, political ecology is presented as a way of enhancing the dynamics of local human-environmental relations (Peet and Watts, 1996) and linkages between power relations and the interests of different actors. There are many more examples of studies focusing on politics of scale and multi-scale analysis of environmental problems which review the plurality of social actors framing the politicized environment (Bryant, 1992; Bryant and Bailey, 1997; Bakker, 1999; Sneddon *et al.*, 2002; Brown and Purcell, 2005; Lebel *et al.*, 2005; Molle, 2007; Zimmerer and Bassett, 2003), and draw on the notion of 'scale politics' influenced by political economy and geography

(Howitt, 1993, 2003; Delaney and Lietner, 1997; Jones, 1998; Brenner, 2001; Meadowcroft, 2002; Brown and Purcell, 2005; Lebel *et al*., 2005; Molle, 2007; Sneddon *et al*., 2002), while some studies focus on the role of power and knowledge in shaping the discourse on environmental change and political analysis of the way environmental problems are framed by different social actors (Forsyth, 2003) and the politics of fisheries knowledge in the MRB (Hirsch, 2006).

Grossman (2000) pointed out that debates over political ecology centre on the place and priority of the environment itself as a research focus, or pay attention solely to politics and political economic forces on the environment as modified by human relations rather than on environmental factors themselves. Examples of this view can be found in Zimmerer (1996), Grossman (2000), and Scoones (1999). There is also, however, a differing point of view as given by Vayda and Walters (2009), who criticized political ecology for becoming simply 'politics without ecology'. In contrast, Watts and Peets (2004) argued that political ecology has been cognizant of the ecological processes. Walker (2005, 76) disputes in "Political Ecology: Where is the Ecology?" that such critics' charge is "*an exaggeration; while some political ecology has indeed branched in directions that do not engage biophysical ecology or environmental change directly, the tradition of careful examination of environmental change (rooted in older cultural ecology) remains alive in political ecology today*".

Robbins (2004; 2011) reviewed the contemporary frameworks of political ecology and categorized them into: degradation and marginalization, conservation and control, environmental conflict, and environmental identity and social movement. Contemporary political ecology also uses language as a means to achieve a critical perspective and enable cultural sensitivity (Robbins, 2004; 2011; Peet and Watts, 2004; Walker, 2005). Some authors point out that language matters as it further explains how power, language, and culture shape decisions (Forsyth, 2003; Robbins, 2003; Zimmer and Bassett, 2003; Latour, 2004; Walker, 2006). Likewise, language can also polarize environmental problems, yielding flat characters (good guys and bad guys) (Robbins, 2004) and the complexity of environmental decisions in terms of uncertainty, debate, and risk (Forsyth, 2003). Hence, contemporary political ecology tends to use language to shape nature and environmental interests.

Stonich (2001) argued that political ecology must balance the cultural/social construction of the environment with a meaningful and comprehensive analysis of the environmental construction of the social and the cultural. These debates led to the growing role of poststructuralism/postmodernism and discourse theory that has been applied in the new directions of political ecology. However, there is much to be done which can energize the future status of the political ecology field, for instance the unification of core and concept literature of political ecology. Forsyth (2008, 13) concluded that *"political ecology should not adopt separate understandings of politics or ecology, or see one as a guide to the other. The challenge for political ecology lies in understanding both environmental and political change in ways that enhance social justice, but which do not impose a priori notions about each*". There are broader studies in the integration of LEK and scientific knowledge for environmental management under the lens of political ecology. Examples of such studies can be found in related topics such as: linking social-ecological systems and management (Berkes *et al.*, 2008), community-based natural resource management (Larson and Soto, 2008), an evolution of co-management (Berkes, 2009), polycentric governance of climate change and economic systems (Ostrom, 2009; 2010; 2012), and the political ecology of caribou conservation (Bixler, 2015).

2.5.1 Integrating Political Ecology and PPGIS approach for fisheries management on the Mekong River

"[*O*]*ne productive way to integrate geospatial technologies and political ecological reseearch is through participatory GIS" (*Zimmerer and Bassett, 2003, 282). In their work, they suggested this may be a future direction in Political Ecology.

The PPGIS approach and political ecology tend to be far from being integrated at first glance, especially when considering the different pathways and heritage of the two approaches. The PPGIS is germane to the use of GIS technologies to broaden public participation with local communities in decision-making processes (Harris and Weiner, 1996). Political ecology brought in the political dimension to the study of environmental problems in developing countries with respect to decisions by different actors, including the impacts of international actors (Bryant and Bailey, 1997). Zimmerer and Bassett (2003) explicated that PPGIS refers to interactive mapping on the Internet in the global North, while referring to involvement of local communities during the stages of image interpretation and map making in the global South. However, the common ground of those two global themes is that "*the interpretation of landscapes and participatory mapping are inherently political processes*" (McCusker and Weiner, 2003, 282). Hence, in order to unpack the fisheries political process on the Mekong River, the political ecology framework there will need to be revealed.

The relationship between political ecology and conservation of natural resources is advanced by a number of studies. For example, Little *et al.* (1987) revealed that environmental deprivation is interrelated with the problem of unequal access to natural resources and poverty, which tends to occur in Latin America and developing regions. This aspect highlights the effort needed to link natural conservation to economic development by addressing ecological, resource use, socio-economic concerns, and inclusion of local communities in conservation and management. (Cater and Lowman, 1994; Western and Wright, 2013). In addition, a number of studies address conflicts over land, flora and fauna, soil, and water (Bryant, 1992), or those surrounding common-pool resources (e.g. Sheridan, 1988; Carney, 1993), while others scrutinize the relationship between access conflicts in the commons and ecological change in aquatic habitats and wildlife in marine environments (e.g., Stonich, 1995; Yong, 2001; Young, 2003). Interestingly, the similar condition of relationships between access conflicts in the commons and ecological change also applies to the freshwater habitat of the Mekong River as follows: the process of transnational enclosure has restructured community relationships with the commons (Santasombat, 2011), their commons are impacted by developments driven by political-economic interests (Sneddon and Fox, 2006), which are controlled by powers of the market, regulation, force, and legitimation.

The concept of Third World political ecology is multi-levelled or multi-scaled (Bulkeley, 1997; Cox, 1998), and achieves a reconciliation between the concepts of political ecology, political economy, and an examination of local knowledge within the context of natural resource decisions (Blaikie and Brookfield, 1987; Bryant and Bailey, 1997) and fishery studies aiming towards effective environmental management (McGuire, 1998). Bryant and Bailey (1997) describe five main aspects of the Third World political ecology: (1) a specific environmental problem; (2) power relations among different actors; (3) inter-linked political and ecological problems of a specific geographic region; (4) socio-economic characteristics such as class, ethnicity, and gender; and (5) the interests and actions of actors in political-ecological conflicts.

A critical Third World political ecology can be unpacked to frame the analysis of fisheries resource politics for PPGIS on the Mekong River. Firstly, a specific environmental problem is the involvement of the public in fisheries resource exploitation in a developing country. Second, power relations among different actors are manifested in multi-level stakeholders in the MRB (see Hirsch, 2000; 2004; Molle *et al*., 2009; 2012; Dore and Lazarus2009). Third, fisheries management is interlinked politically and ecologically to a specific geographical location, namely the MRB. Fourth, the local community level is a focus of interest in Third World political ecology, particularly in the context of the *chaopramong* community in Na Waeng, which has socio-economic and political characteristics. Fifth, the activities which actors use to engage with villages may reveal areas of potential political-ecological conflict. In this research, the Third World political ecology conceptual framework will be used to analyse PPGIS in fisheries management, while the discussion of fisheries resource politics will use a critical Third World political ecology perspective, which focuses on the concepts of power and relations, scale, power of knowledge, interests of actors and common-pool resources.

"Power and relations" is a principle of a political ecology of the Third World's environmental problems, which is the idea that the relationship between actors (ie. states, business, non-governmental organizations, famers etc.), and the links between actors and the physical environment, are conditioned by power relations. (Bryant, 1992; Bryant and Bailey, 1997). Additionally, Bryant and Bailey (1997) emphasized the closely intertwined role of power and human-environmental interactions, which also exists in the literature from a number of fields discussing the political, economic and cultural dimensions of power, as can be seen in the works of Foucault (1977), Mann (1986), and Cox (1987). Bryant and Bailey (1997) briefly addressed this in three interrelated questions:

(1) What are the various ways and forms in which one actor seeks to exert control over the environment of other actors?

(2) How do power relations manifest themselves in terms of the physical environment?

(3) Why are weaker actors able to resist their more powerful counterparts?

These questions will be applied to frame the analysis of PPGIS for fisheries management on the Mekong River.

"Scale" plays a prominent role in political ecology and has great significance in the analysis of power and relations in this research. In addition, the element of scale is shaped by the understanding of actors, and is likely to be an on-going, dynamic, economic, and political process (Delaney and Leitner, 1997). Marston (2000) contends that scale, while a contested and multifaceted concept, is becoming widely accepted as a result of social construction and should be considered a relational, rather than fixed, concept inclusive of size and level. Similarly, Brenner (2001) argued that studies of scale necessitate an understanding of the social construction of scale and its resulting usefulness for comparing relationships between scales but not for analyzing isolated scales. According to Howitt (2003) and Neumann (2009), the politics of scale is a theorization that incorporates three key concepts; namely, scale is socially constructed, historically contingent, and politically contested. Marston *et al*. (2005) identified three problems with politics of scale theorization, including the confusion between scale (size) and level (hierarchy), the local/global binary that assumes inherent differences between scales without a proper analysis of either, and the presupposition of fixed scales.

In the context of the Mekong River, Lebel, Garden and Imamura (2005) revealed that the politics of scale is dominating Mekong governance. They indicated how cross-level and cross-scale interactions are the key characteristics of Mekong water resources development and politics and identified four key strategies of scale making and its politics: "*telling stories, building alliances, deliberating and controlling technologies*" (*ibid*, 10). While Dore and Label (2010, 78) argued that "*scale and level politics contribute to the context and influences the process, content, and outcome possibilities from deliberative engagements. Informed multi-stakeholder deliberations that are sensitive to multiscale and multilevel interests appear crucial to influencing powers, challenging the way issues and stakes are framed, and negotiating for* [their interest]".

"Power and knowledge": "*The exercise of power perpetually creates knowledge and, on the other hand, knowledge constantly induces effects of power*" (Foucault, 1980, 52). In other words, the role of power and knowledge in shaping the discourse on environmental change and political analysis of the way environmental problems are framed by different social actors (Forsyth, 2003) and power may simultaneously have enabling and constraining effects upon knowledge (Turton, 1991). Different actors have taken on the mantle of leadership in environmental issues, and this is especially true in the MRB. The politics of environmental knowledge reflects the variegated interests within the MRB, in all scales and delimited sectors (Hirsch and Cheong 1996). Contreas (2007, 235) postulated that "*the interplay between different discourses, power and knowledge has turned the Mekong region into a highly charged terrain for the unfolding drama, both overt and subtle, of domination and resistance*". For further discussion see Section 6.4.2.2: Politics of LEK of *chaopromong* as a political machine.

"Interests of actors" refers to an actor-oriented approach in the study of society-environment relations and is advanced by Bryant and Bailey (1997), which allows an analysis of the role and significance of selected actors in environmental change and enables an assessment of the motivations, interests, and actions of different actors and their relative political strengths and weaknesses. Consequently, this approach makes politics central to the analysis of the interaction of actors over environmental and other resources, and recognizes that even weak actors possess some power to pursue their interests (*ibid*, 24-25). Whilst acknowledging how the interests of individual actors or multi-scale interests of diverse actors may perhaps both be bound to particular levels, spatial relationships and places help make the case for more innovative mechanisms that bring multi-level and multi-centered interests to a mutual forum (Lebel *et al*., 2005).

A focus on the interests of actors or on scale alone can lose sight of the power and relations of different actors or *vice versa*, hence all of those themes should be inextricably interwoven in the research. Such is the case with Sneddon (2003), who used actor-network theory in order to include a number of social and natural entities to explicate the relationship between scale and power through the initiation and installation of the irrigation development on the trans-basin Khong-Chi-Mun (KCM) project in northeast Thailand. He elucidated the fact that political struggles concerning the KCM Project, other projects and "*other local nodes of conflict at specific dam sites are largely about maintaining the set of relations among Thai political agents and development agencies that confer the KCM project its power effects and capacity to reach across scales*" (Sneddon 2003, 2246). He stated that the KCM project shed light on inherent contradictions that were exposed when state agencies were appointed mediators as their primary motivation is economic development. In the resulting conflicts over water resources control and access, he explained that tracing the relationship between scale and power through the complex network of actors at multiple scales is significant, particularly when conceptualizing the river basin as a site of political and economic struggles is required in order to carry out further analysis of conflict in the river basin and conflict in social processes in which scale is constructed and contested by actors.

Another interesting case is the Chao Phraya river basin in Thailand, about which Molle (2007, 361) noted "A political ecology approach sees river basins as politicized arenas where different actors who use water and/or are subjected to externalities vie for access to the resources, for protection or compensation, and use their social or political power to elicit or impose regulations and interventions in line with their individual interests.

"Common-pool resources or commons" defines common-pool resources (CPR) or commons as a "natural or manmade resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use" (Ostrom, 2011, 30). Examples of commons are groundwater basins, grazing areas, fishing grounds, forests, irrigation canals, bridges, the atmosphere, lakes, oceans, rivers, and other bodies of water, and may be owned by national, regional, or local governments, by communal groups, by private individuals or corporations, or be used as open access resources by whomever can gain access (Ostrom and Hess, 2007). It is also true that the concept of commons is intrinsic to political ecology through an examination of the sharing and overlapping realms in which different actors perceive the 'commons' as theirs, and the construction of multiple forms of exclusion based on varying claims.

The Mekong River is seen as a bioregional transboundary commons in which the commonality of the shared resources are grounded in the interconnected nature of the river system (Hirsch, 2006), with its overlapping and intertwining spatial and temporal scales of biophysical and ecosystem services in the complex environmental politics (Geores, 2003; Dore and Lebel, 2010), the process of transnational enclosure reforms community relationships with the commons (Santasombat, 2011), placing commons in the political economy as they are at risk by developments driven by political-economic interests (Sneddon and Fox, 2006), and the "governing of the commons" (Ostrom, 1990) is an age-old problematic involving issues of conflicts and poverty (Mathur, Sitirith and Öjendal, 2001). The Mekong River is drowning in the classical dilemma, the "Tragedy of the Commons" (Hardin, 1968), which stressed that all "commons" will be threatened if no coercive authority controls the situation; hence the construction of some sort of regulation of commons is the need. However, as Ostrom (1990) argued, the spontaneous construction of such regulating institutions is uncommon.

Overall, reconciling political ecology with the PPGIS approach of this research could draw common insights into the political dimension of the study of environmental problems in the Mekong River with respect to the five concepts of power and relations, scale, power of knowledge, interests of actors, and common-pool resources. Framing the research from a political ecology perspective could provide some insight into the political process in Na Waeng fishing communities on the

Mekong River.

2.6 Fisheries management on the Mekong River

2.6.1 Approaches to fisheries management

Fish resources underpin the livelihoods of millions of people in many countries, and especially in developing countries, as they provide a safety net in terms of sources of food and income for people living alongside rivers. However, fisheries are under intense pressure from a wide range of anthropogenic disturbances, such as altering land use, modifications to river flow regimes, riparian and physical habitat loss, and the intensive exploitation of fish stocks, among others (Arthington *et al.,* 2004). These pressures are jeopardizing fish resources and, as a consequence, a far greater number of freshwater species are in decline or becoming endangered in many rivers. Effective fisheries management is therefore essential in order to improve the chances that this lifeline can be sustained for future generations.

Several major conservation organizations, including the FAO, WWF and The Nature Conservancy, have independently reached similar conclusions with regard to the fundamental goals of biodiversity conservation. These conclusions include an emphasis on maintaining the integrity of ecosystems and the evolutionary processes that sustain biodiversity, and maintaining viable species populations.

The above organizations have also concluded that in order for this to occur, the following fisheries management techniques are required. To control fisheries in space and time, they must have closed and protected areas in place, as well as closed seasons, to allow stocks to replenish. Fisheries must also put in place controls on people's behaviours, usually through licensing systems. Another aspect of fisheries management that must be addressed is the equipment used, such as establishing a minimum mesh size for nets. Finally the above organizations also agree that there need to be fish catch quotas in place if fisheries are to remain sustainable in the future (FAO, 2003).

- *Closed or protected areas,* or the closure of geographically-defined areas, are management measures that can be introduced to protect nursery grounds and spawning aggregations, or avoid habitat destruction in certain areas. In Lake Chilwa, in the southern region of Malawi in Africa, a management program is in place to protect the deep pools used by the remaining fish when the lake dries on an annual basis (FAO, 2003). In Khong district, on the Mekong River in the southern part of Laos, local communities have initiated fisheries conservation zones to protect deep pools during the dry season, for fish sanctuary proposes. In the 1990s a number of successful examples of deep-water pool protection in Thailand were established with the support of the "Friends of Nan" in Nan Province.
- *The implementation of closed seasons* is a general measure used to protect fish during the breeding season, to provide protection during spawning or during a particularly vulnerable and critical life-cycle stage. For example, the Thai Fisheries Department has a regulation in place stipulating a closed season during the fish spawning season, which lasts at least three months, and begins at the start of the wet season, or in May. The period of time set for the closed season depends on fish habitat behaviours and the locations involved. However, this management measure can be applied incorrectly for political and economic reasons; for example, the closure of fishing areas near to tourist sites in Lake Kariba, Zimbabwe (Malasha, 2002).
- *Fishing licenses* are promoted based on a biological rationale and for controlling the number of individual fishers or vessels at certain times and in certain areas. In some areas of the Lower Songkham River Basin, in northeast Thailand, along tributaries of the Mekong River, customary rights for fishing grounds are operated by local fishers and local governments, and these require fishing licenses (Khumsri *et al.,* 2009). Such mechanisms tend to be

used to inform government policy on fisheries, and enable fisheries management legislation, plus generate revenue for the related authorities, and this leads to such mechanisms being used for income generating purposes rather than to control fishing activities.

- *Mesh size and gear regulations* are mechanisms used to conserve spawning stock and increase long-term fish yields. The choice of mesh size and type of gear used depends on the purpose of the fishing activity. For example, on the Mekong River, fishers use traps to catch some, mostly smaller, types of fish the riverbanks, and drift gillnets in running water where the catch generally involves larger species. During the spawning season, some areas have to implement seasonal gear regulations, such as the banning of gillnets and limiting the size of lift nets to less than two meters.

- *Fish catch quotas* are a mechanism used to limit the amount of fish that can be removed from a fish stock. This method requires a fair amount of investment in monitoring resources, and is most commonly implemented in European riverine fisheries, but is not often seen in freshwater fisheries in Asia, including the Mekong region, because of the monitoring and control efforts required. In relation to this, mechanisms used to control market demand or setting market quotas for fish catches tend to be used instead. However, many policymakers and scientists agree that such mechanisms tend not to be stringent enough, are rarely monitored properly, or fail completely due to people's ignorance of the relevant regulations. In some cases, *chaopramong* sell their daily quotas to others, who can then trade freely with third parties. Those *chaopramong* who operate in a relatively uneconomical way are likely to sell part of their quotas, while the more economically efficient (usually companies) can purchase additional individual transferable quotas (ITQs). ITQ strategies are based upon a purely economic perspective;

that the solution to the "tragedy of the commons" is to make the water resources private property (Olson, 2006) or tradable, making it difficult to manage and control fisheries mechanisms.

It can be seen that fish quotas have been applied primarily to address economic concerns rather than concerns of biological over-exploitation or excess harvesting capacity. Interestingly, the Mekong fisheries working group, including the Cambodia, Lao and Thai agencies, MRC and others, , applied this catch quota strategy to conserve critically-endangered species such as the Mekong Giant Catfish (Sukamasavin, 2009). The conservation strategy sets annual harvesting limits to no more than 10 adults under current conditions and no more than 20 in the longer term.

2.6.2 The fisheries management institutions in Thailand

The Department of Fisheries in Thailand (DOF) has been given a water governance mandate by the Ministry of Land and Agriculture. The main mandate of the DOF is to ensure sustainable utilization of fisheries resources and the environment by implementing research into and the development of fisheries, including the management of fish and other aquatic animals, in order to enable Thai fisheries to produce sufficient quantities for domestic and international consumption (Department of fisheries, 2008).

The DOF has implemented a decentralized system, delegating responsibility to multiple units at the central and regional administration levels. Figure 2.2 shows the organizational structure of the DOF in Thailand. As can be seen, the structure has two levels. First, there is the central administration - the ordering of the organizational structure, which reflects the power hierarchy of the top-down management approach. At the top of the structure is a director-general who controls the decision-making process within the organization. He or she has subordinate consultation committee members including the deputy director-general, senior experts, administration development groups, the inspector general, and internal auditing groups. The organization uses functional structures to group jobs together along functional lines, such as the secretariat, finance, personnel, planning and fisheries, and the information technology centre. Within these structures, each division plays a specialized role and handles large volumes of transactions. The regional administration structure has two levels for each of the 75 provinces in Thailand, these being the provincial fisheries level and the district level offices. The regional officers are asked to perform duties based on the specific needs of the organization at a given time and their own expertise levels. Even though a decentralized administrative system has been implemented across most Thai government organizations, the final decisions are still controlled by the central administration, for ratification and to ensure that such proposed work plans or strategies enhance national policies.

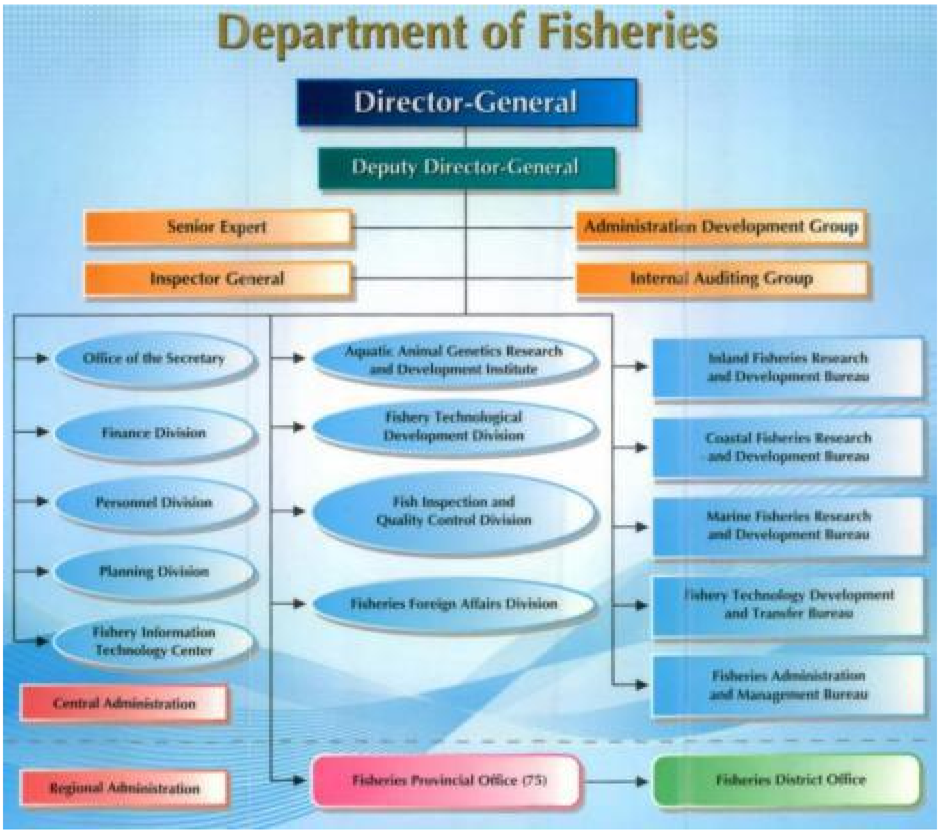

Figure 2.2: Central administration structure of the Department of Fisheries in Thailand. (Source: Department of fisheries, Bangkok, 2008)

Fisheries management strategies are based on the Fisheries Act of 1947, which is now almost seven decades old. The rules and regulations governing fisheries management relate to fishing methods (legal and illegal), seasonally prohibited fishing methods, licensing, and the protection of spawning grounds. The department's provincial and district officers are responsible for implementation and monitoring programs, to ensure that no illegal fishing practices occur. The DOF has submitted a new, draft 'Fisheries Laws and Legislation' document, but this has been on hold and awaiting government ratification since 1996. One important aspect of the new legislation is a proposal to use participatory approaches with regard to community fisheries management activities. This would be a good starting point for the democratization process, as it would allow local people to be part of the decision-making processes, and may contribute to the introduction of a sustainable environment for fish, plus the conservation of fish resources.

In addition, the legal framework is clear on how creative and proactive local governments can be within the decision-making process, which is not very, and this ensures that almost all decisions come from the top and work their way down. However, the political situation in Thailand is presently unstable, as can be seen by the number of social and political movements that have formed over the last couple of years. On the surface, there are two main factions – the anti-government and pro-democracy groups – and they have remained relatively unaltered over recent years. Another problem is that the government has not given the draft fisheries laws and legislation a high degree of priority in comparison to health care and education. This perhaps helps to explain why there has been no action taken on the proposals first made in 1996, and why Thailand is still using legislation that is now nearly 70 years-old.

2.6.3 Community-based management on the Mekong River

2.6.3.1 Fisheries management in Khong, Champasak, Lao PDR

The most well-known fish conservation zone (FCZ), which was the main focus of the Lao Community Fisheries and Dolphin Protection Project on the Mekong River, is in Khong District, Champasak Province in southern Lao PDR. It was established by Earth Island Institute, with the support of Lao Communities Fisheries, and ran from 1993 to 1997, and there was a follow-up project in1997-1999 (Baird, 2006). The project had apparently succeeded in increasing fish stocks and catches by fishermen. As a result, the model of co-management in Khong district has been put in place in Laos government policy in to ensure the protection of brood-stock and spawning grounds so as to support sustainable fisheries management and food security. Later on, some NGOs used the successful FCZ model and collaborated closely with the Lao government to establish FCZs at over 150 sites on the Mekong's mainstream and major tributaries in seven Laos provinces (mekongfishnetwork, 2013).

Therefore, the community-based fisheries management activities in Khong show that the LEK of *chaopramong* can facilitate fisheries management and act as a powerful tool for empowering local *chaopramong* within the decision-making process on management regulations. In the Khong FCZ, fishing communities have supported the initiation and enforcement of regulations that are eminently suitable for their communities. At the same time, the local government has endorsed each community's regulations, with only minor interference (Baird, 1999; 2007). The regulations developed can be classified into three: defined protected areas, the implementation of gear regulations, and a ban on fishing for certain species at certain times and in certain places. The details of this are as follows:

1) Protected areas: The establishment of FCZs in deep-water (10 to 50 meters) and in deep pools along the Mekong River during the dry season, or all or

some parts of the rest of the year. Local communities understand that deep pools serve as fish sanctuaries, nursing grounds, and fish migration shelters.

2) Gear regulations include limits on use of the following gear:

- Fish traps that can block waterways at the beginning of the wet season, as this kind of gear can interfere with fish migrations or even shorten spawning migration periods.
- The banning of “water banging” (using long metal poles to bang the water and scare fish into nets) and spear fishing with lights on at night, because these methods are too effective and catch a large number of brood fish.

3) A ban on fishing for certain species at certain times or in certain places, including:

- Juvenile snakeheads (*Channastriata*)
- Frogs (*Rana* spp.) and tadpoles (*Rana* spp.) at the beginning of the wet season
- Inundated forest habitats; encouraging local communities not to cut down wetland trees and bushes in the Mekong mainstream.

2.6.3.2 Rehabilitation of Biodiversity along the Mekong River through Community Participation - In Phosai and Natan, Ubon Ratchathani, Thailand

The project was established by the Global Environment Facility (GEF) in partnership with the United Nations Development Project (UNDP). The goal of this project is to build awareness of biodiversity features in local communities using LEK and a participatory approach in order to preserve riparian forests and fishing grounds as conservation zones along the Mekong River. This project is taking place in eight communities across two districts: Phosai and Natan (The GEF Small Grants Programme, 2012). The conservation zones are both seasonal and year-round, and have been endorsed by each responsible village since the project started in 2008.

Right now, the project is being implemented by each village chief [*Phuyaibaan*], to ensure the sustainable use of natural resources. In addition, local villagers believe that the project's practices allow fish to mature more fully before harvesting, so increasing fish production (as per communication with author, 2012). Interestingly, even though such practices and regulations have only been implemented on the Thai side, neighbouring communities in Laos are also following the relevant regulations to a surprising degree. This shows that there is a tendency to support, replicate and implement such project initiatives. This may well be due to the fact that the local communities have communicated the project's effectiveness to their Lao neighbours. Such programs could therefore be used on a wider scale, as a form of trans-boundary management.

2.6.3.3 Community-based fisheries management in Ubon Ratchathani, Thailand

The existing fisheries management legal framework tends to conserve fish species and protect spawning grounds. Provincial fisheries offices have been ahead of the central administration in implementing new policies, and have started working with local communities by establishing fish conservation areas near to temples. Temples, or committees based at the temples, manage, organize and monitor fish conservation areas with the support of the provincial fisheries offices. This initiative has been introduced without support from the central administration and in spite of the old fisheries laws and legislations which do not allow for it. These conservation areas seem to have been successful, because Thai culture greatly respects Buddhist practices. For instance, in Ubon Ratchathani, the fisheries office has established over 100 conservation areas around the province, all near temples. The program not only aims to promote sustainable practices, but is devoted to instilling conservation attitudes among the involved communities.

2.6.3.4 Trans-boundary fisheries management in Cambodia and Vietnam

Since 2009, there has been a trans-boundary fisheries management programme in place between neighbouring districts in Prey Veng Province, Cambodia and Dong Thap Province in Vietnam (MRC, 2012a). This spot is where the Mekong River in Cambodia merges into the Mekong Delta in Vietnam. The project was established with assistance from the Cambodian Fisheries Administration and the MRC Fisheries programme. The rationale is to improve the livelihoods of people who rely on the fisheries resources on the both sides of the border. As a consequence of the implementation of this trans-boundary management programme, a conservation zone has been established, and this has helped reduce the pressure on fisheries resources, with a remarkable increase in fish abundance noted. Based on the success of this initiative, there have been discussions about introducing additional projects further upstream in the upper parts of the Mekong River, between Bokeo in Lao PDR and Chiang Rai in Thailand.

2.6.3.5 Local ecological knowledge (LEK) in fisheries management

As interest in the use of LEK in terms of resource use increases, and a more extensive body of literature is made available for researchers, debates over the merits of using the LEK or qualitative anecdotal knowledge of local communities, in addition to scientifically acquired data, in the management of natural resources have increased. Some critiques of LEK argue that the accuracy or quality is not high enough to be consistently useful.

Notably, more research on LEK in the field of resource management has been undertaken by a wider range of investigators, especially those who see it as crucial for effective fisheries and coastal management (Dyer and McGoodwin, 1994; Aswani and Lauer, 2006; Hall and Close, 2007). The significance of LEK as an information source for researchers and fisheries managers is its inherent spatial component (Johannes, 1993), as this can facilitate fisheries management. For instance, *chaopramong* tend to perceive the environment as a non-linear representation of space, often positioning themselves in relation to places and landmarks along the riverbank (pers. communication, 2012; Brodnig and Mayer-Schonberger, 2000). In addition, LEK tends to have a more localized scale and better temporal knowledge than scientific data gathering; for example concerning the number and species of fish harvested, riverbed characteristics and river depth (Close and Hall, 2006), fish migration patterns (Johannes, 1989), and species distribution. All of which are associated with environmental characteristics (Berkes *et al.*, 2001) and assessments of fish and fisheries based on the LEK of *chaopramong* along the Mekong River (Baird and Flaherty, 2005).

According to Rambaldi *et al.* (2006a), determinations using a cartographic visualization are "the most effective way of communicating information about the location and spatial characteristics of the natural world and of society". In fact, LEK is inherently a spatial component; therefore, LEK can be incorporated through a spatial information translator or GIS, and be unified into the GIS environment, thus supplementing scientific-based information for decisions makers (Close and Hall, 2006; De Freitas and Tagliani, 2009; Macnab, 2002; Anuchiracheeva *et al.*, 2003). Therefore, GIS can bridge the gap, allowing the LEK format to be turned into quantitative data and a scientific platform. Some LEK data, such as riverbed characteristics and fish species, can be cross-checked for quality and accuracy using GIS.

As described in the previous section regarding the use of PPGIS tools such as sketch maps or mental maps to perceive LEK, this practice represents a big move from inherently techno-centric to non-traditional GIS users, and also a transfer of empowerment in decision-making processes, corresponding to the theme of water governance. This research study should help empower LEK, spatial knowledge, and data accessibility among all local stakeholders, building environmental awareness and leading to the democratization of water management.

Therefore, a thorough analysis of existing LEK, as a ‘negotiating knowledge frame’ to support fisheries management, is a significant part of this research. Given this, there is a conceptual and operational challenge in facilitating the two systems: LEK and GIS, especially since *chaopramong* and scientists tend to visualize the world differently.

2.7 Overview of the Mekong River Basin

Rainfall plays an important factor in determining the seasons in wet-dry monsoonal climates, and especially in southern Asian countries such as India, southwest Sri Lanka, and in Southeast Asia including Thailand, Vietnam, the west coast of Burma and Malaysia, plus north Australia and Sierra Leone (Ramage, 1971; Balek, 1983). Therefore, tropical river flows in these areas are affected by such monsoonal regimes.

The largest of the Asian rivers - the Yangtze, Salween, Irrawaddy, Red and Mekong - all originate on the Tibetan Plateau at around 4,500 metres above sea level. The Yangtze flows across central China, the Salween and Irrawaddy flow through Myanmar into the Indian Ocean, and the Red runs through Viet Nam into the Gulf of Tonkin. From its source, the Mekong is the largest river in Southeast Asia, and ranks as the world’s tenth largest river according to mean annual discharge (475,000 million m^3), the twelfth longest river (4,880 kilometres) and the 21st largest river basin (795,000 km^2) (Pantalu, 1986; Gupta and Liew, 2007).

The Mekong River Basin (MRB) can be divided in two distinct regions: the Upper Mekong Basin, which lies within China and Myanmar, and the Lower Mekong Basin, which lies downstream of China, and encompasses Laos, Thailand, Cambodia, and Vietnam. The Upper Mekong Basin covers approximately 24% of the total catchment area of the MRB and provides 18 % of the water that flows into it. Laos contains the largest catchment area, 25% of the MRB, and distributes the highest water flow to the Mekong River; 35% of the MRB (Table 2.2).

Table 2.2: Characteristics of the Mekong River catchments

Country	Area (km2)	Catchment area as % of the Mekong basin	Flow as % of the Mekong basin
China	165,000	21	16
Myanmar	24,000	3	2
Lao PDR	202,000	25	35
Thailand	184,000	23	18
Cambodia	155,000	20	18
Vietnam	65,000	8	11
Total	795,000	100	100

Source: MRC, 2005

2.7.1 Hydrological and geomorphological zoning

The Mekong basin was formed due to extrusion tectonics associated with the collision of the Indian and Eurasian plates, the uplift from which formed the Tibetan Plateau (Peltzer and Tapponnier, 1988). The pan-shaped basin is divided into six major geomorphic zones; the Lancang River basin in China (the upper Mekong basin), the northern highlands, the Khorat-Sakon Plateau, the eastern highlands, the southern uplands, and the lowlands (see Figure 2.3).

However, there is no one definitive division of the Mekong River. The Mekong River Commission (MRC) (2005) divides the basin into six major hydromorphological reaches, which take into consideration the hydrological regime, physiography, land use, and natural resources development. Furthermore, Gupta and Liew (2007) and Carling (2009) classify the Mekong's geomorphological areas into six and eight zones, respectively (Figure 2.4; Table 2.3). However, the justifications for their zoning are slightly dissimilar, though the similarity between the river geomorphology and geographical locations can clearly be seen.

Figure 2.3: The six major geomorphic zones of the Mekong Basin (source: MRC, 2004)

Figure 2.4: Gupta's eight geomorphological zones on the Mekong River (source: Gupta and Liew, 2007)

According to the hydrological and geomorphological zonings used along the Mekong River, the upper part of the Mekong, from its source to Vientiane (MRC Zone 1 and Zone 2), is the longest rocky stretch in the Mekong, running for approximately 3,220 km. This zone runs through the mountainous northern highland regions of the Mekong's landform profile (Figure 2.4).

MRC Zone 1, from the source of the river to Chiang Saen in Thailand, is dominated by Yunnan components and plays a significant role in the Mekong's morphology. As far downstream as Kratie (>1,500 km), the low-flow hydrology of Zone 1 has an impact, and it has been reported that 30% of the average dry season flow comes from the upper part of the river (MRC, 2005).

MRC Zone 2, from Chiang Saen to Vientiane, is bedrock confined and contains many rapids. This zone is dominated in both the wet and dry seasons by the

Yunnan components; the hydrological response here being the most natural and undisturbed within the lower Mekong.

MRC Zone 3 extends from Vientiane to Pakse. The upper part of this river zone is alluvial, largely single channel and sinuous, and it is increasingly bedrock confined in the southernmost 300 km of the zone (Mukdahan to the Mun River confluence near Pakse). The hydrology of this zone is influenced by tributary systems originating in Laos and Thailand.

MRC Zone 4 stretches from Pakse in Laos to Kratie in Cambodia. This is a bedrock-confined multi-channel complex, with islands, major rapids and waterfalls, such as the Khone Falls. The main hydrological contributions along this reach come from the Se Kong, Se San and Sre Pok River catchments in Laos, Cambodia and Vietnam respectively.

From Kratie to Phnom Penh (MRC Zone 5), and from Phnom Penh to the delta (MRC Zone 6), the river is alluvial. MRC Zone 5 includes the hydraulic complexities of the Cambodian floodplain and the Tonle Sap, and over 95% of the total flow here occurs in the mainstream.

The last MRC zone is Zone 6, which runs from Phnom Penh to the delta and into the South China Sea. This zone contains flood-prone fluvial floodplains and the tidally-influenced delta. Here the mainstream divides into a complex and sometimes artificial system of branches and canals.

Table 2.3: Hydrological and Geomorphological zones along the Mekong River

Hydrological reach (MRC, 2005)	Carling, 2009	Gupta & Liew, 2007	Channel Material/ Length (km)	River Units
Zone 1: Dominated by the Yunnan component	Zone 1: China – the source of the river – to Chiang Saen in Thailand	-	Sedimentary rock/2,565	-
Zone 2: Dominated in both the wet and dry seasons by the Yunnan Component. (natural and undisturbed)	Zone 2: Bedrock single thread channel—Chiang Saen to Vientiane: Deep pools, bedrock benches	1a: Chinese border to Nam Ou	Rock/500	1a: Steep straight channel with few transverse features or rapids
		1b: Nam Ou to 30km upstream of Nam Loei	Rock/250	1b: Steep straight channel with a large number of transverse features and rapids
		1c: 30 km reach upstream of Nam Loei	Rock/30	1c: Incised meanders with uniform width
		1d: Nam Loei to 5km upstream of Vientiane	Rock/130	1d: Wide straight channel with sediment
Zone 3: Contributions from large tributaries in Laos and Thailand	Zone 3: Alluvial single thread or divided channels—Vientiane to Pakse	2a: Vientiane to Pakranh	Alluvium/100	2a Wide and shallow meandering channel with sediment
		2b: Pakranh to Mukdahan Channel width: 800-1300m	Alluvium/400	2b Near-straight channel with solitary bars and islands
		*3: Mukdahan to Mun confluence near Pakse	Rock/200	3. Lower rock-cut channel
Zone 4: Contributions from the Se Kong, Se San and Sre Pok River catchments.	Zone 4: Bedrock anastomosed channels: Pakse to Kratie, Siphandone (4000 islands reach)	4: Pakse to MuangKhong	Composite/150	4. Composite channel
		5: Muang Kong to Stung Treng	Alluvium and rock/200	5. Anastomosed channel in rock and alluvium

Table 2.3: Hydrological and Geomorphological zones along the Mekong River (cont.)

Hydrological reach (MRC, 2005)	Carling, 2009	Gupta & Liew, 2007	Channel Material/ Length (km)	River Units
Zone 5: Complexities of the Cambodian floodplain and Tonle Sap Lake	Zone 5A: Alluvial meandering/an astomosed channels—Kratie to Phnom Penh: Scroll bars, back waters, overbank flooding, upstream of confluence with Tonle´ Sap River Zone 5B: Tonle´ Sap Lake and River: seasonally reversing flows	6: Stung Treng to Kampong Cham	Alluvium/ 225	6. Structure-guided alluvial channel (Sambor to Khum Angkor Ban)
		7: Kampong Cham to Phnom Penh	Alluvium/ 50	7. Free alluvial channel
Zone 6: Complex control by an artificial system of branches and canals	Zone 6: Alluvial Deltaic Channels—Phnom Penh to ocean: Distributaries, no marine influence in upper delta	8: Phnom Penh to ocean	Alluvium/ 330	8. The delta (Phnom Penh to the sea)

Source: Adapted from MRC, 2005; Gupta, 2007 and Carling, 2009.
Remark: * The study site.

2.7.2 Climate

Climatically, the Mekong can be divided in two distinct zones; the upper and lower Mekong river basin zones. The upper Mekong River runs through the Tibetan plateau; the area is a highly mountainous and tundra dominated region, and is almost permanently snow-covered. The lower part of the Mekong is dominated by the Southwest monsoon, and so experiences abundant rainfall from May to October, with a dry season lasting from November to April (Table 2.4). Between August and October, the lower Mekong experiences tropical cyclones, so this is the wettest time of the year, and the land around the river is prone to flooding. The northeast monsoon influences the lower basin in late October, bringing dry cold air from the north to the lower basin areas, with the exception of Vietnam.

Table 2.4: Generalized climatic seasons in the Lower Mekong River basin

Cool/Cold		Hot/Dry			Wet					Cool/Cold	
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NE Monsoon		Transition			SW Monsoon					NE Monsoon	

Source: MRC, 2005

2.7.3 People and livelihoods

The dominant social feature of the Mekong River is the diversity of ethnic groups, languages, and cultures that exist there, with a diversity of ethnic groups living in Cambodia, China, Laos, Myanmar, Thailand and Vietnam. Each language in these countries uses a different name for the river. Near the source in Tibet, the river is called *Dza-chu*. Heading downstream, it is referred to as the *Lancang Jiang* in China, and *Megung Myit* in Myanmar. Laos and Thailand use *Nam Khong* and *Mae Nam Khong* respectively. In Cambodia it is known as the *Tonle Thom* and at the end of its course in Vietnam it is called the *Sông Cửu Long*. Smaller groups within each country also have special names for the river. The Mekong River Basin is home to over 70 million people, and this number is projected to grow by at least 50% by 2020 (United Nations, 2005). Though many population projections have been produced based upon various criteria and scenarios, they project similar growth patterns.

The World Bank (2004) projected population growth in the LMB by analysing countries' growth rates (Table 2.5). The population has been projected to grow, from the year 2000 to 2020, from 55 to 74 million. By country, Cambodia is projected to grow by 68%, Laos by 55%, Vietnam by 29% and Thailand by 22% over this period. In 2010, the natural birth rate for Laos was the highest, at 2.1%, followed by Cambodia (1.6%) and Vietnam (1.2%).

Interestingly, the low percentage of people who use improved sanitation in rural areas is likely to be related to the increased rate of population in the lower Mekong countries, as it possibly implies that the population growth rate in rural area tends to be higher than in the urban areas. This may also lead to increased pressure on river resources in the near future.

Table 2.5: Country and Lower Mekong Basin population figures

Country	Country Populations (whole country boundary)						Lower Mekong Basin Populations		
	Y2000 (million)	Y2010 (million)	Projected Y2050 (million)	Rate of natural increase (%) Y2010	% who use improved sanitation (2008)		Population (million)		Increase rate (%) of population
					Urban	Rural	Y2000	Projected Y2020	
Cambodia	12.8	15.1	23.8	1.6	67	18	9.8	16.5	68
China	1269.9	1338.1	1437.0	0.5	58	52	-	-	-
Laos	5.2	6.4	10.7	2.1	86	38	4.9	7.6	55
Myanmar	45.9	53.4	70.8	0.9	86	79	-	-	-
Thailand	60.7	68.1	73.4	0.6	95	96	23.1	28.2	22
Vietnam	79.0	88.9	113.7	1.2	94	67	16.9	21.8	29
Total	1473.5	1570.0	1729.4				54.7	74.1	

Sources: Adapted from World Bank Vientiane 2004, United Nations, Department of Economic and Social Affairs, Population Division, 2007 and Haub and Yanagishita, 2011.

Remarks: Rate of Natural Increase (RNI): Birth rate minus the death rate, implying the annual rate of population growth without regard for migration (expressed as a percentage). Percentage of population using improved sanitation: An improved sanitation facility is defined as one that hygienically separates sewage from human contact. Data is from WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (www. wssinfo.org/datamining/tables.html).

2.8 Deep pools

2.8.1 The distinction between 'pool-riffle' and 'deep pool'

The characteristics of natural riverbeds develop into a variety of landforms due to the influence of fluvial geomorphic processes and fluvial ecosystems. Deep pools play a part within these systems, but developing an exact definition of a deep pool in terms of its morphological and hydrological processes, as well as its ecological functions, is a challenge, especially in large rivers.

In general, the literature uses the term 'pool' to refer to the deeper sections of a river, while shallow sections and areas of faster-moving water are called 'riffles' (Welcomme, 1985; Gordon *et al.,* 2004).. Some authors define the term 'pool' in combination with the characterisation of a river stretch, such as a 'pool-riffle-run' sequence, which includes deep river reaches with low flow velocities and fine bottom substrate (Allen, 1995), or 'gravel riverbed' (Gordon *et al.,* 2004). Welcomme (1985) stated that the alternation of pools and riffles, which arise from often pronounced changes in gradient, is the main morphological characteristic of so-called rhithron reaches (Figure 2.5). Generally, pool-riffle sequences occur in meandering alluvial rivers with mixed riverbed materials and sizes (Gordon *et al*., 2004), and in streams

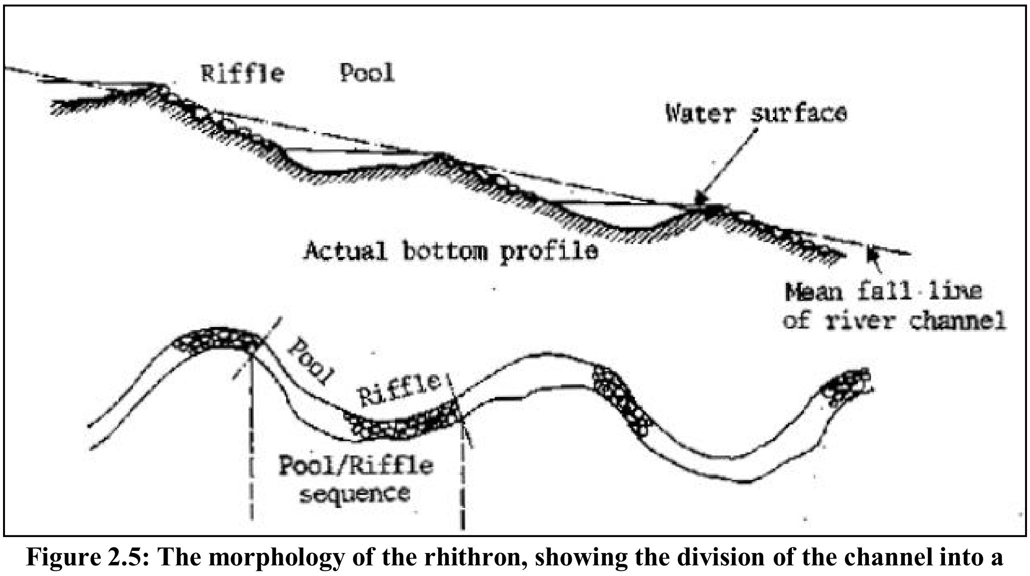

Figure 2.5: The morphology of the rhithron, showing the division of the channel into a sequence of pools and riffles. Source: Welcomme (1985).

with high flow variability (Jowett and Duncan, 1990). In addition, most studies have worked on pool-riffle sequences formed in gravel-bed rivers in temperate climates, but have paid scant attention to rivers in tropical climates.

In addition, the pool-riffle areas are important habitats for fish. Pools provide spawning gravel and low-flow habitats for larger fish, while riffles provide feeding habitats for benthic invertebrates and juvenile fish, and resting areas for fish travelling from pool to pool (Welcomme, 1985; Power, 1987; Gelwick, 1990; Harvey and Stewart, 1991; Newbury, 1995 and Gordon et al., 2004. The number of species found in riffles versus pools varies from stream to stream, and temporal patterns occur in terms of species richness and fish abundance (Bart, 1989; Gelwick, 1990). Furthermore, pool-riffle sequences tend to play a role in natural food chains and the predation of fish habitats, such as among loricariids in Panama and cyprinids in Oklahoma (Power, 1987).

Examining the terms ‘pools’ and ‘deep pools’, it is apparent that both terms tend to be used interchangeably, since they are often applied in river geomorphological studies to discuss the processes involved in pool maintenance. However, generally the term ‘pool’ seems to be most widely used. The term ‘pool’ was adapted by Wohl and Legleiter (2003), who studied a pool-riffle sequence formed in granite bedrock in the North Fork Pondre River in Phanton Canyon, with a depth of between 0.8 and 2.6 meters. Pools are associated with lateral constrictions where the channel intersects with a bedrock ridge. Moreover, the stronger constrictions stimulate flow direction and bed scour, leading to even deeper pools.

Baigun *et al*. (2000) refer to ‘deep pools’ as having a depth greater than 0.8 metres, based on thermal characteristics and morphometric features that influence pool occupancy by adult Summer Steelhead fish in Steamboat Creek, Oregon. Dolan *et al*. (1978), meanwhile, define a deep pool as any place where the water depth exceeds twice the average depth of the river (in their case 20 m). They found that most deep pools occur in pool-rapid sequences and are associated with brecciation and faulted bedrock. The greatest density of deep pools tends to occur in highly fractured Precambrian gneiss and schist. The generalized model of a rapid-pool tributary involves flows within brecciated zones, which transport material to the main river where it is too large to be carried downstream. This material then forms a channel constriction, which causes accelerated flow and the formation of rapids.. The high velocities associated with a zone of brecciation and with faulted bedrock, lead to scouring below the rapids, and hence, over time, deep pools are formed. On the other hand, Lisle and Hilton (1992) studied pool dimensions and refer to deep pools as pools that are generally classified as streambed depressions formed on the main section of a river channel, using the approximate lowest water level as a horizontal datum. Deep pools have also been identified based on a geomorphic statistical analysis (GSA) of fisheries in the Lower Mekong Basin (LMB) (Halls *et al.,* 2013).

Two hypotheses seem to form the origins of the term 'deep pools' in the LMB. First, local language terms in Laos and Thai refer to 'deep pools' as *wang/vern/wang nam luek/loump* (literally 'pool water deep'). The first project making reference to the phenomena, was the one advised by Ian Baird in Khong district in Laos, in which he argued for the adoption of local ecological knowledge (LEK) for deep pools or deep-water pools, as he referred to them in his studies (see Baird, 2006; Baird and Flaherty, 2005). Based on the work already done in Khong, the MRC started working on this issue as part of fisheries research, but with wider coverage area of the Mekong region. Local *chaopramong* in Khong have long known about the value of relatively deeper sections of river, in particular at deep pools, as fish sanctuaries, so fish conservation zones based on deep pools have been established locally, and in the region the term 'deep pools' is used instead of pools. As a result, deep pools are defined based on their function in fisheries ecology research in the LMB, rather than their morphological and hydrological characteristics, as they act as vital fish refuges during the dry season (Poulsen *et al*., 2002b). A characteristic of almost all the fish sanctuaries in the FCZs in Khong is that they have been established in relatively deep depressions or pools with an approximate depth of around 2.5 m or more in the dry season, when they provide relatively deeper water than in the surrounding riverbed and are therefore important for local fisheries (Baird, 2006). Similarly, *chaopramong* in the adjacent district to Khong, in the area from the border between Laos and Cambodia downstream to Kartie, classified relatively deep depressions as deep pools, even though they were only 3-5 m in depth (Chan *et al*., 2003).

Another study by Chan *et al*. (2005, 2) defined a deep pool as "*significantly deeper than surrounding areas and holds water in the dry season, during which it may become disconnected from the main river. A deep pool is also defined ecologically as being of significance for the conservation of a number of fish species*.". Viravong *et al.* (2006), based on a hydroacoustic survey, observed that the morphology and depth of deep pools in southern Laos and north-eastern Cambodia are variable and tend to be significant factors in determining the number of fish seeking shelter in particular deep pools. The fish revealed a preference for deep pools with serrated rocks with steep, almost vertical, sides.

Lastly, the term 'pool' is used in the book 'River Fisheries' by Welcomme (1985), in relation to the morphological and hydrological characteristics of the rhithron or elevated zone of a river. Different types of deep pool have also been identified based on both physical and hydrological characteristics. The term 'deeps' and 'shallows' are used in this connection, and the term 'deeps' has been used (Poulsen *et al*., 2002a; Halls *et al*., 2013) in fisheries research in the LMB.

2.8.2 Identifying deep pools in the Lower Mekong Basin

The locations of deep pools in the LMB were identified during this study using two research methods; namely, LEK-based surveys with *chaopramong*, and geomorphic statistical analysis (GSA) of the Hydrographic Atlas of the Lower Mekong River.

Firstly, research using the identification of deep pools through the use of LEK and hydro-acoustic surveys has been carried out in Cambodia, Laos, and Vietnam, with the MRC mapping the locations of more than 200 important deep pools in the lower Mekong River; on the Mekong mainstream and on tributaries of the Great Lake in Cambodia (MRC, 2008a). In this study, the non-random sampling locations of deep pools were identified from LEK and field surveys, using depth measuring equipment and with reference made to bathymetric maps (Figure 2.6). The approximate locations of important deep pools were determined through discussions with village chiefs and sketch maps drawn by *chaopramong*. These locations were compared to depth contours contained in the MRC Hydrographic Atlas for 1992 and geo-coordinated by using a Global Positioning System (GPS). The coordinates of the deep pool locations were recorded using the GPS, while the maximum depth of each of the deep pools and their local name provided baseline information. In some pools, additional variables, including fisheries conservation zones, the length and area of the deep pools, the number of fish species, and the number of *chaopramong*, were also included. All of this information has been highly significant in helping to establish fish conservation and monitoring programs in some communities.

Lastly, based on the identification of deep pools from a GSA of the Hydrographic Atlas of the lower Mekong River, the MRC mapped the locations of 419 important deep pools in the mainstream Lower Mekong River (Halls *et al.*, 2013; Figure 2.7). The geomorphic statistical analysis ended at the Cambodia and Vietnam border due to the availability of digital versions of the Hydrographic Atlas and the bathymetric map at that time. The zero-crossing method identifies shallow and deep pool areas of the riverbed above and below the overall profile of the riverbed depth (Figure 2.8). The overall trend can be a simple mean depth or a moving average depth which takes into account changes in channel morphology. This method generated essential information on the morphological characteristics of deep pools on the lower Mekong River, including depths, lengths, entry and exit slopes, a river bed roughness index (BRI), and the shape, area and volumes of deep pools (Figure 2.9; Table 2.6).

Notably, the result of deep pools' study using a GSA of the Hydrographic Atlas of the lower Mekong River, did not aim to either challenge LEK-based deep pool surveys or ignore the local value to fisheries of shallow deep pools. The result of GSA identifies the minimum depth of deep pools as just 3.1 m, which is relatively shallow. Even though these two characteristics of knowledge are distinguished on the basis of methodologies and epistemological philosophy (Howes and Chambers, 1980), LEK provides supplemental and vital information that cannot be generated by an acoustic survey (e.g. on fish species and fishing grounds). The result of the GSA can be explained in terms of the method of conducting depth soundings from the bathymetric survey, which used a 1 km cross-sectional survey method (measured by a tool in GIS) along the Mekong River (Figure 2.10). Therefore, it is possible that some deep pools were not identified because they were in gaps between the survey transects.

2.8.3 Deep pools in the Lower Mekong River

A geomorphic statistical analysis of the Hydrographic Atlas of the mainstream Lower Mekong River showed the presence of 419 deep pools. Deep pools were found along the entire length of the study reach, on average every 5.3 km along the river thalweg, which is the line of lowest elevation within a river. The median pool-to-pool spacing was found to be 3.7 km (range: 0.6 to 34.4 km), with the deepest identified pool being 90.5 m in depth - located at the study site and in a heavily constricted bedrock reach between Mukdahan and Pakse. The longest pool (18.5 km) was found in an alluvial reach downstream of Phnom Penh in Cambodia.Overall, the median pool depth was 21.4 m (range 3.1 to 90.5 m), and the

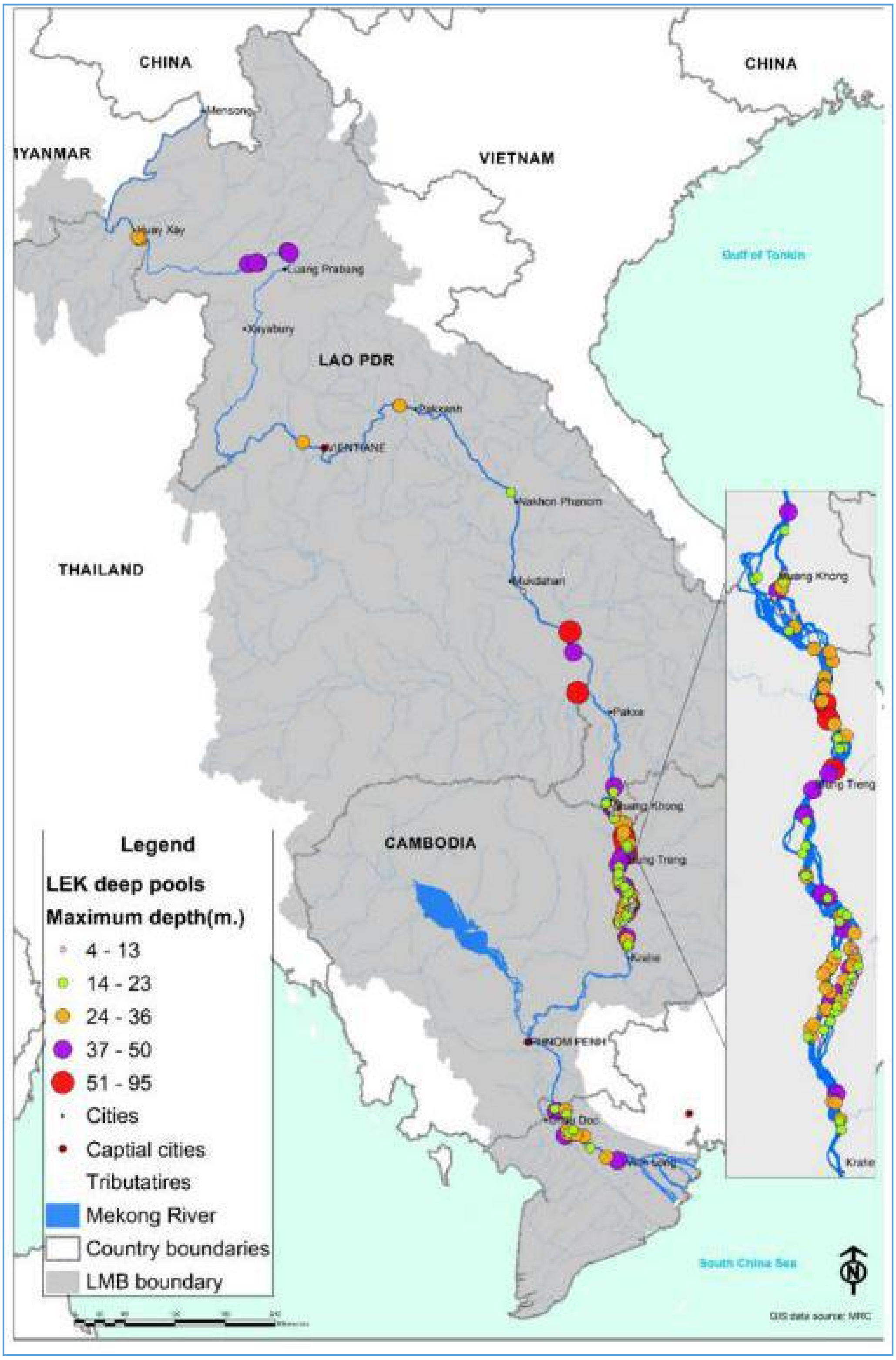

Figure 2.6: Deep pools on the Mekong River, identified from local ecological knowledge (LEK)

(GIS data source: MRC, 2008b; Prepared by Author, 2014)

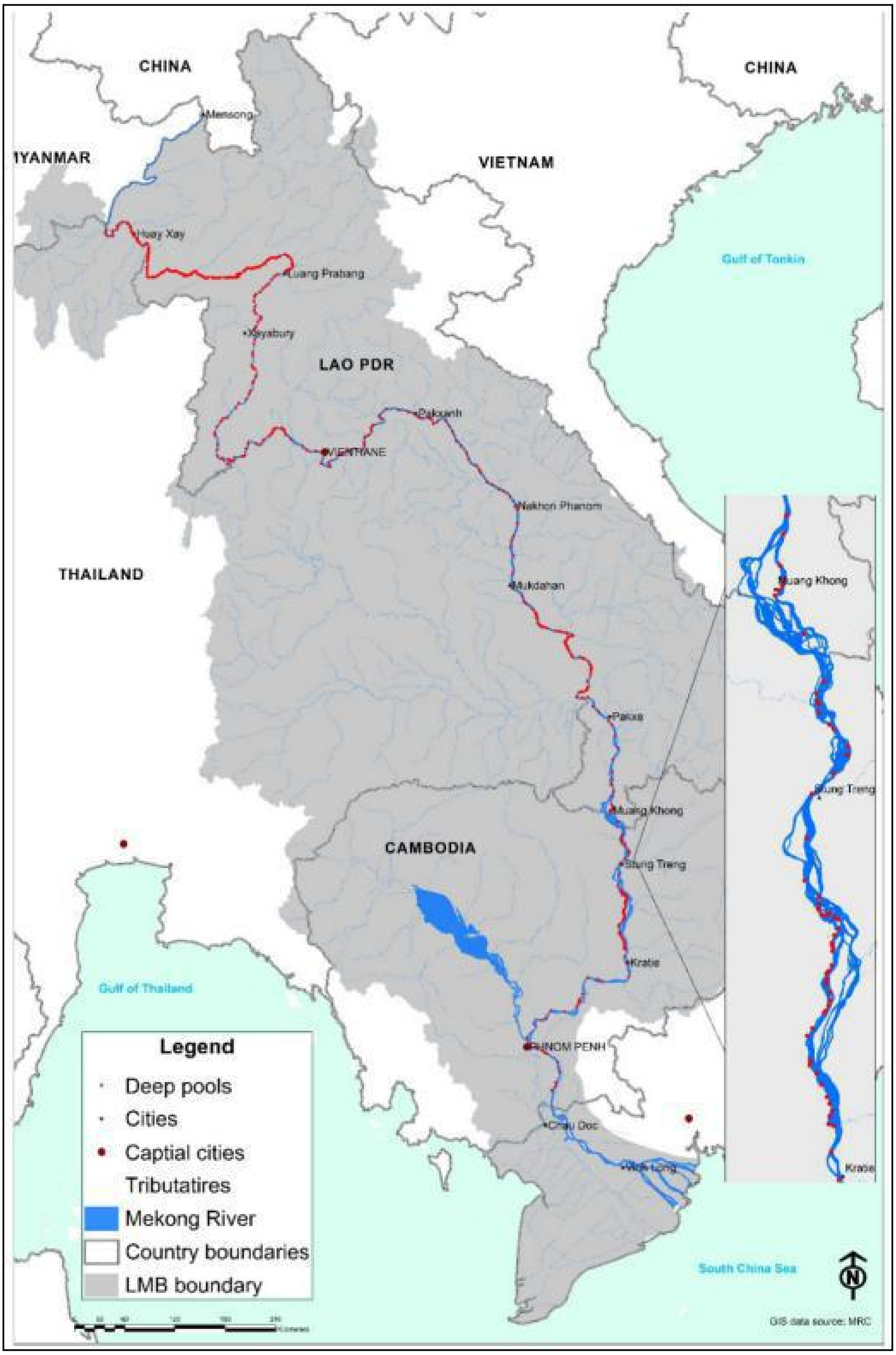

Figure 2.7: Deep pools on the Mekong River, identified from a geomorphic statistical analysis

(GIS data source: MRC, 2008b; Prepared by Wisesjindawat, 2014)

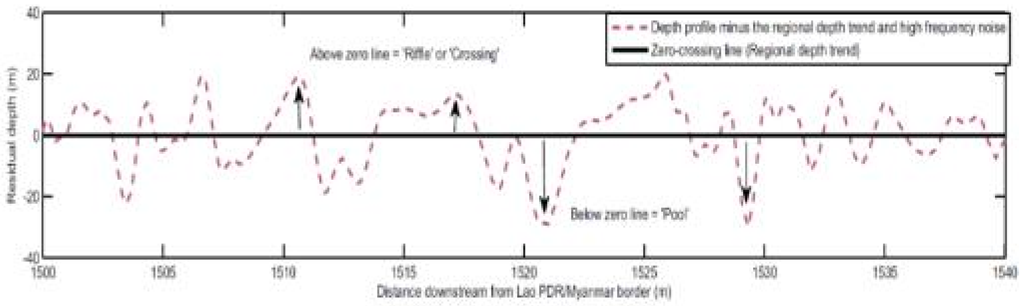

Figure 2.8: The zero-crossing method identifies shallow and deep pool areas of the riverbed, based on a geomorphic statistical analysis

(Source: Halls *et al.,* 2013)

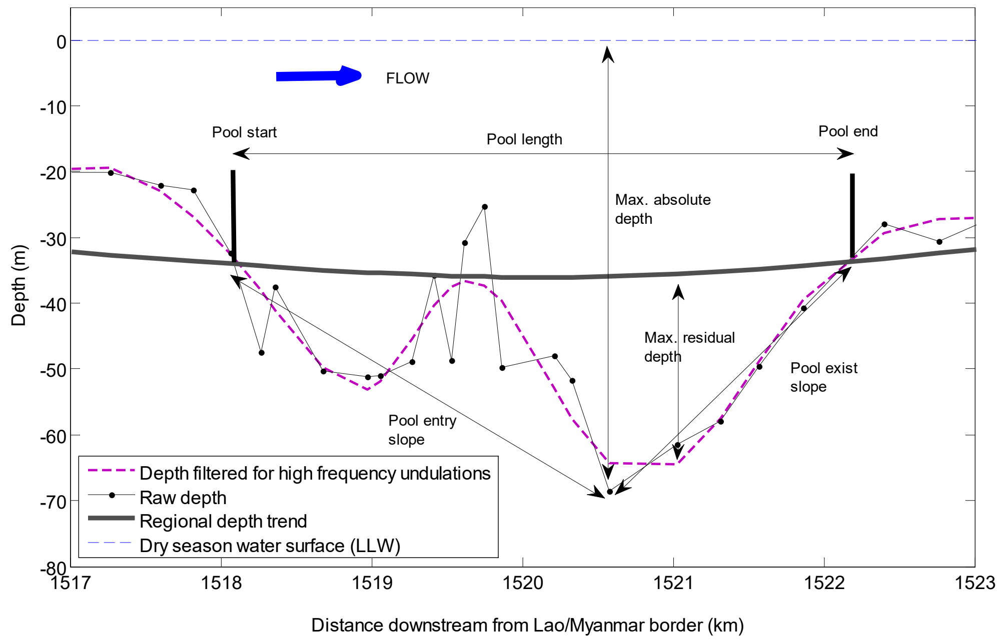

Figure 2.9: Identifying pools and crossings and estimating deep pool dimensions from the Mekong riverbed long-profile, using the zero-crossing method

(Source: Halls *et al.,* 2013)

Table 2.6: Descriptions of deep pool dimensions and morphological characteristics (from Figure 2.9)

Field name	Units	Descriptions
poolNo	-	Pool number - pools are numbered sequentially from upstream (Lao PDR/Myanmar border) to downstream (Cambodia/Vietnam border)
depth_abs	m below LLW*	Maximum absolute pool depth below the dry season water level (LLW). This point is defined as the pool centre
depth_res	m below LLW	Maximum residual depth below the regional trend in riverbed depths
depth_mean	m below LLW	Mean depth of each pool based on an interpolated bathymetric surface (TIN)
poolLeng	m	Pool length in the downstream direction
entSlp	m/m	Pool entry slope (slope between pool start and pool centre points)
extSlp	m/m	Pool exit slope (slope between pool centre and pool end points)
roughness	dimensionless	Roughness of the riverbed within each pool. Calculated as the mean absolute deviation (MAD statistic) of the high frequency component of the riverbed long profile (see text for explanation).
area	m^2	Pool area at the water surface during the dry season
volume	m^2	Pool volume below the dry season water level (LLW). Volume is derived from an interpolated surface of riverbed bathymetry (TIN) and the areal extent of each pool at the water surface.

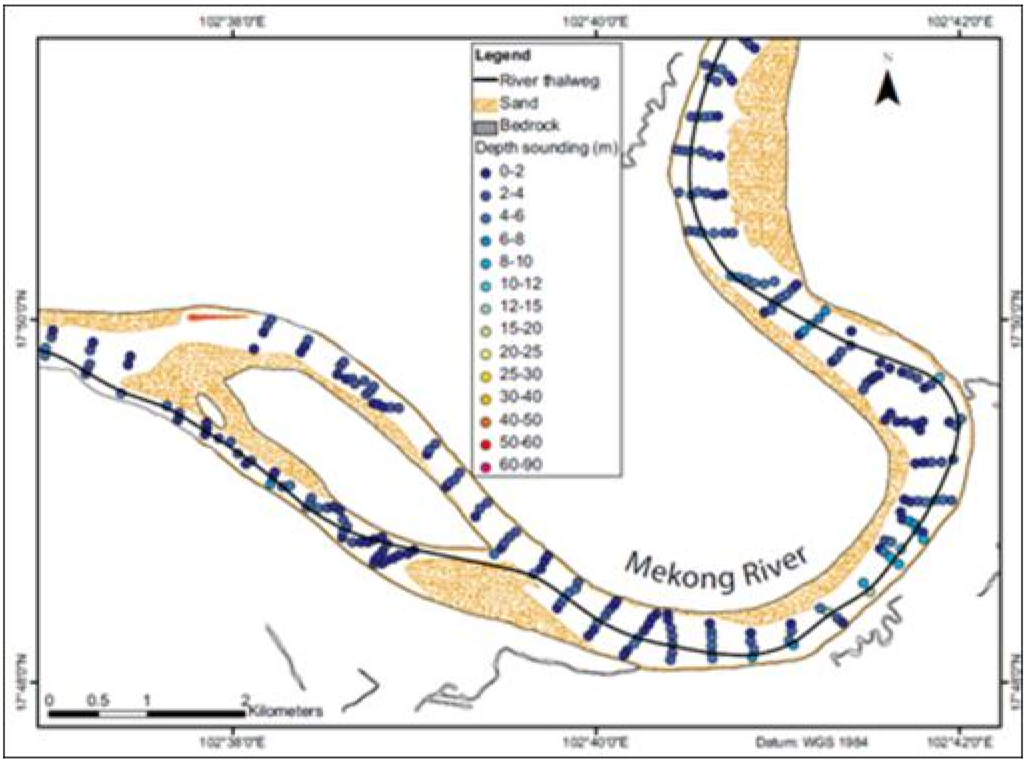

Figure 2.10: Example of a map from the Hydrographic Atlas of the Lower Mekong River (Source: MRC, 1996 in Halls *et al.*, 2013).

median pool length 1.6 km, (range 0.1 to 18.5 km). All the pool dimensions are heavily skewed towards low values, that is, shallow, short and small-volume pools are more common than deep, long and large-volume pools. Positively skewed data is common in nature, so the median is often considered more representative of the central tendency of highly skewed data.

The median surface area of the pools found along the Lower Mekong River was found to be 16.7 ha, but the range was large (0.726 to 729 ha). Similarly, the range of pool volumes was also large, at 0.029 to 122 million m^3. The median pool volume was 1.55 million m^3, which is equivalent to 620 Olympic-sized swimming pools. The roughness of the riverbed, as represented by the bed roughness index (BRI), ranged between zero (a perfectly smooth bed) and 17 m (a very rough bed) in bedrock pools, while the median BRI was 2.7 m. It should be noted that the BRI is most useful as a relative rather than absolute measure of riverbed roughness within pools. Pools identified along the Lower Mekong River can be classified into six major types (Figure 2.11). In alluvial reaches, pools are most commonly found at meander bends and next to side bars in straight sections of the channel. Pools are also found at confluence zones, downstream of large mid-channel islands, or at major tributary junctions. A small number of forced pools also exist at occasional lateral constrictions to the channel in alluvial reaches of the river. In bedrock and mixed bedrock-alluvial reaches, forced pools associated with channel obstructions and lateral constrictions were the most common type of pool. Forced pools can typically be found immediately downstream of constrictions in the outer channel, caused by a narrowing of the valley or constrictions to the inner channel due to local bedrock outcrops.

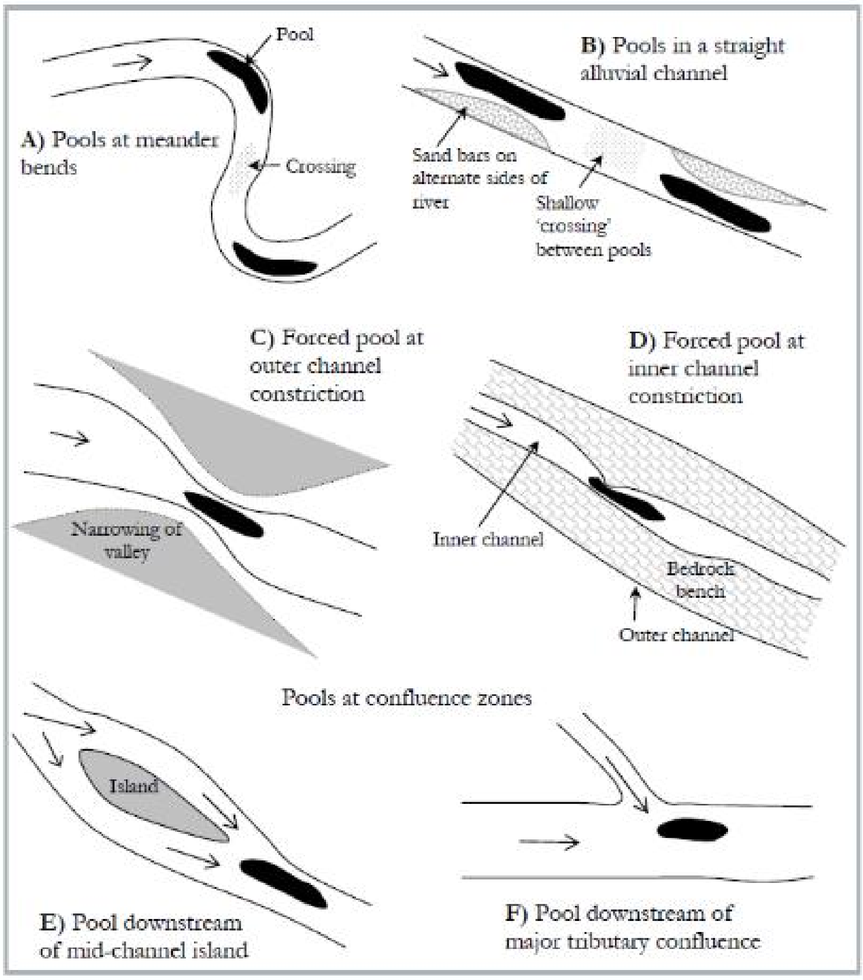

Figure 2.11: The main types of deep pool found along the Lower Mekong River
(Source: Halls *et al.,* 2013)

2.9 Fish Migration

Animal migration is the episodic movement of animals from place to place associated with variable resources utilization, in search of food, a suitable place to breed and an appropriate temperature condition. Many scientists agree that fish migrations are synchronized movements carried out by species at specific stages of their life cycle, and occur in a cyclical process and across a wide range of geographical areas.

Lucas *et al.* (2001) identified two main elements that may engage in freshwater fish migration behaviour. First, there are factors from the external or environmental conditions, and second, there is the internal status of fish behaviours

(Figure 2.12), those that stimulate fish to migrate. Individual fish may respond differently to the same stimulus (Colgan, 1993). The physical capacity of fish to migrate has been studied, finding that freshwater fish with wide strong bodies, that use energy metabolism strategies and oxygen transport, are able to enhance their swimming performance, such as the salmonids and *rheophilic* species.

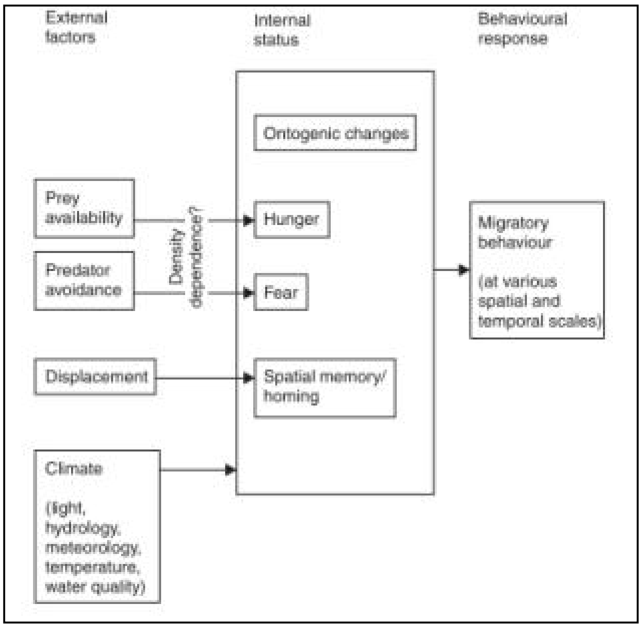

Figure 2.12: Flow diagram of the nature and influence of internal and external factors on migration

(Source: Lucas *et al*., 2001)

The migration of fish has customarily been thought to support movement between three functional habitats (Figure 2.13), these being *feeding*, *refuge*, and *reproductive (spawning)* habitats. Individual fish can minimize the reduction of their ontogeny and life cycles (Northcote, 1984) through migration. Some studies have found that feeding migrations of adult and sub-adult fish are related to the pattern of rainfall and seasonal inundation of floodplain habitats (Welcomme, 1979; 1985). However, terrestrial environments are often seen as the most important cause of hydrological fluctuations. Along with these aspects, *post-displacement movements, recolonisations*, and *exploratory fish migrations* tend to lead to the passive dispersal of fish in different directions. This situation is considered to be the most critical for fish, and can deliberately interrupt their life cycles (Detenbeck *et al*., 1992; Lucas *et* *al*., 2001). Some ecological studies have examined environmental parameters, such as moon phases or temperature, and also survival in terms of living conditions, food and predation, and their influence on fish migrations (Baker, 1978; in McKeown, 1984).

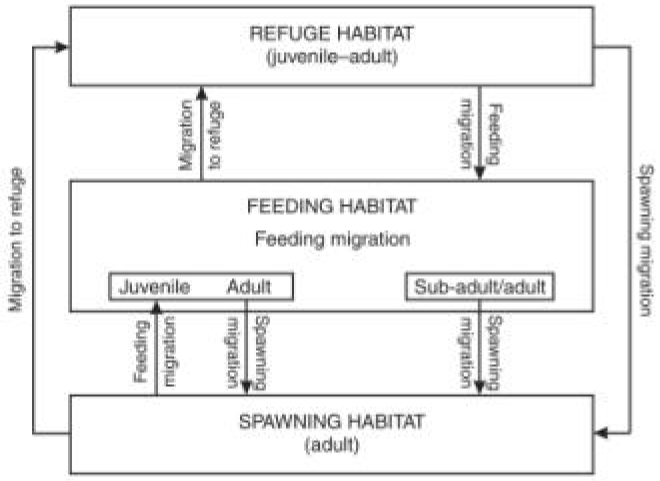

Figure 2.13: Schematic representation of migration, based on movements between the three functional habitats (Source: Lucas *et al*., 2001)

2.9.1 Fish migrations in the Mekong River

Fish are broadly classified by the Mekong fisheries they support, to provide a better understanding of fish migrations and fish reproduction activities. Fish in the Mekong can be divided into two groups: "black fish" and "white fish" (Welcomme, 1979; 1985), a classification system similar to that used in Bangladesh (Sao-Leang and Dom Saveun, 1955). Recently, a "grey-fish" category has been added, as a short-distance migration group (Chanh *et al*., 2001; Welcomme, 2001).

"Black fish" species are able to endure the de-oxygenated water conditions found in dry season floodplain water bodies, and may spend most of their lives in a single water-body such as a lake, or in a swamp adjacent to a river channel. They are generally defined as non-migratory, even though they normally migrate for short seasonal movements between permanent and seasonal water bodies, and flooded areas, during the monsoon season. Examples of black fish species in the Mekong include the

Climbing Perch (*Anabas testudineus*), the Clarias Catfish (*Clarias batrachus*) and the Striped Snakehead (*Channa striata*).

"White fish" species, meanwhile, mainly inhabit river channels, and longitudinally migrate up- and down-stream, as well as laterally to adjacent river tributaries and floodplains during the monsoon season, before returning to their river habitats at the end of the flood season or before the dry season starts. Examples of white fish species include some of the cyprinids, (*Cyclocheilichthysenoplos* and *Cirrhinus microlepis*), and members of the River Catfish family (*Pangasiidae*). Some species of white fish migrate due to water level changes (Baird *et al*., 2004; Baran *et al*., 2005), while other species migrate due to changes in lunar patterns (Baird *et al.*, 2004).

In addition, "grey fish" species are seen as sitting between the two other groups, the black- and white-fish, as they undertake only short journeys between floodplains and adjacent permanent and seasonal water bodies within the floodplain (Chanh *et al*., 2001; Welcomme, 2001).

The hydrological, ecological, and morphological characteristics of the Mekong River have been employed to class fish migratory systems, and for the purpose of trans-boundary management and basin development planning. Three migration systems have been classified: the lower, middle, and upper Mekong migration systems (Figure 2.14; Baran, 2006). These systems are naturally interconnected, and fish can migrate between them.

The ecosystem and hydrological regime play an important role in maintaining fish attributes within each migration system (Table 2.7). The influence of hydrological patterns creates migration behaviours and floodplain habitats, which are especially important. Furthermore, the key migration triggers for Mekong fish are water-level and water current, discharge levels, precipitation, the lunar cycle, water colour and turbidity, and the apparition of insects (Poulsen et al., 2002b).

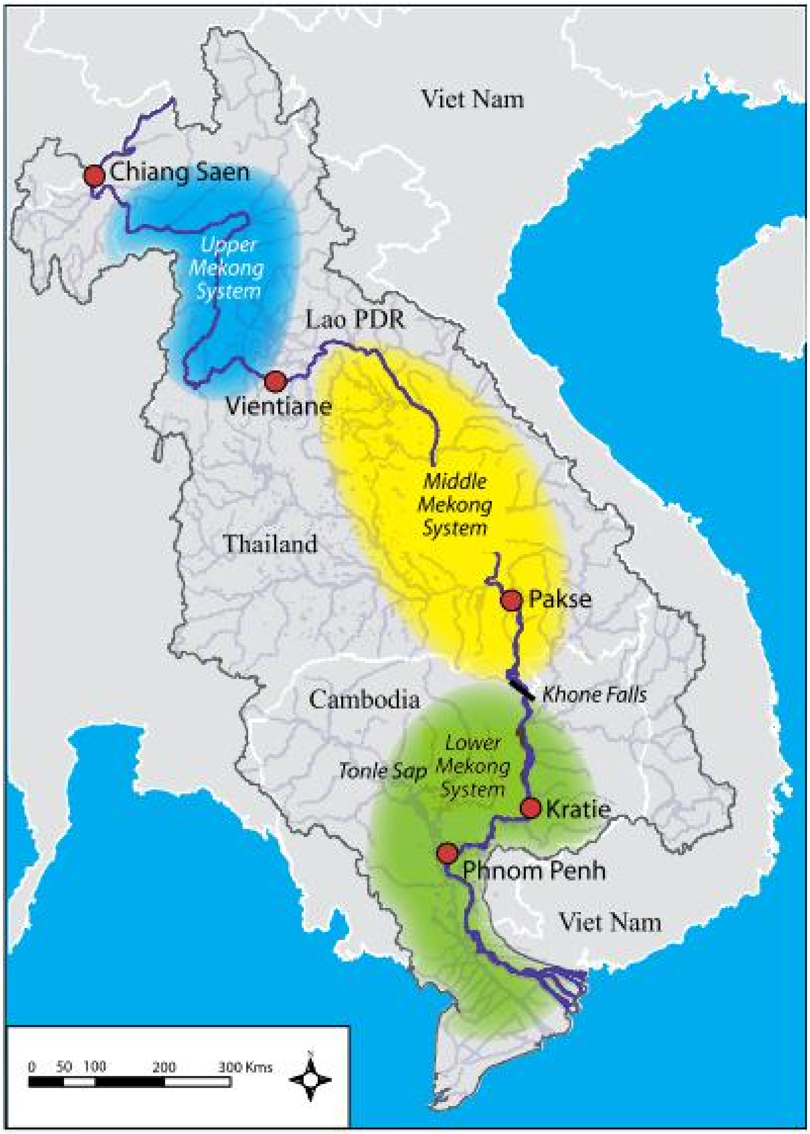

Figure 2.14: The three migration systems in the Lower Mekong Basin
(Source: Baran, 2006, 6)

Table 2.7: Ecological attributes of fish migration in the Lower Mekong Basin

System	The Lower Mekong	The Middle Mekong	The Upper Mekong
Dry season refuge habitats	Deep pools' stretch of the Mekong mainstream, particularly in the Kratie-Stung Treng reach	Deep pools' stretch of the Mekong mainstream and within major tributaries.	Occur throughout the extent of the system.
Flood-season feeding and rearing habitats	Floodplains in the Mekong Delta, in southern Cambodia, and in the Tonle Sap system.	Floodplains of this system; mainly associated with major tributaries.	Floodplains of this system; mainly associated with major tributaries.
Spawning habitats	Rapids and deep pool systems in the Kratie-Khone Falls reach, and in the Sesan River catchment. Floodplain habitats in the south (e.g. flooded forests associated with the Tonle Sap Great Lake)	Rapids and deep pool systems in the mainstream. Floodplain spawning habitats associated with tributaries.	Rapids alternate with deep pools.
Migration routes	The whole mainstream from the Mekong Delta to Khone Falls, and major tributaries; the Tonle Sap River; the Sesan, Sekong, and Srepok Rivers.	Connections between the mainstream (dry season habitats) and major tributaries (flood season habitats).	Migration corridors between downstream dry-season refuge habitats and upstream spawning habitats.
Hydrology	The annual flood pattern in the Tonle Sap system and in the Mekong Delta.	The annual flood pattern in the inundation of floodplain areas along major tributaries.	The annual flood pattern that triggers fish migrations and causes inundation of floodplains.

2.10 Conclusion

This chapter has reviewed a number of concepts pertinent to this research study, including GIS, local knowledge and epistemology in GIS, the PPGIS approach, an overview of political ecology, fisheries management on the Mekong River, an overview of the Mekong River, and deep pools and fish migrations in the Mekong River. The significance of the research can be found in two main aspects; filling a gap in knowledge and contributing to the goal of empowering marginalized communities through local decision-making processes. The research concepts are associated with the complex multi-disciplinary fields which cross traditional boundaries, involving a combination of two key fields - physical and human geography- through the use of GIScience for problem solving. The application of GIS should provide a better understanding of the relationship between deep pool geomorphology and both fish ecology and the livelihoods of *chaopramong*. The next chapter will describe the research methods used in detail, including the river and *chaopramong* surveys, with respect to the methodological framework of the PPGIS process.

CHAPTER 3

Start Fishing: Research design and methods

"What kind of amulets have you been wearing during your work?"

Question posed by a 65 year-old fisherman in *baan* [village] Na Waeng[1]

3.1 Overview

This chapter presents the research design and methods I employed to collect data about the Mekong River, the local fish catch and the study of *chaopramong* [fishermen]'s livelihoods in Na Waeng. It also explores the potential for eliciting local ecological knowledge (LEK) from *chaopramong* and for using Public Participation GIS (PPGIS) in fishing communities in order to facilitate fisheries management activities. The chapter includes some observations about the research background and my prior experience and interests, as these influenced the development of the study and the direction in which the project unfolded. My fieldwork also included some moments both of excitement and of self-reflection.

The approach I used reflected an attempt to address participatory fishery management issues in a systematic way, without having to overcome the barriers created by GIS technology, thereby allowing the fullest use of LEK. My research methods enabled me to utilize simple PPGIS practices such as sketch maps, mental maps and PPGIS workshops.

The following section will elaborate upon the river survey and *chaopramong* survey processes, and the PPGIS practices used, as well the other methods employed; for example, key informant interviews, GIS technology and the analysis of secondary data.

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[1]*baan* Na Waeng or Na Waeng village is one of five target villages, which is in Na Waeng- a sub-divisional administration of Khamarat, Ubon Ratchathani province, Thailand. In this research I will use the term *baan* Na Waeng to refer to Na Waeng village, to make it clearer when distinguishing between the specific village and the sub-divisional unit.

3.2 Research design

This research study is founded upon my long-standing relationship with the Mekong River Commission (MRC), where I previously worked as a GIS specialist and project coordinator for a number of projects, including one developing a deep pools atlas for the Mekong River. As a result of this work, I was fortunate to be directly involved in the gathering of information about deep pools, and during this process it became apparent that a number of questions about the nature and function of deep pools had still not been answered. By identifying deep pools from a geomorphic statistical analysis using a digital bathymetric map of the lower Mekong River and a zero-crossing method, the MRC was able to map the locations of more than 400 important deep pools in the Lower Mekong Basin (Halls *et al.*, 2013). The deepest deep pool (90.5 metres in depth), is located between Na Waeng in Ubon Ratchathani, Thailand (the study site) and Lakhonepheng in Salavan, Lao PDR. As a result, I became very interested in trying to take a more detailed look at the area. However, I am not a physical geographer by training, and the scope of the research would require me to take an holistic approach; linking a scientific understanding of deep pool dynamics with *chaopramong*'s livelihoods. In many ways, this was a task which would need to draw upon both human and physical geography traditions in equal measure to tackle a complex of this interdisciplinary research.

The overall conceptual framework of the methodological approach (Figure 3.1) used in this study was comprised of a number of key elements. These included a definition of the research questions and data collection activities, the integration of LEK into GIS through the use of the PPGIS approach, and spatial analysis. When this methodological framework was overlaid on to the different phases of the PPGIS process (shown on the right hand side of Figure 3.1), it provided a link to the different PPGIS activities outlined in Table 3.1.

There were four main organizational processes which had to be carried out when applying PPGIS to the study of fisheries management activities, these being: 1. a preparatory phase, 2. mapping the river's ecology and surveying the *chaopramong*'s livelihoods, 3. mapping the conservation zones, and 4. mapping the management plan. In addition, each phase had to describe the activities, actors, geographic information technology (GIT) tools, GIS procedures and expected outputs, as well as the participation tools used and the levels of participation.When this methodological framework was overlaid on to the different phases of the PPGIS process (shown on the right hand side of Figure 3.1), it provided a link to the different PPGIS activities outlined in Table 3.1.

Although the project was driven by curiosity and the research was neither commissioned nor sanctioned by any official body, I was fortunately invited to present my research outcomes to the local government by the officer of Ubon Ratchathani Fisheries Department. Thereafter, in addition to applying the PPGIS approach, local *chaopramong* were encouraged to participate in the planning and decision-making processes. With this in mind, the strategies applied in practice (the management plan mapping phase shown in Figure 3.1) will be left to the villagers [*chaobaan*] and local authorities to implement. This can be seen as using PPGIS to achieve its ultimate aim, as these two groups of people will be fully responsible for deciding whether or not to act on the fisheries management plan presented to them.

GIS technology plays an important role in the analysis employed in this study, but not the central role, which instead is occupied by PPGIS. The reason for this is that GIS practices often act to dis-empower local people, as was described in Section 2.4.1. GIS procedures have to be carried out by the researcher using ArcGIS 10.1 and its associated spatial tools, such as spatial analysis and 3D analysis. The workflow activities required for GIS components include database design, data compilation and map standardization, digital processing and spatial analysis, and then the visualization of maps for the subsequent decision-making process. The work for this study began by eliciting LEK from *chaopramong*, which they use their daily life, and this was then transferred into a GIS platform before being collated into a spatial fisheries database. As the goal of this study was to present a transparent approach, I involved local people in the GIS process, so they would also be able to see their LEK being put into practice in the scientific platform of GIS during the workshop. This seemed a more realistic approach than trying to have them use it on a daily basis. It is well known that accessibility to GIS data and software, as well as the technical knowhow needed to effectively operate the GIS itself, are in general troublesome barriers to the use of the technology (Harris and Weiner, 2002; Elwood, 2006a).

One research area where GIS was a far more appropriate tool to use than PPGIS was when investigating the characteristics of deep pools in riverbed rock channels, plus the associated analysis of the geomorphic processes involved. Satellite images were used in order to obtain an overview of the land cover, and to help provide a better understanding of the environmental context at the study site. The images used were Landsat 5-126-49 and Landsat 7-126-49 (November, 2011), which were downloaded from the image archives of the University of Maryland. Satellite images were also used from Google Maps 2011 during the PPGIS workshop held.

In addition to the digital data outlined above, a fish-finder, GPS, and other equipment was employed to survey the deep pool profiles and the fish biomass of each pool, in order to improve understanding of their physical and ecological functions. The data acquired in this way included the deep pools' locations, as well as their length, width, depth, substrate, temperature, water discharge patterns and fish biomass.

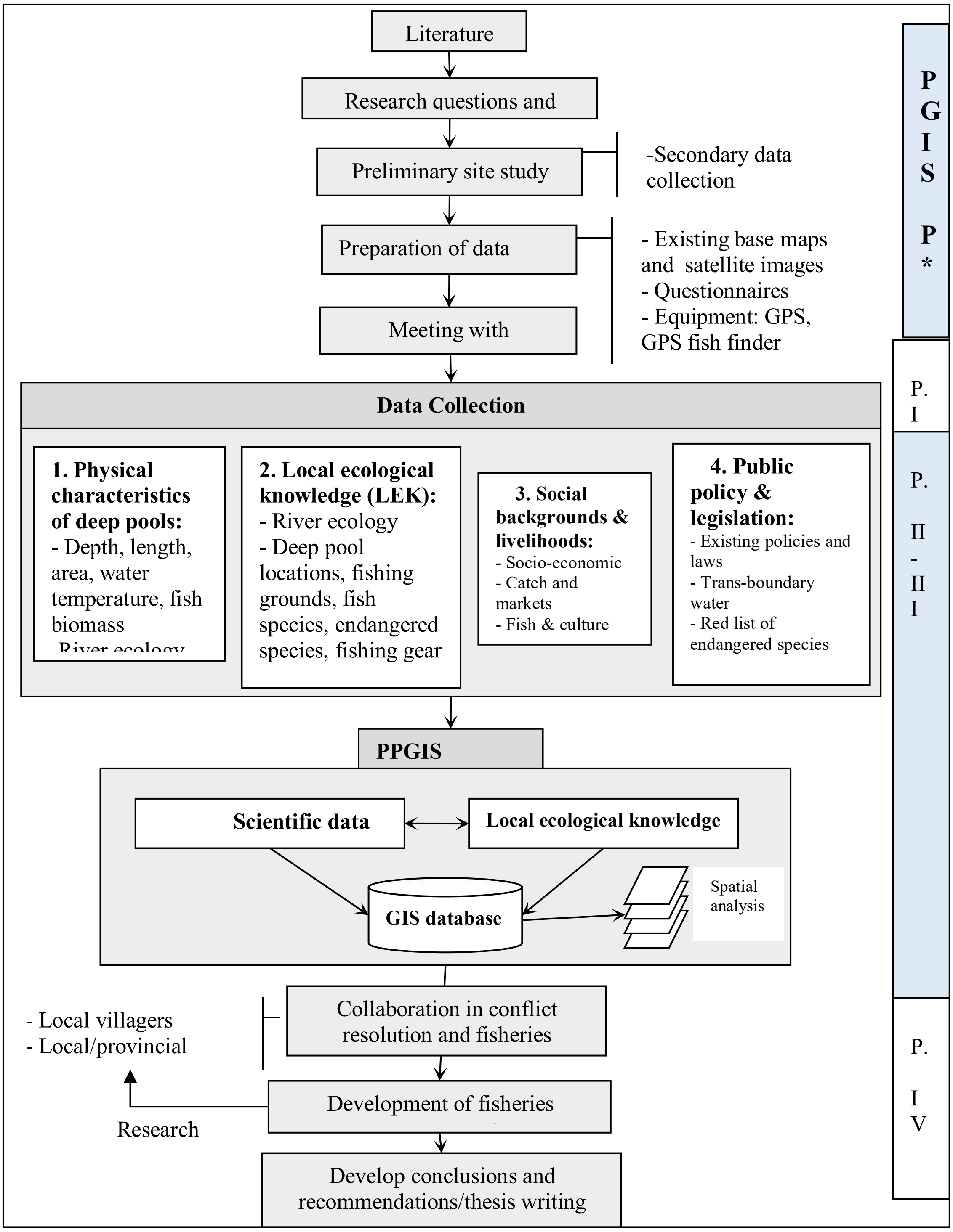


Figure 3.1: Conceptual framework of the methodological approach
Remark: PPGIS P* is the PPGIS process phases shown in Table 3.1.

Table 3.1: PPGIS processes used for fisheries management activities on the Mekong River at Na Waeng, Ubon Ratchathani province in Thailand

	Phases			
	I. Preparatory phase	**II. Mapping of the river's ecology and surveying fishermen's livelihoods**	**III. Conservation zone mapping**	**IV. Management plan development**
Activities involved	Stakeholder analysis; baseline survey; transparencies	Sketch mapping; deep pool and river ecology survey; LEK; structured interviews; catch monitoring	Boundary agreement demarcated on ground by actors	Agreement of participatory fisheries inventory
Actors	Local governors; village chiefs; fishermen	Village chiefs; fishermen	Local governors; village chiefs; fishermen	Local governors; village chiefs; fishermen
GIT tools	Topographic sheets; deep pool maps; transparency overlays	Topographic sheets; GIS base maps; Fish finder GPS	GIS maps; deep pool maps; socio-economic indicators; river ecology and fish species maps	GPS and compass for inventory; topographic sheets
GIS procedures	GIS database design	GIS data compilation	GIS data compilation and processing; spatial analysis	Map visualizations, fisheries GIS database
Outputs	Village study report, GIS database design	Deep pool and river ecology sketch maps; deep pool maps; river ecology maps, catch data	Fisheries management boundary map;(GIS) showing use in temporal zones	Map of management zones
Participation tools	PRA tools	Participatory mapping; ecological survey; structured interviews	Participatory mapping for management	Participatory inventory
Degree of participation	Consultation	Consultation; empowerment	Mediation; empowerment	Decision-making for zoning; some empowerment

Source: Adapted from McCall and Minang, 2005

The research study could be broken down into three phases, in line with the PPGIS processes shown in Table 3.1. These were: 1. a preparatory phase, 2. mapping of the river ecology and *chaopramong*'s livelihoods, and 3. conservation zone mapping. In addition, a ground survey was conducted at the proposed study site, to gain a better picture of the site's geology and environmental parameters, and a field site ground survey was also carried out using the satellite images. The following sections will explore the research approach and methods used, which included:

1. A preparatory phase: Engaging in the study as an outsider
2. Mapping of the river's ecology and surveying the *chaopramong*'s livelihoods: A river survey and a *chaopramong*'s survey
3. Conservation zone mapping: A PPGIS workshop was held with *chaopramong*, to facilitate the development of fisheries management activities.

3.3 Phase I: Preparatory phase:

3.3.1 Engaging in the study as an outsider

Before embarking on a description of the different research phases, it may be helpful to provide some contextual information about my positionality as the researcher, and the circumstances under which the project evolved. I am from Bangkok, but for the purposes of the research, myself and my family moved to Ubon Ratchathani, the largest city (population 225,000) and capital of the province of the same name, in order to have easy access to the study site, Na Waeng, which is roughly 115 kilometres from Ubon Ratchathani.

Over the previous eight years, during my employment with UNESCO, Bangkok office and the MRC Secretariat office in Laos, I undertook substantial amounts of fieldwork in the Mekong region. The work included ground truth checking of satellite image accuracy, collaborating with local villagers on the collection of water level data for flash flood monitoring in Chiang Rai, Thailand, and inventorying of the Plain of Jar sites in Xieng Khoung, Lao PDR. From these experiences, I learned to listen to local people or listen to villagers.

Also during my four years with UNESCO, I gained experienced with Unexploded Ordnance (UXO) and conducted some UXO mapping in Xieng Khoung, Laos. During the Indo-China War 1964-1973, it is estimated that over 30 percent of the bombs dropped over Laos (> 2.5 million tons) failed to detonate (http://www.state.gov, 2010). It is a sad fact that the noise of bombs exploding nowadays can mean local people (often children) in Xieng Khoung have been accidently injured by UXO. Their understanding and sense of place and location in the jungle and knowledge of safe walking paths avoiding UXO led me to develop a trust of local knowledge while exploring the Plain of Jars for sites.

The challenges of this work were not related to living in a remote area, without electricity, sanitation, limited water use during the dry season and UXO underground. Rather, it was extremely difficult for a Thai woman working with senior Lao men, as there are certain cultural constraints. First, there was an aspect of power relationships between Laos and Thai, with Thailand playing the role of bigger brother and Laos the younger brother in what is a somewhat love-hate relationship (see Evans, 2002; Creak, S., 2011). Second, there is a strong gender role in Laos for women, who are primarily responsible for household chores, so my position and personality was totally different from local social expectations. However, by showing a great respect for local people, the senior survey team members and Laos culture, I was able to cope with this difficulty. For example, a consultative working style was generally applied while we made a survey plan, and I wore conservative Laos skirts [*sin*] when we worked at the office or had meetings. In addition, while conducting field surveys I assisted my team members with their tasks even though I acted as a GIS technical advisor for the team. This experience trained me to be mindful and respectful of local people and their culture; hence the experience of working with local people is not too unusual for me and in turn added to the quality of village-based research in Thailand.

3.3.1.1 Preliminary work at the study site

"Researcher often questions her or his positionality and multiple identities as a visitor and researcher in a new geographic context." (Hawthorne *et al.,* 2015, 23)

The project feasibility study was carried out in February 2011 and I managed to obtain numerous good contacts for this research from my previous work with the MRC, which helped me to open the front gate to communities. "*Do you have any funding for your study*?" This question was asked by one focal *chaopramong* at the Ladcharoen village, whose name was suggested by a fisheries officer of Udon Thani. *Nong* (younger brother) K (pseudonym) used to collect fish catch monitoring for one project of MRC and the Udon Thani Fisheries Inland Fisheries Research and Development Centre. My answer to him was, "I am a PhD student at NUS, I am here to conduct research related to LEK, fish and deep pools", and this is how I introduced myself to local villagers as my positionality as an academic researcher. The conversation continued regarding the limited research funds a student is allotted, which cannot be compared to organizations such as the MRC or the governmental sector, followed by a number of discussions about the goals of the research project. It should be noted that I maintained this positionality as an academic researcher as my personal introduction to all five fishing communities, even though I did not have any existing personal contact in some villages.

Cloke *et al*. (2004, 193) suggested that in order to help bridging social gaps the researcher should remember to treat "*people as knowledgeable, situated agents from whom researchers can learn a great deal about how the world is seen, lived and works in and through real places, communities and people"*. An unexpected question raised by *Nong* K was: "*What does my village stand to gain from your research*? *There are many organizations come to interview us and collect data about catches* *and disappeared."* I had to confess that his question made me aware of my positionality in relation to the research objectives and in relation to the study villages. In addition, his question reflected local societal perceptions of me and my potential for destabilizing existing power relations, especially in collaborative fieldwork, as a researcher who does not wear any hats to represent any firm or organizations at all. Whilst I come from the same country, Na Waeng could often feel like a peculiar world away from the busy hustle of life in Bangkok. However, I am personally very passionate that my research is a knowledge creation, not just a product (England, 1994), but finding ways to enable reflexive interaction between myself and villagers was more challenging than during my previous work experience. I will elaborate how I overcame the social barriers in the next section.

By conducting a preliminary study of the sites, I was able to gather background information for the research, and had the chance to assess the feasibility of the study. However, the foremost achievement of these visits was that it allowed me to integrate into the fishing communities and give community members a chance to decide whether or not they trusted me.

Upon concluding a preliminary study of the sites and discussing my plans with *chaopramong*, I found that Na Waeng had not previously used a community-based fisheries management system, nor was anyone there familiar with the PPGIS approach. Furthermore, I found that over-fishing was occurring in some fishing communities in the area, such as the village Bong Khew in Khamarat district.

Another positive aspect in my selection of the study site was the possibility of collaborating with villagers, fellow researchers and the Thai Fisheries Department. There was also a strong likelihood that the Thai Fisheries Department and the Fisheries Department of Ubon Ratchathani University would collaborate at the site, due to its significance with regard to deep pools. The Fisheries Department at Ubon Ratchathani University supported my research project by offering me the use of its water monitoring instrument, as well as expertise regarding its use. In addition, they also offered to have fellow PhD scholars work on-site on integrated aspects of the project, on the condition that a formal collaboration be organized in the future.

3.3.1.2 From outsider to insider

As a dedicated academic researcher it is possible to devote the necessary time to developing an in-depth critical understanding of the LEK of fishermen and their livelihood on the Mekong River. The five target fishing villages in Na Waeng were selected by the *kamnan* [Na Waeng sub-district headman] and some of *phuyaibaan* [village chiefs], who understand the area of Na Waeng very well. All five villages are between 10 to 25 kilometres from the town of Khemarat. Na Waeng is the furthest village from the town, and perhaps more importantly, is not accustomed to visitors staying as it is not a tourist site. In addition to being in a remote area, there are not many shops at Na Waeng, or even basic health services. Thus all materials for conducting the river survey had to be obtained from Khemarat.

I stayed in Khemarat for about two months in February to March of 2012, preparing the river survey, conducting key informant interviews, setting up collaborations among the communities and local leaders. In addition, I had some shorter visits and followed up work until the PPGIS workshop was held in March of 2013. During the two months of field work, I was based in a little guesthouse in Khemarat and I travelled from Khemarat to the fishing communities on a regular basis to carry out data collection and collaborative research activities. The owner of the guesthouse, a local teacher, questioned why I was there and wanted a monthly rental contract. After she understood what I was planning to do, she very helpfully gave me a few teacher contacts in *baan* Na Waeng, and they then helped me gain greater trust in the village. It was an unexpected snowball effect of being in a small area where personal relationships still play a great role in gaining acceptance.

At the beginning of my research journey, I first started staying by myself in Khemarat town. I felt like an alien from another planet and villagers knew I did not come from there as well. The most startling issue I found during my PhD research was the fact that my own class cultural identity was being re-created. Whilst I worked for UNESCO or MRC, the organization was the gatekeeper that enhanced my power and relations when collaborating with other line agencies and villagers in ways that allowed me to gain access for field work and information. Contrariwise, during the experiences of my PhD research I constantly felt I was very insignificant in this little town and felt rather nervous during the field work. At the same time, I was perplexed by the scales of power tipping in my direction, such that my class identity somehow reversed itself through my PhD research. I was re-negotiating my positionality constantly as a Thai researcher and someone working from a higher education standpoint. This made me self-conscious of taking advantage of *chaopramong* who are designated as a disempowered people in Thailand (Vail, 2008) "*in asking for people's time for an interview without being able to offer much specific benefit in return*" (Scott *et al*., 2006, 32).

To overcome the social barrier between the researcher and villagers in the five target fishing villages in Na Waeng took a conscious effort to de-emphasize 'position' and to concentrate clearly on the research goals. Ethnographic methods recognize that the researcher is not a neutral, objective, recorder of events, an 'observer' in the field (Cloke *et al*., 2004).

Gaining access to the local fishing communities in Na Waeng, and in neighbouring communities in Laos, was also a challenge, as I was an 'outsider'. I made contact with key members of the sub-district administration office (TAO) in Na Waeng, and *phuyaibaan* in the study communities in both Thailand and Laos. I had already developed useful contacts at Ubon Ratchathani University, and these contacts were able to function as gatekeepers, enabling me to gain easier access to the communities. However, I still required formal permission to conduct my fieldwork, so a formal request was sent from the National University of Singapore and the Ubon Ratchathani University, and this paved the way for me to work with the local fishing communities in Na Waeng, as well as those in Laos. I also had the opportunity to meet some local governors, to whom I introduced my research in Na Waeng, including the Director of TAO, *kamnan* and the *phuyaibaan* of each of the study villages. Overall, this preliminary visit allowed me to forge relationships and develop a rapport with a number of local leaders at different levels, as well as *chaopramong* in the communities. The development of this network provided invaluable support and experience during my field work.

It became very important to me that I step out of this bubble of being an outsider. There were also some misunderstandings concerning my positionality, such as local *chaopramong* asking me when I was going to release fish into the Mekong River, which is a common practice of the Department of Fisheries in Thailand and I simply answered "I am a researcher, not a government officer". Eventually, my peculiar pronunciation of *Isan* (the northeast dialect of Thailand see Section 4.2 for more details) accent made villagers always questioned me about my ability to understand *Isan*, which is due to the fact that it is unusual for people from Bangkok. At the same time my peculiar *Isan* accent provided a good laugh for local villagers, especially since some letters in *Isan* will use an 'h' instead of an 'r' sound, which is not easy for me to pronounce correctly. An example of this is provided by the phrase 'riding a boat', which in *Isan* is 'khi heu' [ขี่เฮือ], while in central Thai it is 'nạ̀ng reụ̄x' [นั่งเรือ].

Furthermore, my five-year old son was with me occasionally while I visited villages and conducted river surveys. Sometimes, my son was riding his green bike with local kids while I conducted key informant interviews with local fishermen. Although at times it was difficult, as childcare errands ate into the research time, I recognised it was always easier to start a conversation with villagers when you were with children. This situation reminds me of when my son was a baby and I easily made friends with strangers while holding or towing him along on work assignments. There were many times that we had lunch with villagers and their kids and then they could continue playing. Even though the lunch was simple sticky rice, fried omelette and a little bowl of spicy sauce [*jaew*], it enabled those in the village a chance to get better acquainted with us and build trust. When I arrived in the villages without my son, villagers always asked about him. I presumed that with a children-centred culture in *Isan*, and in general in the Mekong region, people feel at ease when you are with kids. Unexpectedly, at the initial stage of research my son gave me a way to bridge the gap between being an outsider and insider and allowed me to further foster relationships and established trust between the villagers and myself. Occasionally, the hospitality extended to me by villagers was well beyond my expectations. For example, when working until very late in the evening, the villagers did not want me to drive back into town by myself. In another example, a fisherman in Na Waeng offered to teach me how to cast a cast net into the Mekong River; the most challenging part of which was standing on the tiny wooden boat while casting. It was a special memory, and again, showed those with whom I was working that I was interested in them and wanted to understand what they had to teach.

Chaopramong in Na Waeng became accustomed to my presence, and felt comfortable going about their daily activities while I was around. This was especially so after the firing of warning shots by Laos soldiers that occurred during the river survey. After that incident (see details in next section), the *chaopramong* were interested in speaking with me. They often started their conversations with me by discussing that event and, moreover, they felt comfortable to talk and were more willing to share their life and experiences in general. As a result, these relationships gave me a better understanding of local culture and lifestyles, as well as providing common ground for me to develop a broader conceptual framework for the research.

Many studies have argued that researchers can concurrently be to some extent an insider, and to some extent an outsider, if involved in qualitative research of this kind (Labaree, 2002). In the case of my research, I was an insider to the extent that *chaopramong* were sufficiently comfortable with my presence that we were indeed able to talk in general about news, schools and making jokes. To some extent, they gave me security, warning me not to go out by myself at night or walk along the Mekong River during night time. When I was in Khamarat for my field survey, many cases were reported of villagers and kids having been accidently shot at night while frog hunting along the Mekong River on the Thai side by a local border police patrol who were looking for smugglers. On the other hand, I was an outsider when it came to any potentially contentious internal community issues, such as goods and drug trafficking, and human trafficking and we avoided talking about these issues in depth. These local community issues might explain some unexpected circumstances during my field survey, in particular that my car was stopped a few times by Thai custom's officers who were wary of my presence in the communities.

The outcome and form of the interactions can depend upon the researcher's personality, emotions, gender, ethnicity, social class, professional position and interviewing skills (Labaree, 2002). This infers that the personal qualities and theoretical points of departure of the researcher can influence the outcome of the research.

As elaborated earlier, my previous work experience has been largely concerned with villagers, to listen to villagers and be reflexive about villagers, which means striving to be both ethically sound and politically empowering in relation with (less privileged) peoples and places under study (Labaree, 2002). The approach of this research is grounded in the concept of promoting the LEK of fishermen by using a PPGIS approach in collaborative research between insiders and outsider. Even though GIS is not a neutral tool, and the use of GIS is not without its problems (e.g. Pickles, 1995; Curry, 1998; Crampton, 2001; Elwood, 2006a), a PPGIS approach can be beneficial as a means of merging LEK and outside expert's knowledge and information. Similarly, such studies often focus on maps completed by individuals or local groups with more experience in an area, rather than maps from the perspective of a newly immersed researcher or research team (Boschmann and Cubbon, 2014, 238; Hawthorne *et al.,* 2015). These issues may go some way towards overcoming "subjective and objective" components of the research position and are meaningful in the context of this research and my engagements with it.

Undertaking this research has involved a lot of responsibility in terms of consciousness surrounding my presentation, position and ultimately my influence on the research participants or *chaopramong* in the research process. A key issue is that the results of a qualitative study will be seen through the researcher's eyes and interpretations. By explaining the approach I have taken and the reflections and considerations during my research journey, the credibility of the research data has been increased to ensure that the conclusions drawn by the researcher are valid and supported by empirical research evidence.

3.4 Phase II: Mapping the river's ecology and surveying the *chaopramong*'s livelihoods

3.4.1 The river survey

The Mekong River is one of the most challenging tropical freshwater environments in which to work, due to its physiology and geopolitical nature. First of all, the river is generally very turbid as a result of the suspended sediment originating upstream and turbidity varies considerably between the dry and rainy seasons. This means water visibility is very poor, and added to this, the water velocity is high. Most *chaopramong* are aware of the river's powerful nature, and so have a deep respect for it, not only its physical aspects, but also its spiritual nature, and there are many superstitions surrounding it. Some of these superstitions (e.g. Naga legend, *Chao Pho* [guardian spirit] Xe Namnoi are described further in Section 4.5.5.

Geopolitically, the transparency of the nation state border formed by the river also impacts upon local customs and experiences. *Chaopramong* are conscious of the possibility of conflicts arising, and those I spoke to hinted at the night-time security issues and various border conflicts that occurred. At night, local villagers generally do not go out fishing on the river, or hunt alongside it, due to border security issues. In the worst case, people have been killed; shot-at or given warning shots when fishing too close to the other side. It should be noted that there is no physical border barrier between Laos and Thailand in this area, and people have traditionally had full access to the river for their livelihoods, as well as for trade.

"I heard loud noises four times one morning; they came from Lao soldiers' rifles."

Author, 2012

During my water survey, I received support from the Fisheries Department in Bangkok, who provided me with an echo-sounder. The Fisheries Department also offered me expert support on how to use the instrument and gave me use of their boat, while the cost of the field survey, approximately 1,000 USD, was borne by the researcher. Once this help had been organized, the survey team, which consisted of three fisheries officers, transported their boat by truck from Bangkok to Khamarat. The boat was a simple fibreglass model with attached canopy and had 'Fisheries department' in tiny lettering in Thai on one side of the boat. The boat size was very compact, approximately 1.5 metres wide and 6 metres long. Initially, while we were discussing the survey plan, I made several attempts to convince the survey team from the Fisheries Department to install their equipment on a local boat instead of using their own boat. However, they insisted on working from their own boat due to the survey being relatively simple and their desire to get started right away.

Once this help had been organized, I informed local villagers and the Thai marine police ahead of the survey. On the first day of the water survey at Phomueng village, while testing and trialling both the instrument and getting accustomed to the river, an incident occurred. I was sitting in the middle, carrying maps and handheld GPS while the person at the front was working on the eco-sounder and the person at the back was the driver. When our boat was approximately five to eight meters from the Lao shore, having been carried there by the water current and rapids, a group of soldiers suddenly appeared, lowered their rifles and fired four shots across our bow. We therefore had to stop our exploration of the deep pools and made a rapid retreat to safer waters. I had had experience working in Laos for almost seven years, with some parts of my work taking place in remote areas that required local soldiers to provide security detail. This made it all the more unbelievable that the soldiers would open fire from the river bank. After that, I made a report to the Thai marine police and the Khamarat Border Patrol police regarding this unexpected circumstance.

I was requested by the Thai marine police to discontinue the survey until the issue could be resolved. Therefore, the field survey had to be put on hold until there was clarification between the Laos and Thai communities. It was later stated that the misunderstanding arose because the Laos communities were unfamiliar with the boat. It is true that the Fisheries Department vessel was not flying a Thai flag, though it looked very different to the normal, small wooden fishing boats used in the area by local people. The survey team from the Fisheries Department returned to Bangkok the next morning. The survey had to come up with a backup plan to continue my work to deploy the survey equipment.

A snowballing technique was used to ask villagers at *baan* Na Waeng, Phomueng and Bungkeylek to give referrals to Laos *chaopramong* in order to continue the river survey in the latter two areas. *Chaopramong* at Phomueng suggested that I meet an immigrant registration patrol officer at Phomueng checkpoint. He was a well-known and trusted person in both Laos and Thai communities in Phomueng. He knew of the "shots across the bow" situation and his collaboration with Laos villagers assisted me in continuing the river survey in the conflicted area.

3.4.1.1 Investigation of the characteristics of deep pools and their relationship to fish habitats

A Fish-Finder GPS system was employed to continue the river survey, with the support of Professor Alan Ziegler from the Department of Geography, National University of Singapore and one of his PhD students, Nick Jachowski. This instrument can be deployed on any local fishing boat, and I will elaborate upon its use in the next section. This instrument is essential if one wants to gather information on river morphology and the spatial variability of fish densities. The river survey was then conducted during the dry season, in March 2012, around each of the study's five fishing communities and with the participation of local *chaopramong* and their boats.

To improve my understanding of the physical and ecological functions of deep pools, the river survey was conducted in two parts. First, it investigated the characteristics of deep pools along the river bedrock channels and their relationship with fish habitats (Figure 3.2). The areas covered by this part of the survey included the deep pools' locations, as well as the riverbed characteristics, river depths, fish biomass and ecological variables. Second, plankton densities and other riverine ecological variables were investigated (Figure 3.3), as these factors can determine the distribution of fish habitats. The following materials, tools and instruments were employed during this part of the research:

- A Humminbird 998c SI Fish-Finder and External GPS Combo
- A Handheld YSI 556 Multi-parameter Water Quality Meter
- A Handheld YSI 60 pH

- 2020we Portable Turbidity Meters
- Plankton nets: 20 and 60 micrometre mesh net for collecting zooplankton and phytoplankton, respectively.
- A water-collection bottle (Ruttner bottle)
- A handheld Global Positioning System (GPS) instrument
- GIS data and base maps
- Satellite images: Landsat 5 and 7 path 126 row 49

During the first part of the river survey, I designed a wooden u-shaped bracket to attach to the bow of a *chaopramong*'s boat. On one side of this bracket was attached the fish-finder's transducer, and on the other side was attached a water sensor (Figure 3.2). All the instruments were calibrated prior to the survey, to ensure they functioned properly and were ready for use in the field. Due to the constraints placed on the study activities by the border location and due to time, the survey could not be conducted safely at all points along the 30 kilometre stretch of river between the various sites. As a result, the survey had to be conducted separately using different boats from each village, to allow safe and effective surveys to be carried out. Therefore, the design of the bracket used allowed for simple transport between each village and for easy installation on each boat. The fish-finder's transducer and water sensor were placed just below the surface of the water, providing greater coverage of the water column in shallow areas. Initially, the survey route was designed as a zigzag along the river, to cover the rough pattern of the deep pools and gain a better understanding of the river bed. However, the zigzag path could only be conducted in villages where there were no border disputes, as this method necessitated sailing close to both riverbanks in order to obtain accurate results. As a consequence there was only one location in which a zigzag pattern was used – at Ladcharoen village, where the deepest pool was located. At the other four villages, the survey could only be conducted along the part of the river where deep pools were located, so a full cross-sectional survey could not be carried out. During the survey, real-time data were recorded every 30 seconds (the survey covered 986 data points in total) by manually pressing the 'save' button on the fish-finder and saving the file in a .png file format. Screen shots were saved on a secure digital (SD) memory card (Figure 3.3), and were later downloaded to computers. At the same time, the handheld GPS was used at 45 locations on the river, and water-related data were captured at these points using the YSI 556, which included water temperature, pH, and dissolved oxygen (DO) levels. In addition, the 2020we Portable Turbidity Meter was used to collect water samples for an examination of turbidity levels.

3.4.1.2 Application of the Humminbird Fish-Finder

Generally, the Humminbird® fish-finder is employed by sports and commercial *chaopramong*, due to its cost ($100-3,000 USD), and the ease with which it can be operated and the information it displays. Interestingly, due to its capabilities and compact size, it is often used to detect river bed characteristics and collect data on aquatic habitats - both freshwater and saltwater, in the natural resources management field (Kolding, 2002; Stundl *et al*., 2008; Nelson *et al*., 2010).

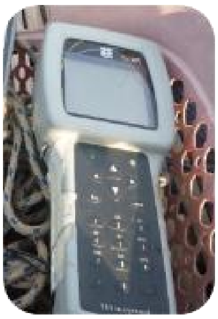
The specification of the Humminbird 998c SI Fish-Finder and External GPS Combo has three major components: a transducer, processing and display unit, and a power source (www.fishfinder-store.com, 2014). The 50-channel GPS offers high speed tracking and the memory can store up to 3,000 waypoints. The transducer provides information to the processing and display unit using high frequency ultrasound, and receives the echo which can reach depths of up to 1,500 meters using a sonar dual beam 200 kHz/20°@-10db.

River survey being conducted

A deep pool, 61.3 m. in depth

Equipment installed on a wooden u-shaped bracket

Fish-finder, map and handheld GPS instrument



Handheld YSI 556 instrument

Water sample measurement using a portable turbidity meter

Figure 3.2: River survey and equipment used

(Source: Author, 2012)

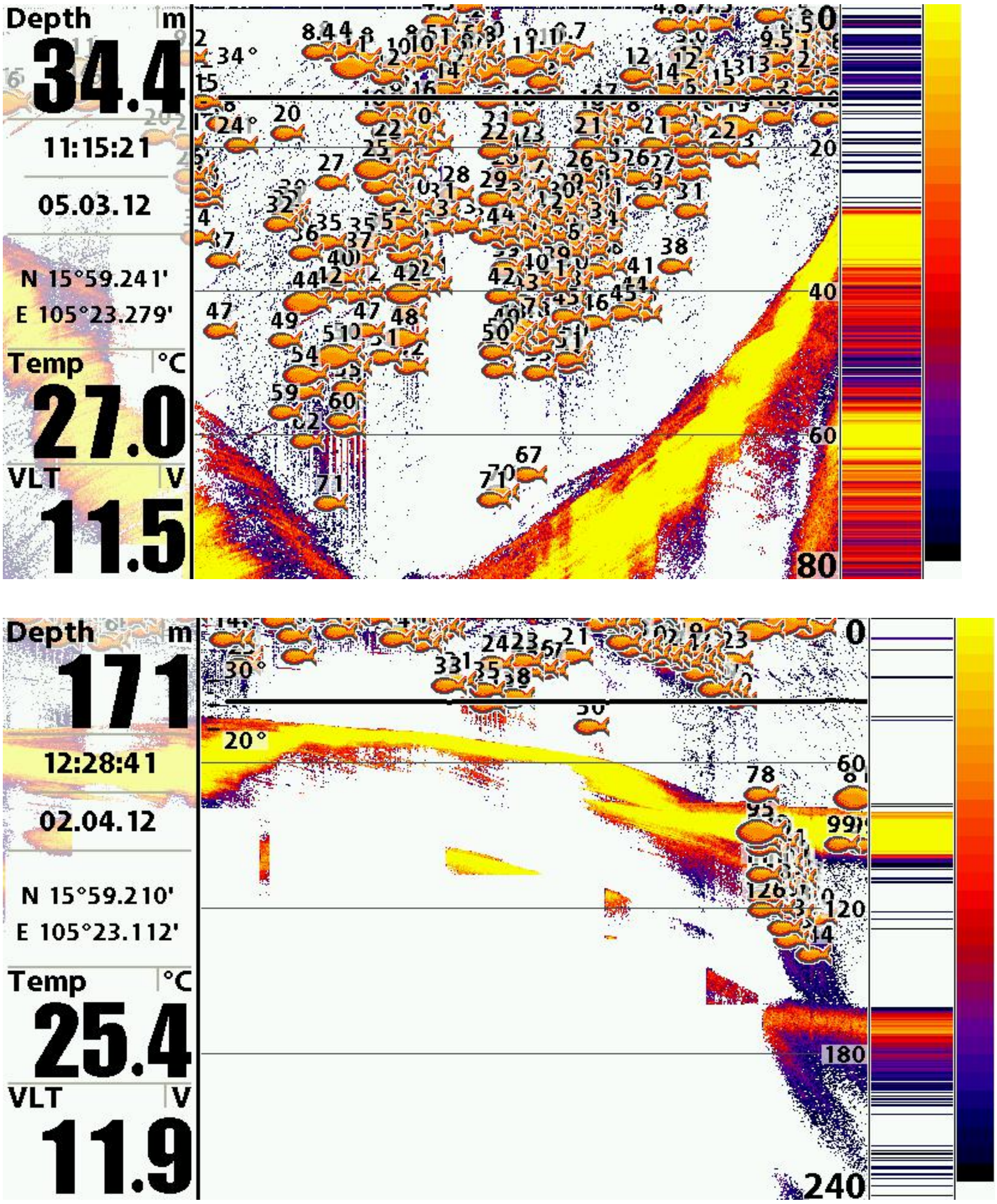


Figure 3.3: Screen shot from the Fish-Finder, containing: (i) on the left, data on locations, times, depth below the transducer, and water temperature, and (ii) on the right, river bed characteristics, size of the fish identified and their depth.

(Source: Author, March 2012)

The echo delay and modifications to the returned sound are displayed on a monitor, which contains data on the following (see Figure 3.3):

- Location and time
- Depth below the transducer
- River bed characteristics
- Size and features of underwater structures: objects, vegetation etc., and
- The number and relative size of fish in the scanned area. The size of the fish can be calculated based on a signal which varies according to the size of the fish's swim bladder.

Based on the availability of equipment and the support of the Geography Department, the Humminbird 998 csi Fish-Finder and External GPS Combo were used for the river survey. Some studies have employed the Humminbird Fish-Finder using side-scan sonar technology, notably to help with manatee conservation in the dark, tannin-stained freshwater systems of Tabasco, Mexico (Gonzalez-Socoloske and Olivera-Gomez, 2012). In their study, it was found that over 80% of manatees could be detected using sonar, with most found to be resting in depressions or pools. The advantage this study offered is that manatees are very large; 480 to 1400 kg in weight, and so were easily identified.

Hydro-acoustic survey, which works on the same principles as a Fish-Finder sonar technology, was employed to gather information in the Siphandone area of Southern Laos during 2003 (Kolding *et al*., 2002). The study showed that deep pools in the Mekong River appear to be well-suited to hydro-acoustic monitoring during the dry season in conditions of laminar flow. Additionally, the study found that LEK of *chaopramong* can be a valuable part of the information puzzle. Another fish-finder technology was also used by the MRC to gather information regarding the morphological, geometrical and ecological characteristics of 30 deep pools along the Mekong River during the dry season in March 2008 and 2009 (Halls, 2012). The technology was used by the MRC to provide a better understanding of river ecology and to capture data efficiently. The results showed a high fish density under the water. If attached to a GPS instrument, the technology can record data which can be further processed in GIS, as described in the next section. On the other hand, the number of Mekong River fish species has been estimated to be greater than 1,300, and includes fish species that anglers and scientists may seldom encounter. However, despite the limitations of the technology in terms of identifying fish species, using local ecological knowledge, as provided by the *chaopramong*, and a catch monitoring logbook, I was able to identify fish species making use of deep pools on the Mekong River (Bao *et al.,* 2001).

3.4.1.3 Plankton density characteristics and the river's ecological parameters

The second part of the river survey planned to explore the river's ecological parameters, information which would help determine the relationship between fish density and the ecology of the river (Figure 3.4). The water monitoring instrument used was provided by the Fisheries Department at Ubon Ratchathani University, who also provided expertise regarding how to use the instrument. A handheld GPS was also used at the nine sampling locations, which are near to deep pools in the study area. At each site, water temperature, pH, dissolved oxygen (DO) and turbidity levels were measured using a handheld YSI 556 at approximately 10 centimetres depth from the water surface. Salinity was then determined through the use of a YSI 60. Water samples were collected using a Ruttner bottle at five meter depth along the river, and the samples were analysed for their alkalinity and ammonia-nitrogen content by the Analysis and Testing Laboratory at the Faculty of Science, Ubon Ratchathani University, Thailand[2].

[2] Applying the standard: National Environmental Board No. 8 (1994), issued under the Enhancement and Conservation of National Environmental Quality Standards Act 1992 re: water quality in surface water. Published in the Government Gazette, Volume 111 Part 16, dated February 24, 1994.

Handheld YSI 60 and 556

Testing measuring water

Collecting water samples

Bottles of water samples

Collecting water samples using a plankton net

A plankton net

Figure 3.4: Plankton density and water quality survey/equipment

(Source: Author, 2012)

The surface water used to examine plankton densities was collected using plankton nets – 20 and 62 micrometre mesh nets used specifically for collecting zooplankton and phytoplankton, respectively (Edmondson and Vinberg, 1971). The samples were collected in front of the boat's motor in order to avoid fuel contamination on the water's surface, at nine locations. The water samples were then stored prior to analysis at the Analysis and Testing Laboratory of the Fisheries Department in Bangkok, Thailand. The zooplankton samples were preserved in 4% formalin while the phytoplankton samples were preserved in Lugol's solution then placed in a cooler before being taken to the laboratory for analysis in Bangkok. The samples were analysed under an inverted microscope, with species identified using keys developed by Durand and Levêque (1980), Canter-Lund and Lund (1995), and Fernando (2002).

3.4.2 Survey of chaopramong

One very well-known method used in social science is the qualitative survey or participant survey in an actual field or a study area, within which "our concept of the *messiness* of the field attempts to situate the complicities, complexities, and ambiguities of relationships and interventions, anachronistic standards of positivistic empiricism are brought to bear upon it" [emphasis added] (Breglia, 2009, 140). Theory needs to be derived from the ground up, hence allowing social phenomena to be revealed through intensive fieldwork, which is more important than testing particular hypotheses or applying abstract theory (Eyles, 1988; Atkinson and Hammersley, 1994). Along those lines, I employed a mixed methods approach, thus allowing me to tackle research questions from different angles, and thereby constructing base knowledge claims on pragmatic ground (Creswell, 2003, 20).

In this study, I engaged with and collected diverse types of data to provide a better understanding of the LEK of *chaopramong* and their livelihoods in five fishing communities. These can be divided into three main methods. First, key informant interviews were conducted to gain a better understanding of *chaopramong*'s livelihoods and to help promote their use of LEK with regard to fisheries management. Two different kinds of interviews were carried out in parallel: structured (individual) interviews, and focus group interview using sketch maps to elicit *chaopramong*'s LEK of the river, which is one of the PPGIS tools. Second, I used field observations and field notes to gain a better understanding of the fishing communities in general. Last, I documented fish species by monitoring catch information for one month during the dry season. All of these three components were separate activities; and thus did not have to be undertaken at the same time.

3.4.2.1 Key informant interviews

(1) Key informant selection: was conducted with the collaboration of the local leaders- *kamnan* of Na Waeng and the *phuyaibaan* of the five villages at each village's main meeting location. This collaboration with local leaders facilitated the identification of key informants, and without their help the key informant interviews session might have taken longer. Before embarking on the interviews, I informed local leaders about the interview components: structured (individual) interviews, and focus group interview using sketch maps. Two different kinds of interviews were carried out in parallel with assistant of local research assistants (local villagers) and they would take approximately 2-3 hours per village to complete per village, as described in the next section.

A consent form would be used that described key informants' qualifications for the research. Those included *chaopramong* with more than 10 years of fishing experience along the Mekong River who were still living in their communities. This approach was used for all key informants, and then the research could recover the background information gathered from a structured (individual) interview and assess how it related to their LEK of the Mekong River.

Perhaps more importantly, local leaders raised a number of questions regarding the consent form. They were unfamiliar with it and uncomfortable with signing such a formal agreement, even though the significance of the form was explained to them; that it was part of the research process and that confidentiality ethics had to be followed by the university. Generally speaking, they felt more comfortable speaking and interacting informally; therefore, I tried to keep the participant consent process as simple and informal as possible, and so used a verbal, informed consent process.

A certain potential number of key informants per village were discussed with local leaders, and there would be approximately 8-10 key informants per village who were experienced working or retired *chaopramong*. Notably, the population statistics from the TAO office (2013) in Na Waeng, reported that there were 30 *chaopramong* households in three villages- Phomueng, Bungkhylek and *baan* Na Waeng- while Ladcharoen had 40 and Boungmung none. However, the number of *chaopramong* households provided by the TAO office revealed completely homogenous information, which raised the question of data reliability.

During the fieldwork, I developed a trust and a collaboration network with all five *phuyaibaan*. I often visited *phuyaibaan* at their house and brought some fruit and snacks to share with their families, and played with their grandchildren. My son was sometimes there during my visits and his presence, playing with the other kids, had a positive influence. The *phuyaibaan* were very helpful and supportive of my research. We discussed the key informant interview session, and they promised to spread news of it among the *chaopramong*. In addition, refreshments were prepared for key informants during the interview session and they were shared with villagers who were around the venues. *Phuyaibaan* suggested that I cover some transportation costs for key informants, as well as compensating them for the few hours that they spent attending the interview sessions, which involved a half day off from farming or fishing. The key informants were paid in cash the equivalent of a half day's pay at the minimum wage level at the end of the interview, hence I prepared 100 Bath (3USD) in envelopes and asked *phuyaibaan* or my research assistants to hand them over. This was done in an attempt to avoid the issue of power differentials between the researcher and the researched. All the key informants were told at the beginning of the interview session that they would receive payment to cover their transportation costs and time off work resulting from their involvement in the research.

It should be noted all key informants were selected using a snowballing technique and then recruited based on their availability. None of them refused payment or expressed dissatisfaction with the amount given and all expressed pleasure. In some villages, if *phuyaibaan* came to join and/or observed the interview session, I also offered *phuyaibaan* a payment. I considered the issues raised by making payments to participants with reference to the social research ethical guidelines; however, in my research the interview sessions per village was longer than regular interviews, which take only 20-30 minutes per interview period. For my interviews I took key informants for almost half a day, which therefore meant it was both sensible and fair to compensate them for their time and/or income that they had lost. For example, some key informants worked at the pier piloting long-tail boats across the border and when they did not have customers they went fishing nearby. Though not full-time fishermen, some were still interviewed in the capacity as part-time *chaopramong*.

There is an issue of paying or not paying participants to encourage participation in research. Some studies in which participants were unpaid have been characterised as ethically unsound research (Thompson, 1996). On the other hand, Thompson (1996, 3) claimed that making payments can be a way of 'beginning to equalise' the uneven power relationships that exist between interviewer and interviewee, while Goodman *et al*. (2004, 821) argued that "…*it seems obvious that* *they [research participants] should be compensated for their time, especially since the researchers themselves are likely compensated through salaries or other external rewards*". It appears that the use of payments in qualitative research is becoming common in order to compensate participants for their time and energy, and for making themselves available to researchers (Willmott, 1973; Rowlingson and McKay, 1998, Singer and Kulka, 2002). In my research, the payment was in gratitude for the time that they lost and for their daily food and income, without trying to exercise the researcher's power over key informants at all.

Key informants were chosen based on qualifications or attributes most relevant to the research questions (stratified sample, see de Vaus, 1991 cited in Cloke *et al*., 2004, 145), and the term *availability or convenience sample* implies that the participants are selected due to their availability for the researcher [emphasis added] (Thagaard, 2003). In this research, the selected key informants were volunteer participants who have/had at least ten years' experience as *chaopramong* along the Mekong River and also were able to provide a better account of the ecology of deep pools, fish, and the river.

After *phuyaibaan* and I had agreed on the venue, date and time of an interview session, I contacted and reminded the *phuyaibaan* of each village one day in advance and asked him to spread news among *chaopramong* regarding interview session. The methods that *phuyaibaan* used to spread news were quite varied: e.g. using village speaker, telephone, and face-to-face communication. Additionally, I put a sign up about the interview session at the venue and village piers. I put the signs around village piers because that is where most villagers and *chaopramong* gather during the day, which thus allowed me to provide information to *chaopramong* directly. It is noteworthy that snowballing was used for recommendations through villagers in order to gather *chaopramong's* names and contact details. Generally, villagers and *chaopramong* showed a strong interest in talking to me and telling me names of experienced *chaopramong*, and many names were gathered that way.

The availability sample method is not problem-free and the researcher therefore has to be aware of issues that may occur. Every interview session was a valuable time for recovering and studying LEK of *chaopramong,* but there were practical concerns about how to gather them together at the correct venue. In some villages a few *chaopramong*, who were volunteering to join the session, were waiting for me at the venue before the planned time; for instance Phomueng and Boungmueng, while at some villages nobody was there to join the session. On the latter occasions I randomly approached *chaopramong* who were at the village's pier and around the village and asked for their availability for few hours. Many times I was sitting at the back of a *phuyaibaan*'s motorcycle or that of my village's contact person outside a *chaopramong*'s house calling for volunteers. As a result, key informants were selected by both *phuyaibaan* and by myself using my *chaopramong*'s contact name list. Many times, I went to key informants' houses to continue a structured interview individually immediately after the group session at the venue, or sometimes next day having made an appointment beforehand.

Table 3.2: Breakdown of key informants by village and age range.

Village	No. of key informant	Age range
Phomueng	7	49-62
Bungkhylek	2	39-66
Baan Nawang	3	41-65
Boungmuang	3	45-72
Ladcharoen	5	30-48

One pre-requisite for developing a PPGIS approach is to gather foundational data, so the next chapter will provide information essential to understanding the current situation at the study site of Na Waeng.

(2) Key informant interviews session: The interviews took between two to three hours per group or village, and were divided into two main parallel work streams: (1)

a structured (individual) interview (Figure 3.5), and (2) a LEK sketch mapping exercise (Figure 3.6). I conducted key informant interviews at all five villages, along with one or two local field assistants. These assistants helped me during the key informant interviews and their assistance greatly accelerated the data collection process. All of the key informant interviews and discussions were conducted in fishing communities within which people's livelihoods depended on Mekong fish resources. The selected volunteers had to be able to provide a personal account of the river's ecology, fish species and deep pools.

At the beginning of each session, I clarified the purpose of the study and the data collection exercise, the procedures to be used, and the time required from the key informants. I also read out the key points from the list of questions. The two main group interview sessions ran in parallel, which were a sketch mapping group and a structured (individual) interview. Key informants decided amongst themselves which activity they would join to start with. Key informants who had drawing skills or artistic ability decided to work first with the sketch mapping group. The rest of the key informants facilitated in the structured (individual) interviews.

It was assumed that the research participants would receive no significant personal gain from taking part, and I did not require the participants to perform, or engage in any risky activities. Confidentiality was strictly enforced throughout the research process, and the verbal, informed consent required by the NUS International Review Board (IRB) was read-out in the local dialect, informally, as follows:

- You reserve the right to withdraw from the research at any time, or you can choose not to answer any question, or not to discuss any topic that makes you feel uncomfortable.
- You can choose whether or not you wish to have your personal details, such as your name, institution name, designation and

photographs, published in my research or in any academic publications based on my research, if any.

- You acknowledge that during the interviews, audio, visual and written files will be created for purpose of this research. The researcher will normally repeat this point again before taking an individual photograph or tape-recording an interview.
- All materials collected, including quotes and photographs, during the interviews and participant-observation sessions, will be used only for the purpose of this research and any subsequent academic publication(s).

(i) Key informant structured (individual) interview

The interview was field tested with *chaopramong* on the Mun River, which is a tributary of the Mekong River located in the study province. It was then subsequently amended and translated into Thai before its final deployment at the study site.

The questions were broken down into five sections, their aim being to assess the *chaopramong*'s livelihoods as well as their LEK regarding the Mekong River (see Appendix I). As key informants were answering on their behalf of their households, the first section was designed to collect basic demographic data, including that concerning family members and key income information. The second sectioned asked how and why the families turned to fishing and enquired about their level of knowledge on fishing gear. The third section asked the key informants about the significance of deep pools in terms of their physiology, as well as their cultural and spiritual significance and that of the Mekong River itself. The fourth section examined the existing conservation groups in communities. The last section was left open for the key informants to share their opinions on any problems in the study communities.

Flexibility in questioning is a benefit of employing structured interviews (Longhurst, 2003), and I therefore used this method to gather *chaopramong's* background information to help triangulate their LEK data, and thereby also acquired in-depth knowledge and understanding of the research. One of my local field assistants and I conducted the structured (individual) interviews based on the prepared framework of five themed questions, but not necessarily in order they were listed. The flow of conversation not only depended on key informants' experiences, knowledge and expertise, but also relied upon a general conversation at the beginning of interviews to 'warm up' the respondents. For instance, one morning at the pier of Phomueng village, which was the interview venue, we met a key informant who had just finished collecting fish from his fishing net. He was a bit nervous because he had never taken part in a research interview. My nice smile did a lot to break the ice, and that was followed up with a familiar topic of conversation. For his case, questions were related to fish and fishing: which kind of fish have you caught?, are they big?, and are they delicious? What kind of dish will you cook with it? I then started the interview on the third section questions relating to deep pools and fish, and came back to the first section later. Additionally, the flexibility of a structured interview method allowed me to gather some new ideas to be brought up during subsequent interviews based on what key informants had said: e.g. food culture, folk tales, seasonal fishing, and border issues.

The outcome and form of interactions—interview dynamics—as well as the researcher's positionality and power could influence the interview situation and the answers key informants give to the question posted (Cloke *et al.*, 2004). I was therefore very conscious during personal interactions to behave in a courteous and ethical way, and to respect not only the key informants, but also the villagers in general. In term of the conversational sphere, my peculiar *Isan* accent and tone of the interviews were informal, often casual and light, and several times the key informants answered in a joking tone and laughed themselves. I often introduced the idea to key informants that they were my *archarn* [teachers], and I was there to learn from them, which often brought a grin to their faces. I realized then that I had earned their trust and thereafter they felt much more confident about their experience and comfortable to talk and answer. Interestingly, though not surprisingly, with some interviews the answers were limited at first but more plentiful later as the key informants warmed up.

Conducting an interview at the pier of Phomueng village

Conducting a interview at Boungmueng village' meeting hall [*Sala klang baan*].

Looking at fish species

Identifying fish species

Two local research assistants and participants

Preparing the interview location

Figure 3.5: Key informant interview process (Source: Author, 2012)

In terms of being a woman researcher in the *chaopramong*'s world. As a younger woman conducting interviews with senior or older *chaopramong*, who were all men, I had to be mindful of the aspect of 'seniority' in Thai culture and customs in terms of using what is deemed 'most polite' with regards to gestures and behaviour. This means I respected my key informants views and I was careful not to do anything against the culture and customs. For instance, during the interview sessions I stayed calm, smiled and sat properly avoiding pointing my feet to my key informants. Noting in Thai culture and customs the head is considered as the sacred part of the body and not to be touched without permission. In contrast, feet are regarded as the lowest/ dirtiest part of the body and it is very impolite to point to something with one's feet. By maintaining a mindful approach regarding the culture, it was apparent that they were more willing to share their experience as *chaopramong* with me in a similar fashion as 'story telling' to younger kids, specially with questions that were related to beliefs and spirits of the river.

There is a gender discrepancy which generally allows men to act flirtatiously with woman. In hopes of discouraging this behaviour, I dressed modestly and was careful to do so continuously throughout my fieldwork. Also, Often t my son and/or husband accompanied me during the interview sessions, which helped to discourage unwanted attention In looking back, I do not feel this was a major issue in conducting my research. In addition, on a few occasions where I thought my gender could have coloured *chapramong*' responses, they were more willing to speak with me.

One of the research's objective is to explore about *chaopramong*'s livelihood, and how and how much *chaopramong* relies on the fisheries resources as a primary or supplementary income. As stated earlier in section 4.2 that no data revealed regarding the Gross Provincial Product (GPP) of fisheires section down into detail of sub-district level. Furthermore, the GPP of fisheries section is prevailed in a sub-group of agriculture. As a rough guide to the status and incomes of *chaopramong* living in Na Waeng, therefore, the research designed interview questions to tackle the situation for the source and supplement of *chaopramong*'s income mainly came from. Noting, any questions during the interview, I considered the ethical implications I always reminded my key informants be aware of their ability to refuse to answer any questions that they have difficulty answering it.

One technique that was valuable to my research was triangulation, which refers to cross-checking the data collected and conclusions made based on one method with those from other methods (LeCompte and Schensul 1999; Neuman, 2006; Patton 2002). For instance, I sometimes needed translation help from my two local research assistants regarding some words in *Isan* dialect in order to validate and develop a better understanding of the findings. Examples of this happened during a key informant interview, when fishermen told me about an endangered species that they had not seen or caught for a long time. They mentioned *Pla fhalai,* which means *Pla Krabaen Mae nam khong* (a fresh water stingray (*Dasyatis laosensis*)) in Thai, so I validated my understanding with my local research assistant. Another example is *Paew*, which means *Loeng Namlouk* (thalweg) in Thai. Often *chaopramong* referred to *paew* as a strong water current instead of a deep section of the river. My preconception of being in full control of the interview was challenged, but working through my research assistants as a 'neutral mouthpiece' (Fuller and Toon, 1988, cited in Edwards, 1998) was a pleasurable experience.

Data analysis:

Structured (individual) interviews were used as the primary means of data collection to gain insights about *chaopramong*'s livelihood and experience in relation on the Mekong River. During the interviews, my assistants and I recorded key informants' responses on the interview forms, noted and tape-recordings were also used to ensure that we understood them correctlyand could double check after the interviews took place. This data was later analysed from each of the sources described above by coding transcripts, documents, and notes from observations. This process of coding and analysing was done throughout data collection; each instance of analysis informed subsequent data collection (Strauss and Corbin, 1998). In this way, not only did the key informants' voices come through in the final reporting of the themes that emerged, but they also emerged through data collection. The data of all key informants was entered into Microsoft EXCEL, then later coded based on emergent patterns and themes (LeCompte and Schensul, 1999; Bernard, 2011). Once all the data was cleaned and coded, I used descriptive statistics e.g. percentage, frequencies. Furthermore, some of coded data from the village level was integrated into GIS to provide a visualization on maps. Find detailed in section 4.5.1-4.5.4. Some qualitative data, I analysed by using the interview data, field observations, as well as archival research to describe the relevance of the research context, which described Sacralization of the Mekong River in Na Waeng and Fishing territories in section 4.5.5-4.5.6.

(ii) LEK sketch mapping

Sketch mapping techniques have been used in support of participatory rural appraisals over a number of decades due to the fact that they are able to capture the personal blueprints people conceptualize in their minds based on experience to navigate and make sense of the world (Lynch, 1960; Ladd, 1970; Niem Tu and Doherty, 2007). For this study, these techniques involved using *chaopramong* as the key informants in order to develop spatial representations of the Mekong River by drawing maps on a large A0 sized piece of paper. This process was carried out in parallel with the same group of key informants who had completed the structured (individual) interview in the previous session.

Sketch mapping refers to spatially referenced maps of individual or group experiences (Boschmann and Cubbon, 2014) and can be conducted using various methods depending upon the artistic ability of the different participants (Sherman *et al*., 1979; Hirtle and Jonides, 1985), for example using blocks and cardboard (*ibid*), pencil-and-paper sketches (Lynch, 1960; Lee, 1968; Ladd, 1970; Maurer and Baxter, 1972; Aberley, 1993; Al-Kodmany, 2002; Dennis, 2006), interactive sketch map in GIS software (Harris and Weiner, 1998; Ceccato and Snickars, 2000; Doran and Lees, 2005; Hawthorne *et al*., 2006; Kwan, 2008; Lopez and Lukinbeal, 2010; Wridt, 2010). Hence, before embarking upon the field work, the LEK sketch mapping process using a blank piece of paper and a pencil, was initially tested on a fishing village located next to the Mun River. Although it is a very simple method to use, an initial field testing of the LEK sketch mapping process would show whether it could be used with *chaopramong* as part of the main study.

The main purpose of the main sketch mapping sessions was to elicit the LEK of *chaopramong* using a commonly used PPGIS tool, the eventual aim being to facilitate future fisheries management activities. Such sketch maps are able to reflect knowledge on river ecology and natural resources, such as the locations of deep pools and fishing grounds, as well as riverbed characteristics during the dry season (see Figure 3.6). Any significant outputs which occurred during the mapping process and associated discussions were transferred into the GIS platform for future reference purposes.

I repeated the verbal consent process before conducting the individual photograph and tape-recording sessions carried out during the sketch mapping discussions, as this part of the process was conducted in parallel work streams with the key informant interviews session. To recap, key informants who had a drawing skill or an artistic ability decided to work on sketch mapping group, and they were the key people who drew sketch maps based on grounded knowledge provided by other key informants who were not in the structured (individual) interview session. Simple stationery was prepared for this activity; including sheets of blank A0 and A4 paper, pencils and coloured markers. Simple open-ended questions were used to kick-start the sketching process if needed. Examples of such open-ended questions are: Where is your village? Where is the river? Where is the road? And what colours or symbols represent certain features?

Again, I was conscious during personal interactions to behave in a well-mannered and ethical way, and to respect the key informants. Similarly, I ensured that during the structured interview the conversational atmosphere was casual and light. My most important role as a researcher was to encourage and provide answers to the key informants' questions in a non-confrontational style. Moreover, I handed the key informants their pencils to start the process of sketch mapping, which sent them out feeling more empowered (Chambers, 2007), then I listened and learned from the key informants.

Before sketch mapping sessions started, I explained that the purpose of the sketch maps was to reflect knowledge of river ecology and natural resources, such as the locations of deep pools and fishing grounds, as well as riverbed characteristics during the dry season. There was one question raised by key informants regarding the months during the dry season that they should draw on the paper. It reflected the precise information that they had acquired through time and experience building up an understanding of the environment.

Furthermore, the sketch mapping process could enhance the credibility and validity of the results of LEK map. During this session, key informants enthusiastically shared and discussed their knowledge about the river's characteristics, fishing grounds and so on, and while the process allowed key informants to express their knowledge, it also allowed cross-checking of data quality and data completeness among the group.

○ An LEK sketch map of Na Waeng village ○○ Drafting and discussing ○○○ Starting point for sketching ○○○○ Sketching and discussing ○○○○○ Sketching

Figure 3.6: Conducting an LEK sketch mapping session (Source: Author, 2012)

3.4.2.2 Field observations

Employing participant observation allows a researcher to paint an in-depth portrait of the study informants and their community and, as described by Schensul (1999, 91), involves: *"the process of learning through exposure to or involvement in the day-to-day activities of participants in the researcher setting".* Having an open-minded and non-judgmental attitude is one of the main characteristics a researcher should have during an observation exercise (DeWalt, DeWalt & Wayland, 1998, 267; DeWalt and DeWalt, 2010). In other words, the more open a researcher is to new ideas, the better the absorption of new ideas will be. In this study, observations were carried out during the fieldwork and when I conducted my preliminary site study, both while staying at the study site. These observations allowed me to better understand the on the ground reality of the *chaopramong*'s daily lives, the social interactions that take place among the fishing groups and with others, and the fishers' social positions within their communities. For example, in some fishing communities, fishing grounds are a property right that can be passed from one generation to the next or can be sold, such as the fishing grounds alongside *baan* Na Waeng and Ladcharoen villages. Another interesting example of this is the way in which some *chaopramong* define themselves as part-time *chaopramong*, with two distinct groups existing. First there are those who are employed or work full-time, but in the morning and/or evening also fish using their own nets. Those in the second group are also employed, but work close to the Mekong River piers, on long-tail boats or on cross-border boats. As a result, when they do not have customers or passengers, they go fishing nearby. By using field observations, I was able to further refine and add to the social and cultural information I already held about the communities from the key informant interviews session.

During my field work, I visited the communities informally on a regular basis, and also stayed within the communities. The greatest advantage of this approach was that it allowed me to maintain a balance between involvement and detachment; to try to remain as objective as possible during the research. However, it is impossible to be completely objective as our subjectivity always comes into play. This style of research can be defined as moderate participation, as it allows a researcher to maintain a balance between being an insider and outsider (see DeWalt *et al.*, 1998, for more details on this type of participant observation).

Furthermore, I had the privilege of being invited to two official events. The first was an annual event to celebrate the Thai Queen's birthday (12th August), which is also Thai Mother's Day. It was organized by the Fisheries Department of Ubon Ratchathani on the 8^{h} August, 2011 (Figure 3.7). The main activity was the government releasing of some fish into the Mun River, with the intention of increasing the number of species to alleviate poverty and to increase biodiversity in the river. Secondly, I was invited to attend the local government's meeting organized by the TAO of Na Waeng office at Nongmeungchom village (Figure 3.8). The aims of this meeting were to discuss the developing local infrastructure with villagers, identify problems that occurred, and further the development plan in the village. I learnt that villagers had suffered with drought during the dry-season, which was surprising given their close proximity to the Mekong River. These events allowed me to observe and interact with provincial governmental officers and officers of the TAO of Na Waeng, while also observing and interacting with villagers more casually than when conducting interviews. It provided me with the opportunity to see people and the fieldwork in a different light. Furthermore, I gained more opportunities to immerse myself in the field in a more effective manner, and I learned more about their life, culture, and communities, as well gaining a greater understanding of some of the problems they face.

Figure 3.7: Celebration of Thai Queen's birthday on the 8th August, 2011, organized by the Fisheries Department of Ubon Ratchathani (Source: Author, 2011).

Figure 3.8: Local government's meeting on the 13th March, 2013- TAO of Na Waeng office and villagers at Nongmeungchom village, Na Waeng, Khamarat in Ubon Ratchathani. (Source: Author, March 2013)

3.4.2.3 Fish catch monitoring

This study looks at the role deep pools play in terms of fisheries management and how they influence the livelihoods of *chaopramong*. To this end, during my research I collaborated with five fishing communities in Na Waeng, collecting data regarding fish catches and identifying fish species based on the informants local knowledge and experience. The data collected formed the basis for describing the contribution fisheries make to their livelihoods and so their level of dependence upon them.

Catch and fishing effort/gear data were collected by specially trained local villagers or *chaopramong* in the study fishing communities. These trained villagers lived near the fishing piers and could be trusted to provide fish catch information. Furthermore, I prepared a sign for the purpose of conducting the catch monitoring activities in the study communities. Simple training was given on how to record data using the pre-prepared catch monitoring forms (see Appendix II). I also provided a list of 238 fish species (see Appendix III) present in the mid-migration section of the Mekong River, running from north of the Khone Falls to Loei in Thailand, in order to help them collect the fish catch data. The monitoring form and list of 238 fish species had been adapted from one produced by the Udon Thani Fisheries Inland Fisheries Research and Development Centre. The form was of a simple design and allowed the *chaopramong* to fill-in details regarding the fishing gear used, the fish species or groups of species seen, and the locations of their catches. The river has several different characteristics over the study area, meaning the fishing gear used varies across different sites, as do the fish species found there.

In order to collect the information systematically, the survey had to gather data at the five fishing locations over the same one month period in the dry season. The sampling took place during a 30-day period between 25 February and 25 March 2012 while I was staying in the area to conduct my field work. I hired some local *chaopramong* to collect the data, my role being to control the data collection parameters so that a systematic method was followed. The information recorded during this activity was as follows:

- Name and type of fishing gear used
- Amount of each type of fishing gear used

- Catch locations
- Number of times gear was placed per day
- Amount of time the gear was used for fishing, and
- Weight and length of each species (or groups of species) in each catch

3.4.2.4 Archival research

Generally speaking, archival research may seem slightly tedious when compared to fieldwork, which is seen as vibrant, adventurous and essential for many researchers. However, archival research plays a vital role in helping to gather background information during research projects. The secondary data it produces is an indispensable source of information that can provide extensive coverage of the research basis and context, as well as geographical, historical, social and economic data, which allows a more intensive investigation to take place (Church, 2002).

The aim of this study is to explore use of the PPGIS approach when researching the conservation of ecological functions surrounding deep pools, as well as the livelihoods of *chaopramong* in the study area. As a result, I made extensive use of previous surveys on deep pools from a number of resource archives, and in particular those focused on the Mekong River, such as studies undertaken and published by the MRC. However, I was only able to find general information about deep pools, but information pertaining to their ecological functions was sparse. In addition, using the PPGIS approach, I was initially going to investigate freshwater fisheries management processes in the study area and in this regard the archives helped me develop a comprehensive understanding of the research topic and identify the gaps in existing research.

Archival research materials were collected from both governmental and non-governmental organizations. These included the Department of Fisheries offices in Bangkok and Ubon Ratchathani, Thailand, the Udon Thani Fisheries Inland Fisheries

Research and Development Centre, the Sub-district Administrative Authority of Na Waeng, the NUS scholars archive, the MRC and IUCN, as well as relevant journals. Other necessary information, including GIS base maps and deep pool characteristics data was collected from the MRC. A geological map of Ubon Ratchathani was obtained from the Department of Minerals and Resources in Bangkok, Thailand, while a digital elevation model (DEM) and Landsat satellite images of the study area were gathered from Maryland University, using its free, online earth science data archive.

3.5 Phase III: Conservation zone mapping

The intention during this phase was to facilitate an improvement in fisheries management activities by conducting a PPGIS workshop focused on the conservation of ecological functions relating to deep pools and the livelihoods of local *chaopramong*. The workshop was designed around the PPGIS process, using GIS technology in tandem with the *chaopramong*'s and community leaders' LEK, the aim being to further develop and refine fisheries management activities in their communities. The PPGIS process aims to empower marginalized *chaopramong*; allowing them to utilize their knowledge regarding river ecology and fish. The information gathered would be essential for the development of any future decision making processes.

3.5.1 Public Participation GIS (PPGIS): PPGIS workshop

The aim of a PPGIS workshop was to reinforce environmental awareness regarding the Mekong River among participants, and to initiate participatory fisheries management processes. This workshop was financially supported by the Mekong Program on Water Environment and Resilience (M-POWER)[3]. The reason Thai and

[3] The Mekong Program on Water, Environment and Resilience (M-POWER), with the support and collaboration of the Australian Agency for International Development (AusAID) and through the CGIAR Challenge Program on Water and Food (CPWF).

Lao *chaopramong* were included is due to the fact that local water resources are governed by both countries, plus no fishing barriers exist on the Mekong River.

3.5.1.1 Identification of stakeholders:

The most widely referenced stakeholder definition has been proposed by Freeman (1984, 46): "*A stakeholder in an organization is (by definition) any group or individual who can affect or is affected by the achievement of the organization's objectives".* The definition of 'stakeholder' is nevertheless highly contested (Miles, 2012). The identification of stakeholders is not a straightforward task, especially in the fisheries context of the Mekong River, where the water resources are shared between riparian countries. In order to do so, the research adopted the identification of stakeholders used by World Bank (1996), Townsley (1998) and Mackinson *et al.* (2011), which distinguished two types of stakeholders (Table 3.3). Primary stakeholders, who are directly affected positively or negatively by proposed interventions/policies; and secondary stakeholders, who are indirectly affected by proposed interventions/policies. To ensure that I was including all potential knowledgeable participants, I consulted lecturers at Ubon Ratchathani University regarding the stakeholders who might be interested in participating in the PPGIS workshop. In total, 25 relevant local stakeholders participated, including: Thai and Lao *chaopramong* (the latter volunteered), *kamnan, phuyaibaan*, officers and the director of the TAO in Na Waeng, one lecturer and a number of graduate students from the Fisheries Department at Ubon Ratchathani University (Table 3.3). Notably, no fisheries officers attended the PPGIS workshop.

Power does play a role in multilevel stakeholder meetings or participation and, as noted by Barringer and Harrison (2000), not all stakeholders are equal. Indeed, stakeholder involvement often starts by determining which stakeholders are deemed "important" (Harrison and John, 1996). As a consequence, the views of stakeholders who are not deemed important, such as marginalized people and local communities, can be distorted or influenced by the views of those who are deemed important (Allen, 2003, 96). Such power relations normalize subjects to speak, think and act in particular manners (Foucault, 1994).

In this research, the development of the PPGIS methodology challenged dominant power relations, reduced inequalities, and fostered empowerment within the research process facilitated through the integration of *chaopramong's* LEK (Harris and Weiner, 1996; Kyem 1996; Mather 1998; Jordan, 1998). The PPGIS workshop formed an interactive environment where *chaopramong* were able to be actively involved in spatial decision making in fisheries management.

Table 3.3: Breakdown of stakeholders by groups

Types of stakeholders	Stakeholders	Total number	Male	Female	Time for attendance
Primary	Director of the TAO in Na Waeng	1	1	-	Opening speech session
	Officer of the TAO in Na Waeng	2	1	-	Morning session
			1		All day
	Kamnan	1	1	-	Morning session
	Phuyaibaan	6	5	1*	All day
	Lao *chaopramong*+Thai focal person	3+1	4	-	All day
	Thai *chaopramong*	5	5	-	All day
	Fisheries officers	-	-	-	-
Secondary	Academics/scholars	6	3	3	All day
Total		25	21	4	-

Remark: * a village committee member from Ladcharoen village.

3.5.1.2 Preparation of PPGIS workshop:

Before embarking on the PPGIS workshop, a letter discussing the research collaboration was sent to the TAO in Na Waeng, prepared by the Fisheries Department at Ubon Ratchathani University in their capacity as the lead research organization behind the workshop. This collaboration letter discussed: using a TAO's meeting room, inviting officers of the TAO in Na Waeng, and collaborating in inviting *phuyaibaan* and one or two *chaopramong* from each of the five study villages to attend the workshop. This meant that the *phuyaibaan* was in charge of selection the *chaopramong* who would attend the workshop. All the workshop expenditure was borne by the researcher with the financial support of M-POWER. I asked about the process and permissions involved for Laos participants to attend the workshop, which was fine as long as they did not stay overnight in Na Waeng. It should be noted that there are local immigrant border check points in some villages on both the Thai and Laos sides of the Mekong River. Laos and Thai people can cross the border for shopping and trade on a daily basis as long as they pass a simple check with an immigrant registration patrol.

Importantly, I had already contacted and researched the possibility of using the TAO office for arranging the workshop before the request letter was sent out. Another reason for using the TAO's meeting room was to bring to the attention of the TAO in Na Waeng the importance of a participatory approach to natural resources management in their area, which was excluded from the TAO's activities in Na Waeng's existing rural development plan and strategies.

I went to meet the key contact people (focal points) in all five study villages in order gain support for bringing Laos *chaopramong* to attend the workshop. The focal points from two villages, Ladcharoen and Phomueng, both agreed to help by collaborating with Laos *chaopramong* on this matter. I provided the two focal points with my introductory letter in Thai, prepared by Ubon University, as well as the workshop agenda. However, only Laos *chaopramong* collaborating with Phomueng village could attend the workshop because the distance was less than 10 km from the TAO's office, whereas Ladcharoen was too distant at 25 km away. One noteworthy point is that the Phomueng focal point was a well-known and trusted person with both the Laos and Thai communities because he was working as an immigrant registration patrol officer at Phomueng checkpoint. In addition, he was a person who helped me to continue the river survey in the area where the "shots across the bow situation" had occurred. During the workshop, he also attended the event with Laos *chaopramong* which helped put them at ease.

Additionally, two invitation letters to the PPGIS workshop, prepared by the Fisheries Department at Ubon Ratchathani University, were sent to the Fisheries Department of Ubon Ratchathani and *phuyaibaan* Nahinngeon. However, no representative from the Fisheries Department joined, and only *phuyaibaan* Nahinngeon and his team attended the workshop. I developed the personal contact with *phuyaibaan* Nahinngeon during the fieldwork and learned that his village has developed community-based natural resources conservation along the Mekong River, supported by an NGO. *Phuyaibaan* Nahinngeon agreed to be one of the workshop speakers.

(1) The PPGIS workshop:

Before it started, I explained the purposes of the workshop and the agenda (Table 3.4), which contained two main sessions: (i) communications and knowledge exchange with respect to fisheries management activities on the Mekong River, and (ii) a PPGIS workshop. Languages used in the PPGIS workshop were Central Thai, *Isan* and Laos. The verbal informed consent was read out as four points as described in section 3.4.2.1 and the key informant interviewees and participants were informed about video recording during the PPGIS workshop.

Table 3.4: Workshop on 'A Public Participatory Geographic Information System for Fisheries Management Activities on the Mekong River'

Study Area: Na Waeng, Ubon Ratchathani, Thailand

14th March 2013; At the Na Waeng Sub-district Administrative Authority Office

8.00 - 8.45	Registration
8.45 – 9.00	Welcome by Mr. Phreecha Sheudee, Director of TAO
Morning session:	
9.00 – 9.15	Director of Na Waeng Sub-district Administrative Authority
9.15-10.00	Presentation: 'Where have the fish has gone, and Fisheries management on the Mekong River? By Associate Professor Thonthong Jutagate, Fisheries Department of Ubon Ratchathani University
Coffee and tea break	
10.15 – 11.00	Presentation: 'Rehabilitation of Biological Diversity along the Mekong River through Community Participation in Phosai and Natan, Ubon Ratchathani, Thailand'. By Mr. Prasith Meekham, Nahinngeon village leader
11.00-11.30	Discussion about the 'Impact of environmental change on fisheries along the Mekong River'
Lunch	
Afternoon session:	
13.00-14.45	Workshop on 'PPGIS for fisheries management'
	Attendees divided into two groups; *phuyaibaan* and *chaopramong*
Coffee and tea break	
15.00-16.00	Presentation of outcomes from each group

Associate Professor Thonthong Jutagate (Figure 3.9) gave a presentation on fisheries management mechanisms, the implications of fisheries management activities for the Mekong River, and also raised awareness of the decline in fisheries production levels on the river. The second presentation was given by Mr. Prasith Meekham, the *phuyaibaan* of Nahinngeon village (Figure 3.10), based on the project, 'Rehabilitation of Biological Diversity along the Mekong River through Community Participation'. He also outlined the need to produce guidelines for community-based management, and described past case experiences to the participants. The last part of the workshop included a discussion about: 'the impact of environmental changes on fisheries in the Mekong River', the aim of which was to gauge the participants' level of environmental awareness (Figure 3.11).

The second session was in the afternoon. PPGIS was used to facilitate the initiation of bottom-up development practices, through the integration of LEK into the research driven decision-making process. Along with these aspects, the PPGIS

Figure 3.9: Presentation on "Fisheries management" by Associate Professor Thonthong Jutagate (Source: Author, 2013).

Figure 3.10: Community conservation case study, presented by Mr. Prasith Meekham, Nahinngeon (Source: Author, 2013).

Figure 3.11: Discussion about the "Impact of environmental change on fisheries on the Mekong River" (Source: Author, 2013).

process, which overcomes the barriers of GIS technology to elicit local knowledge, helped to link people and natural resources together in a more sustainable manner (Christie *et al.,* 2002; McCall, 2004; Poole, 1995; Shepherd *et al.,* 2004). The workshop attendees were split into two groups: *phuyaibaan* and *chaopramong*. This was done to avoid conflicts over power or the decisions made by either group. After the group sessions, a 'bridging the gap stage' was employed by merging the two groups together to decide how to incorporate public opinion into the decision making process on fisheries management activities.

(2) The PPGIS methods and tools:

The PPGIS methods and tools were intensively used in the second session in the afternoon. The criteria used to select PPGIS tools for use in the workshop were as follows: the tools should be portable, compact and easy to install; and they should also be easy to use and understand in order to break down the barrier of the GIS techno-centric approach.

The *phuyaibaan*'s group was facilitated by the lecturer and discussed the possibility of developing a community fisheries management process (Figure 3.12). PPGIS tools, an A1 sized topographic map of Na Waeng, and a satellite image of Na Waeng showing locations of the deep pools (Figure 3.15), were all employed during this discussion. Together their information helped to provide a common understanding of Na Waeng's environmental setting. The PPGIS tools were applied in combination with the strategy planning aspect of the workshop.

Within the *chaopramong*'s group (Figure 3.13 and 3.14), the PPGIS tool used was a satellite image map from Google Maps 2011, which aimed to elicit LEK from the *chaopramong*. This was printed on a vinyl banner measuring two by five metres. In addition, I prepared stickers of various shapes and sizes to provide map symbols for the participants to stick on the vinyl banner. The workshop then explored participatory approaches that could be used to facilitate LEK and listened to the

Figure 3.12: Group discussion of *phuyaibaan* (Source: Author, 2013).

opinions of the *chaopramong* with respect to fisheries management activities. This session afforded group members the chance to utilize and use their LEK while they were reading the prepared map and discussing the map symbols. The satellite image map was visually interpreted by *chaopramong*, and they identified the main locations in their villages (schools, temples, reservoirs, and streams) and selected symbol stickers to put on the map. Additionally, LEK contributed some scientific information on locations of fish by size, fishing grounds, and deep pools, which enhanced the power of *chaopramong's* LEK. The PPGIS tools and their practical application opened up some of the most salient issues and ideas of unaccountable LEK to renewed scrutiny. All the LEK of *chaopramong* and *phuyaibaan* would be incorporated as part of the decision-making process of the fisheries conservation area at the end of the workshop. Notably, I and the research assistants (graduate students from the Fisheries Department of Ubon Ratchathani University) acted as facilitators, to equip participants with the stickers for the map.

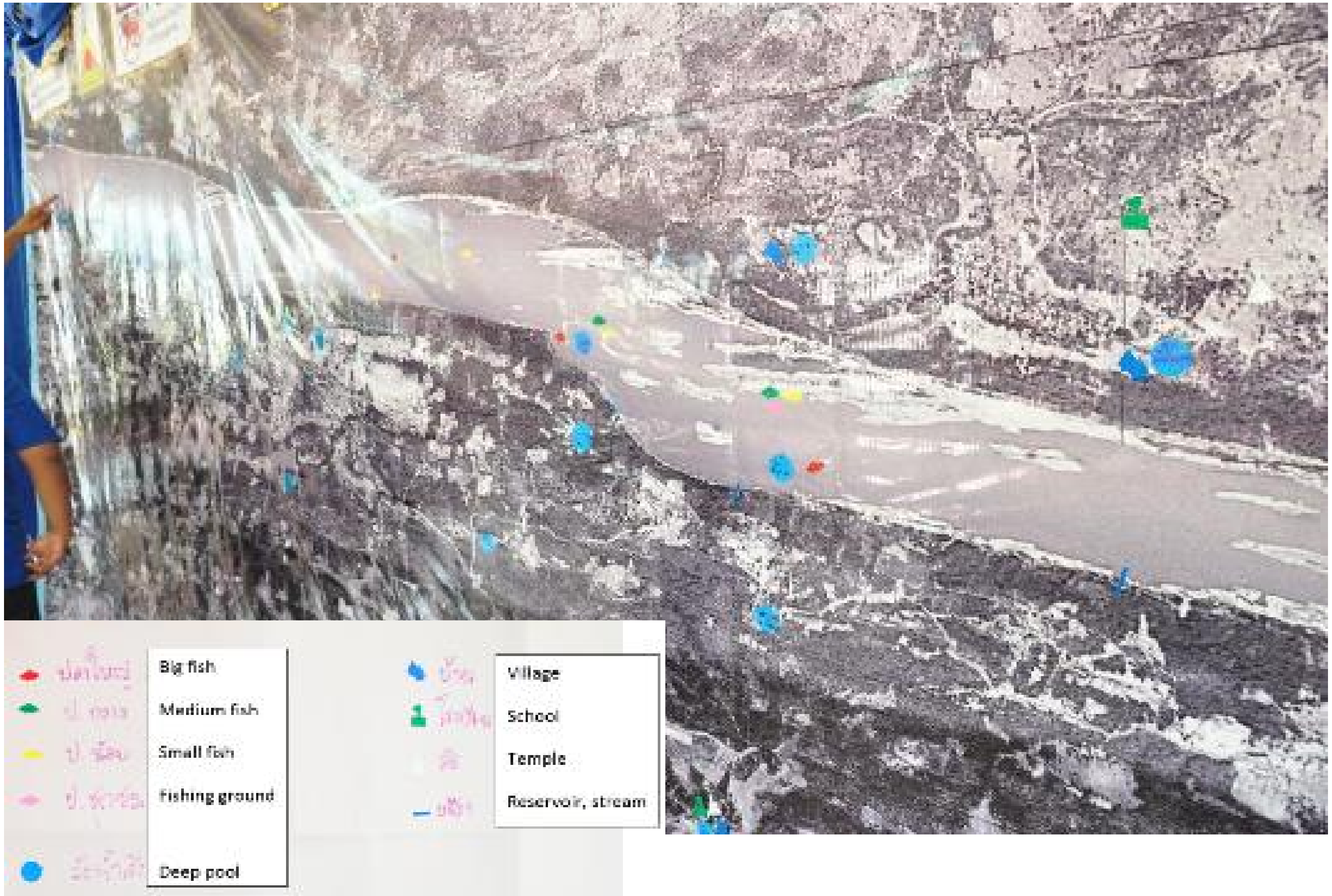


Figure 3.13: Acquired LEK information on map and map legend (Source: Author, 2013).

Figure 3.14: Laos and Thai *chaopramong* identifying their village locations (Source: Author, 2013).

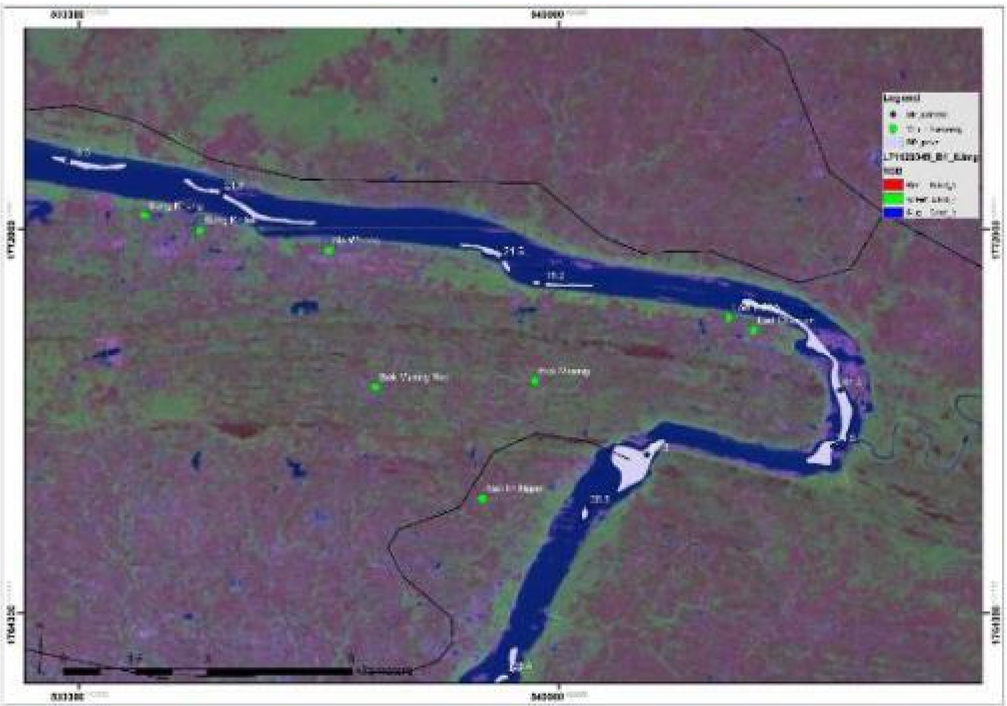


Figure 3.15: PPGIS tools – a topographic map (above) (Source: TAO office of Na Waeng, 2013) and a Landsat satellite image showing deep pools around Na Waeng (below) (Prepared by Author, 2013).

(3) Tipping positionalities of the researcher:

The PPGIS workshop was successful with kind assistance and collaboration of the Fisheries Department at Ubon Ratchathani University, which acted as the researcher's gatekeeper. Collins (1999) stated that participatory workshops can draw together two key aspects. Firstly, the workshops include a group of participants working together to provide comment and insight about an issue that is important to their community. Secondly, it includes an individual's contributions and views on particular events that are essential to their community. In this case the PPGIS workshop formed the central issue for the communities regarding the impact of environmental change on fisheries on the Mekong River. The workshops sought to elicit LEK of *chaopramong* using the PPGIS method outlined above, which it was hypothesized could facilitate a greater understanding of the ecology of Mekong River and enable communities to facilitate local fisheries management.

"*Nevertheless, positionality is dynamic. Our lives are in flux and as a result so are our subject positions. In that regard we are always in a state of "betweeness"* (Nast, 1994).

One day before the workshop was held, I was feeling a bit nervous because I was afraid that not many participants could join the workshop. I went to organize and prepare the meeting room at the TAO office and again reminded the focal person of the TAO about the workshop. During the workshop, I was confounded when the scales of power tipped in my direction. I was re-negotiating my position from that of a researcher to multiple roles as a master of ceremony and a facilitator. For example, I acted as MC for the workshop, aiming to facilitate and direct the workshop according to the schedule. This role as MC set the tone for the workshop, which sounded official in the beginning whilst the Director of the TAO was giving the opening address. Then the tone relaxed and became more informal and light as participants warmed up and got used to one another. Moreover, all participants communicated in *Isan*, which helped ease and enrich the atmosphere.

Interestingly, whilst I remained neutral and objective with respect to the workshop process, as a facilitator my role was to ensure that the workshop's objectives were effectively met, and to ensure full involvement and 'buy-in' from the participants involved. To do so, I ensured that every participant was introduced at the beginning of the workshop, which helped to break the ice. In particular, it significantly helped at the beginning to introduce Laos and Thai *chaopramong* to the local leader group comprising *phuyaibaan, kamnan*, the TAO officer and/or the director of the TAO. Generally, in Na Waeng, there is a monthly meeting among the local leader group so they were familiar with each other.

All participants were keen to raise questions with the key speakers, especially with the *phuyaibaan* of Nahinngeon village regarding how to set up and monitor community-based management programs. The talk by the *phuyaibaan* of Nahinngeon village, which is a neighbour of Ladcharoen village, was in *Isan*, which enriched the atmosphere. His story allowed participants to reflect upon the fact that community-based conservation management was neither too alien nor too difficult to manage. As a facilitator, I was as calm and emphatic as possible, and I followed up questions in a non-confrontational style.

In the afternoon session, during the PPGIS workshop, the meeting room was too hot and most participants were laughing and discussing the work in casual way. I was a facilitator of the mixed Laos and Thai *chaopramong'*s group, during which the *chaopramong* were smiling and laughing during the identification of village locations, fishing grounds, and so on. Some participants also joked about the location of restaurants where their friends liked to visit. It is noteworthy that the relationship between Laos and Thai *chaopramong* was friendly, and there were no attempts to enforce control or draw any great political and economic advantage from such forms of territorial conflict.

Moreover, a facilitator's personality can influence the workshop style, and it is necessary to balance ones personality with the situation. It simply means that, for the purposes of the PPGIS process, I took a neutral stance. I stepped back from the detailed content and from my own personal views, and focused purely on the work process. My research assistants and I were standing in the crowd simply to equip three Laos *chaopramong* and six Thai *chaopramong* participants with the stickers for the map. I assisted *chaopramong* participants in making notes for their map legends (Figure 3.13), which provided locations of fish by size, fishing grounds, deep pools, villages, schools, temples, reservoirs and streams. Their identification of fish location by size of fish, which they had acquired through their daily life, gave a surprising insight into how intensive their environmental knowledge really was.

Being female, the two research assistants and I might change the situation in certain settings in terms of positioning in the *chaopramong*'s group. One comment overheard from the *phuyaibaan*'s group was as follows: "*…I would like to be at chaopramong's group. Why? Look look there are ladies.* [*Laughing*]…." All participants in the PPGIS workshop were male, except for the three of us. I did not perceive that being a female led to me being treated like an inferior by participants in any way; however, *chaopramong* were more willing to speak to us and felt at ease to work with us in the group. I thought our gender could have coloured their responses and that it would compromise their research participation. On the other hand, the discussion's atmosphere in the *phuyaibaan*'s group seemed to be serious but productive, with a number of notes being added on the board regarding the possibility of developing community-based fisheries management (as explained in discussion later in section 7.2.4.1).

At the last session, a ‘bridging the gap stage’ was employed by merging the *phuyaibaan* and *chaopramong*’s groups together to decide how to incorporate their opinions into the decision making process on fisheries management activities. *Phuyaibaan* and *chaopramong* who came from the same place discussed the conservation area for their village by investigating the LEK information added to the prepared satellite image map. Later, I asked all participants about their decisions regarding conservation areas by order of their seat around the U-shaped meeting table. I noticed the power that was exercised between groups: *chaopramong* preferred their *phuyaibaan* to give their opinion about the conservation area before them, even when a *chaopramong* was in a position to talk first (as elaborated in discussion later in section 7.3.1.2).

3.5.1.3 Participant observation

Participant observation activities during the workshop provided me with valuable information, not only about the participants’ perceptions and interpretations of their environment and communities, but also their views on the PPGIS approach and process. A number of participatory actions were carefully monitored, as follows: participant interaction and use of the PPGIS tools, and an informal discussion regarding environmental change on the Mekong River and fisheries management activities. These participant observations were voice and video recorded, photographed, and notes were also taken. During the workshop, my interaction with the focus group participants allowed me to come into close contact with them, increasing my level of understanding and sensitivity regarding their needs, desires and opinions about fisheries management and the PPGIS tools being employed.

3.5.1.4 Feedback form of the PPGIS workshop

A series of simple, open response questions was designed to gather opinions and comments from the participants after the PPGIS workshop was completed. These proved to be quite valuable. The feedback form collected information about the evaluation of the PPGIS workshop and consisted of three open-ended questions regarding the usefulness of the PPGIS tools, the possibility of developing fisheries management in the communities based on the outcome of the workshop, and general comments (Appendix IV). Hence, the participants were allowed to offer feedback more fully and freely with respect to the workshop and outcomes of it. The outcome of the feedback can be found in section 7.2.4.2..

3.6 Data reliability and limitation

Even though I made every attempt to guarantee the reliability and validity of the research methods and techniques, it should be stressed that the findings of this research may have some problems. With respect to minimising the potential data problems that may occur, the mixed-method techniques of this research were well-prepared and based upon consultation with experts in the relevant fields, and they were also often discussed with my supervisor.

There are some general limitations to this research because the study area, covering five fishing communities, is large given the limited time, funding, and assistance available. In addition, the study area is on the contentious Mekong River border between Laos and Thailand. In terms of fieldwork methodology, it was not feasible to conduct the continuous zigzag method of data gathering at all five fishing communities during the river survey. The survey of individual *chaopramong* household in the five fishing communities was also impossible, but this research conducted a structured (individual) interview of *chaopramong* to represent their households instead of emphasized on the individual concerned. The structured (individual) interview of *chaopramong* provided an overview of their livelihoods and seemed highly appropriate for the research.

Fish catch monitoring data was collected for 30 days in all five fishing communities by trained local villagers or *chaopramong*. However, it should be noted that data completeness of catch monitoring was not very well documented, e.g. the size of gear used by *chaopramong* each day. In fact *chaopramong* employed many types and sizes of gear during fishing; hence the analysis of catch per unit effort (CPUE) could not be calculated. However, the catch monitoring was useful in describing the contribution fisheries make to *chaopramong* livelihoods, and their level of dependence upon them. In particular, fish species were recorded which provided useful information regarding the habitats in Na Waeng and migratory of fish species during the dry season.

By describing the research approach and taking all limitations into account, I often checked during the fieldwork whether the data from key informants and from assistants represented their points of view in order to avoid the occurrence of misunderstandings or misinterpretations. As the researcher I take full accountability for all the contents and any mistakes.

3.7 Conclusions

This chapter discussed the mixed method approach I applied to undertake a study of PPGIS when used with fisheries management activities; an approach which combined the fields of physical and human geography through the use of GIScience for problem solving. This approach was then combined with two very different types of survey: a river survey which gathered information on the ecological functions of deep pools using 'fish finder', plankton nets and water sensors, and a survey of *chaopramong*'s livelihoods using participation observations carried out during key informant interviews and field observations. Along with these lines of enquiry, the PPGIS tools also allowed me to capture several key LEK elements regarding the river and people's perceptions of and attitudes toward conservation management.

One pre-requisite for developing a PPGIS approach is to gather foundational data, so the next chapter will provide information essential to understanding the current situation at the study site of Na Waeng.

CHAPTER 4

An introduction to Na Waeng's resources and population

4.1 Introduction

In this chapter, I introduce and describe the research setting – from a historical and modern-day perspective – in order to contextualise socio-economic and biophysical information related to the study area of Na Waeng. Due to the amount of data available from the government's statistical office and research centres, I was able to examine some information from Ubon Ratchathani provincial level and from Na Waeng sub-district level, and this was enough to provide a basic outline of the situation in the study area, such as the Gross Provincial Product (GPP), and annual rainfall and average temperature figures for the district. Moreover, this chapter elaborates the background information on *chaopramong* [fishermen] that I gathered from the key informant interviews during field study. This includes questions about how to become *chaopramong*, types of *chaopramong*, and boat uses in the five fishing communities. Last but not least, the baseline information regarding the sacralization of the Mekong River and fishing territories in Na Waeng are deliberated.

4.2 Overview of the study area

Na Waeng is one of nine sub-districts in Khemarat District, Ubon Ratchathani Province, and is roughly 115 kilometres from the centre of Ubon Ratchathani town (Figure 4.1; longitude 105°15'E to 105°258'E/latitude 15°59'N to 16°025'N). The sub-district runs alongside the rich natural resource base of the Mekong River for 30 km, while Song Khone in Savannakhet, Lao PDR lies on the opposite side of the river.

Ubon Ratchathani is a large province in the northeast of Thailand, within a larger area commonly known as '*Isan*'. This is also an area dominated by ethnically

Lao-Thai people (also referred to as *khon Thai Isan*). The province is about 629 km from Bangkok, but the capital is easily accessible by land and by air. Ubon Ratchathani province covers an area of 15,819 square kilometres, the fifth largest province in Thailand and the second largest in the northeast region. The province is divided into 25 districts administratively, as well as 216 sub-districts and 2,699 villages. According to the Ministry of Interior, between 2001 and 2011, the total population grew from 1,779,752 to 1,816,057 – the third most populous province in the country. Slightly more than 50% of the total population is male, and the average population density is 113 people per square kilometre (National Statistical Office, 2013). The major religion is Buddhism (more than 90% of the total population), and so a wide variety of religions is not found in the area.

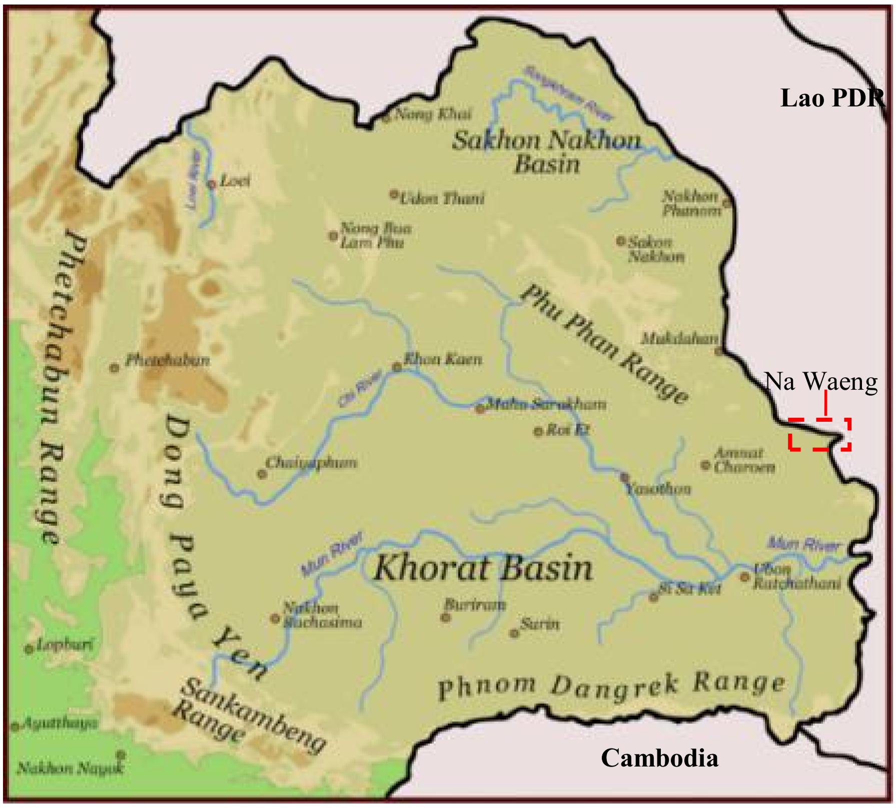


Figure 4.1: Na Waeng – the study area, and the topography of the Khorat Plateau (source: Wikipedia, 2013)

The Office of the National Economic and Social Development Board (NESDB) publishes Gross Provincial Product (GPP) figures based on current market prices, in order to measure the production activity of the district economy. These figures reveal large differences across the province in terms of wealth and the relative importance of manufacturing versus agriculture. In 2011, the GPP per capita in Ubon Ratchathani was 44,800 Thai baht (THB), or around 1,500 USD per capita (NESDB, 2013). The same survey showed that Ubon Ratchathani is ranked ninth in terms of GPP in the northeast region and 66th in the country. The key business sectors are manufacturing (79.7%) and agriculture (20.2%). The fisheries sector, which is a sub-group of agriculture, only represents 0.6% of the province's total production activity.

The term *na* [นา] in Thai means 'paddy field' while *waeng* is the word in *Isan* for a type of plant known as *kok* in Thai, the scientific name of which is *Typha angustifolia L.* (Central Laboratory and Greenhouse Complex, 2009). This plant is commonly used to make thatch, baskets and other woven products. Generally speaking, the name Na Waeng reflects the mind-set of the early settlers in the area, who worked as rice farmers, something still obvious today.

There is archaeological evidence to suggest that communities have existed alongside the Mekong River in the Na Waeng area over a very long period. For example, Khmer architecture in the form of a stupa can be seen at a temple in the community. Evidence suggests that the most powerful empire in the lower Mekong region after the early first century was Chenla (as named by the Chinese or "Kambuja" by Khmer), which was pre-eminent both culturally and technically, and also in terms of the foreign trade it carried out across the Southeast Asia region (Kelly and Shuter, 2006).

The total land area covered by Na Waeng is 57.18 square kilometres, most of which is either built-up (34.2%) or agricultural land (31.2%). The rest of the land area is made up of forested, multiple use land, and water bodies, at 12.7%, 11.6% and 9.9% respectively (Sub-district Administrative Office of Na Waeng, 2013).

Na Waeng consists of 13 villages and has a total registered population of around 1, 742 households or 7,160 people (2011). Out of the total number of villages, only five are located along the Mekong River – where the people depend on fishing for their livelihoods – these being Phomueng, Bungkeylek, *baan* Na Waeng, Boungmoung and Ladcharoen. It is these villages which are the subject of this research study.

According to a census carried out by the Sub-district Administrative Office of Na Waeng in 2013, the five study villages hold 753 households and 2,987 people; 4% of the total population residing in Khemarat district. Among the five villages, the biggest village (largest population) is *baan* Na Waeng (861) and the smallest is Boungmoung (196), (Figure 4.2). In general, the number of men is slightly higher than the number of women; the exception being *baan* Na Waeng; 450 women, 411 men.

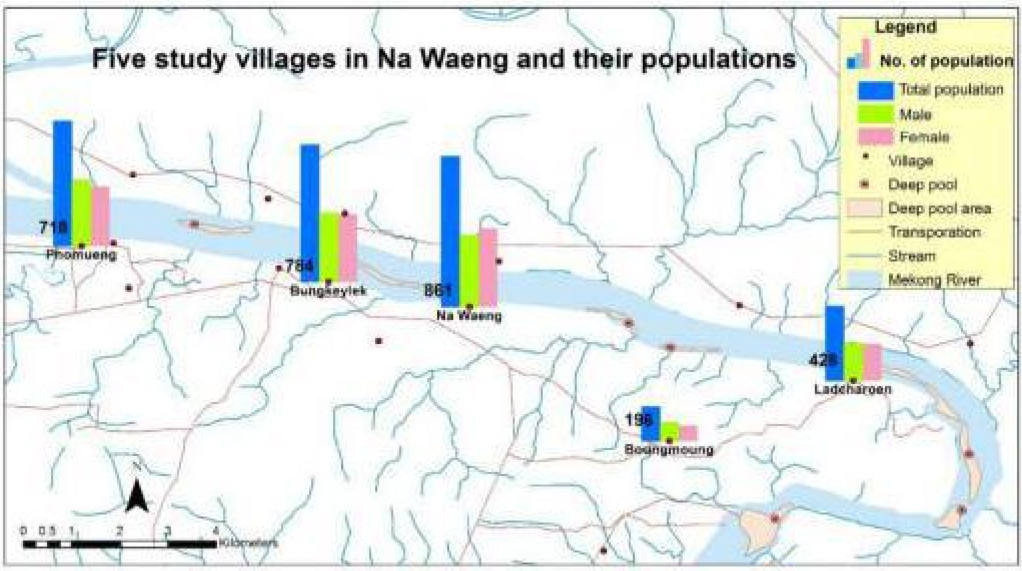


Figure 4.2: The five study villages in Na Waeng and their populations
(Map prepared by Author, 2014)

4.3 Topology and Geology

Most of the land in Na Waeng consists of rolling hills which in general slope to the east – towards the Mekong River, and elevations in the area range from around 30 to 200 metres above mean sea level. One rocky outcrop of coarse-grained Cretaceous sandstones and conglomerate extends from west to east in the area, representing the deeply-weathered remnants of the Phu Phan mountain range (Lee, 1923; see Figure 4.3). The Department of Mineral Fuels (2013) in Thailand has found that an anticlinal structure running in an west-east direction and perhaps parallel to the Phu Phan mountain range, can be found in the Khemarat area, the district adjacent to Na Waeng. In addition, a number of feasibility studies searching for petroleum deposits within this structure have been conducted, hoping to find a domestic energy source.

Na Waeng is located on the eastern side of a saucer-shaped tableland, which is commonly known as the Khorat Plateau. The average elevation of the area is around 200 metres above sea level. The Khorat Plateau was formed by the uplift of two perpendicularly-arranged faults in the earth's crust, one in the west which runs from north to south – the Phetchabun fault, and the other which runs east to west – the Phu Phan fault (Figure 4.4). As a consequence, the underlying sedimentary rocks are tilted rather than uniformly uplifted. The escarpments at the edge of these uplands overlook the Chao Phraya River basin to the west and the Cambodian plains to the south.

Generally, the sedimentary sequence around Ubon Ratchathani consists of an initial rift sequence of Carboniferous to Triassic sediments, and a sag sequence of Late Triassic to Cretaceous sediments which are part of the Khorat Group, itself a mainly sedimentary subsequence (Department of Mineral Resources, 2010). The area can be divided geologically into six units: alluvial deposits, and the Mahasarakham (KTms), Khok Krut (Kkk), Phu Phan (Kpp), Sao Khua (Ksk), and Phra Wihan (JKpw) formations (Figure 4.4, Table 4.1). It can be seen that the formations in Na Waeng consist of two units: the Khok Krut (Kkk) and the Phu Phan (Kpp).

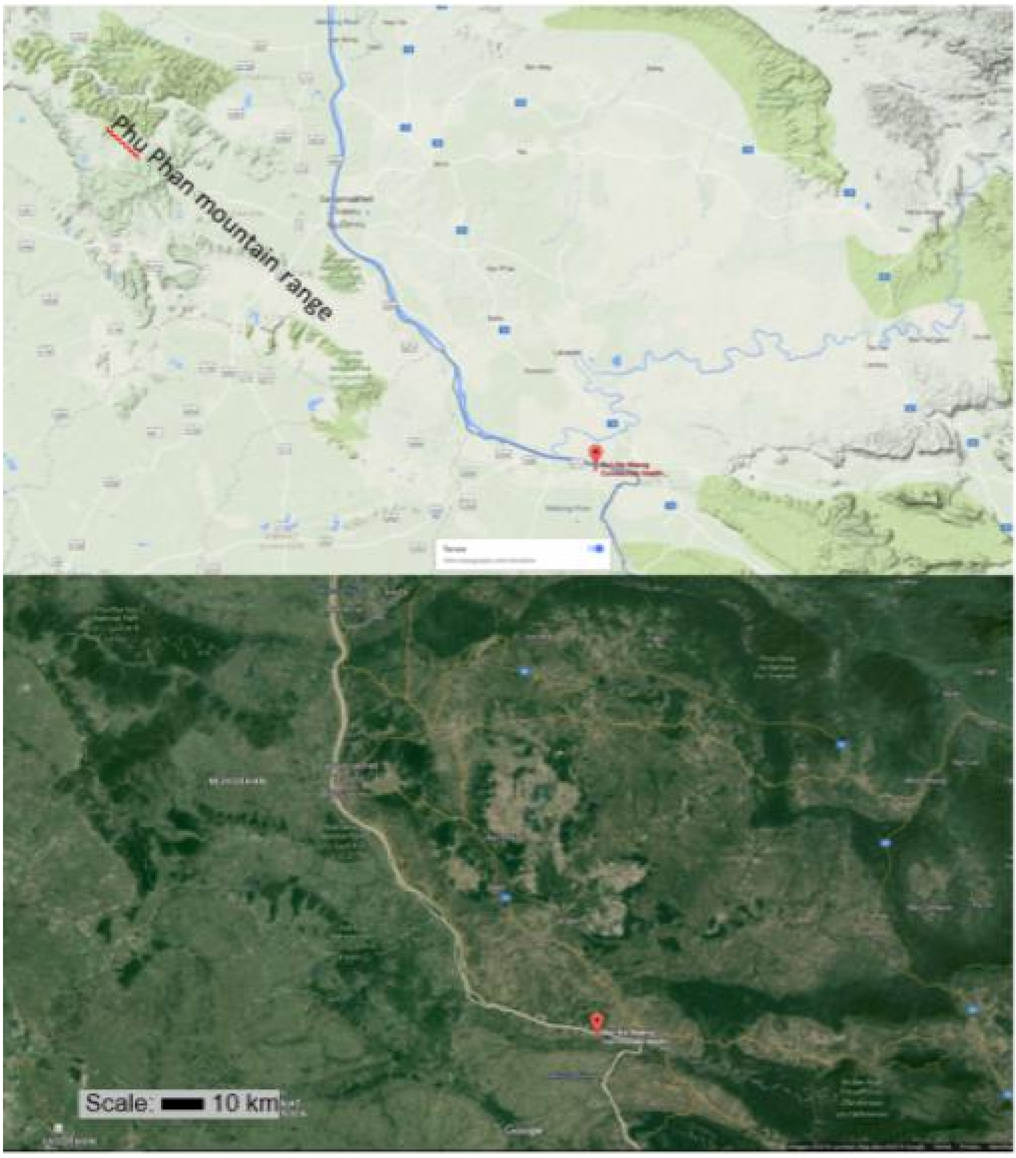


Figure 4.3: Topography of Na Waeng in Ubon Ratchathani Province, Thailand

Note: Red pins show a location of *baan* Na Waeng (Source: Adapted from Google Maps, 2016)

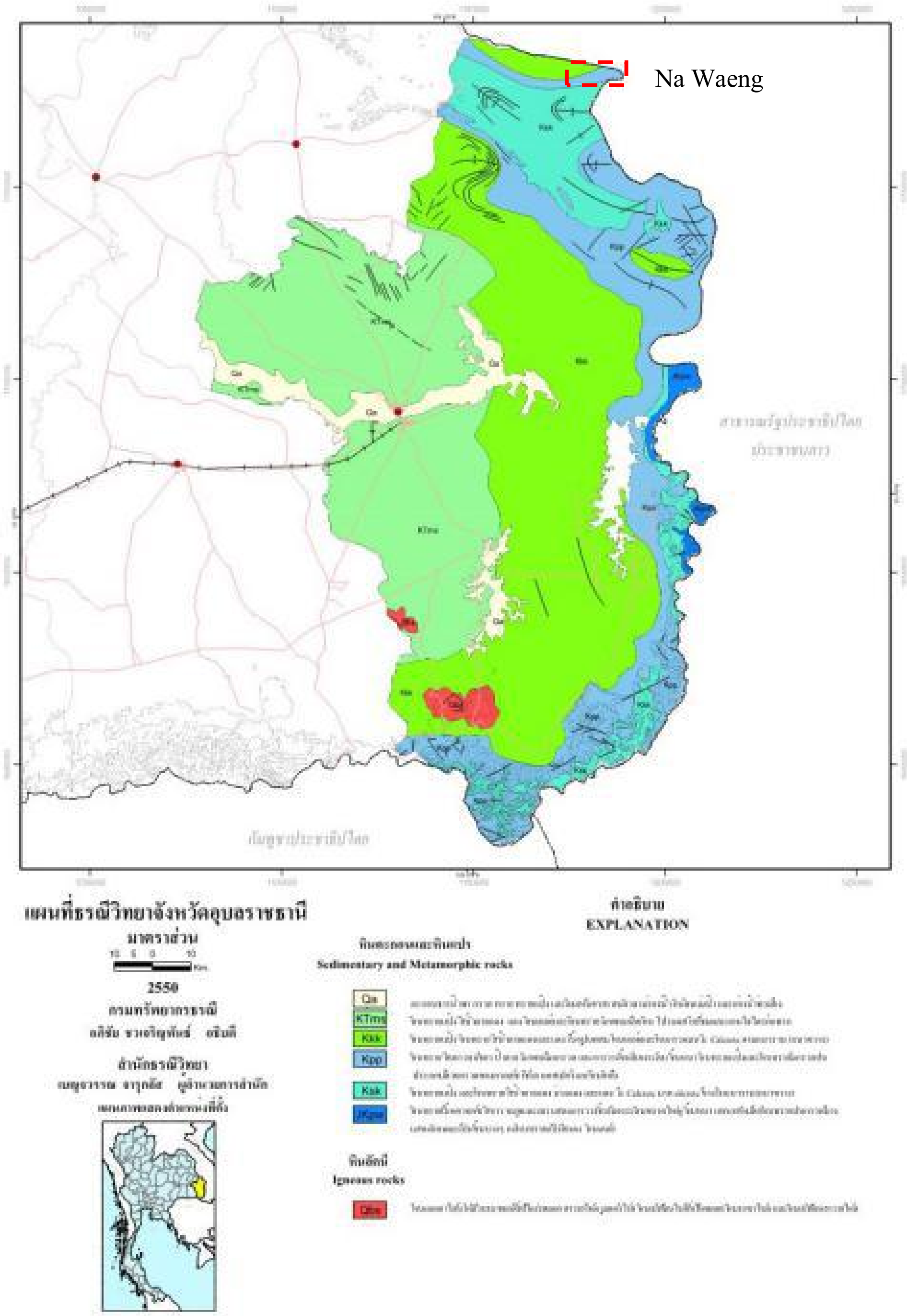


Figure 4.4: Geological map of Ubon Ratchathani in Thailand (Source: Department of Mineral Resources, 2010). See Table 4.1 for translation of geological units

Table 4.1: Geological description of the Khorat groups (from Figure 4.4)

ABBREVIATION	TYPE OF ROCKS	KHORAT GROUP/ FORMATIONS	AGE (my.)
Qa	Alluvial deposits: sand, silt, clay and fine-grained gravel	-	QUATERARY
KTms	Clay stone, shale, siltstone and very fine-grained sandstone: red and reddish brown, with rock salt and evaporate rocks are cross-bedded.	Mahasarakham	CRETACEOUS
Kkk	Siltstone, clay stone and sandstone: brown, reddish brown, fin-medium-grained, moderate to poorly sorted, micaceous, cross-bedded and calcrete horizons are present.	KhokKrut	
Kpp	Sandstone: grayish white, conglomerate, medium to coarse grained, poor sorted, sub-angular to sub-rounded, with pebbles of quartz, chert, red, gray, black, brown and volcanic rock fragment and quartzite, cross-bedded, siltstone and clay stone, gray to dark gray, thin bedded and conglomerate are interrelated locally.	PhuPhan	
Ksk	Quartzitic and arkose sandstone: purplish brown, medium-grained, poor sorted, moderately cemented, small-scale cross-bedded, siltstone and clay stone, reddish brown, calcrete and silcrete horizons, conglomeratic sandstone, fossils are found in some locally.	Sao Khua	
JKpw	Sandstone: grayish white, quartzitic, fine to coarse grained, moderately well sorted, sub-rounded, with pebbled of quartz gray and black charts, quartzite, cross-bedded, conglomeratic sandstone, siltstone, clay stone, gray to dark gray, thin bedded, are interrelated locally.	PhraWihan	CRETACEOUS - JURASSIC
Qbs	Alkali and olivine basalt: with megacrysts of hawaiite, mugearite, basanite, nephelinehawaiite	-	TERTIARY

4.4 Climatic conditions

There are three distinct seasons in Ubon Ratchathani. During the wet season, which lasts from May to October, the heaviest rain occurs during August and September, when flooding often happens as a result of cyclonic depressions crossing the area from the South China Sea. During the cold/dry season, which runs from November to January, the northeast monsoon brings cool temperatures to the area, and this is followed by a very hot, dry season which lasts from February to April.

Over the period 2002 to 2011 (latest data available), the total annual rainfall was somewhat lower than average during the first four years – from 2002 to 2005, then after 2005 the rainfall amounts fluctuated (see Figure 4.5). The driest year was 2005, when the annual rainfall figure was 1,323 millimetres (mm), which was below the 30-year average of 1,357 mm. Two years later, 2007 was the wettest year of the decade, with a total annual rainfall figure of 2,030 mm.

Interestingly, in terms of average temperatures over the same period, 2002 recorded both the hottest and the coolest days: 36.3°C and 19.7 °C respectively, as shown in Figure 4.6. In general, the annual average minimum temperature varied from 19.7°C to 22.7°C, with the highest values ranging between 32°C and 36°C.

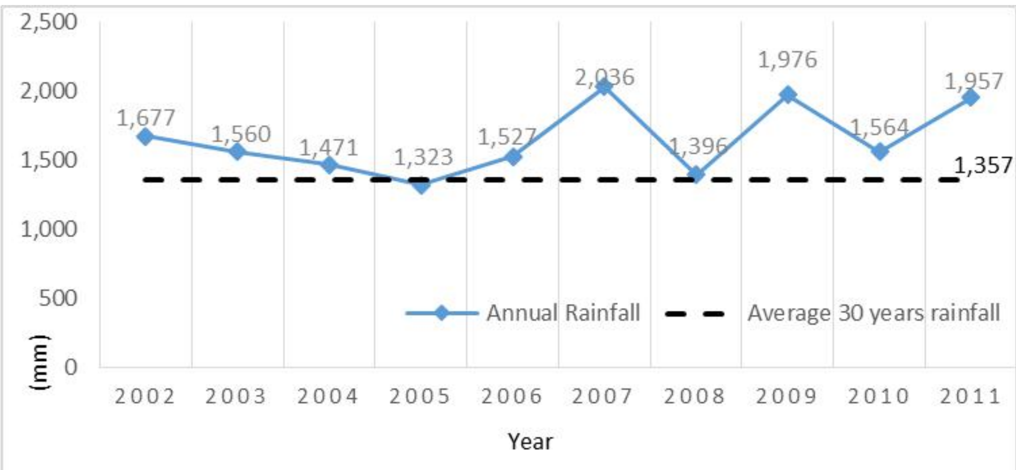


Figure 4.5: Total annual rainfall for the period 2002 – 2011, plus the 30-year average rainfall figure; both for Ubon Ratchathani in Thailand (Source: National Statistical Office, 2013).

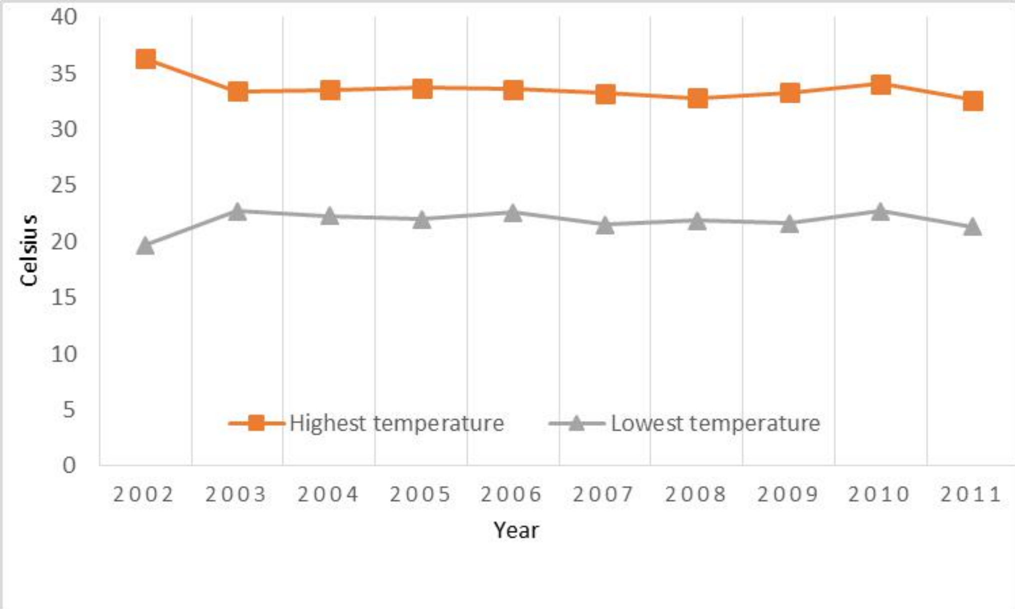


Figure 4.6: Annual average temperature for 2002 – 2011 in Ubon Ratchathani, Thailand (Source: National Statistical Office, 2013).

4.5 *Chaopramong* in five fishing communities

After the key informant interviews were conducted with *chaopramong* (see section 3.4.2) and personal observations had been carried out (see section 3.4.2.2), in total 20 male *chaopramong* were represented in the study from the five fishing communities in Na Waeng. The average number of years fishing experience of the participants was 20 years, with the majority of *chaopramong* (40%) aged 60 and above, but ranging between 30 and 72 years-old. The age groups 30 to 40 and 41 to 60 each represented 30% of the total number of participants (Figure 4.8-A). Overall, most were early settlers who have lived in their villages for more than 15 years (95%), while only 5% have lived there less than 15 years and moved to the area from other provinces. Of the total sample, 85% of the *chaopramong* who were asked, 'Are you the head of the household?' responded yes, while 15% said no.

It is important to note that the research design did not intend to prevent female *chaopramong* from being part of the key informant interviews. However, it is mostly male *chaopramong* who are in charge of fishing on the Mekong River where the water current is powerful. Additionally, fishing requires not only the skill of manoeuvring the boat and deploying fishing gear, but also the physical strength to carry and to cast the heavy gear efficiently. Therefore, most *chaopramong* are male and could demonstrate more detailed LEK. However, female *chaopramong* may also have relevant LEK about fish. For instance, there are some female *chaopramong* and kids engage in fishing from the shore using scoop nets [*sa-wing*], harpoons [*cha-moueng*], and single hook bamboo pole and line [*bet*]. Furthermore, mostly it is the women who are usually in charge of cooking and preserving fish.

4.5.1 Overview of *chaopramong*

This census includes data on the number of households, plus work activities by business sector, including agriculture, fisheries and non-agricultural activities (Figure 4.7). Overall, the agricultural sector is the biggest, followed by non-agriculture and fisheries. It should be noted that, in reality, more than one major business activity can take place in any given household, so the total number of households per business sector is higher than the total number of households. Of this number, Ladcharoen has the largest number of households who rely on fisheries (40 households), while Boungmoung has none.

The average annual income per household per key business sector (Figure 4.8) also reflects this outcome, as the highest incomes come from the agricultural sector. Note that the incomes derived from fisheries are included as a sub-group within the agriculture sector. In overview, all of these villages rely on agriculture; more than 70% out of all the business sectors. The highest annual average incomes for 2013 were in Ladcharoen (53,000 THB or ~1,600 USD), while the remaining villages tend to earn lower incomes, in the range 42,000 to 45,000 THB or 1,200-1,300 USD per year.

The average household size in the survey was 3.3 persons per household, with an equal number of male and females. This figure is higher than the national average of 3.1 persons per household, but lower than the northeast regional average of

3.5 persons per household. The majority of households (75%) had four to six members, with only 20% having one to three members. The remaining households (5%) had seven members in their families, the largest number in the survey group (Figure 4.9-B).

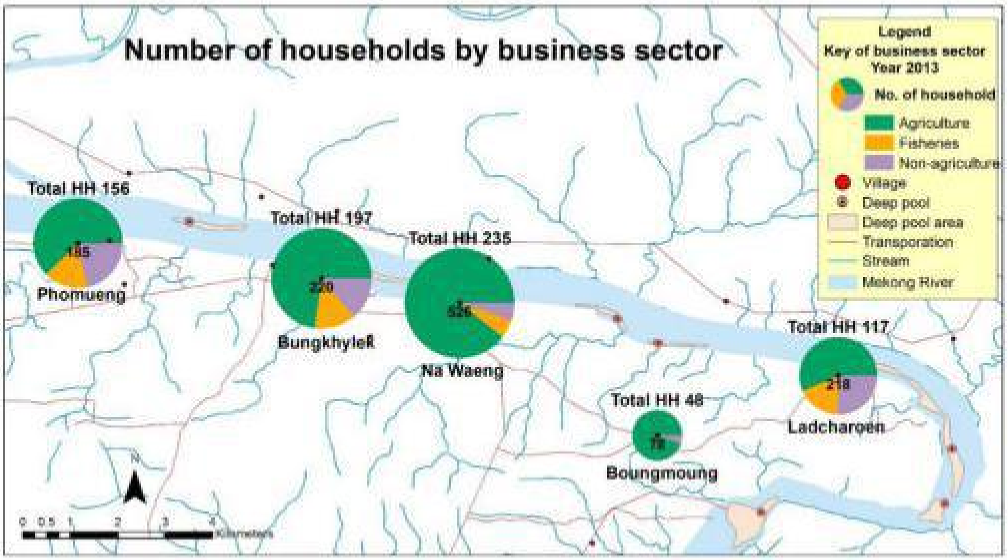


Figure 4.7: Number of households by business sector in the five study villages

(Total HH: The total number of households per village; the number inside the pie chart is the total number of households in all of the key business sectors) (Map prepared by Author, 2014).

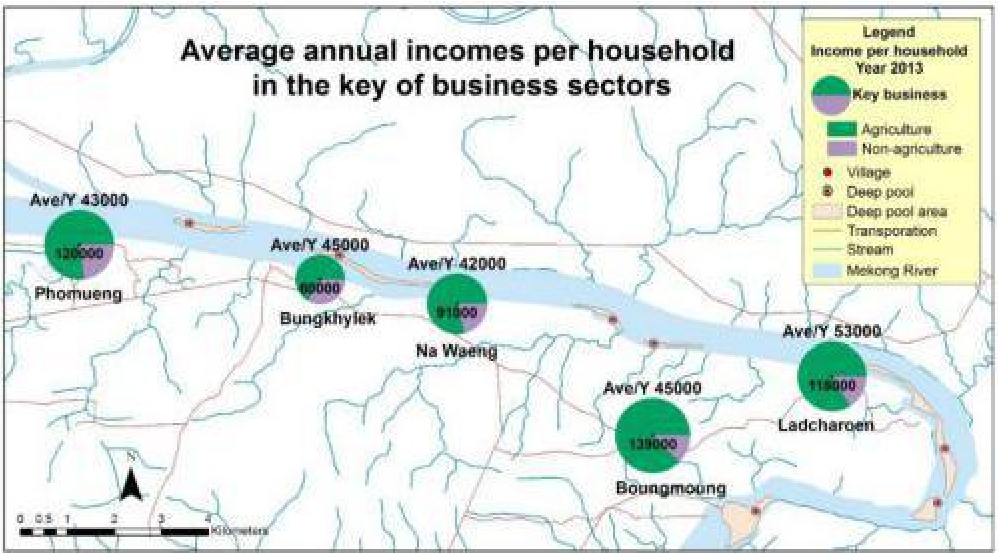


Figure 4.8: Average annual incomes per household in the key of business sectors for the five study villages.

(Ave/Y: Annual average income per person per village (THB/person/year); the number inside each pie chart is an annual average income per household for all key business sector (THB/household/year)) (Map prepared by Author, 2014).

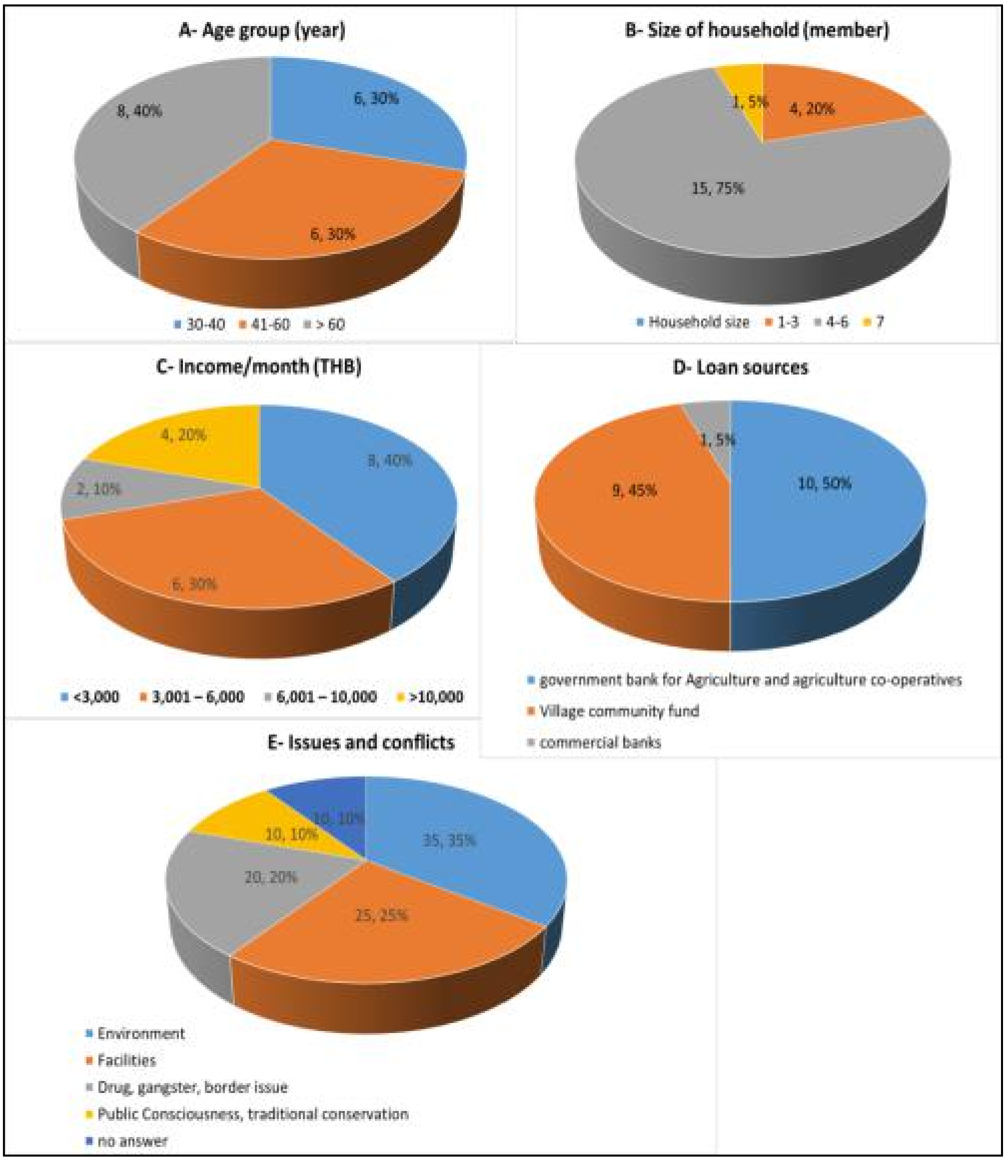


Figure 4.9: Survey information of *chaopramong*'s livelihoods

The study's fishing households derive their incomes from a wide range of sources. As might be expected, agriculture is the primary occupation, including rice, cassava and corn farming. A large proportion of the households (40%) earn a monthly income of less than 3,000 THB but, interestingly, the group that earns more than 10,000 THB per month (20%), is larger than those who earn 6,001 to 10,000 THB (10%), though it is smaller than the group earning 3,001 to 6,000 THB (30%) (see Figure 4.9-C). In order to meet basic needs or invest in productive endeavours, 75% of the households said they take out loans from the government bank, 50% from agriculture co-operatives, 45% from the village community fund, and 5% from commercial banks (Figure 4.9-D). While comparing the income of chaopramong in Na Waeng with the GPP per capita in Ubon Ratchathani, which as stated earlier in section 4.1 was 44,800 THB per year or 3,700 THB per month, it reveals that almost 40% of chaopramong's households were living under the poverty line.

The survey also asked about problems encountered in the communities and areas for improvement, and poverty reduction was not mentioned among the surveyed households. The most mentioned issue category was the environment, including river bank erosion and over-fishing (35%), followed by community facilities (25%), drug and border issues (20%), public consciousness and traditional conservation measures (10%), and finally those with no opinion (10%) (Figure 4.9-E).

4.5.2 Becoming a *chaopramong*

Most of the respondents said they became *chaopramong* by choice, learning from their relatives as children, and gaining ecological knowledge through personal observations of the river during the different seasons. As a result, their LEK plays a vital role in helping them to understand the navigation routes in the river, riverbed characteristics, and where best to catch fish. Most of the *chaopramong* agreed that deep pools are key fish habitats and spawning grounds, contain an abundance of fish, and act as fish refuges during the dry season; similar results to the research findings concerning the function of deep pools.

4.5.3 Types of *chaopramong* and boat uses

Chaopramong in the study area can be classified into three types, according to the amount of time they spend fishing. According to the interviews, there are occasional *chaopramong* (20%), part-time *chaopramong* (60%) and full-time *chaopramong* (20%). In Ladcharoen, the occasional *chaopramong* fish during festivals and fishing competitions in April, or fish during their holidays. Most of the fish caught by these *chaopramong* are consumed at home. The occasional *chaopramong* interviewed in Ladcharoen village prefer to use fishing rods for recreational fishing, as rods are easy to use and require no installation.

In terms of importance and effort, the part-time *chaopramong*'s fishing activities are on a par with or slightly below their permanent jobs as daily wage workers, government officers, private business owners and farmers. Perhaps not surprisingly, these *chaopramong* use most of the fishing gear types available, and some make their own gear – for use and for sale. However, limits on their time mean they normally use gear which takes up little time to install and use, such as traps and stationary gillnets, as these can be installed in advance, left overnight and revisited during the day, to collect the fish. Most of the fish caught are eaten at home or sold at the market. For instance, popular species include *Hemibagrus filamentus* (Blacktailed Catfish, *pla kod mor*: ~220 THB/kg), which is served in restaurants, and *Datnioides undecimradiatus* (Mekong tiger fish, *pla lard, pla seo tor*: ~300 THB/kg), which is kept in home fish tanks. In Bungkhylek, the part-time *chaopramong* have formed a group to take advantage of the abundant fish stocks that exist during the fish migration period in the dry season, during which time they use large-scale fishing gear such as dragnets to catch certain fish species, such as the Mekong giant catfish and schools of fish from the *Cyprinidae* and *Cobitidae* families.

Lastly, professional *chaopramong*'s livelihoods depend entirely on fishing, and they work either individually or as daily wage workers and/or contract *chaopramong*. These fishers can be found in all five fishing communities, but there are only a few cases. Perhaps not surprisingly, and similar to the previous group, they use a wide range of fishing gear, and have much more practical experience of using each type. For the paid workers and contract *chaopramong*, they invest little in fishing gear when compared to the other categories of *chaopramong*. The use of modern gear using modern materials, such as gillnets, cast nets and dragnets is highly efficient and tends to be concentrated in the professional fishing industry. It is noteworthy that I found no evidence of local regulations being used with regard to fisheries conservation among the communities.

In terms of the boats used (see Figure 4.10), most *chaopramong* use motorized boats, especially in Ladcharoen where the river has strong currents, whirlpools and rapids. In some parts of the river where the water flows slowly, boats without engines can be used, mostly around *baan* Na Waeng.

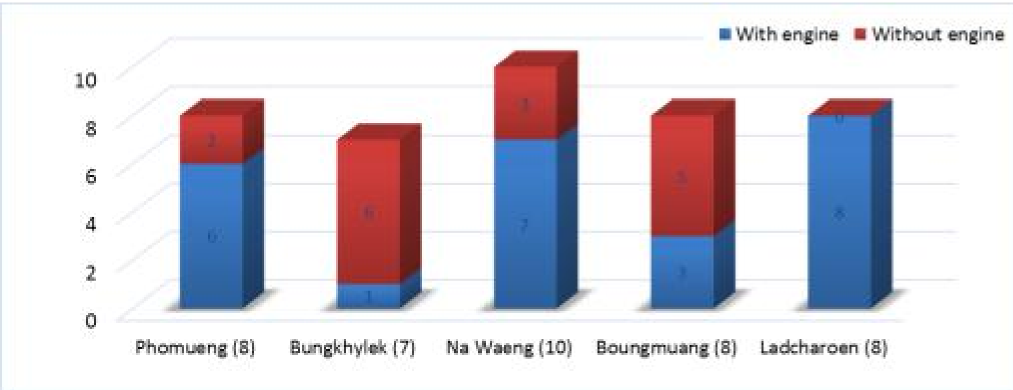


Figure 4.10: Types of boat used in five fishing communities in Na Waeng

4.5.4 Catch rates and fisheries income

Catch Per Unit Effort (CPUE) is commonly accepted as a more accurate index of fish stock size (Ricker, 1975; Prouzet & Dumas, 1988), because it can provide beneficial information regarding fisheries management activities and can therefore help predict patterns in terms of fisheries resources (Bunt and Cowx, 1991). This study employed the CPUE method to present baseline data in line with the gear used (Table 4.2), and fisheries incomes in the five study villages (Table 4.3). It should be noted that one limitation of this study is that I could not calculate CPUE for the time spent using each type of gear, as *chaopramong* employ more than one type of gear during their fishing activities, and so use different mesh sizes per catch. Therefore, I could only calculate CPUE over a time unit of 30 days, for ad hoc catch monitoring for all gear. Table 4.2- C excludes drag net usage as this was only used once during the catch monitoring period, making its time unit only one day while fishing rods that were used for recreational fishing purpose only are similarly excluded.

Table 4.2: Fishing gear used, fishing effort (A) and catch rates (B, C) during 30-day catch monitoring programme in Na Waeng.

A

Village	No. of voluntary fishermen	Type of fishing gear					
		Trap	Drag net	Fishing rod	Long line hooks	Drift gillne	Stationary gillnet
Phomueng	8	3	-	-	4	4	3
Bungkeylek	7	4	1	-	3	-	5
Na Waeng	10	9	-	-	6	5	8
Boungmuang	8	1	-	-	1	7	2
Ladcharoen	8	1	-	1	7	2	2
Total	41	18	1	1	21	18	20

B

Village	Type of fishing gear (kg)						Total catch (kg)
	Trap	Drag net	Fishing rod	Long line hooks	Drift gillne	Stationary gillnet	
Phomueng	5	-	-	60.8	36.9	81.4	184.1
Bungkeylek	36	9.5	-	14	-	59.4	118.9
Na Waeng	48.4	-	-	62.8	-	301	412.2
Boungmuang		-	-	0.5	16.5	4.3	21.3
Ladcharoen	3.2	-	13.6	172.1	6	68.1	263
Total	92.6	9.5	13.6	310.2	59.4	514.2	999.5

C

Village	CPUE of fishing gear				Total CPUE (kg)
	Trap	Long line hooks	Drift gillnet	Stationary gillnet	
Phomueng	1.7	15.2	9.2	27.1	53.2
Bungkeylek	9.0	4.7	-	11.9	25.5
Na Waeng	5.4	10.5	0.0	37.6	53.5
Boungmuang	0.0	0.5	2.4	2.2	5.0
Ladcharoen	3.2	24.6	3.0	34.1	64.8
Mean	3.8	11.1	3.6	22.6	41.1
CPUE(catch/gear/day)	0.1	0.4	0.1	0.8	1.4

Table 4.2-A shows the types of fishing gear and fishing methods used by the study *chaopramong* in the five villages. The largest number of *chaopramong* is shown in *baan* Na Waeng, with ten, and they have the largest catches (Table 4.2-B). These *chaopramong* tend to use six different types of fishing gear during the dry season, these being long line hooks, stationary gillnets, traps, drift gillnets, drag nets, and fishing rods (Table 4.2-A). Table 4.2-B shows the level of variability in the different types of gear used per catch (kg); the top three gear types being stationary gillnets, long line hooks and traps.

The one month average of CPUE values obtained for the gear used (Table 4.2-C) reveals a high degree of variability between the different types of gear used, with stationary gillnets, long line hooks, traps and drift gillnets used, in that order (0.8, 0.4, 0.1, 0.1 catch/gear/day). The types of gear used are similar throughout the villages, except some *chaopramong* in Ladcharoen and Bungkhylek who favour fishing rods and dragnets, respectively. The types of fishing gear used reveal the economic status of the fishers, with the highest fishing incomes to be found in Ladcharoen, at 3,925 THB per person per month (Table 4.3). The catch per person per month values for Ladcharoen (33 kg) rank second behind *baan* Na Waeng (41 kg), and an analysis of the composition of fish catches or fish landed (described further in section 6.3.2 on figure 6.8) among these two villages helps explain this, as in *baan* Na Waeng the catch mostly includes *Henicorhynchus siamensis* [*pla soi khao*] (price: 50 THB/kg), while in Ladcharoen it is *Pangasius bocourti* [*pla yang*] (price: 100 THB/kg). These prices refer to the mid-range merchant's price offered to the *chaopramong* in the relevant village; therefore, the incomes of those in Ladcharoen are higher than in *baan* Na Waeng, and also the highest among the study villages (see Table 4.3).

Table 4.3: Fisheries income of the five study villages

Village	Fisheries		
	Catch/person/month(kg)	Total income/month (THB)	Income/person/month (THB)
Phomueng	23	27,196	3,400
Bungkeylek	17	11,080	1,583
Na Waeng	41	31,276	3,128
Boungmuang	3	1,907	238
Ladcharoen	33	31,401	3,925

4.5.5 Sacralization of the Mekong River in Na Waeng

People in Na Waeng have strong spiritual beliefs regarding deep pools and the Mekong River, and this is reflected in the telling of folktales. For example, it is believed that strong spirits live in deep pools, caves and rivers, and on islands, so it is dangerous for fishing boats to pass such places without offering prayers. In addition, it is good luck to catch a lot of fish after *chaopramon*g have asked the spirits for permission. In some cases, they reveal their sacred vows to the River guardian spirit "*kho kin kho yaak kho pu kho pla kor hai dai na pho*" [ขอกิน ขออยาก ขอปู ขอปลา ก็ให้ได้ นะพ่อ], which means "ask for eat ask for food ask for crab ask for fish then give me to have it, the guardian spirit", or some traditional ways of paying respect to the spirits by washing their faces with river water before fishing. Whist catching fish, *chaopramon*g would not say "fish is too big" or while eating food nearby the river, "I am full" otherwise it would be a bad luck and they might not catch any big fish at all. It is believed that the tributaries of the Mekong River in Laos and Thailand, especially in the Northeast of Thailand or *Isan*, are the remnants of fighting between the *nagas* (mythical creatures living in the Mekong River). Every year, during the sixth month of the lunar calendar (around mid-April) in Cambodia, Laos and Thailand, they celebrate New Year, during which time Buddhist ceremonies are held to honour the sacred river spirits. Villagers [*chaobaan*] in Na Waeng and Nakho village in Laos will arrange the Buddhist ceremony for *Chao Pho* Xe Namnoi [guardian spirit of Namnoi stream]. Xe Namnoi is a tributary of the Mekong River in Laos.

While paying attention to the root of these beliefs, Buddhism is the predominant religion of people living along the Mekong River from the headwaters to the Mekong delta. Hence Buddhism has not only influenced those people, but also has created folk narratives and the common perception of the relationship between Buddhism and the Mekong River. According to Hongsawan (2011) there are four major kinds of folk narratives that construct the sacralization of the Mekong River as explained in the following brief description.

Firstly, there are narratives about the origin and the characteristics of the Mekong River, which is believed to have been created by the power of the lord of Buddha who separated the Himalaya mountain range, allowing the water reserved at the top of the mountain to flow down and become the mainstream for humankind

(Gargan, 2002, 22–23 and Bell, 2007, 19, 31). Some believe among "*the Buddhist people of highland Tibet in the upstream part of the Mekong that the river also signifies a powerful accumulation of merit and a return to nature* " (Yoon, 2009, 30).

Secondly, there are narratives about sacred objects and sacred places. For instance footprints and images of the Lord Buddha, and stupas enshrined in the area of the Mekong River are evidence which reflects the beliefs and practices of people living along the river banks. An interesting example is the La Nong Stupa, which is in the middle of the Mekong River in Muang district, Nong Khai province in Thailand. It is believed that, originally, this stupa was located on the river bank of the Mekong River and was submerged beneath the river when the river changed its direction. Since then, the villagers have believed that the Buddha's relics were instead taken care of by the Naga in his underworld kingdom. This therefore illustrates the villagers' perception of the Mekong River as a sacred river containing the Buddha's relics.

Thirdly, there are narratives about sacred animals and sacred trees. Folk narratives concerning the Mekong River told in various communities along the river have enhanced the peoples' perception that the animals inhabiting the river are somehow related to Buddhist belief. The giant catfish, widely known as an important species of fish living in the Mekong River, has been accepted as a sacred fish and its narrative is related to the legend of the river. The giant catfish is perceived by local people as being "pure" and "clean", as it is a large animal that eats only plants and is harmless to other kinds of fish in the river and, moreover, its eyes look downwards like the eyes of the Buddha do in images (Hongsuwan, 2009, 155). Another narrative relates to the Maneekote, which is a sacred tree found in the middle and south of the Mekong River. In Laos, the people worship this tree as if worshipping the Lord Buddha as Rama, as an episode from the Buddha's life records his eating of the fruit from this sacred tree.

Fourthly, narratives explaining rituals and traditions reveal relationships between the Mekong River and folk Buddhism in the calendrical rites. For instance, in *Isan* and Laotian tradition there is the rite of *lai rue fai* (decorating the boats with lanterns and flowers) to worship the Buddha. A similar lantern lighting festival also happens in Cambodia, which is connected to belief if and worship of Naga; as well as to worship the Buddha. Another interesting phenomenon that is found in the *Isan* region and in Laos is named *bang fai phya nak*, which is a folk explanation for the phenomenon of red fire balls that emerge from the Mekong on the full moon day of the eleventh month or on the last day of Buddhist lent[4].. Some people explain that the event is related to the folk belief that this was the way Naga, when seeing the Buddha descending to earth after visiting his mother in heaven, expressed his joy by spitting fire as the symbol of paying respect to the Buddha.

4.5.6 Fishing territories

In terms of fishing territories, the traditional practice is to use community boundaries; however, some *chaopramong* have great difficulty following this rule. If a fisherman breaks this rule, an informal verbal warning will be given by the owner of the fishing territory and a fine of around 4,000 THB will be imposed if it happens again. Similarly, but on a country scale, along the river border between Laos and Thailand there have been reports of warning shots fired, and even deaths occurring when Thai *chaopramong* cross the border line to Laos. Thai *chaopramong* and Thai navy police disclosed that a few cases had occurred around Phomueng, Bungkhylek and *baan* Na Waeng villages in the last few years. Notably, during the field survey in March 2012 an incident occurred which is described previously in Section 3.4.1. On the other hand, the interviewed Thai *chaopramong* said that they apply a verbal warning at first if Lao *chaopramong* operate within their fishing territories or over the border line.

[4] Buddhist lent is a three-month annual retreat for Theravada practitioners or monks during the rainy season. The lent usually start in between July to October according to the lunar calendar of those year. (see Buddhapadipa Temple, 2016)

Nevertheless, both Laos and Thai *chaopramong* also reported that the line demarcating the border between Laos and Thailand is unclear both in terms of political discussions and physical visualisation, so this particular border issue should be discussed and resolved at the international level. The uncertainty relates to the perception that either all the islands in the Mekong River belong to Laos or, alternatively, the navigation stone markers [*Rong Nam Louk* or *paew*], positioned in the river during the French colonial period, constitute the border. In this connection, according to the office of the Geographer (1962), the signing of the *Treaty of Peace and Convention between France and Siam on 3 October 1893* determined that Siam renounced all rights to islands in the river. In subsequent discussion the two countries agreed in 1926 that the boundary in the Mekong altered with the thalweg of the river, except where islands exist (Office of the Geographer, 1962) (Figure 4.11).

G. Convention for the Regulation of Relations between Siam and Indo-China signed at Bangkok on August 25, 1926.

The convention altered the boundary in the Mekong in the sense that the thalweg of the river was to be followed except where islands exist. In this event the islands were to adhere to Laos and "in those parts of its course in which the Mekong is divided into several branches by islands separated from the Siamese shore at any time of the year by running water, the boundary line is formed by the thalweg of the branch nearest to the Siamese shore."

The Convention further added "At those points where the filling up with sand or the drying up of the branch of the river nearest to the Siamese shore would permanently attach to such shore islands formerly separated from it, the boundary line would, in principle, follow the former thalweg of said branch of the river thus filled up with sand or dried up."

"However, the Permanent High Commission of [the] Mekong shall be called upon practically to examine each case of this kind that might arise, and they may then propose to move such boundary on to the nearest thalweg of the river..."

"There are definitely attached to Siamese territory the lands in the river known under the names of Don Khieo, Don Khieo-Noi, Don Noi, Don Nhiat, Don Banphaeng, Rat Saipeh-Veunkoum, Don Keokong-Dinnau, and Don Somhong, which can be considered as part of the Siamese shore..."

Figure 4.11: Convention for the Regulation of Relations between Siam and Indo-China signed at Bangkok on August 25, 1926 (Office of the Geographer, 1962).

4.6 Conclusion

This chapter has attempted to introduce and describe the study area, the aim being to prepare readers for the analytical part of this dissertation, providing them with an idea of the nature of Na Waeng's resources and its population. Most people in Na Waeng rely on agriculture as their main source of income, for their social organization and cultural assets. Fisheries resources play role in part of food and additional income in the five fishing communities in Na Waeng. According to the interviews, being a *chaopramong* is of their choice and fishing on a part-time basis (60% of the total interviewed). Among the five fishing communities, *baan* Na Waeng is the biggest village, the largest population and reveals the highest catch per person per month values (41 kg). While, the highest fishing incomes to be found in Ladcharoen due to the majority of composition of fish catches' price is higher than the composition of fish in *baan* Na Waeng. Therefore, LEK of *chaopramong* to identify fish species in the composition of fish catches play a crucial role in an asset of fisheries information that should not be ignored by researchers and decision makers in fisheries management.

Geologically, Na Waeng sits on an anticlinal structure running in a west-east direction, and the rocky outcrops in the area limit agricultural production. In addition, the structure of this anticline influences the geomorphology of the Mekong River; a key factor in the development of deep pools in the area. The following chapter will elaborate upon the geomorphology of the deep pools to be found around Na Waeng.

CHAPTER 5

The Geomorphology of Deep Pools

5.1 Introduction

Deep pools found along the Mekong River form part of the deep streambed that exists in the main river channel, and they are widespread along the length of the river and its tributaries. Using a similar approach to the study of Lisle and Hilton (1992), the Mekong River Commission (MRC) has used geomorphic statistical analysis and the zero-crossing method to identify more than 400 deep pools in the main channel of the Lower Mekong River -. A deep pool is a streambed depression that forms in a river's main channel, leaving a negative residual on the horizontal datum as defined by the approximate lowest water level. The development of greater levels of knowledge on the characteristics of deep pools, may contribute to a better understanding of the Mekong's geomorphology and the function of deep pools as refuges for many fish species during the dry season. Therefore, the aim of this chapter is to investigate the characteristics of those deep pools in the study area around Na Waeng and the controls placed on them, by exploring their topography and geomorphological structures, and by applying regression analysis.

I know of no previous work that has examined the prominent cluster of deep pools around Na Waeng, one of which is the deepest example on the Mekong River, at 90.5 m in depth. Interestingly, while conducting the river survey, in March 2012, I found one additional deep pool with a depth of 171 m (water depth), as measured in the dry season, making it deeper than the one mentioned above. Therefore, it will be interesting to investigate the reasons behind the characteristics developed by such deep pools, and I will do so in the discussion section of this chapter.

5.2 Data processing and analysis

The data processing and analysis carried out for this study aimed to visualize deep pool characteristics and their controls, using regression analysis and by exploring the topography and geomorphological structure of the study site and the surrounding region. The sources for the data collected can be divided into three:

(1) River survey: A river survey captured information (see Section 3.4.1) regarding the deep pools' characteristics and their relationships with fish habitats (see Figure 5.1)

(2) GIS base maps and data from the MRC: GIS base maps of the Mekong River, a hydrographic atlas (see Figure 5.2), the morphological characteristics of the deep pools (see details in Section 2.8, Table 2.5), river depth sounding, and Mekong Digital Elevation Model (DEM).

(3) Other sources: SRTM, scene12649 - from the University of Maryland, and a geological map of northeast Thailand from the same university's Department of Minerals and Resources.

In order to investigate the geomorphology of the study's deep pools, a large number of spatial model inputs and processes were used to form the data needed for the spatial analysis tools used in ArcGIS 10.1. As can be seen in Table 5.1, spatial parameters and input variables were used to aggregate the data before entering it into the GIS database, after which all the data could be used for visualization, variables measurement, and both three dimensional and statistical analysis.

For this study I used regression analysis[5] to measure any relationships between the deep pools' characteristics, using the statistical software package Minitab 16.2.3. Table 5.2 shows a complete list of the 12 independent variables used, which are those considered to influence the morphometric characteristics of the study's deep

[5]This statistical technique is the most commonly applied to derive a correlation between pool-riffle characteristics and river geomorphology (Wohl and Legleiter, 2003; and Thomson and Hoffman, 2001).

pools. Along with channel characteristic variables, six independent variables (Table 5.3) were derived based on the measurement methods shown in Figure 5.3, and using the hydrographic atlas as a baseline.

Table 5.1: Spatial model inputs

Theme	Input data	Spatial analysis methods	Model variables	Source
Administrative boundary	• Sub-district administrative boundary	Clip	• Na Waeng administrative boundary	• Thailand Environmental Institution (TEI), 1996
Village	• Google Earth satellite map, 2011	Digitization	• Village	• Google Earth, 2011
Transportation			• Transportation	
Mekong River	• Channel outline • Tributaries • Dry season channels and obstructions • Morphology • Depth sounding points	Clip	• Channel outline • Tributaries • Dry season channels and obstructions • Types of river bed • Depth sounding	• MRC, 2008b
The hydrographic atlas	• Raster (PDF file)	Merge, geo-referenced, measuring tool (Figure 5.3)	• Hydrographic atlas of Na Waeng	• MRC, 1992
			• Channel characteristics/morphometric (variable no 7-12)	• Wisesjindawat, W
Geology map of NE Thailand	• 1:250000 paper map	Scan, geo-referenced, clip	• Geology • Fault line	• Department of Mineral Resources, Thailand
River bed morphology	• River survey in Section 3.4.1 and depth sounding points from MRC	Append, clip, 3D analysis, surface analysis	• Riverbed characteristics • Thalweg point • DEM	• Wisesjindawat, W
Topography of Na Waeng	• DEM	Clip, 3D analysis, surface analysis	• DEM of Na Waeng and adjacent areas	• SRTM scene12649, USGS, 2006

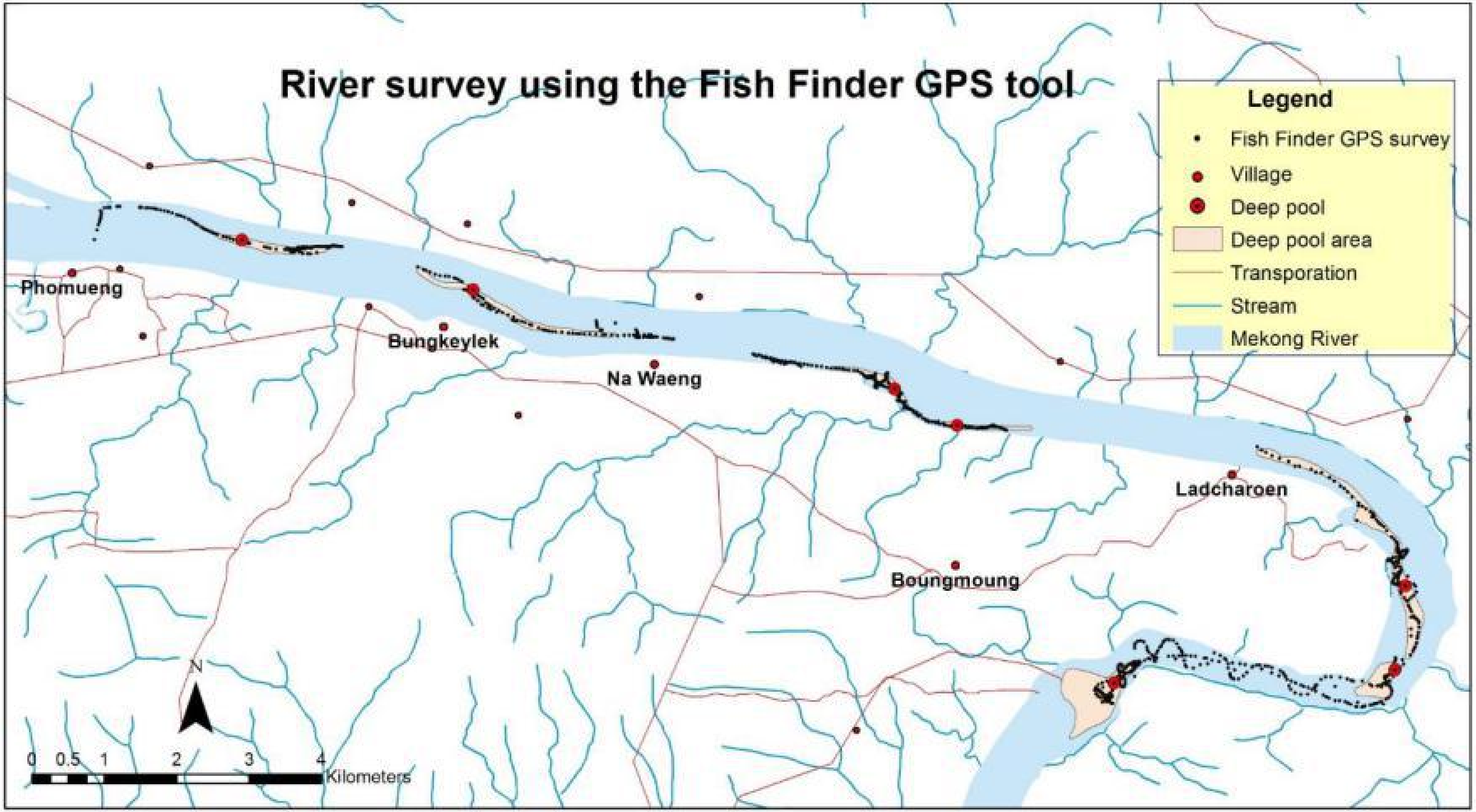


Figure 5.1: River survey using the Fish Finder GPS tool (986 sampling records). Prepared by Author, 2014

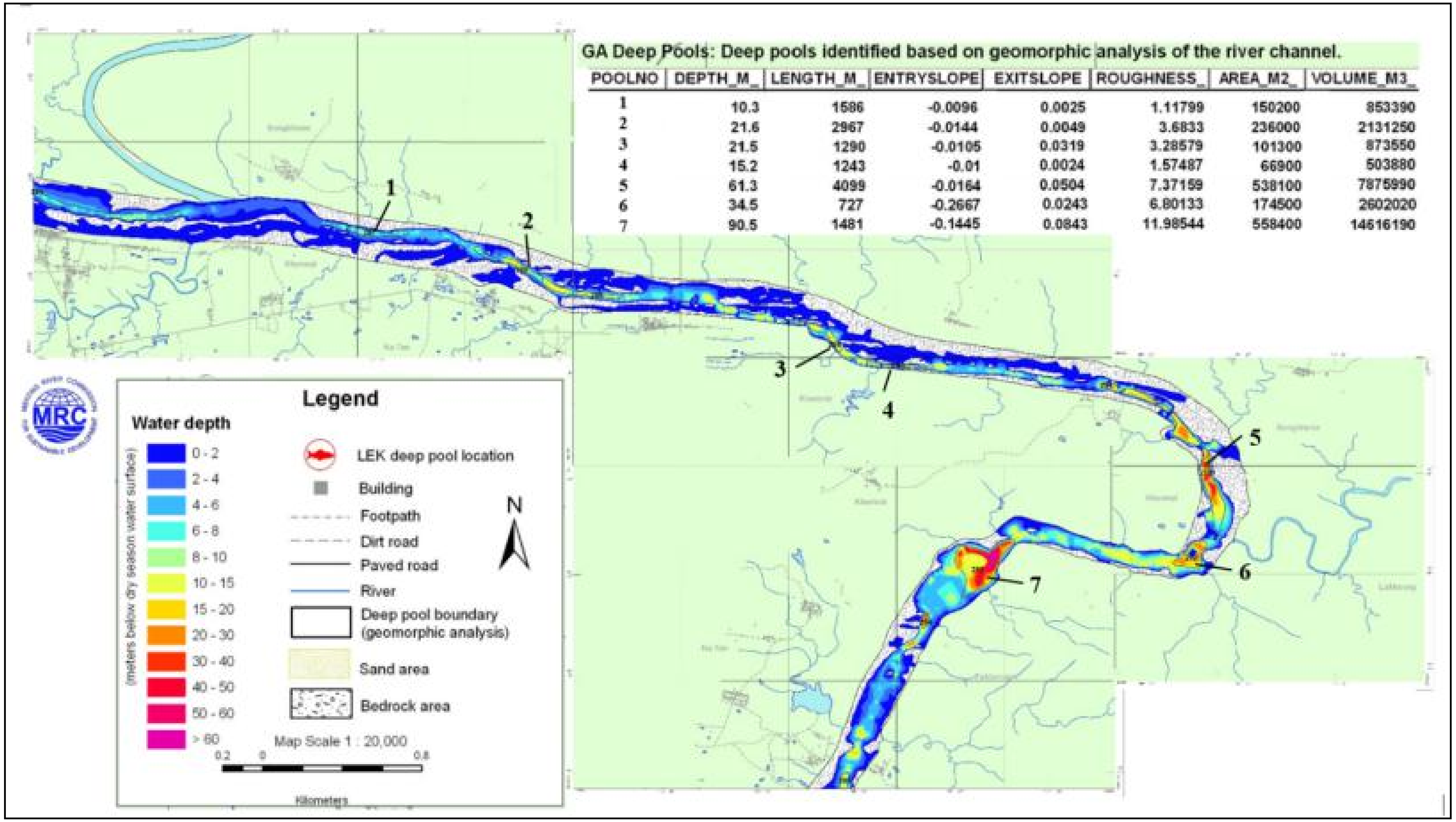


Figure 5.2: Identification of deep pools from a geomorphic statistical analysis in Na Waeng (Data source: adapted from Halls *et al.*, 2013).

Table 5.2: Summary statistics for deep pool and river channel morphometric variables (n=7)

No.	Variables	Minimum	Median	Maximum	Mean	Standard Deviation	Coefficient of variation	Skewness	Kurtosis
1	Maximum depth(m)	10	21.6	90.5	36.4	29.2	0.80	1.31	0.82
2	Length(m)	727	1,481	4,099	1,913	1,185	0.62	1.30	0.85
3	Entry-slope(m/m)	0	-0.01	-0.01	-0.07	0.10	-1.49	-1.71	2.10
4	Exit-slope(m/m)	0	0.02	0.08	0.03	0.03	1.06	1.11	0.66
5	Roughness(m)	1	3.68	11.99	5.12	3.85	0.75	0.91	0.30
6	Area(m2)	66,900	174,500	558,400	260,771	203,631	0.78	0.95	-1.05
7	Deep pool’s centre river width(m)	580	730	863	748	102	0.14	-0.45	-0.51
8	Deep pool’s centre constriction width(m)	73	284	382	261	108	0.41	-0.88	0.12
9	Upstream river width(m)	437	845	952	754	176	0.23	-0.97	0.46
10	Upstream constriction width(m)	160	315	523	311	120	0.39	0.56	0.73
11	Downstream river width(m)	444	835	974	753	176	0.23	-0.84	0.40
12	Downstream constriction width(m)	185	315	895	382	238	0.62	2.07	4.80

Table 5.3: Anticipated influence of morphometric characteristics on the six independent variables

No.*	Control variables	Anticipate on pool maintenance
7	Deep pool, centre bank, full river width(m)	Indication of average velocities
8	Deep pool, centre constriction width(m)	Surrogate for the width of recirculating eddies
9	Upstream bank, full river width(m)	Indication of approach velocities
10	Upstream constriction width(m)	Indication of jet and backwater development
11	Downstream bank, full river width(m)	Indication of average velocities
12	Downstream constriction width(m)	Indication of average velocity conditions over riffles

Source: Adapted from Thomson and Hoffman, 2001

*Referenced number of variables from Table 5.2.

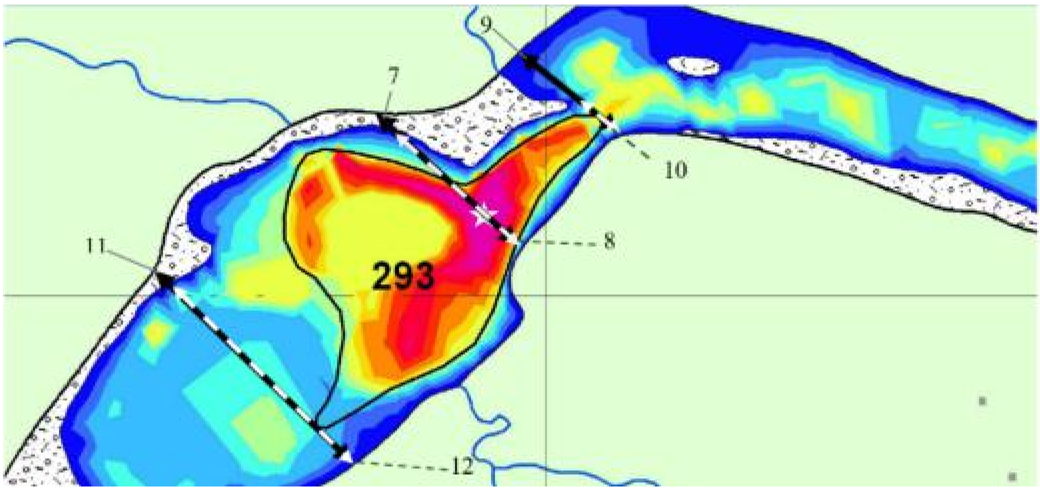


Figure 5.3: Plan view of a deep pool's morphology, showing the measurement locations used to quantify the river channel variables.

The hydrographic atlas was imported to ArcGIS 10.1 to serve as a base map, and variables no. 7-12 were manually measured and calculated as shown in Table 5.3**.**

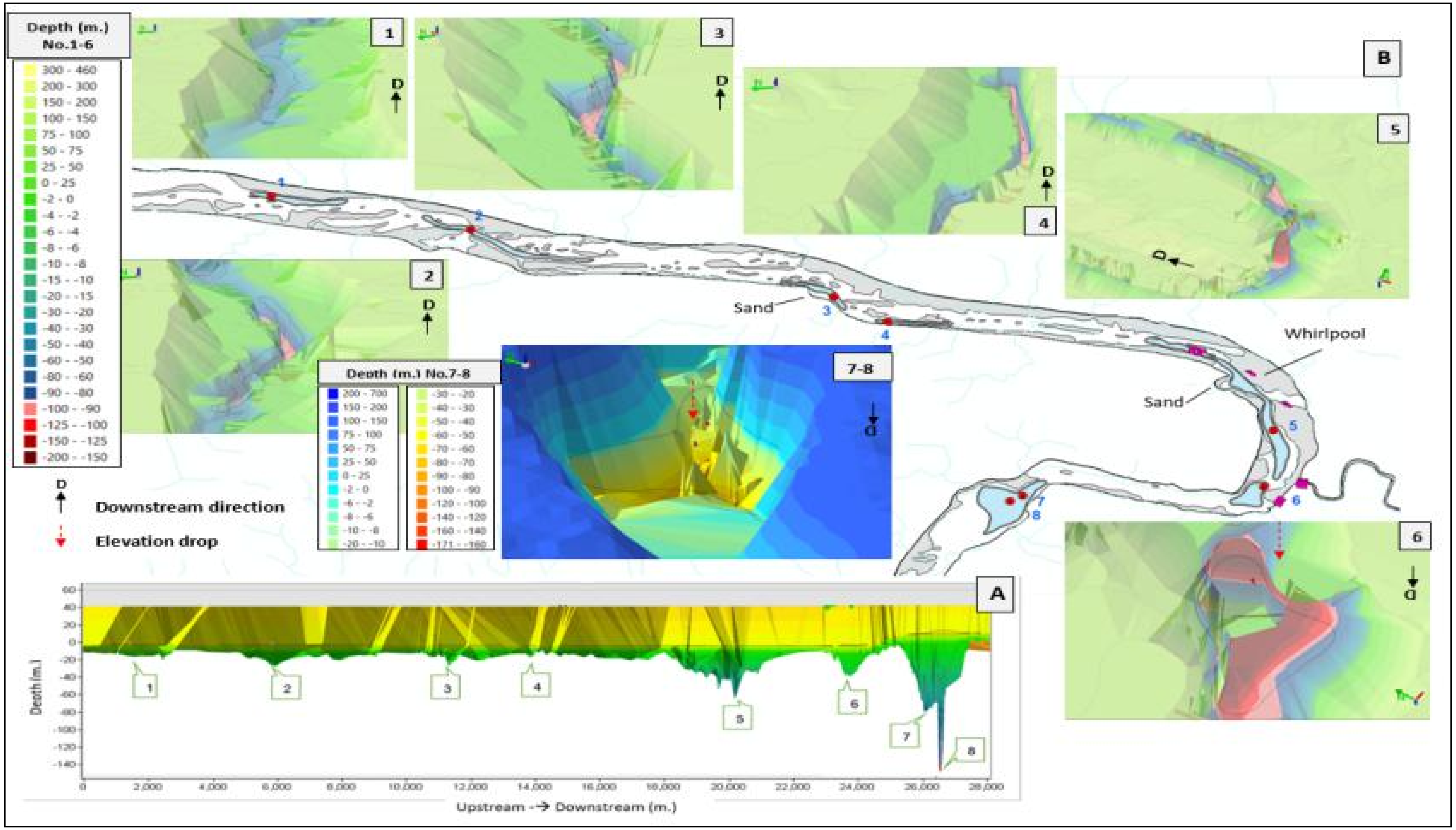


Figure 5.4: Characteristics of the study's deep pools. A- Longitudinal profile of deep pools. B- Characteristics of deep pools show in 3-dimensional model.

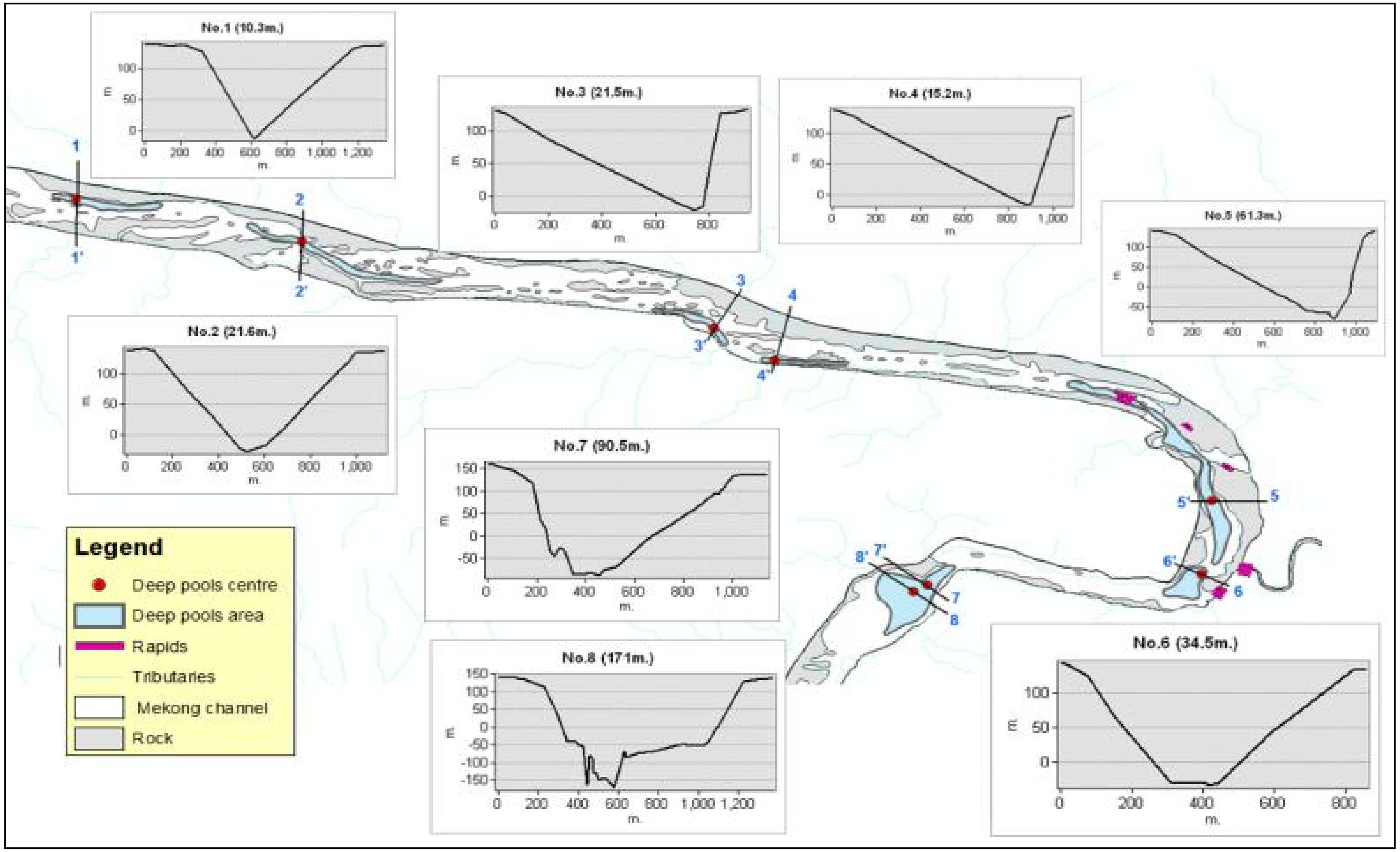


Figure 5.5: Channel cross-sections of deep pool locations in Na Waeng

5.3 Results

5.3.1 Geometry of deep pools

The 28 km channel shown in Figure 5.4-A is characterised by boulders, sand, whirlpools and rapids. All seven deep pools in the area have a lateral bedrock constriction, hence a portion of the river channel wall protrudes approximately 10m (Gupta and Liew, 2006) into the channel. It can be seen clearly in the 3-dimensional model shown in Figure 5.4-B and the cross-sections shown in Figure 5.5, that the pools are asymmetric and relatively narrow, and are scoured on the inside of the channel. These pools can be classified as 'forced' type pools, based on the presence of an inner channel constriction, as described in Section 2.8.3. Deep pools 1 to 4 occur and scour on the inside of the channel and have been elongated in the river; hence, they are long pools stretched by the river's constriction in terms of width. After these pools, the water passes through two hairpin bends where the deep pools have deeper inner channels, and where there are adjacent rapids, rock exposures and surface whirlpools. Deep pool 5 is situated at the hairpin bend, but deep pools 6 to 8 are shorter due to vertical drops and scouring. These vertical drops or drops in elevation are shown by the red arrows for deep pools 6 to 8 in Figure 5.4-B, which reveals a graduated colour profile, with the darker shades of red indicating greater river depths and blue shades shallower depths.

The summary statistics for deep pools and river channel morphometrics shown in Table 5.2 for variables 1 to 6 were identified using the geomorphic statistical analysis carried out by the MRC, and as described in Section 2.8.2. Figure 5.3 and Figure 5.4 reveal that the deepest deep pool (pool 7: 90.5 m or 296.92 feet) based on the MRC's data analysis, is located between Na Waeng and Lakhonepheng in Lao PDR, while the shallowest deep pool is just 10 m deep (pool 1). The longest deep pool is located on the river point bench (pool 5: 4,099 m.), and the shortest deep pool is downstream of this (pool 6: 727 m). The mean deep pool depth was found to be 36.4 m, while the mean deep pool length is 1,913 m. Riverbed roughness is characterized using the bed roughness index (BRI), which ranges between 0 to 17m (the higher the BRI, the rougher the riverbed). Within the study site, the riverbed roughness ranges between 1 and 11.9, and interestingly, the highest roughness index figure was found to be around the deepest deep pool.

In addition, Table 5.2 shows summary statistics for the dependent variables (7 to 12) used in the regression analyses. Based on data taken from the study site, the depth variable is significantly related to riverbed roughness, the exit-slope, the area, the upstream bank full river width, and the downstream constriction width, at statistically significant p-values of <0.05; 0, 0.001, 0.003, 0.011 and 0.025 respectively (Table 5.4). In other words, deeper pools are associated with greater riverbed roughness levels, a steeper exit slope and a smaller area. Narrower upstream bank full river widths and wider downstream constriction widths also correspond to deeper pools. It can be seen clearly in Figure 5.6 that the fitted line plots for the deep pool depths correspond to all the anticipated variables, except the upstream bank full river widths. Furthermore, the figure shows two data points plotted in red that are not a good fit with the equations, or are unusual data-wise, as can be seen in Figure 5.6-B (deep pool 3) and Figure 5.6-E (deep pool 7). The first point shown is to be found in deep pool 3.

Table 5.4: Regression analysis results for deep pool geometry values

Variables	Adjusted R-squared (%)	p-value ($p<0.05$)	Correlation (R value)
Maximum depth (m)			
Roughness (m)	92.02	0.000	0.97
Exit-slope (m/m)	90.18	0.001	0.96
Area (m^2)	81.99	0.003	0.92
Upstream bank full river width (m)	70.66	0.011	-0.87
Downstream constriction width (m)	59.76	0.025	0.82
Roughness (m)			
Area (m^2)	65.83	0.016	0.85
Downstream constriction width (m)	57.96	0.029	0.81
Deep pool's centre constriction width (m)	56.59	0.031	0.80
Upstream bank full river width (m)	54.57	0.035	-0.79
Exit-slope (m/m)			
Upstream bank full river width (m)	90.29	0.001	-0.96
Roughness (m)	82.72	0.003	0.93
Area (m^2)	63.83	0.019	0.84
Downstream constriction width (m)	53.21	0.038	0.78
Deep pool's centre constriction width (m)	50.45	0.045	0.77

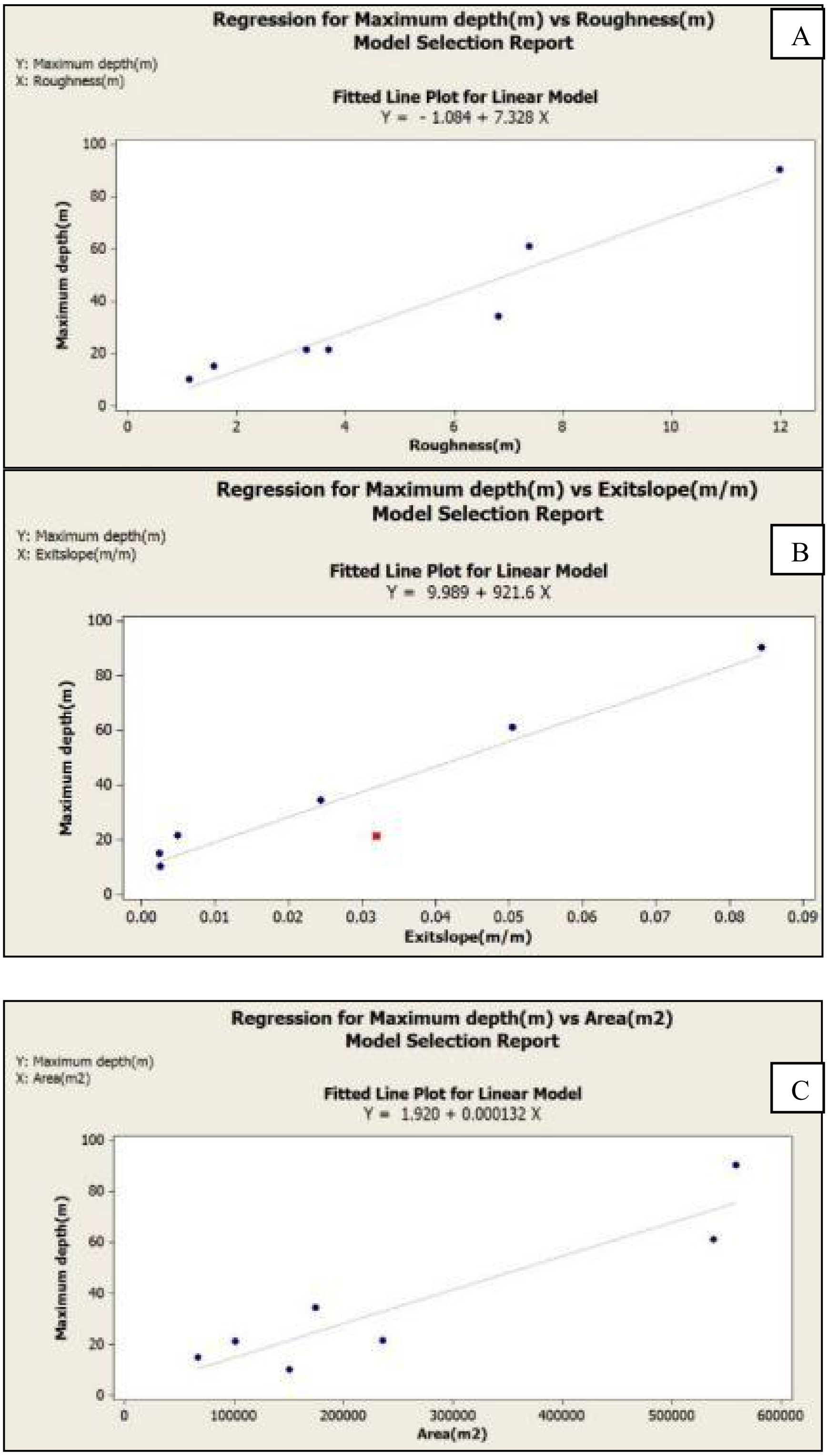


Figure 5.6: Deep pool depths versus selected quench variables (A-E)

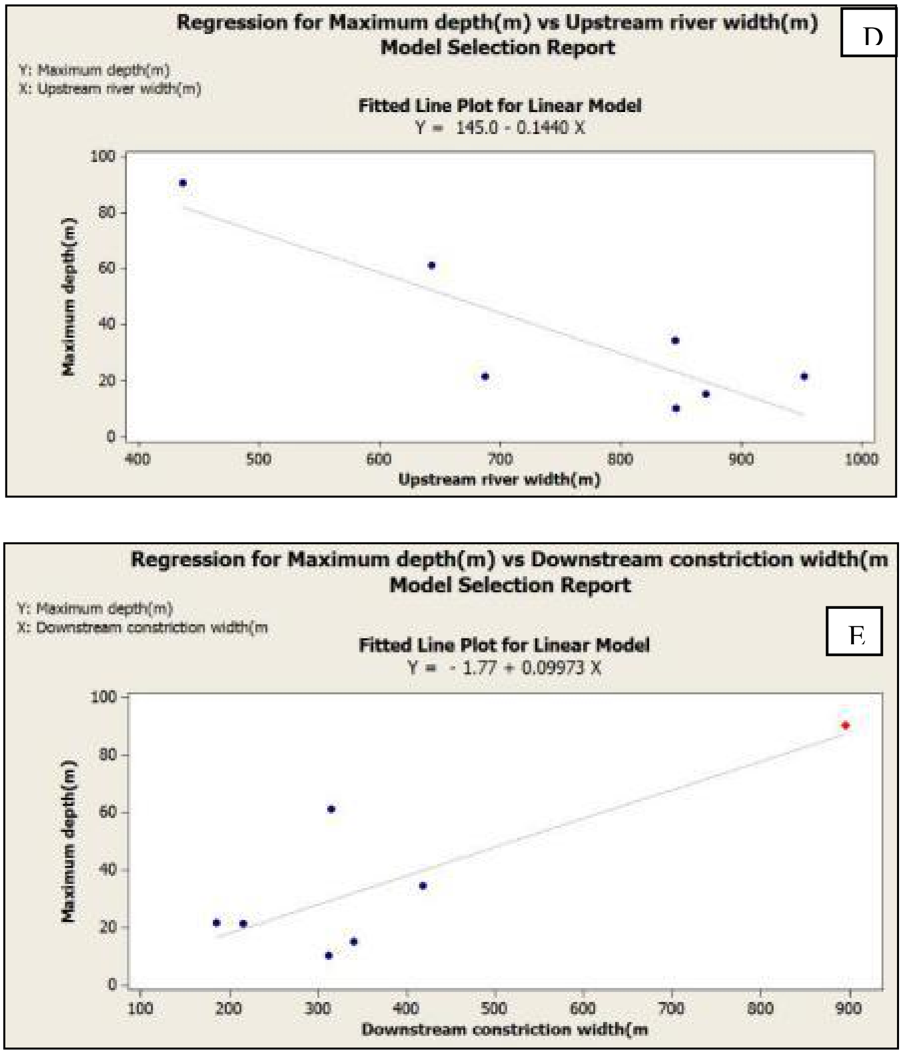


Figure 5.6: Deep pool depths versus anticipated quench variables (A-E) (cont.)

The roughness of the study site's riverbed is influenced by the size of the deep pools, the downstream constriction widths, deep pool centre constriction widths, and upstream bank full river widths, at p-values of <0.05; 0.016, 0.029, 0.031 and 0.035 respectively (see Table 5.4). According to the results, higher riverbed roughness levels correspond to larger deep pools, broader downstream constriction widths, wider deep pool centre constrictions, and narrower upstream bank full river widths. In line with this, Figure 5.7 clearly shows the relationships among the variables, but also shows one data point - plotted in red (Figure 5.7-C) - that is not a good fit with the equations, or has unusual data.

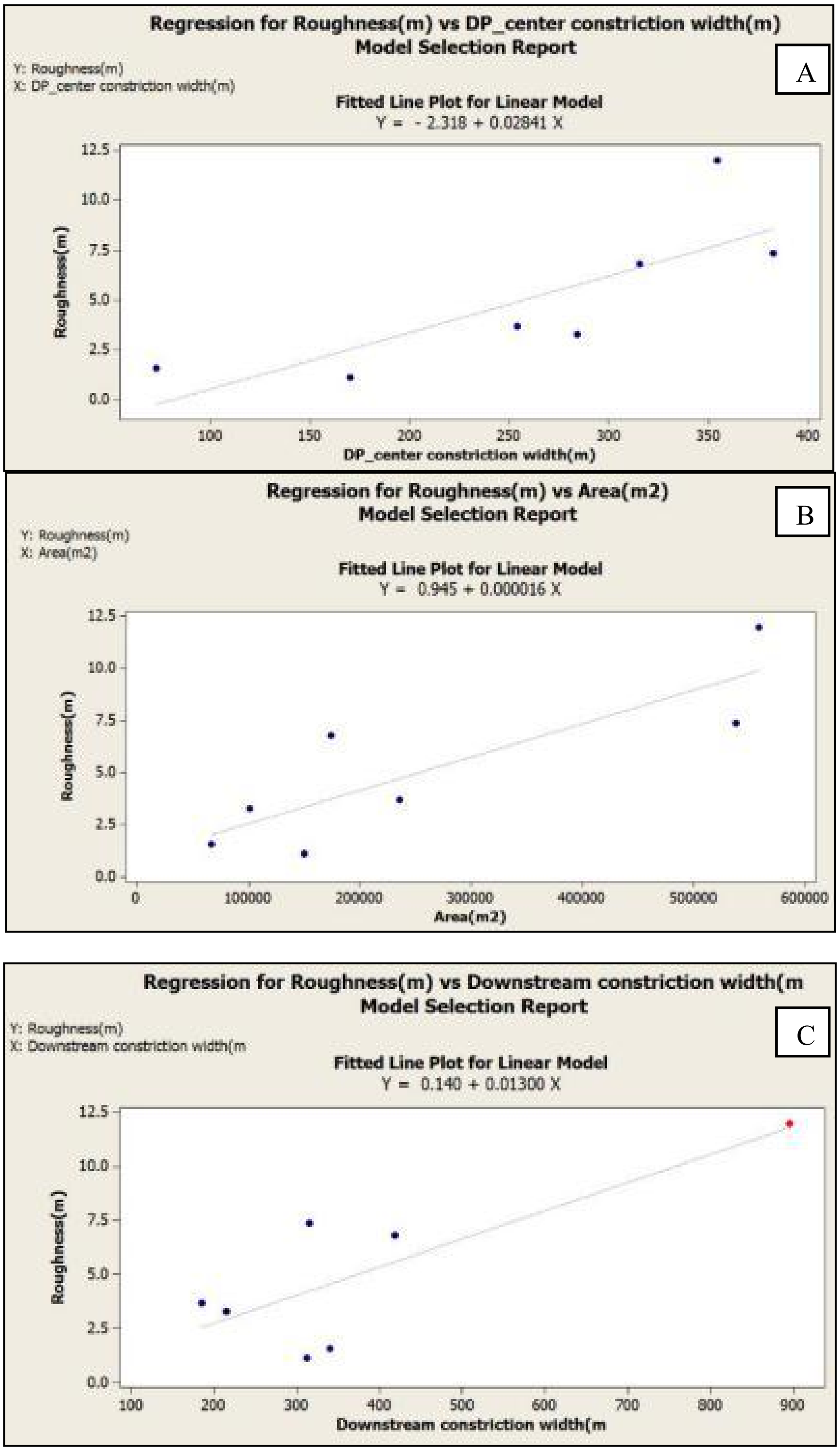


Figure 5.7: Riverbed roughness versus anticipated quench variables (A-D)

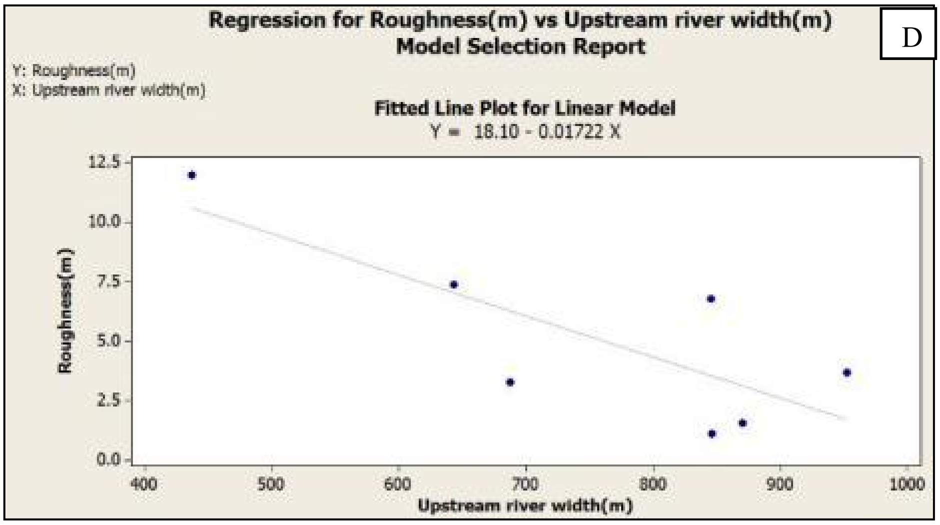


Figure 5.7: Riverbed roughness versus anticipated quench variables (A-D) (cont.)

The study site's exit-slope rates are influenced by upstream bank full river widths, riverbed roughness levels, the sizes of the deep pools in question, the downstream constriction widths, and the deep pools' centre constriction widths, giving p-values of <0.05; 0.001, 0.003, 0.019, 0.038 and 0.045 respectively (see Table 5.4). According to these figures, higher exit-slope rates correspond to narrower upstream bank full river widths, while higher exit-slope rates tend to occur with higher riverbed roughness levels within the deep pools, larger deep pools, wider downstream constriction widths, and wider deep pool centre constriction widths. It should be noted that regression analysis figures for the fitted line exit-slope plots correspond to all the anticipated variables, except for upstream bank full river widths (Figure 5.8). One data point is also shown in red (Figure 5.8-D), and this point does not fit well with the equations, which may represent the unusual nature of the data.

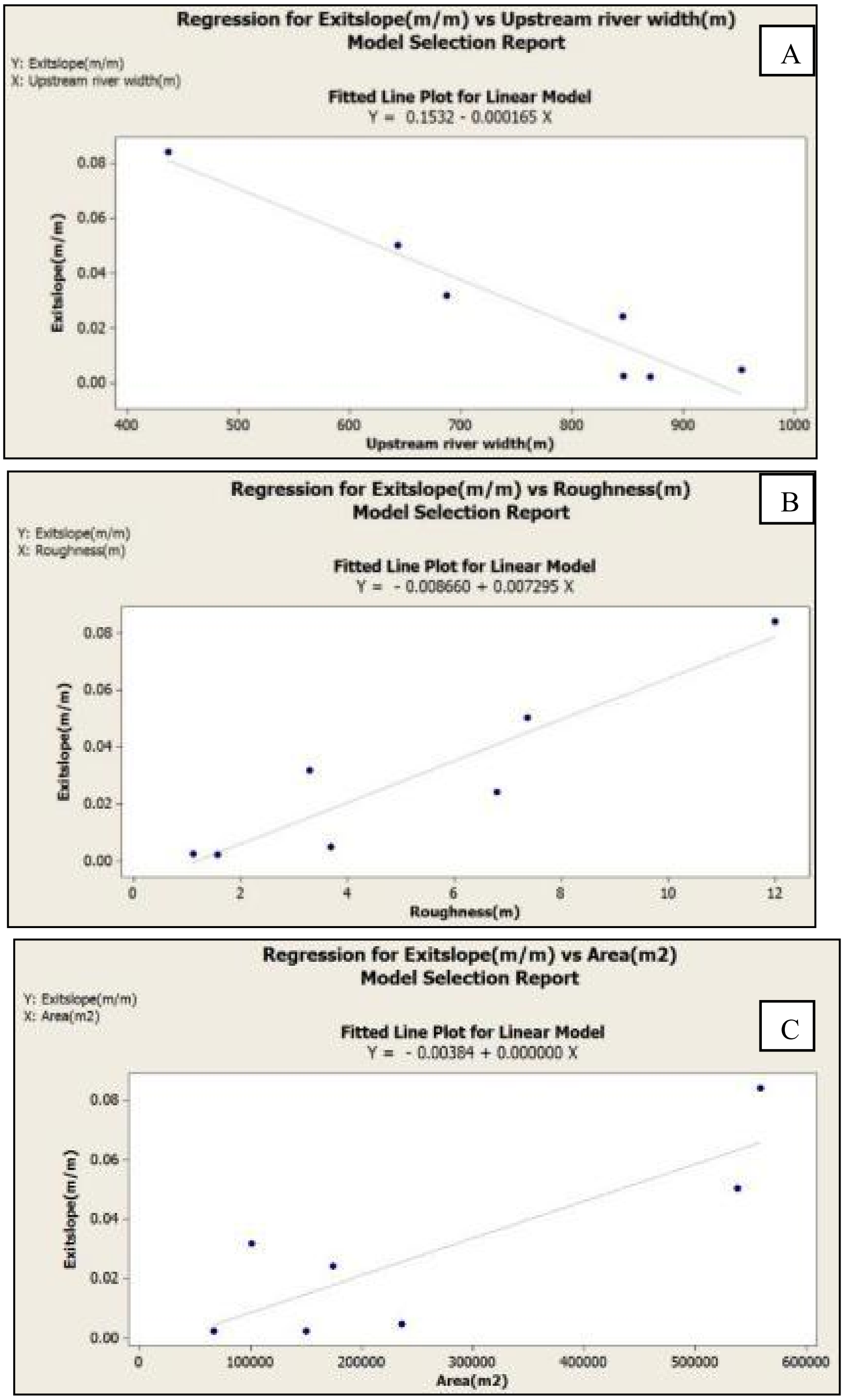


Figure 5.8: Exit-slope rates versus anticipated quench variables (A-E)

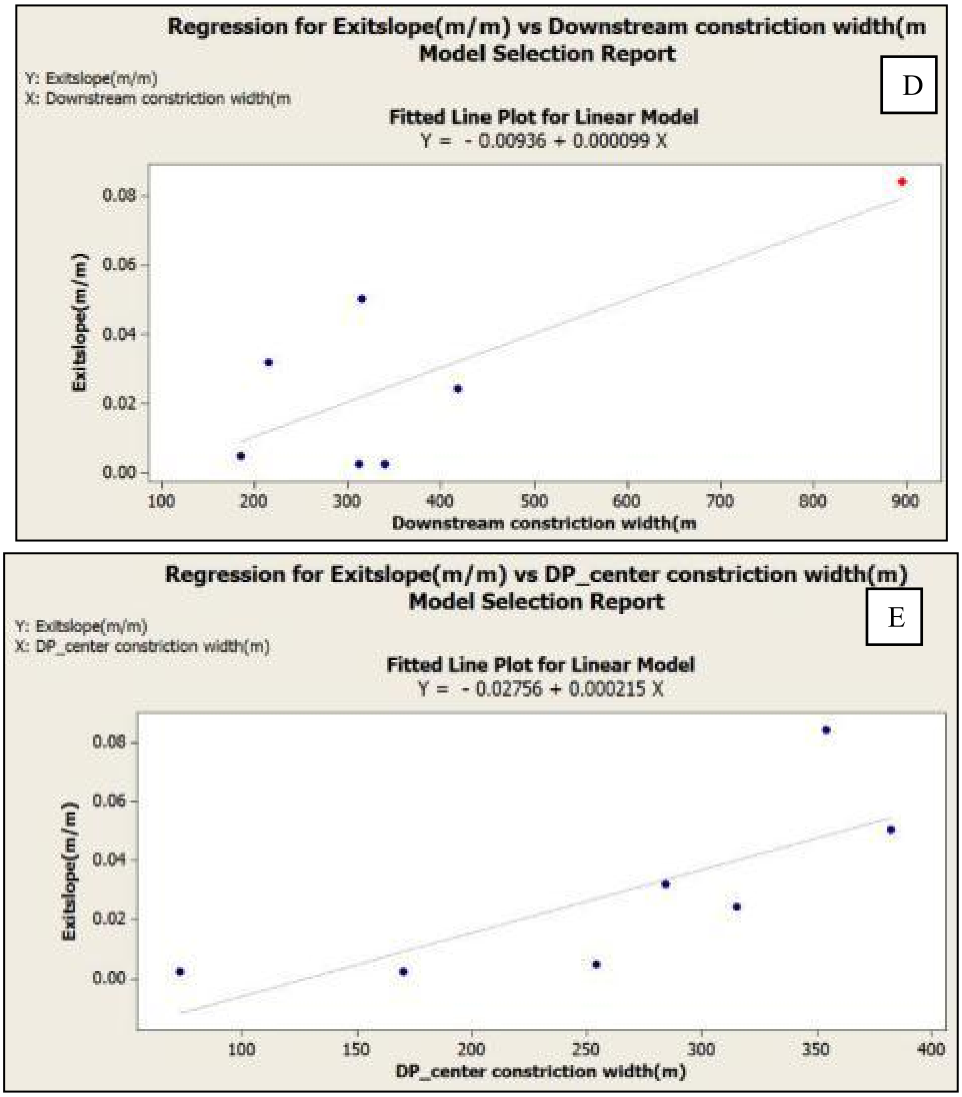


Figure 5.8: Exit-slope rates versus anticipated quench variables (A-E) (cont.)

5.4 Discussion

The geomorphology of the riverbed around Na Waeng consists of a lower rock-cut channel, as described in Section 2.7.1, which lies between Mukdahan in Thailand and Suvannakhet in Laos and runs to Khong Chiam in Ubon Ratchathani, Thailand, for approximately 200km. Na Waeng is approximately 90 km downstream from Mukdahan and Suvannakhet. Figure 5.9 shows Na Waeng in a red box, and it can be clearly seen that the river suddenly turns east near the anticline in Chanuman, Mukdahan at kilometre marker 1088, at which point the river constriction width varies between 400 and 1,000 m, measured using a spatial measurement tool on the

ArcGIS 10.1 software. The average slope of the Mekong River in this area (Mukdahan to the Mun confluence near Pakse, see Section 2.7.1 in Table 2.2) is 0.0002 degrees, and the river depth changes by more than 20 m between the wet and dry seasons. These changes have a profound impact on bed shear stress, unit stream power, channel erosion, and sediment transport levels (Gupta and Liew, 2006), and such a hydrological regime may have an influence on river morphology.

Situated at a large bedrock outcrop constriction in Na Waeng, and with boulder sedimentary rock exposures along its bed and banks (Figure 5.10), the main features of this section of river include a collection of deep pools, five rapids and one high turbulence whirlpool[6] (Figure 5.10-C). The whirlpools that occur in constricted channels lead to radically altering sediment-transport patterns and pool formations (Clifford, 1993; Matthes, 1947; Mlynarczyk and Rotnicki, 1989). According to several researchers who have investigated bedrock constrictions, pools and rapids are associated with and controlled by geomorphological processes or structure control, rather than the hydraulic control (Dolan *et al.,* 1978; Thomson and Hoffman, 2001). For instance, Dolan *et al*. (1978) and Howard and Dolan (1981) found most deep pools occur in pool-and-rapid sequences, and are associated with brecciation and faulted bedrock. From my research, I can conclude that the Mekong River at Na Waeng contains lateral controls of bedrock and large boulder outcrops, and that these are associated with deep pools. Therefore, my discussion regarding control of the study site's deep pools' characteristics will cover two key areas: geomorphological control and hydraulic control.

[6]The dangerous nature of the Khemarat whirlpool is well-known locally, and so those navigating this section of the river show respect. Unfortunately, a number of local villagers and fishermen have still lost their lives in this whirlpool.

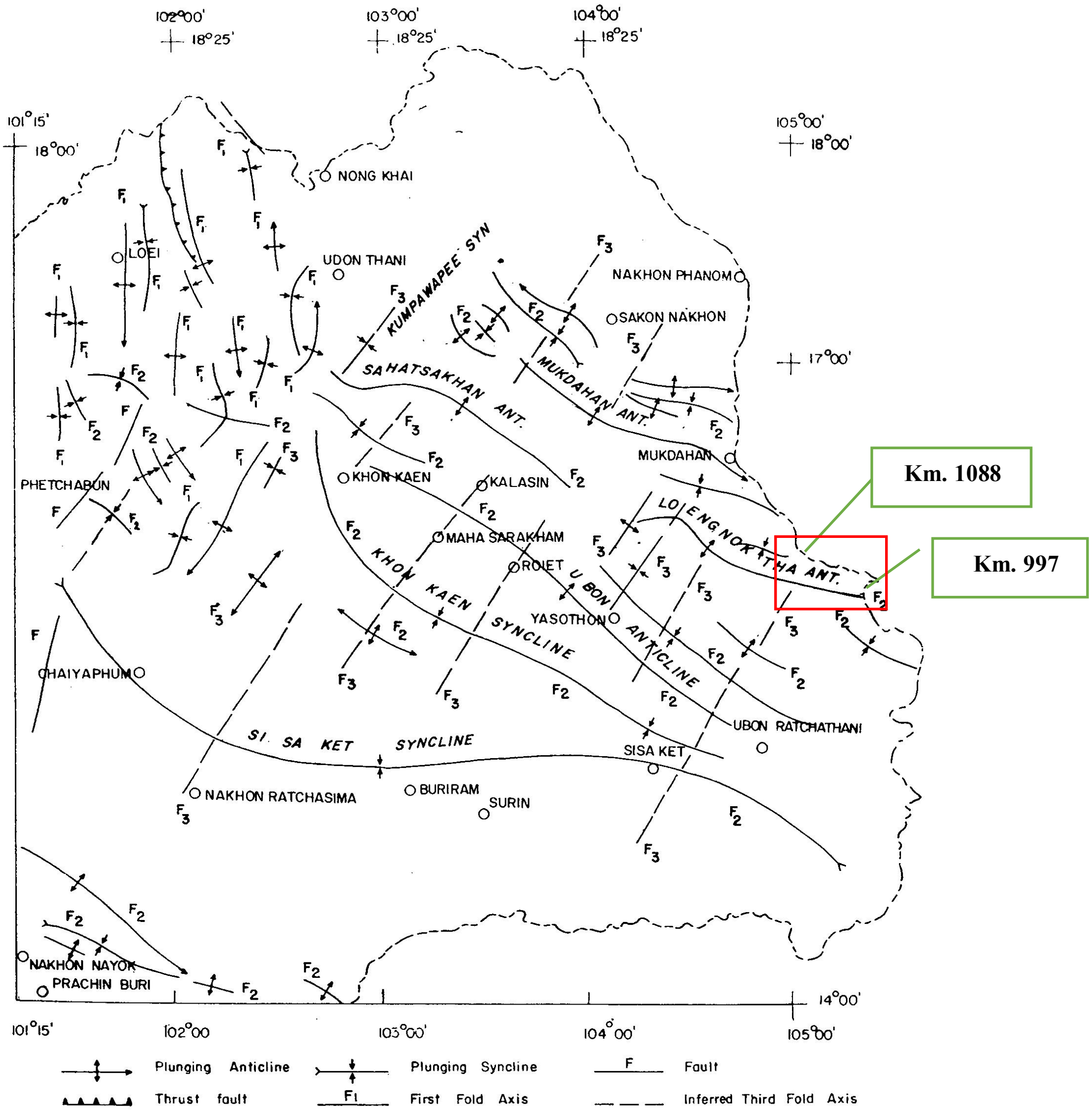


Figure 5.9: Deformations in the Khorat Plateau, as interpreted from Landsat 5 imagery (source: Adapted from Chuaviroj, 1997).

The red box represents the study area, while green boxes indicate the kilometre markers – representing the upstream distance from buoy "0", which is located at the river's mouth in the Mekong Delta (Hydrographic atlas, MRC, 1992).

Figure 5.10: A-Bedrock outcrop constriction in Na Waeng. B-Undercutting of bedrock by the river produces overhangs that eventually break and leave broken slabs along the river. C- Khemarat Whirlpool.

5.4.1 Geomorphological control on deep pools

The two dominant structural features in the Khorat Plateau run parallel to and are associated with sutures located at the northern and western margins of Indochina. First, the north-south trending in the west of the plateau is associated with the Nan-Uttaradit suture zones, which are represented by the Phetchabun Fold belt and the Sayabouri Basin (Figure 5.11), while the second is a northwest-southeast trend which is associated with the Song Ma and Song Da sutures, and this feature includes surface structures such as the Annamitic fold belt, the Nam Theun Basin and the Khammouan, Nam Leuk and Phu Phan uplifts. More details about these fold belts are available in Cooper *et al.* (1989).

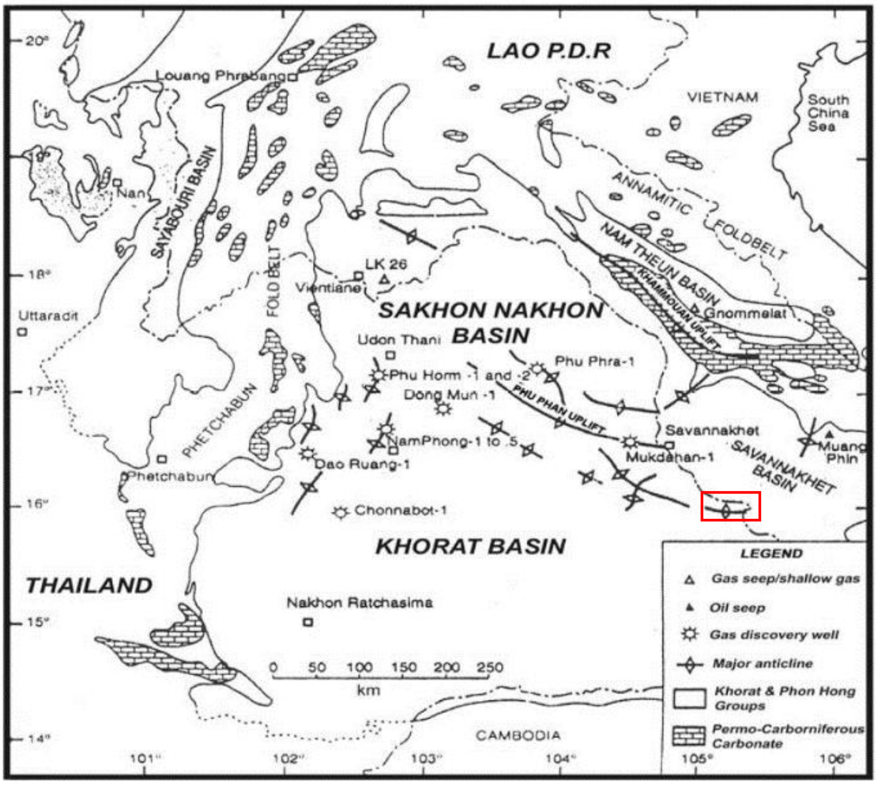


Figure 5.11: Surface geological features of the Khorat Plateau (source: Lovatt-Smith and Stokes, 1997). The red box represents the study area.

The Khorat Plateau and the area adjacent to it in the western part of Laos were subject to tectonic events over three episodes in the late Cretaceous to Pleistocene periods. This interpretation is based on aerial photographs and Landsat-5 images (Chuaviroj, 1997). Figure 5.9 shows the fold axes of the oldest deformation (F1), running in a north-south direction, which occurred in the Late Cretaceous period due to a collision between the Shan-Thai and Indochina plates. The second deformation (F2), running in a north-west direction, occurred when the Indian and Eurasian plates collided in the Himalayan orogeny during the Lower Tertiary period, producing the Phu Phan range. This trend can be found in the east of the region, including Na Waeng. The youngest deformation (F3) occurred as part of the prolonged progression of the Himalayan orogeny during the Miocene-Pleistocene period, and runs in a northwest-southeast direction. The final and fourth stage happened due to the structural development of active faults around the rim of the Petchabun Basin (Thanomsap, 1992). These deformations formed not only the dominant folding structures found in the area, but also some dominant faults in the region as a whole. This information explains evidence for the structural grain of the Khorat Plateau, a feature that dominates the Na Waeng stretch of the Mekong River. This structure exists on several scales around Na Waeng**.** As can be seen in Figure 5.9, Na Waeng is located on the eastern side of a saucer-shaped tableland, where there is evidence of regional control structures running in a west-east direction, and parallel to the Phu Phan mountain range. The Na Waeng unit is controlled by the second deformation (F2), and includes the major anticlines to be found in the region, these being the Phu Phan uplift or Mukdahan anticline, the Loengnoktha anticline, and the Khammouan uplift. In addition, the Na Waeng stretch of the Mekong River lies between a local anticline at Chanuman in Mukdahan to the north, and the Loengnoktha anticline (F2) to the south. Therefore, these anticlines influence not only the course of the Mekong River, causing it to turn to the east, but also control the underlying sedimentary sequence which tilts along the anticlines (see the geological map of Ubon Ratchathani, Thailand in Section 4.3: Figure 4.4). The sequence formations in Na Waeng, the Khok Krut (Kkk) and Phu Phan (Kpp), generally consist of siltstone, sandstone and conglomeratic sandstone. The lower contact with the underlying Sao Khua formation is very sharp and erosive. Furthermore, the continuing dominance of these anticlinal structures impacts the physiography around Na Waeng, which consists of an elongated sandstone outcrop extending from west to east, and generally sloping toward the Mekong River. This sandstone outcrop represents the deeply-weathered remnants of the Phu Phan mountain range, and it is an outcrop that occurs at other points along this part of the Mekong River (Figure 5.12).

Furthermore, Na Waeng is the site of preferential weathering and erosion caused by the presence of structures, joints, fractions and lineation. It can be clearly seen in Figure 5.13 that the Na Waeng section of the river has structures that show predominant N-S and W-E orientations. According to Chuaviroj (1997), the orientation of these structures was determined by a collision between the Indian and China plates, or during the second deformation period. These structures are the result of stresses exceeding rock strength, and so providing channels for the migration of fluids through solid rock (Whipple *et al*., 2000). As a consequence, most of the linearity shown by the tributaries around Na Waeng indicates that they follow this system of structures. An examination of Figure 5.14 shows the locations of deep pools in the study area, which is situated between two anticlines; an upstream anticline near Chanuman in Mukdahan, and a downstream anticline near Loengnoktha. My research found strong evidence that the local structure control for deep pools1 to 4 is closely associated with this tributary sequence, and that the control for deep pools 5 to 7 is closely associated with the rapid sequence (Figure 5.4-5.5). Furthermore, one additional deep pool, 171 metres in depth (Figure 5.14, deep pool 8), is closely aligned with the adjacent structure system: the Loengnoktha anticline and tributary sequence.

Figure 5.12: Sandstone outcrop representing the deeply-weathered remnants of the Phu Phan mountain range.

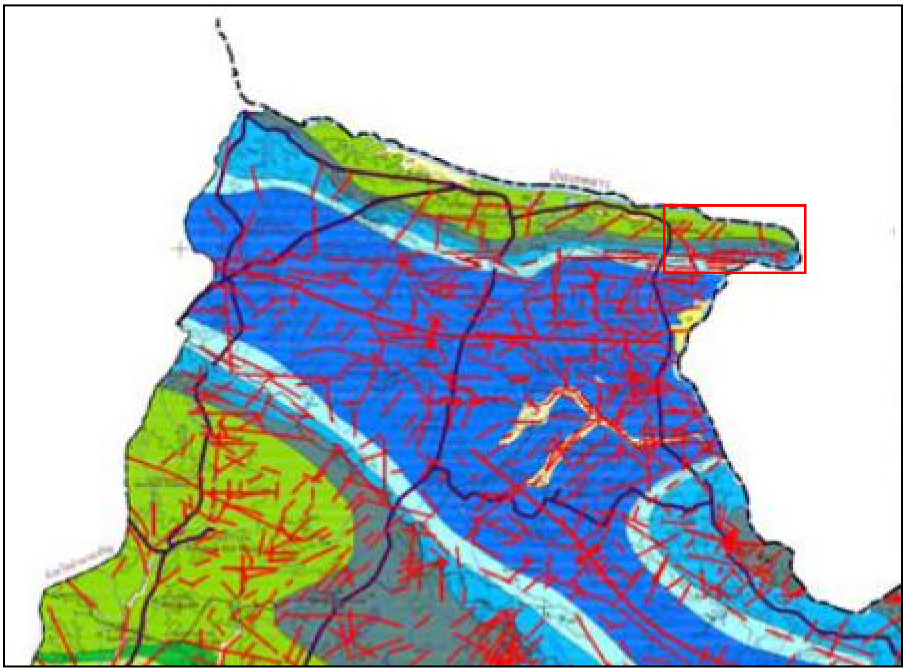


Figure 5.13: Joints and factions in the eastern Khorat plateaux (source: DMR, 2010). The red box represents the study area.

A study of the deep pool-rapid and deep pool-tributary sequences can be found in Dolan *et al.*'s (1978) study, which found that deep pools tend to be controlled by geological processes. They found that structural control of rapids and pools, and the rapid-pool sequences in the Colorado River, within the Grand Canyon, is associated with brecciation and faulted bedrock. This is similar to the study of Howard and Dolan (1981) which found that narrow channels with rapids and deep pools are associated within the sections of the canyon where Precambrian crystalline rocks dominate. The highest density of deep pools occurs in the highly fractured Precambrian gneiss and schist. The generalized rapid-pool-tributary model involves a flow within brecciated zones which transports material to the main river, but is too large to be carried downstream. This material forms a channel constriction, leading to accelerated flows and rapids that flow against the riverbed. The high velocities associated with these zones of brecciation and with the faulted bedrock, lead to a scouring below the rapids, and hence deep pools are formed over time. These two studies provide a clear explanation of the reasons for the presence of deep pools around Na Waeng that are generally deeper than other areas in the Mekong River.

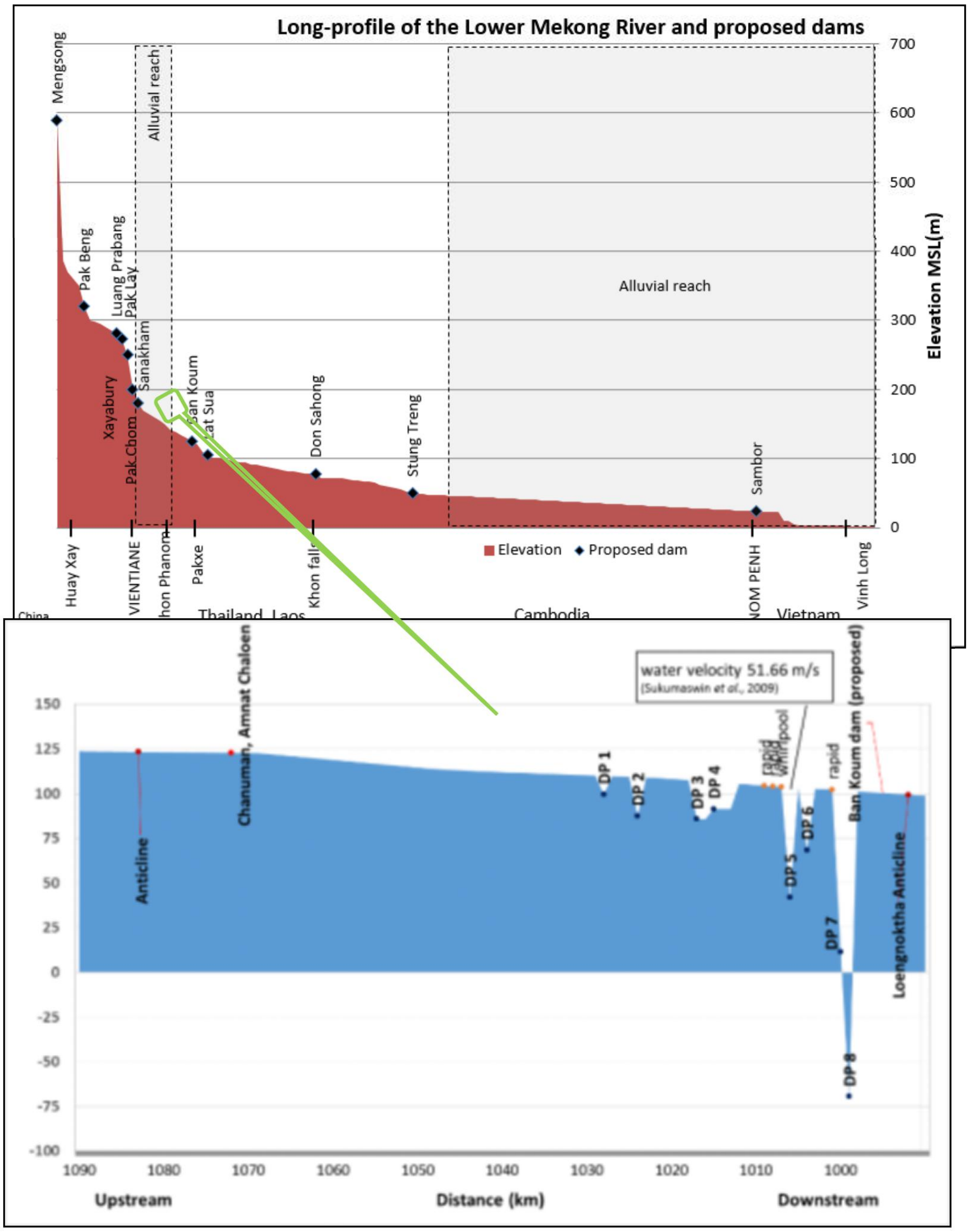


Figure 5.14: Long-profile of the Lower Mekong River and proposed dams (above). Longitude depth profile showing the locations of channel features, geomorphological controls and a proposed dam (below).

Note that the locations of deep pools in the study area are shown in the profile only. The kilometre marker shows the distance of the site from buoy "0", which is located at the mouth of the Mekong River (Hydrographic atlas, MRC, 1992).

5.4.2 Hydraulic control of the deep pools

The regression analysis indicated several significant relationships between control of the study's deep pools and the response variables, mainly related to the geometry of the deep pools and the channel constrictions. The deeper deep pools correspond to higher levels of riverbed roughness, a more pronounced deep pool exit-slope, larger deep pool areas (size), narrower upstream bank full river widths, and wider downstream constriction widths. Significantly, two of these variables, riverbed roughness and deep pool exit-slope, are also strongly related to depth. The width of the river at the deep pools' centre constriction points is correlated with riverbed roughness and deep pool exit-slope variables. Interestingly, no significant relationship was found between the length of the deep pools and other variables.

Various studies have also investigated the control of pools or deep pools, and whether the geometry of pools is influenced by flow energy or discharge, sediment transport (Wohl and Legleiter, 2003) and local site conditions such as channel constrictions (Thomson *et al*., 1998). Generally, these studies are concerned with pool-riffle sequences in alluvium channels; however, the same principles are likely to be relevant in the case of the Mekong River, but to a lesser degree. The stronger the jets created at channel constrictions, the larger the pools tend to be (Lisle and Hilton, 1992; Schmidt *et al*., 1993; Wohl and Legleiter, 2003). Large obstructions such as bedrock outcrops or large amounts of wood debris along a riverbed result in intense secondary circulations that scour pools, and 85% of pools found along the Jacoby Creek in California occur adjacent to obstructions or bends (Lisle, 1986). As a consequence of constricted flows, the water increases in velocity, mobilizing particles from the riverbed and forming pools, which can be found in many rivers, such as the North Fork Poudre River, the Colorado River within the Grand Canyon (Kieffer, 1985), and the Mekong River. Furthermore, whirlpools that occur at constricted channels lead to radically altered sediment-transport patterns, which also form pools

(Clifford, 1993; Matthes, 1947; Mlynarczyk and Rotnicki, 1989), and it is this process that leads to deeper pool depths around Na Waeng. Deep pools around Na Waeng are forced to travel between channel obstructions and constrictions towards the inner channel, enclosing the thalweg of the river (Figure 5.3; for example, deep pools 1-5), and form two scour-paired deep pools (Figure 5.15: deep pools 6 and 9, and 7 and 8). This channel obstruction segment is riddled with boulder sedimentary rock along the riverbed and riverbanks, and around the rapids, whirlpools and deep pools.

Examining the geometry of the pools, pool depths vary in line with flow energy and sediment transport levels, plus average channel gradient, while pool lengths have a negative relationship with channel gradient (Wohl, 1993). Lisle and Hilton (1992) only mentioned that high velocity jets entering pools tend to influence both pool depth and length, while Wood-Smith (1995) stated that pool depth can be controlled by the width of any channel obstructions, the flow approach angle, and the degree of upstream channel slope. Similarly, Jackson *et al*. (2009) found that the bedrock flow control in the Bulu reach area of the lower Congo is highly energetic. Turbulent and secondary flow structures can span the full depth of flow, up to more than 165 metres in depth. The regions of flow separation near the banks are isolated from one another, and from the opposite bank, by high shear, and high velocity zones with depth-average flow velocities that can exceed 4 m/s. In the adjacent downstream area of Khemarat whirlpool, the water velocity of deep pool 5 was 51.66 m/s, measured by flow meter in March 2009 at 1.2 meter depth reading (Sukumaswin *et al*., 2010), which is a very high level of turbulence when compared to the pool in Balu reach of the lower Congo. This may help to explain why deep pools around Na Waeng are generally deeper than other areas of the Mekong River.

Along with these aspects, various studies have examined controls placed on the geometry of pools, producing similar outcomes to each other; however, the findings from flume experiments carried out by Wood-Smith and Hassan (2005), and

Thomson (2006), help explain the geometry of the deep pools in Na Waeng and why this area has the deepest deep pools on the Mekong River. The variations in depth between the primary and secondary pools (Figure 5.15) create chaotic behaviours due to feedback mechanisms between the hydraulics and scouring, and due to the local turbulence and sediment transport, leading to wake zones and eventually impacting the morphology of deep pools in the area.

Having analysed the longitudinal profile, I found two extra deep pools, characterized as paired deep pools (pools 8 and 9 in Figure 5.15). I also found short, deep pools (pools 6 and 7; Figure 5.15) with vertical drops in terms of bed elevations of approximately 25 and 80 metres for pools 6 and 7 respectively. Scour pools were also found. Deep pools that develop with non-streamlined obstructions are shorter but deeper than those with streamlined obstructions, because the wake zones or strength of the strong jets tend to create higher turbulence levels and generate a greater maximum depth of scour.

In addition, the deepest parts of the primary pools or deep pools' centre were commonly found near obstructions (see map of deep pools 6 and 7); while the deepest parts of the secondary pools were found opposite areas without obstructions (see location of deep pools 8 and 9). These results are analogous with the position of the centre of deep pool 6 (34.5m in depth), and the secondary deep pool 9 (41.5 m in depth). Likewise, the same was found in primary deep pool 7 (90.5 m in depth), which is near to an obstruction (Figure 5.15), and secondary deep pool 8, which at 171 metres in depth is significantly deeper than deep pool 7. The above explanation is supported by the location of pools that switch from one wall to the other, thereby generating local turbulence and sediment transport that then enhances bed scour. Hence, the initial bed scour began a self-enhancing feedback loop that assures the development of one pool in relation to the next (Thomson, 2006).

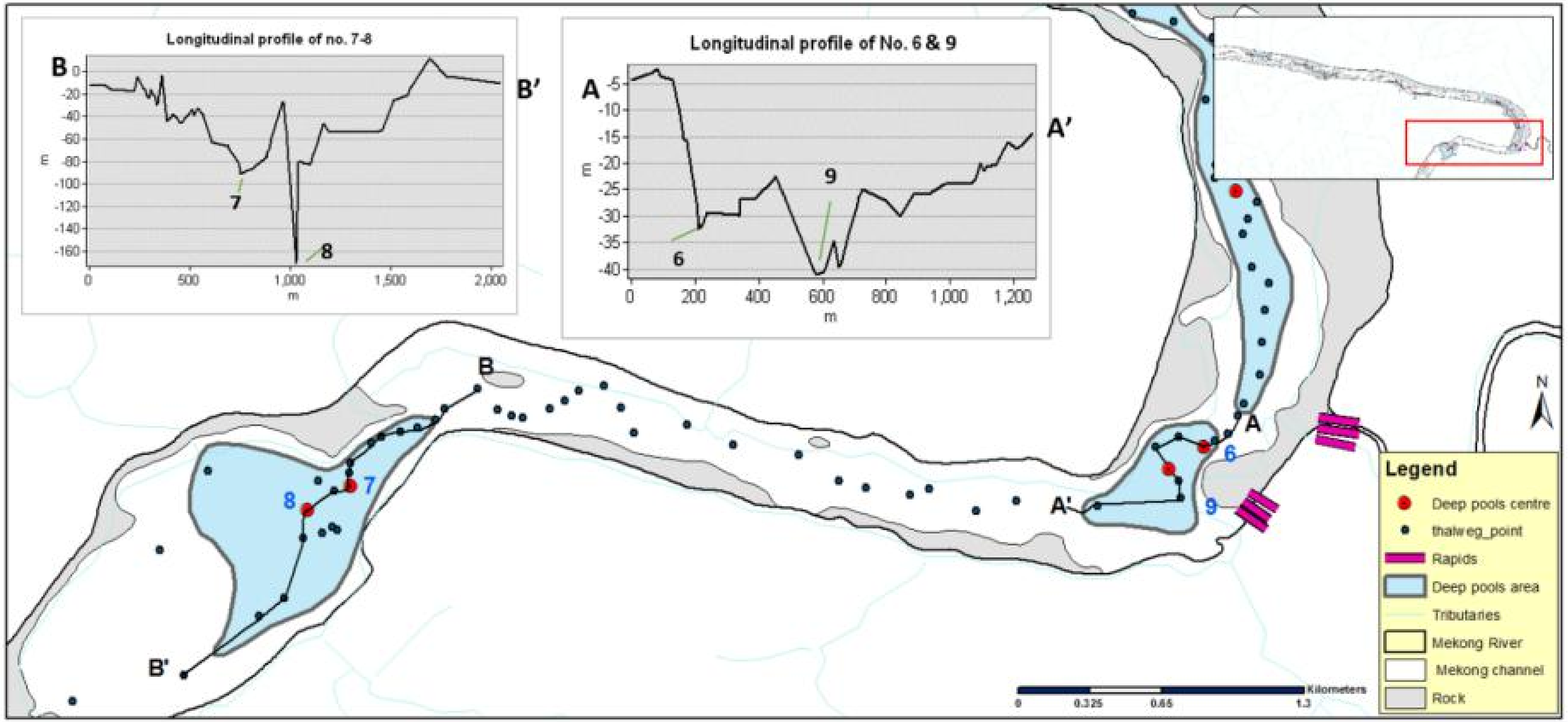


Figure 5.15: Longitudinal profile of primary deep pools 6 and 7 and secondary deep pools 8 and 9.

The results of my research compare well with Thomson and Hoffman's (2001) studies of the dependent variables impacting upon deeper deep pools. Their results highlighted the different geometric aspects of the study pools using regression analysis, and this indicated that pool depth is influenced, in order of importance, by pool exit-slope width, constriction gradient, constriction width, and the exit-slope expansion. My research found that the most prominent dependent variable for deeper deep pools is a higher riverbed roughness level, which is not surprising when investigating bedrock characteristics. Wohl (1998) meanwhile, described a bedrock channel morphology reflecting the interactions between erosive processes and the resistance of the channel substrate, as created by bedding, joints and lithological contacts.

Connected to this, some studies have stated that grain resistance is a function of riverbed roughness, causing energy losses as a consequence of skin friction and form drag on individual grains in the bed (Einstein and Barbarossa, 1952; Parker and Peterson, 1980). Therefore, a bedrock riverbed is characterized by irregularly eroded bedrock, and the resulting turbulence and hydraulic diversity levels mean a greater potential for bed erosion, leading to the occurrence of deeper and bigger deep pools. Regarding the cluster of deep pools in Na Waeng, the result from the regression analysis indicates that the deepest deep pool (90.5 m) also shows the highest level of riverbed roughness. Interestingly, similar results were found on the bedrock reaches along the Mekong River; that is, higher levels of roughness are more pronounced in bedrock rather than in alluvial reaches (Halls *et al.,* 2013). In addition, many studies have found that deep pools in bedrock constrictions tend to be deeper than those in alluvium reaches (Halls *et al.,* 2013) and, as expected, the more constricted the channel is, the deeper the deep pools are likely to be (Wohl and Legleiter, 2003). Therefore, riverbed roughness is a highly promising factor influencing deeper deep pools, as well as size, which is influenced by local site conditions such as channel constrictions.

The deep pool exit-slope variable is as significant as riverbed roughness in terms of helping to create deeper deep pools, as is shown by the slight difference in p-value, as shown in Table 5.4. In this study the deep pool exit-slope (some studies call it a 'pool tail') is defined as encompassing the stretch of river from the central section of a deep pool, or the deepest point, to the end of the deep pool. This is in line with Thomson *et al.*, (1996), which describes the exit-slope as–the section of channel bed downstream from the deepest section of the pool that slopes upstream to a riffle. According to Petit (1987) and Thomson *et al.* (1996, 1999), the pool exit-slope represents an area of strong, turbulent energy dissipation and increased sediment deposition. Hence, it can greatly influence the wake zones and vortex shedding moderately responsible for pool scour. In addition, some studies have found that pool exit-slope is significantly correlated to channel bed gradients (Thomson *et al.*, 1996) and a decrease in sediment particle size (Thomson *et al.*, 1999). Therefore, deep pool exit-slope zones tend to provide vital spawning areas for fish (Hunter, 1991).

5.5 Conclusion

The Mekong River around Na Waeng exhibits a uniform morphology along its 28 km length; the channel has nine deep pools, five rapids, and one area of significant water turbulence surrounding the Khemarat whirlpool. My conclusion regarding control of the study's deep pools' characteristics covers two key areas: geomorphological control and hydraulic control.

First, the information found in this study has revealed the channel characteristics of these features and how they are structurally controlled due to regional and local fracture patterns. Second, the result of regression analysis indicates that the deeper deep pools correspond to higher levels of riverbed roughness, a greater deep pool exit-slope, larger deep pool areas, narrower upstream bank full river widths, and wider downstream constriction widths. Significantly, two of these variables, riverbed roughness and deep pool exit-slope, are also strongly related to depth. The width of the river at the deep pools' centre constriction widths is correlated with riverbed roughness and deep pool exit-slope variables. Interestingly, no significant relationship was found between the length of the deep pools and other variables. As noted above, this is a different conclusion to that found by some others.

In the next chapter I will describe in detail how deep pools play a vital role in maintaining the effectiveness of the Mekong River as a fish sanctuary during the dry season, and then go on to discuss the potential effects of basin development in the Mekong, especially in relation to dams.

CHAPTER 6

Fisheries Ecology and Management

6.1 Introduction

One of the first issues faced when studying fisheries management activities on the Mekong River is the phenomenon of deep pools and the vital role they play with regard to fish refuge habitats and their relationship to the greater ecosystem and livelihood of chaopramong [fishermen]. The development of models capable of predicting the distribution of fish abundance and species richness are of vital prominence, given the increasing importance of fisheries conservation in recent years. Over the last decade predictive modelling of species distribution has become a powerful tool; supporting conservation and natural resource management decision making (Drew et al., 2011; Jopp et al., 2011), and helping to identify and establish potential species restoration or reintroduction areas. However, in some instances there is no scientific data available for comparison with the LEK of chaopramong.Such is the case in Na Waeng, where LEK is the only available source of information, for example concerning fish species identification and river ecological knowledge, which can support and explain those scientific models in the five fishing communities studied here. Therefore, this chapter will investigate fish abundance and fish species richness, and their relationship with the ecology of the Mekong River in Na Waeng. Emphasis is given to the ways that the LEK of chaopramong not only can complement and provide feasible support to fisheries management and community management, but also considers how LEK should be given equal consideration to scientific knowledge. The study's catch sampling activities were carried out in the five fishing communities in Na Waeng over a 30-day period during the dry season (25 February to 25 March 2012), when deep pools act as fish refuges and associate fish spawning grounds for some species. Two key sampling techniques were used to determine fish abundance and fish species richness, these being: (1) scientific information regarding fish densities, water quality, and plankton densities, which can contribute to community based fisheries management, and (2) local ecological knowledge (LEK) regarding fish species and fish catches gathered from local *chaopramong* in the five fishing communities.

6.2 Data processing and analysis

Data processing and analysis was carried out using the river survey information regarding fisheries ecology (see Section 3.4.1), in order to model fish abundance and fish species richness. This was done using an R-program classification and regression tree (CART) analysis. The results of this analysis were then split into four main components: fish density, water quality, plankton density, and fish species. Figure 6.1 shows the conceptual data processing model used, which was based on these four key environmental parameters within the GIS platform. CART statistical analysis was used to analyse the measured parameters in order to model fish abundance and fish species richness.

Morgan and Sonquist (1963) introduced CART into the social sciences, while Breiman *et al.* (1984) provided a comprehensive review of the statistical basis of the technique. CART uses a regression tree technique to identify interactions between different explanatory variables. It is a non-parametric multivariate classification technique which is most commonly implemented using a recursive partitioning algorithm (Ciampi, 1991; Hand, 1997). The technique uses a binary decision tree that is built by splitting a node into two child nodes homogeneously and repeatedly, beginning with the root node that contains the whole learning sample and terminating with a node that the algorithm cannot partition any further, which then represents the most homogenous group (Breiman *et al.,* 1984). The results of applying CART are represented graphically for ease of visual understanding and, as described in the results section of this chapter, the top root node represents the undivided data and the most important variable in the model.

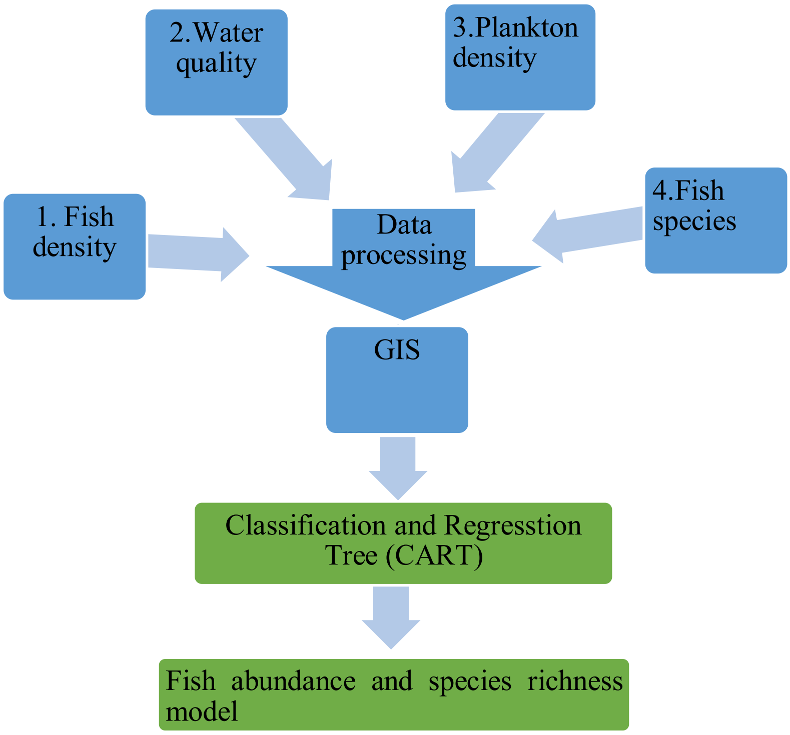


Figure 6.1: Conceptual model of the data processing and analysis of environmental parameters – to determine fish abundance and species richness.

According to Breiman *et al.* (1984) the CART analytical process is completed by the R-program software using a computational process which contains four basic forms of analysis. Firstly, a "tree building" step is used, during which a tree is built based on the recursive splitting of nodes. Each resulting node is assigned a predicted class, constructed based on the distribution of classes in the study dataset occurring in that node and the decision cost matrix. The assignment of a predicted class to each node is based on whether or not that node is subsequently split into child nodes. The second form of analysis is referred to as the "stopping the tree building" process. At this point, a "maximal" tree has been created, which possibly over-fits the information contained within the study dataset. Thirdly, a "tree pruning" process is carried out, which results in the creation of a sequence of simpler and simpler trees, based on the cutting-off of increasingly important nodes. Lastly, an "optimal tree selection" process takes place during which the tree which best fits the information in the study dataset - but does not over-fit the information - is designated from among the sequence of pruned trees.

CART analysis has been applied extensively over the last decade for purposes of data exploration and for modelling complex ecological data (De'ath and Fabricius, 2000; Fukushima *et al.*, 2011). Moreover, CART analysis has proved to be an effective and powerful tool for describing species distributions and assemblages (Fukushima *et al.*, 2011). CART analysis has also been applied regularly for data mining activities, and discussions of the CART model are available in Breiman *et al.* (1984) and Chipman *et al.* (1998). In addition to comparing the performances of CART, these authors highlight the advantages of using CART analysis over other classification methods, and multivariate regression (Lewis, 2000; Razi and Athappilly, 2005). Briefly, the positive features of CART analysis include: (1) the ability to use different types of response variables, including numerics, categoricals, ratings, and survival data, (2) the capacity for interactive exploration, description, and prediction to be carried out, (3) invariance to transformations of explanatory variables, (4) easy graphical interpretation of complex results involving interactions, (5) model selection by cross-validation, and (6) the existence of procedures for handling missing values.

Assessing fish abundance and species richness in the study area would not have been possible without being able to gather statistics, and the situation in this study is therefore suited to the use of CART analysis. Since CART is a non-parametric procedure used for predicting continuous dependant variables using categorical prediction variables, and has a capacity to analyse large data sets, it is an appropriate technique for the prediction of the variable set used in this study. In addition, a stepwise regression procedure was carried out using SPSS, but the results showed a lack of any significant contribution towards the prediction of dependant variable values for the two models: fish abundance and species richness. However, CART analysis was able to provide some insight into the explanatory parameters possibly affecting fish abundance and species richness levels. The 16 parameters seen in Table 6.2 – using 986 sampling points per parameter – were determined to explain the two models. For the CART analysis itself, both response parameters were *log (x+1)* transformed to stabilize any variances. The optimal tree size was determined using an R^2-value and complexity parameters to measure how well the model fitted the dataset on which it was built. In general, CART is referred to as a classification tree if the response variable is qualitative, and as a regression tree if the response variable is quantitative (Breiman *et al.,* 1984; He *et al.,* 2010), and in this study, both these approaches were used – to model fish abundance and species richness respectively.

During the field survey, four data collection methods were used to gather 18 environmental parameters in Na Waeng: Fish Finder GPS, water sensors, a water quality sampling survey, and LEK (Figure 6.1). At the end of data processing, 16 environmental parameters were used to model fish abundance and species richness using CART analysis, while the other two recorded parameters were the northing and easting geographic coordinates for the monitoring locations or sampling points. All parameters could be precisely presented in the GIS (see Figure 6.2).

By ensuring that the surface water sampling locations were positioned at the centre of deep pools, within the deep pools, and in areas adjacent to deep pools, deep pool characteristics across the study area were well presented, with any variations along the river's course being clearly shown. The 'water sensor sampling method' was used to collect samples at 45 points, measured using the YSI 556 sensor at 15 cm-depth, which included water temperature and pH, d*issolved oxygen* (DO) levels and also turbidity (see Table 6.1 and Section 3.4.1). Also, the 'water quality sampling method' used measured water quality and plankton levels at nine sampling locations, which included the four previously mentioned parameters, plus salinity, transparency, alkalinity, plankton density, and zooplankton density (Table 6.1). It should be noted that the number of water quality sampling locations was limited due to the high cost of laboratory data analysis and the physical obstacle of water turbulence. The water quality sample collection process required the use of water monitoring instruments and systematic collections, and so was time consuming (see Section 3.4.1). As a result, for deep pool 6, where strong turbulence was encountered, the water quality sampling had to be restricted to the centre of the deep pool, for safety reasons.

With only a limited amount of sample data available, values for those locations for which there were no measurements could be interpolated using techniques available in the powerful GIS, such as "Interpolation Method", which is part of the ArcGIS Spatial Analyst extension. This is a technique based on the principle of spatial auto-correlation, which measures the degree of relationship between objects and can predict unknown values lying between sampling points, (Child, 2004). In this study, much geographic information was collected at irregular intervals, as it was not possible to take measurements from all the desired locations. As a result, there was a need to estimate values for those locations at which there were no data available. One common method used to interpolate points of equal value is the continuous isoline, or contour line on a map, which can be used, for example, to plot temperature, precipitation, diffusion of pollution, and elevation data.

Development of the fish abundance and fish species richness models was based on the total number of Fish Finder GPS sampling points (986 points), the research-delineated 45 water sensor sampling points, and nine water quality and plankton measurement points. The GIS then provided spatial analysis, plus interpolation and spatial joins, in order to compile the environmental parameters used in the model (Figure 6.3).

Interpolation – using the Inverse Distance Weighted (IDW) interpolation method contained within the Spatial Analyst extension of ArcGIS 10.1 – was used here to map the variables. The IDW interpolation is the most suitable method for the spatial modelling of water quality, due to the low number of errors produced when compared with other methods (see Jha *et al.*, 2010; Oke *et al.*, 2013). All the sample data taken using the water sensor sampling method (45), the water quality sampling method (9), and the LEK of fish species in each village (5), were used in the calculation of each interpolated cell per parameter or raster data (see Figure 6.3). In total, ten environmental parameters and two sources of turbidity were merged before the interpolation process took place, and the entire process was repeated in the GIS spatial interpolation model 10 times (Figure 6.3) in order to prepare the data for CART analysis. A feature dataset representing the outline of the Mekong River was used for the mask, and only cells that fell within the specified shape of the river's outline were given values on the first output raster (Figure 6.3-A; Plk_Riv (raster)). The output raster represented the cells extracted from the Idw_Plk (raster), in other words those corresponding to the routes defined by the mask-river outline. In order to compile the environmental parameters used, the Idw_Plk (raster) was converted into a contour line (vector), as a requirement of the spatial join function. The output vector (Figure 6.3-C; Plk_Riv_Contour_GPS (986 points)) is contained within the value of Plk_Riv_Contour (polygon) in Figure 6.3-B. Using this interpolation technique, all 986 sampling points were joined to 16 parameters in one sampling point, then the spatial join technique was used to merge all the sampling points into one file. Each file, with an inset of 16 environmental parameters (Table 6.2), was then used to analyse and develop the fish abundance and fish species richness model using R-programme CART analysis (version 3.0.2).

Table 6.1: Description of data processing parameters used to develop the fish abundance and fish species richness models

Parameters	Unit	Character	Type	Fish Finder GPS	Water sensor	Water quality and plankton measurement	LEK	*Data processing
River depth	m	S	N	Y	-	-	-	1
Minimum depth of fish	m	B	N	Y	-	-	-	
Maximum depth of fish	m	B	N	Y	-	-	-	
Fish count (Fish abundance)	no. of fish/point	B	O	Y	-	-	-	4, 1
Temperature	°c	P	N	Y	Y	Y	-	1, 2
Easting	degree	C	N	Y	Y	Y	-	1
Northing	degree	C	N	Y	Y	Y	-	1
pH	-	P	N	-	Y	Y	-	1, 2
DO	ppm	P	N	-	Y	Y	-	
Turbidity	mg/l	P	N	-	Y	Y	-	
Salinity	ppt	P	N	-	-	Y	-	
Transparent	cm	P	N	-	-	Y	-	
Alkalinity	mg/l	P	N	-	-	Y	-	
Density of plankton	cell/l	B	N	-	-	Y	-	
Density of zooplankton	cell/l	B	N	-	-	Y	-	
Fish species per village	no. of species	B	N	-	-	-	Y	1, 2, 5
River width	m	S	N	-	-	-	-	3
Channel width in the dry season (river constriction width)	m	S	N	-	-	-	-	3
Total number of sampling records	-	-	-	986	45	9	1	986

Remarks:The character of the variables is denoted as: B = biotic, C = coordinate point, P = physical and S = spatial. Data type: N = numeric, and O = Ordinal.

*Data process descriptions: 1. Data aggregated into the GIS database, 2.Spatial interpolation and spatial-join techniques used in GIS, 3.Measuring tool in GIS (as described in Figure 5.2) used to quantify river channel width, 4. Manual count of fish/point and classification of fish abundance into 12 classes, from 0, 1-9, 10-19, 20-29, …99 and >100 fish, 5. Descriptive statistical analysis.

Table 6.2: Descriptive statistics of the 16 environmental parameters used to develop the fish abundance and fish species richness models

No.	Parameters	Unit	Mean	Minimum	Maximum	SD
1	River depth	m	24.14	0.2	171	27.92
2	Minimum depth of fish	m	3.19	0.8	19	3.39
3	Maximum depth of fish	m	18.42	1	144	25.63
4	Fish count (fish abundance) (qualitative data,12 classes)	class	-	0	>100	-
5	Temperature	°c	27.93	25.1	35.4	2.05
6	pH	-	8.1	6.9	9.1	0.29
7	DO	ppm	4.27	1.9	8.8	1.60
8	Turbidity	mg/l	2.65	0.6	7.2	1.29
9	Salinity	ppt	0.52	0.44	0.77	0.09
10	Transparent	cm	52.47	37	73	9.26
11	Alkalinity	mg/l	58.59	54.8	64.5	2.05
12	Density of plankton	cell/l	4,230,933	2,500,000	9,000,000	1,346,402
13	Density of zooplankton	cell/l	127,363	90,000	190,000	24,473
14	Fish species per village	no. of species	16	8	29	7.29
15	River width	m	742.36	370	1270	172.01
16	Channel width in the dry season (river constriction width)	m	348.27	73	921	204.76
Total number of sampling records			986	986	986	986

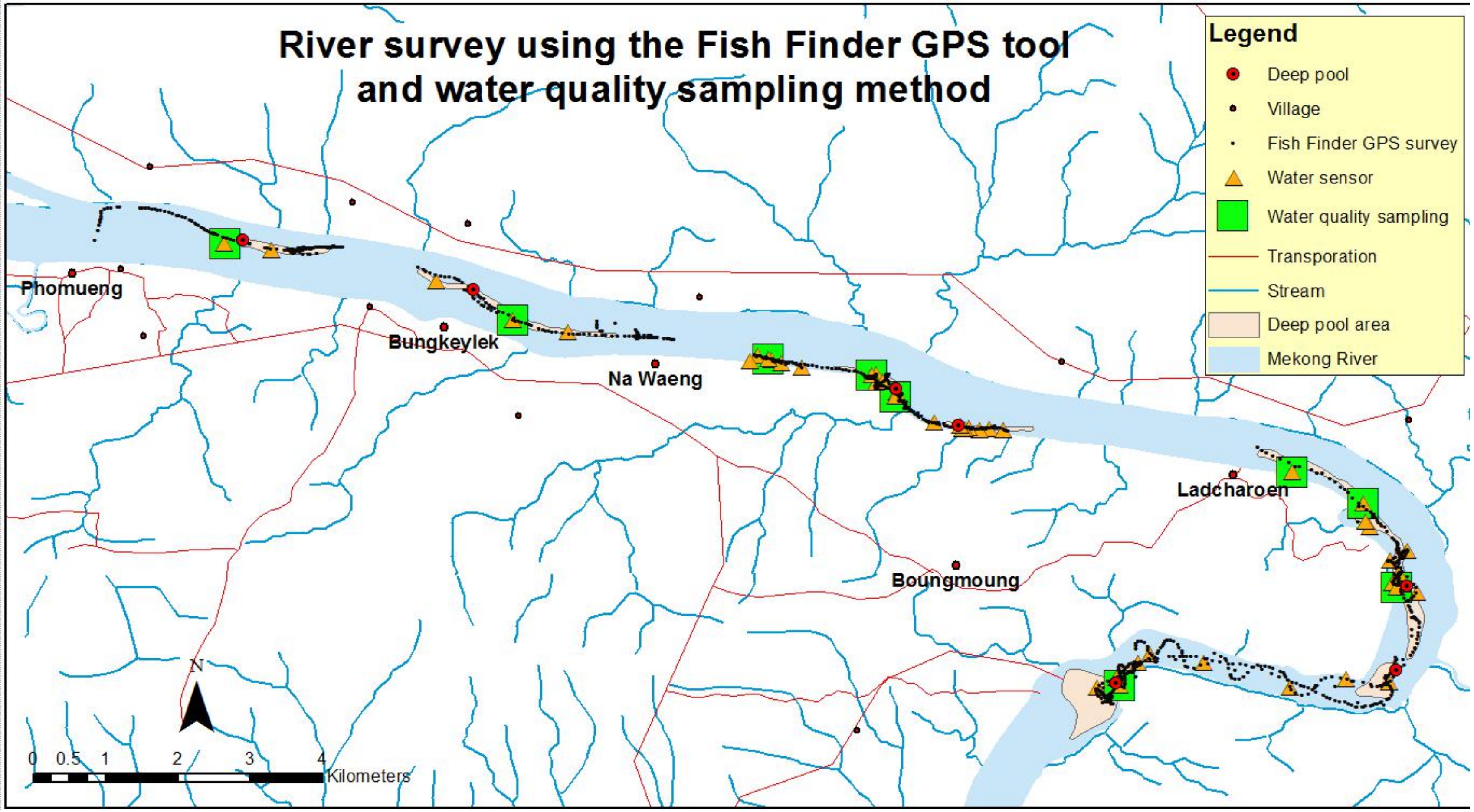


Figure 6.2: River survey using the Fish Finder GPS tool and the water quality sampling method.

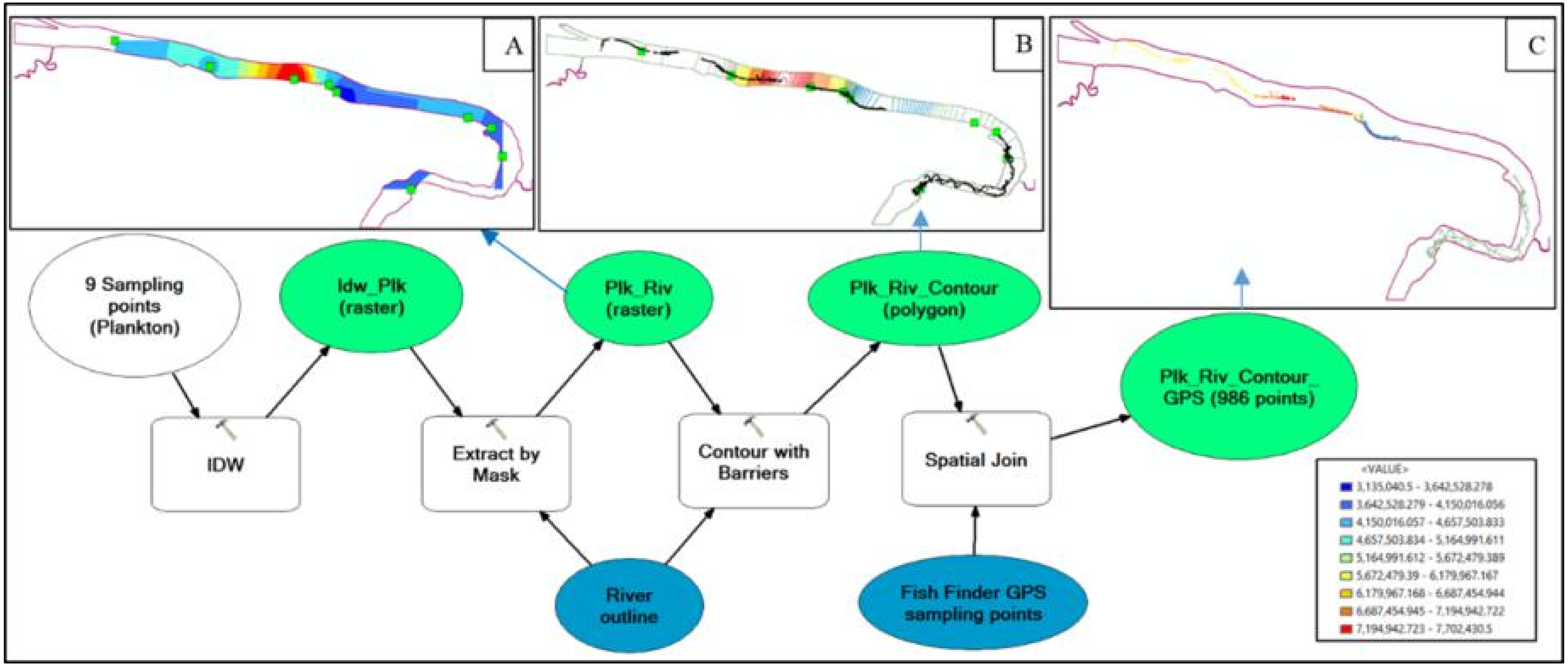


Figure 6.3: Spatial interpolation model in GIS

Remark: ‘Plk’in this model represents a parameter of density of plankton and a legend box refers to the value of density of plankton (cell/l).

6.3 Results

6.3.1 LEK of *chaopramong*: fish species

In order to develop an approach for the appropriate conservation of fish, baseline information on fish diversity within the five fishing communities was required. It can be argued that the LEK of *chaopramong* regarding fisheries resources is based upon observations during in everyday activities and, as stated in Lauer and Aswani's (2009) study, is therefore a practice-oriented approach. In other words, LEK is a collective embodiment of knowledge as context, practice, and belief that emerges from the influence of interactions within the ecosystem (Gadgil *et al*., 1993, Berkes *et al*., 2000, Tengö and Belfrage, 2004, Lansing and Fox, 2011,Tengö *et al*., 2007, von Heland, 2011). The LEK of *chaopramong* may not disagree with scientific or research perspectives that rely on time series data or sophisticated conventional methods that are time consuming and may themselves be inconclusive. However, the limitations of technology capable of identifying fish species quickly meant the LEK of *chaopramong* became important as baseline data to support scientific knowledge. Thus, the LEK of *chaopramong* assisted my analysis of fish communities and species assemblages, scarcity of fish species, and fish ecology in Na Waeng, which is elaborated in the following sections.

6.3.1.1 Fish communities and species assemblages

Ad hoc catch monitoring surveys were undertaken over a 30-day period (25 February to 25 March 2012) (see Section 3.4.2.3), with the help of 41 volunteer *chaopramong* in the catch registration areas of the five fishing communities in Na Waeng. The data from catch monitoring were collected by local villagers and/or *chaopramong* who were specially trained by the researcher. The majority of the trained local villagers and *chaopramong* lived near the fishing piers and could be trusted to provide fish catch information. During this period, catch monitoring programmes were carried out within the full diversity of habitat types in the Mekong

River (deep pools, caves, rapids, riffles and stagnant water), and also recorded all types of fishing gear used by *chaopramong* in the five study villages in Na Waeng. A total catch of 991.3 kg was recorded. The largest total landing weights in terms of catch per village were recorded in *baan* Na Waeng (412.2 kg), Ladcharoen (263 kg), Phomueng (184.1 kg), Bungkhylek (118.9 kg) and Boungmuang (21.3 kg).

Local villagers and/or *chaopramong* recorded 29 species of fish, representing 11 families (Figure 6.4), with *Cyprinidae* representing the largest proportion (37.9%; 11 species), followed by *Bagridae* (13.8%; 4 species), *Pangasiidae and Siluridae* (both 10.3%; 3 species), and *Cobitidae* (6.9%; 2 species).

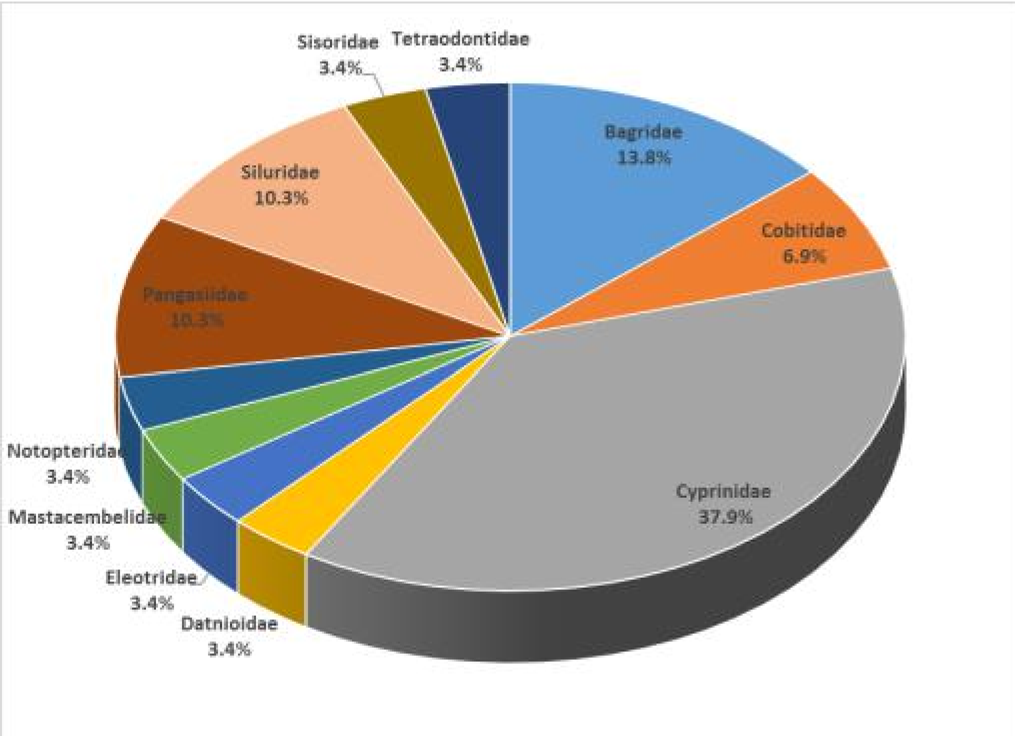


Figure 6.4: Fish found in the five study villages of Na Waeng during the dry season in March, 2012 (30 days).

The Bagridae/*Hemibagrus filamentus* (Bagrid catfish) family, Cyprinidae/*Barbonymus altus* (Red tailed tinfoil; *pla tapien thong* in *Isan*) family, and *Labeo chrysophekadion* (Black sharkminnow; *pla ka dum*) family were the most widely distributed fish species found in the study area (Table 6.3). The largest catches by fish species were as follows: *Henicorhynchus siamensis* (Siamese mud carp; *pla soi khao*; 287.5 kg) – mostly found near *baan* Na Waeng, *Pangasius bocourti* (Shark catfish; *pla yang*; 285.7 kg) – mostly found near Ladcharoen village, and *L. chrysophekadion* (Black shark minnow; *pla ka dum*; 134.7 kg) – mostly found in Phomueng village. On the other hand, most fish were landed in small amounts weighing less than 0.5 kg including the following: Cyprinidae/*Hampala macrolepidota* (Hampala barb; *pla kra suub kheed*), *M. erythrospila*, *Parachela oxygastroides* (Glass fish; *pla tab*), and *Mastacembelus armatus* (Tiretrack eel; *pla lod dum;* different origins to the Mastacembelidae family).

The study also found 9 of the 11 threatened Mekong fish species according to the 2015 IUCN Red List of Threatened Species (IUCN, 2015). For instance, a 9.5 kg *Pangasianodon gigas* (Giant Mekong catfish; *pla buek*) was caught at Bungkhylek, and two juvenile fish of 0.5-0.8 kg and 37-38 cm in length were caught at Ladcharoen. This species is classified as "critically endangered". *Probarbus labeamajor* (Thicklip barb; *pla earn hang mum*) is listed as endangered and was caught at both Phomueng and Boungmuang. Vulnerable species caught included *Cyprinus carpio*[7] (Common Carp; *pla nai*) at Bungkhylek, *Cirrhinus microlepis* (Small scale mud carp; *pla nuan chan*) at Phomueng, and *Datnioides undecimradiatus* (Mekong tiger fish; *pla lard*) at *baan* Na Waeng and Ladcharoen. In addition, near-threatened species were caught, such as *Chitala blanci* (Featherback; *pla tong lai*) at Bungkhylek, and *Mekongina erythrospila* (Minnows or River carps; *pla sa-ee*), *Wallago attu* (Great white sheatfish; *pla kao khao*) and *Bagarius yarrelli* (Goonch; *pla khae*), which were caught near every study village.

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[7]Although *Cyprinus carpio* is regarded with disfavour in many areas, it is not considered an immediate problem in the Mekong River (Welcomme and Vidthayanon, 2003) and the Chao Phraya River basin (Suvarnaraksha *et al*., 2012). However, there are some local concerns about this species in Southern Lao PDR where *chaopramong* blame it for declines in local fish species because it eats the eggs of other fish (ibid; Termvidchakorn and Hortle, 2013).

6.3.1.2 Scarcity of fish species

During the key informant interviews (see Section 3.4.2.3), *chaopramong* identified 16 species as being scarce (Table 6.4). The way they classified such scarce fish was on the basis that certain species have not been caught for number of years. Some *chaopramong* reported that they had 'heard' about endangered species being caught, which reflects the fact that they often 'hang out' at gazebos [*sala*] near piers, and they therefore know which kinds of fish were caught in each community.

It can be noted in Table 6.4, that 11 out of 16 species that *chaopramong* had considered scarce correspond with the 2015 IUCN Red List of Threatened Species. For instance, *pla fa lai* (*Dasyatis laosnesis*) is listed as endangered, while *pla loem* (*P. sanitwongsei*) and *pla buek* (*P. gigas*) are both on the critically endangered list, and *chaopramong* reported that they had not seen those species for over 10 years. Interestingly, three out of the other five species identified as 'scarce', but not on the 2015 IUCN Red list, have been found by studies to be in decline or potentially vulnerable due to fisheries pressure. For instance, *pla lai yak* or *pla tu nha* (*Anguilla marmorata*) is identified as a vulnerable species (Vishwanath and Mailautoka, 2012; Living River Siam and Chiang Khong Conservation Group, 2006[8]), *pla koun* (*Wallagonia micropogon*) is endangered (Living River Siam and Chiang Khong Conservation Group, 2006), and *pla maew (Lycothrissa crocodilus)* is vulnerable (Vidthayanon C., 2005).

As shown above, the LEK of *chaopramong* regarding fish species and fish scarcity mostly agrees with scientific information. Hence, the LEK of *chaopramong* should not be regarded as anecdotal or uncritical knowledge, instead it should be treated as equally important as scientific information in understanding harvester and species interaction (Close and Hall, 2005).

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[8] Generally known as Tai or Thai Baan Research at Chiang Khong, the Mekong River (Ghan Vijai Jaobaan)

Table 6.3: Distribution of fish species in the five study villages of Na Waeng, Ubon Ratchathani

Family	Scientific name	Species authority	Status	Commmon name	Phomueng	Bungkhylek	Na Waeng	Boungmuang	Ladcharoen
Bagridae	Hemibagrus filamentus	(Fang & Chaux, 1949)	-	Blacktail catfish	+	+	+	+	+
	Hemibagrus nemurus	(Valenciennes, 1840)	-	Yellowtail catfish	-	-	+	-	+
	Hemibagrus wyckioides	(Fang & Chaux, 1949)	-	Asian red tailed catfish	+	+	+	-	+
	Mystus albolineatus	(Roberts, 1994)	-	Mystus catfish	-	+	+	-	-
Cobitidae	Acanthopsis spp.	(Sauvage, 1876)	-	Loach	-	+	-	-	-
	Botia helodes	(Sauvage, 1876)	-	Tiger botia	-	+	+	-	-
Cyprinidae	Barbonymus altus	(Gunther, 1868)	-	Red tailed tinfoil	+	+	+	+	+
	Cirrhinus microlepis	(Sauvage, 1878)	VU	Small scale mud carp	+	-	-	-	-
	Cosmochilus harmandi	(Sauvage, 1878)	-	River barb	+	+	-	+	+
	Cyprinus carpio	(Linnaeus, 1758)	VU	Comon Carp	-	+	-	-	-
	Hampala macrolepidota	(Valenciennes, 1842)	-	Hampala barb	-	-	+	-	-
	Henicorhynchus siamensis	(de Beaufort, 1927)	-	Siamese mud carp	+	+	+	+	-
	Labeo chrysophekadion	(Bleeker, 1850)	-	Black sharkminnow	+	+	+	+	+
	Labiobarbus lineata	(Sauvage, 1878)	-	-	-	+	+	-	-
	Mekongina erythrospila	(Fowler, 1937)	NT	River carps	-	-	+	-	-
	Parachela oxygastroides	(Bleeker, 1852)	-	Glass fish	-	-	+	-	-
	Probarbus labeamajor	(Roberts,1992)	EN	Thicklip barb	+	-	-	+	-
Datnioidae	Datnioides undecimradiatus	(Roberts & Kottelat, 1994)	VU	Mekong tiger fish	-	-	+	-	+
Eleotridae	Oxyeleotris marmorata	(Bleeker, 1852)	-	Marble sleeper	-	-	+	-	-
Mastacembelidae	Mastacembelus armatus	(Lacepede, 1800)	-	Tiretrack eel	-	-	+	-	+
Notopteridae	Chitala blanci	(d'Aubenton, 1965)	NT	Featherback	-	+	-	-	-
Pangasiidae	Pangasianodon gigas	(Chevey, 1930)	CR	Giant Mekong catfish	-	+	-	-	+
	Pangasius bocourti	(Sauvage, 1880)	-	Shark catfishes	+	+	+	-	+
	Pangasius pleurotaenia	(Sauvage, 1878)	-	Shark catfishes	-	-	+	+	-
Siluridae	Belodontichthys truncatus	(Kottelat & Ng, 1999)	-	Sharp-tooth sheat fish	+	+	+	-	+
	Micronema bleekeri	(Gunther, 1864)	-	Sheatfish	-	+	+	-	+
	Wallago attu	(Schneider, 1801)	NT	Great white sheatfish	+	-	+	-	-
Sisoridae	Bagarius bagarius	(Hamilton, 1822)	NT	Goonch	+	-	+	+	+
Tetraodontidae	Monotrete leiurus	(Bleeker, 1851)	-	Toadfish	-	-	+	-	-
Total species					12	16	22	8	13

Remarks: Status (IUCN, 2015): CR=Critically endangered, EN= Endangered, VU=Vulnerable, NT=Near threatened; Endemic: (+) =occurrence, (-) = no occurrence

Table 6.4: Identification of scarce fish species by LEK of *chaopramong* from the five study communities of Na Waeng, Ubon Ratchathani

Family	Species	Species authority	Common name	Local Thai name	Village					Status	
					Phomueng	Bungkeylek	Na Waeng	Boungmuang	Ladcharoen	IUCN	Other
Anguillidae	*Anguilla marmorata*	(Quoy & Gaimard, 1824)	Giant mottled eel	pla lai yak, pla tu nha	-	y	-	-	y	-	1,2
Channidae	*Channa marulius*	(Hamilton, 1822)	Great snakehead	pla chon geu hao	-	-	y	-	-	NT	-
Cyprinidae	*Aaptosyax grypus*	(Rainboth, 1991)	Mekong giant salmon carp	pla sanaak	-	y	-	y	-	CR	-
	Bangana behri	(Fowler, 1937)	Minnows or carps	pla waa seoun	y	-	-	-	y	VU	-
	Catlocarpio siamensis	(Boulenger, 1898)	Giant carp, Giant barb	pla kraman	-	-	-	-	y	CR	-
	Cirrhinus molitorella	(Valenciennes, 1844)	Mud Carp	pla kaeng	y	-	-	y	y	NT	-
	Leptobarbus hoeveni	(Bleeker, 1851)	Mad carp, Sultan fish	pla poong, pla baa	-	-	-	y	-	NE	-
	Luciosoma bleekeri	(Steindachner, 187)	Shark Minnow	pla sew ow	-	y	-	-	-	-	-
	Macrochirichthys macrochirus	(Valenciennes, 1844)	Long pectoral-fin minnow	pla pra	-	-	y	-	-	EN	-
Dasyatidae	*Dasyatis laosnesis*	(Roberts & Karnasuta, 1987)	Mekong freshwater stingray	pla fla lai	y	y	y	y	y	EN	-
Engraulidae	*Lycothrissa crocodilus*	(Bleeker, 1850)	Sabretoothed Thryssa	pla maew	-	y	-	-	-	-	3
Pangasiidae	*Pangasius sanitwongsei*	(Smith, 1931)	Giant Pangasius	pla loem	y	y	y	y	y	CR	-
	Pangasianodon gigas	(Chevey, 1930)	Giant Mekong catfish	pla buek	y	-	y	-	y	CR	-
Sciaenidae	*Nibea soldado*	(Lacepède, 1802)	Soldier croaker	pla kaeo	y	-	-	-	-	NE	-
Siluridae	*Wallagonia micropogon*	(Ng, 2004)	Sheatfishes	pla koun	y	y	-	y	y	-	2
Sundasalangidae	*Sundasalanx praecox*	(Roberts, 1981)	Dwarf noodlefish	pla tou gok	-	y	-	-	-	-	-

Remarks: Endemic: (y)= fish scarcity; Status: Status (IUCN, 2015): CR=Critically endangered, EN= Endangered, VU=Vulnerable, NT=Near threatened; Other: 1= Vishwanath and Mailautoka, 2012; 2 = Living River Siam and Chiang Khong Conservation Group, 2006); 3 = (Vidthayanon C., 2005).

6.3.2 Scientific knowledge: Fish ecology

6.3.2.1 Spatio-temporal model of fish abundance

(1) Temporal model of fish abundance

The environmental parameters from Figure 6.2 were added to the R-program to help develop a classification analysis regression tree for fish abundance in the dry season (Figure 6.6). The text box shown in Figure 6.5 shows the command file (pool.txt) used to analyse the 16 parameters as described earlier in Table 6.2. The model fit was assessed using the 'rpart' function, which refers to 'Recursive partitioning and regression trees'. The first argument of the function included a model formula, with the '~' symbol standing for "is modelled as". The script used "no__of_fis" (class of fish density, text character) as a response variable. The print function provided an abbreviated output,the 'plot' function was used to plot the tree, and the 'text' commands were used to create the character labels for each plot.

As mentioned previously in Section 3.4.1, water temperature, pH, DO, salinity, and turbidity levels were measured in situ, using a handheld YSI 556 at approximately 15 cm depth from the water surface. Water samples for plankton density measurement were collected from surface water, while those for measurement of alkalinity and ammonia-nitrogen content were collected using a Ruttner bottle at 5 m depth along the river.

The results of this analysis are shown in Figure 6.6 where the classification tree retains 11 terminal nodes, consisting of the following five predictor variables: water depth, DO level, river channel width in the dry season, pH level, and density of zooplankton. The most important variable in relation to the occurrence-probability of fish abundance is water depth, and the key factors determining the occurrence-probability of high levels of fish abundance are water depth, river channel width, DO level, pH level, and density of zooplankton, as can be clearly seen on the right of the regression tree.

```
dat=read.table("pool.txt", header=T, row.names=1)
names(dat)
 [1] "Fish_den"   "no__of_fis" "No_Fish_sp" "Min_F_dep"  "Max_F_dep"
 [6] "Depth"     "Temp"      "Turbinity"  "Salinity"  "Alk"
[11] "Plk"       "Zoo"       "DO"        "PH"        "Riv_wid"
[16] "Cha_wid"
dat1=dat[,1:3]
dat2=dat[,4:15]
library(rpart)
fit <- rpart(dat1$no__of_fis ~ dat2$Min_F_dep + dat2$Max_F_dep + dat2$Depth + dat2$Temp + dat2$Turbinity +
dat2$Salinity + dat2$Alk + dat2$Plk + dat2$Zoo + dat2$DO + dat2$PH + dat2$Riv_wid + dat2$Cha_wid)

printcp(fit)
plotcp(fit)
summary(fit)


plot(fit, uniform=TRUE, main="Classification Tree for Numbers of fish")
text(fit, use.n=TRUE, all=TRUE, cex=.8)
```

Figure 6.5: R-program script for the CART used re: fish abundance model.

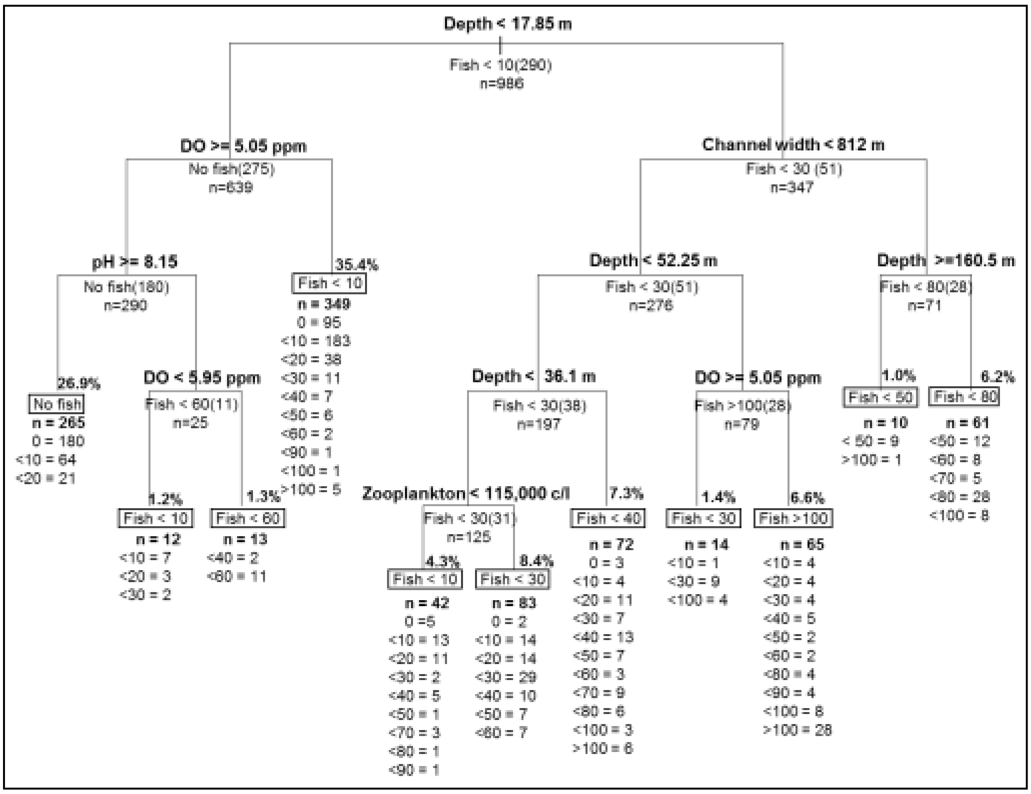

Figure 6.6: Classification tree analysis – dry season fish abundance model for Na Waeng.

Figure 6.6 shows the partitioning of the training dataset for ecological variables, which was based on the rule used for labelling each split. If the condition designated by the rule was met, the variables were split to the left, and if not, they were split to the right. The box at each terminal node shows fish abundance levels, in which the percentage at each terminal node represents the occurrence-probability of fish abundance, which is defined as the total number of observations per node, out of the total population (n=986). The label 'n' represents the total number of observations (fish density cases) for a given node, while 'no. fish' (n=265) represents the number of fish density cases (no. fish=180, fish <10=64, fish <20=21). Details of the fish densities are as follows: 0 = no fish, <10 = 1-9 fish, <20 = 10-19 fish…., and >100 = more than 100 fish. The values within the parentheses represent the observed fish densities at each node.

Theoretically, CART analysis is used to predict the relative significance of different variables for identifying homogenous groups within the training dataset (Breiman *et al.,* 1984; see Section 6.2 for the technical explanation). The model of fish abundance suggests that a threshold water depth of 17.85 m is the primary split at which to identify the occurrence-probability of fish densities. On the left of the regression tree, a water depth of less than 17.85 m suggests there will be a low fish density (i.e. one of less than ten fish (29.4%)). Using the same threshold water depth, a DO level greater than or equal to 5.05 ppm and a pH level greater than or equal to 8.5 indicate a high probability of low occurrence of fish densities (26.9%). On the other hand, when the pH level is less than 8.15, there are two occurrence-probabilities for fish densities: less than 10 fish (1.2%; DO level 5.05-5.95) and less than 60 fish (1.3%; DO level greater than or equal to 5.95). The last occurrence-probability for fish density on the left side of the regression tree is less than 10 fish, which occurs when the DO level is lower than 5.05 (35.4%).

On the right side of the regression tree – at a water depth exceeding the threshold (17.85 m) – the river channel width variable is presented to determine the river depth range and the fish density levels, based on different DO levels and zooplankton densities. Generally speaking, the probability- occurrence of fish tends to be less than 30 when the channel width is less than 812 m and the water depth is between 17.85 and 52.25 m. Using the same criteria for channel width (< 812 m) and water depth (17.85 to < 52.25 m), there are two occurrence-probabilities for fish density: less than 10 fish (4.3%; zooplankton density level lower than 115,000 cells/litre) and less than 30 fish (8.4%; zooplankton density level higher than or equal to 115,000 cell/litre). Another occurrence-probability for fish density – less than 40 fish – occurs when the water depth is between 36 and 52.25 meters (7.3%).

Where the water depth is 52.25 meters or more, but less than 160.5 m, a probability-occurrence of the fish density being less than 30 fish (1.4%) occurs when there is a DO level of 5.05 ppm or higher. On the other hand, when the DO level is below 5.05 ppm, a fish density of higher than 100 fish occurs among 6.6% of the total population.

Where the channel width is 812 m or more, and the water depth is 160.5 m or more, the probability-occurrence of fish is less than 50 (1.0%). When the water depth is shallower than 160.5 m, a fish density of less than 80 fish occurs for 6.2% of the total number of population.

(2) Spatial model of fish abundance

The GIS has a potential function to integrate not only qualitative but also quantitative data as long as the data is inherent to geographical location, which can then provide a better understanding and visualization of data relationship to environmental contexts. This study shows that CART analysis and spatial analysis using GIS techniques can be incorporated to provide a reasonable spatial model of fish abundance, based on the research carried out at Na Waeng.

A plausible explanation for the above relationship is shown in the following table, which contains the rules built by CART but written as SQL expressions in the study model (Table 6.5). SQL query expressions were used in ArcGIS to select a subset of features and table records, or attributes of the model of fish abundance. Those values were then used to predict the fish abundance values. Predicted data were interpolated using the IDW method and an interpolation tool in the ArcGIS Spatial Analyst extension (see Section 6.2 for the technical justification), and then mapped to reveal a spatial model of fish abundance for the Mekong River in Na Waeng (Figure 6.7). The above explanation shows how a significant number of geomorphological and physio-chemical variables can facilitate the prediction of fish abundance and species richness in the Mekong River, as well as certain aspects of its river and fish ecosystem structure. This knowledge allows for an increasing volume of quantitative information to be introduced into any model of the deep pools' function during the dry season.

Table 6.5: Rules used in the spatial model of fish abundance

Occurrence probability of fish abundance	Rules or SQL expressions	No. of records
No. fish	"Depth"<17.85 AND "DO">=5.05 AND "PH">=8.15	265
<10_1	"Depth"<17.85 AND "DO">=5.05 AND "PH"<8.15 AND "DO" <5.95	12
<10_2	"Depth"<17.85 AND "DO"<5.05	364
<10_3	"Depth" >= 17.85 AND "Chanel width" < 812 AND "Depth" <52.25 AND "Depth" <36.1 AND "Zoo" <115000	42
<30	"Depth" >= 17.85 AND "Chanel width" < 812 AND "Depth" <52.25 AND "Depth" <36.1 AND "Zoo" >= 115000	83
<30	"Depth" >= 17.85 AND "Chanel width" < 812 AND "Depth" >= 52.25 AND "DO" >=5.05	14
<40	"Depth" >= 17.85 AND "Chanel width" < 812 AND "Depth" <52.25 AND "Depth" >= 36.1	72
<50	"Depth" >= 17.85 AND "Chanel width" >=812 AND "Depth" >=160.5	0
<60	"Depth"<17.85 AND "DO">=5.05 AND "PH"<8.15 AND "DO" >=5.95	13
<80	"Depth" >= 17.85 AND "Chanel width" >=812 AND "Depth" < 160.5	57
>100	"Depth" >= 17.85 AND "Chanel width" < 812 AND "Depth" >= 52.25 AND "DO" < 5.05	64

In this study a high probability of fish occurrence was related to water depth, which generally explains the significance of deep pools and their role. The spatial model of fish abundance developed for this study is graphically expressed in Figure 6.7's graduated colour map, which spans the colour spectrum between red and blue. The darker red shades indicate higher levels of fish abundance, while the blue colours indicate lower levels. The distribution of high fish abundance levels (red to yellow) corresponds with deep pool locations, in particular those of greater depth; namely, deep pool 7 [named by *chaopramong vern khan ya ci*], deep pool 5 [*vern tham toum*], and deep pool 6 [*vern kloon*] all in Ladcharoen village, and deep pool 3 [*vern som hoong*] in *baan* Na Waeng.

A statistical model of fish abundance does not provide specific information on species diversity and behaviour. Therefore, it is essential to combine this scientific model with the LEK of *chaopramong* regarding species and their behaviour when attempting further explanation. The results from catch monitoring in the five fishing communities (Figure 6.8) informed explanations of the function of deep pools as a key habitat for migratory fish. Indeed, 98% (975.2 kg) of the total catch can be classified as migratory fish and these include both white fish and grey fish. White fish (85%; 848 kg) migrate in a lateral pattern and live mostly in deep pools, mainstream habitats during the dry season, and others (respectively 56%, 40% and 4% of the total white fish count by weight).

Regarding the dietary composition of fish species in this study, most are carnivorous (11 species) and omnivorous (11 species), with the rest being herbivorous (7 species). However, the flexibility of their diets means many freshwater fish vary in terms of their size and seasonal location within the system (Welcomme *et al*., 2006; Pusey *et al.,* 1995).

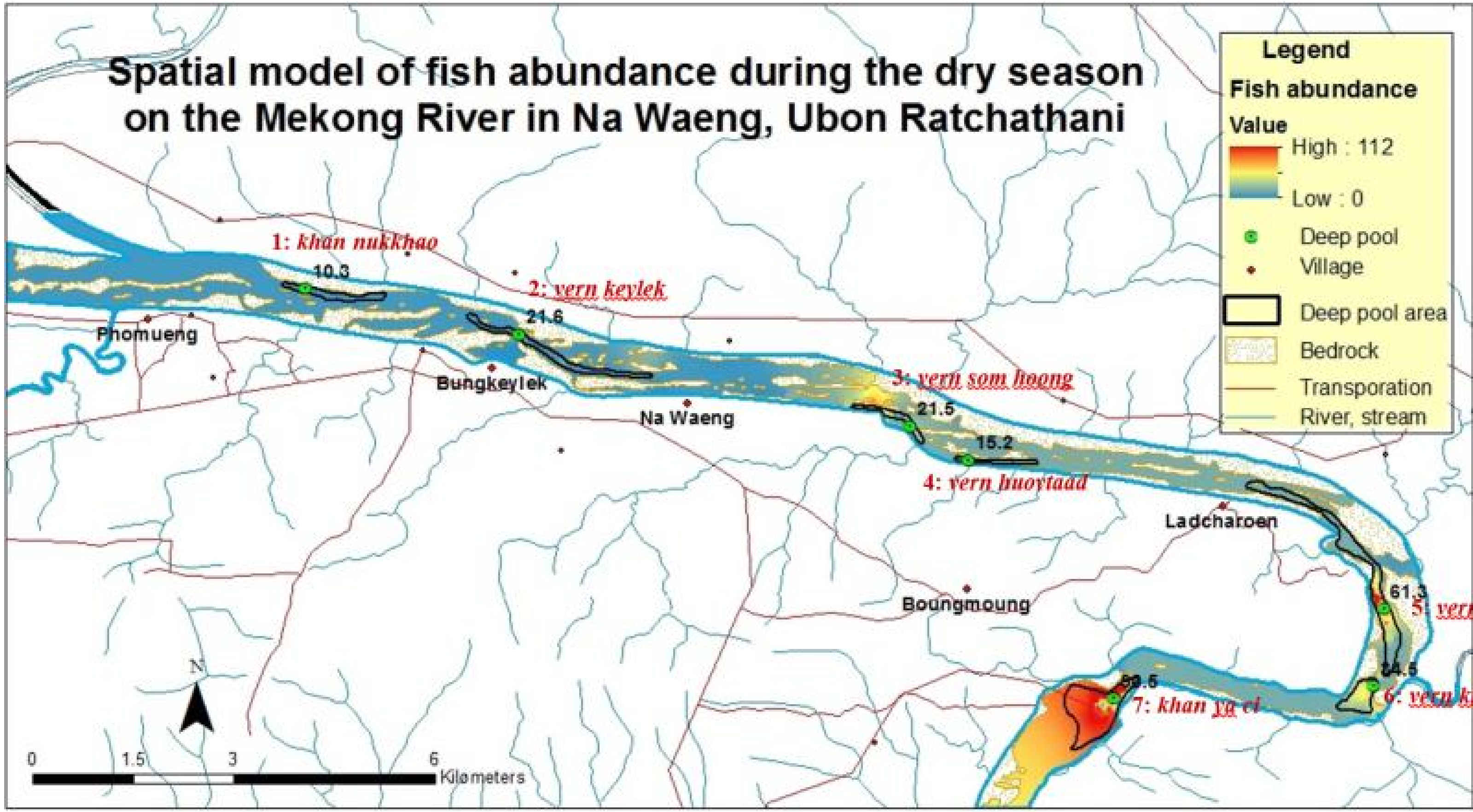

Figure 6.7: Spatial model of fish abundance on the Mekong River–in Na Waeng, Ubon Ratchathani, Thailand

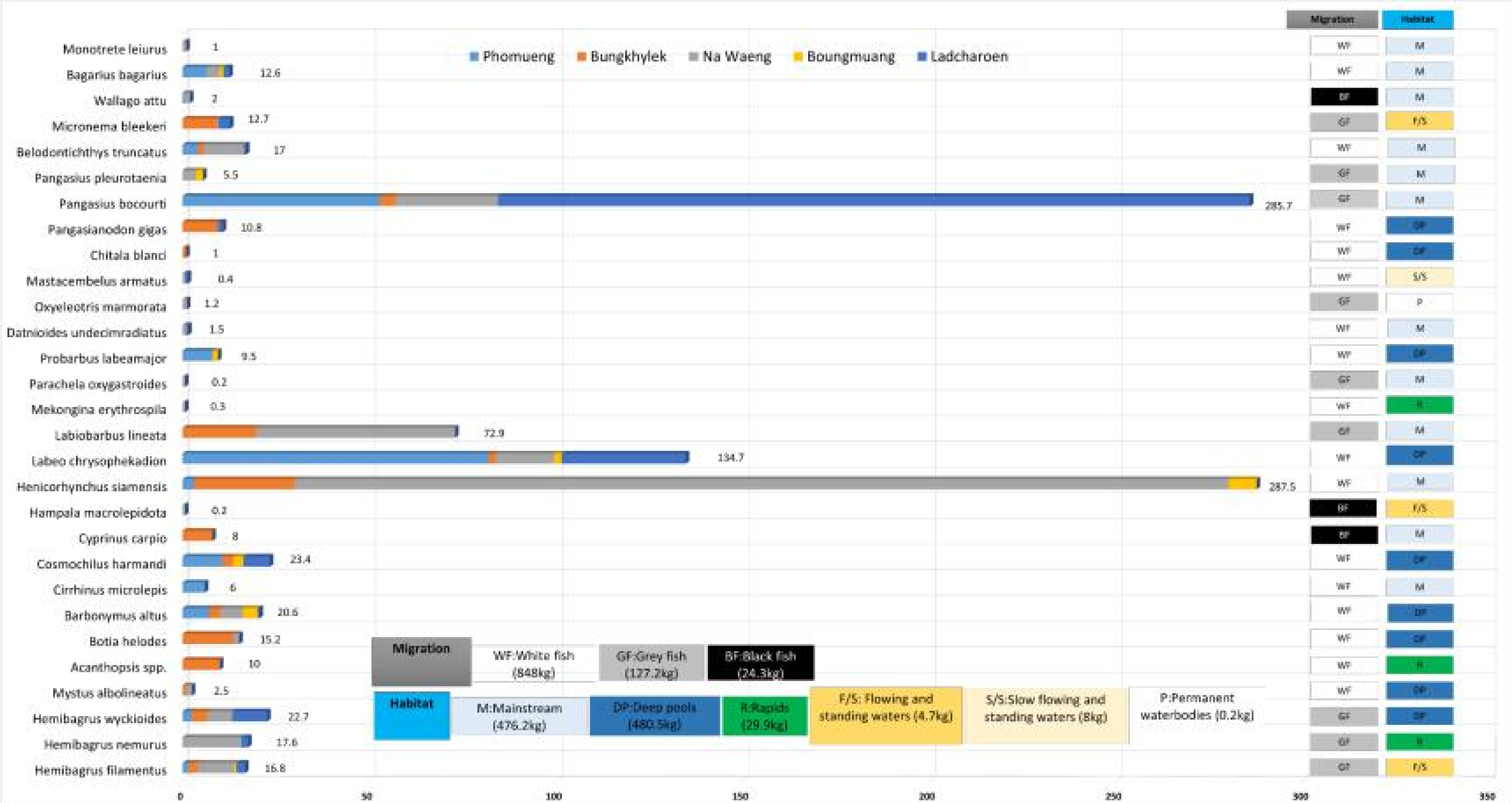

Figure 6.8: Fish species landed (kg) during the dry season (30 days) in Na Waeng (Migration behaviour: Baran, 2006; Froese and Pauly, 2014; Fish habitats: MFD-MRC, 2003; Food: Poulsen et al., 2004; Vidthayanon, 2008.

The white fish can be categorized into three dominant families, as follows: (i) 55% of the total weight of white fish is Cyprinidae/ *H. siamensis, L. chrysophekadion*; (ii) 36% is Pangasiidae/*P. bocourti*; and (iii) 4% is Bagridae/ *H. filamentus, H. nemurus*. In terms of diet, the major communities of white fish are herbivorous and omnivorous (51% and 41% of the total white fish, respectively).

Grey fish (13%; 127.2 kg) migrate in a bilateral pattern or school for spawning in tributaries during the wet season and migrate to the mainstream during the dry season. Grey fish tend to live in the mainstream (86%), deep pools (11%), and in other locations (3%), based on the total weight of grey fish caught in the study area. The three dominant grey fish families found were as follows: (i) 74% Cyprinidae/ *Labiobarbus lineata* (*pla kui rham)* and *B. altus* (*pla tapien thong*), (ii) 12% is Cobitidae/ *Botia helodes* (*pla mhu laai*), and (iii) 10% *is* Sisoridae/*Bagarius yarrelli* (*pla khae)*, of the total weight of grey fish. The assemblage is dominated by herbivorous species (74% of the total grey fish), such as *L. lineata* and *B. altus*.

The black fish species (2%; 24.3 kg), meanwhile, tend to stay in the flooded forests or still water areas throughout the year, comprised the following: (i) 93% Bagridae/*Hemibagrus wyckioides* (*pla kod keaw*), (ii) 5% Eleotridae/*Oxyeleotris marmorata* (Marble sleeper; *pla bu trai*), and (iii) 2% *M. armatus* (Tiretrack eel; *pla lod dum*), of the total weight of black fish. All of these black fish are carnivorous. However, these fish tend to live on the mainstream during the dry season, and enter the flooded forests during the wet season.

The majority of the catch at Ladcharoen village, where the spatial model of fish abundance reveals high fish abundance [deep pool 7, 5, 6 - *khan ya ci, vern tham toum, vern kloon*, respectively], provides information on the high deep pool habitat, in particular for white fish. The vast majority of those fish are *P. bocourti* [*pla yang*] and *L. chrysophekadion* [*pla ka dum, pla e-tuu*], which constitute93% (244.7 kg) of the total catch in Ladcharoen (263.6 kg). The only deep pool inhabiting grey fish caught at Ladcharoen was *B. yarrelli* [*pla khae*],with just 1.7 kg recorded during the monitoring period. In light of this similarity between modelled and actual catch data, another deep pool that shows high fish abundance is in *baan* Na Waeng [deep pool 3- *vern som hoong*], where 78% of the total catch of 414 kg comprised white fish favouring either mainstream (276.6 kg) or deep pool (47.2 kg) habitats, among which *H. siamensis* [*pla soi khao*] and *P. bocourti* [*pla yang*] were the main species present. Furthermore, another major fish species landed was *L. lineata* (*pla kui rham)*, which is a grey fish of mainstream habitats (53.4 kg or 13% of the total catch in *baan* Na Waeng).

The above explanation of results clearly shows the role of deep pools as a shelter for many species, including indigenous and migratory fish, and as spawning areas for some species during the dry season. In this regard, deep pools may be considered one of the core factors influencing fish ecology in the Mekong River, and are therefore important to the development of fisheries conservation areas.

6.3.2.2 Spatio-temporal model of species richness

(1) Temporal model of species richness

The environmental parameters from Table 6.2 were added to the R-program to help develop a regression tree for species richness in the dry season at Na Waeng (Figure 6.9). A similar concept was used to that previously described in Section 6.3.1.1 regarding the command file, but in the species richness model 'No_Fish_sp' (number of fish species, number) was used as a response variable (Figure 6.10).

The regression tree for species richness in the dry season at Na Waeng (Figure 6.9) has seven terminal nodes, consisting of the following four predictor variables: density of zooplankton, density of plankton, the DO level, and turbidity. The most significant variables in terms of species richness are zooplankton and plankton, as they provide a crucial source of food for the fish. As described earlier in Section 6.2, the R^2-value is a prediction of how well the model is expected to perform in relation to its predictive reliability; thus the closer all split model R^2 values are to 1, the better the predictive reliability performance of the model. The coefficient of determination or R^2 of the total splits model was 0.92, within which R^2 of the first split was as high as 0.54 (Figure 6.10).

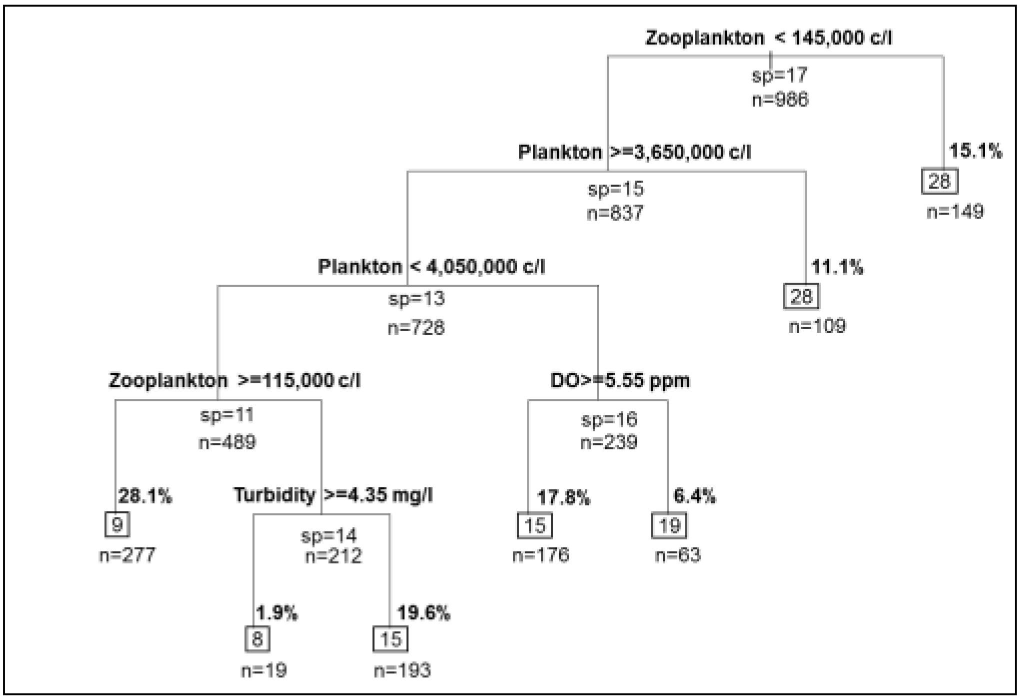

Figure 6.9: Regression tree for species richness in the dry season at Na Waeng

The values shown in the boxes at each terminal node represent estimated species richness levels, with the occurrence-probability of species richness (%) shown at the top-right of each box. The occurrence-probability of species richness is defined as the total number of observations per node out of the total population (n=986). The label 'sp' represents species richness values, while 'n' represents the total number of observations at a given node.

From the study results, the highest probability of species richness (28.1%; 9 species) occurs when zooplankton density levels are between 115,000 and 145,000 cells/litre, and plankton density is between 3,650,000 and 4,050,000 cells/litre. The second highest probability of species richness (19.6%; 15 species) occurs when the plankton density level is lower than 4,050,000 cells/litre, zooplankton density is lower than 115,000 cells/litre, and the turbidity level is lower than 4.35 mg/l. On the other hand, when the turbidity level is 4.35 mg/l or higher, it tends to predict the lowest probability (1.9%) of species richness (8 species).

The third highest probability of species richness (17.8%, 15 species) is predicted when the zooplankton density level is under 145,000 cells/litre, plankton density is 4,050,000 cells/litre or higher, and the DO level is higher than 5.55 ppm. Along with the previous criteria given for plankton density, when the DO level is under 5.55 ppm, the probability level is low, at 6.4% or 19 species.

```
> rsq.rpart(fit)

Regression tree:
rpart(formula = dat1$No_Fish_sp ~ dat2$Min_F_dep + dat2$Max_F_dep +
    dat2$Depth + dat2$Temp + dat2$Turbinity + dat2$Salinity +
    dat2$Alk + dat2$Plk + dat2$Zoo + dat2$DO + dat2$PH +
    + dat2$Riv_wid + dat2$Cha_wid)

Variables actually used in tree construction:
[1] dat2$Alk_surf dat2$Salinity dat2$Temp

Root node error: 52394/986 = 53.138

n= 986

        CP nsplit rel error   xerror      xstd
1 0.544285      0  1.000000 1.001859 0.0308378
2 0.343263      1  0.455715 0.457259 0.0125589
3 0.075578      2  0.112452 0.114755 0.0041234
4 0.013064      3  0.036874 0.038601 0.0036109
5 0.010000      4  0.023811 0.025733 0.0028879
```

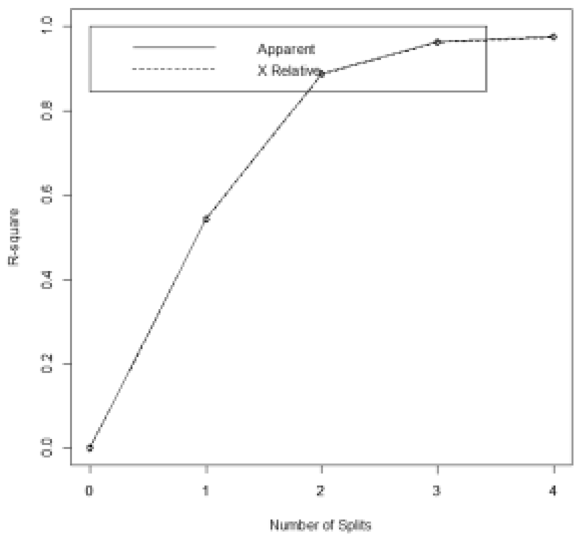

Figure 6.10: R-program script and R2 results of the total splits model for species richness

Another interesting probability (15.1%, 28 species) occurs when zooplankton density is 145,000 cells/litre or greater, while a lower probability (11.1%, 28 species) leads to plankton density levels of 3,650,000 cells/litre or less.

(1) Spatial model of species richness

The development of models capable of predicting the distribution of fish species richness is of vital importance, in particular given the increasing importance of fisheries conservation in recent years. Although species richness levels were identified through the LEK of *chaopramong* for 29 species, more species may have been recorded due to the similarity of species, or the presence of small fish schooling together during the migratory period. The result shows that CART analysis and spatial analysis using GIS techniques can provide reasonable predictions of the spatial distribution of species richness, based on the research carried out at Na Waeng.

Table 6.6 shows the rules built by CART, but written as SQL expressions. The SQL query expressions were used in ArcGIS to select a subset of features and table records or attributes for the model of species richness. These were then used to predict values for species richness. Using the ArcGIS Spatial Analyst Tools extension, predicted data were interpolated using the IDW method (see Section 6.2 for the technical justification), with an interpolation tool using a 15 metre resolution. The output data were then extracted by developing a 'mask' of the Mekong River, and the data were then mapped to visualize a spatial model of species richness along the river at Na Waeng (Figure 6.11).

Table 6.6: Rules used in the spatial model of species richness

Occurrence probability of species richness	Rules or SQL expressions	No. of records
28	"Zoo" >=145000	149
28	"Zoo" < 145000 AND "Plk" <3650000	109
19	"Zoo" < 145000 AND "Plk" >= 3650000 AND "Plk" >=4050000 AND "DO" <5.55	63
15	"Zoo" < 145000 AND "Plk" >= 3650000 AND "Plk" >=4050000 AND "DO" >= 5.55	176
9	"Zoo" < 145000 AND "Plk" >= 3650000 AND "Plk" < 4050000 AND "Zoo" >=115000	277
8	"Zoo" < 145000 AND "Plk" >= 3650000 AND "Plk" < 4050000 AND "Zoo" < 115000 AND "Turbidity" >=4.35	19
15	"Zoo" < 145000 AND "Plk" >= 3650000 AND "Plk" < 4050000 AND "Zoo" < 115000 AND "Turbidity" < 4.35	193

Figure 6.11 shows the spatial model of species richness developed for this study, corresponding to the graduated colour map and spanning the colour spectrum between red and blue. The darker red shades indicate higher levels of species richness, while blue colours indicate lower levels. The distribution of high species richness levels (red to yellow) corresponds to primary production or food sources for fish. Interestingly, the highest levels of species richness shown are around *baan* Na Waeng and Bungkhylek. Likewise, the result from the catch monitoring programme demonstrated the highest number of species were recorded in *baan* Na Waeng, Bungkhylek, Ladcharoen, Phomueng, and Boungmuang, at 22, 16, 13, 12, 8 species respectively.

Geographically speaking, river characteristics and local channel morphology explain the variation in fish species composition in Na Waeng. At *baan* Na Waeng and Bungkhylek the river channel shape creates an impoundment and an island barrier (Figure 6.12). This type of river channel morphology is pronounced only in these two villages in the study area. This river characteristic tends to lead to a variety of water flow characteristics; from standing water, to slow flowing areas, and also strong water current in rapids and the mainstream. These conditions could favour the presence of five species that are not associated with highly turbulent water habitats, all of which were reported only at *baan* Na Waeng and Bungkhylek. These species are *H. macrolepidota*, which is frequently found in impoundments (Rainboth, 1996) or streams with running water and sandy to muddy bottoms (Talwar, and Jhingran, 1991), while *C. carpio* favours slow flowing or standing water and soft bottom sediments, whereas *Mystus albolineatus* and *M. leiurus* mostly inhabit flowing and standing water, but *M. albolineatus* especially presents around submerged woody vegetation (Rainboth, 1996). Lastly, *O. marmorata* prefers standing water with dense water plants (*ibid*). Therefore, the variety of local channel morphologies found adjacent to only these two villages may attract species and create a larger variety of fish habitats than are found near other villages.

The results section above shows how important geomorphological and physio-chemical variables can facilitate the prediction of fish abundance and species richness in the Mekong River. It was found that a high probability of fish occurrence is related to water depth, which generally explains the significance of deep pools and their role as a shelter for many species, including indigenous and migratory fish, and as spawning areas for some species during the dry season. In this regard, deep pools may be considered one of the key factors influencing fish ecology in the Mekong River, and so should be considered of vital importance when developing fisheries conservation areas. The predictions of the species richness model suggest a strong relationship with fish productivity, which is fundamental to the management and preservation of biodiversity. These two models will be elaborated in the discussion section later.

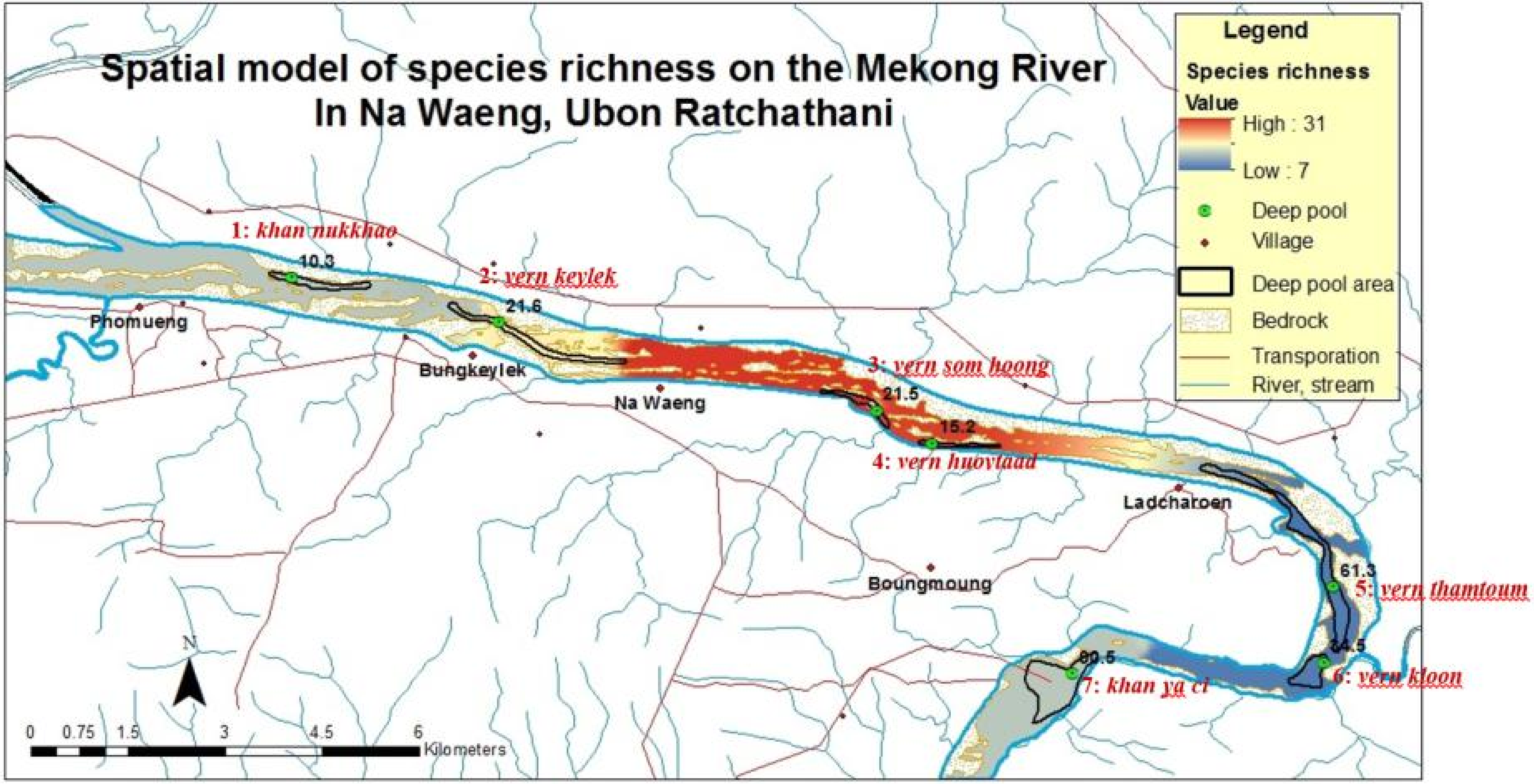

Figure 6.11: Spatial model of species richness on the Mekong River–in Na Waeng, Ubon Ratchathani, Thailand

Figure 6.12: Variable river channel characteristics– including impoundments and island barriers –around *baan* Na Waeng and Bungkhylek village

6.4 Discussion

6.4.1 Fish ecology and deep pools

6.4.1.1 Physio-chemical factors affecting fish abundance and species richness

The CART analysis developed in this study in the main confirmed the predicted correlation between the presence and characteristics of deep pools, and fish abundance and species richness levels during the dry season along the Mekong River. However, any important relationships between geo-morphology and fish abundance/species richness levels have yet to be revealed. A total of 16 variables covering 986 points were used to identify these relationships using the two models, and these showed a similar relationship for both geomorphological and physio-chemical variables. However, the most significant factors explaining the differences in primary variables identified by these two models are described below.

In general, fish communities are influenced by historical, evolutionary and biogeographical processes, as well as species' interactions and environmental variations, as these influence the communities' abundance and distribution (Ricklefs, 1987). According to Connell (1975), the distributions of animals across available habitats are generally mediated by three factors: food availability, predation intensity, and tolerance of physio-chemical conditions. Ordinarily, food availability in rivers is regulated by the fluvial geomorphic processing of organic materials within the stream (Jacobson and Coleman, 1986; Hupp *et al.,* 2008). These fluvial geomorphic processes, which form pools and riffles influence the basic habitat use and habitat abundance patterns found in all rivers, including the Mekong, which has over 400 deep pools.

The CART analysis developed in this study in the main confirmed the predicted correlation between the presence and characteristics of deep pools, and fish abundance during the dry season along the Mekong River. The predictions made by the fish abundance model (see Section 6.3.2.1) corresponded closely to the geo-morphological variables of water depth and river channel width in the dry season, and also the physio-chemical variables of DO concentrations, pH levels, and zooplankton densities. According to the fish abundance model, these relationships allowed us to conclude that a water depth threshold of 17.85 m seems to be a key indicator of the occurrence probability of fish density levels. Therefore, when the water depth is less than 17.85 m, an occurrence probability of fish density between no fish and up to 60 fish will be related to the physio-chemical variables of DO and pH level. Meanwhile, when the water depth is greater than 17.85 m, the occurrence probability of fish density will be mainly influenced by the geo-morphological variables of water depth and river channel width. For instance, the wider and deeper a river, the more likely it is that the occurrence probability of fish density will be between 30 and 80 fish. In addition, at water depths between 36 and 53 m, the occurrence probability of fish density will be mainly influenced by the physio-chemical variables of DO level and density of zooplankton. Moreover, the predictions of the species richness model reveal a strong relationship with variability in zooplankton and phytoplankton densities, both of which are a crucial source of food for fish, as well as with DO levels and water turbidity levels.

Not surprisingly, the geomorphological variables of water depth and river channel width influence the overall level of fish abundance. There is also the fact that during the dry season, deeper water provides shelter and refuge from predators, while the temperature regime of deep water is also generally colder than shallow water (Wooley and Crateau, 1983; Schlosser, 1987; Harvey and Stewart, 1991; Englund and Krupa, 2000; Magalhães *et al.,* 2002). A great majority of people, and especially *chaopramong* in Khong in the south of Laos, believe that fish take refuge in deep pools in the dry season in order to escape from the high temperatures in shallower water (Baird, 2006).

The hydrological regime is possibly the most significant physical variable affecting chemical characteristics and biological communities (Matthews, 1988), and the major factor controlling fish community patterns (Halls and Welcomme, 2004). My research also reveals a strong relationship between the depth and width of the river, so that if the hydraulic radius increases, so does velocity, meaning that water flow strength depends on the existence of channels of a given width, as is explained by Manning's equation *(*Manning, 1891*).* Flow velocity regulates energetic costs, food supply, and the downstream transport of propagules (Vannote *et al.*, 1980; Muth and Schmulbach, 1984; Schlosser, 1998; Bond and Downes, 2003; Kemp *et al.*, 2011). Therefore deeper waters, wider rivers, and greater downstream discharges lead to increased diversity parameters (Horwitz, 1978), which may explain the high density level of fish abundance in deep water.

In addition, a river's velocity (Thompson *et al.*, 1998) and strength of flow will have a pronounced impact on the most well-established water quality indicators, such as DO concentrations. Similarly, many studies have emphasized the significance of water quality variables, particularly DO levels and pH, for aquatic communities, showing that only a few species can inhabit acidic water conditions, and that the optimum pH range is 7.5 to 8.5 (Jackson *et al*., 2001). In addition, water temperature is a key variable for fish survival, because it affects fish physiology and behaviour (Caissie, 2006; Hrachowitz *et al.,* 2010). Temperature also directly regulates DO levels in the water, affecting spawning times, growth rates, and the spatial-temporal distribution of species (Baron *et al.,* 2002; Jackson *et al.,* 2001; Magnuson *et al.,* 1979; Prchalová *et al.,* 2006). However, in the CART analysis, no water temperature variables were selected for inclusion in the final models, although water temperature tolerance varies somewhat between species and also between life stages.

Biologically speaking, an appropriate DO level is absolutely essential for the survival of all aquatic organisms, and also invertebrates such as clams, crabs, phytoplankton, and zooplankton, all of which are crucial sources of food for fish (Welcomme, 1985). Fast, turbulent streams expose more of the water's surface area to the air and tend to have lower temperatures and more oxygen than slow flowing streams or backwaters (Giller and Malmqvist, 1998). Natural river purification processes require adequate oxygen levels to exist, as these permit aerobic life forms to develop as a by-product of photosynthesis. Hence, systems with a high abundance of aquatic algae and plants may also have high concentrations of oxygen during the day and low concentrations at night when primary producers switch to respiration (Francis-Floyd, 2003). On the other hand, if the oxygen circulation between the surface and deeper layers is poor, which may occur due to physical, chemical, biological, and microbiological processes, as well as anthropogenic effects, this may adversely affect the functioning and survival of biological communities. Mostly, species become distressed when DO levels drop to 4 to 2 ppm (Francis-Floyd, 2003), and this study confirms the relationship between DO levels and the low probability of fish densities. The model here states that when DO levels are lower than 5.05 ppm, the probability of fish density is low at less than 10 fish. However, in this study's results, the mean DO level value is 4.27 ppm, covering the range 1.8 to 8.8 ppm, which is slightly higher than the average harmful level.

An additional contributory factor is zooplankton, so this was selected for inclusion in the model of fish abundance and species richness levels. The zooplankton factor of the fish abundance model is related to the geomorphological variables of water depth and river channel width. The model here confirms that when the water depth is less than 36.1 m, a higher probability of fish density is positively correlated with zooplankton density level. The model suggests the occurrence-probabilities for a fish density of 10-30 fish. In term of freshwater zooplankton density, spatial heterogeneity may relate to physical factors (George and Edwards, 1976; Watson, 1976; Patalas, 1981), especially as its density increases with water depth (Dumont, 1967). This is consistent with the result of this model. Some zooplankton are surface dwellers and may perhaps be readily aggregated by wind-driven water motion (Langford and Jermolajev, 1966; Malone and McQueen, 1983), whereas those living in less turbulent waters and at greater depths have been found to be the most heterogeneous (Dumont, 1967; Pinel-Alloul *et al.*, 1988). The result of this study's catch monitoring programme also found some mid-water living fish that feed on zooplankton, e.g. *L. lineata*, which were caught in greatest abundance at Bungkeylek and *baan* Na Waeng. The latter village recorded the highest density of zooplankton (187,500 cell/l) in this study.

The zooplankton factor of the species richness model appears to be a key control on highest probability of fish occurrence and is correlated strongly with density of plankton, DO levels, and turbidity. There are existing research data on this direct relationship, and phytoplankton production is considered a nutritional response by zooplankton (Longhurst and Herman, 1981). The abundance of zooplankton is pertinent when wishing to follow peaks in phytoplankton production, as shown for the

Paraná River by Bonetto (1976), which attracts some fish species, creating fish abundance and diversity in rivers. Having said that, the relative abundance of zooplankton levels have generally been attributed primarily to differences in flow and a number of other minor factors such as turbidity, DO levels, and conductivity (Welcomme, 1985). The same is also true of factors that support phytoplankton growth. These are very complex and interrelated with physio-chemical environmental factors, such as DO levels, temperature, visibility, and the availability of nutrients, nitrogen and phosphorous (Goldman and Horne, 1983). This provides further evidence to support the prediction model of species richness in this research, which suggests that it is not only related to the abundance of zooplankton and phytoplankton, but that DO levels and turbidity are also important.

Shifting to a regional spatial scale, numerous studies have indicated that species richness has a tendency to increase downstream, as the greater diversity and extent of aquatic habitats allows for colonisation by additional species (Sheldon, 1968; Schlosser, 1982; Angermeier and Schlosser, 1989; Harvey & Stewart, 1991; Arunachalam, 2000). Low species richness at high altitudes reflects the low variability of food supplies available (Tongnunui & Beamish, 2009) while in the lowlands the higher species richness reflects the richness of food nutrients and natural food sources, which are also enhanced by the flood pulse effect (Junk & Wantzen, 2004). The same is also true of the biodiversity in the three main Mekong migratory zones (Figure 2.14), within which there is a decrease in species richness moving from the lower (669), to middle (366), and upper (262) Mekong migration zones (Baran, 2010). The lower Mekong migratory zone encompasses freshwater, estuarine and marine environments and faunas, and as a consequence sees invasions of coastal species into freshwater areas, up to the Tonle Sap Lake and even upstream into the higher Mekong migratory zone (*ibid*). An alternative explanation of species richness in the lower Mekong system, is provided by the Tonle Sap Lake in Cambodia, which is the fourth highest ranked fish diversity lake ecosystem worldwide, with 197 species recorded in FishBase (2009) (cited in Baran, 2010, 7). Some species only occur downstream of the Khone Falls, which constitute a natural barrier to marine visitors, such as the *Engraulidae* (anchovies), *Polynemidae* (threadfins), and *Ariidae* (sea catfishes) (Roberts and Baird, 1995).

At the local scale as in Na Waeng, the model reveals that local river morphology influenced fish species and richness. Many studies have found that higher discharges infer a larger volume of water for fish to occupy, and an increase in river flow results in greater fish species richness due to the greater heterogeneity of local fish habitats (Guégan *et al.,* 1998; He *et al.,* 2010). The phenomenon of increased species richness with increasing habitat diversity may reflect the well-documented relationship between depth, discharge and velocity (Gorman & Karr, 1978; Matthews, 1998; Oberdorff *et al*., 1995; Xenopoulos and Lodge, 2006). Therefore, the variety of river characteristics that occur at *baan* Na Waeng and Bungkhylek tend to lead to a greater variety of water flow characteristics and fish habitats than can be found at other study villages.

6.4.1.2 Ecology of deep pools and the implications for conservation

The above explanation shows how a significant number of geomorphological and physio-chemical variables can facilitate the prediction of fish abundance and species richness in the Mekong River, as well as certain aspects of its river and fish ecosystem structure. This knowledge allows an increasing amount of quantitative information to be introduced into any models of the deep pools' function during the dry season. In this study a high probability of fish occurrence was related to water depth, which generally explains the significance of deep pools and their role as a shelter for many species, including indigenous and migratory fish, and as associated spawning areas for some species[9] during the dry season. The main result of this study is highly complementary with the findings of the studies by Baran, Baird and Cans (2005) and Baird (2006). In this regard, deep pools may be considered one of the core factors influencing fish ecology in the Mekong River, and are most important in developing fisheries conservation areas.

At the regional scale, the fauna of rivers have a tendency to be more comparable in adjacent drainages and interconnected river systems. Tropical Southeast Asian river basin fish species are dominated by Cyprinids followed by Silurids (Matin-Smith & Tan, 1998; Campbell *et al.*, 2006; Nguyen & De Silva, 2006), and this dominance of those two fishes is also apparent in the Mekong River. However, the fish assemblage and community is unique in each region (Kottelat, 1998), and in this study those dominant groups are followed by the *Bagridae, Pangasiidae, Siluridae* and *Cobitidae*. The *H. siamensis* [*pla soi khao*] (287.5 kg) and *P.bocourti* [*pla yang*] (285.7 kg) shared the highest percentage of abundance in this study, and produced very similar overall catch weights. Those species, together withthe Cyprinids distribution, reveal that the Mekong fauna is most closely paralleled by the fauna of the Chao Phraya River, which lies adjacent to and west of the Mekong basin in the central region of Thailand. This similarity reflects recent or continuing interconnected drainage and suggests that the upper Mekong was connected to the Chao Phraya Basin in the past (Yap, 2002; Valbo-Jorgensen *et al.*, 2010). The Mekong and Chao Phraya River also have greater than 50% of their fish fauna in common (Kottelat, 1989).

The hydrological regime was the foremost factor controlling temporal and spatial dynamics of fish communities and migratory behaviour in the Mekong River,

[9] Baird *et al.* (2001) described only one species that used deep pools as a spawning area in the South of Laos e.g. *Boesemania microlepis* [*pla ma*], while Poulsen and Valbo-Jorgensen (2001) mentioned many species that spawn in association with deep pools in the Kratie-Stung Treng region of northern Cambodia. e.g. *Boesemania microlepis, Mystus wyckioides, Chitala ornata, Micronema apogon, P. hypophthalmus, C. microlepis, P. jullieni, Catlocarpio siamensis* and *P. gigas*.

where fish change habitats between the mainstream (dry season habitats) and major tributaries (flood season habitats) (Winemiller, 1996; Welcomme & Halls, 2004; Baran, Baird and Cans; 2005), resulting in a vast diversity of fish fauna in the Mekong ecosystem. It has been discovered that some white fish species use the Mekong mainstream as a dry season refuge and the Songkhram River (Mekong tributary) floodplain as feeding grounds: for instance, *Heligophagus waandersii, Pangasianodon hypophthalmus, Pangasius conchophilus, P. bocourti, P. djambal, P. krempfi, P. larnaudiei, P. polyuranodon,* and *P. sanitwongsei* (Poulsen *et al*., 2002b). Notably, *P. bocourti* was a species found in most villages in this study, except at Boungmuang village. A closer look at flood season habitats in the Mekong's three tributaries in the northeast of Thailand, namely the Gam and Songkhram River in Nakhon Phanom province (to the north of Na Waeng) and the Mun river in Ubon Ratchathani (south of Na Waeng), has been undertaken by many researchers (Srisatit *et al*. (1981); Duangswasdi and Chookajorn (1991); Boonyaratpalin *et al*. (2002); and Phomikong *et al*. (2015)). It was reported that Songkhram River (181 species), where there is no dam along the river course, has the highest species richness among the three tributaries in Thailand and other tributaries in Laos (Valbo-Jørgensen *et al*., 2009). Before damming occurred, the dry season fish assemblage of those three tributaries in Thailand was mostly dominated by grey and black fish, e.g. *Rasbora dusonensis*, *Osteochilus vittatus*, *O. marmorata*, and *L. lineata* (Phomikong *et al*., 2015). The latter two species of black fish were also present in Bungkeylek and *baan* Na Waeng villages. However, the temporal variation of species richness in the Songkhram River was changed noticeably across the different seasons. It was higher during the flood season than in the dry season due to the presence of some white fish species in the lowest site attached to the Mekong River, e.g. *Cyclochelichthys spp*., *Mystacoleucus marginatus*, *Hypsibarbus pierrei*, and *Pangasiid* fishes (*ibid*). Moreover, particularly at the beginning of the rainy and flood seasons, the Mekong tributaries revealed a high proportion of fish larvae of different species that had either hatched within the floodplain of the tributaries or had drifted from upstream reaches in rising floodwaters - e.g. migratory cyprinids and pangasiids (Hortle, 2009a). In overview, this gives some indication of the dynamics behind the fish diversity present in Na Waeng.

Deep pool habitats in the Mekong River have been recorded by many researchers. For instance, Poulsen *et al*. (2002b) listed 39 species reported to use deep pools as a dry season habitat, while Baird (2006) stated that 51 species reported by local *chaopramong* use deep pools in Khong District, Champasak Province in southern Laos. The study of Baran, Baird and Cans (2005) revealed more deep pool habitats than Poulsen *et al*. (2002a) and recorded a range of fish species, e.g. *Hemisilurus mekongensis, Hemipimelodus borneensis, Hemibagrus wyckii, Gyrinocheilus pennocki, Cosmochilus harmandi, Arius stormii*, and *Bagrichthys spp*. In my study only *C. harmandi* [*pla ta kark*] was recorded from those listed previously. Interestingly, a few studies have reported that deep pools in the mainstream attract larger fish species; for example, *Pangasius sutchi* migrates to the deepest reaches of the Mekong River - between Sambor and Stung Treng in northern Cambodia - during the dry season (Soa-Leang and Dom Saveun, 1955). Meanwhile, a comparative study of the catch-per-unit-effort for gillnets set between the surface and the deep water found in deep pools in Khong District found that 10 out of 18 species caught in the deep pools were 27% to 78% larger than those caught near the surface (Baran, Baird and Cans, 2005). In addition, some studies have employed hydro-acoustic methods, for example in Khong District (Kolding, 2002) and in a sample of 30 deep pools deeper than 10 metres in Cambodia and Lao PDR (Viravong *et al.,* 2006), although both were unable to identify the species present. The same is also true for this study, but according to the screen captures (Figure 6.13) from the Fish Finder GPS in deep pools around Ladcharoen village, deeper areas do in general seem to attract larger fish.

As described in Section 2.8.1, three main migratory system fish were identified within the Mekong mainstream, belonging to the middle-Mekong migratory system. The ecosystem and hydrological regime play a vital role in helping to maintain the attributes of dry season migratory fish habitats, connecting the boundary of the lower-Mekong migratory system at Khone Falls, to upstream areas as far as Vientiane in Laos. This migration route is significant in helping to support fisheries in Laos and Thailand (Coates, 2001; Poulsen and Valbo-Jørgensen, 2000; Warren *et al.,* 1998; Singhanouvong *et al.,* 1996), as it serves as a dry season habitat for fish that spend the wet season on the floodplains of major tributaries.

According to Baird (2011, 6), "*A high proportion of wild fish taken from large rivers in the lower and middle Mekong Basin, including in the Khone Falls area, are "highly migratory," meaning the fish migrate long distances during clearly defined migrations*". Baran (2006) assessed that approximately 87% of mainstream fish in the Mekong exhibit migratory behaviour. Among the white fish species group, the dominant species is the cyprinid *H. siamensis* [*pla soi khao*], and this was also found to be dominant in my study. This species has a short life span and a fast rate of reproduction, within one year (Zalinge *et al.,* 2004), and is an important source of food throughout the lower Mekong Basin, as it forms the basis for a large range of traditional fermented fish products. The Mekong and its associated river systems are interconnected and they therefore have many species in common, as was also found in this study. For example, a number of important fish migrate during January to March, including schools of small cyprinid fish, whose movements are triggered by changes in the lunar phases and in hydrological conditions. They migrate from the Tonle Sap Lake in Cambodia to Laos during the dry season (Baran, 2006, Figure 6.14), and can be found in the mainstream and in deep pools. Other cyprinid species commonly found are *L. chrysophekadion, L. lineata* and *C. harmandi.* In addition, *P. bocourti*, which is one of the Pangasiidae catfish that migrates over the Khone Falls

(Baird, 1998; Singanouvong *et al.,* 1996; Baird *et al*., 2004), spends the dry season in deep pool refuges in the Mekong mainstream, particularly between Kratie and Khone Falls. This fish is caught in large numbers during the migration period, especially in the Mekong Deltain Vietnam (Poulsen *et al*., 2004). Additionally, some species such as *Cyclocheilichthys enoplos* and *C. microlepis* are largely encountered as juveniles and sub-adults in the lower-Mekong migratory system and as adults in the middle-Mekong migratory system (Poulsen *et al*., 2002b).

Along with information on the number and weight of fish landed, the study recorded and evaluated the minimum and maximum lengths of the fish by species (Figure 6.15), the purpose being to assess the level of fish development and provide a greater understanding of fishing patterns among the *chaopramong* during the dry season. The study found that most fish caught were beyond the juvenile stage or fully grown (blue bar above black dot in Figure 6, with the exception of three species: *C.carpio* (*pla nai*), *H. macrolepidota* (*pla kra suub kheed*), and *P. labeamajor* (*pla earn hang mum*). Additionally, an example of *P. gigas* (*pla buek*) was caught using long line and hooks at Ladcharoen village, and at just 37 cm long is in the juvenile stage (30-50cm) (Froese & Pauly, 2014) (fishbase.org). This study also found some other juveniles, being mostly white fish of the species *C. carpio, P. labeamajor, and P. gigas* (Figure 6.15). All the fish species mentioned previously, with the exception of *H. macrolepidota,* spawn in the floodplains or tributaries, where they feed until the water begins to recede at the end of the flood season (Poulsen *et al*., 2004). They then move back into deep pool habitats in the Mekong mainstream during the dry season. Likewise, some black fish species, namely *Cyclocheilichthys enoplos* and *C. microlepis,* are mainly caught as juveniles and sub-adults in the lower-Mekong migratory system and as adults in the middle-Mekong migratory system (Poulsen *et al*., 2002b).

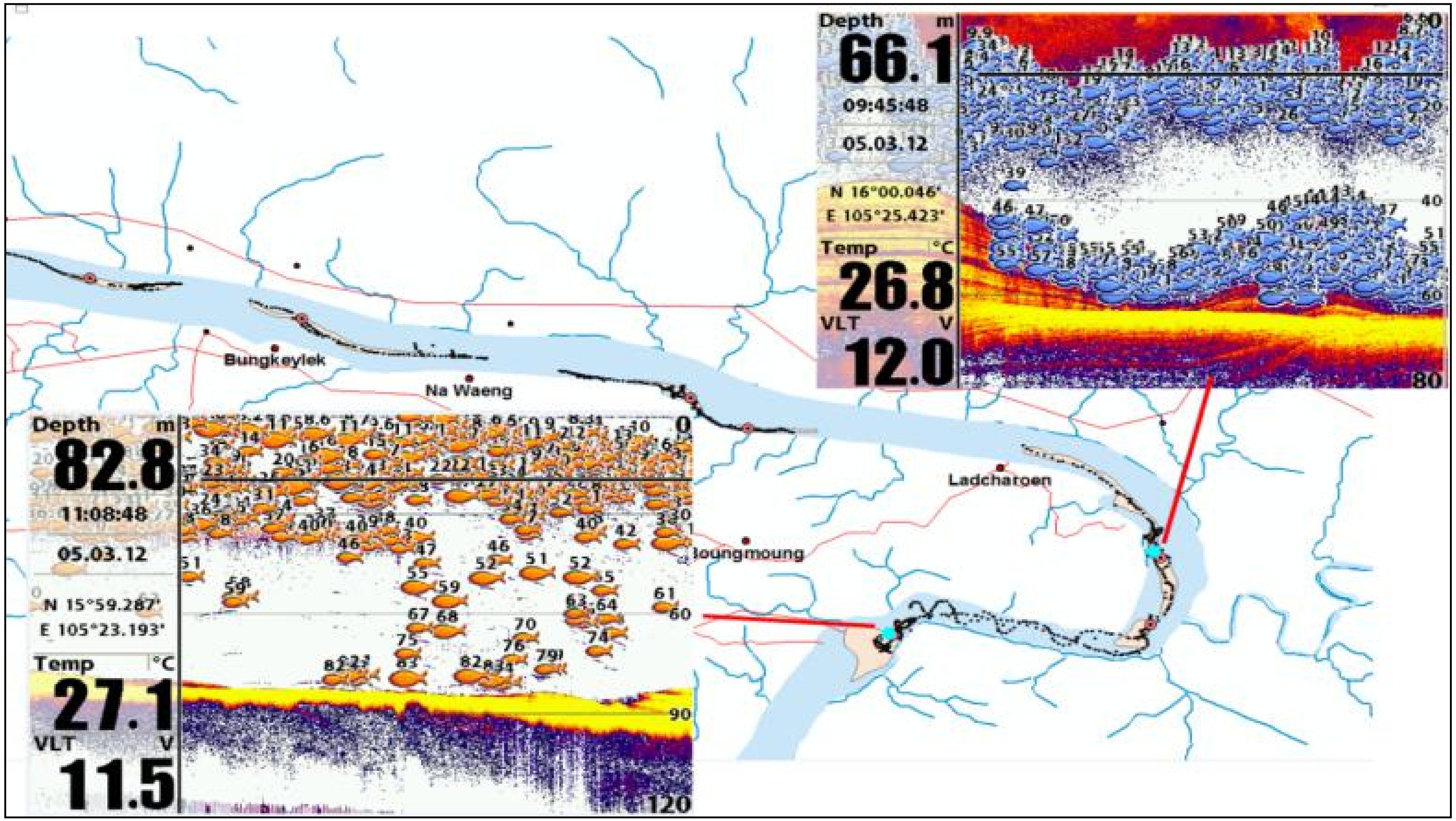

Figure 6.13: Screen prints from the Fish Finder tool (blue dots), showing areas near deep pools (red dots) around Ladcharoen village. Recorded on the 5th of March, 2012.

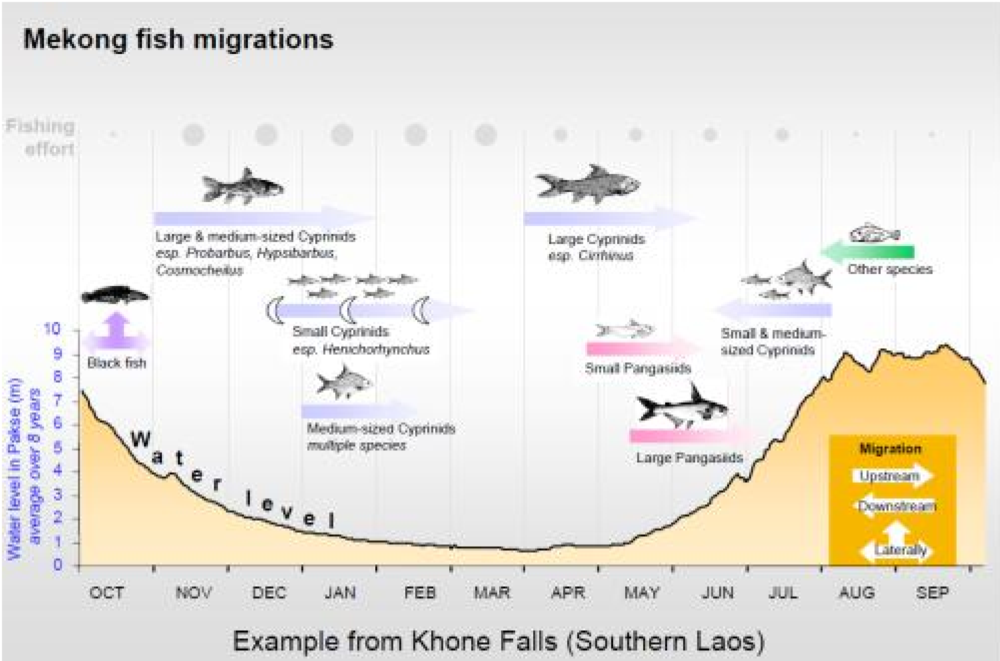

Figure 6.14: Migrating fish found around the Khone Falls (Source: Baran, 2006; figure based on Baird, 2001)

Pantalu (1970) stated that *P. gigas*– an endangered Mekong giant catfish species–is suspected of carrying out very long migrations, along with other species in the Mekong, including *Pangasianodon pangasius, Pangasianodon sanitwongsei, Cirrhinus auratus* and *Probarbus jullieni*. Although the Mekong giant catfish is considered to be endangered, some have been caught with weights of over 100 kg in traps set in the Hou Sahong Channel (Mollot *et al.,* 2007; Baird, 2011). In addition, this study identified juvenile *P. gigas,* possibly because the deep pools around *baan* Na Waeng and Ladcharoen village may be a spawning ground for this species, in addition to the upper reaches of the river near Bokeo-Chiang Khong, further downstream between Kratie and Stung Treng in northern Cambodia, and around Khong district in Laos, where the species has also been sporadically reported. Additionally, *chaopramong* at *baan* Na Waeng also reported that a *P. gigas* [*pla buek*] of over 100 kg was caught at *Vern* (deep pool) Somhong at *baan* Na Waeng ten years previously (pers. comm., 2012). This information regarding the probable existence of a spawning ground for the Mekong Giant Catfish in Na Waeng, is supported by the

LEK surveys carried out by the MRC for the period 1999 to 2001 (Poulsen *et al.*, 2004), although that study remains controversial for some researchers.

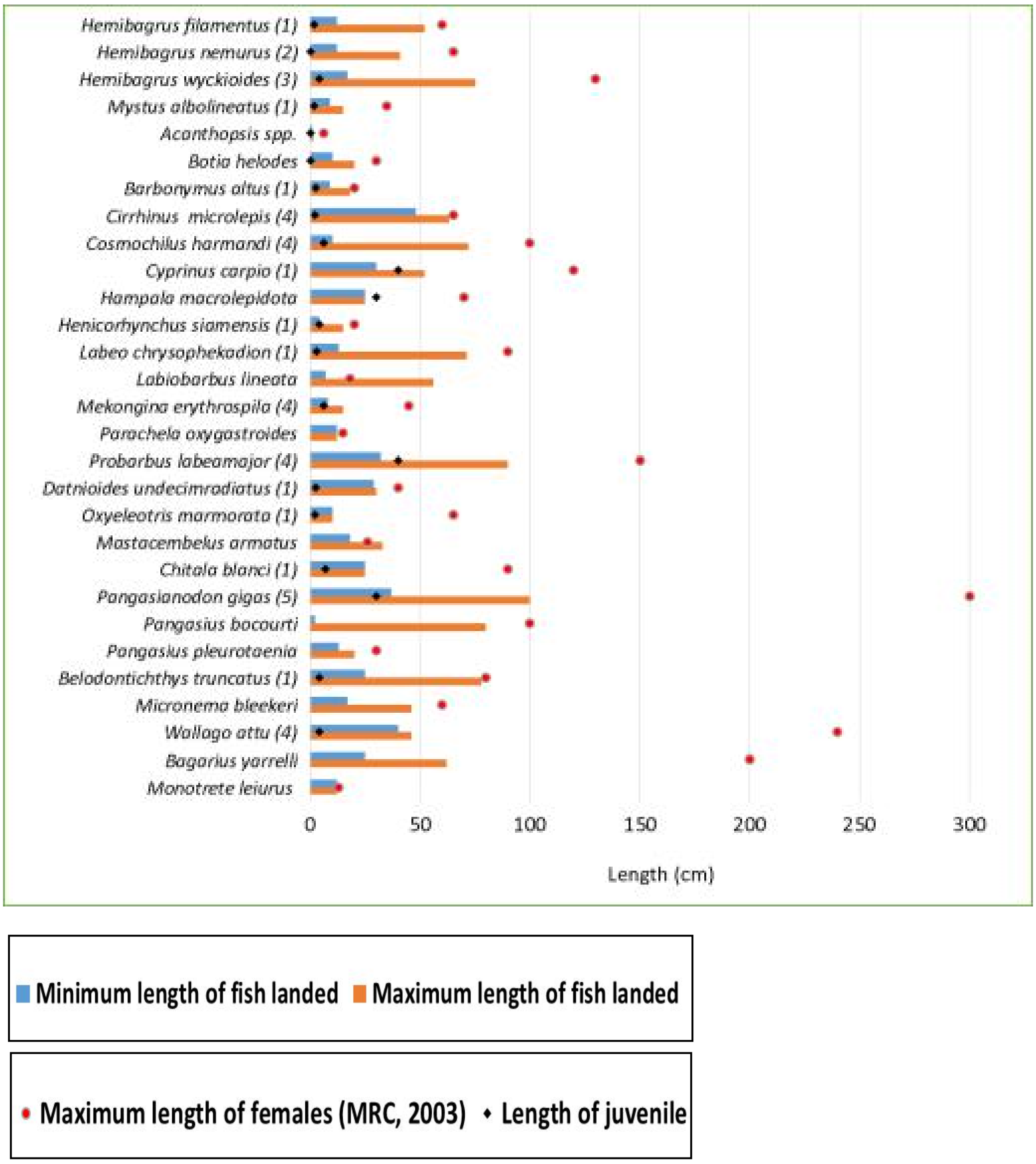

Figure 6.15: Comparison of minimum and maximum fish lengths for the fish landed, the maximum lengths of females taken from the Mekong Fish Database (MFD version 2003: MRC, 2003), and the lengths of juvenile fish collected from a number of sources, including fish base and journal articles.

(The values in parenthesis next to the fish species names refer to the following data sources: (1) Termvidchakorn & Hortle, 2013 (2) Jiwyam, 2012 (3) Seriously fish.com, 2014 (4) Poulsen & Valbo-Jørgensen, 2000 and (5) Froese & Pauly, 2014 (fishbase.org).

6.4.2 Fisheries management implications

6.4.2.1 The challenges of fisheries management on the Mekong River

It is widely acknowledged that more than 10 million people along the Mekong River rely on fisheries as their main food production and income source on a daily basis. Fish production in the lower Mekong Basin provides one-quarter of the world's freshwater fish catch – or approximately 2.64 million tons (Zalinge *et al.,* 2004) from 10 million tons worldwide (Baran *et al.,* 2007), and the vast majority of fish caught is consumed locally. Cambodia receives 80% of its national animal protein intake from fish caught on the Mekong (MRC, 2004); therefore, fisheries management plays an immensely important role for this region with respect to two key issues.

Firstly, there has been little scientific information and knowledge gathered with regard to river conservation and management activities along the Mekong River (Baird and Flaherty, 2005; Arthington *et al.,* 2004), and this reflects a more general lack of scientific information on tropical rivers systems. Examples of the lack of information needed to inform fisheries management and environmental impact assessment activities are in the areas of the genetic analysis of major fish species populations, species richness levels, and river and fish biodiversity levels (Arthington *et al.,* 2004). Indeed, although it is a fairly well-known river system, in relation to the Mekong Roberts (1993, 58) mentions that "*...the entire field of fish reproductive biology, including timing and stimulus of reproductive migrations, time, place and requirements for spawning, physiological adaptations of eggs and larvae, and comparative reproductive biology of carps, catfishes, and other groups under natural conditions, is largely untouched...*". Another example of an information gap is the lack of a universally accepted number of fish species in the Mekong River, for which estimates range from 1,200 (Rainboth, 1996), to 1,300 (Zalinge *et al.,* 2004), and even more than 1,700 (Coates *et al.,* 2003), with several hundred more species unknown (Dudgeon, 2000). As a consequence, information on the conservation status of fish species is mostly out of date, unreliable and inadequate, rendering attempts to develop fisheries conservation management initiatives or tools ineffective.

Lastly, the Mekong River ecosystem has been continually threatened, with the number of riverine species becoming fragmented due to human activity. The activities of upstream countries may affect downstream nations and so have regional implications in terms of trans-boundary environmental issues on a temporary, seasonal or even permanent basis. For instance, in the northern part of the lower Mekong Basin, between Chiang Khong in Thailand and Huay Xai in Laos, projects aimed at improving navigation by the removal of rapids have already altered flows, reduced fish populations, and affected communities along the Mekong River. Each former rapid's rocks remain as debris on the riverbanks in these project areas (Dubeau *et al.*, 2004), threatening in particular critically endangered species such as the Mekong Giant catfish, whose spawning habitat is along this stretch of the river (Hogan, 2013).

Currently, the most controversial topic concerning the Mekong River is the increasing trend towards basin development, and especially the building of dams. Over the past decade, an increasing number of hydropower projects have been implemented along the Mekong mainstream, with nearly 20 dams built (SavetheMekong.org, 2010; Figure 6.16). Of these, eight sites are located in the upper Mekong Basin, with three operational, two under construction, and three planned. Furthermore, it has been reported that eleven dams are being proposed for the lower Mekong Basin, and the first two are already under construction: the Xayaburi dam (in the middle-Mekong migratory system) and Don Sahoung (in the lower-Mekong migratory system). These dams are highly controversial for Mekong riparian countries and environmental conservationists concerned about their future impacts on people, rivers and fish.

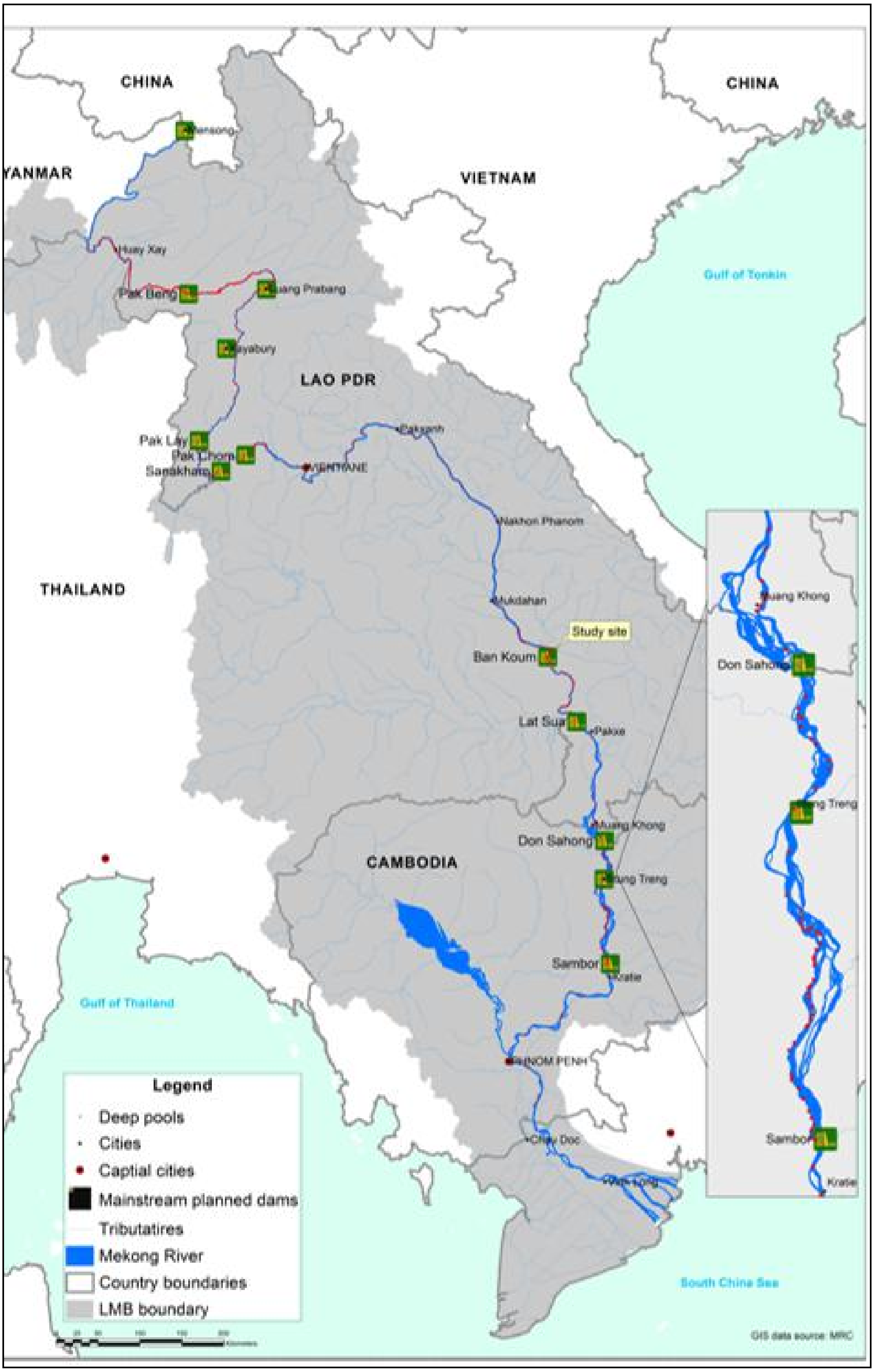

Figure 6.16: Deep pools, plus mainstream dams proposed in the lower Mekong Basin (Map prepared by Author, 2014)

Many scientists have warned about the environmental damage likely to be caused by dams both locally and regionally in the Mekong Basin. The number of migratory fish living in the lower and middle-Mekong migrations systems (between the delta and Vientiane) is far larger than in the upper migration system in northern Lao PDR (Barlow *et al.,* 2008). Therefore, dams built within the lower and middle-Mekong migratory systems are likely to have a much greater impact on fisheries production in the lower Mekong Basin than dams built in the upper reaches.

Baird (2011) has conducted many studies in the Khone Falls area near the Don Sahong dam, and has stated that the dam will not only change the volume of water flowing, thereby directly impacting fish habitats, but it will also block fish migration routes from the Mekong Delta to the middle part of the Mekong, and adversely impact upon the livelihoods of people living along the river. It is true that when the fish migration routes are blocked, the number of fish and also fish diversity levels will be reduced, thereby having a direct and negative impact on fisheries stocks and fish food production. Such a scenario may increase poverty levels among people who rely on fish as their major protein and income source, and probably decrease the number of fish available as food on a global scale.

While the potential effects of basin development in the Mekong have been explored, little is known about the potential impacts of basin development on the riverbed phenomena of deep pools and their relationship with fish habitats. Generally, hydropower dams impact upon water flows and sediment transportation, denying fish access to deep pools (Mekong River Commission, 2008). More specifically, sediment deposited as bed-load in the riverbed upstream of dams will tend to fill deep pools there, while also leading to a deepening of deep pools downstream of dams, which will change flow velocities and turbulence, and ultimately affect both the quality and quantity of this critical fish habitat (Halls *et al*., 2013). The hydraulic conditions created by dams include a backwater effect upstream of the constriction and an increase in water surface slope at the constriction, leading to increased water velocities and the formation of a fast flow jet that scours the riverbed downstream (Thompson *et al*., 1998). Turbulence downstream of the constriction also contributes to bed scour, thus elongating the pool in the downstream direction (Thompson, 2007). Without these hydraulic conditions, sediment will tend to deposit in pools. Similarly, reduced water surface gradients and flow velocities in reservoirs are likely to reduce the sediment transport capacity of the river and lead to the accumulation of sediment in pools.

Basin developments such as dams are also likely to distress fish communities in the Mekong, not only by blocking channels and fish migration routes, but also due to changes in physio-chemical variables and water quality. According to Ward and Stanford (1979) and Petts (1984) and Welcomme (1985), such developments have an impact on riverine ecosystems both upstream and downstream, leading to a restructuring of fish communities. A typical example of such an intervention is the increased rate of silt deposition upstream of dams, leading to failed fish reproduction, changes in the quantity and type of food available, and a reduction in the number of non-visual predators and omnivores. In addition, such developments can also alter water temperature variations, due to low flow regimes, in turn leading to changes in spawning behaviours for cold and warm water spawners. Downstream of dams, meanwhile, the nutrient cycle it altered, leading to increasing numbers of benthic omnivores and an abundance of planktonivorous fish. According to Baird (2011), gas supersaturation could occur downstream of dams, such as the Don Sahong Dam, which is damaging to the internal organs of living organisms such as fish.

An additional example of dam development on one tributaries of the Mekong River is the Yali Falls Dam on the Sesan River in Vietnam, which has caused significant impacts to the water flow regime, water quality, and fisheries that not only threaten the physiology of the river, but also the food and income security of local communities along the river (Wyatt and Baird, 2007). The impacts of the Yali Falls Dam on deep pools along the Sesan River have been studied, highlighting that in Voen Say District, Cambodia, some 100 km downstream from the dam, siltation has reduced one deep pool's depth by 90 percent, thereby dramatically decreasing the number of fish species present (Fisheries Office Ratanakiri Province Cambodia, 2000). Greatly reduced numbers of fish species were reported by villagers along the Sesan River (Baird & Meach, 2005 in Wyatt and Baird, 2007), while some species such as *Macrochirichthys macrochirus* [*pa hang fa*], which was listed as Near Threatened in the 2013 IUCN Red List, have disappeared.

Similarly, there has been a pronounced impact along the Hinboun River as a result of the Theun-Hinboun Dam in Khammouane Province, central Laos (Poulsen *et al*., 2002a). It is therefore likely that the siltation transport regime related to deep pools may be altered upstream and downstream of the dams planned for Ban Koum, which is less than 15 kilometres downstream of the deepest deep pool (171 m) in the Mekong River at Na Waeng (Figure 5.11). In truth, most of the planned dams are located in bedrock-influenced reaches where the deeper deep pools are to be found (Halls *et al*., 2013), because bedrock foundations improve the strength and bearing capacity of dams, and have less potential for impermissible seepage to occur (Wahlstrom, 2012).

One key challenge faced by fisheries management activities on the Mekong River is the lack of data available on fish biota and the threat posed by basin developments, and especially dams. In some areas, the use of destructive gear has been reported, and even in the research study site, explosives and electro-shock methods have been used to catch fish. The threat to biodiversity ranges from the local to the regional scale, and on the regional scale, developments can promote extensive habitat loss, ecosystem simplification, and reduced water quality and quantity. Recently, one solution has been to adopt a bottom-up approach, and this has already been used effectively for the FCZ in Khong District, and at Champasak in southern Laos (Baird, 1999; WWF, 2002). Bao *et al.* (2001) provided a good example of progress in terms of fisheries management activities on the Mekong River, using the LEK of local *chaopramong* to carry out research and formulate policy.

***6.4.2.2 Politics of LEK of chaopramong* as a political machine**

"*The studies that acknowledge the different meaning which local communities attach to the fisheries hold the potential to produce knowledge that is less amendable to state-centric reasoning and technocratic trade-off paradigms. This, in turn, could enable the inclusion of alternative visions on the basin's development to the current debates*" (Molle, Foran and Kakonen, 2012, 345).

Many studies have indeed attested to the fact that the LEK of *chaopramong* can help improve knowledge about ecology, migration, reproduction, feeding habits, and changes in abundance of a diverse array of fishing resources (Johannes, 1981; Poizat and Baran, 1997; Johannes *et al*., 2000; Huntington *et al*., 2004; Baird, 1999; 2001; 2006; 2007; Baird and Flaherty, 2005; Silvano *et al*., 2008, 2009; Silvano & Begossi, 2012), which also contributes to fisheries research, management and policies. However, in some cases this LEK is framed within scientific research and political agendas of the government agencies and investors. Numerous examples of fisheries research on the Mekong River incorporate LEK of *chaopramong* by putting their knowledge base to use in a more systematic and comprehensible way. For instance, the results from key informants interviews and field observation helped me to summarize the LEK of *chaopramong* regarding river ecology and deep pools, as well as get access to fishery resources and endangered species as described earlier in Section 6.3.1. Another case in point is the MRC fisheries program, which has incorporated LEK to support fish monitoring programs in the LMB in order to gather data on fish biota, fish abundance, fish migration routes, and the identification of deep pool locations (Singhanouvong *et al*., 1996; Poulsen & Valbo-Jorgensen, 2000; 2001;

Poulsen *et al*, 2002b). Most of Baird's studies (e.g.1996; 1999; 2005) drew upon the deep knowledge of *chaopramong* participants in research and practice to further significantly develop communities-based and cooperative fisheries management in Khong in the south of Laos.

The fisheries officers in Ubon Ratchathani also drew my attention to the level of LEK held in the local community, where members have a better understanding of their environment than those in power would expect. Similarly, the LEK of *chaopramong* is also ignored by the central government. One example of the use of this knowledge can be clearly seen in the way *chaopramong* choose and build their fishing gear to suit the season and fish behaviour. For example, one fish trap, called the *tuum* (Figure 6.17), is designed to trap main-channel fish, with the trap used along the river bank during all seasons. It is designed so as to trap only small fish, typically those eaten all-year-round. The *gha* trap is designed to channel the fish into a chamber, after which they cannot escape. This trap is made of small pieces of wood similar in size to toothpicks. These are connected to the trap in a circular fashion, and so act as a valve, which opens to allow fish in, but prevents their escape. Fisheries officers told me that the LEK of *chaopramong* is useful and reliable because "*they are living with the river and they know the best of their environment*." Moreover one fisheries officer admitted that community-based fisheries management programs will help sustain a conservation-focused environment more effectively than the mechanisms contained within the proposed fisheries laws and legislation. The reason for this is that the current programs are based on there being an understanding of local conservation issues. This means that even those who are wary of central government control are willing to follow what they see as the community's rules. An example of a successful program is the one managing over 100 fish conservation areas near to the temples around Ubon Ratchathani (see Section 2.5.3.3), which was supported by the provincial fisheries department, and should continue with their monitoring work.

However, this program was initiated without financial support from the central government, and at the moment the monitoring programs need some essential support and financial assistance to be provided by the central government's offices.

Figure 6.17: On the left, a vertical vase trap for small fish – normally placed along the river bank. In the northeast dialect (*Isan*) it is called a tuum. On the right a fisherman is making a channel trap, or gha. Source: Author, 2013

Some Department of Fisheries programs have failed to take into account river biodiversity and have also ignored LEK, causing a further erosion of local support for government initiatives. There is a clear lack of scientific understanding and biodiversity awareness on the part of the DOF; for instance, on the Mun River in Ubon Ratchathani in Thailand, where the tributary enters the Mekong River at the Laotian border, some local *chaopramong* disagreed with the government releasing the fish species, *Tilapia nilotica* [*pla nin*], into the river on National Day. The government's intention was to increase the number of fish species, thereby helping to alleviate poverty and increase biodiversity in the river. However, the result was that the fish species not only ate all the plankton, but also native fish eggs (personal communication, January 12th 2011). It then took the government over a year to admit its mistake to the local *chaopramong*, though the *chaopramong* had understood the threat and consequences right from the start (Royal Forest Department, 2012).

Similarly, the government released a farmed fish, Silver Barb [*pla taphian*] **(***Barbodes gonionotus*), into the Mekong River around the community of Sam Phanbuk in Ubon Ratchathani. Some *chaopramong* in the community of Sam Phanbuk reported that these fish did not school in sheltered areas or deep pools, but stayed along the river bank and were caught for food later on. Some local *chaopramong* suggested that the farmed fish needed time to adapt to the new environment; one cannot simply release a non-native species into an environment and expect it to thrive. Hence, the government should have studied previous attempts to release farmed fish into the river and learned what was required to ensure that the released fish could adapt successfully. These incidents have led to a further erosion of local support for government initiatives, and provide a good example of how a problem could be easily prevented if officials used a holistic approach and first sought local knowledge.

There are other signs that an appreciation of local knowledge still remains important and recognised as 'Tai or Thai Baan Research' [*ngan wiijai tai baan* in Thai]. The latter research process empowers local villagers to take ownership of the research, while looking for better ways to manage their local resources following the impact of the Pak Mun Dam, which was built in 1994 in Ubon Ratchathani (Sretthachau, 2002). The local villagers mistrusted the role of the state and the owner of the Pak Mun Dam who appointed academics to represent their knowledge and interests. In response, local villagers acted as primary researchers and took control over the process of designing the research, collecting data, and writing about their environmental perception in order to manage their own livelihoods, with some support of NGO staff who acted as research assistants (*ibid*).

The Tai Baan Research conducted an impact assessment study of the opening of the dam's sluice gate for a trial period, approximately 14 months (June 2001-August 2002) (Sretthachau, 2002). The study's outstanding outcomes provided a great negotiation framework between local stakeholders and the government in terms of defining the positive effects of opening the dam's sluice gate on their communities, which benefitted not only fish biodiversity in the Mun River ecosystem, where over 150 fish species returned, but also improved the livelihoods of local *chaopramong* along the river (*ibid)*. Between 2002 and the present day, the government determined a "compromise" option, closing the dam for 8 months and opening the gates for 4 months during the wet season, although the Pak Mun communities are still struggling to permanently decommission the dam to restore their lost livelihoods (*ibid*).

The Tai Baan Research approach has gained acceptance by a number of researchers and civil society groups and has been replicated throughout the Mekong Region. The only exception is the MRC's Fisheries program which, ironically, has promoted the use of LEK of villagers in Mekong fisheries research as a whole (Molle, Foran and Kakonen, 2012, 345). For example, the MRC's Fisheries reports have not referenced the findings of the Tai Baan Research [*Sala Phoum* in Cambodia] in the MRC's stakeholder consultation. Interestingly, the Tai Baan Research is centred upon a participatory approach to local resources management while the MRC-centric approach is based on the experts and technocrats who reveal this 'mind' knowledge (*ibid)*. Hirsch (2004) explained that by undertaking the research themselves, the MRC revealed its positionality in terms of using the research as a negotiation tool in a battle for power and political representation among stakeholders.

The connection between knowledge and political power is the central issue affecting policy regarding water resources management and hydropower development on the Mekong River. Whose knowledge? Knowledge for whom? Who pays for conducting knowledge-gathering research? Hirsch (2004) used the word 'politics of funding' to describe the situation in which hydropower development acts as a knowledge driver through environmental impact assessment (EIA) consultants who conducted studies to serve the requirement of clients who commissioned the work. "*Finally and in many cases dominating the knowledge production process, is the swathe of consultancies associated with large scale resource projects (notably dams and mines) that require environmental impact assessments (EIAs) including fisheries impact studies.*" (*ibid,* 95).

Perhaps the most significant example of such EIA projects is the Yali Falls dam in Vietnam, which had a negative impact on the weaker downstream country of Cambodia, where impacts to fishery resources and livelihoods of villagers along the Sesan River occurred as a result of short-sighted development policies (Wyatt and Baird, 2007). As a consequence of the dominant interests of the Vietnamese government, a gaping loophole in legal enforcement when conducting trans-boundary EIAs on the Mekong's tributaries, and no bilateral communication channels even via the MRC, the Cambodian government has had to deal with a range of impacts but with no proper compensation plan (*ibid*; Hirsch and Wyatt, 2004). Additionally, the EIA for the Yali Dam was carried out by one of a group of companies selected by the Vietnamese government, but the Cambodians were never informed and, worse still, the report neglected to consider downstream impacts (Wyatt and Baird, 2007). Baird & Meach (2005 as cited in Wyatt and Baird, 2007) argued that *chaopramong* along the Sesan River reported on the highly negative impact of the Yali Falls dam on fishery resources even when dam construction had only just begun. However, the Vietnamese government has questioned the reliability of LEK of *chaopramong* along the Sesan River, rather than addressing the issue of constructing the dam without an

EIA study that fully assessed its impacts, which has resulted in high impacts to downstream villagers in Cambodia (*ibid*).

Here it is worth considering the uncertainty surrounding the MRC's pivotal role, as the regional inter-governmental organization, formed in 1995, which has a strong mandate to sustain the Mekong River environmentally and socially and acts to support mutually beneficial relations among member countries (MRC, 1995). Moreover, efficient and effective management of the MRC's policy-making process aims to ensure that cooperative decisions are made for the benefit of all Mekong citizens. On the contrary, the Yali Dam case has brought into question "*…the MRC's capacity and mandate to resolve a trans-boundary conflict involving two of its member countries. Clearly, it has not been able to resolve the issue. The MRC has been hampered by its own lack of mandate and commitment to the institution as a governance body, both in responding to community complaints and in enforcing assessments."* (Wyatt and Baird, 2007, 438). There are cases where the MRC has moved forward positively to support an EIA study, such as the post-impoundment impact assessment of Nam Xong Dam in Laos, for which ADB were commissioned as consultants. But even though the study found uncompensated losses valued at almost US$2 million, which reflected the impacts upon fish catches within 13 affected communities, this result has yet to be released publicly 24 months after its completion and more than seven years after the dam was completed (Hirsch, 2004).

Numerous studies have highlighted negative impacts caused by the Mekong mainstream dams, which are perceived to be decimating the river's fisheries and agriculture and affecting the livelihoods of over 40 million people (e.g. ADB, 2004; MRCS/WUP-FIN, 2007; MRC, 2010). Several further dam development projects on the mainstream are nevertheless under construction, despite concerns raised by neighbouring countries, international organizations, media, civil society, and scientists. The MRC commissioned the International Centre for Environmental

Management (ICEM) to carry out a Strategic Environmental Assessment of Hydropower on the Mekong Mainstream, in order to assess future impacts resulting from the construction of 11 proposed mainstream dams. The study found that the dams could seriously degrade the river's biodiversity, causing a loss of 26-42% of fish in the river system, while also displacing over 100,000 people (ICEM, 2010).

Regarding recent dam development on the Mekong mainstream, the NGO International Rivers (2011) revealed critical flaws in the EIA for the Xayaburi Dam. Hirsch added that although this EIA collected data in the affected downstream area, it did so without consulting local people, which contradicted international standards for EIA studies. The flaws in the Xayaburi EIA can be summarized as follows: there was a lack of analysis of key technical information, including on fisheries and aquatic resources, hydrology, sediment transport, and dam safety in the event of earthquakes; the study examined impacts only within 10 km downstream of the dam site rather than basin-wide; and no study examined impacts that may occur when the other ten planned mainstream dams are operational.

However, at the political level, when the four member countries of the MRC failed to reach a consensus on the first mainstream dam, namely the Xayaburi dam in Laos (MRC, 2011c), the Laos government unilaterally decided that its dam planning was safe and sound and started dam construction, followed by a number of other mainstream dams, such as Don Sahong dam in the South of Laos. As the only trans-boundary Mekong organization involved in this case, many stakeholders had high expectations that the MRC could show leadership and be able to negotiate in a fair manner regarding trans-boundary upstream and downstream impacts (Molle *et al.*, 2009).

Knowledge is power in the political arena of the Mekong River, including the existing knowledge of local communities, business sectors, scientists, governments, and organizations. Each actor is pursuing, with varying degrees of enthusiasm and fairness, the goals of enhancing and sustaining the quality of livelihoods and ecosystem services on the Mekong River before it is permanently damaged. Those stakeholders have a role to play in the political process by deliberating and expressing voices of dissent, and by carefully scrutinising projects on the Mekong, for instance through the platform of public hearings arranged by a number of NGOs regarding the impact of dam development. However, their voices are often ignored and paralyzed within political arenas and their knowledge is manipulated to serve the political agendas. There thus remains a need for the transformation of the weak governance of the Mekong River and MRC, towards a more transparent political process, and democratization of water management.

6.5 Conclusion

The CART and spatial analyses using GIS techniques developed in this study in the main confirmed the predicted correlation between the presence and characteristics of deep pools, and fish abundance and species richness levels during the dry season along the Mekong River. First, the predictions made by the fish abundance model corresponded closely to the geomorphological variables of water depth and river channel width in the dry season, and also to the physio-chemical variables of DO concentrations, pH levels, and zooplankton densities. In this study a high probability of fish occurrence was related to water depth, which generally explains the significance of deep pools and their role as a shelter for many species, including indigenous and migratory fish, and as spawning areas for some species during the dry season. In this regard, deep pools may be considered one of the main factors influencing fish ecology in the Mekong River, and also help highlight the importance of developing fisheries conservation areas. Second, the predictions of the species richness model suggested a strong variable relationship between primary and secondary production in the river, as phytoplankton and zooplankton act, respectively, as food sources for fish and other organisms. The development of this model is of vital importance, given that it contributes to supporting conservation of fisheries based on scientific information and can help in providing guidelines to decision makers in the region.

This research included the LEK of *chaopramong*, who have a spatial perception of biodiversity and ecology in their communities, and especially knowledge of fish species and biology and associated river ecology and characteristics. It was found that the LEK of *chaopramong* was validated by the scientific model of this research, which means such useful and meaningful information can be incorporated within scientifically-focused research. For instance, a scientific model of fish abundance alone cannot always determine fish abundance in specific species in terms of diversity and behaviour. Consequently, it is crucial to combine this scientific model with the LEK of *chaopramong* regarding species and behaviour in order to further explain the scientific result. The LEK of *chaopramong* has the potential to offer valuable support to fisheries management and should be given equal consideration to scientific knowledge.

There are many documented cases where governments have failed to manage and plan in relation to fisheries resources due to a lack consultation with local communities, who know best about their environment. This calls for an alternative collaborative approach to empower local communities to participate in both the research and management processes. In this regard, in the next chapter I will describe in detail how I used the LEK of local *chaopramong*, through the use of the Public Participatory GIS approach, to initiate a bottom up approach towards fisheries management. Perhaps more importantly, participatory GIS mapping on a satellite image base is used to facilitate the LEK of *chaopramong* within the fisheries management framework, which offers a useful way forward.

CHAPTER 7

A Public Participatory Geographic Information System For Fisheries Management

7.1 Introduction

This chapter presents the findings from my research into the use of a Public Participatory Geographic Information System (PPGIS) with fisheries management activities in Na Waeng, the case study site. The study used the PPGIS approach to elicit chaopramong's local ecological knowledge (LEK) of the Mekong River and transform it into a scientific platform able to be used to support fisheries management activities on the river. My analysis of the PPGIS approach is divided into three: an introduction to the stakeholders in Na Waeng, the PPGIS processes and tools used, and an evaluation of the PPGIS approach. In this discussion, I will assess the outcomes of the fisheries management activities studied and their development when using PPGIS among relevant stakeholders in Na Waeng. In particular, I will articulate the implications of PPGIS's use by policy and decision-makers in support of fisheries management activities on the Mekong River.

An overview outcome of this part of my research chapter with the aspect of promoting LEK of chaopramong in tandem with GIS tools to create more sustainable Mekong fisheries and make river management more democratic, I produced a video called "Distant Voices" which can be found at the following link: http://mekongcitizen.org/2016/03/02/distant-voices-the-role-of-local-knowledge-in-mekong-fisheries-management/.

7.2 Public Participatory GIS for fisheries management

7.2.1 An introduction to the stakeholders or actors

A starting point for the research program was to investigate the relevant institutional stakeholders, including organizations, social groups, and individuals, who have an influence and a high stake in the local management of resources. The details of this investigation were described in Chapter 3 (Section 3.3.1) under Phase I of the PPGIS process, during the preparatory phase of the study. In the latter chapter, I described the social situation at the study site, and also my engagement with local governmental organizations and communities, using expert opinion, focus groups interviews, structured interviews, or a combination of all of these.

I held meetings with various stakeholders in order to enhance my understanding of the power relations that exist within and between the communities. First, I held informal discussions and semi-structured interviews with the Director of the TAO of Na Waeng, to establish their work mandate and water resources management activities in the study area. Following this, I had another meeting with the director of the TAO to describe my research activities. It should be noted that Na Waeng had not previously used a community-based fisheries management system, nor was it familiar with the PPGIS approach; therefore, these two concepts were unfamiliar to most local stakeholders when I arrived there.

Second, using a similar approach, I organized appointments and interviews with the provincial fisheries officer and the director of the Fisheries Department in Ubon Ratchathani, the fisheries officer responsible for fisheries laws and regulations, and a Khemarat fisheries officer (for further details see Section 2.6.2: "The fisheries management institutions in Thailand"). Furthermore, I was invited to participate in some Fisheries Department activities in Ubon Ratchathani on Thai National day; the Thai King's birthday. The government released some fish into the river with the intention of increasing the number of fish species available, alleviating poverty, and increasing biodiversity in the river. However, many local communities are sceptical of the government's claims with respect to this activity (see detail in Section 6.4.2).

Finally, an iterative process comprising scoping interviews, focus groups, and follow-up interviews was conducted with the fishing communities to identify the organizations, interventions and issues under investigation. Also, secondary literature reviews concerning key stakeholder information were analysed in order to identify and summarize information related to the study stakeholders, as shown in Table 7.1. The information in the table is classified into six internal and external actor groups, describing the roles, administrative arrangements, interests, available resources and conflicts between people, groups, laws and regulations.

I included four people in my research to represent internal stakeholders in Na Waeng. The first was the Director of the Na Waeng TAO [*Aor Bor Tor*], a local politician with a mandate to develop and improve Na Waeng's infrastructure and facilities. On the surface, this position is the most powerful in Na Waeng, as the Director can initiate or reject a plethora of projects. The Na Waeng sub−district headman [*kamnan*], who is the chief of all the villages in a sub-district, and village chiefs [*phuyaibaan*] replicate the TAO function at the commune and village levels, respectively. These three stakeholders receive salaries according to rates set by the Ministry of Interior. Unfortunately, these three decision-making stakeholders, who act inside the communities, have objectives to promote sustainable natural resource programs as only a marginal component of their mandate. Villagers and *chaopramong* are the only people who hold LEK and are also faced with issues relating to insufficient incomes and fishing territories among the communities. Given that villagers and *chaopramong* lack a voice and influence in political debates, the PPGIS process (as demonstrated in this research project) has the potential to empower and strengthen their voices and ability to influence decision-making processes that affect their lives.

Table 7.1: Description of the Key Stakeholders in Na Waeng

	Stakeholders	Role/Function	Administrative Arrangements	Interests	Resources	Conflicts/Comments
Insider	Director of Na Waeng Sub-district Administrative Authority (TAO)	Ensures the efficiency and equity of facilities and services	Elected by sub-district council. Four year term as a local politician, not a civil servant	• Rural development and implementation • Local political power	• Political power • Finances	• No relevant mandate to promote sustainable natural resource programs
	Na Waeng sub-district headman [*kamnan*]	Replicates TAO functions at the commune level	Elected by village chiefs. Full-time civil servants; job evaluation every 5 years	• Rural development and implementation • Local political power • Income	• Limited political power • Customary powers/respect	
	Village chiefs [*phuyaibaan*]	Custodian of the village	Elected by villagers. Full-time civil servants; job evaluated every 5 years	• Local political power • Customary powers/respect • Income	• Limited political power • Customary powers/respect	
	Villagers/*chaopramong*	Participate in village development activities	Independent	• Income	• LEK	• Fishing territories among countries and communities. • Fishing ground right and territories. • Losing riverine land rights.
Outsider	Fisheries officers	Implement fisheries laws and regulations	Full-time civil servants	• Implementing fisheries laws and regulations	• Authority-power	• Enforcement of fisheries laws and regulations
	Academics/scholars	Research activities	Organizations; Universities, NGOs, Government research	• Research • Policy proposals	• Authority based on experience and knowledge • Research grants	

The second group of external stakeholders in Na Waeng are the fisheries officers. This includes both the fisheries officers at the provincial level, and also the district level officers, though they are sometimes both located in the regional offices. These people are asked to perform duties based on the specific needs of the central administrative organization as well as their own levels of expertise. The main mandate of the regional fisheries officers is to ensure the sustainable utilization of fish resources and the environment, by implementing fisheries laws and regulations. In other words, these people are entitled to exercise a certain amount of authority and power. Last there is the group of academics and scholars, whose mandate and duties are based on their knowledge and experience. They have the power to facilitate fisheries management activities in the communities.

7.2.2 Public Participatory GIS processes

When applying PPGIS to the study area's fisheries management activities, I divided the research into three phases (see Section 3.2 and Table 3.1 for more information), these being: 1. a preparatory phase, 2. mapping the river's ecology and surveying the *chaopramong*'s livelihoods, and 3. mapping the conservation zones. In phase I, the PPGIS process was used for base map preparation. In phase II, the PPGIS process involved map-based interviews to elicit the LEK of *chaopramong*, while phase III involved holding a PPGIS workshop to explore and develop the conservation practices used by local *chaopramong* (Figure 7.1). This figure also shows the intensities of and reasons for people's participation at each level, as well as the stakeholders involved in each part of the PPGIS process. The intensities of participation refer to the term 'participation ladders' as used by Catley (1999), which shows higher involvement and higher quality participation progressing from low to high intensity level. These are starting from manipulative participation (I1), to passive participation (I2), participation by consultation (I3), participation for material benefits (I4), functional participation (I5), interactive participation (I6) and self-mobilization

(I7). According to McCall (1998), there are three key levels of participation, ranging from facilitation (‘F’) through to empowerment (‘E’), which can be described as a continuum running from ‘F’ (‘satisfying external objectives’), to ‘E’ (‘internally driven empowerment’). Hence, the further on an activity is in the continuum, the better the contribution made by PPGIS to the empowerment of decision-making processes.

The overall outcome of the PPGIS processes indicates the improvement of inter-group dialogue between stakeholders, and shows higher involvement and higher quality participation progressing through the use of PPGIS tools, which in this study were sketch mapping and participatory mapping based on satellite imaging during the PPGIS workshop. Figure 7.1 shows the PPGIS processes from phase I, which were prepared by and required only my input. Then, the PPGIS processes were introduced after eliciting LEK from the five local communities using sketch mapping (see Section 7.2.3.1 for a more detailed description). To facilitate future fisheries management activities, the hard copy sketch maps produced were treated as local ecological scientific baseline information, and were also compared with the GIS baseline and satellite image to establish the reliability of the data. The processing of GIS data allowed me to take the assembled LEK of *chaopramong* and translate their spatial knowledge and information, such as fishing grounds, deep pools, and other landmarks, into the GIS platform. This baseline information was used in the preparation of the PPGIS workshop and the fisheries management workshop, giving stakeholders from the five local communities a platform from which to participate in the workshop decision-making process. Most of the stakeholders who participated in the sketch mapping also attended the fisheries management workshop. In addition, the three key types of participation were promoted during the fisheries management workshop in order to produce the fisheries management conservation maps. The intensities of participation and the stakeholders involved in each part of the PPGIS process indicated higher involvement progressing from I2 as passive participation to I6 as interactive participation at the PPGIS workshop for fisheries management. As mentioned in Section 3.2, the ultimate aim of implementing PPGIS in the study area is to ensure that the sub-district administrative organization (TAO) and the communities are fully responsible for deciding whether or not to act on the fisheries management plan that was developed by them.

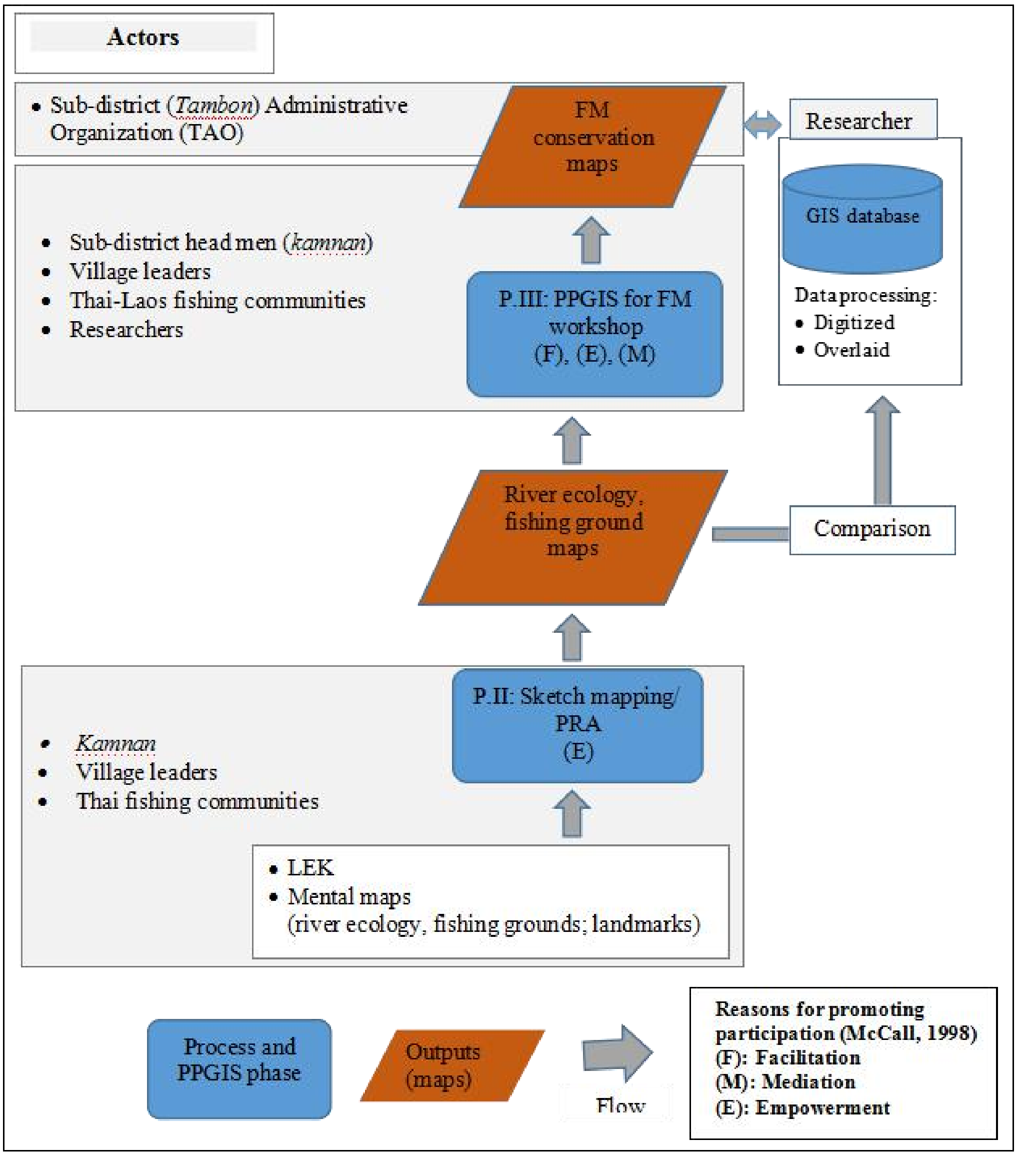

Figure 7.1: Participatory GIS processes/Purposes of participation

7.2.3 Public Participatory GIS tools

7.2.3.1 Sketch mapping

The main purpose of the sketch mapping sessions was to elicit the LEK of chaopramong, which is a commonly-used PPGIS tool and the classic participatory rural appraisal (PRA) tool, with the eventual aim being to facilitate future fisheries management activities. This activity was based on data collected primarily through 'LEK sketch mapping' (see Section 3.4.2.1 (2)) carried out with chaopramong at the five study sites. Such sketch maps are able to reflect knowledge on river ecology and natural resources. The vibrant LEK of chaopramong tends to perceive the environment's space as comprising both linear features such as roads and streams, and non-linear elements such as landmarks and fishing grounds.

It is likely that many researchers and scientists have overlooked the use of LEK, regarding it as neither reliable nor derived from formal processes. On the other hand, I found that the *chaopramong* had gained vital experiences from their daily lives and so were able to very accurately identify their LEK as part of the sketch mapping exercise.

(1) The significant characteristics of the LEK:

The LEK possessed by the study's *chaopramong* embodied information about the inherent relationships in their daily lives and within their communities or space. Their information could be classified into three key types of features: points, lines and polygons. These comprised, for example, the locations of their communities, rivers and fishing grounds, the riverbed characteristics, and community boundaries. Information could be classified based on a scientific system, as qualitative, quantitative and semi-quantitative. In addition, it contained some timescales. For example, qualitative information concerning the attributes of land parcels along the river and the ownership of fishing grounds. Quantitative information might relate to land use and changes to it, or perhaps fish densities and sizes. Semi-quantitative information might relate to the ranking of fisheries management conservation zones, or temporal aspects relating to seasonal changes in river characteristics, fish species, and aquatic plants. The LEK represents an expert repository based on people's backgrounds and experiences (Minang and McCall, 2006). For instance, the *chaopramong* displayed expert knowledge with regard to river characteristics (see Figure 7.2-A), while the chief of the village turned out to be an expert on land parcel attributes (see Figure 7.2-B).

Moreover, LEK is a type of knowledge with a cognitive structure, and is reliable due to its foundation in generations of practical knowledge and experience. The study's *chaopramong* could locate themselves and subsequently their LEK both accurately and reliably, and revealed a substantial amount of information on how to develop a fisheries management framework. The vital LEK was assessed by comparing the sketch maps with a professional map, such as those available in Google Earth. Figure 7.3 shows a comparison between a sketch map of Phomueng village in Na Waeng and Google Earth. It can be seen that the orientation of a road (red), of tributaries (blue), village locations (red star), and a reservoir (blue triangle), are similar. In addition, the sketch map also records the riverbed characteristics and fishing grounds (orange circle), which *chaopramong* experience every day during their fishing activities. This provides further evidence that LEK of *chaopramong* offers additional information about fishing grounds beyond the baseline data of scientific information.

Another example of LEK assessment is presented in Figure 7.4, which shows a comparison between LEK on deep pool locations elicited during the PPGIS workshop using a participatory GIS mapping on the base of satellite images, and scientific information about deep pool locations taken from the MRC (inset map). As can be seen, the LEK map identified an additional three deep pools: A1, B1 and B2, as shown in Figure 7.4. In Section 3.4.1.1, the results of a detailed survey of riverbed features were presented, with results derived from an echo-sounding exercise and GPS transects taken during the study, together with echo-sounding data from the MRC. The images show the river as a cross-section and are detailed in Figure 7.4. The results of the survey work corroborate the features identified during the LEK sketch mapping process, providing confidence in the accuracy of the LEK information. Using a 3D analysis in ArcMap10.1, the riverbed elevation and cross-section were also generated.

Regarding deep pool A1 [*vern kan klang*], this has an approximate depth of 5 to 6 meters and is located near a tributary's mouth at Xe Banghiang in Salawan, Laos. The river is generally shallow at this point, with sediment possibly flowing from the tributary's mouth into the Mekong. Interestingly, during a sketch-mapping session, local chaopramong drew a fish symbol at this location (shown as an orange circle in Figure 7.3). This action is supported by the known significance of deep pools for local fisheries, and pools as shallow as only 2 to 5 meters deep in the mainstream and tributaries are classified as deep pools due to their importance for local fisheries and fish sanctuaries (e.g. in Khong, Laos (see Baird, (2006); Kratie, Cambodia (see Chan et al., 2003) and see details in Section 2.7.1. Furthermore, Figure 7.4 shows an inset map of B1 [*vern kaimaefuk*], and B2 [*vern kanyeng*] deep pools, which although identified by local chaopramong, were not detected using the scientific analysis. A possible explanation can be seen clearly in the long shape of deep pool 5 [*vern thamtoum*] and the riverbed profile for the other, which has multiple deeper areas.

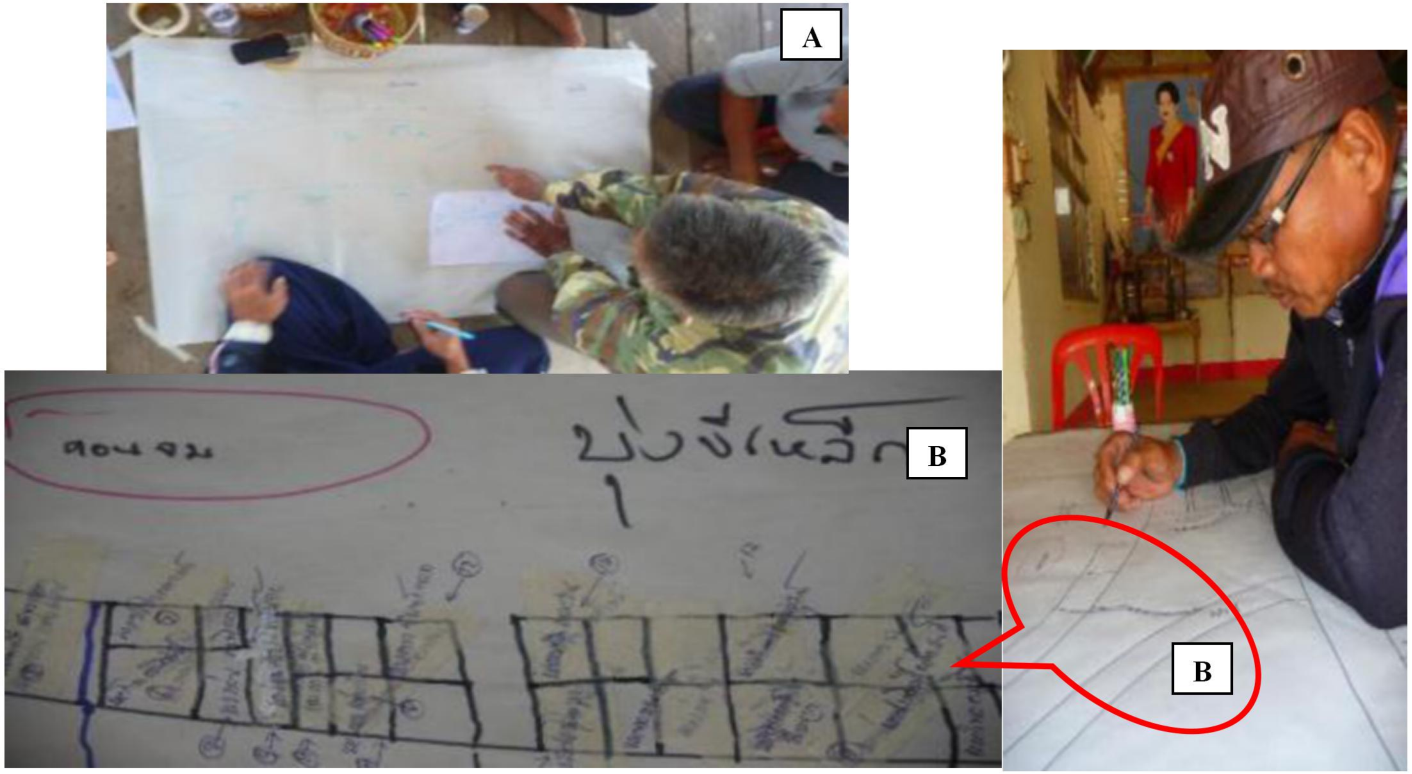

Figure 7.2: A- a group of *chaopramong* at Namueng village drawing characteristics of the Mekong River.
B- the chief of Bungkeylek village drawing land parcel attributes alongside the Mekong River.

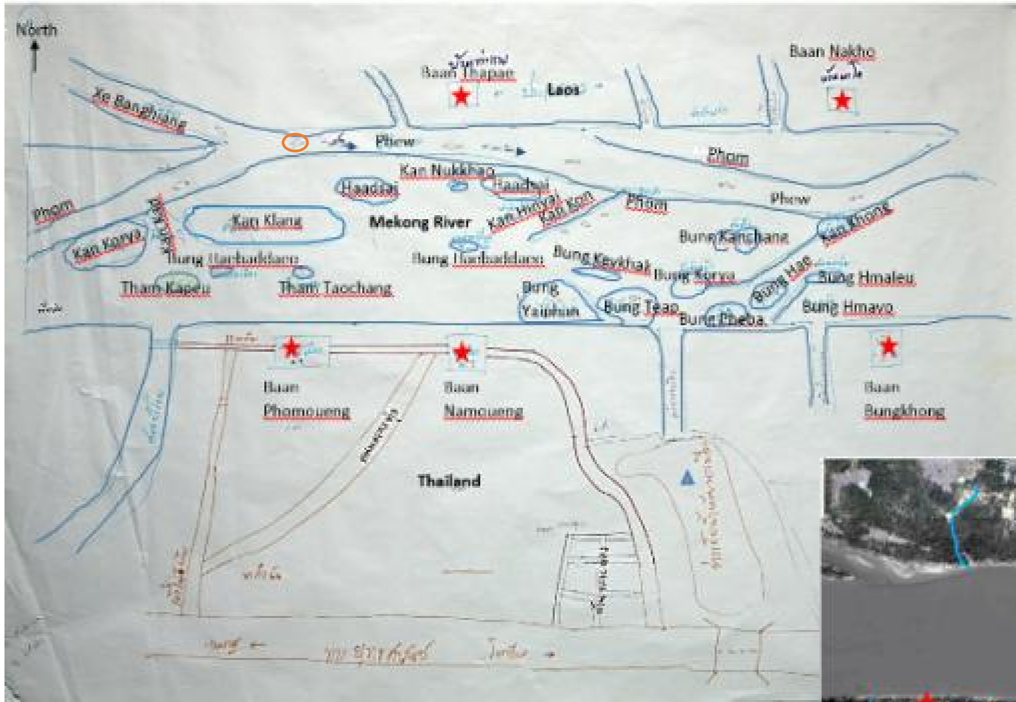

Figure 7.3: Comparison of an LEK sketch map of Namueng village (above) and a satellite image from Google Earth (lower). Noting the local place name of LEK map was translated into English.

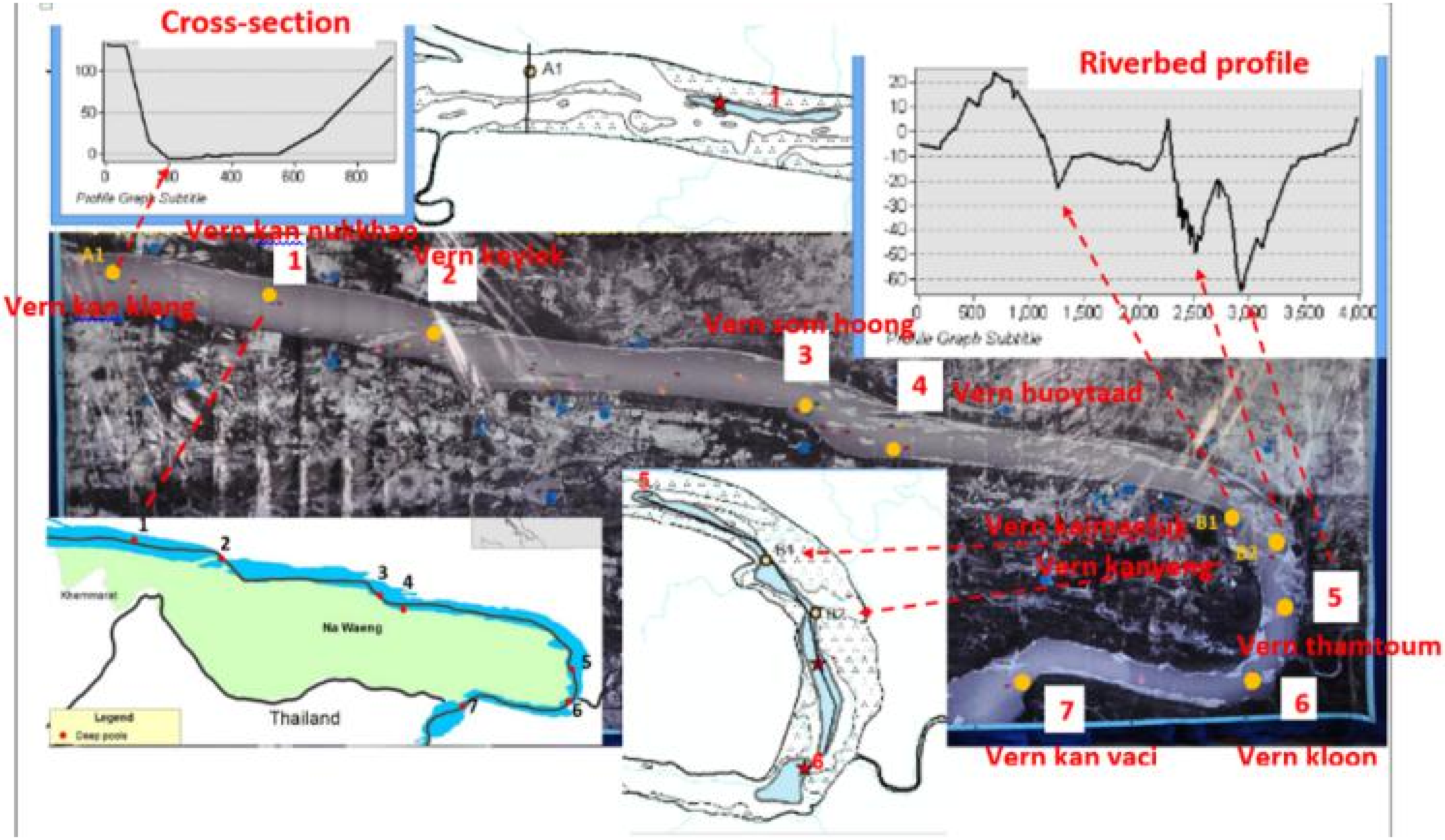

Figure 7.4: Comparison of deep pool locations using LEK (orange dots) and scientific analysis (red dots, lower left figure) – as analysed by the MRC. The A1 LEK deep pool location compares with the cross-section, and the B1 and B2 LEK deep pool locations compare with the longitudinal riverbed profile of deep pools.

The LEK of the *chaopramong* is significantly different from the analysis carried out using only scientific information from the hydrographic atlas and zero-crossing method. Therefore, the analysis of deep pools based on the scientific model reveals only one side of the coin, for example only the key deep pools' dimensions and morphological characteristics), while the other side of the coin is provided by the LEK of *chaopramong*, which includes information on fishing grounds, riverbed characteristics and fishing practices. This group of people fully rely on their local fisheries and demonstrate a deep spatial connection and spatial perception of their own communities that draws upon cumulative experience and knowledge of biodiversity and ecology.

(2) LEK of *chaopramong* on the characteristics of the Mekong River in Na Waeng

The sketch mapping session relied upon the LEK of *chaopramong* on river ecology, natural resources, and artificial features along the river (Figure 7.3). The vibrancy of *chaopramong*'s LEK is also displayed by the fact that their knowledge also has played a part in the creation of common local names or geographical place names for describing characteristics of the river as listed below.

A *bung* [บุ่ง] is a fishing ground, which *chaopramong* identify through their experience of being able to catch fish regularly there, or by recognizing that the area has a high fish density. Examples are Bung Keylek at Bungkeylek village and Bung Thamtoub at Ladcharoen village.

A *don* [ดอน] is an island, being a mass of land surrounded by water, mainly composed of rock, which is mostly or completely submerged during the wet season and shows up as an island during the dry season. Examples are Don Somhong at *baan* Na Waeng and Don Jom at Bungkeylek village.

A *haadsai* [หาดทราย] is a sandbar created by river sand deposition, which mostly occur near *Kan* (see below) during the dry season, for example the *haadsai* near Kan Khon at Phomueng village. In some areas, *haadsai* can also be found along the riverbank as a sandy beach. Examples of the latter can be found at Ladcharoen village, which is a tourist site for swimming in the river.

A *kan* [คัน] is a submerged linear rock feature that is aligned across the river channel. It is similar to *keang* (see below), but the speed of fast-flowing water is lower than at *keang*.

A *keang* [แก่ง] is a set of rapids, which is area of shallow, rocky, fast-flowing water where most of the rock is visible during the dry season. *Keang* are mostly found in Ladcharoen village's section of the river where the gradient of the riverbed is relatively steep. Examples of this feature are found at Keang Palakuy and Keang Kanyeng.

A *pha* [ผา] is a river cliff with boulder sedimentary rock exposures along the riverbed and banks. *Pha* are mostly found in Ladcharoen village, which is situated beside a large bedrock outcrop constriction. An example of this feature is found at Pha Pakthamyai.

A *phew* or *phewnamluk* [แปว, แปวน้ำลึก] is a thalweg, which is the deepest and strongest flowing water channel in the Mekong River. It is used for navigation by big boats, while local villagers along the Mekong River will used this physical feature as an international border, in addition to the stone makers.

A *phom* [ป้อม] is one of a series of stone markers, which were built during the French colonial era (1893–1945) for use as navigation channel markers (Foreign Affairs Department, Lao PDR, 2009). Local villagers along the Mekong River still use these stone makers for navigation, due to their location within the thalweg of the River, and also as border markers.

A *tham* [ถ้ำ] is a cave, which is a hollow place composed of big stones, which can be found both on land and underwater. Few *chaopramong* know how to catch fish in *tham* as it requires experience of the unusual river flow characteristics existing in such locations. Moreover, some *chaopramong* also avoid fishing in *tham* because they are viewed as sacred places for the river spirit.

A *veun* [เวิน] is a deep water area and another term used for the deep pools studied in this research. *Chaopramong* believe that *veun* have high fish abundance and act as a refuge habitat for some fish species during the dry season (e.g. *pla bung* (*P.gigas*) and *pla yang* (*P. bocourti*)).

In this connection people's use of 'toponyms' or place names for particular locales can reflect specific connections to the environment, flora and fauna, culture, ethnicities, politics, and history of a place (see Zelinsky, 2002). The LEK maps on river ecology reveal place names that are richly endowed with *chaopramong*'s experiences and environmental perception on a daily basis. This means that place names embedded within the LEK of *chaopramong* also reflect their livelihood and cultural narratives of fishing and, as such, their LEK is inherently geographical. Thus the place names described above are related to particular physical features, for example *don jom* is used for a submerged island, but the place name Don Somhoong also reflects the vegetation that grows on the island- Somhoong is the Thai name for the plant *Sterculia foetida* L. (from http://www.pharmacy. mahidol.ac.th/siri).

The most valuable aspect of local *chaopramong*'s knowledge is that it not only supports in-depth scientific research, but also can reduce the time and cost of research operations; for instance, by identifying the fishing grounds for certain fish species, while also providing a better understanding of *chaopramong*'s fishing culture and livelihood. Much of the LEK needed for a considered approach to fisheries resource management is neglected, even though they are intrinsically connected. Hence, LEK can be a vital source of information. Using participatory GIS mapping with LEK can help to fill any gaps found, for example by aggregating LEK into a scientific platform based on satellite images, as I will explain in the next section.

7.2.3.2 Participatory GIS mapping on the base of satellite images

The PPGIS workshop provided a link to Phase III of the PPGIS process development activity by using participatory GIS mapping, as illustrated in detail in Section 3.5.1. To recap, the aim of the PPGIS workshop was to initiate conservation of the ecological functions surrounding deep pools, and so protect the livelihoods of local *chaopramong*. The workshop included a variety of activities involving local *chaopramong*, local leaders (*kamnan, phuyaibaan*) and local government units, as well as the community as a whole. There were a total of 25 participants from Laos and Thailand. These participants became involved in fisheries management planning and implementation activities through use of the PPGIS approach.

The PPGIS workshop was split into two main sessions. In the first, communications and knowledge exchange exercises were carried out with respect to fisheries management activities on the Mekong River. This session aimed to raise awareness regarding the impact of environmental change on fisheries along the Mekong River by creating a better level of understanding of fisheries management mechanisms, and providing an experience of Nahinngoen community-based fisheries management guidelines, based on inputs from academic and local villager participants. Lastly, the PPGIS workshop was organized around the use of GIS technology in tandem with the LEK of the Thai and Lao *chaopramong*, with the aim of initiating fisheries management activities within their communities.

The disclosures made by the participants, plus the observations I made during the PPGIS workshop, can be summarized as follows.

Firstly, it was found that some *chaopramong*'s and local government staff's knowledge and awareness regarding fisheries management mechanisms were relatively poor, meaning fish resources in the study communities are in general fully or over-exploited, even though fishing is only a part-time occupation and partial income source for many local people. In addition, the government does not regulate or control fisheries management mechanisms along this stretch of the Mekong River. Mostly, fish are released into the tributaries or canals in order to promote fish diversity and population.

With reference to the over-exploitation mentioned above, some *chaopramong* generally still employ illegal fishing gear and practices, such as the use of explosives, gasoline spills to trap fish, and the use of fine-mesh fishing nets (2.5 cm) during the fishing season[10].

Secondly, there was a discussion regarding the impact of environmental change on fisheries in the Mekong River, as it was felt this could help promote fisheries management improvements, and raise the level of awareness on conservation and environmental protection practices, thereby protecting fish resources for the next generation. The discussion appeared to confirm that the participants have a thorough understanding of environmental issues and the changes taking place. For instance, fisheries are under intense pressure from a wide range of anthropogenic disturbances, in particular those that apply direct pressure to fish resources and, as a consequence, have led to freshwater species decline and even some species becoming endangered. Examples of these disturbances include:

1. *Land use changes*:
    i. Local *chaopramong* observed that the fish population has tended to decline in recent years, due possibly to chemical run-off from nearby paddy fields, where pesticides are applied to protect crops from insects, herbicides to kill weeds, and fertilisers are used to increase crop yields.

[10] It should be noted that using small mesh size nets as stated here, does not imply that all small nets should be banned for catching fish; it really depends on the size of fish involved. Some small fish species, such as *Henicorhynchus spp.*, have a largest recorded specimen of just over 10 cm long (Froese & Pauly, 2014 in fishbase.org), meaning *chaopramong* have to use small mesh size nets to catch some small fish species.

Interestingly, *chaopramong's* knowledge and awareness regarding the harmful effects of pesticide usage on humans and fish turned out to be similar to the scientific facts regarding the relative risks posed by such substances to humans and animals (see Aktar *et al.*, 2009).

2. *Modifications to the river flow regime*:

   i. Dam developments have the greatest impact, for example, the proposed Ban Koum dam in Phosai district, Ubon Ratchathani. The proposed dam is 10 km downstream of the deepest deep pool in the Mekong River or *Vern Kanyaci*. The chaopramong were aware of the situation concerning the Ban Koum dam construction project, and knew that it may or may not happen, but was probably just postponed at the moment due to its highly negative impact on their livelihood.

   ii. Artificial river embankments in the study area have led to a decline in the income security of local people. Furthermore, many people living alongside the river have lost their family land, as many did not have formal title to it, and have also lost the land they traditionally used as riverside gardens during the dry season. They told me that they cannot win in this situation; they will either lose their family land to inundation, or from naturally occurring erosion.

   iii. *Intensive exploitation of fish stocks*: Local *chaopramong* spoke of the fishing practices and behaviours they currently employ. Some *chaopramong* use tried and tested modern fishing gear and small mesh size nets during the spawning season, as these help increase the size of the fish catch and allow them to meet market demand, plus provide an income for their families. The traditional practices they employed of not catching immature fish, not catching fish during the spawning season, and releasing them if they were caught, are now ignored by some *chaopramong*.

Thirdly, the *phuyaibaan* of Nahinngoen village revealed that the workshops and meetings already supported by NGOs, such as the Global Environment Facility (GEF) and UNDP, have enhanced the environmental awareness of the local *chaopramong*, local leaders and local government officials engaged in water management activities. Community empowerment is now being encouraged through the networking of local organizations. At the village level this can be seen among people, both within and between villages, who share similarities in terms of social backgrounds and occupations.

Fourthly, some participants highlighted the fact that discussing and enacting community fisheries management activities is a relatively long-term process, especially if based on a consultative approach, and that it requires strong political will or donor driven support. It was also mentioned that many co-management activities appear to be donor driven, including Nahinngoen's community management framework. Donors who sit outside the government system and its regulations may help play a catalytic role; to accelerate the process of policy or legal reforms otherwise carried out slowly by governmental systems (see Section 7.3.2 for a further discussion on this).

Finally, there is clear agreement that the development of community fisheries management activities is vital if the communities wish to preserve fish stocks for future generations, and for securing their food and incomes. As a result, both the Thai and Lao study participants have now set up eight fisheries conservation areas close to temples, their communities, the river's tributaries and in deep pools (Figure 7.5). However, such a community-based fisheries management framework will need to be supported by the following:

1. The development of programs which are aimed at further building environmental awareness among local people; linking people and water management activities together in a sustainable manner.
2. The establishment of fisheries management mechanisms such as rules and regulations; for example:
   i. Establishing a minimum mesh size[11] for fishing nets to catch fish during the fishing season. Hence, a minimum mesh size limit will not only protect immature fish, but should also be large enough to protect spawned fish.
   ii. The implementation of closed seasons, for example during spawning and fish migration periods.
   iii. The implementation of conservation areas.
3. Development of a bilateral fisheries management agreement between Laos and Thailand. However, this will involve a relatively complicated process, especially as it requires strong political will and support. Due to the fact that the Mekong River is an international river, one that shares its water resources with a number of countries, a consultative approach may be required to sustain effective fisheries management activities.

[11] According to the FAO (1984, para. 4), it is difficult to determine the best mesh size for a multi-species fishery. "There are basically two reasons for regulating mesh size. One is to conserve the spawning stock and the other is to increase the long-term sustainable yield" (*ibid*).

Figure 7.5: Public Participatory GIS for fisheries management in Na Waeng, Ubon Ratchathani, Thailand. The orange boxes show the locations of the fisheries conservation areas initiated by the villagers.

7.2.4 Evaluation of the PPGIS workshop

Evaluating the success of PPGIS projects is often difficult as results are hard to quantify (see Jordan, 2002; Meredith *et al.*, 2002; Dunn, 2007; Sieber, 2009). In my research, during the workshop in Na Waeng I sought to evaluate the effectiveness and degree of public participation and the practical lessons learned by the public while engaging in fisheries management on the Mekong River. I used two social science techniques to help with my evaluation of the PPGIS workshop: namely, personal observation as described in a 'true participation' session, and also a feedback form completed after the PPGIS workshop had ended.

7.2.4.1 True participation: Clutter behinds the scenes

Based on my personal observations of how participants contributed their knowledge and opinions during the PPGIS workshop, there was a shift from passive participation in the early stages, towards more active and intensive participation towards the end of the workshop's activities.

The PPGIS workshop comprised two sessions: (i) communications and knowledge exchange with respect to fisheries management activities on the Mekong River and (ii) The PPGIS workshop.

(i) Communications and knowledge exchange: For the participants, this session began by listening to two presentations and ended with a discussion session about: 'the impact of environmental changes on fisheries in the Mekong River'. Overall, during the workshop, participants were active and raised questions relating to their concerns and actively discussed issues that they face. However, there existed a political hierarchy within the group of local leaders (*kamnan, phuyaibaan*) and *chaopramong* who attended the morning session of the PPGIS workshop, which was about communications and knowledge exchange with respect to fisheries management activities on the Mekong River. There were signs that power was being exercised during the session, in particular in the early stages of discussions when only a limited number of participants were willing to speak. It often occurred that local leaders, who a have position and status in their village structure, raised problems and opinions and controlled and dominated the session, while Laos and Thai *chaopramong* mostly listened and remained silent.

However one participant, who was a *chaopramong* of Ladcharoen village, broke the ice and was confident about talking in public as well as expressing his ideas about fishing territories between Nahinngeon and Ladcharoen villages during the talk by the *phuyaibaan* of Nahinngeon village, based on the project, 'Rehabilitation of Biological Diversity along the Mekong River through Community Participation'.

The *chaopramong* commented that "*Your village conserves fisheries resources in many areas along the Mekong River, but your villagers come to catch at my village."* This was met with some laughter from participants in the background.

The *phuyaibaan* of Nahinngeon village answered "*I will solve this issue and tell my villagers about fishing territory*."

After this exchange, the atmosphere in the workshop became much more friendly. Most participants felt at ease and were confident to express their opinions openly. However, there were some passive participants who remained silent throughout the morning session including Laos *chaopramong* and one woman who was a member of Ladcharoen village's committee.

(ii) The PPGIS workshop was an interactive environment where *chaopramong* were able to be actively involved in spatial decision making in fisheries management. In this session, the workshop attendees were split into two groups: *phuyaibaan* and *chaopramong*. This was done to avoid conflicts over power or the decisions made by either group. The session produced very active and intensive participation in terms of work and sharing of ideas in both groups. Even though this PPGIS workshop was in the afternoon, and the meeting room was too hot, approaching 40°C with no air-conditioning, most participants were laughing and discussing the work in a relaxed way.

The group of *phuyaibaan* discussed the possibility of developing a community fisheries management process, and participants generally shared their ideas with one another and actively participated in annotating the prepared maps. Interestingly, the most active participants were *phuyaibaan* from *baan* Na waeng and Bungkeylek, both of whom were 'old-timer' *chaopramong* and older than others. They happily added their LEK to the prepared maps and openly discussed fisheries resources with their group. During the discussion, they proposed fisheries conservation areas around their villages, for example at Na Waeng Temple and Kan Keylek, due to high fish densities in those areas.

The group of *chaopramong* added their LEK of fisheries resources and landmarks to the prepared maps. I found that during the participatory GIS mapping on the satellite image base and throughout its working process, both Laos and Thai *chaopramong* were able to and throw themselves into the process, and as a result open-up some of the most salient issues and ideas of unaccountable LEK to renewed scrutiny. For example, during the PPGIS process the power of LEK was reinforced when scientific information on locations of fish by size, fishing grounds, and deep pools, was found to closely match information provided by the *chaopramong*. Interestingly, the working process encouraged and empowered some passive participants, in particular Thai and Laos *chaopramong* who had remained silent at the beginning stage, to actively and equally participate in the mapping process. Hence, the ownership of LEK during the mapping process provided the basis for empowerment. In particular, Laos *chaopramong* who were in minority group in this workshop (three Laos participants), felt confident, relaxed and provided their LEK openly during the participatory mapping session.

There were also some people who attended the workshop who were mainly silent during the whole process. One example of this was a woman from Ladcharoen village, who was the only female participant in the workshop. Although not a *chaopramong*, she was the owner of a homestay in the village and a member of Ladcharoen village committee, and her motivation for participating in the PPGIS workshop was in order to stay informed. . She stated that "*I would like to stay up to date with what is happening*." In Mekong fisheries society, fishing is mostly a male domain due to the weight of gear, the skill of riding boats, and their local knowledge of river ecology and characteristics gained through their fishing practice. Hence, male participants played a major role in the sketch mapping and participatory GIS mapping session.

After the group sessions, a 'bridging the gap stage' was employed by merging the two groups together to decide how to incorporate public opinion into the decision making process on fisheries management activities. All the LEK of *chaopramong* had been added to the prepared satellite image map during the previous session. Using the prepared satellite images map, which showed landmarks, fisheries resource locations, and a map legend, the *chaopramong* and *phuyaibaan* discussed within their village groups to decide on the locations of fisheries conservation areas. At this stage, the LEK of *chaopramong* was recognized by *phuyaibaan* and thus was empowered to become part of decision making process. As indicated in Figure 7.1, the three key types of participation (F, M, E) were promoted during the PPGIS workshop in order to produce the fisheries management conservation maps. Moreover, the intensities of participation of stakeholders involved in each part of the PPGIS process indicated progressively higher involvement, thus during the PPGIS workshop for fisheries management participation moved from a passive I2 level towards an I6 level of interactive participation.

However, there were signs of power being exercised during the explanation of the proposed fisheries conservation zone in some villages. For example, the *chaopramong* of *baan* Na Waeng and Bungkeylek preferred their *phuyaibaan* to go ahead and explain their reasons before taking their turns.

7.2.4.2 Feedback of the PPGIS workshop:

The feedback form at the end of the PPGIS workshop consisted of a series of open-ended questions, which is a common social sciences survey technique. One of the main advantages of the open-ended questions is that they allow the inclusion of new information from participants without forced answers, therefore the answers from respondents can provide new and deep insights into issues (Bernard, 2011). The main drawback of such open-ended questions is that their answers are complex to code and interpret (*ibid*).

To assess the public participation and the practical lessons learned by the public engaging in fisheries management on the Mekong River in Na Waeng during the workshop, the feedback form consisted of three open-ended questions addressing the usefulness of the PPGIS tools, the possibility of developing fisheries management from the outcome of the workshop in the communities, and general comments. The main theme of public participation focuses on the empowerment of local communities or marginalized people. To facilitate consideration in this concept and to better assess stakeholders' views and understanding of the public participation process, I interpreted and categorised respondents' answers or comments, and then characterised the view of participants in terms of the participation intensity level. These levels extend from initial information sharing, to consultation, involvement in decision-making by all stakeholders, initiating actions and empowerment (Water-Bayer and Bayer, 1994; Selener, 1997; McCall, 2003; 2004). Admittedly my assessments are subjective and may be disputed; indeed a goal of this feedback is to evaluate the outcome of the PPGIS workshop and to explore respondents' in-depth opinions of the workshop. Hence, the feedback from the PPGIS workshop, which is presented in Table 7.2, might be biased by people's interpretations of respondents' answers.

Twenty participants completed a feedback form at the end of the PPGIS workshop (Appendix IV). Overall, there was a total of 25 participants (including myself) but 4 participants – the Director and officers of the TAO in Na Waeng, and *kamnan* - attended only the morning session (see section 3.5.1.1). It should be noted that some respondents had more than one comment for one question and so I grouped their comments in relevant categories. Hence, the count number of comments (n) for each question is variable.

Overall, almost all the workshop participants found the PPGIS tools useful (Q1, n=34), according to the feedback form completed at the workshop. The most popular response was that the PPGIS tools (Table 7.2) used during the workshop can assist at the 'information sharing' level of participation intensity as it provides a better visualization of their communities (44%). The second most popular opinion was that the PPGIS tools can create opportunities for participation in decision making processes and engagement in water resources issues, which aligns with the 'involvement in decision making process' level of participation intensity.

With regard to the development of fisheries management (Q2, n=20), responses from the workshop indicated a high possibility of development, but it needed time for discussion and 'consultation' among stakeholders (50%). The second most popular opinion was that the initiative on fisheries management could be implemented in their communities (30%). This comment aligns with the 'empowerment' level of participation intensity. While in terms of the general comments from the respondents (Q3, n=20), the majority (45%) revealed that the workshop was useful for their communities, and they intended to develop community-based fisheries resources management in their communities. This comment aligns with the initiating actions' level of participation intensity.

Table 7.2: Participation intensity analysis of participatory GIS workshop

Q1: The usefulness of the PPGIS tools.

Participation intensity*	Respondent's answer	Count	%
IS	Providing a better visualization of communities.	15	44
C	Collaboration with officers is needed for data accessibility.	2	6
ID	Creating new opportunities for participation in decision making process and engaging in water resources issues.	14	41
IA	Developing a communities-based fisheries resources management is useful for their communities due to conservation of water resources for the next generation.	3	9
Em	-	-	-
		34	100

Q2: The possibility of the development of fisheries management from the outcome of the workshop.

Participation intensity	Respondent's answer	Count	%
IS	Gaining some new knowledge about not catching small (juvenile) fish during spawning season to sustain the fisheries resources.	2	10
C	The outcome needs time to discuss among stakeholders before it can happen.	10	50
ID	-	-	-
IA	Starting point of solving problem and monitoring programs are needed.	2	10
Em	The outcome of this workshop can implement in their communities.	6	30
		20	100

Q3: General comments

Participation intensity	Respondent's answer	Count	%
IS, C, ID, Em	-	-	-
IA	The workshop is useful for their communities, and they show intension to develop a communities-based fisheries resources management in communities.	9	45
	Developing a bilateral program for fisheries resources management.	4	20
	Requiring some of the government's activities and actions to release fish in the river for increasing number of fish species, and checking for illegal fishing gear that occurs in the communities.	4	20
	Requiring some follow up programs.	3	15
		20	100

Remark: Participation intensity* (McCall, 2003; 2004; Water-Bayer and Bayer, 1994; Selener, 1997): Information sharing (IS), Consultation (C), Involvement in decision-making by all stakeholders (ID), Initiating Actions (IA), Empowerment (Em).

7.3 Discussion

7.3.1 Public Participatory GIS for fisheries management in Na Waeng

PPGIS is a useful tool to use during facilitation exercises, as it supports mediation activities and empowers local people. The outcomes from integrating the *chaopramong*'s LEK into future fisheries management are expected to lead to greater competence and the increased democratization of water resources management activities on that section of the Mekong River. The PPGIS approach used in this study did reasonably well at improving dialogue between the relevant stakeholders, enhancing the administrative processes, and introducing practical mechanisms to support a fisheries management approach. Even though it represented the first stage in terms of involving local fishing communities in the decision-making process, by mapping actions using PPGIS tools, the villagers involved showed a strong desire to improve water resource-related issues and become more involved in fisheries management decision-making processes.

PPGIS can be described as representing a shift from a traditional top-down approach, to a bottom-up one in which democratization is introduced to allow for equitable access to natural resources and to empower local communities within the decision-making process. Participatory approaches are closely associated with the concept of good governance, and are a key element in its application; helping with participation, the rule of law, transparency, accountability, legitimacy, effectiveness and efficiency, as well as equity, developing a strategic vision, ecological soundness, empowerment and partnerships (especially those spatially grounded in communities), and also improving competency levels (UNDP 1997; Van Kersbergen and Waarden, 2001). However, this study has not focused explicitly on the creation of good water governance, for the participation criteria described above also complement the concept of PPGIS, as defined above. This study, by introducing the concept of a shift from a traditional top-down approach to a bottom-up one, aims to introduce greater democratization and equality within the natural resources management process, so this should also be included within the definition of PPGIS. Furthermore, the concepts introduced by the study participants complement the idea of a "public participatory geographic information system" (PPGIS), one whose aim is to integrate management processes for the benefit of local communities, community development and water resources, through the use of GIS and maps as tools. It is evident that the use of LEK of *chaopramong* is promoted through the use of PPGIS tools and it is hoped this will lead to increased democratization within water governance activities along the Mekong River.

7.3.1.1 Empowerment knowledge and skills acquisition through the use of PPGIS tools

The perspective of empowerment through PPGIS application does not lend itself to easy interpretation because of the various definitions of participation and empowerment that differ markedly depending on who defines it (Kyem, 2002b). Empowerment in this research refers to the promotion of the distant voices of local *chaopramong* so they can be heard and therefore gain respect for their LEK as a negotiating framework in the decision-making process. The evidence from this research suggested that there was considerable empowerment of communities through the PPGIS mapping process and use of its tools in the decision-making process. This is similar to the definition of 'empowerment capacity' in Corbett and Kelly (2005, 28) who state that " *Empowerment capacity refers to aspects of the deeper process of change in the internal condition of an individual or community that influence their empowerment.".* However, the outcome of this research would need to be sustained with further involvement and commitment from stakeholders and a suitable budget to reach the real empowerment where communities could have an increased social influence.

As described in the previous section, the application of PPGIS for fisheries management in this research was divided into three phases, each of which showed different levels of stakeholder engagement with the PPGIS tools. It can clearly be seen that through the PPGIS process there were signs of progression of participation intensities towards empowerment level, which was reflected in higher involvement of participation intensities. Significantly, the PPGIS workshop for fisheries management saw participation intensities rise from a passive to interactive level of participation. In similar vein, the use of PPGIS tools in each phase was far more important and more empowering when it was selected to make it appropriate to the context of the PPGIS process. This can empower the LEK of *chaopramong* and enable *chaopramong*'s voices to be included in the decision making process. Table 7.3 displays a breakdown for each phase, the PPGIS tools used, the involvement of stakeholders, and relevant advantages and disadvantages of those tools.

Phase 1 - the preparatory phase was mostly carried by me with the aim of introducing the research to relevant stakeholders, field survey preparation and study of the geography of Na Waeng. During this phase topographic maps (paper), GIS based maps, and handheld GPS were deployed for field survey. The disadvantage of using technical tools and of creating GIS based maps is that the process can create techno-centric barriers between *chaopramong* and researchers.

Phase 2 - concerned mapping the river's ecology and surveying the *chaopramong*'s livelihoods. Two activities were involved in this phase.

1) Sketch mapping involved mainly gathering the LEK of *chaopramong* from relevant stakeholders in order to produce LEK of river characteristics and fisheries resources, with the researcher in the role of facilitator. This tool was easy for local communities to use and flexible enough to adapt to working in village or rural conditions. However, it was slightly difficult to erase mistakes when annotating maps and the drawing showed a distance distortion in term of map scale accuracy.

2) Mapping the river's ecology using a handheld GPS, and a Fish-Finder and External GPS Combo. This activity aimed to survey the river's characteristics. The survey data collection involved mostly Thai and Laos *chaopramong* and the researcher. The tools helped local *chaopramong* to have an exposure to the technology and attracted participation, created curiosity and interest, and helped with the transparency of the survey. On the other hand, the data processing of survey data was conducted by the researcher only.

Phase 3 - mapping the conservation zones. This phase aimed to initiate the development of fisheries management in Na Waeng by using participatory GIS mapping on a base of satellite image maps (a vinyl banner 2.5 m long), some topographic paper maps and GIS based maps. The tools provided visualization and familiarity with study sites with rapid identification of landmarks and allowed the LEK of participants to be visualized on base maps, which improved accuracy in comparison with sketch mapping. These activities brought together various types of stakeholders to initiate the development of fisheries management. It is worth noting that as a side benefit, the end product map of the participatory mapping will be sent to the *phuyaibaan* of *baan* Na Waeng, based upon his request during the PPGIS workshop.

The representation and involvement of PPGIS in the fisheries management process in Na Waeng (Table 7.3) revealed the ownership of LEK of local communities. The capacity for empowerment was demonstrated through the PPGIS process, which improved the opportunities and capacity for decision support. Most of the *phuyaibaan* and *chaopramong* were actually involved in most phases of the PPGIS process. It is worth noting that the *phuyaibaan* who was involved in sketch mapping, was an 'old-timer' *chaopramong* from *baan* Na Waeng and Bungkeylek and, therefore, the research uses the term "LEK of *chaopramong*" for the sake of consistency. Some activities of *phuyaibaan* and *chaopramong* could only be considered partial participation because of a requirement for technical knowledge and background, for example during the river characteristics survey, which used a handheld GPS and a Fish-Finder and External GPS Combo. Though this was only partial participation, it nevertheless showed implied knowledge and skills acquisition through the exposure to new GIS tools (King, 2002; Kyem, 2002a). On the other hand, the director of the TAO and fisheries officers[12] did not get involved with any PPGIS tools at all and the technical data of river characteristics survey and GIS data processing were dealt with by the researcher alone.

Furthermore, the sketch mapping process helped to increase the credibility and validity of the results of LEK maps. During this session, key informants enthusiastically shared and discussed their knowledge about the river's characteristics, fishing grounds, and so on. The process allowed key informants to express their knowledge while also allowing the cross-checking of data quality and data completeness within the group. It can clearly be seen that the *phuyaibaan* and *chaopramong* owned their LEK, which was then displayed during the sketch mapping and fisheries conservation area mapping process. The sketch maps (see Section 7.2.3.1) gave clear evidence that the LEK of *chaopramong* can provide more information and knowledge of the river's characteristics, fisheries resources and local names than was subsequently produced using GIS.

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[12] It should be noted that no fisheries officers participated in the PPGIS workshop even though a formal invitation letter was sent to the Ubon Ratchathani Fisheries Department, prepared by the Fisheries Department at Ubon Ratchathani University as the research collaborative organization for the PPGIS workshop.

Table 7.3: Representation and involvement in PPGIS for fisheries management process and tools

Planning phases	PPGIS tools	Involvement of Stakeholders							Advantages/usefulness	Disadvantages
		T	K	P	TC	LC	W	R		
I. Preparatory phase	-Topographic maps (paper); - GIS based maps; - GPS	-	-	-	-	-	-	Y	- Providing visualization and based maps of study sites; - Building interest and trust with local communities.	- GIS techno-centric with barriers created by a GIS expertise, the ontology of GIS data. - Introduction about the researcher and GIS tools are needed because misunderstanding and suspicion may arise in sensitive areas e.g. border areas, conflicted areas. - Limited group in information accessibility.
II. Mapping the river's ecology and surveying	- Sketch mapping	-	P	Y*	Y	-	-	-	- It allows LEK to be visualized in map form. - It provides big scale maps: more detail of water resources and river characteristics than based maps. - Flexibility that can adapt working in village or in rural condition. - Easy to find material for mapping: paper, pencils, marker pens. - It gives orientation of the study site well. - It shows sense of place and direction, e.g. north, south. - Good for non-traditional GIS users.	- Slightly difficult to erase the mistaken drawing. - Distance distorted in term of map scale accuracy. *Noting: an old-timer *chaopramong* from *baan* Na Waeng and Bungkeylek
	- GPS handheld - Fish-Finder and External GPS Combo.	-	-	P	P	P	-	Y	- Shows high technical efficiency to collect data and position. - It helped local communities to have an exposure to the technology. - Attraction participation, created curiosity, interest and transparency.	- Techno-centric in data processing.

Table 7.3: Representation and involvement in PPGIS for fisheries management process and tools (Cont.)

Planning phases	PPGIS tools	Involvement of Stakeholders							Advantages/usefulness	Disadvantages
		T	K	P	TC	LC	W	R		
III. Mapping the conservation zones	- Participatory mapping based on satellite image maps - Topographic and GIS based maps	Y	-	Y	Y	Y	Y	-	- Simply to do in village/rural conditions which has no electricity. - Providing visualization and easily familiar with study sites and easily identify landmarks. - It allows LEK to be visualized in based map form, which is improved accuracy in comparison with a sketch mapping. - Building interest and trust with local communities. - Empowerment knowledge and skills acquisition through the use of GIS tools. - Good for non-traditional GIS users.	- Require some guideline during the workshop
	- Fisheries conservation area map and GIS database	-	-	-	-	-	-	Y	- Providing based maps and GIS database of the result of study.	- Techno-centric in data processing. - Limited in information accessibility.

Remark: Stakeholders: **T= TAO's officer, K=*Kamnan*, P=*Phuyaibaan*, TC=Thai *chaopramong*; LC=Laos *chaopramong* W=Woman villager R= Researcher;**
Involvement level**: Y= Full, P=Partly, '-'= No)**

"*The technology should be giving voice to local people, to the extent of putting local people on a more equal footing with external experts and decision-makers, such as claimed for PGIS used in land reform in South Africa...*" (McCall, 2003, 556). In a similar vein, *chaopramong*'s voices were empowered through the use of the LEK that was elicited and displayed on the PPGIS workshop map output for fisheries conservation area management in Na Waeng. The PPGIS tools assisted in empowering the LEK of *chaopramong* and promoting their voice as a one of the stakeholders. Furthermore, the PPGIS workshop map output was an effective visualisation which strengthened the validity of the GIS tool to break down the techno-centric barrier, and raise the transparency of the PPGIS process (*ibid*).

7.3.1.2 Power versus empower

Rambaldi *et al*. (2006b) considered mapmaking and maps as a means, a practice, and not an end. The PPGIS workshop map output and outcome represented the starting point for promoting the use of LEK and facilitating the LEK of *chaopramong* as a negotiating framework, a move which would encourage the democratization of community management processes. However it is not a simple process. As described earlier, the outcome of the PPGIS workshop and strategies applied in practice will be left to the villagers and local authorities to implement, or not. The result of PPGIS process improved participation levels from the low starting point to subsequently much higher levels. Similarly, the results of feedback from the PPGIS workshop were promising in that respondents indicated a very high possibility that the outcomes of the workshop could be implemented subject to further consultation among stakeholders, which is similar to the argument of Corbett and Kelly (2005). Furthermore, the Na Waeng case study mirrored the situation in many other PPGIS projects, in that it bestowed power on stakeholders who were unready to use it (see Kyem, 2002b; see Section 7.3.2). As Kyem (2002b, 22) explained "..*community empowerment is a political process that entails redefinition of existing* *power relations between the haves and have-nots in a community. Empowerment is an investment that involves risk taking, occasional failures and disappointments, constant reviews of strategy and persistence. Considered in the context of PPGIS projects that attempt to empower underprivileged groups in society, empowerment cannot be a simple, straightforward process. It is a task that is entangled with the intrigues of organizational life, including power sharing and changing alliances that may never happen, or take a very long time to materialize*."

Chambers (2006) and Rambaldi *et al.* (2006b) discussed the 'tipping positionality' of stakeholders in the participatory approach and PPGIS process, whereby some groups can be empowered through the process while others lose out. It is constructive, therefore, to ask the question: who gains and who loses in the participatory process? In this research the group of *chaopramong* were empowered through the use of the participatory mapping process used to elicit their LEK, which highlighted their ownership of knowledge concerning river characteristics and fisheries resources. But this situation can lead to two contrasting patterns of power change: some *chaopramong* were empowered by bringing their LEK to be recognized, while others were marginalised by having their power taken away. The change in the power system might lead to political changes, which could be positive or negative for PPGIS implementation (Craig and Elwood, 1998). The example of the negative impact of PPGIS implementation that caused conflicts that affect local politics in Ghana (Kyem, 2001) and indigenous peoples in New Zealand (Laituri, 2002). Along with this aspect, during the PPGIS workshop there was an exposure of LEK of *chapramong* of fisheries resources on the Mekong River. If this exposure is used for the benefit of fisheries businesses or private entities, it could be harming the fisheries resources and livelihood of *chapramong.*

Local elites do not relinquish their power easily (Carver, 2001). It was notable during the final 'bridging the gap' session of the PPGIS workshop that *chaopramong* avoided expressing their own opinions about the selection of their fisheries conservation areas before their *phuyaibaan*. From this situation, I can draw two conclusions. Firstly, some key members who have relatively powerful positions in the village could play more than one role in the community structure. For instance, one person can be a *phuyaibaan,* and at the same time he can be the father of a *kamnan* or father-in-law of a *chaopramong*. Secondly, it may be the case that *chaopramong* either did not want to undermine the power of *phuyaibaan* or maybe aimed to actually reassert the *phuyaibaan*'s authority. It is worth noting that the aspect of 'seniority' in Thai culture and society is in practice quite strong, both in rural and urban areas, in terms of age, status, social rank, and in some situations where wealth is counted. This established practice is very strong and deeply rooted in Thai society and is reflected in the Thai phrase "*Doen tam phuyai mha mai kat*", which literally implies that by "Walking behind an elder no one will be bitten by dogs". Nevertheless, if the person holding power is interested in the learning process, then this could provide a very positive opportunity and big advantage when establishing fisheries conservation areas for their villages, as was the case with the *phuyaibaan* in *baan* Na Waeng and Bungkeylek in this research. Therefore, there is a possibility to push forward a development program for fisheries management in Na Waeng.

7.3.1.3 Gendered spatial knowledge

As described earlier in Section 7.2.4.1, women participants were low in number in this research. Only one participant from Ladcharoen village took part. All of the *chaopramong* participants in this research were men, mainly due to their fishing experience around powerful and dangerous water currents, which have whirlpools, rapids, and other obstacles. Hence, the LEK of *chaopramong* in this research was collected exclusively from men, which meant that the considerable LEK of women *chaopramong* was omitted. I did not purposely exclude female *chaopramong* and all male *chaopramong* were voluntary participants and contributed their LEK freely.

From my personal observation, cultural norms played a key role in limiting the participation of women in this research. Additionally, family life and society in general in rural communities in Thailand has been traditionally male-dominated, although women are granted considerable respect. It can be seen in this study that males dominated leadership roles in the communities in Na Waeng; for example, the director of the TAO and TAO's officers, *kamnan, phuyaibaan* and village committee members are all men, while the only exception to this case was found in Ladcharoen village. Moreover, traditional gender roles are strongly emphasized in Na Waeng. For instance, this was reflected in the lives of my two local research assistants, who were a sister (20 years old) and brother (17 years old). The girl finished school at grade 9 and worked on the farm to help her family, while the boy went to college with the aim of becoming a navy soldier. Their parents said that a "*Girl no needs to have high education, she will get married anyway*." In a nutshell, all members of rural Thai society are regarded as equal in rights, where unequal distribution of resources and rights is accepted. On the other hand, in big cities women and men are very lax about gender roles, as they are both working to look after their families and have competitive personalities.

Interestingly, the word *chaopramong* in Thai, means 'a person looks for fish [*khon ha pla*]', which does not imply that the male gender is dominant among those involved in fishing. On the other hand, 'fisherman' in English does imply the dominance of males in fishing, and it raises a concern of gender exclusion in some societies. However, women play a major role in fisheries, including some fishing activities in Thailand and throughout the Mekong region. There are some types of fishing gear that women and even children use to catch fish along the Mekong River because of its light weight and ease of use. In Na Waeng, I found some women used a *sawing* [scoop net] to catch fish from the Mekong River. Another example of gear that women use along the Mekong River is a hand-held lift net, which goes by different names depending on the language. For example, it is *sa doong* in Thai, *ka dung* in Laos, *chnnuok sre* in Khmer, and *vó* nets in Vietnamese, but they are mainly used by men in Vietnam (MRC, 2012a). Furthermore, women have an influential role in fisheries marketing, and fish processing in Na Waeng. These positions tend to be held by women involved in fisheries in the Mekong River countries (Mahasarakarm, 2007). During the field survey of this research, most *chaopramong* answered the question about where to sell fish with the answer, "*I catch fish, my wife knows where to sell it*." This means women are also involved in fisheries activities. Remarkably, most of the owners of village and market fish retailers in Khemarat were women. In fact women who tend to work in, or close to their home or village, have a greater opportunity to meet and talk with various people unlike men who are out working (Kyoko *et al*., 2003 in Mahasarakarm, 2007).

7.3.2 Pushing forward fishing management in Na Waeng

Promoting and empowering the LEK of *chaopramong* within the decision-making process, and promoting participatory fisheries management around Na Waeng, will be encouraged through the networking activities of local organizations at the village, district, provincial, regional, and national levels, as well as through NGOs.

One possible avenue for LEK application by the government is to the Fisheries laws and legislation, which should be reviewed and/or revised to be relevant to the present situation as they are now almost 70 years old. The key to fisheries management is managing the people involved more than the natural resources. The government does this by prohibiting some fishing methods altogether all year round, prohibiting others on a seasonal basis, and also through the licensing and protection of spawning grounds. The central fisheries administration office normally announces changes, on a yearly basis, to fisheries staff in the provincial government. On the

Mekong River, the provincial fisheries administration encourages *chaopramong* not to fish during the wet season or during the fish spawning and nursing season, between May and September or during the red water[13] [*lau-do-nam-daeng*], though the exact time frame varies depending on the location. Furthermore, fines of 5,000 to 10,000 THB, or one year in prison, can be imposed on those found to have broken the fisheries laws. For instance, in 2010, the latest year for which fisheries statistics are available, 14 cases of illegal fishing were detected by the Ubon Ratchathani fisheries patrol unit (Pak Mun Dam Fisheries Patrol Unit, 2013). However, Thailand has a serious problem with corruption, and it is therefore possible to use influence or money to get around the laws. Most of these illegal fishing practices involved the use of large-scale fishing gear, large cylinder traps, barrage constructions, electro-fishing, and the placement of fishing nets across the river. These activities, as well as overfishing in some areas along the Mekong River, for example in Nong Khew village in Mukdahan, have led to a depletion of fisheries resources in the Mekong basin, which I found was corroborated during my field survey.

Capacity and environmental awareness building needs to be raised in local communities and within the Department of Fishery (DoF) in government. On one hand, the government has not used conservation awareness building programs to create a better understanding among local communities in some areas, and as a result, knowledge of the fisheries legislation in many areas is limited. The result of this is persistent misunderstandings regarding conservation and the laws associated with it. Without building awareness, local communities believe the laws say only 'no fishing' or 'stop fishing'. In reality, they can continue to fish, but with certain restrictions regarding the gear they can use and the times when fishing is allowed. On the other

[13] During the rainy season, an increase in water volume and flow can increase sediment load from the river bank to river channel. Such turbid water will appear murky or red-coloured in appearance. Hence, the Department of Fishery uses the term 'red water' as a description of the closed season for freshwater fishing. Baran (2006) indicated that the first rainfalls at the end of the dry season trigger breeding and reproductive migration of 11 fish species in the Mekong River.

hand, the capacity and awareness building program should be applied to the DoF. The example of officers lacking scientific understanding and biodiversity awareness was discussed previously in reference to releasing some non-native fish species in the Mun River and the Mekong River. Additionally, by law there is no fishing allowed in the rainy season; however *chaopramong* could not fish anyway because there is too much water during the rainy season or spawning season (Baird *et al*., 2001; Baird & Flaherty, 2005; Baran, 2006). This illustration may explain the situation that has led to a further erosion of local support for government initiatives and why illegal fishing activities continue to be carried out by the very people they hurt the most.

One possible avenue for application of fisheries management by local communities is the establishment of fisheries conservation areas nearby temples, *bung, vern*, and the Mekong River's tributaries near their villages. The finding of the PPGIS workshop also has provided valuable insights into local communities' fisheries management, suggesting that it is a possible mechanism that can be set up. Also, the participants are aware of the negative impact of environmental changes on fisheries in the Mekong River, which encourage them to move forward to initiate the community-based fisheries conservation programs. The purpose of fisheries conservation areas indicates an interaction with their LEK of the river, local wisdom, and limited water resources, which tends towards sustainable development. A reason why they decided to site conservation areas near temples is due to Laos and Thai culture, which pays great respect to Buddhist practices and local wisdom. Some participants chose conservation areas on *bung, vern*, and tributaries near their villages, because it is easy to conduct monitoring programs there. Whilst some *verns* are located on the thalweg, both Laos and Thai participants decided not to choose such locations unless there was a bilateral program of communication or agreement among Laos and Thai communities due to the border issue.

The community-based fisheries conservation programs will not only aim to promote sustainable practices, but also are devoted to building public environmental awareness and to the instilling of conservation attitudes in the communities. Based on the bottom-up principle, the democratization approach allows local people to be part of the decision making-processes which may contribute to a sustainable environment and management of fisheries conservation. In addition, one fisheries provincial officer admitted that community-based fisheries conservation programs would help to sustain environmental conservation better than the mechanisms of fisheries laws and legislations. This is due to the fact that the programs are built on the understanding of local conservation issues and practices. Additionally, the fisheries provincial offices in Ubon Ratchathani have been ahead of central administration in implementing their new policies, and they have started working with local communities by establishing fish conservation areas near temples. Committees of temple managers organize and monitor fish conservation areas with the support of the fisheries provincial offices. This has been done without support from the central administration and in spite of the old fisheries laws and legislations. For instance, in Ubon Ratchathani the fisheries office established over 100 conservation areas, called "*wang pla*", across the province in the environs of temples. One such program was put into practice at the Klang temple, which is situated on the Mun River. The programs not only aim to promote sustainable practices, but also are devoted to building public environmental awareness and to instilling conservation attitudes in local communities. Therefore, even people who might be wary of central government control are still willing to follow what they see as the community's rules. This is important since the study can provide a means for identifying opportunities for the development and improvement of freshwater fisheries management in the Mekong River.

Unfortunately, the establishment of fisheries conservation areas near temples may actually cause degradation of the river's ecosystem when temple sanctuary areas are developed for tourism. A Buddhist practice is to help others, to do good things and to create positive karma for oneself, so this idea is manipulated into practices such as releasing fish, feeding fish, releasing birds, and releasing turtles. Local vendors selling fish and birds in cages for release are often observed around riverside temples in Southeast Asia, especially in Thailand. The birds have broken wings so they cannot fly away and the vendors can catch and resell them. During my research field survey I visited Paksaeng temple in Khemarat, Ubon Ratchathani, which is on the Mekong River. Vendors sold inland fish species, eels, small fish and small tortoise to release in the temple sanctuary area on the Mekong River. This activity may cause similar problems to the government's release of non-native fish into rivers (e.g. at the community of Sam Phanbuk in Ubon Ratchathani). These non-native fish species may harm indigenous populations and pose a threat to the river's ecosystem. Therefore, guidelines for implementation should be developed to ensure effective fisheries conservation that will lead to sustainable water resources practices. To make this a reality there will need to be strong support to help build environmental awareness, from outsiders, including NGOs.

Another possible avenue for promoting fisheries conservation is through outside agencies. The process would need to draw energy both from external and internal sources (FAO, 2005). Outside agencies may serve a catalytic role, promoting an enabling environmental conservation by facilitating policy, legal and institutional reforms, but empowerment ultimately depends on local communities generating their own energy and power, through self-help projects and other stakeholder initiatives, in order to reinforce a sense of harmony and common purpose. Examples of successful conservation projects with support from NGOs include fisheries management in Khong, Laos (see Baird, 2006 and Section 2.5.3.1), and rehabilitation of biodiversity along the Mekong River through community participation in Phosai and Natan,. In Ubon Ratchathani, Thailand, there is the case in Nahinngeon village used in the

PPGIS workshop (see section 2.5.3.2) and Tai Baan Research at Chiang Khong, which conducted research with Laos and Thai local villagers and established fisheries conservation management (see http://www.livingriversiam.org/index-eng.html).

Promoting programs that will increase environmental awareness among local communities and local institutions regarding sustainable fisheries management activities can also be proposed. To obtain support from the government regarding participatory fisheries management activities in Na Waeng, the entire local government hierarchy will need to be convinced of its potential, and the positive outcomes that can be achieved. Promoting a participatory fisheries management framework at government and management levels will require a personal approach to be taken with officials, to raise awareness of the importance of water resources, especially at the sub-district or Tambon Administrative Organization (TAO) levels, as these represent the local institutions.

According to the Royal Thai Gazette (1994), which was later reinforced by the Thai Constitution of 1997, local people are encouraged to participate in natural resource management activities through local institutions (UNCSD, 1997). This reflects the wording of the RIO declaration on the environment and development in 1992 regarding public participation in environmental protection, as it encourages states and governments to ensure that all interested groups are part of the process when making environmentally critical decisions (UNCED, 1992). The local government, in the guise of the TAO and its committees, is comprised of local representatives nominated by an election process, plus officers appointed by the government. It is recognized as the key local institution by most people, and has both authority and budgets allocated from central government for the purpose of developing local infrastructure over a four-year elected term. However, from the perspective of natural resources management, there is an authority at the TAO level without clear scope or roadmap, as the legislation of Tambon Council and Tambon

Administrative Authority Act, B.E. 2537 (1994) only detailed the TAO mandate in 1994 in Part 2: section 23 no. 4 as "*to manage protect, look after and maintain natural resources and the environment*" (www.Thailaws.com, 2016).

One positive sign is that the TAO institution is generally considered a formal and legitimate local organization under administrative law, and so can potentially act as a key player in the development of a community fisheries management framework. Hence, some social researchers on fisheries issues have suggested that the TAO could be a local institution which represents local fishing communities and might, therefore, be responsible for the management functions and authority delegated from the government (Yamao and Suanratttanachai, 2002, in Anuchiracheeva *et al.*, 2003). This is reasonable, as fishing is one of the main income sources in Na Waeng and other fishing communities along the Mekong River.

More recently, inland water resource management authorities have examined the Lower Songkham River Basin (LSRB) in the Northeast of Thailand [*Isan*]. The study showed that it was possible to ensure that the local community property rights regime complied with the state by involving the DoF, according to the Fisheries Law of 1947 and TAO as a local institution (Ruddle and Satria, 2010). Kuaycharoen (2002) indicated that the change of the barrage fishery of the Nong Nam Yai community from private to community property had led to a structural change in rights and duties in the relationship between people and resources, which combines such formal institutions as a Village Committee and the TAO with a belief in ancestral spirits used in fish conservation zones. The systems maintained both the individual's and community's rights. It was reported that certain parts of ponds were reserved for villagers or groups of villagers, while the locations and rights of individuals to install large sets of fishing gear is recognized via an auction system (Khumsri *et al.*, 2009). This example of inland water resource management in the LSRB further demonstrated that there is a possibility to promote participatory fisheries management around Na Waeng, which will be encouraged through the networking activities of local organizations.

This scenario of public participation in village development activities is supported by personal observations made by participants at village development forums, to whom it seemed the program was arranged to improve poverty reduction as an overt and public action, but with covert political participation. Hence, local villagers of the right calibre are motivated to become more involved in village issues (Figure 7.6). There are provisions within the traditional governance system for affected individuals to state their views and argue their case in public, plus closed meetings are also held. The majority of participants in this study were voluntary, but were allowed to raise issues with government representatives at the forums with respect to improving infrastructure in the village as a reward for participating. As expected, the issue of natural resources management was not raised during the forums, nor was it on the agendas at all. Interestingly, these forums seemed to be manipulated; they were used as an opportunity to gain political support for an upcoming TAO election. This may have highlighted the low priority given to natural resources management policies, both within the local government and at the community level. In other words, the development of community based natural resources management is unlikely to happen in the near future, due to the lack of support shown by the local government in Na Waeng.

Correspondingly, in Anti-politics Machine (Ferguson, 1994) stated that the exercise of a state's power was made possible through development projects to alleviate community problems, which were reduced into merely technical problems that effectively hide from view any political factors that entangle in them. It happened in the case of *Isan* where the recurring water shortages and drought in the dry season have persuaded the government to run many water development projects to augment water supply, which, in turn, reshapes the waterscape of the region (see Molle *et al.*, 2009). Examples include the "Greening Isan Project" [*Isan Khiew*] or Green Isan and the "Khong-Chi-Mun Project", which were supported by the General Chatichai Choonhavan government (1988-91). The "Water Grid Project" to divert water and transfer water from Lao tributaries of the Mekong to *Isan* occurred at the time of Thaksin Shinawatra's government (2001-2006).

Figure 7.6: Public participation in village development activities at Nongmeungchom village, Na Waeng, Khamarat in Ubon Ratchathani (Author, March 2013)

The *Isan Khiew* Project (led by General Chatichai Choonhavan), was advised by the King to alleviate the severe water shortage in *Isan* by providing water sources. Water was transported to villages in need by military trucks, which were proudly flagged with banners reading '*namphrathai chak nai luang'* or the water from the kindness of the King's heart. Activities including the installation of hand-pumping stations or electricity-run pumping for groundwater, waterways construction, and creating artificial rain [*fon loung*] were carried out. The project not only aimed to solve the immediate problem of water scarcity, but also was designed to ensure state control and tackle the problems of national security (Missingham, 2003). At the end of the day, the Isan Khiew Project fell far short of the goal and was costly, but it supplied political power for General Chatichai Choonhavan, who was popular in Isan grassroots and later became Prime minister with his “New Aspiration Party” [Phak Khom Vang Mai] in 1990. Likewise, “the Water Grid of Thaksin” had the goal to triple Thailand's irrigated area in five years with a nationwide tap water system installed by 2005 (Bangkok Post, 3 May 2004). These examples showcased the spreading of political propaganda as a means of gaining political power, but there were few implications at the local level. Similarly, the village development forums that were arranged by the TAO of Na Waeng also can be seen as attempts by those in power to maintain that power versus acting as a catalyst for any real change.

In theory, under the rule of law, Thailand claims to grant rights to people; however, their rights can be overridden by power in some cases. The perception of public participation can vary: it can be presented as a mere political manipulation as in the case of public participation village development forums at Na Waeng, while in the Western legal systems it is considered as a procedural safeguard. In Thailand, public hearings become a controversial issue where different conflicting interests are confronted. It is often the case that those in high positions desire to retain power for themselves, and if local communities must acquire greater power to manage and protect their environment, then it can only happen through a struggle for their autonomy as in the case of Xayaburi Dam construction project (see section 7.3.3.2). The issues of public participation and involvement in governance mechanisms are a pragmatic, imperative approach towards demonstrating the presence of representative democracy in Thailand. In fact, public participation has been on the government agenda for over 50 years, but has been implemented in earnest for less than a decade, to improve rural development and promote local voices. However, with no firm rebuttal from the government regarding delayed laws on this topic, my presumption is that the country as a whole, with its unstable political climate, conflicts of interest and diverse motivations within institutional systems, significant power wielded by certain groups, a poor education system and lack of awareness of public participation, is simply not ready for public participation to be implemented within its governance mechanisms.

7.3.3 Commons and power struggle:

Engagement in management of shared water resources or commons that underpin fisheries and livelihoods of people on the Mekong River requires various interactions and involves a diversity of dynamics as one moves from the local to regional and national scales. Hirsch (2006, 105) suggested that the Mekong River involved "*bioregional transboundary commons in the sense that the Mekong River Basin is a transnational area defined by a natural boundary within which the commonality of the shared resource is based on the interconnected nature of the river system*." Therefore scales are not fixed as they are "*perpetually redefined, contested and restructured in terms of their extent, content, relative importance, and interrelations"* (Swyngedouw 1997, 141), while scales also separate hierarchies of responsibility and accountability (Hirsch, 2001; Sneddon, 2002; Lebel *et al*., 2005; Molle, 2007). Through this section, the commons or commons-pool resources are the social and political space where people develop a sense of belonging and have an element of control and power over their lives (The Ecologist, 1993). I will analyse water as commons that share and create conflicts over the Mekong River, relative to which they can form political spaces and scales relating to locality and region.

7.3.3.1 Locality: not-free-for-all

Local communities along the Mekong River in Na Waeng create collective rights over fishing grounds [*loung*] as *de facto* rights over them, and through which their ownership of fishing ground is restricted to those families, relatives, and partners. Fishing grounds are a common shared in the context of the local scale, which involves of power relations among stakeholders in the politics of scale, position and place as used in Lebel *et al*., 2005. The locality context here is explained as a relationship of shared commons among fishing communities in Thailand and bilateral agreements between Laos and Thailand. In this research, two classifications of collective rights over fishing grounds found (i) rights as an authorized user and (ii) rights as an owner.

(1) Rights as an authorized user

The authorised user has rights to place small gear which include fish traps, long line hooks, and stationary gillnets on the Mekong River. The rule of such rights is “first come first served” or the first occupants of these fishing grounds at the beginning of each fishing season are accepted as the sole rights holders per fishing season only and others are not allowed to access. These rights are defined by fishing community members based on local custom. This situation is widespread in many parts of the Mekong region.

(2) Rights as an owner.

The rights as an owner of a fishing ground were respected as private ownership rights that passed through their families. These rights are defined by fishing community members based on local custom, which is similar to the previous rights. However, the system works in a commercial way; so there is a right to own, sell or lease valuable fishing grounds. This research found that only *baan* Na Waeng, Bungkeylek and Ladcharoen villages hold this system. This may be explained by the fact that the *baan* Na Waeng and Bungkeylek communities were early settlers in Na Waeng, while Ladcharoen is situated in an area of high fish abundance, so there are financial gains to be made by using a system that allows ownership. In some areas, where fishing grounds had high harvesting rates or a high rate of fish density, leasing costs reached approximately 5,000 THB per month (~150-200 USD) and some were co-owned with Laos *chaopramong* as reported in Ladcharoen.

In a similar vein, this situation is widespread in many parts of the Mekong region. Such rights are a particularly common practice in the southern parts of the region, for instance in the area of Khone in Muang Khong, and Champasak province in the South of Laos. Roberts and Baird (1995) stated that the renting costs to install two 14 cm gillnets [*looang moon*] near the mouth of Hoo Sahong for two months was 10,000 kip or around 14 USD at that time. Furthermore, this common practice is also found in Sam Phan Bouk, Pho Sai district, Ubon Ratchathani province, around Chiang Khong area in Chiang Rai province, at Thakho Tai village on Mun River (pers. comm., 2012), and Songkham River, whichare all tributaries of the Mekong (Khumsri *et al*., 2009).

Chaopramong revealed that conflicts over fishing ground user rights of both kinds of rights, happened among *chaopramong* within villages, between villages, and also bilaterally between Laos and Thai *chaopramong*. If any *chaopramong* breaks the rules, and in some cases fish were stolen from the true owner's gear, an informal verbal warning will be given by the owner of the fishing ground and a fine if it happens again. These rules applied to both Laos and Thai *chaopramong*. Mostly, the discourse on such matters stopped at the informal verbal warning level. This shows that there is a strong ability for local communities to decide what is 'right' and police their own communities with regards to infractions of set standards.

Another interesting conflict was raised during the focus group discussion of *phuyaibaan* in the afternoon session of the PPGIS workshop. Their group discussed the possibility of developing a community fisheries management process. The *Phuyaibaan* from *baan* Na Waeng and Bungkeylek, who were old-timer *chaopramong*, talked about conflicts over fisheries and shared a case of power relations between local influential persons and local villagers and *chaopramong*. They explained that there was a case of a fishing ground being grabbed by a local influential person who was wealthy and had support from local politicians, and even local villagers and *chaopramong* who occupied fishing grounds first each year.

The conversation during the focus group discussion of *phuyaibaan* in the PPGIS workshop went as follows:

***Phuyaibaan* Bungkeylek (A):** “In my village the best location for fisheries conservation area is nearby *kan* Keylek, very high fish abundance. However, every year there is a group of people will set up a “*ouen*” [a lift net] (Figure 7.7) on this proposed conservation area. Sometime they placed their *ouen* where they think is best for fishing even some places are occupied beforehand”.

A lecturer from Ubon Ratchathani (B): “Are there any rules to own fishing grounds, likes first comes, first served?”

A: “I think it is a personal power or influential person who can do it. The poor cannot reserve the good fishing ground. There were many cases that the influential person took away those fishing ground from the poor and we had to accept it. I think those rich and powerful person in my community might object to the open fisheries conservation area.”

As we see here, the *phuyaibaan* employed a narrative based on a selective situation of a village’s problem in order to construct a space of political mobilization and participation as was explained by Walker (2009). However, the *phuyaibaan* was not trying to challenge the state or researchers; rather he was trying to underline the conflict in the state’s development schemes as well as their benefits in doing so. Additionally, most *chaopramong* believe that lift nets have had a highly negative impact on fisheries resources as they harvest all size of fish including juveniles during spawning season or during the red water between May to September. A particular criticism is that the system and power that enables a few wealthy groups to exploit fisheries resources destructively is disrespectful of the rights *chaopramong* hold over fishing grounds, which creates inequality of access and creates conflict among *chaopramong*. Furthermore, this gear obstructed other fishing gear and therefore excluded other *chaopramong* from having access to what are meant to be shared fisheries resources.

A similar situation also occurred in the Lower Songkham River Basin (LSRB) in *Isan* where a barrage fishing gear auction system was aimed to share the benefits of fishing commons; however, it became the main cause of fisheries degradation as the system was secured by wealthy groups through the auction system, which made it very difficult for the *chaopramong* to win (Khumsri *et al*., 2009). It is worth noting that the barrage fishery in the LSRB can create income for the owner of between 1,516 and 31,513 USD per year,while the cost of the auction varied from 88 to 8,823 USD (*ibid*). Another complicated issue in the LSRB was that fisheries resources were managed under a complex and multiple set of overlapping, complementary and conflicting individual, common and state property rights, which required the involvement of the TAO and Department of Fishery due to a lack of clearly defined property rights and rules, and a mismatch between local and state institutional arrangements for fisheries management (*ibid*).

Figure 7.7: "Ouen" or a lift net for catching fish on the Mekong River around baan Na Waeng and Bungkeylek in the beginning of May or beginning of rainy season. (Author, 5 May 2012)

7.3.3.2 Mekong (un)commons:

On the Mekong River, water and fish are subject to "commons grabbing" by powerful political decision-makers and investors, the main drawback of which is that it is at the expense of local people's livelihoods as they depend for their lives and cultures on these natural ecosystems. The Mekong was defined in terms of the transboundary management of rivers whose waters and catchments are shared by several countries (Hirsch, 2006), while transnational commons in the Mekong are water and fish (Hirsch, 1998). Whilst the idea of commons "*implies shared interests based on a degree of common vision*", it often created conflicts of interest among users (Ahmed and Hirsch, 2000, 5). The foremost facet of the Mekong River is seen as the energy of life that produces food, water and income for people who live along the river. As Mr. K, who is a *chaopramong* at Ladcharoen village, told me "*The Mekong means everything for me and my life*." On the other hand, the Mekong River as a whole is defined as "the new battery of Southeast Asia", based on the number of hydropower projects that have been constructed and are planned, which will produce an enormous amount of electricity power for the Mekong region. Hence, the Mekong commons will face pressures at all levels, from local to large-scale modifications, due to the number of hydropower projects that have occurred and are planned. As explained in Section 6.4.2, there a many potential impacts of basin development on the riverbed phenomena of deep pools and their relationship with fish habitats, while in terms of the politics of *chaopramong's* LEK, decision makers do not give it enough credit. In other words, decision makers are reluctant to hand over power to local people. Furthermore, the term 'politics of funding' was used to describe the situation of hydropower development as a knowledge driver by environmental impact assessment (EIA) consultancies who conducted studies to serve the requirement of clients who commission them. Hirsch (2000, 24) asserted that "*dealing with these influences requires attention to the level at which they are manifest*".

Political ecology has been engaged as a beneficial approach in critically analysing Mekong River Basin Development (Bakker, 1999; Sneddon and Fox, 2006), as it shed light on the relationships between politics, power, people's livelihoods, and environmental change in the Basin. The Mekong River is similar to many areas of the world, for example the Ganges River and Nile River, where water is a power source and a resource that is controlled by powerful actors (Sneddon and Fox, 2006). As in the case of the construction of Xayaburi Dam on the mainstream of the Mekong River, water as a form of commons has been grabbed and controlled by powerful actors from Thailand and Laos, which was likewise the case with the Don Sahong Dam construction project. The construction engineers design dams to block the river from one bank to the other, so Laos cannot push forward the building of the Xayaburi Dam without approval ignorance from Thailand. The proposed Xayaburi Dam project has behind it powerful private actors, investors and state-backed actors from both Thailand and Laos, including as the main driver the Electricity Generating Authority of Thailand (EGAT),which as a firm customer will benefit from an agreement to purchase 95% of the electricity produced. As stated earlier in Section 6.4.2, the EIA for the Xayaburi Dam has unresolved critical flaws, and the project was opposed by both Cambodia and Vietnam for being contrary to the 1995 Mekong agreement and for ignoring the 'Procedures for notification, prior consultation and agreement' (PNCA) process and guideline produced by the MRC. Nevertheless, Perkins Coei (2011 as cited in Middleton, 2014) as the legal firm commissioned to assess the case concluded that "*Lao PDR's unilateral action to premature terminate the PNPCA process, without allowing its neighbour countries to properly conclude the process, violates the Mekong Agreement, and therefore international law*".

The MRC as an inter-government organization has struggled to consensually negotiate the basin development projects' approval (Stone, 2011). Mr Hans Guttman, CEO of the MRC Secretariat, saw his role as an "investment facilitator" while sustaining the Mekong environment (Hirsch, 2006). In other words, he acted as a regional facilitating and advisory body for the member countries, but was under controlled by the power and governance of the MRC members. He responded to the Save the Mekong Coalition members call to halt construction of Xayaburi Dam by saying that "..*MRC is not a regulatory body and does not have a mandate to call a halt to construction work*" (MRC, 2012b, 2). By looking at the governance structure of the MRC, the MRC Secretariat was under the four governance member countries (MRC, 1995), hence it shows that the CEO's position is as a governance facilitator with no absolute power over the governance at all due to dominance of regional politics.

The Xayaburi Dam has continued to move forward even though it is a highly controversial project for multi-level stakeholders and in the face of academic critiques, and while neglecting the long-term impact to the Mekong ecosystem and the Mekong's citizens. This is despite the fact that the dam will create negative consequences on fisheries as wild fisheries, which account for 47-80% of total animal protein intake in the region (Hortle, 2007). Moreover, the dam barrier will not only block the path of migratory of fish (40-70% of fish in the basin) (Barlow *et al*., 2008; Baran and Myschowoda, 2008), but also alter flow regimes, which can create bed-load in the riverbed and affect the riverbed phenomena of deep pools and their relationship with fish habitats that play a vital role during the dry season.

Considering the challenging of the impact of hydropower development, Hirsch (2006, 112) indicated that "*the national "common good" [emphasis in original] evoked through the "national interest" [emphasis in original] take precedence over and usurps the local commons*", which is certainly the case on the Mekong River. Fish and water are local commons that have been used and accessed by the people along the river, and to which they assert their use rights. There is a clear path to the loss of local people's common rights; the poor will be poorer. Bush (2008) described dependence on fisheries as the cause of the poverty of people in the Mekong region. There is much advice offered to people facing development challenges, including mitigation measures and tools to alleviate the loss of food production, for example the growth of aquaculture production. However, it is not as simple as it looks to replace the food loss and may involve unaffordable costs (Pretty, 2000). Moreover, there needs to be a deepening of the process of public hearings, especially for those most vulnerable to the risk of hydropower impacts (Middleton, 2014), and to negotiate interests among stakeholders from the governance, civil society, and local community angles, with an aim to enhance equitability and sustainability in managing these Mekong commons (Hirsch, 2006). The problem goes deeper than fisheries production and, rather, concerns social justice, water rights, and politics and power in the Mekong River Basin (Arthur *et al*., 2011). Not least, such alternative strands of advice and food replacement production programs will be unnecessary if in the beginning the developers or power holders had given further rights to the poor, listened to their concerns, and considered the enormous negative impacts of basin development on the river ecosystem and livelihoods, rather than play politics with the Mekong commons and be concerned only with their own financial security.

7.4 Conclusion

This chapter has explored the use of the LEK of *chaopramong* as a 'negotiating knowledge frame' in support of fisheries management on the Mekong River by using a Public Participatory Geographic Information System (PPGIS) approach, including participatory sketch mapping and public participatory GIS workshops. Through the use of the participatory mapping, the LEK of *chaopramong* regarding fishing grounds, fish size, species, and density of fish population, and river ecology, can be incorporated into a GIS platform on the base of satellite images while avoiding the technocratic barriers inherent to GIS. The main result of my study highlights that PPGIS can further empower the voices of *chaopramong*, who have traditionally been ignored, into the decision-making process, whereas the political dimension to the *chaopramong's* LEK is not given enough credit as it means handing local people more power, although it has nevertheless been shown to be useful for scientific research and for enhancing long-term legitimacy of management. Additionally, the PPGIS and participatory mapping process revealed the issue of environmental commons shared by their communities, and also highlighted the power struggles surrounding such commons operating at multiple political scales.

In summary, the outcome is useful for providing a visual understanding that offers directions for fisheries conservation areas as a starting point, and enables fisheries management decisions beyond Na Waeng and the villagers directly involved. However, the positive outcome of this research will need further development in terms of time, involvement and commitment of stakeholders, and budgets in order to reach a situation where communities enjoy real empowerment and an increased social influence. Thus, the study suggests the drive to increase democratization of fisheries management still needs strong support from local governments and/or non-governmental organizations with the will to empower and to secure the continuity of communities' management programs.

CHAPTER 8

Conclusion and Recommendations

8.1 Conclusion

This research project has presented an interdisciplinary analysis of the Mekong River's resources. A combination of methods have been drawn equally from human and physical geography, employing a holistic approach to link the scientific understanding of the dynamics of deep pools and their relation with fish ecology during the dry season. The local ecological knowledge (LEK) of *chaopramong* [fishermen] was incorporated within such an approach in order to recommend an appropriate fisheries management approach for the study area, Na Waeng, by using a Public Participatory Geographic Information System (PPGIS). The main aims were divided into five objectives as follows: (1) To investigate the key characteristics of deep pools found in the riverbed rock channels of the Mekong River in the study area, and to understand their role with regard to fish habitats and the consequences of their potential disappearance; (2) To study the LEK of *chaopramong*, and how this knowledge is related to their understanding and use of deep pools; (3) To study the role deep pools could play in fisheries management activities; (4) To develop a number of fisheries management strategies using a PPGIS approach and GIS spatial analysis, and (5) To assess current outcomes of the fisheries management activities and their development using PPGIS.

The potential effects of development activities within the Mekong Basin have been explored previously, and there is now a greater awareness of the environmental issues in the area. This can be seen by the number of activists and NGOs that have opposed the construction of controversial dams on the Mekong River. However, little is known about the potential impacts of basin developments on the riverbed phenomena of deep pools and the relationship such pools have with fish habitats. In this study, strong evidence is provided to support the significant role deep pools play in the lives of both fish and fishers along the course of the Mekong River. I can, therefore, conclude that deep pools represent valuable refuges, habitats, and spawning grounds for certain Mekong fish species during the dry season. As a result, the main outcomes of this study are the policy implications that the findings have in terms of improving fisheries resources management and conserving deep pools along the river's course.

Deep pools found along the Mekong River form a part of the deep streambed that exists in the main river channel, and such pools are widespread along the entire length of the river and its tributaries. The development of knowledge regarding these deep pools' characteristics may contribute to a better understanding of the geomorphology of the Mekong as a whole, as well as the function of deep pools as refuges for many fish species and spawning grounds for few a fish species during the dry season. This element of the work falls under my first objective. During my research, I investigated the characteristics of seven deep pools identified by the MRC in the study area around Na Waeng, in Ubon Ratchathani Province, Thailand, and I also examined the controls placed upon them. The significance of this site is that it contained the deepest known pool on the Mekong River at 90.5 m deep. Interestingly, while conducting the river survey, in March 2012, one additional deep pool (pool 8) was discovered. During the survey in the dry season this pool had a measured maximum depth of 171 m, making it far deeper than any other previously identified on the Mekong River.

I explored the topography and geomorphological structures of deep pools by applying regression techniques and GIS analysis. The results suggest that the reason why the deep pools around Na Waeng are generally deeper than at other points along the river's course is due to two main reasons. First, the geomorphological control on deep pools is due to the structural grain of the Khorat Plateau, which was subject to several major tectonic events and created dominant faults in the region. Additionally, the local fracture patterns of preferential weathering and erosion, caused by the presence of structures, joints, fractions, and lineation also influenced to structure control for deep pools. Second, hydrological control on deep pools is associated with hydraulic conditions, meaning there is a greater potential for bed erosion (scour), leading to the occurrence and maintenance of deeper and bigger pools. Regression analysis highlights pool characteristics mainly related to their geometry and the channel constrictions present. Deeper pools have higher levels of riverbed roughness, greater exit-slope gradients, larger pool areas, narrower upstream bank-full river widths, and wider downstream constriction widths.

The phenomenon of deep pools and the role they play with regard to fish habitats was analysed by the classification and regression tree (CART) analysis. This fell under objectives 1 and 3. The main results of the CART analysis confirmed the deep pools' ecological function and the implication for fisheries by projecting the spatio-temporal predicted correlation between the presence/characteristics of deep pools and fish abundance/fish species richness levels during the dry season along the Mekong River. A large dataset of 16 variables covering 986 points was used to identify these relationships, using the two models described previously. These models showed a similar relationship for both geomorphological and physio-chemical variables in relation to fish abundance/species richness levels. First, the temporal model of fish abundance corresponded closely to water depth and river channel width in the dry season, and also the DO concentrations, pH levels and zooplankton densities. Whilst integration of the temporal model of fish abundance into the GIS system provided a confirmed visualization that a high probability of fish occurrence was related to water depth, which generally explains the significance of deep pools and their role. Several deep pools were particularly significant in this regard, these were: deep pool 7 [known locally as *khan ya ci*], deep pool 5 [*vern tham toum*], and deep pool 6 [*vern kloon*] in Ladcharoen village and deep pool 3 [*vern som hoong*] in baan Na Waeng. Second, the temporal model of species richness suggests a strong variable relationship between primary and secondary production in the river, as phytoplankton and zooplankton act as food sources for fish and other organisms. Again, the benefit of GIS analysis, as described in spatial model of species richness, offers a geographical explanation as to why the highest level of species richness shown is found around *baan* Na Waeng and Bungkhylek village. It is because the variability in local channel morphology provides different habitat conditions. An impoundment and island barrier morphology is only pronounced in these two adjacent villages and may attract species and create a larger variety of fish habitats than other villages. Hence, the results of the spatio-temporal model of fish abundance/fish species richness can not only identify the ecological significance of deep pools, but also can highlight other aspects of fisheries management and conservation.

The LEK of *chaopramong* can help provide validation for, and thereby strengthen, the scientific model, which is a key outcome for research objective 2. Scientific models of fish abundance and species richness alone cannot necessarily determine fish abundance in specific species diversify and behaviour. Therefore, it is essential to juxtapose the results predicted from scientific models with the LEK of *chaopramong* regarding species and behaviour. The additional explanation provided by LEK is important. For instance, the results of the 30-day catch monitoring survey during the dry season in March in five study villages, revealed the identification of fish species, information regarding the function of deep pool ecology during the dry season as a shelter for many species, including indigenous and migratory fish, and confirmed their role as associated spawning areas for some species. The main results of this study are highly complementary to the studies of Baran, Baird and Cans (2005) and Baird (2006), especially, in that deep pools were considered one of the core factors influencing fish ecology in the Mekong River, and of pivotal importance in the development of fisheries conservation areas. In a similar vein, the LEK of *chaopramong* also identified scarcity of some fish species, which can push forward the need for fisheries management, especially at *baan* Na Waeng and Ladcharoen villages where the identification of some endangered and immature fish species found during monitoring was pronounced. An example of such species was *Pangasianodon gigas* (Mekong giant catfish; *pla buek*).

The PPGIS approach provides a unique tactic for engaging the *chaopramong* in decision making through its goal of incorporating their LEK into a contextualized and complex GIS platform, and by stimulating the participation and empowerment of distant voices into the decision-making process. This part of the project addressed research objectives 4 and 5. The PPGIS approach and participatory mapping process contributed to the development of a transparent dialogue between the relevant stakeholders and administrative processes. It also served to introduce practical mechanisms for the use of LEK as a 'negotiating knowledge framework' in support of water resources management activities. Even though this study represents a first attempt at involving local fishing communities in the decision-making process in the five fishing communities in Na Waeng, a high degree of interest was generated in terms of community members wishing to help improve water resource management, and become involved in the fisheries management decision-making process.

According to the results and conclusions of this study, some potential areas for further investigation relating to local communities' participation in fisheries management and/or natural resources management and policy making activities should be considered. The significance and advantages of local community participation in fisheries management activities have been presented in this study. I have found that there is a greater possibility of conserving natural resources through sustainable management activities when local communities, which are often very wary of central government control, are brought into the decision-making process.

The setting up of community-based fisheries conservation areas near temples, on fishing grounds, and in deep pools reveals an interaction between practicality and the villagers' LEK of the river's ecology, thereby creating easy management of village monitoring programs. If this occurs, then the local communities involved will be much more willing to follow what they see as their community's rules. This approach may also create a democratized natural resources management regime, one in which rules are created of the people, by the people, and for the people.

This research also confirms a remarkable conclusion since much of the interplay between discourse, power and knowledge unfolds locally, such as in Na Waeng. This research has, in various ways, raised issues that warrant a response not only in the form of research regarding the significance of deep pools in term of geomorphology process, as a fish refuge habitat during the dry season, and the impact upon them from basin development on shallower deep pools. But also the research has revealed in the domain of political action. The politics of knowledge and empowerment of local voices are ignored by decision makers, which are of paramount concern in the creation of spaces and distance between stakeholders-local communities, NGOs and the governments for enhancing long-term legitimacy of water management.

The situation in Na Waeng is certain to affect the trajectory of the Mekong River in regional scale in term of complexities of commons management in the Mekong (un)commons situation. The case study of Na Waeng in a locale with informal commons management regime, this research revealed the complex relationships among lateral and bilateral commons management pattern in light of contemporary challenges related to multiple scales of governances and the Mekong regional economies.

The Mekong Basin, which is considered a transnational commons, is sharing among the Mekong citizens. However, the challenge of transnational commons runs as deep as a cold war. There are also concerns over social justice, water rights, and politics and power in the Mekong Basin. There can not be a happy ending until good water governance interplays with good management and collaboration among the governments in terms of improving transparency and efficiency of participation and dialogue, in which the consideration of action should start it now.

8.2 Contribution to the wider academic community

This research contributes towards the on-going debate regarding 'Critical GIS' and 'GIS and society', particularly in developing a better level of understanding of the methodological approaches for deploying GIS in participatory environmental management in communities. As such, it will help influence the ongoing debate taking place about the use of GIS and its role in society. This study represents one of the first occasions in which the ecological functions and geomorphic processes involved in deep pools on the Mekong River in Na Waeng have been explored in detail, adding to existing knowledge concerning the significance of deep pools as fish habitats. In addition, the PPGIS approach employed here was initially used to investigate freshwater fisheries management processes in the Mekong region.

I would argue that this study has made several key contributions to the wider academic work in this field. Firstly, this research makes use of interdisciplinary studies, those which cross traditional boundaries, combining the fields of physical and human geography through the use of GIScience in order to resolve relevant problems, and also integrating this approach with other fields of study such as fisheries, fish ecology and anthropology. Particularly, this research will contribute to the integration of PPGIS and political ecology. This integration proffers a methodological framework to reveal issues of local knowledge production, politics of knowledge, context, local and bilateral politics and last but not least power relations addressed in this research are major concerns in the application of PPGIS to geographic research. Therefore, this research employs the PPGIS approach which brings in the PPGIS tools and techniques that are engaged within the context of political ecology to study the way of life of local people and their knowledge production. PPGIS and political ecology situate local people at the centre of this research.

Secondly, this research utilizes a triangulation of methods, including PPGIS methodology, qualitative survey and with political ecology framework. This contributes to the ongoing debate about the integration of qualitative and quantitative information and methodologies. Hence, the methods cover of the interdisciplinary focus research, which can bridge the gap among multiple disciplines. An example of this in this research is that it can help to improve insight into the socio-ecology of the river ecosystem and its relation to *chopramong*'s livelihood. Furthermore, LEK of *chaopramong* in term of fish species is validated by the scientific model of fish abundance and richness in this research.

Thirdly, it has filled a knowledge gap within the existing literature, regarding the ecological functions of deep pools and the geomorphological processes that influence them. Deep pools are a complex phenomenon, and their study still needs to be integrated with a range of perspectives, to provide a more comprehensive understanding of their nature. Here, I have provided strong evidence to support the significant role deep pools play in the lives of both fish and fishers along the course of the Mekong River, meaning this study can help fill a gap in knowledge generated by empirical and theoretical studies to date. The findings confirm that deep pools act as valuable refuges, habitats, and spawning grounds for certain Mekong fish species, particularly during the dry season.

Lastly, the findings of this study have demonstrated the use of local ecological knowledge (LEK) to empower local people through use of the PPGIS approach. It will prove of value to local communities both inside and outside the study area, while also contributing to the ongoing debate regarding 'GIS and society'. For many decades GIS approaches have often excluded local knowledge and the needs and priorities of local/marginalized groups, mainly due to the technical barriers to their use created by the substantial hardware, software, data and GIS expertise needed for them to be applied properly (Elwood 2009b). As a result, the PPGIS approach has emerged in response to these shortcomings with GIS. The main result of my study highlights that PPGIS approach and use of its tools can further empower the voices of local communities into the decision-making process. For example, aggregating LEK of *chaopramong* into a scientific platform based on satellite images revealed the ownership LEK of *chaopramong* and accountability of LEK of *chaopramong* into fisheries conservation management during the PPGIS workshop. PPGIS can be described as representing a shift from a traditional top-down approach, to a bottom-up one in which democratization is introduced to allow for equitable access to natural resources and to empower local communities within the decision-making process.

Inspired by the ongoing debate on LEK, here I studied the LEK of *chaopramong* and their relationship with deep pools in terms of river ecology and fisheries management. Exploring these issues will not only contribute to the existing literature on GIS and PPGIS practices, but also help to provide a better understanding of how to represent and incorporate community inputs within development activities, with the goal of empowering marginalized communities. The 'public' in my research is defined as the *chaopramong*; hence, the GIS base maps used incorporated the LEK of *chaopramong*, alongside the PPGIS method of using mental maps to evoke and display ecological knowledge, such as the locations and boundaries of deep pools and fishing grounds.

It is likely that many researchers and scientists have overlooked the use of LEK, regarding it as neither reliable nor derived from formal processes. On the other hand, I found that the *chaopramong* have vital experiences gained over the course of their lives, and so were able to very accurately demonstrate their LEK as part of the sketch mapping exercises carried out. I found that through the use of the PPGIS approach; sketch mapping and participatory GIS workshops, the LEK of the fishers on fishing grounds, fish size, fish species and densities, as well as river ecology, could be incorporated without the technical barriers generally associated with the use of GIS systems. The results of the scientific survey work corroborated the features identified during the LEK sketch mapping process, providing confidence in the accuracy of the LEK data gathered. The most valuable aspect of local *chaopramong*'s knowledge is that it is able to support in-depth scientific research, and can reduce the time and cost of research operations; for instance, by identifying the best fishing grounds for certain fish species. In fact, LEK can be a vital source of information if researchers can aggregate it into a scientific platform. Using participatory GIS with LEK can therefore help to fill any gaps and contribute to the on-going debate regarding 'GIS and society'.

In addition, the nature of PPGIS research and practices means it attempts to shape and reconstruct the use of GIS technologies and GIS research into wider contexts of application. PPGIS respects the views of local people by empowering their local knowledge and using it to influence decision-making processes. This is a response to the ongoing debate about GIS and society, and constitutes an effort to interweave the range of spatial technologies that exist. In this research through the use of the participatory mapping, the incorporation of *chaopramong*'s LEK into a GIS platform on the base of satellite images avoided the technocratic barriers inherent to GIS. The PPGIS situates GIS technologies more effectively within their social and public context. This achievement empowers the voice of *chaopramong* and their knowledge, and facilitates the local community management or co-management of resources.

8.3 Policy Implications

The goal of this research is to ensure that fisheries management activities are included in future policy making and systems circles from two perspectives, first, there are fisheries management implications, this recommendations' goal is to support the fisheries conservation aspect on the Mekong River. Second, inclusive questions of key environmental issues of hydropower development on the Mekong River in the EIA study

8.3.1 Fisheries management implications

The results of this research confirms that the integration of LEK of *chaopramong* by using PPGIS approach leads to greater competence and increased democratization within the water governance process along the Mekong River. The PPGIS approach used in this study was reasonably successful in helping to develop a transparent dialogue between the relevant stakeholders and administrative processes, and also at introducing practical mechanisms for the use of LEK as a 'negotiating knowledge frame', and in support of water resources management activities. Even though this study represents a first attempt at involving local fishing communities in the decision-making process, a high degree of interest was generated in terms of community members wishing to help improve water resource management activities, and become involved in the fisheries management decision-making process.

There was clear agreement among the stakeholders that the development of a community fisheries management regime is a vital pre-requisite for the involvement of communities in any fish stock preservation programme, one that will help future generations secure their food and income sources. The implementation of a community fisheries management framework will be assisted by threefold:

(1) The development of programs to increase environmental awareness among local people, those which can link people and water management activities together in a sustainable manner.

(2) The establishment of community-based fisheries conservation areas near temples, on fishing grounds, and in deep pools reveals an interaction between practicality and the villagers' LEK of the river's ecology, thereby creating easy management of village monitoring programs.

(3) The development of a bilateral fisheries management framework involving Laos and Thailand.

One possible government-led route for moving towards this approach would be to revise fisheries laws and legislation; to bring them into line with the present-day situation, as the current laws are now almost 70 years old. This will be particularly important with regard to the official recognition of community-based or co-management fisheries arrangements, and also for developing mechanisms to allow the affected fishing communities to participate in the decision-making processes. In addition, effective financial support should be given to the provincial fisheries offices, so that they can continue co-operating with local communities and expand the establishment of fish conservation areas, likes the case of Ubon Ratchathani Fisheries Department (see section 7.3.2). Last but not least, designing and implementing programs to monitor fish conservation management activities in local communities should be considered, to sustain and develop any new practices.

According to the results and conclusions of this study, some potential areas for further investigation related to local communities' participation in fisheries management and/or natural resources management and policy making activities should be considered. The significance and advantages of local community participation in fisheries management activities have been presented in this study. I have found that there is a greater possibility of sustaining natural resources through sustainable management activities when local communities - which are often very wary of central government control - are brought into the decision making process. If this occurs, the involved local communities will be much more willing to follow what they see as their community's rules. This approach may also create a democratized natural resources management regime, one in which rules are created of the people, by the people and for the people.

8.3.1.1 Recommendations to the government and non- government organizations

1. Revise Thai fisheries laws and legislation.
2. Communication on fisheries laws and legislation needs to be improved, to ensure full understanding exists among local communities and other parties concerned.
3. Design programmes that will raise awareness among fishermen, communities and local institutions about sustainable fisheries resources for the benefit of future generations.
4. The line demarcating of Laos and Thailand along the Mekong River is unclear in terms of political discussions and physical visualisation, so this particular border issue needs to be discussed in more detail, and then resolved at the international level.

8.3.1.2 A spatial model of species richness and fish abundance

My research shows that CART analysis and spatial analysis using GIS techniques can provide reasonable predictions of the spatial distribution of species richness, based on the research carried out at Na Waeng. More specifically, research can assist scientists, mangers and policy-makers within the appropriate spatial zone for fisheries management on the Mekong River.

8.3.2 Inclusive questions of key environmental issues of hydropower development on the Mekong River in the EIA study

While the potential effects of development activities within the Mekong Basin have been explored, and there is now an increased awareness of the environmental issues involved, little is known about the potential impacts of basin developments on the river bed phenomena of deep pools and their relationship with fish refuge habitats during the dry season. Specifically, the result from this research confirms the role of deep pools both in CART analysis and spatial analysis using GIS techniques and in support of LEK of *chaopramong* on fish species knowledge. Regarding recent hydropower development on the Mekong mainstream, the NGO International Rivers (2011) revealed critical flaws in the EIA for the Xayaburi Dam that there was a lack of analysis of key technical information on environmental issues, including on fisheries and aquatic resources, hydrology, sediment transport, and dam safety in the event of earthquakes. The lack of understanding of the potential impacts of hydropower developments on the river bed phenomena of deep pools shows a real gap, and lack of understanding in the EIA study.

8.4 Recommendations for future research

This thesis originated in my personal curiosity regarding the deepest pool previously identified along the Mekong, one with a depth of 90.5 m. Such pools are remarkable physical features influenced by hydrological and geomorphological processes, and have complex relations with fish ecology and *chaopramong*'s livelihoods. At the same time, the Mekong River is being altered by basin developments, and so is aligned closely with my desire to promote environmental sustainability across disciplines, in an effort to secure the long term health of the Mekong River and, thus, the many millions of people who depend on it for their livelihoods as well as their culture. These critical linkages provide focus from an environmental and geographical perspective. There are many other research areas that could be further explored in order to follow up the results of this research project. The dataset created for this study is unique and will be a vital asset to other, future research in this topic area.

8.4.1 Ecology of deep pools

Any future research must be directed towards developing a greater level of understanding of deep pool characteristics, and how the overall 'riverscape' influences the distribution of such pools. Once this level of understanding is improved, guidelines for sound habitat conservation and restoration activities should be developed. As a result, future habitat studies focused on other parts of the Mekong River, or on other tropical rivers, should be integrated on a large spatial and temporal scale. In addition, comparative studies of fish abundance and species richness models should be carried out, with the data sets used studied in more detail in order to create a long term dataset, one that will help with model predictions.

As comparatively little research has been conducted on the Mekong River, other research work should consider the interactions between deep pool hydraulics and morphology, and/or the morphological changes resulting from related channel disturbances. The issues of climate change and basin development are likely to have a large impact around the world, as well as in the Southeast Asian region, due to the fact that changes in the energy released by water flows will affect the geomorphology of deep pools, and the ecology of fish therein, as well as the lives of people who live alongside rivers. This is especially true when we look at the local scale and how social-ecological adaptations influence people living along rivers.

Due to the constraints placed on the river survey activities in this study, resulting from a lack of ADCP and water flow instrumentation at NUS and at Ubon Ratchathani University, any future work related to the study of fish ecology and/or deep pools' ecology should consider using water flow parameters in any model developed.

It should be noted that any future projects carried out along this stretch of the Mekong River will require the researcher and/or project personnel involved to have trusted connections in place among organizations in both Laos and Thailand, in order to deal with any security issues that arise during river survey activities; a fact of life when dealing with a river that forms the border between two countries.

8.4.2 PPGIS for bilateral or trilateral fisheries management

Should further studies of PPGIS for bilateral fisheries management be undertaken, the work should take into consideration the reality that Laos and Thai fisheries laws and regulations are separate, and gaining access to both sides of the river can be a challenge. This was certainly a limiting factor for this research. However, research conducted on both sides of the river, or in both countries would, in my opinion, lead to a better understanding of the conditions under which the transboundary conservation of water resources in the Mekong River is working and how this could be improved.

8.4.3 Commons property rights and conflict on the Mekong River

More research is also needed on the dynamics of the social institutions within which management of fisheries commons takes places and is shared not only among villages, but also between countries. For instance, in Ladcharoen and Hindok villages in Thailand and Laos, respectively, *chaopramong* from two countries successfully share fishing grounds and conduct trade. More work is also needed on the strategies through which *chaopramong* in different circumstances gain access to common fishing areas and reach agreements within and between their groups.

8.4.4 LEK of women chaopramong and gender relations in Isan

As described in Section 7.3.1.3, the LEK of *chaopramong* in this research is based on men only, which means that the considerable LEK of women *chaopramong* is overlooked. Cultural norms also played a key role in limiting participation of women in this research. Hence, longitudinal studies focused on social aspects would help to improve the understanding of gender relations as a dynamic process through which particular activities, roles and responsibilities are moderated. This could provide answers as to why women *chaopramong* were underrepresented, even though women influence and participate in many activities in fisheries. In particular, the LEK of women *chaopramong* needs further research.

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APPENDIX I: A structured (individual) interview

Prior Verbal Informed Consent Statement:

Thank you for agreeing to take part in this research. In doing so, you understand that any information you give is strictly confidential and your answers will be used only for the purposes of my (Wisa Wisesjindawat Fink) completing PhD thesis and possible future academic research papers. All data will be securely stored and not used for commercial purposes. Furthermore, you participate voluntarily and are under no obligation to answer every question, and if you wish, you may terminate the interview at any point.

1. **Personal background:**
   - 1.1. Name
   - 1.2. Home village, district, province, country
   - 1.3. How long have you been in this village?
   - 1.4. Ethnicity/languages
   - 1.5. Age/Gender
   - 1.6. Are you a fisherman? (Full-time fisherman, Part-time fisherman (having more than one job), Seasonal fisherman)
   - 1.7. How long have/had you been a fisherman?
   - 1.8. How many members are in your family? Are you a head of the family?
   - 1.9. If married, how many children?
   - 1.10. What is your income per household/month?
   - 1.11. Do you have any loan? If so, what___?
   - 1.12. Do you have any debt? If so, what___?
   - 1.13. What other sources of income do you obtain outside the fishing/what do you do with them?
   - 1.14. Activity purpose income (baths/week)

2. **Becoming a fisherman:**
   - 2.1. How have you become a fisherman? (Choice, assignment, accident? – who decided?)
   - 2.2. How long have/had you been a fisherman?
   - 2.3. What did your training consist of? (Practical, theory)
   - 2.4. Which kind of fishing gears can you use? Which one do you own it?
   - 2.5. How/what do you know about sense of river?
   - 2.6. How do you know where to catch fish?
   - 2.7. Does your family orcommunity have a special fishing place? Place name? (Refer to sketch map, all geographical landmarks, names kindly mark on the map.)
   - 2.8. Are you using this place together with other families or communities? Fishing territories?

     Who gave you the right to use the fishing-ground / grounds and who registered this?

2.9. For how long have you attained the right to use the ground? What form of use, possession and property do you have on this ground?
2.10. Do you need a special permission to fish (contract, license, quota, ticket)?

2.11. Do you have to pay for the right to fish, to which authority, and how much?

3. **Deep pools and fish:**
    3.1. What do you know about deep pools?
    3.2. Are there any relationships between fish and deep pools? If so, what?
    3.3. Are there any relationshipsbetween deep pools and belief, spirit? If so, what?
    3.4. How/what do you know about fish? (Refer to Appendix III : List of fish species).
    3.5. Do you know about endangered fish species? If so, what are they?

4. **Institutions:**
    4.1. Do you or your family know that there is a conservation group in the village? If so, what___? How long has it been established?
    4.2. Do you or your family take part in the conservation group? If you are, what do you do?
    4.3. Are you affected by any legislation or regulations regarding conservation? Government or local regulations? If so, what?
    4.4. What is your feeling about the regulations if any?
    4.5. If there is local regulation regarding fisheries conservation among communities, to what extent can it help your communities and livelihood?

5. **Recommendations:**
    5.1. In your opinion, what key changes would improve the community livelihood?
    5.2. Are there any problems in the community? If so, what?

APPENDIX II: Catch monitoring form

1. Date: ..../2012

2. Village: ....

3. Name of fisherman: ....

4. Place to catch: ....

5. Weather:

6. Sunny Cloudy Overcast Raining

7. Water level: Rise Stable Down

Other: ....

8. Wooden boat or Engine boat Size of engine: ....Horse power

9. How many hours that you spend for fishing? ....

10. Type of gear, size, number:

....

....

....

....

....

.... page 1

Time	Name of fish	Number of fish	Weight (kg)	Longest length (cm)	Sampling	
					Yes	No

Page 2

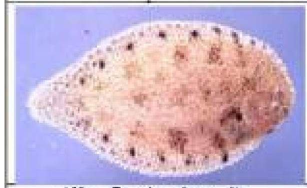
APPENDIX III: List of fish species in the mid-migration section of the Mekong River


001 Dasyatis laosensis


002 Anguilla marmorata


120 Monopterus albus

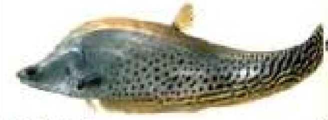

136 Cynoglossus microlepis


139 Euryglossa harmandi


140 Euryglossa orientalis, Brachirus orientalis


118 Mastacembelus armatus

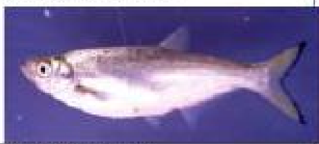

119 Macrognathus siamensis


004 Chitala blanci


003 Chitala ornata


006 Megalops cyprinoides


005 Notopterus notopterus


011 Paralaubuca typus


007 Tenualosa thibaudeaui


143 Clupeichthys aesarnensis


017 Luciosoma bleekeri


10 a,b Hampala dispar


009 Lycothrissa crocodilus

050 Hampala dispar

028 Amblyrhynchichthys truncatus

066 Osteochilus hasselti

051 Hampala macrolepidota

031 Cyclocheilichthys repasson

201 Cyclocheilichthys apogon, Systomus apogon

067 Osteochilus lini

042 Systomus orphoides (Puntius orphoides)

202 Rasbora aurotaenia

162 Labiobarbus kuhli. Dangila sp. cf. lineata

53 Thynnichthys thynnoides

203 Rasbora paviei

034 Puntioplites falcifer

204 Puntius partipentazona

039 Barbonymus gonionotus

040 Barbonymus altus

038 Barbonymus schwanenfeldii

205 Parambassis siamensis

030 Cyclocheilichthys furcatus

029 Cyclocheilichthys enoplos


045 Hypsibarbus lagleri


027 Cosmochilus harmandi


023 Probarbus jullieni


068 Osteochilus melanopleura


123 Anabas testudineus

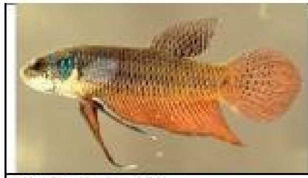

024 Probarbus labeamajor

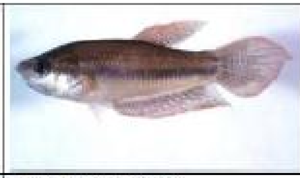

206 Henicorhynchus lobatus

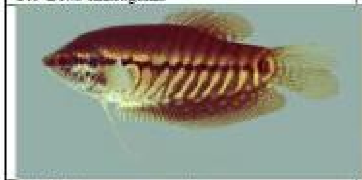

122 Pristolepis fasciatus

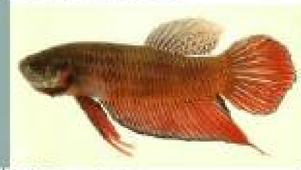

207 Trichopsis vittata

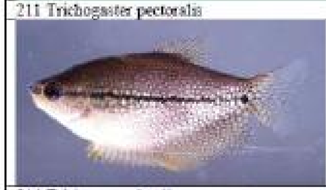

063 Henicorhynchus siamensis


209 Betta smaragdina


208 Trichopsis schalleri


211 Trichogaster pectoralis


210 Betta splendens


214 Trichogaster leeris

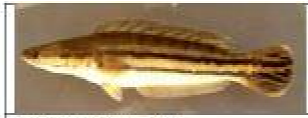

212 Trichogaster microlepis

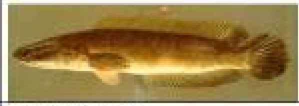

127 Osphronemus exodon, Osphronemus gouramy

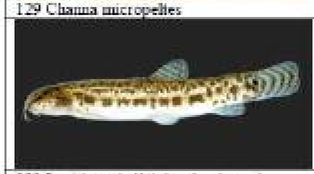

213 Trichogaster trichopterus


58 Labeo chrysophekadion


137 Oreochromis niloticus

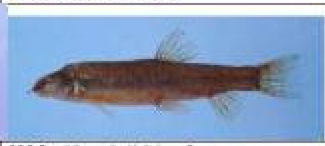

129 Channa micropeltes


128 Channa striata


222 Lepidocephalichthys berdmorei


117 Xenentodon cancila


224 Lepidocephalichthys hasselti


223 Lepidocephalichthys furcatus


225 Acanthopsoides gracilentus

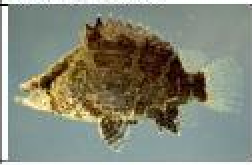

226 Acanthopsoides delphax


79 Botia helodes


77 Botia modesta


158 Clarias macrocephalus


116 Clarias batrachus




166 Cirrhinus cirrhosus


215 Cyprinus carpio

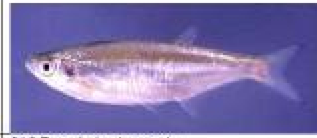

217 Labeo barbatulus


167 Hypophthalmichthys molitrix

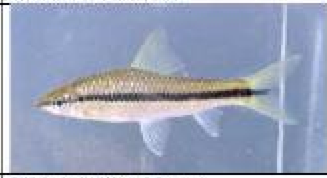

219 Parachela williaminae


216 Parachela oxygastroides


221 Crossocheilus reticulatus

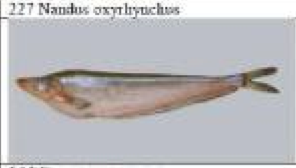
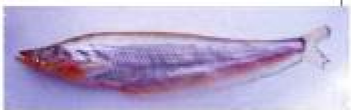
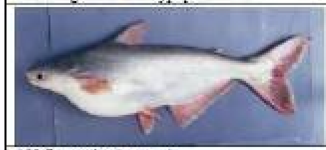

218 Parachela siamensis

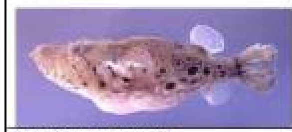

131 Oxyeleotris marmorata


220 Crossocheilus atrilimes


185 Channa lucius


184 Channa limbata, Channa gachua

98 Ompok krattensis	227 Nandus oxyrhynchus
	
97 Micronema bleekeri	96 Micronema apogon
	
104 Pangasianodon hypophthalmus	228 Micronema micronema
	
103 Pangasius bocourti	102 Pangasius conchophilus
	
105 Pangasius Krempfi	107 Pangasius larnaudii
	
106 Pangasius polyuranodon	179 Pangasius macronema
	
101 Helicophagus waandersii	108 Pangasius sanitwongsei

	
85 Hemibagrus wyckioides	84 Hemibagrus filamentus
	
229 Mystus atrifasciatus	89 Heterobagrus bocourti
	
88 Mystus singaringan	230 Mystus albolineatus
	
99 Wallago attu	173 Mystus mysticetus
	
232 Monotrete suvatti	231 Wallago leerii
	
234 Monotrete leiurus	233 Monotrete cochinchinensis

	
133 Datnioides undecimradiatus	52 Catlocarpio siamensis
	
56 Labeo rohita	193 Toxotes microlepis

APPENDIX IV: Feedback of the PPGIS workshop

1. Do you think PPGIS is useful for your communities? How?

____

____

____

2. Are there any possibilities that the result of this workshop can replicate into your communities? How?

____

____

____

____

3. Comments? Recommendation?

____

____

____

____