FISH SANCTUARIES IN THE TONLE SAP GREAT LAKE (CAMBODIA)

By

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Chheng Phen

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LIST OF ABBREVIATIONS

CPUEn	: Catch per unit effort in abundance
CPUEw	: Catch per unit effort in biomass
DO	: Dissolved oxygen
DoF	: Department of Fisheries
EC	: Electrical Conductivity
FAO	: Food and Agriculture Organization
FCZ	: Fisheries Conservation Zone
FS	: Fish Sanctuaries
IFReDI	: Inland Fisheries Research and Development Institute
JICA	: Japan International Cooperation agency
MAPs	: Marine Protected Areas
MRC	: Mekong River Commission
MRCs	: Mekong River Commission Secretariat
NPar	: Non Parametric
pH	: Potential Hydrogen
Sig	: Significant
TDS	: Total Dissolved Solids
USM	: Universiti Sains Malaysia
WUP	: Water Utilization Project
WWF	: World Wild Life Fund

SANKTUARI-SANKTUARI IKAN DI TASIK BESAR TONLE SAP (KEMBOJA)

ABSTRAK

Lapan sanktuari ikan iaitu Pi Stoun, Chroy Sdey, Kampong Preak, Reang Til, Dey Roneat, Park Konteal, Kampong Pluk dan Ba Lot terletak di beberapa tempat yang berbeza di Tasik Besar Tonle Sap. Ia diwartakan pada 1987 dengan purata keluasan 2,616 hektar, berfungsi sebagai tempat perlindungan ikan sewaktu musim kering. Sanktuari-sanktuari ini dilindungi sepenuhnya daripada aktiviti perikanan sepanjang tahun, berbanding kawasan akses terbuka dimana aktiviti perikanan adalah dibenarkan sepanjang tahun atau semasa musim memancing terbuka. Tujuan kajian ini adalah untuk menilai keefisienan lapan sanktuari ikan yang sedia ada dengan menjalankan tinjauan biologi dan sosiologi pada Jun 2005 (musim memancing tertutup) dan Disember-Januari 2006 (musim memancing terbuka). Jala pukat digunakan di setiap sanktuari dan lebih kurang 3-5 km jauh daripada sanktuari di kawasan akses terbuka. Di samping itu, sebanyak 166 pemegang saham sekitar Tasik Tonle Sap telah diwawancara. Hasil kajian ini menunjukkan semasa musim memancing tertutup,

Biojisim ikan dan banyaknya ikan di Pi Stoun, banyaknya ikan di Dey Roneat dan kekayaan spesis ikan di Park Konteal adalah tinggi secara signifikan berbanding sanktuari yang lain. Semasa musim memancing terbuka, Pi Stoun, Reang Til dan Dey Roneat mempunyai biojisim dan kekayaan spesis yang secara signifikannya lebih tinggi. Sanktuari Kampong Preak dan Kampong Pluk pula mempunyai biojisim yang tinggi secara signifikan. Tujuh puluh lima spesis ikan ditangkap semasa kajian ini dijalankan, dimana dua spesis ikan iaitu *Henicorhynchus siamensis* dan *Paralaubuca typus* menunjukkan bilangan yang tinggi di Tasik Tonle Sap sepanjang

tahun. Tinjauan dengan pemegang saham menunjukkan bahawa mereka percaya yang sanktuari-sanktuari ikan yang wujud sekarang adalah sangat penting sebagai kawasan perlindungan ikan, terutama sekali semasa musim kering. Mereka juga bersetuju lokasi sanktuari yang sedia ada berada di kawasan yang sesuai, kecuali Park koteal. Walaubagaimanapun, kebanyakannya bersetuju bahawa pengurusan sanktuari sekarang tidak berapa efektif dan penangkapan ikan secara haram sering berlaku dalam kawasan sanktuari semasa musim kering.

Kesimpulannya, sanktuari-sanktuari ikan di Tasik Tonle Sap adalah efektif dalam memelihara biodiversiti ikan dan member kebaikan kepada perikanan. Di peringkat individu, sanktuari-sanktuari Pi Stoun, Kampong Preak, Reang Til, Dey Roneat dan Kampong Pluk adalah sangat efektif. Sanktuari Chroy Sdey dan Park Konteal adalah kurang efisien dan sanktuari Ba Lot adalah tidak efisien. Lebih banyak kajian perlu dijalankan untuk menilai keefisienan sanktuari Chroy Sdey, Park Konteal dan Ba Lot

FISH SANCTUARIES IN TONLE SAP GREAT LAKE (CAMBODIA)

ABSTRACT

Eight fish sanctuaries namely Pi Stoun, Chroy Sdey, Kampong Preak, Reang Til, Dey Roneat, Park Konteal, Kampong Pluk and Ba Lot are situated in different parts of the Tonle Sap Great Lake. They were established in 1987 with average area of 2,616 ha, to be act as fish refuge during dry season. These sanctuaries are totally protected from fishing activities in the whole year round, as compared to the open access areas where fishing activities are allowed either in the whole year round or in the open fishing season. The purpose of this study was to assess the efficiency of eight existing fish sanctuaries by conducting biological and sociological surveys in June 2005 (close fishing season) and in December-January 2006 (open fishing season). Trammel nets were used within each sanctuary and about 3-5 km away from the sanctuary in the open access area. In parallel 166 stakeholders around the Tonle Sap Lake were interviewed. The study showed that during close fishing season, fish biomass, fish abundance in Pi Stoun, fish abundance in Dey Roneat and species richness in Park Konteal were significantly higher than their test sites. In the open fishing season, Pi Stoun, Reang Til and Dey Roneat had significantly higher biomass and species richness than their test sites. Kampong Preak and Kampong Pluk sanctuaries had significantly higher biomass than their test sites. Seventy five fish species were caught during the period of the study; with two fish species *Henicorhynchus siamensis* and *Paralaubuca typus* showing high abundance in Tonle Sap in the year round. Survey with stakeholders showed they strongly believed the existing fish sanctuaries are very important for fish refuge, especially in dry season. They also agreed that the current locations of those sanctuaries are at the right place,

with exception of Park Koteal sanctuary. However, most agreed that the current sanctuaries management is not effective, and poaching is frequent in some sanctuaries during dry season.

In conclusion, the Tonle Sap fish sanctuaries seem to be effectively protecting fish biodiversity and benefit the fishery. At the individual level Pi Stoun, Kampong Preak, Reang Til, Dey Roneat and Kampong Pluk sanctuaries are very effective. However, Chroy Sdey and Park Konteal sanctuaries are less efficient. In particular, the Ba Lot sanctuary was not efficient. More studies should be conducted to further determine the efficiency of Chroy Sdey, Park Konteal and Ba Lot sanctuaries.

CHAPTER 1

INTRODUCTION

Fishery is a vital activity to ensure food security and provision of protein to about 13 million people in Cambodia. The sector secures the supply of about 80-90% of animal protein to Cambodian population. Particularly, the inland fisheries contribute 90% of Cambodia's fish production (Sam *et al*. 2003). It also generates employment either directly or indirectly through associated activities for over 2 million Cambodians. Cambodian freshwater fisheries contribution to economic, social well being of the rural poor and food security is probably higher than other countries (Baran 2005). Some findings suggest that per capita consumption of fresh and processed fish was nearly 75 kg per annum for the communities living in and around the waterway, river, lakes and flood-land (Ahmed *et al.* 1995). The value of the catch at the landing site rank from USD 100 to 200 million, and increase up to USD 250 to 500 million at higher level in the marketing chain (Van Zalinge *et al*. 2000). The reliance of fisheries resources in the Tonle Sap region will remain high in the next decade as an immediate source of income and food security.

The serious decline in some fish stock and the threatened status of some fish species has led numerous scientists in the world to promote the idea of protected areas, sanctuary, conservation zones, reserved areas or no-take areas, as one of the management tools in fisheries, as well as species conservation (Lubchenco *et al.* 2003; John 2003; Halpern 2003). Bearing this belief in mind, probably all countries in the world have been setting up their own protected areas either territorial or wetland. Unfortunately, very few protected areas were set up in freshwater areas. Cambodia is one of the few countries in the world to have freshwater fish sanctuaries. Tonle Sap fish sanctuaries are believed to be set up before 1950s (Deap 1992), with a main purpose of fish refuge during dry season. There is a serious lack of study to determine the efficiency of the current fish sanctuaries. This study was done to assess the abundance, biomass, size, and species richness in the fish sanctuaries compared to the open access fishing domains. Social factors are also reviewed to integrate the social dimension of fish sanctuaries management.

1.1 OBJECTIVES OF THE STUDY

Main objective of the study:

1. To determine the water quality inside and outside the 8 fish sanctuaries; such as, water temperature, pH, DO, conductivity, and water transparency;
2. To determine fish assemblage, inside and outside the 8 fish sanctuaries; and
3. To determine the perception of villagers and officials about the existing 8 fish sanctuaries, in order to facilitate fisheries management.

1.2 CLIMATE OF CAMBODIA AND TONLE SAP

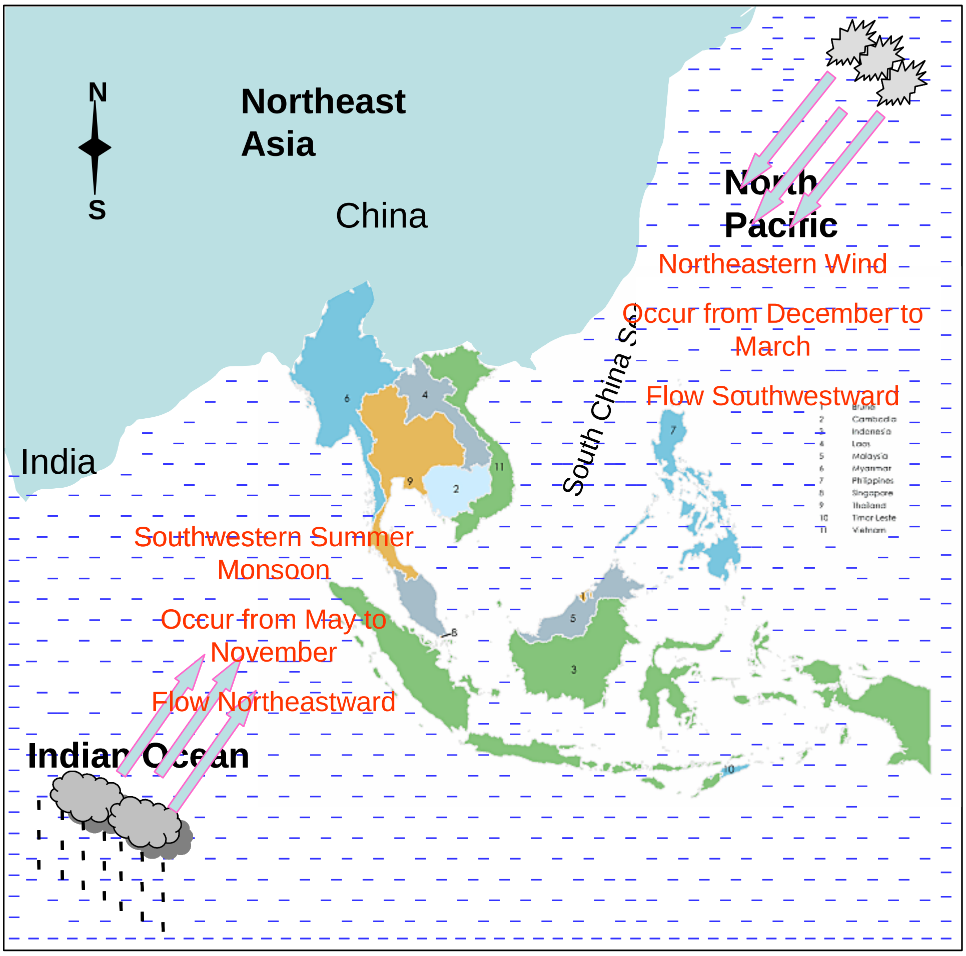

Figure 1: Monsoon's regime in Cambodia (After Takehiko 2001)

Generally, there are two main seasons in Cambodia, wet and dry season. The climate of the country is similar to other countries of Southeast Asia: dominated by monsoons, better known as tropical wet and dry, which distinctly marks seasonal differences. In summer, the southwest monsoon is drawn landward from the Indian Ocean (Figure 1). The flow is reversed during the winter, and the northeast wind sends back dry air over the Southeast Asia peninsular. The southwest monsoon brings the wet season from May to November. December to April is considered as dry season (Takehiko 2001). During dry season, from December to March, the northeast wind brings dry air to the region. The warmest period of the year is during April and May. This is a short transitional period, which is marked by some difference in humidity but by little change in temperature, intervening between the alternating seasons.

Temperatures are fairly uniform throughout the Tonle Sap Basin area, with only small variations from the average annual mean of around 25°C. The maximum mean is about 28°C where the minimum mean is about 22°C. Minimum temperatures rarely fall below 10°C. January is the coldest month, and April is the warmest. Typhoons or tropical cyclones that often devastate coasts of Vietnam rarely causes damage to Cambodia (Takehiko 2001).

The total annual rainfall average is between 100 and 150 cm, which is the heaviest rainfall in the Southeast Asia region. Average annual rainfall in the Tonle Sap Basin-Mekong Lowlands area falls between 130 and 190 cm. However the amount of rainfall varies considerably from year to year. Rainfall around the basin increases with elevation. The heaviest rainfall area is the mountainous area along the coast in the southwest, which receives from 250 cm to more than 500 cm of precipitation annually as the southwest monsoon reaches the coast. And most of the water drains mainly to the sea; only a small quantity goes into the rivers flowing into the basin. The relative humidity is high at night throughout the year; usually it exceeds 90 percent. During the daytime in dry season, humidity averages about 50 percent or slightly lower, but it may remain about 60 percent in wet period (Cheang 1973; Murakami 1987).

Coexisting with the normal monsoons, there is the abnormal monsoon, result of the irregular season: climate change and natural disaster, very heavy rain, or extremely dry (Swaminathan 1987). For example, in these last few years, the season seemed to come one month later, whereby the rain usually starts in late June or early July.

1.3 STUDY AREA: MEKONG

Figure 2: Map of the Mekong River

The Mekong River is Cambodia's largest river. The annual discharge of the Mekong is 475 million m^3 (Mekong River Commission 1992). The maximum mean discharge is 54 times the minimum mean discharge (Welcomme 1985); or 30 folds according to Mekong River Commission statistic. In term of species diversity, the Mekong River is among the top three rivers in the world, after the Amazon and the

Zaire (Dudgeon 2000). There are about 1,200 fish species document in the Mekong, (Rainboth 1996; Rainboth and Jensen 1996).

The Mekong dominates the hydrology of the country, with a total length of 4,200 km, the Mekong River is the world's 12th longest river (Mekong River Commission 1992). This river originates in mainland China, flows through Myanmar, Thailand, Laos PDR, Cambodia and Southern Vietnam before emptying out into the South China Sea. The Mekong enters Cambodia from the northern part of the country, known as "*Lback Khone*" in the Khmer language, which means "Khone Falls"

In Cambodia, from Khone Falls, the Mekong River flows across Stung Treng province, Kratie province, Kampong Cham province and Kandal province. In Phnom Penh city, with its three alternative arms to different directions, the Bassac River and Mekong Krom river flow almost parallel downward to south-eastward across Kondal and Prey Veng Provinces into the southern Vietnam and continues further to the South China Sea. The Tonle Sap River turns in the opposite direction with the Bassac and Mekong Krom River. It flows north-westward, through three provinces Kandal, Kompong Speu and Kampong Chhnang, linking with the Tonle Sap Great Lake at Chhnok Tru (Figure 2).

1.4 TONLE SAP

The Tonle Sap River lies from Chak Tomok (Phnom Penh) to Chnok Tru., with a total length of approximately 120 km. This river is the main inflow and drainage of the Tonle Sap Great Lake. Recent study of the Tonle Sap water balance by the Mekong River Commission Secretariat, Water Utilization Project, Japan International Cooperation Agency and Tonle Sap Livelihood Project (2004) concluded that the Tonle Sap River flow, the Tonle Sap runoff and overland flow present respectively 50%, 40% and 10% of the Tonle Sap Lake inflow.

The Tonle Sap Great Lake plays the role of buffer for the Mekong River system floods. The Mekong River swells with water during the monsoon season reaching a flood discharge of 40,000 m^3/s at Phnom Penh. By the end of June, the flow of the Mekong Krom (Lower Mekong) and the Bassac Rivers fed by monsoon rains, increases to a point where its outlets through the delta cannot handle the enormous volume of water, resulting in extensive flooding of adjacent floodplains for 4-7 months. Its floodwaters reverse the flow of the Tonle Sap River, which then has a maximum inflow velocity of 1.8 m/s and enters the Great Lake, increasing size its size from about 5,600 km^2 to 30,000 km^2, and raising the water level by an average of 12 m (Mekong River Commission 1992). The Great Lake then acts as a natural flood retention basin (Figure 3). After the Mekong's waters crest, the flow reverses and water flows out of the engorged lake reaching a maximum outflow rate of 8,000 m^3/s and, over the dry season, increase mainstream flows by about 16%, thus helping to reduce salinity intrusion in the lower Mekong Delta in Vietnam (Sarkkula *et al.* 2004). By the time the lake water level drops to its minimum surface size, a 20-30 km bank wide of inundated forest is left dry with deposits of a new layer of sediment.

In term of economic importance, the Great Lake Tonle Sap fisheries account for 60% of the current annual commercial fisheries in government statistic (Ahmed *et al.* 1998). The approximate total fish catch of the Tonle Sap was 120,000-150,000 tonnes (Mekong River Commission 1999). It contributes to approximately 36% of Cambodia's total fish production of 290,000 to 430,000 tonnes (Van Zalinge *et al.* 2000).

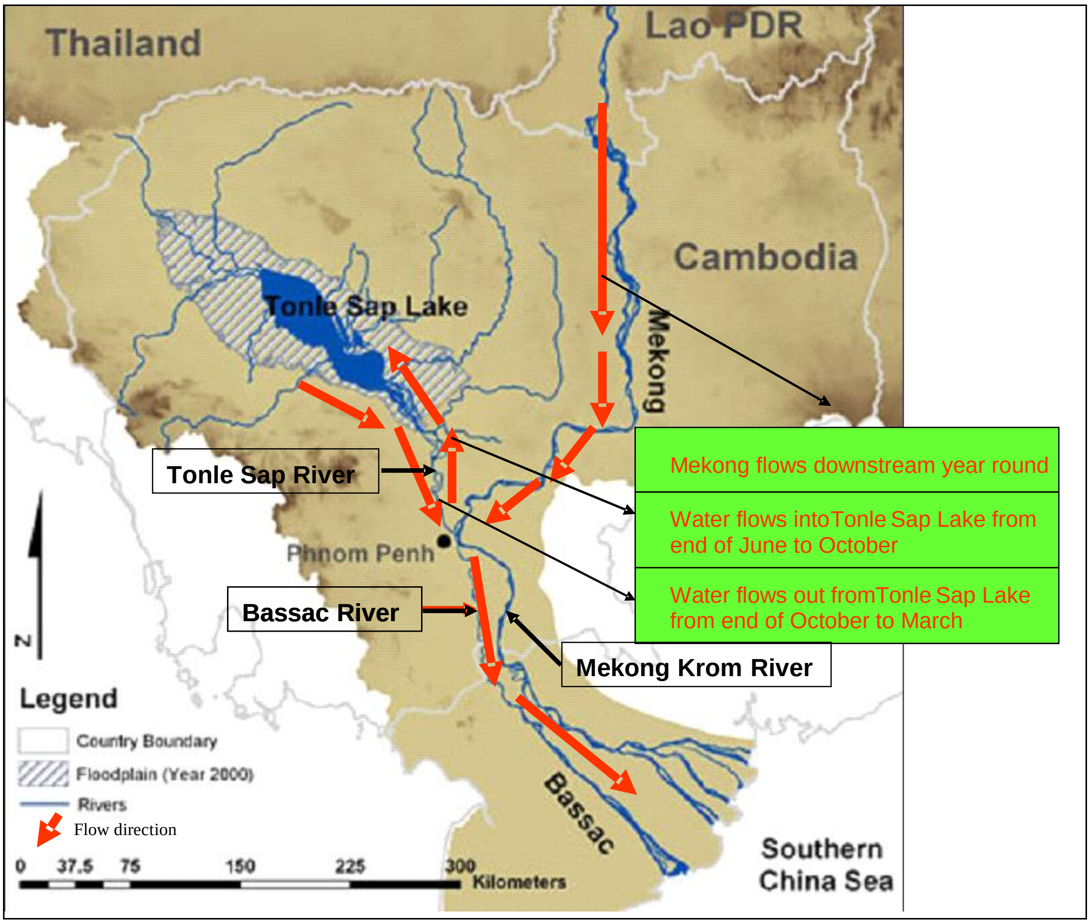

Figure 3: Map of freshwater system in Cambodia (Mekong River Commission 1999)

1.5 ECOLOGY OF THE SYSTEM

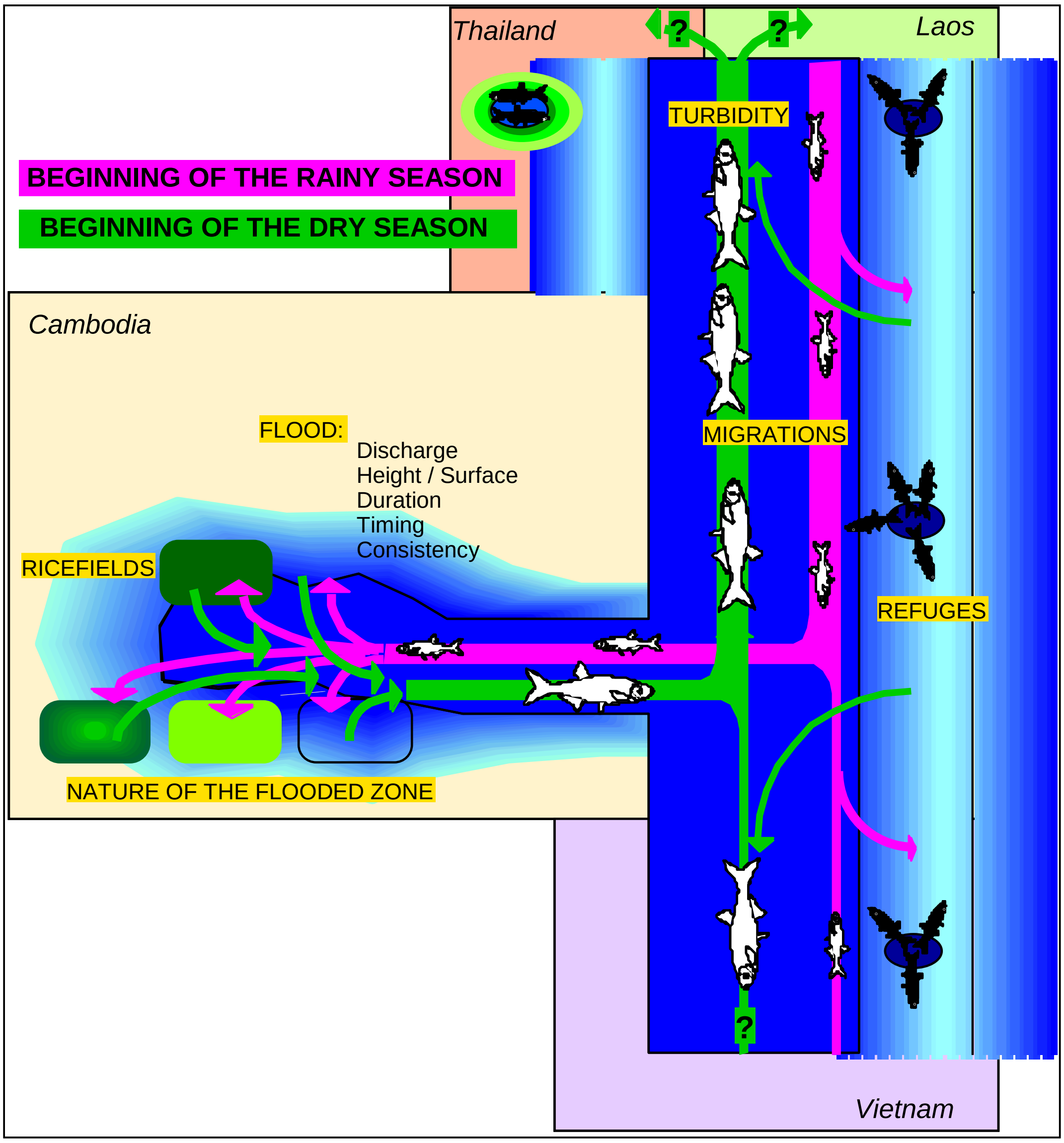

Figure 4: Cambodia's fish migration routes (After Poulsen and Valbo-Jørgensen 2000)

Cambodia's freshwater fish migration is a big trans-boundary issue between riparian countries. There are very few documents concerning conventional biology study of Mekong fish migration by tagging. Hogan *et al*. (2000) concluded that the value of tagging experiments in an area as large and unknown as Amazon is doubtful. Due to some constraint in using conventional biology methods, local knowledge has been recognized as a valid and important source of ecological information (Poizat and Baran 1997; Baird 1999). For example, inferring from interviews Baird *et al.* (1998a) reported that some 4,000 tonnes of fish are caught per annum in the Khong district (mostly above the falls); a large part of which consists of species having migrated up from Cambodia. Similarly, Van Zalinge *et al.* (2000) reported that there is probably a dry season movement downstream of fish from Cambodia floodplains into Vietnam as supported by the existence of Dai fisheries in Vietnam, which operate at the same time as Dai fisheries in Cambodia (Baran 2005). Fish migration is an important feature of river ecosystem in most of the major tropical rivers. There are two peak migration seasons per year: June-August and December-February (Figure 4). Each of these migration seasons is corresponding to one fishing season (See seasonal variables for timing of fishing seasons). In June-August migration, migrating fish move with the water current and disperse all over the Mekong lower basin, especially in the Tonle Sap for feeding and reproduction. In November, the water gradually decreases and migration fish moves back from the inundated areas to the Tonle Sap Great Lake, River and the Mekong. From December to February, the water current flows very strongly southward from the Great Lake into the Mekong River; this induces long distance migratory fish to move downstream (Sam 1999). During the migration peak in the Tonle Sap River, an average of 34 tonnes of fish per hour (i.e., about 3 million fishes per hour) are caught by the entire Dai fisheries (Baran *et al.* 2001). Often fish migrates several hundred km in order to reach spawning ground or fertile feeding ground. This kind of migration is called longitudinal migration. Some fish species only migrated from mainstream or open lake to its associated floodplains. This kind of migration is called lateral migrations. Some other fish species scarcely migrated compare to the two groups somewhat can be considered as sedentary fish.

The important commercial species are often broadly categorized as "Black Fish" and "White Fish" (Mekong River Commission 2003). These two groups of fish differ from each other in ecology, habitat and migration. "Black Fish" species is able to survive in swamp or plains all year round with limited lateral migrations. Conversely, most species of "White Fish" have shown strong lateral and longitudinal migrations.

1.6 CHARACTERIZATION OF THE STUDY SITES

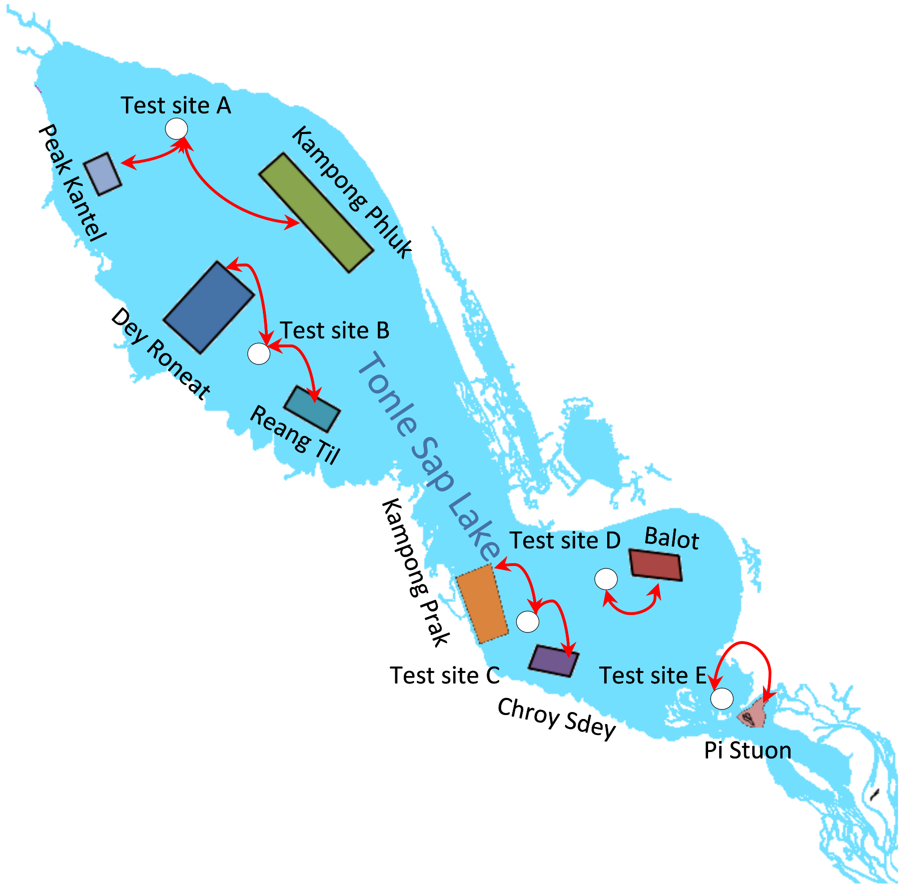

Figure 5: Map of the 8 fish sanctuaries and 5 corresponding test sites in the Tonle Sap Lake

Table 1: Coordinates of the 8 fish sanctuaries in Tonle Sap Lake

Name of Sanctuary	X (Easting)	Y (Northing)
Pi Stoun	E104 28 07.9	N12 31 52.5
	E104 30 00.9	N12 31 03.6
	E104 30 23.3	N12 33 35.4
Chroy Sdey	E104 14 22.8	N12 35 00.2
	E104 14 57.1	N12 36 31.6
	E104 17 39.7	N12 35 59.0
	E104 17 05.1	N12 34 26.5
Kampong Preak	E104 09 20.4	N12 40 58.8
	E104 11 49.4	N12 41 59.3
	E104 13 04.3	N12 37 12.3
	E104 11 01.9	N12 36 26.4
Ba Lot	E104 21 17.0	N12 41 07.0
	E104 21 03.6	N12 42 45.4
	E104 24 23.1	N12 42 22.8
	E104 24 35.8	N12 40 45.7
Reang Til	E103 58 46.2	N12 53 26.5
	E104 01 40.7	N12 51 51.3
	E104 00 47.1	N12 50 25.0
	E103 57 52.6	N12 52 01.5
Dey Roneat	E103 53 23.8	N13 01 36.4
	E103 55 54.6	N12 59 25.7
	E103 52 19.0	N12 55 32.9
	E103 49 50.0	N12 57 42.7
Park Konteal	E103 44 27.4	N13 07 54.4
	E103 45 58.9	N13 08 35.4
	E103 46 54.8	N13 06 34.6
	E103 45 24.5	N13 05 53.4
Kampong Pluk	E103 56 10.3	N13 07 16.9
	E103 57 48.9	N13 08 43.5
	E104 03 52.7	N13 02 22.0
	E104 02 16.4	N13 00 54.7

See detailed description of each site in (Annex A)

CHAPTER 2

LITERATURE REVIEW

2.1 FRESHWATER SANCTUARIES IN THE WORLD

Very few protected areas have been set up in inland water bodies. At the same time, scientific literature contains relatively little information addressing the issue of freshwater protected areas, although there are abundant documents that related to large terrestrial and marine protected areas. After literature searching, I could only access few papers written by Baird *et al.* (1998a); Baird *et al*. (1998b); Baird (1999); Baird (2001) which mainly focused on traditional ecological knowledge (TEK) and co-management strategies on sanctuary management, or Fisheries Conservation Zone (FCZ) in southern Lao PDR and other briefly mentions freshwater protected areas in other places around the world.

Numerous FCZs have been set up in Lao PDR. There is therefore diversity of freshwater protected areas in Laos. It can be in back swamp, lime mine pond, Pagoda pond, stream, river, pool (deep pool), and lake. Almost all fish sanctuaries in Khong district have all been established in relatively deep depressions or pools, especially mainstream Mekong, while some are relatively shallow, reaching just 2.5 m deep in the dry season, others 50 m deep in the dry season. The mean depth is 19.5 m. The largest FCZ in area is 18 ha, the smallest 0.25 ha, and the mean size is 3.52 ha (Baird *et al.* 1998a; Baird *et al*. 2000). Based on some traditional and catch per unit effort fish monitoring methods, which were conducted by villagers, there is both fishery and conservation benefits from the FCZ within one year. The villagers reported that after one year of being protected, approximately 51 fish species increased in fish appearances or catch in the FCZs (Baird 2006).

Apart from geographical and ecological setting of the FCZs, the author gives more emphasis on the efficacy of a co-management approach, which was a success in managing FCZs and aquatic resource in Khong District. (Baird 2001) concluded that FCZs are not panaceas for solving all the fisheries problems in Laos or in the Mekong River Basin, but they represented important management tools that should not be overlooked. It is clear that the aquatic co-management program has largely been successful in improving management strategies and practices related to aquatic resource harvesting. The main successes as viewed by Khong District and villagers have been (1) increase of village solidarity, (2) increase of natural resource management capacity at government and village level, and (3) observed and/or perceived increases in fish and frog stocks and catch (Baird 1999). This author proposed that there are many factors of explaining the success of aquatic co-management in Khong District: firstly, the Laos government authorized the community (village) to manage their own aquatic resource. It is known as village law which is regulated by villagers, provided that they do not conflict with national laws or the constitution (Baird 1999). Secondly, in Laos sense of social equality and unity between villagers is still strong. Finally, the village is very practical, flexible and precise, in enforcing needed regulations. Some regulations such as: part or year round no fishing zone, bans on stream blocking, bans on spear fishing with lights, explosives, chemical and electricity juvenile fish conservation, especially snake head juvenile.

2.2 HISTORICAL REVIEW OF FISH SANCTUARIES IN CAMBODIA

2.2.1 HISTORICAL REVIEW OF FISHING LOT IN CAMBODIA

Fishing lot system is understood to have been initially introduced in 1863 as a feudal patronage system during the reign of King Norodom. The revenues collected from those fishing lots were used to pay for the French Protectorate Government (Touch 2005). Given the unsatisfying use of the aquatic commons, many poor resources users protested strongly. The result was that the Cambodian Government abandoned the fishing lot system in 1884. Bearing this in mind, the system was then modified and greatly formalized by the French Protectorate Government in 1908. The revenues from this reformed system were allocated for the development of public infrastructures such as roads and railways for Cambodia (Touch 2005). After the independence in 1954, a legal framework of the fishery was provided by promulgating the Fishery Law of 1956.

The profitable Cambodian inland fisheries have resulted in much conflict between resources users. In the 1960s, there were often reports of lot owners and managers being killed due to disputes with local officials and villagers (Tarr 2002). During the civil war, the Lon Nol government could not control this huge resource; therefore, in 1973 this regime banned all fishing lots. And in 1975, after the Khmer Rouge seized power, most of the fishing activities were abandoned, fish in the Tonle Sap faced no threat from the Khmer Rouge. Stocks were at their peak during their rule (Tarr 2002).

Fishing was revived again by the Soviet-support socialist government of the People's Republic of Kampuchea, established after the overthrown of the Khmer Rouge in 1979. Fishing lots were handed to solidarity groups of fisher families. The concession (tax) was to be paid in the form of fresh or salted fish to the state (Chheng

2000). This was the first time, after more than a century, that people were relatively free to fish where they wanted. Moreover, there was an abundance of fish following the low pressure on stocks during the Khmer Rouge period (Degen *et al.* 2000).

2.2.2 FROM FISHING LOTS TO FISH SANCTUARIES

Synthesizing the above history of Cambodia's fishing lot, it is widely believed that freshwater fish sanctuaries have been applied in Cambodia long time ago. Although French scientists under the Protectoral had reconvened the location of fish protected areas in the lake (Chevey and Le Poulain 1940). The experienced people who have lived with Cambodia’s fisheries all their life cannot tell when the first sanctuary was set up, but they know that two fish sanctuaries in Pursat Province: Kampong Preak and Reang Til existed in the Great Lake before 1950s (Deap 1992). Two other fish sanctuaries: Kampong Pluk in Siem Reap province and Phat Sandai (Pi Stoun) in Kampong Thom province were set-up during the 1960s. Formerly, these two places were the commercial fishing lots, but the owner of the lots was fishing illegally, the government revoked the fishing license and converted these two fishing lots into fish sanctuaries (Nu 1992; Heng 1992).

After 1979, only some parts of the lake were accessible, the rests were still under the control of Khmer Rouge guerrilla. However, the fishing area and aquatic exploitation was progressively recovered by the Cambodian Government. Realising the value of fisheries resources, in 1987, the Cambodian government set up eight fish sanctuaries in the Tonle Sap Great Lake by reassigning four former fish sanctuaries and converting the other four from commercial fishing lots to fish sanctuaries. Among the four that had been newly established, two are in Pursat province (Chroy Sdey and Dey Roneat), one in Kampong Thom province (Ba Lot), and one in Battambang Province (Park Konteal, Preak Toal commune). The unique criterion to allocate those sanctuaries was the depth of water in dry season in the lake (personal communication from Mr. Chhoun Sophat who was a member of fish sanctuaries working group at that time).

2.3 FRESHWATER FISH SAMPLING METHOD

Capture and recapture methods, remote sensing using hydro-acoustics, poisoning are not suitable for the Mekong fisheries in southern Laos (Cowx 1995; Baird 1999). Baird (1999) concluded that catch per unit effort (CPUE) is the best approach. This approach can be based on 3 techniques. The first method is the fishery officer direct sampling and data recording. This method results in accurate measurements, also fish species identification should generally be good. However, there is the disadvantage that officials are likely to fish somewhat differently than local fisheries. Moreover, this method was more costly due to per diem and travel costs. The second method is villager sampling and fisheries officer data recording. The advantage of this method are good quality and lower cost compared to method one. However, there is the disadvantage that officials must be present when catches are brought to shore. Sometimes, the fisheries feel bothered by the data collection process, and may attempt to avoid bringing the fish for officials to record. The third method is villager sampling and data recording. The cost of this method is quite low but in order to obtain an accurate data, individuals selected for the sampling and data recording needed to be properly trained.

There are approximately 150 fishing gears are used in Cambodia (Deap *et al*. 2003). The gear used depends on season, species targeted and social economic context. In Cambodia fishing is categorized in three scales: large scale fishing, middle scale fishing and small scale fishing. Each scale has its own corresponding fishing gears. For example, the large scale fishing, also known as fishing lots, is done by using bamboo fences to encircle the lot (Nao *et al*. 1999). Similarly, Dai fishing (bag net) is to use a huge bag net to fill a vast volume of water outflow from the Tonle Sap Great Lake targeting small Cyprinid (*Henichorhynchus* sp.). The middle scale fishing encompasses some type of gears such as seine net, arrow-shaped trap, long gillnet etc. Among the top 10 gears within this scale, gillnet was ranked first in term of catch in biomass (Van Zalinge *et al*. 2000). This gear is the most popular in Cambodia and Vietnam (Amarasinghe and De Silva 1999; Paul *et al*. 2002; Long 2003; Baran 2004;). Trammel net is a special net that is more effective than gill net (Acosta 1997; Long 2003; Baran and Chheng 2004).

2.4 WATER QUALITY

2.4.1 WATER TEMPERATURE IN RELATION TO FISH

Fish can only survive over a range of temperatures (Wootton 1990), depending on species, stage of development, and acclimation (Alabaster and Lloyd 1982). For example, the goldfish with the proper acclimation can tolerate a range of temperature from 0 to 40 ^{o}C (Fry 1971) or on the contrary, the Antarctic fish die at a temperature a little above 5 ^{o}C The rate of metabolism in poikilothermic animal depends upon temperature. However, according to (Wohlschlag 1964) there is a plateau, described as the zone of thermal acclimation, in which the metabolism increases only slightly in response to an increase in temperature. In the absence of limiting factors, a rise in temperature will increase the metabolic rate of the fish (Hochachka and Semero 1984). Apart from this, (Beamish 1978) had mentioned that temperature also affects swimming performances. The maximum speed of prolonged, aerobic swimming increases with a temperature up to the maximum, but then declines with any further increase in temperature.

After reviewing numerous publications, Alabaster and Lloyd (1982) recognized that, (1) any change in the natural temperature regime produces changes in the behavior of the fish and in the composition of the fish communities (2) different temperature conditions are required at different times of the year to meet the needs of different life stages of the fish, and (3) permissible increments temperature above natural values and maximum permissible levels cannot be envisaged for the fish communities as a whole, but may tentatively be assessed for groups of fish having similar thermal requirement at different given times of the year. However, as oxygen concentration is negatively correlated with temperature, therefore, the effects of high temperature are complicated by the lower solubility of oxygen at such temperature, so the direct lethal effect of temperature may be difficult to disentangle from any effects of low oxygen concentration (Wootton 1990)

2.4.2 PH IN RELATION TO FISH

The acidity or alkalinity of the water is an important factor to be considered. The pH rank that is not directly lethal for the fish is 5-9 (Alabaster and Lloyd 1982). By establishing a water quality criteria for pH value Orsanco (1955) pointed out that although the fish had been found at pH value of 4-10, the safe range was 5-9 for a the maximum productivity, the pH value should lie between 6.5 and 8.5. The affect of pH on the fish relatively varies with their age (Lloyd and Jordan 1964). The acidity also affects the primary productivity of the lake

2.4.3 DISSOLVED OXYGEN IN RELATION TO FISH

Sensitivity of fish to low concentrations of dissolved oxygen (DO) differs between species, between the various life stages (eggs, larvae and adults) and between different life processes (feeding, growth and reproduction). The minimum constant value of 5 mg/l would be satisfactory for most stages and activities in the life cycle. However, Brungs (1971) suggested that where conditions are otherwise favorable, lethal effects on fish would be avoided by maintaining DO levels above 3 mg/l. Although for some species, this limit could be much lower. Result of research showed that acclimation of fish to low DO can take place, the length of time required increasing with decreasing temperature; at low temperatures, acclimation may not take place. Oxygen supersaturated water resulting from phytoplankton activity is unlikely to be (Weatherley 1970). At lower concentration of DO the rate at which the water is pumped over the gills of the fish may be increased, therefore increasing the amount of poison in contact with the gill's surface where it is absorbed (Hicks and De Witt 1971).

2.4.4 CONDUCTIVITY IN RELATION TO FISH

Kirschbaum (1979) indicated a conductivity increase at the start of the rainy season as salts are washed from the soil. From then on, further rainfalls cause a steady decline in conductivity, which then rises again in the dry season Water electrical conductivity may affect the development of fish gonads. This problem has been studied in detail by Kirschbaum and Westby (1975); Kirschbaum (1979) who proved that gonad recrudescence and successful reproduction of *E. virescens* could be repeatedly provoked by a systematic imitation of the rainy season continuous decrease in water conductivity. Increasing conductivity alone was effective in causing gonad regression. Similar results have been obtained in the laboratory with *Apteronotus leptorhynchus* and *S. macrurus* (Kirschbaum 1984).

2.4.5 TURBIDITY AND SUSPENDED SOLIDS IN RELATION TO FISH

Turbidity and suspended solids in water are resulting from soil erosion, from engineering works during which large volumes of earth are disturbed, from forestry operations, from the discharge of sewage, sewage effluents, mining wastes, pulp and paper mill wastes, and other industrial effluents (Lloyd 1960). Not all species of fish are equally susceptible to suspended solids, and not all kinds of solids are equally harmful. There are two systems, which have been used to measure water turbidity, one is weight of solid per unit volume of water and the other is light transmittances of Secchi disc reading, (Alabaster and Lloyd 1982). There are probably no sharply defined concentrations of a solid above which fisheries are damaged and below which they are quite unharmed. Also sufficiently high concentrations of suspended solids can kill the fish, directly, increase their susceptibility to disease, reduce their rate of growth, modify their normal movements within freshwater, reduce the area suitable for spawning and kill developing eggs. In addition, the quality of natural food available to fish can be reduced. However, in tropical systems, such as river or natural estuaries, turbidity is quite high but it is very well tolerated by fish and contributes to providing nutrients to the ecosystem and thus to increasing it productivity.

CHAPTER 3

METHODOLOGY OF THE STUDY

3.1 VARIABLES

3.1.1 SEASONAL VARIABLE

The close season for middle-scale fishing is defined as follow: (1) from 1 June to 30 September for the inland fishing domains located north of Tonle Chaktomuk parallel latitude N11 33 25.9 and (2) from 1 July to 31 October for the inland fishing domains located south of Tonle Chaktomuk parallel latitude N11 33 25.9 (Cambodia's Fisheries Law 2006).

Close fishing season and open fishing season were chose as the seasonal variables. Ideally, the sampling should take place at the middle of each fishing season. However, due to funding constraints and delays, the sampling had to carry out in June 2005 and late December 2005 and early 2006, mean the sampling carried out by first haft of each fishing season.

3.1.2 ENVIRONMENTAL VARIABLES

Due to limited budget, five most critical water quality parameters temperature, potential hydrogen (pH), dissolved oxygen (DO), electrical conductivity (EC), and water transparency were selected as suggested by some senior scientists; such as Dr. Randy Brumett, Dr. Juha Sarkkula, Dr. Bernard de Merona, Dr. Guy Vid, and Dr. Bernard Hugueny.

3.1.3 FISH COMMUNITY VARIABLES

Based on the objective of the project, three fish community variables were selected. The three variables consist of species, biomass and total length of individuals.

Species:

Each individual fish specimen was directly identified by using Rainboth (1996) as identification reference. In order to ensure the accuracy of the database, after all fish data was entered into an Excel Worksheet.

Weight:

A 2-gram unit electrical scale was used. After species identification, each big fish specimen was weighed and recorded. If numerous small fish species were caught, the fish were weighed as a whole, and then counted.

Length:

After species identification and weighing, each fish specimen was measured for total length. Out of a group of small fish of the same species, 5 individuals were randomly selected as representative to measure the total length.

3.1.4 SAMPLING SITES

Due to limited budget and logistic constraints, it was decided to take only 5 sites as test of 8 sampling sites. Therefore, three test sites are used twice to test for 2 sampling sites each. Figure 6 shows comparison map between sanctuaries and test sites for fish sampling and water quality sampling in the 2 seasons

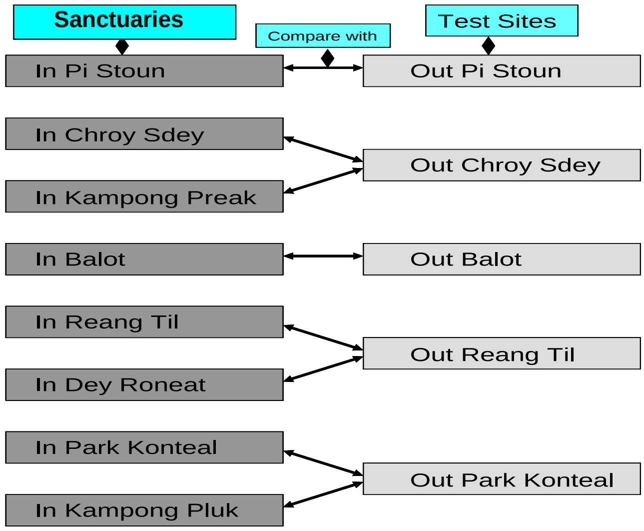

Figure 6: Map of comparison between sanctuaries and test sites