Section 1: Fisheries Assessment

Monitoring sales of fish and other aquatic animals at retail markets in Phnom Penh, Cambodia

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ABSTRACT

Phnom Penh, Cambodia's capital city has a population of over one million people, of which about 700,000 live in the main central urban area. Inland fish and other aquatic animals are sold at 29 main markets that are supplied from several landing sites and from other diverse sources. We monitored sales at six of these markets in early 2003 and assessed the total numbers of traders in late 2003. Fresh inland fish comprised about 85% of the weight sold of all fresh fish and other aquatic animals. Snakeheads (Channidae) comprised around 40% by weight of all fresh inland fish sold, and with a few other species, made up most of the sales. Exotic species (from aquaculture) comprised only about 1% of sales, so virtually all fresh fish sold were indigenous wild fish or indigenous species grown in floating cages and fed on other small wild fish of lower value. Hence, wild inland fish (either directly or indirectly) still provide most of Phnom Penh's fish supply. The most important other aquatic animals were marine and freshwater shrimps (Penaeidae and Palaeomonidae).

In the 29 markets, over 2,000 people sell aquatic products and about 90% of sellers are female. Based on our limited data, the total daily inland fresh fish sales in these markets were of the order of 12 tonnes/day in March-May and 19 tonnes/day in October 2003, with a value of US$15-24,000 per day. Preserved inland fish sales are also very important but were not quantified. This small-scale industry is the primary supplier of fish to the city and is a significant employer, in particular providing opportunities for women in an environment where they can manage their own businesses. Fish marketing also supports many associated industries.

Sales showed no daily patterns and quantities generally varied by about 10-20% from day-to-day. A five-day monitoring programme would therefore provide quite representative data for any market. Monitoring markets poses particular challenges that require novel approaches which we discuss for those planning similar studies.

KEY WORDS: Cambodia, Mekong, fisheries, markets

INTRODUCTION

The residents of Phnom Penh, like those of many large cities in Southeast Asia, rely on local retail markets to provide the fresh and preserved aquatic produce that forms an essential part of their diet. Because they are intermediate between producers and consumers, monitoring sales in these markets can reveal trends in the type, quantity and price of produce available.

This paper documents three such monitoring surveys carried out in central Phnom Penh during 2003. Data from a fourth survey, which involved long-term monitoring by a selected group of 20 traders in six markets, is not yet ready for publication. The completed surveys include:

1. An initial 15-day survey of one large market, Bang Keng Kong; this was a trial survey designed to evaluate the time and procedures required to carry out a short, intensive, 'whole-market' fresh fish survey of a selected group of markets. In this phase, conducted during early 2003, we monitored all market stalls that sold fresh fish. Data from the survey helped to identify patterns,

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or trends, in fresh fish sales and to evaluate if produce from 'outlying' sources were causing duplication of some results.

2. Five-day 'whole-market' fresh fish surveys (also conducted in early 2003) of five more markets: Chass, Central, Olympic, Toul Tom Pong and Oresey markets. These, together with Bang Keng Kong, form a group of six 'key markets' that are the source of the data used in the analysis of the 'whole-market fresh fish' surveys and most of the data used in the analysis of the 'market-frame' surveys (see Results section).

3. A 'market-frame' survey involving 29 markets; in the process of interviewing traders during the earlier surveys, we learned that 29 markets in central Phnom Penh sell fish, a far greater number than the five to ten we had assumed previously. As a result, the 'market-frame' survey, conducted during October and November 2003, included 23 new markets in addition to the six 'key markets' surveyed earlier in the year.

4. As well as providing a general description of the fish markets, this study aimed to establish if it is possible to obtain accurate data on sales, to document aspects of the methods of surveying and estimate the cost of implementing such monitoring. The study also sought to establish whether surveys of this type would reveal broader trends in the fisheries, such as the changes in the number and type of species, the size of individual species on sale and prices.

Phnom Penh, the capital city of Cambodia since 1866, is located in the centre of the productive floodplains near the confluence of the Tonle Sap (Sap River) and Mekong River (Griffiths 2000). Although depopulated under the rule of the Khmer Rouge (1975 – 79), the city has since been re-occupied and largely re-built or newly built. Rapid expansion since 1995 and major infrastructural changes (to roads, buildings, energy supply, and the airport) in 2001-2003 have dramatically transformed the city. Along with this transformation and a rapidly expanding population has come an expansion of trade both into and out of Phnom Penh.

The 1998 census (National Institute of Statistics 1999) recorded a population of approximately one million people in the city. About 60% of these people live in the main urban area, which sprawls west along the airport road (Figure 1). The national annual population growth rate is 2.5%. In the city, this figure is higher; in 2003 the population of central Phnom Penh was probably in the region of 700,000 people.

The urban area is mainly medium-density, with shop-houses and stores along larger streets. Small streets and alleys connect a diverse mix of dwellings. Dense aggregations of makeshift houses line waterways and spread across vacant lands. Most of the inhabitants buy their food supplies in traditional Asian-style markets that have been re-developed (or have sprung up) over the last decade in response to the improved security situation and a stabilised cash economy.

As our studies only began in 2003, and much of the analysis of the data is still ongoing, this paper can only present some of the initial findings. We hope, however, that the paper is a useful introduction to the

methods of monitoring fish sales and that it will give some guidance to other researchers who wish to undertake similar studies. We are confident that, while our paper deals with markets in Phnom Penh, the lessons learned during our studies will be applicable throughout the region.

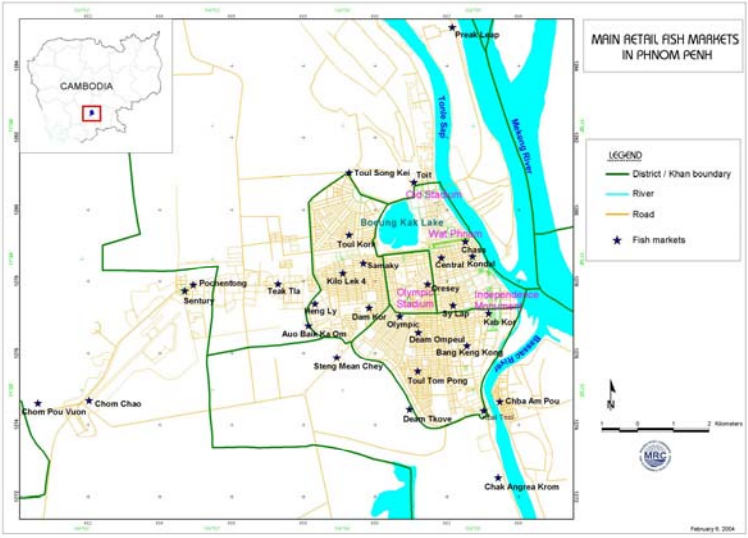

Figure 1. Location of main retail markets in Phnom Penh

Structure of the markets

Large retail markets are highly visible and accessible covering whole city blocks in Phnom Penh; Central Market, for example, covers approximately four hectares. Smaller markets are less obvious, and access via narrow streets or alleys is restricted. Older, generally well-constructed markets with cement walls, stalls and roofs, date back to the French colonial period (Central Market was built in 1937), whereas the newer markets are ramshackle with constructed stalls of varying degree and quality. All

Figure 2. A typical stall in the uncovered area of Chass market showing *Pangasius* and cyprinids for sale

spread to some extent onto adjacent streets and alleys, hindering accurate enumeration of stallholders.

In the markets, numerous small stallholders sell a wide range of fresh and preserved produce most of which is brought in daily from suppliers close by. Stallholders have to pay a minimal fee to a market manager who takes charge of policing the market and pays rent to the local council. All purchases are for cash; traders accept US dollars as well as other foreign currencies, along with the Cambodian currency, the *Riel*.

Phnom Penh has a few Western-style supermarkets that cater to a small affluent population. Foodstuffs typically found in supermarkets are also available in traditional markets; here they sell, along with various consumer products, in bulk or in smaller amounts. In the traditional markets, food produce is rarely refrigerated. Although some traders do use ice, most sell fish, and other food products, either alive or freshly killed. The lack of refrigeration favours retailing of fish, such as snakeheads (Channidae) and climbing perch (Anabantidae), able to survive with little water as well as other aquatic animals (OAAs) such as frogs, crabs and turtles that can tolerate long periods without water. Many traders kill and process live animals immediately prior to sale and sell large quantities of preserved fish and OAAs (salted, dried, fermented, or made into paste or sauce).

Figure 3. Drying snakehead and *Pangasius* fillets outside Oresey Market; the largest market for preserved fish

Monitoring fish sales

When this study began in early 2003, we believed that only five to ten markets in central Phnom Penh sold significant quantities of fish. However, while we were monitoring the six key markets, traders and others told us that many more markets than these sold large amounts of fish. Eventually, 29 retail markets were included in the study. We also found trading within or between markets is a common practice. Traders may re-sell produce in the same or different markets; some buy produce from wholesale markets, such as Oresey, and then re-sell it in other retail markets. Indeed, because of this inter and intra-market commerce our records probably include the same fish sold twice or more.

Those who are familiar with cities that host large centralised markets with established data collection systems might be surprised by the sheer diversity of fish on sale in Phnom Penh and by the lack of accurate official data. Therefore, as well as providing a general description of the fish markets, this study also evaluates feasibility of acquiring accurate data and assesses the methodologies and costs involved in such monitoring. In addition, we wanted to know if these data would bring to light broader trends in the fisheries such as changes in the composition of species, size and price. As the study only began in 2003, this paper serves simply as an introduction to the subject and provides a limited analysis of the data to illustrate some key points for those wishing to pursue similar studies.

Sources of aquatic products

Products for sale in the markets of Phnom Penh come from landing sites along the Tonle Sap River, or from wholesalers of live fish, as well as a variety of other dispersed sources. Three of the major landing sites are on the Tonle Sap. The four principle sources are:

1. Chiriang Chomreh, the main site, is 9 km north-west of Phnom Penh and receives fish from many sources around the city including: fishing lots and fish cages on the Tonle Sap and Great Lake, the Mekong and Bassac Rivers, and by barge from Viet Nam. From discussions with on-site traders and our own visual inspections, we estimate daily sales during October 2003, were in the region of 20-30 tonnes.

2. Ratini, a smaller but similar site, situated approximately 2 km upstream of Chiriang Chomreh, sells mostly live fish (mainly tilapia and *Pangasius*) from pond and cage culture. Daily sales are in the order of 10-20 tonnes.

3. Chnok Tru is a large fish processing area situated approximately 160 km upstream at the entrance to the Great Lake. Truck or barges transport large quantities of fish from this site to Phnom Penh; apparently Chiriang Chomreh or Chba Am Pou wholesale markets sell most of these fish (see Table 1). At Chnok Tru, poor-quality river fish considered unfit for human consumption sell mainly as feed for fish reared in ponds along the Tonle Sap and Great Lake; these fish are also largely destined for Phnom Penh.

4. Adjacent to Chba Am Pou, beside the Bassac River close to Phnom Penh, is another fish market that sells only live snakeheads, mostly large *Channa micropeltes*, but also some smaller *Channa striata*. Traders bring live fish to this market in metal containers on trucks mainly from the site of a river ferry on the Mekong at Neak Leuong, approximately 60 km downstream of Phnom Penh. These fish arrive at Neak Leuong by boat from cage culture operations in southern Cambodia and Viet Nam. Several other provinces, including Kandal, Kratie, Kampong Chhnang, Chhnok Tru and Preay Veng, also send snakeheads to this wholesale market. The owner of the market estimates these various sources bring in between five to seven tonnes daily.

We estimate that in 2003 these four wholesale markets sold between 35-60 tonnes of fish per day. Although market traders outside the urban area buy some fish, most was destined for retail markets in

Phnom Penh. In addition, in a city where people commonly chose to eat out, restaurateurs probably account for significant additional sales.

As well as buying from wholesale markets many stallholders trade directly with fishers, farmers, collectors, and intermediaries, who bring small quantities of fish into the city from the surrounding countryside by motorbike, some travel up to 50 km/day to do so. Retailers are typically female; a few have their own small ponds or access to other sources of fish. Husbands commonly purchase and transport products, or help their wives to purchase and transport their goods. Whilst it is not possible at this stage to quantify total fish and OAAs from these diverse sources, they certainly boost the figures of produce coming to the cities wholesale markets.

Trucks also bring fresh and preserved fish and OAAs from Cambodia's substantial marine coastal fisheries through ports at Kompot and Kompong Som, about 160 and 230 km respectively from Phnom Penh. Most traders sell either marine or inland produce; few sell both.

Figure 4. Processing of snakehead (*Channa micropeltes*) at Chiriang Chomreh; the largest wholesale market in Phnom Penh

METHODS OF TRIAL MONITORING

Whole-market fresh fish monitoring

This study, initially focused on one large market (Bang Keng Kong), monitored and recorded the fresh fish sales of all traders over a period of 15 days. The objective was to document day-to-day variations in sales and to determine the amount of time needed to carry out a short, intensive, market survey. Within this period, it was possible to establish if patterns existed and to determine whether outlying sources were causing a duplication of results.

Each day, the monitoring team questioned sellers about the amount and type of fish and OAAs they had for sale, and visually corroborated their replies. Whilst they do not keep accurate written records of sales, traders own, and use, reasonably accurate (based on limited checks) weighing scales. In addition,

sellers are able to judge weight quite well (also based on limited testing of individual sellers).

It is important to understand that traders are generally reluctant to discuss the details of their sales. They are busy, there is no incentive to answer questions, and they are concerned about the possible repercussions (such as taxation) of doing so. In addition, they believe that it is unlucky to discuss sales early in the morning. However, their reluctance was over come by offering a small monetary incentive of ten to twenty US cents a day.

Following the survey at Bang Keng Kong Market, we extended the scope of the monitoring to include sellers at five other large markets; these new surveys lasted five days each.

Market frame survey

In order to ensure that future monitoring is representative, we undertook a market-frame survey to identify the key characteristics of the markets' fish trade. These included the number of stalls, the gender of the sellers and the broad categories of produce on sale. For the purpose of the survey, we define a 'stall' as any site selling fish; it may be a clearly marked space within a regulated area of the market or just a simple site where traders spread their produce on a floor mat. Both covered and uncovered areas of the markets hold fish stalls. However, because they are more difficult to access we restricted our survey of the uncovered areas to the six 'key markets'.

In these six 'key markets' we counted the number of stalls selling different kinds of aquatic produce; inland indigenous fresh fish, inland introduced fresh fish, inland fresh OAA, and so on. The details of theses categories are given in Table 2. In the other 23 markets we counted only the stalls that sold fresh inland fish. However, because we believe that it is representative of all markets, we used the data recorded in the six 'key markets' to gain an overall impression the fish-market trade in Phnom Penh by extrapolating this data to the other 23 markets in the survey.

Figure 5. A typical two-female stall in the covered area of Central Market

Fish Identification and Taxonomy

With two exceptions, we used Mekong Fish Database (MFD 2003) to identify fish species. The common bagrid catfish, formerly referred to as *Mystus nemurus* and incorrectly attributed to *Hemibagrus filamentus* in the MFD, is classified here as *Hemibagrus* aff. *nemurus* in accordance with Kottelat (2001); in the case of the common cyprinid, *trey riel*, the classification by Roberts (1997) is adhered to. This taxon comprises two common species: *Cirrhinus lobatus* and *Cirrhimus siamensis*, which some authors classify as *Henicorhynchus*. Time constraints prevented us from separating the other cyprinid species sometimes sold with *trey riel.*

RESULTS

Table 1. *Number of stalls and traders (subdivided by gender) selling inland fresh fish in covered market areas, central Phnom Penh*

Name of market	Stalls				Sellers		
	1 female	2 female	1 male & 1 female	Total stalls	Female	Male	Total
Bang Keng Kong	24	4	14	42	46	14	60
Chass	33	1	2	36	37	2	39
Central	38	4	4	46	50	4	54
Olympic	59	5	17	81	86	17	103
Toul Tom Pong	23	6	12	41	47	12	59
Oresey	37	4	5	46	50	5	55
Total for the six key markets	**214**	**24**	**54**	**292**	**316**	**54**	**370**
Dam Kor66	66	10	15	91	101	15	116
Kon Dal	75	4	4	83	87	4	91
Chba Am Pou	50	5		55	60	0	60
Samaky	46	1	3	50	51	3	54
Toit	38		5	43	43	5	48
Toul Song Kei	22	5	3	30	35	3	38
Pochentong	27	4	1	32	36	1	37
Teak Tla	29		4	33	33	4	37
Kbal Tnol	14		7	21	21	7	28
Kilo Lek 4	22		2	24	24	2	26
Sentury	22	1		23	24	0	24
Preak Leab	13	5		18	23	0	23
Deam Tkove	22			22	22	0	22
Steng Mean Chey	12		2	14	14	2	16
Deam Ompeul	9	1	2	12	13	2	15
Kab Kor	15			15	15	0	15
Chom Pou Vuon	11			11	11	0	11
Chak Angrea Krom	6		2	8	8	2	10
Toul Kork	9			9	9	0	9
Auo Baik Ka Om	6		1	7	7	1	8
Chom Chao	7			7	7	0	7
Sy Lap	7			7	7	0	7
Heng Ly	4			4	4	0	4
Total for all markets	**746**	**60**	**105**	**911**	**971**	**105**	**1,076**

Note: Data collected between Oct and Nov 2003. Only the first six markets were monitored in detail. The table does not include sellers in uncovered areas, sellers of OAAs or sellers of marine produce.

Market frame survey

Nine hundred and eleven stalls in the covered areas of the 29 markets sold fresh inland fish (Table 1). However, in the six 'key markets' in addition to the 292 stalls in the covered areas a further 114 stalls also sold fresh inland fish, making 406 in total. In these markets, the ratio of total stalls/stalls in covered areas was 1:1.39 (406/292). Using this ratio to extrapolate to the other 23 markets, we estimate that, in total, 1,267 stalls and 1,496 traders sell fresh inland fish.

In the six 'key markets', 684 stalls sold one or more of the categories of fish and OAAs listed in Table 2. Of these, 573 (83.8%) sold inland products, 143 (20.9%) sold marine products and 32 sold both. The ratio of stalls selling any aquatic product to those selling fresh inland fish was 1:1.68 (684/406). By multiplying total estimated number of fresh inland fish stalls (1,267 - derived from Table 1) by this ratio we concluded that, in all, 2,129 stalls sold some kind of aquatic product.

Using the same ratio we estimate the total number of sellers of all aquatic products to be about 2,512 of which some 2,104 (83.8%) sold inland fish and OAAs. Approximately 90% of the traders sampled were female; we considered this high proportion representative of all the markets. As well the sellers, other people working for the stalls include labourers, generally on a part-time basis, and husbands, who commonly assist with transportation as well as other tasks; these additional workers add considerably to total number of people employed in the trade.

Table 2. *Number of stalls selling each category of product in the six key monitored markets*

Category	Bang Keng Kong	Chass	Central	Olympic	Toul Tom Poong	Oresey	Total	%
Inland FF Indigenous	45	40	46	85	69	111	396	58%
Inland FF Introduced	7	3	1		1	10	22	3%
Inland PF Indigenous	9	10	15	17	23	82	156	23%
Inland PF Introduced								0%
Inland OAA Fresh	21	6	15	26	28	41	137	20%
Inland OAA Preserved		4	3	3	2	3	15	2%
Marine FF	5	3	10	6	10	13	47	7%
Marine PF			9	4	5	35	53	8%
Marine OAA Fresh	2	2	18	11	5	19	57	8%
Marine OAA Preserved			2	4		27	33	5%
Inland FF All	**45**	**40**	**47**	**85**	**70**	**119**	**406**	**59%**
Inland All	**51**	**46**	**65**	**105**	**95**	**211**	**573**	**84%**
Marine All	**6**	**4**	**33**	**19**	**17**	**64**	**143**	**21%**
Total	**55**	**49**	**90**	**119**	**109**	**262**	**684**	**100%**

Notes: Data from October and November 2003. FF=fresh fish, PF=preserved fish, OAA=other aquatic animals. Totals are those stalls selling either or both of the included categories rather than the sum. The percentages do not add up to 100% because some stalls sell products in more than one category.

Table 3 shows the total quantity of all aquatic produce available for sale on a single day during the onset of the flood recession (October to November). At this time of year much of the fish and OAAs on sale is in the form of preserved produce, however, we were unable to get information on daily sales of this type

of foodstuff from the sellers. At Oresey, by far the most important market for preserved fish, traders sell a large variety of dried, salted and fermented fish products, both in bulk and in smaller amounts. As other markets often resell produce originating from Oresey, the large quantities we recorded to some extent reflect double counting.

Table 3. *Weight (kg) of all aquatic products on sale on a single day in the six key monitored markets*

Category	Bang Keng Kong	Chass	Central	Olympic	Toul Tom Poong	Oresey	Total	%
Inland FF Indigenous	1,453	888	962	1,672	1,319	2,102	8,395	21
Inland FF Introduced	46	12	15	0	2	186	261	1
Inland PF Indigenous	111	165	778	486	390	21,110	23,040	58
Inland PF Introduced	0	0	0	0	0	0	0	0
Inland OAA Fresh	223	46	154	213	143	375	1,154	3
Inland OAA Preserved	0	23	18	14	9	39	103	0
Marine FF	47	32	1,037	62	145	166	1,489	4
Marine PF	0	0	773	48	59	851	1,731	4
Marine OAA Fresh	25	105	1,640	162	135	708	2,775	7
Marine OAA Preserved	0	0	60	35	0	680	775	2
Inland FF All	**1,499**	**900**	**977**	**1,672**	**1,321**	**2,288**	**8,656**	**22**
Inland All	**1,833**	**1,133**	**1,927**	**2,385**	**1,863**	**23,812**	**11,952**	**30**
Marine All	**72**	**137**	**3,510**	**307**	**339**	**2,405**	**6,770**	**17**
Totals	**1,905**	**1,270**	**5,437**	**2,692**	**2,202**	**26,217**	**39,722**	**100**

Notes: Data from October-November 2003. FF=fresh fish, PF=preserved fish, OAA=other aquatic animals. Amounts of preserved products are for daily quantities 'on sale' and not daily quantities sold, whereas amounts of fresh fish are approximate daily sale quantities.

The amount of fresh inland fish on sale at this time (8,656 kg) was nearly two and a half times the amount on sale during the whole-market survey carried out in February to May (the combined average daily sales at Bang Keng Kong and the other five 'key markets' was 3,708 kg – Tables 5 and 6). This increased volume is a result of higher catches at the start of the flood recession period.

We multiplied the total weight of fresh inland fish sales in the six markets by the ratio of stalls in all markets to stalls in the six 'key markets' (911/406) to estimate the total quantity of fresh inland fish on sale in one day. This estimate, of 19.4 tonnes, is considerably lower than the estimates of fish brought into the city from wholesale markets (35-60 tonnes) made at about the same time. While sellers market some fish via other channels, this discrepancy suggests the wholesale market figures are overestimates. Increased sales of preserved fish made up for the lower level of fresh fish sales earlier in the year (approximately 12 tonnes/day).

Whole market fresh-fish monitoring

Table 4 summarises the data obtained from the 15-day survey of Bang Keng Kong market; it shows that while inland fish comprised the bulk of fresh aquatic animals sold, per kilogram they realised less value than OAAs. Marine fish accounted for only a small portion of sales (2.8%) and were on average less valuable than inland fish. Virtually all of the inland fish were indigenous species; the only introduced species recorded during the period of the survey, the Nile tilapia (*Oreochromis niloticus*), comprised

less than 1% of the total sales. On average, marine invertebrates (squid, cuttlefish, shrimps and crabs) realised a higher value than fish.

Table 4. *Summary of 15-day survey of fresh aquatic animals on sale at Bang Keng Kong market, central Phnom Penh*

Origin	Sub-category	Total (kg)	%	Value (Riel)	Value (US$)	%	Mean US$/kg
Inland	Fish	14,676	88.3	73,167,716	18,292	77.6	1.25
Inland	OAAs	560	3.4	6,692,200	1,673	7.1	2.99
Inland	Sub-total	15,236	91.6	79,859,916	19,965	84.7	1.31
Marine	Fish	467	2.8	1,772,000	443	1.9	0.95
Marine	OAAs	925	5.6	12,681,000	3,170	13.4	3.43
Marine	Sub-total	1,392	8.4	14,453,000	3,613	15.3	2.60
All	**Total**	**16,628**		**94,312,916**	**23,578**		**1.42**

Notes: Data collected between 21 Feb and 7 Mar 2003. US$1.00 = Riel 4,000

We could not easily differentiate produce from wild fisheries from that sourced from aquaculture. In fact, little 'pure' aquaculture is practised near Phnom Penh; usually wild fish are caught as fingerlings and reared, or if they are larger, fattened or 'grown-out', in cages and ponds. Wild fish, either freshly caught or as a component of fishmeal, also provide most of the fish used in feed for aquaculture.

The variability of fish sales at the Bang Keng Kong market during in the 15-day monitoring period are summarised in Figure 6. Total sales of inland fresh fish ranged from 481 to 1,590 kg/day.

The six most common of the 52 fish species recorded made up about 53% of total sales by weight (Figure 6). The data shows no patterns suggestive of regular weekly variations in sales and traders confirmed that there were no particularly important days when sales may be higher or lower. Weekend sales are also indistinguishable from weekday sales. Sales were unusually low on 1 March because on that day many sellers attended a wedding.

Choosing the optimum duration of a survey that will both generate valid results and be cost effective is difficult because variation of sales volumes has no apparent cause. On one hand, monitoring on this scale, and for this length of time, is very difficult to sustain. On the other hand, surveying the market for just a single day could prove misleading because the total catch varies daily and there a risk the survey will hit an unpredictable unrepresentative day, such as the day of the wedding.

However, based on our experience of the earlier surveys, we believed that a five-day period is sufficient to obtain valid and representative samples. In order to test this assumption, we calculated five-day rolling averages from the data recorded during the 15-day survey of Bang Keng Kong market (Table 5). As the five-day rolling averages lie with the range of +15% to -18% of the 15-day mean, we concluded that five-day surveys will provide valid data, and that the days thus freed up are better spent assessing more markets. However, taken individually, the variability of the most common species is greater than the whole population; this may be significant depending on the objectives of future surveys.

The value of sales shows similar variability, for example the 5-day rolling averages for the value of total

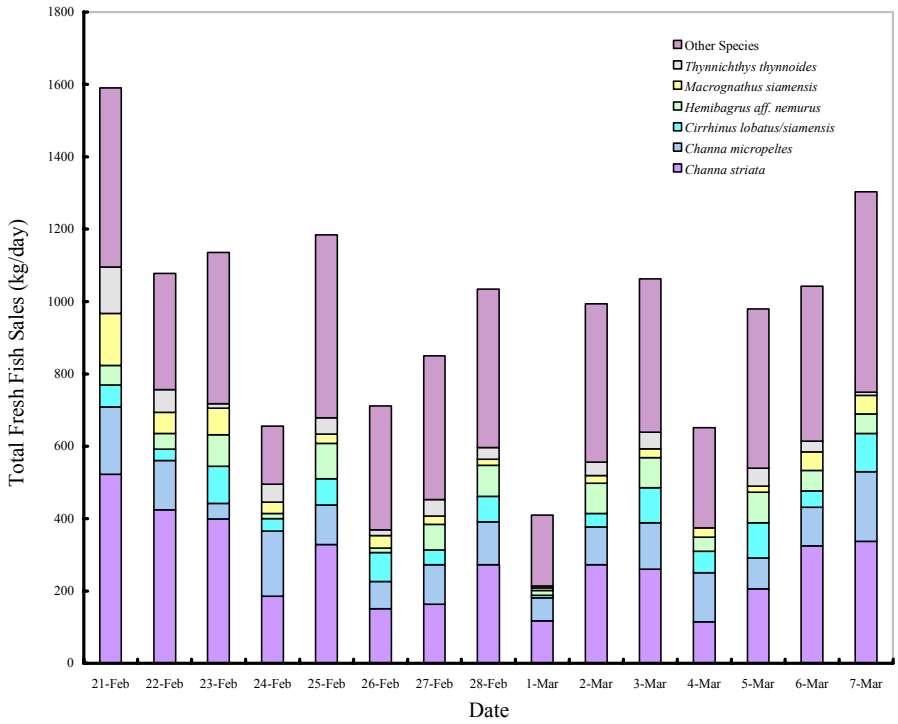

Figure 6. Total sales of inland fish in Bang Keng Kong market over 15 days; showing the six most common species

Table 5. *Weight (kg) of fish produce on sale (5-day rolling averages and 15-day mean value) at Bang Keng Kong market, central Phnom Penh*

Mean total weight	***Channa striata***	***Channa micropeltes***	***Trey riel***	***Hemibagrus* aff. *Nemurus***	***Macrognathus siamensis***	***Thynnichthys thynnoides***	**Other species**	**All fish**
Day:				**Rolling Average**				
1-5	372	131	60	59	66	60	380	**1,128**
2-6	298	108	64	51	44	37	349	**953**
3-7	245	103	66	57	37	34	365	**907**
4-8	220	119	60	56	26	38	369	**887**
5–9	206	95	54	56	21	29	376	**838**
6-10	195	94	47	53	21	27	362	**799**
7-11	217	105	50	67	19	33	378	**870**
8-12	207	110	54	61	19	30	354	**830**
9-13	194	103	60	61	19	35	355	**819**
10-14	236	112	67	69	28	41	401	**945**
11-15	248	129	81	63	34	34	424	**1,007**
Min. of 5-day means	194	94	47	51	19	27	349	**799**
Max. of 5-day means	372	131	81	69	66	60	424	**1,128**
15-day mean (all data)	272	118	63	58	40	41	389	**978**
Ratio min/15-day mean	0.71	0.80	0.75	0.87	0.46	0.67	0.90	**0.82**
Ratio max/15-day mean	1.37	1.11	1.29	1.18	1.65	1.47	1.09	**1.15**

Notes: Trey riel = *Cirrhinus lobatus* and *C. siamensis*. This data was used to generate the bar chart in Figure 6.

fresh fish sold varied between +11 to – 19% of the 15-day mean. Again, this level of variability is probably acceptable for most assessments of the value of produce on sale at markets.

Not withstanding these conclusions, fuller assessment of possible future monitoring options and survey methodologies requires data sets acquired over longer periods. Therefore, we will continue to monitoring individual sellers for a period of one year, and, by sub-sampling the data generated, we hope to compare the results derived from differing sampling intervals and durations.

Table 6. *Total weight (kg) of inland fresh fish sales over a 5-day period (Monday – Friday) in the five of the 'key markets', central Phnom Penh*

Total weight on day	Chass	Central	Olympic	Oresey	Toul Tom Pong
1	425	449	589	679	503
2	470	410	630	633	474
3	628	400	672	596	432
4	590	484	634	674	490
5	623	441	662	627	435
Average	547	437	637	642	467
Min.	425	400	588.5	596	432
Max.	628	484	672	679	503
Min/mean (%)	78	92	92	93	93
Max/mean (%)	115	111	105	106	108

Note: Data collected between 7 April and 16 May 2003.

Data obtained from monitoring carried out at the five other 'key markets' in mid-2003 are summarised in Table 6. These show that only minor variability occurs over a 5-day period. At four of the markets total sales varied by less than 11% and at Chass market by about 20%. No particular day stands out as consistently high or low in any of the markets. These data suggest that even monitoring for as little as one to two days could provide an acceptable indication of the short-term total volume of sales.

Table 7. *Proportional contribution by weight of most common species on sale in the six 'key markets', central Phnom Penh*

Species (%)	Chass	Central	Olympic	Oresey	Toul Tom Pong	5-market mean	Bang Keng Kong
Channa striata	9	29	10	33	27	21	28
Channa micropeltes	38	28	13	10	12	20	12
Wallago attu	4	11	3	9	13	7	3
Hemibagrus aff. nemurus	7	5	6	6	7	6	6
Micronema apogon	4	7	7	6	2	5	2
Cyclocheilichthys enoplos	1	5	8	8	3	5	3
Pangasius larnaudii	7	0	6	3	1	3	1
Mystus multiradiatus	3	0	3	2	8	3	1
Hemisilurus mekongensis	1	8	1	1	3	2	2
Parambassis spp.	2	0	4	4	0	2	2
Other species	24	8	40	18	25	24	41

Notes: Data was collected from all the markets during a 5-day survey recorded between 7 April and 16 May 2003. Additional data was collected from Bang Keng Kong market during a 15-day survey recorded from 21 Feb to 7 March 2003. Total weights are the same as those in Tables 5 and 6

The composition of species in these five markets was also similar to that at Bang Keng Kong; the largest proportion of total sales consisted of snakeheads with a few other species making up the remainder. Differences between Bang Keng Kong and the other markets probably reflect the time of year, or season, when the monitoring took place. *Trey riel* for example, comprised about 6% of sales at Bang Keng Kong but were relatively unimportant (<1% of sales) at the other five markets because large catches are made only during the flood recession from November to February. The two introduced species, the Nile tilapia and the silver carp (*Hypophthalmichthys molitrix*), made up less than 1% of sales.

DISCUSSIONS AND CONCLUSIONS

This study set out to quantify the retail fish trade in the markets of Phnom Penh, and to present an overview and some preliminary results as a primer for those seeking to carry out similar work in Cambodia or in the Lower Mekong Basin.

We believe that while many important lessons (listed below) learned during the surveys apply mainly to Cambodia they could also be applicable more regionally.

1. Interview a variety of people before monitoring begins to identify the number and type of markets. Document the number and gender of sellers and the types of products they sell prior to selecting the traders to monitor.

2. Offer traders a small incentive to overcome their general reluctance to provide information. Visually verify responses to questions.

3. Traders do not like to be disturbed prior to making significant sales in the morning; they considered it unlucky.

4. Most traders (about 90%) are female, so they may respond best to female interviewers.

5. Raw data (sales quantities) obtained in one-day surveys may be quite inaccurate.

6. Groups of similar species are often recorded as single species; *trey riel*, for example, comprises two main species plus a small proportion of other species.

Monitoring can be carried out on three levels:

1. A one-day survey of the numbers of traders and products in a market provides a good descriptive framework for designing further sampling surveys.

2. Whole market estimates of quantities and prices for each market trader provide complete information, but are time-consuming to obtain. The data in this study showed that the total amounts and composition of sales of inland fresh fish remained relatively stable during short sampling periods. Therefore, short-term monitoring for five days should provide reasonably

representative results.

3. Daily logbook monitoring of individual traders provides long-term data, which, if correlated with whole-market data, can be used to estimate whole-market sales.

However, we carried out this study over a very short period, but ideally, to obtain a truly representative picture, data collection should continue for one year. However, despite its short duration, the study has revealed some important information:

1. Indigenous inland fish are by far the most important component of sales of all aquatic animal foods in the markets of Phnom Penh. This is surprising given the large proportion of ethnic Chinese and Vietnamese who prefer marine species.

2. Snakeheads dominate sales because they are high quality fish that can be brought to market alive. Snakeheads come from three sources: wild-capture, captured and fattened in pens, and aquaculture. Cage culture of snakeheads has increased dramatically over the last few years, because they can be fed low-value fish, especially *trey riel*, so providing one efficient way of attenuating the seasonal flux of fish. Their market value is about three to five times that of *trey riel*, which reflects well the economics of conversion (about 3:1 or 4:1), transport, and sale of live fish.

3. OAAs are sold in relatively small quantities but fetch a relatively high value compared with fish. Their high value suggests that there is considerable scope for increasing their production.

We regard the other features of the data presented in this paper are only indicative until further information becomes available.

In contrast to the situation in developed countries, markets in Cambodia support many small suppliers and vendors, most of whom are self-employed women. Sales are for cash. There is little investment in infrastructure or refrigeration, and most food is fresh and from local sources. Despite this apparently 'undeveloped' situation, Cambodian markets continue to deliver a highly nutritious range of fresh foods (fish, meat, vegetables, and fruit) at relatively low prices, so caution should be exercised in any plans to 'improve' them or to develop more capital-intensive Western-style supermarkets.

ACKNOWLEDGEMENTS

We wish to thank Mr Ouch Vuttha for preparing the map of markets and Mr Joe Garrison for providing photographs and useful comments on the text.

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Drift of fish juveniles and larvae and invertebrates over 24-hour periods in the Mekong River at Phnom Penh, Cambodia

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ABSTRACT

Fish production in the Mekong River system depends largely upon fish spawned in productive floodplain habitats during the wet season. Many of the important fish of the lower Mekong system are flood-spawners; they spawn at the start of and during the wet season, producing large numbers of eggs that hatch quickly. The resultant larvae and juvenile fish then drift downstream in the current of the river. Understanding the spatial and temporal distribution of these larvae and juveniles in the body of the river is a prerequisite to accurate monitoring this drift.

This study, therefore, set out to investigate the distribution of the drift fauna at various times during the day and at different positions within the body of the river. The study took place, at a single location, over three days in early July 2003. Fish and invertebrates were sampled using bongo nets set near the surface of the river and close to the riverbed. A pair of samples were taken every hour (each sample took 30 minutes to collect) to provide 24 pairs of samples per day, or 72 pairs of samples in total.

The 14,000 fish identified during the study belong to 53 taxa. A few fish species made up most of the assemblage; of these about 96% were either Cyprinidae or Pangasiidae. The average density of fish in bottom samples was about three times that of surface samples. This difference was because most drift fish stay near the bottom of the river during the day. At night, when some species move to the surface, the distribution of fish was more even.

The 4,800 invertebrates identified belong to 28 taxa; the most abundant were *Macrobrachium* shrimp larvae/post-larvae, the larvae of filter-feeding caddis flies (Hydropsychidae), and dragonfly nymphs (Odonata). However, dragonfly nymphs and larger shrimps made up most of the biomass. Invertebrates were more abundant in samples taken at night than during the day. Most taxa were more abundant in bottom samples, with greatest densities during the day. Two taxa of predatory dragonfly nymphs and bugs (hemipterans) were most abundant in surface samples taken at night, perhaps because they can see their prey more easily near the surface; this prey may include fish larvae.

The study showed that future long-term monitoring must include both surface and bottom sampling. Furthermore, because most taxa drift for short periods of one to two hours duration, samples taken at regular intervals (e.g. every six hours) may not be representative of the density of the drift as they could catch, or miss, one of these periods. Therefore, for long-term monitoring at least, continuous sampling is probably the best way to get accurate estimates of the density of drifting organisms. During such monitoring, samples should be collected throughout the day, pooled for the time-intervals of interest, and then sub-sampled.

KEY WORDS: Cambodia, Mekong, drift fish, invertebrates

INTRODUCTION

Fish production in the Mekong River system depends largely upon fish spawned in productive floodplain habitats during the wet season. Many of the important fish of the lower Mekong system are 'whitefish'; these live in the main river channels for much of the year and spawn at the start of, and during, the wet season. They produce an abundance of eggs that hatch quickly; the resultant large numbers of larvae and juveniles float down stream in the current of the river (Poulsen *et al*. 2002, Sverdrup-Jensen 2002). Some authors call this downstream movement 'drift', but this usage is inaccurate because some larval and juvenile fish are not entirely passive and they are able move within

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the water body to some extent.

The composition of drift fish fauna in Viet Nam and Cambodia is well known. In Viet Nam, the records of the fauna go back to 1996. Here, specimens of fish larvae can be recovered from the large commercial *dai* nets used to catch *Pangasius* catfish for aquaculture (Nguyen *et al.* 2001, Nguyen 2003). These *dais,* which use 1-1.5 mm mesh nets, between 13 and 30 m wide, also catch large samples of drifting fish. The records to date include least 153 species of fish, belonging to 32 families and 10 orders.

In Cambodia, Chea *et al*. (2003) documented the larval drift in rivers near Phnom Penh, including the Tonle Sap, the Bassac and Mekong, both upstream and downstream of the city. Their study, which initially took place from July to September 2002, was extended into 2003. Every six hours they recorded the fish fauna collected from bongo nets set near the surface of the river. The fauna recorded so far contains over 133 species from 26 families and 16 orders. Their data also shows the drift of most species peaks during the early flood season.

Species of invertebrates also make up a large, and important, portion of the drift fauna and many, including some shrimps, crabs and insects, are part of the fishery. They form an essential element in the food chain, they prey on fish and fish prey on them. Invertebrates are also useful indicators of water quality. This paper presents the first detailed record of the invertebrate drift fauna in the Mekong basin.

However, there are few detailed records of spatial and temporal distribution of the either drift fauna, particularly variations of density within the cross-section of the river and daily or weekly fluctuations in abundance. Knowledge of these variations is essential in the design of future, long-term, monitoring of the drift fauna.

The current survey therefore involved intensive sampling over a short period with the objectives of:

- comparing the composition and abundance of the drift fauna during the day and at night
- comparing the composition and abundance of the drift fauna at the surface of the river and near the riverbed
- determining the best sampling frequency for surveys in the future

METHODS

The drift fauna was studied at a site about 5 km upstream of the well-known Quatre Bras, the junction of the Tonle Sap, Mekong and Bassac Rivers near Phnom Penh (11°34.103'N, 104°56.662'E). This important location is well downstream of many known spawning areas in the Mekong but upstream of the Tonle Sap into which the rising Mekong flow brings fish fry each flood season. At the site, this large turbid lowland river is about a kilometre wide and, at the time of sampling, the water was quite calm to about 100 m from its edge. Families who live by fishing or aquaculture often anchor their floating homes in this calm zone. At the outer edge of the strip of floating homes water depths reached 5 m, here

the current was notably stronger. We employed one of the fishing families to carry out sampling near their home. They took samples 10 m beyond the houses where the water depth was around 6 m and the current typical of the main flow of the river.

Sampling fish larvae and juveniles can use many methods, but in large floodplains simple filtering devices that catch the drifting whitefish larvae and juveniles are most appropriate. We used oceanographic plankton bongo nets measuring 1 m in diameter and 5 m in length with a mesh aperture of 1 mm. This aperture is large enough to allow most sediment and detritus to pass through so that the net does not clog too rapidly, but small enough to retain the drifting larvae of the smallest common species, cyprinids, that are typically around 4-8 mm long.

A current meter, placed in the mouth of each net, recorded the number of rotations of a propeller; multiplying the rotations by the cross-sectional area of the mouth of the net (0.785 m^2) gave an estimate of the volume of water flowing through the net. Heavy metal weights and ropes anchored the nets. Two nets were used, one held about 2 m below the surface (measured to the centre of the net) and another set about 2 m above the riverbed, these are referred to as surface and bottom nets.

The three-day study took place in early July 2003 when the river was in early flood; over the 72-hour period, the discharge of the river increased from 9,850 m^3/s to 12,654 m^3/s. The bongo nets were set on the hour for half an hour (i.e. 06:00 to 06:30; 07:00 to 07:30, and so on) and then their contents washed over a 1 mm sieve. After several days left fixing in ~ 10% formalin they were washed over a 1 mm sieve once more and the fauna separated from the detritus. After inspection under a microscope, the animals were stored in 70% ethanol. Usually the quantity of detritus in a sample was quite small (less than a handful) so additional sorting aids were unnecessary.

Larval and juvenile fish were identified using descriptions from various sources but primarily using the Mekong Fish Database (2003) and other descriptions supplied by Professor Mai Dinh Yen of the National University, Hanoi. Invertebrates were identified mainly using Dudgeon (1999). Most fish juveniles were identified to species level, but many cyprinid larvae could only be attributed to families. Invertebrates were identified to family or to higher level.

As the sun rose at 05:40 and set at 18:30, 13 pairs of samples were collected during the daylight hours. The moon rose between 07:41 and 10:24 and set between 20:46 and 23:00 and, although the moon was waxing during the study period (illumination increased from 6% to 29%), moonlight probably did not greatly affect the levels of illumination in the river.

RESULTS

Over, 97,000 m^3 of water passed through the nets during the three-day sampling period. These large volumes probably mask any minor local variations in the abundance of drift faunas. On average, each sample is the product of 668 m^3 of river water. This is comparable to towing a net, 0.785 m in cross-section, through 851 m of stationary water, assuming no resistance to through-flow. The velocity of the

current through the nets (mean 0.37 m/s, range 0.18-0.55 m/s) is much slower than that of the main river (1-2 m/s) because detritus clogs the nets. This factor may also account for some of the variations in the volume of water filtered.

Fish

Table 1. *Aggregate number of fish and species of fish grouped by family*

Family	Number of individuals	Proportion of total sample (%)	Number of species	Proportion of total number of species (%)
Cyprinidae	10,175	70.85	23	43.4
Pangasiidae	3,566	24.83	12	22.6
Clupeidae	380	2.65	4	7.5
Siluridae	119	0.83	1	1.9
Mastacembelidae	75	0.52	1	1.9
Tetraodontidae	21	0.15	1	1.9
Clariidae	11	0.08	1	1.9
Cynoglossidae	6	0.04	3	5.7
Sundasalangidae	3	0.02	1	1.9
Sisoridae	2	0.01	2	3.8
Soleidae	2	0.01	2	3.8
Belontiidae	1	0.01	1	1.9
Schilbeidae	1	0.01	1	1.9
Total	**14,362**		**53**	

Most fish (96%) and most taxa (66%) were cyprinids (river carp) or pangasiids (river catfish) (Table 1). The drift fauna included three categories of fish: larvae, post-larvae and juveniles of large species, and small pelagic species. Small unidentifiable cyprinid larvae dominated the fish fauna, comprising over 67% of the samples. For the purposes of this paper, these are grouped as Cyprinidae. It is likely that many of these were larvae of the abundant *trey riel* that is now the most common taxon caught in the Cambodian river fishery and comprise two main species, *Cirrhinus lobatus* and *C. siamensis* (Roberts 1997).

The remaining 52 taxa were all identified to species level; these were all juveniles and post-larvae of large species except for some small pelagic species including the clupeids *Clupeoides borneensis, Corica laciniata* and *Clupeichthys aesarnensis,* and the noodle fish *Sundasalanx praecox.*

Table 2. *Comparison of fish density in samples taken from the bottom and surface, during the day and at night*

	Bottom			Surface		
	Total fish	Total vol (m^3)	Mean density ($N^o/1000m^3$)	Total fish	Total vol (m^3)	Mean density ($N^o/1000m^3$)
Day	7,269	25,258	288	1,614	27,905	58
Night	2,763	21,753	127	2,716	21,346	127
Total	**10,032**	**47,011**	**213**	**4,330**	**49,251**	**88**

Overall, the density of fish in bottom samples was about two and a half times greater than in surface samples (Table 2). As the number of fish caught in bottom and surface samples taken at night were broadly equal, this difference was entirely due to the much greater numbers of fish drifting on the bottom during the day.

Table 3 gives a more a detailed breakdown of the data in Table 2. Cyprinid larvae comprise the bulk of drift fauna in bottom/day samples. A few other species (*Pangasius macronema*, *Pangasius* sp.2 and *Ompok* sp.) are also most abundant in these samples. Several species were also particularly rare in surface/day samples, contributing to the difference in overall mean densities between these and bottom/ night samples (see Table 2). The unusual distribution of *Pangasianodon hypophthalmus* (most fry of which were caught in surface/night samples) is particularly interesting as this the main species targeted by the fry fishery.

Table 3. *Mean density (N°/1000 m^3) and total numbers of the 13 most abundant fish*

Species	Bottom			Surface			Mean	3-day Total N°
	Day	Night	Mean	Day	Night	Mean	Density	
Cyprinid larvae	212.3	76.6	149.5	43.0	71.9	54.8	100.0	9,763
Pangasius siamensis	19.4	24.6	21.8	2.4	29.7	14.0	17.7	1,728
P. macronema	30.1	9.7	20.6	2.4	4.2	3.1	11.5	1,127
Pangasius conchophilus	3.8	4.0	3.9	0.2	2.7	1.2	2.5	247
C. borneensis	4.4	1.0	2.8	3.0	1.4	2.3	2.5	246
Pangasius sp. 2	5.2	2.4	3.9	0.0	0.0	0.0	1.9	186
Pangasianodon hypophthalmus	1.0	0.5	0.7	0.4	6.4	3.0	1.9	183
Sikukia stejnegeri	1.8	1.0	1.4	1.4	1.0	1.2	1.3	126
Ompok sp.	3.4	0.0	1.9	1.0	0.1	0.6	1.2	119
C. laciniata	0.9	1.2	1.1	1.4	1.4	1.4	1.2	118
Hypsibarbus sp1	1.7	1.3	1.5	0.6	0.5	0.5	1.0	98
Mastacembelus armatus	1.0	0.5	0.8	0.4	1.4	0.8	0.8	75
Pangasius polyuranodon	0.0	0.4	0.2	0.3	1.9	1.0	0.6	57
Other species	2.7	3.7	3.2	1.4	4.7	2.8	3.0	289
All fish	**287.8**	**127.0**	**213.4**	**57.8**	**127.2**	**86.7**	**147.1**	**14,362**

Note: Mean values are flow-weighted not simple arithmetic averages

Figures 1-3 (over page) illustrate the variation in density through time of the three most abundant fish taxa. Generally, the density of fish varies widely between samples with little evidence for peaks that repeat at a particular time each day. Fish drift seems to occur in random bursts within individual categories of samples (day, night, bottom and surface); most fish appear to drift in a few peaks of short duration. This means distribution of all species was highly skewed, so, for example, most species are present in under half of the samples.

The correlation between the abundance of taxa in pairs of surface and bottom samples was tested by calculating Spearman non-parametric correlation coefficients. A positive correlation indicates the fish are drifting synchronously while a negative correlation suggests the fish are moving vertically within the water column. For all except one species the coefficients were not significant, suggesting little correlation. However, in the instance of *C. borneensis*, the coefficient (Rho = 0.245, p=0.034) shows a

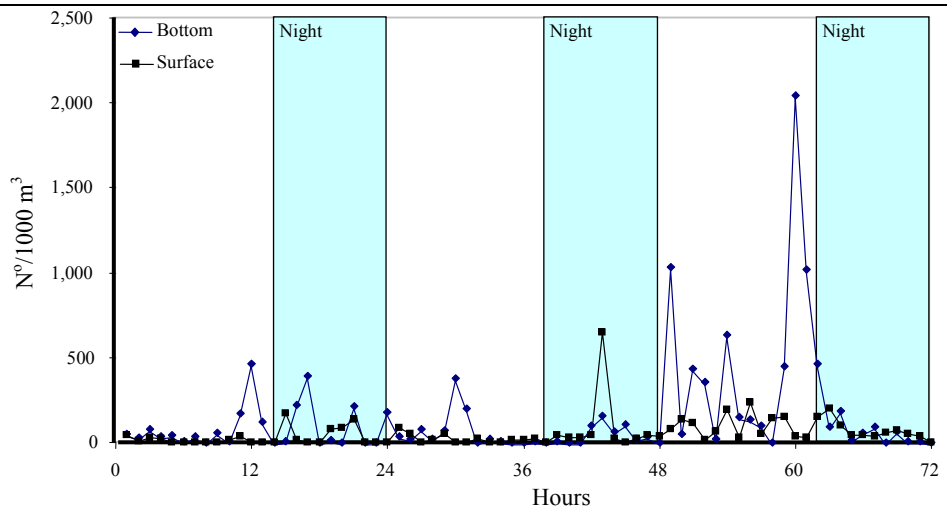

Figure 1. Drift pattern of Cyprinidae larvae

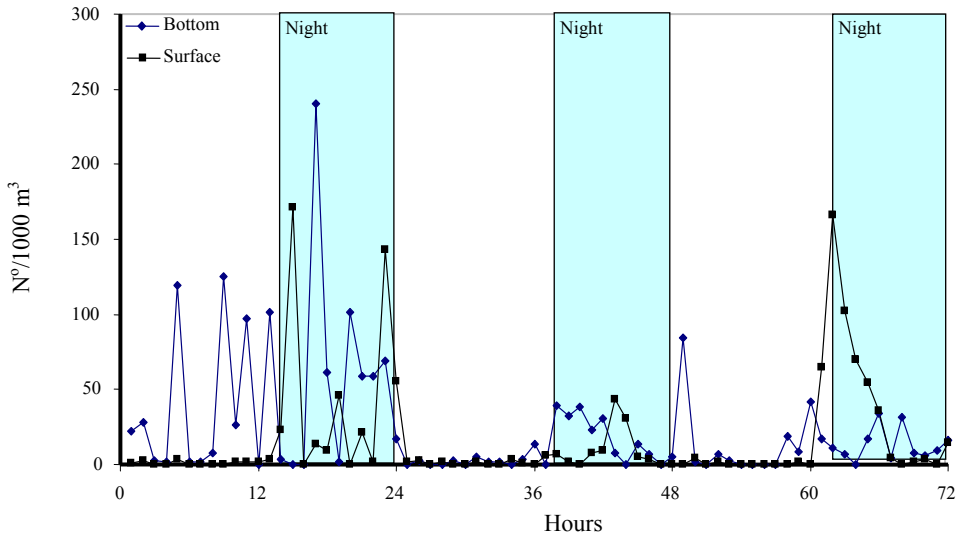

Figure 2. Drift pattern of *P. siamensis*

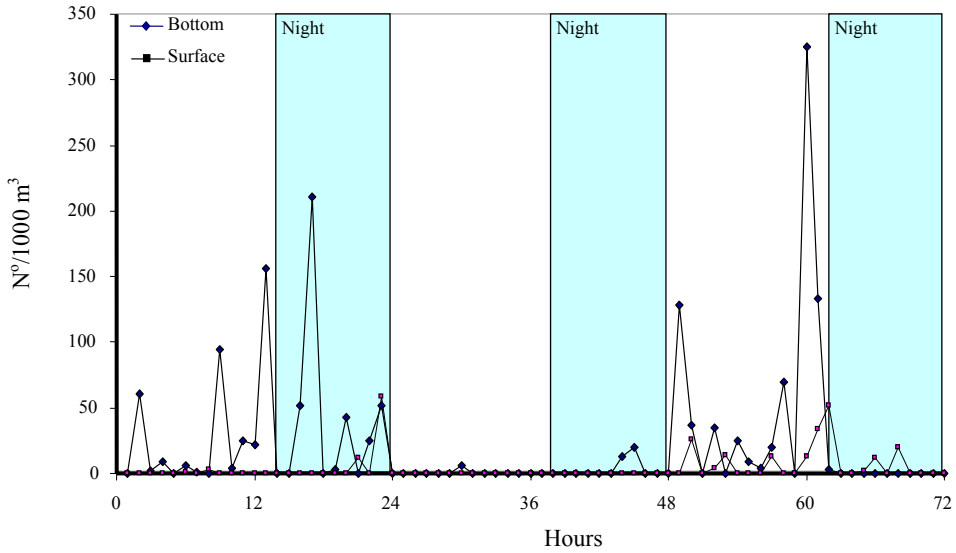

Figure 3. Drift pattern of *P. macronema*

weak correlation between surface and bottom density. Therefore, with the exception of this species, there appears to be no simple relationship between surface and bottom sample densities. The data from the three most common fish illustrates this point well (Figures 1-3).

The main objective of this study was to determine the best sampling frequency for long-term monitoring. Whilst sampling at random time intervals may be statistically ideal, sampling continuously or at regular intervals is more usual and more practical. The effect of increasing the sampling interval (and reducing the number of samples) on the estimates of mean counts of fish has been analysed in Table 4.

Table 4. *The effect of reducing sampling frequency on estimates of the mean abundance of fish*

		Mean abundance (N°/1000m^3)					**Mean as % of mean of all data**			
	Sample interval	**All**	**2h**	**3h**	**6h**	**12h**	**2h**	**3h**	**6h**	**12h**
	N° of samples	**72**	**36**	**24**	**12**	**6**	**36**	**24**	**12**	**6**
Cyprinid larvae	Bottom	150.7	149.0	156.8	241.9	375.6	99*	104	161	249
	Surface	54.0	64.9	61.3	87.2	42.7	120*	113	161	79
Pangasius siamensis	Bottom	23.6	30.1	17.1	20.4	37.6	128	72	87	159
	Surface	16.0	19.5	10.8	14.4	12.9	122	68	90	80
P. macronema	Bottom	22.1	23.7	26.0	35.9	69.6	107	118	162	315
	Surface	3.7	3.7	1.6	2.8	5.6	101	43	76	152
Pangasius conchophilus	Bottom	4.2	4.9	5.3	5.4	7.7	116	125	129	183
	Surface	1.4	2.6	0.5	0.9	0.0	185	36	64	0
Clupeoides borneensis	Bottom	2.9	2.8	2.8	2.6	2.6	98	96	91	90
	Surface	2.4	2.7	2.9	4.6	8.1	109	117	189	331
Pangasius sp 2	Bottom	3.7	4.3	6.7	9.5	18.9	115	182	255	510
	Surface	0.02	0.04	0.00	0.00	0.00	200	100	100	100
Pangasianodon hypophthalmus	Bottom	0.7	1.0	0.9	1.8	3.5	130	119	238	475
	Surface	4.1	0.6	0.5	0.3	0.5	14	12	8	12
Sikukia stejnegeri	Bottom	1.5	1.6	1.5	2.2	2.3	111	100	154	155
	Surface	1.3	1.1	0.9	1.1	0.9	82	70	82	70
Ompok sp.	Bottom	1.4	2.4	4.0	6.9	13.9	176	287	501*	1002
	Surface	0.7	0.9	0.2	0.2	0.4	117	32	26	52
C. laciniata	Bottom	1.0	1.1	1.0	1.0	0.8	106	96	100	83
	Surface	1.4	1.2	1.2	1.1	1.0	82	86	76	73
Hypsibarbus sp1	Bottom	1.5	1.9	2.3	3.0	4.7	123	152	197	305
	Surface	0.6	0.7	0.6	0.9	1.9	108	98	156	312
Mastacembelus armatus	Bottom	0.7	1.2	0.3	0.5	0.3	174	47	79	46
	Surface	0.8	0.7	0.3	0.3	0.5	87	37	32	65
Pangasius polyuranodon	Bottom	0.2	0.2	0.0	0.0	0.0	108	0	0	0
	Surface	1.2	0.4	0.2	0.2	0.0	33	15	20	0
Total	**Bottom**	**217.3**	**226.4**	**227.8**	**335.1**	**538.5**	**104**	**105***	**154***	**248**
	Surface	**91.2**	**103.2**	**83.2**	**115.4**	**75.6**	**113**	**91***	**127***	**83**

Note: * samples used as examples in the following text

The left hand columns of this table show the mean abundance of the most common taxa using the complete data set (all), and the means obtained using subsets of data taken at increasing time intervals,

i.e. at 2, 3, 6 and 12 hours. The columns on the right half of the table give the mean values of these subsets as percentages of the mean value for all 72 samples. For example, if half the number of samples are taken (i.e. every two hours rather than every hour), the estimated mean density of cyprinid larvae for bottom samples changes by only 1%, but on the surface it changes by 20%. For total fish numbers, sampling eight times per day (i.e. every three hours) generates means that are 5% greater (bottom samples) and 9% less (surface samples) than the means derived from the whole dataset. These small differences are not statistically significant.

However, increasing the sampling interval to six hours (four per day) noticeably increases the difference between the means of the subsets and total dataset. Sampling only four times per day overestimates the abundance of fish, by 54% in surface samples and 27% in bottom samples. In the instance of individual species, estimates of abundances using low sampling frequencies deviate even more. In one example, *Ompok* sp., sampling four times a day leads to a variance of 500%. The reasons for the variances depends largely upon whether the subset of samples happens to include a peak in abundance of that species; for example, for Cyprinidae larvae have a single large peak late on the third day (Figure 1).

Table 5. *Summary of the invertebrate drift*

Major group	Common name	Taxon	Total
Coleoptera	Beetles	Dytiscidae la.	1
		Hydrophilidae ad.	23
		Noteridae ad.	8
		Psephenidae la.	1
		Unid ad. Coleoptera	5
Collembola	Springtails	Collembola	2
Diptera	Two-winged flies	Chiron/Culicid pupae	141
		Chironomidaela.	1
		Empididae	1
Ephemeroptera	Mayflies	Baetidae	64
		Caenidae	1
		Heptageniidae	2
		Prosopistoma	65
Hemiptera	Bugs	Corixidae	3
		Naucoridae	78
		Veliidae	1
Odonata	Dragonflies	Corduliidae	3
		Gomphidae	417
Plecoptera	Stoneflies	Perlidae	26
Trichoptera	Caddis flies	Hydropsychidae	950
		Leptoceridae	2
		Philopotamidae	3
		Rhyacophilidae	2
		Unid. Trichoptera Family	8
Copepoda	Copepods	Copepoda	1
Decapoda	Shrimps	*Macrobrachium* la./post arvae	2,858
		Macrobrachium large	46
Isopoda	Isopods	Isopoda	52
Total			**4,765**

Invertebrates

In all, 4,765 invertebrates belonging to 28 taxa were identified (Tables 5 and 6). Table 7 shows that *Macrobrachium* larvae/post-larvae drifted at much higher densities on the bottom than near the surface, and that their greatest density was during the day. Unsurprisingly, the density patterns the total invertebrate fauna mirrors that of *Macrobrachium,* which forms the bulk of the drift. The same is true for omnivores and detritivores, but not for predatory carnivores. The two invertebrate swimming predators, Gomphidae (dragonfly nymphs) and Naucoridae (carnivorous bugs), were most abundant on the surface during the night. The mean density of all but one taxon, Isopoda, was greatest on the surface during the day.

Table 6. *Summary of the invertebrate drift by major groups*

	Total	Per cent
Insects	**1,808**	**37.9**
Coleoptera	38	0.8
Collembola	2	0.04
Diptera	143	3.0
Ephemeroptera	132	2.8
Hemiptera	82	1.7
Odonata	420	8.8
Plecoptera	26	0.5
Trichoptera	965	20.3
Crustacea	**2,957**	**62.1**
Copepoda	1	0.02
Decapoda	2,904	60.9
Isopoda	52	1.1
Total	**4,765**	

Note: Data taken from Table 5

Table 7. *Mean density (N°/1000 m^3) and total numbers of the nine most abundant invertebrates*

Taxa	Bottom			Surface			Mean density	Total Number
	Day	Night	Mean	Day	Night	Mean		
Macrobrachium larvae post-larvae	51.1	42.2	47.0	10.8	16.3	13.0	29.3	2858
Hydropsychidae	13.6	9.5	11.7	6.3	10.5	8.0	9.7	950
Gomphidae	2.8	4.3	3.5	1.9	9.4	5.1	4.3	417
Chiron/Culicid Pupae	1.1	3.2	2.1	0.1	1.9	0.9	1.4	141
Naucoridae	0.5	1.1	0.8	0.2	1.6	0.8	0.8	78
Prosopistoma	1.2	0.9	1.1	0.1	0.6	0.3	0.7	65
Baetidae	1.2	1.0	1.1	0.2	0.4	0.3	0.7	64
Isopoda	0.8	0.6	0.7	0.4	0.3	0.4	0.5	52
Macrobrachium large	0.6	0.6	0.6	0.4	0.4	0.4	0.5	46
Other taxa	0.8	1.4	1.1	0.2	1.7	0.9	1.0	93
All taxa	**73.6**	**65.0**	**69.6**	**20.6**	**43.1**	**29.9**	**48.8**	**4765**

Note: Mean values are flow-weighted not simple arithmetic averages

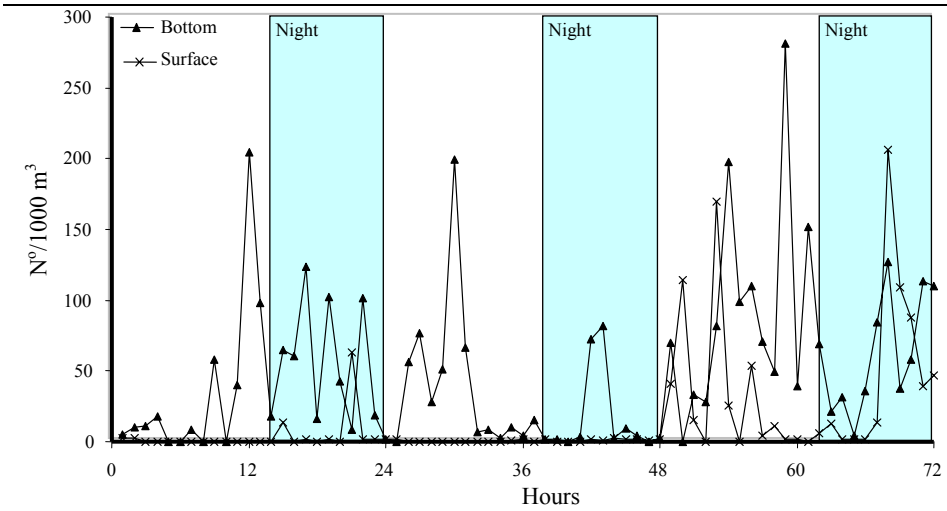

Figure 4. Drift pattern of *Macrobrachium* (shrimp) larvae/post-larvae

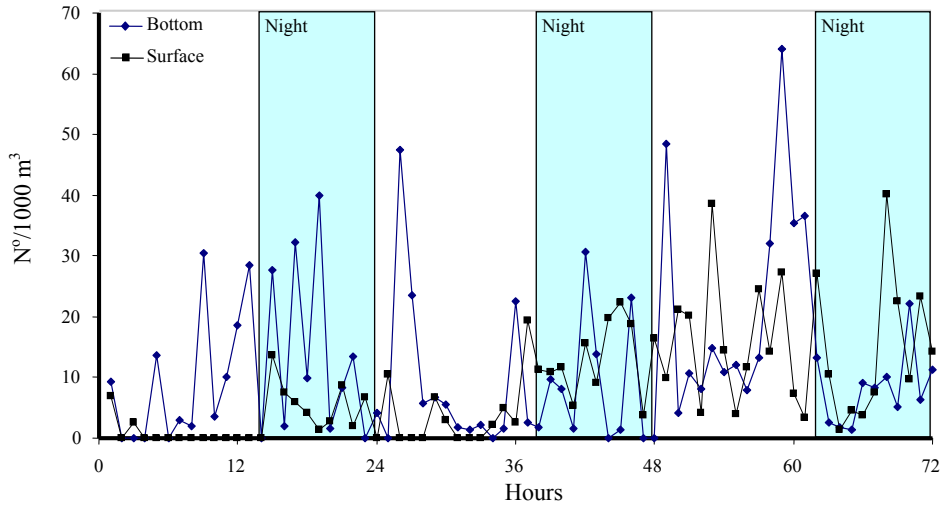

Figure 5. Drift pattern of Hydropsychidae (filter-feeding caddis fly larvae)

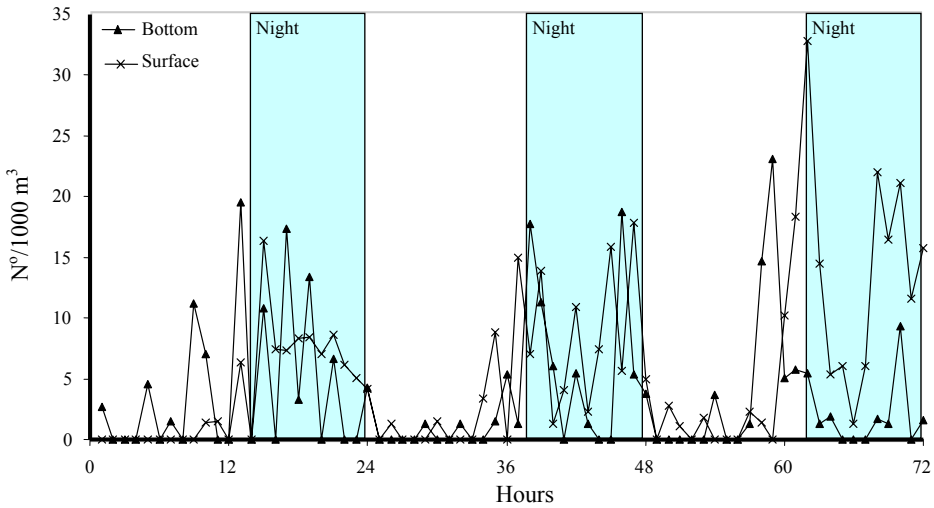

Figure 6. Drift pattern of Gomphidae (predatory dragonfly nymphs)

Figures 4-6 give the temporal drift of the three most common invertebrate taxa. Although drift of *Macrobrachium* larvae/post-larvae do not show regular peaks at the same time in each 24-hour period (Figure 4), the data for the other taxa may show repeating peaks. Hydropsychids, for example appear to be most abundant in bottom samples taken in the early morning and late afternoon (Figure 5) and the density of gomphids reaches a peak at dusk and before dawn (Figure 6). However, only additional data, collected over several more days, will confirm if these patterns are meaningful or just anomalies.

The correlations between the abundance of each taxon in surface and bottom samples were tested by calculating Spearman non-parametric correlation coefficients. For all but one species, coefficients were not significant. However, in the case of *Prosopistoma* sp. (a mayfly) the coefficient (Rho = 0.382, p=0.001) signified a strong correlation between surface and bottom densities. Despite this single example, no simple relationship exists between the density of the invertebrate drift in samples taken from the surface and those from the bottom. The data from the three most common invertebrate taxa illustrates this lack of correlation (Figures 4-6).

Table 8. *The effect of reducing sampling frequency on estimates of mean abundance of invertebrates*

		Mean abundance (N°/1000m^3)					**Mean as % of mean of all data**			
	Sample interval	**All**	**2h**	**3h**	**6h**	**12h**	**2h**	**3h**	**6h**	**12h**
	N° of samples	**72**	**36**	**24**	**12**	**6**	**36**	**24**	**12**	**6**
Baetidae	Bottom	1.3	0.8	1.4	2.0	1.4	65	108	163	165
	Surface	0.3	0.5	0.0	0.0	0.0	149	0	0	0
Chiron/Culicid pupae	Bottom	2.2	1.6	1.5	2.6	1.1	72	66	118	70
	Surface	1.1	2.0	0.3	0.2	0.0	185	26	16	0
Gomphidae	Bottom	3.6	4.1	4.3	3.8	4.9	115	119	105	118
	Surface	5.6	8.0	4.6	4.7	6.6	144	82	85	83
Hydropsychidae	Bottom	11.9	13.7	13.5	17.0	20.9	115	113	143	153
	Surface	8.6	14.4	6.0	6.0	8.4	167	69	70	58
Isopoda	Bottom	0.8	0.6	0.8	0.9	0.6	79	103	118	100
	Surface	0.4	0.7	0.3	0.2	0.2	165	88	46	30
Macrobrachium larvae post-larv.	Bottom	50.3	59.2	48.5	65.2	56.7	118	97	130	96
	Surface	14.9	27.6	6.9	5.1	7.5	185	46	34	27
Macrobrachium large	Bottom	0.6	0.8	0.5	0.7	0.6	136	79	117	77
	Surface	0.4	0.7	0.5	0.4	0.3	149	103	93	40
Naucoridae	Bottom	0.8	1.1	1.3	1.0	0.0	147	168	126	0
	Surface	0.9	1.2	0.6	0.2	0.0	139	62	24	0
Prosopistoma	Bottom	1.2	0.8	1.2	1.5	1.9	66	97	130	238
	Surface	0.4	0.7	0.1	0.2	0.0	189	26	51	0
All Invertebrates	Bottom	73.7	84.0	74.2	96.9	89.2	114	101	131	106
	Surface	33.6	57.1	20.2	17.2	23.4	170	60	51	41

The effect of reducing sample numbers (increasing sampling intervals) on estimates of mean density of invertebrates was compared (Table 8). As was the case in fish, increasing sample may lead to large errors in the estimations of abundance of particular taxa.

DISCUSSION

The dominance of juvenile and larval Pangasiids and Cyprinids in drift populations sampled at the start of the wet season floods corresponds with the findings of other studies in the lower Mekong river system (Chea *et al*. 2003, Nguyen *et al*. 2001 and Nguyen 2003).

The current study reveals spatial and temporal variability in the composition and abundance of the drift fauna. About half of all the fish drift on the bottom during the day. This is consistent with data from Viet Nam, where catches from the large commercial *dais* (which sample the entire water column) were also highest during the day (Nguyen 2003). It appears that fish larvae and juveniles generally avoid surface waters where higher light levels favour visual predators, but there is no obvious reason why the density of the drift fauna is higher during the day than at night. Only one fish species showed a very different pattern, the catfish, *P. hypophthalmus,* drifts in much higher densities in surface waters at night and, interestingly, the fry fishery for this species utilises surface-fishing hooks and nets.

To obtain representative counts of fish density, future monitoring must allow for this depth effect. Sampling across the river section will determine whether these samples, which were taken close to the edge of the river, are representative of the drift as a whole. If they are representative, we estimate that around 120 million fish per day drift in this section of the river during the flood (assuming a discharge of about 10,000 m^3/s, based on MRC hydrological records). Even if this figure is a gross over-estimation (for example, if fish are concentrated near the river's edge), the importance of this huge natural source of recruitment and the impossibility of replacing it by aquaculture (which the drift currently supports anyway) can readily be appreciated.

In their earlier investigations of drift fauna in Cambodian stretch of the Mekong, Chea *et al*. (2003) took six-hourly samples (four per day) from the surface only. As the distribution of peaks of the abundance of drift appears to be random, it is likely that their sampling generates mean values that are representative of only long-term averages. Over short periods however, samples taken at these frequencies will miss many of these peaks thereby causing inaccurate estimation of the mean abundance values. Furthermore, as they did not take bottom samples, the volume of the total drift is probably a gross under-estimate.

Long-term sampling, such as taking 24 samples per day from the surface and bottom (and taking further samples to account for variation across the river), for extended periods is prohibitively expensive. However, as we have demonstrated, if fewer samples are taken, some peaks of short duration may be missed. Continuous sampling may offer a solution. In this method, the aggregated 'all-day' sample day is itself sub-sampled to provide a daily average. This approach is probably preferable as all peaks would be sampled; however the nets still must be cleared and sampled to prevent the them clogging with detritus and to prevent decomposition of (or predation on) fish.

Expect for in instance the one species of herring (Clupeidae), the data did not show any simple relationship between surface and bottom drift of fish (when comparing each pair of samples) indicating that fish are not drifting in synchrony through the water column. Synchrony of this nature produces

positive correlations between surface and bottom samples. Nor are the fish simply moving up and down the water column, which would show as negative correlations. Rather the phenomenon of drift may involve vertical movements, as well as movements between the edges and the mainstream and between sheltered and fast-flowing areas.

Other studies have shown that larval and juvenile fish are patchily distributed because of schooling behaviour, passive movement within the water column and their preference for specific micro-habitats, especially shallow, sheltered edges (Nellen and Schnack, 1975, Bagenal and Nellen 1980, Holland 1986, Sheaffer and Nickum 1986, Casselman *et al.* 1990, Scheidegger and Bain, 1995). While most larval fish may be initially restricted to the area in close proximity to the spawning site, within days to weeks of hatching, they are sufficiently developed to move freely within the water column (Garner, 1996) and may select micro-habitats (Casselman *et al.* 1990, Scheidegger and Bain 1995, Garner, 1996, Watkins *et al*. 1997, Gozlan *et al*. 1998). Moreover, the data for each species include a range of sizes and/or ages, which may individually be showing distinct patterns, a possibility that needs further investigation.

The most abundant invertebrates in drift were larvae or post-larvae of small *Macrobrachium* shrimps, filter-feeding caddis flies (Hydropsychidae), and dragonfly nymphs (Gomphidae). The invertebrates are an interesting mixture of primarily benthic groups (such as shrimps, mayflies, stoneflies and caddis flies), which appear to drift at certain times of the day, principally dusk and dawn, and groups which swim actively for periods in the water column in pursuit of their prey (dragonfly nymphs and some beetles and bugs). Invertebrate abundance in drift samples probably reflects drift within the Mekong River, as well as input from adjacent wetlands.

Another factor may be the hard substrate provided by thousands of floating houses and associated structures that line the river for many kilometres upstream of the sampling site. Hard substrate supports more invertebrates, such as the net-building filter-feeding Hydropsychidae, which would normally be uncommon in a muddy lowland river with unstable substrate. As with fish, highest densities of most drift invertebrate taxa are in bottom waters during the day, although this pattern is less pronounced than for fish.

Dragonfly nymphs and predatory bugs were most abundant in surface waters at night, which may be because they need less light to find prey, including fish larvae. Most taxa showed no simple relationship between surface and bottom drift. The data suggest invertebrate drift peaks around dawn and dusk (as has been reported in many other studies (Dudgeon, 1999)), but more samples would be required to confirm these patterns.

With regard to long-term monitoring of invertebrates, the same considerations apply as were discussed for fish. However, as the peaks of abundance of some invertebrate drift taxa appear to repeat each day there is an even greater chance of bias, with regular, but infrequent, sampling consistently including or excluding particular acmes.

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The *dai trey linh* fishery on the Tonle Touch (Touch River), southeast Cambodia

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Assessment of Mekong Capture Fisheries Component, MRC Fisheries Programme

ABSTRACT

The *dai trey linh* fishery is a previously unstudied bag-net (or stationary trawl) fishery that has operated since 1981 on a distributary river system east of the Mekong near the border with Viet Nam. The fishery, based on seven licensed bag-nets (*dais*), catches primarily *trey linh* and other whitefish that, having migrated out of floodplains, are moving down-river. *Trey linh* are the abundant small cyprinids, *Cirrhinus lobatus* and *Cirrhinus siamensis*, known as *trey riel* elsewhere in Cambodia. The *dais* operate from June to December; other *dai* fisheries in Cambodia operate later in the year. Although licensed, the operators of the *dais* do not comply with licence conditions; for example, they are larger than permitted and fishing goes on for longer than permitted.

Monitoring of the fishery took place during the 2003 season. During this period, the composition of the fish fauna and the size fish changed; the early catch comprised larger fish that had spawned on the floodplain, but later in the season the catch included smaller fish that had grown on the floodplain. Although 161 fish species and one shrimp species were recorded, 80% of the total weight of the catch was made up of only five small cyprinid species, and 69% of this was *trey linh*. Virtually all fish were 0+ fish; i.e. in their first year of life. The size of small fish species increased during the season. Catches peaked between July and September. Most of the catch was exported to Viet Nam for food or for aquaculture feed. The total catch in 2003 was 404 tonnes valued at Riel340 M, or about US$85,000, with an average price of around US$0.21/kg; larger species were more valuable, the most expensive sold for US$1.17/kg.

The 2003 catch was reportedly much lower than in previous years and was only about 20-25% of the 1,600-2,000 tonnes caught in 2002, when unit prices were one-third to one-quarter of 2003 prices. Prices peaked in 2003 when catches peaked as buyers, surprised by the unusually low catch, competed for limited supplies. The small catch in 2003 was a result of the lower than usual flood that reduced fish production; catches were probably also affected by heavy fishing on the floodplains upstream. The dominance of young fish and very small catches of large fish confirm heavy fishing pressure. Illegal mosquito-net fences, set by villagers throughout the floodplain, catch many small fish of all species and limit fish access to habitats. *Dai* operators are in conflict with other fishers, including fishing lot lessees, local villagers, and poachers, as they all catch immature fish that *dais*, or fishers using different tackle, would otherwise catch further downstream. Furthermore, as the brood stock for the fishery may spend the dry season downstream in Vietnamese waters, the *dai trey linh* fishery impacts, and raises, local and cross-boundary issues. Maintaining and increasing fish production would benefit all parties, however to do so requires a concerted effort to reconcile their competing interests.

KEY WORDS: Cambodia, Mekong, river fisheries, fishing, *dai*

INTRODUCTION

Three *dai* (bag net or stationary trawl) fisheries, classified as 'large-scale fisheries' according to 1987 law, operate in Cambodia under licence from the Department of Fisheries. The most well known, the Tonle Sap *dai* fishery, which operates along the Tonle Sap (Sap River) in Phnom Penh and Kandal provinces, has 60 individually licensed and five unlicensed nets arranged in 14 rows. The *dai* catches fish migrating when water drains from the extensive floodplain areas around the Great Lake and Tonle Sap from mid-October to mid-March. This fishery is monitored every year (Ngor and Hem, 2001).

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The fishery described in this paper operates on the Tonle Touch (Touch River) system in Prey Veng province, and is known as *dai trey linh* (Figure 1). The name *trey linh* (or *ca linh* in Vietnamese) denotes a taxon comprising two small cyprinids, *Cirrhinus siamensis* and *Cirrhinus lobatus* (Roberts 1997), that dominate the catch and are known as *trey riel* elsewhere in Cambodia. Other small *Cirrhinus* species and small or juvenile cyprinids are sometimes included in the classification (note that in Khmer *linh* refers to another small cyprinid, *Thynnichthys thynnoides*, which also occurs in *dai* catches). This fishery has seven nets, making it smaller than the Tonle Sap *dai* fishery. There is no accurate published information on this fishery.

The third fishery, known as *dai bongkong* (or freshwater prawn bag net), is also situated in Prey Veng province. This fishery has 13 nets, set to catch the large catadromous prawn *Macrobrachium rosenbergii* (*bongkong*) as well as some fish. Detailed information about this fishery is not available.

The aim of this study, therefore, was to provide basic information about the *dai trey linh* fishery.

Description of the dai trey linh fishery

Location

The Tonle Touch River system begins as an overflow distributary of the Mekong near Kampong Cham (Figure 1). Other distributaries join the river about 20 km downstream of Phnom Penh as well as near Neak Luong (shown as a ferry crossing in Figure 1). Further downstream the river splits into two main branches, the Tonle Touch to the west and Prek Trabek to the east.

Although much of the water in the Tonle Touch River is derived from the Mekong when it overflows during the flood season, the river also drains a catchment area of about 3-4,000 km^2, including the extensive floodplains along the eastern side of the Mekong between Kampong Cham and the

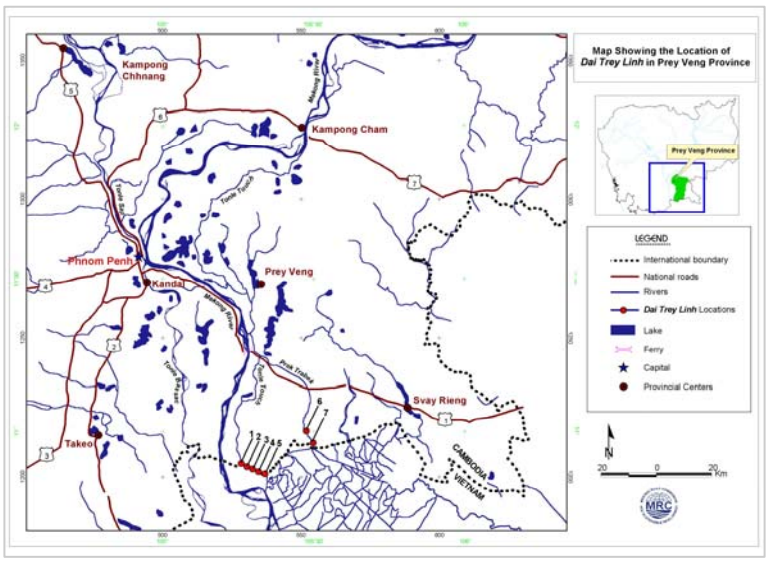

Figure 1. Location of the *dai trey linh*

Vietnamese border. In high-flood years, for example 2000, floods inundate almost the entire floodplain southeast of the town of Kampong Cham to the Mekong River in the west (MRC 2003).

Five *dais* are stationed along the stretch of the Tonle Touch that forms a part of the border between Cambodia and Viet Nam (Nos. 1-5 in Figure 1) and two more (Nos. 6 and 7) operate on Prek Trabek stream. The two rivers meander in a south-easterly direction to join the canal systems of the Vietnamese part of the delta. The floodplain stretches mainly across agricultural land used for single crop rice, but in Viet Nam, irrigation systems such as canals and floodgates allow biannual cultivation of rice.

History and licensing

This fishery started operating in 1981 and was legalised as a large-scale fishery in 1987. Ethnic Vietnamese operate the fishery under an exclusive two-year exploitation concession auctioned by the government to the highest bidder. This is one way the government extracts rent from fisheries. Currently the official fee is Riel52.9 M/yr or about US$13,200/yr.

Season of operation

The *dai trey linh* fishery is permitted to operate from August to December, but in actual fact operates from June to December, and sometimes continues to January; peak catches take place in September. Cambodian fisheries law prohibits operation of other medium and large-scale fisheries during some of this period. The open season for most other fisheries, including the Tonle Sap *dai* fishery, is from October to June. Licence conditions are similar to those of other large-scale fisheries.

Fishing gear

Each licence permits the use of a single conical bag net, or *dai*, to filter river water. The permits specify that the mouth of the net should be no more than 27 m wide and that the *dai* leave space in the river through which other craft may navigate. At the *dai trey linh* fishery however, nets are 40-55 m wide and block 40-60% of the river.

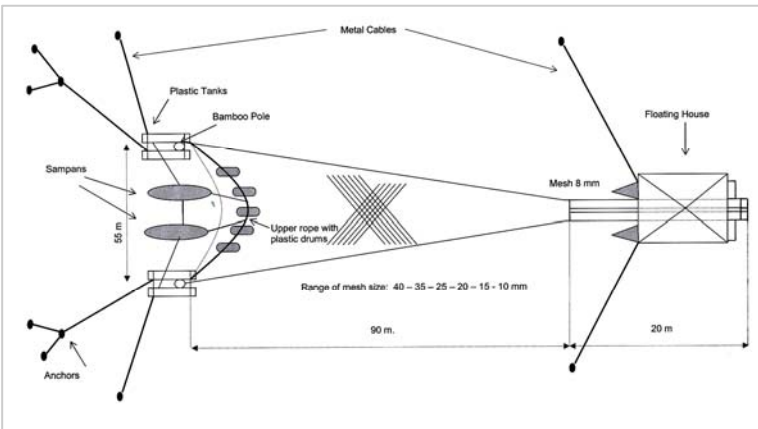

Figure 2. Schematic plan view of *dai trey linh*

Dai width and depth are adjustable; depth is about 7-10 m with a small gap between the net and the riverbed, length is about 110 m and mesh aperture reduces from about 4 cm at the mouth to 0.8 cm at the cod-end.

Each *dai* is suspended from four empty 500 L plastic drums (two each side) that are attached by metal cables to anchors. Two bamboo poles (*dang chhi)* attached to either side of the drums keep the mouth of the net open and adjust the depth of the mouth. Sampans in the centre of each *dai* stretch the upper and lower ropes and keep it stable. The crew of the *dai* use a winch to raise the cod-end of the bag onto wooden boats, which also support a small house.

All but one of the *dais* have one cod-end on the net. *Dai* No. 1 has two cod-ends that the crew empty alternately; this halves the volume of fish handled and reduces the time that fish spend in the net. The crew empty the nets and transfer the fish to live-wells in the hull of transport junks; here they separate the dead or dying fish using hand-nets. Live fish are sold mainly for human consumption while dead fish, which fetch a lower price, sell for fish-feed. The *dai* operators also keep cages of snakehead (*Channa* spp.) along the riverbank, these are fed with dead fish from the *dais*.

Basis for the fishery

The Mekong floods from May to December each year; at Phnom Penh levels usually peak in September when flow is on average about 20 times the minimum flow in the dry season (MRC 2003). The floodwaters inundate large areas and provide rich habitats in which fish can feed and rapidly grow. Many fish spawn upstream of the floodplains in the Mekong River and its tributaries (Poulsen *et al.* 2003). The early floods carry large numbers of fish eggs and fry on to the inundated floodplains. Some riverine (whitefish) species also swim into these flooded areas to spawn and feed. According to *dai trey linh* fishers, this local spawning peaks in the early flood period (usually July) and finishes mid-flood (usually September).

Early in the season, larger whitefish are caught as they migrate back out of the floodplains after spawning. Later, *s*maller fish (fingerlings or fry) are caught as they migrate back to the river after a period of weeks or months feeding on the floodplains. The Tonle Sap *dai* fishery operates later in the year because the Great Lake and its extensive floodplains act as a reservoir to delay the return of flows down the Tonle Sap (Ngor and Hem 2001). Although falling water levels may trigger migration off floodplains to the Tonle Sap, the primary reason is likely to be deteriorating water quality caused by decomposing vegetation. Welcomme (1985) records whitefish, which are relatively intolerant of low oxygen and pH, leaving the floodplains as water quality deteriorated.

River levels at the *dai trey linh* fishery may be still rising at the time of peak catches in September. The *dai trey linh* fishers believe that increasing quantities of 'black water' from floodplains flowing to the river signals the exodus of small whitefish from the floodplain to the river. The earlier migration off the floodplain (compared to the Tonle Sap fishery) probably reflects differences in floodplain hydrology and land use.

METHODS

This study was carried out at the *dai trey linh* fishery from July to December 2003. In order to obtain an accurate estimate of the volume and composition of the catch, data collectors, specially trained in fish identification, were stationed at each *dai* during the weekdays.

Dais operate round the clock during the fishing season and the interval at which the crew empties and clears nets depends on the size of the catch; it may be every one to two hours when the catch is small or up to every ten minutes when the catch is large. Therefore, in order to obtain an estimate the total daily catch, the data collectors weighed ten daytime and five night-time hauls selected at random. In addition, they also took samples from at least four hauls to gauge the composition of fish species in the catch. They used a photo flipchart of over 200 species based on the Mekong Fish Database (2003) to identify the fish. They then weighed sub-samples of fish, sorted by species, using calibrated balances, and took measurements of the length of representatives of some the common species with a measuring board accurate to one millimetre. A number of fish belonging to the most common taxa were dissected to determine the stage of sexual development.

Dai operators provided information on the value of each species and other details about the operation of the business and, along with provincial fisheries officers, gave their views on general aspects of the fishery and its place in the local fishing industry.

RESULTS

Appendices 1-3 give monthly details of the quantity, total value, and unit price of all the species fish recorded during the survey.

Size of catch

Table 1. *Monthly and annual* dai trey linh *catch, 2003*

Dai	**Monthly catches (kg/mo)**						**Total**	**% of total**
	July	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**		
1	44	720	171,701	71,421	7,700	5,040	256,626	63.5
2	22	194	18,459	10,793	5,040	3,361	37,869	9.4
3	23	304	8,085	16,474	2,373	733	27,992	6.9
4	29	53	8,055	11,195	575	322	20,229	5.0
5		97	963	1,762	463	321	3,606	0.9
6		32	36,944	6,143	1,732	620	45,471	11.3
7		170	4,905	4,369	1,960	877	12,281	3.0
Total	**118**	**1,570**	**249,112**	**122,157**	**19,843**	**11,274**	**404,074**	
% of total	**0.03**	**0.39**	**61.65**	**30.23**	**4.91**	**2.79**		

Most *dais* recovered their largest monthly catch during September when over half the total annual haul of 404 tonnes was landed. *Dias* N° 3 and 4 recorded their largest catch slightly later, in October. *Dai* No.1, the *dai* farthest upstream on the Tonle Touch, recovered most (64%) of the total catch.

The catch in July was very low, barely enough to provide some food for the crew of the *dai*. The larger catches in August allowed *dai* owners to feed their snakeheads held in cages nearby. Sales began in September. Vietnamese, who come to the *dais* (expect *Dai* N° 6) by boat, buy nearly all the live catch. In 2003, exports to Viet Nam, largely to Dong Thap Province, accounted for 90% of the *dai trey linh's* production.

Figure 3a shows that the peak catch of the fishery and the peak water level at the Neak Loeung hydrological station were both in September. *Dai* catches increased as water levels rose, with three peaks evident, each separated by 10 days (24th August, 3rd and 13th September). As water levels fell, a series of smaller peaks was evident, separated by 10-15 day intervals. The water level in 2003 was the lowest of the years from 1999 and 2003 (Figure 3b). *Dai* operators said that their catches were about 20-25% of those in 2002, and also lower than in earlier years.

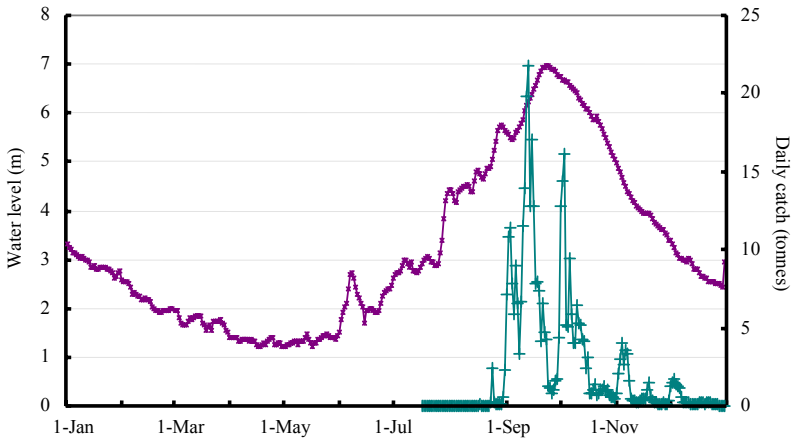

Figure 3a. Weight of catch compared with the level of the Mekong in 2003.

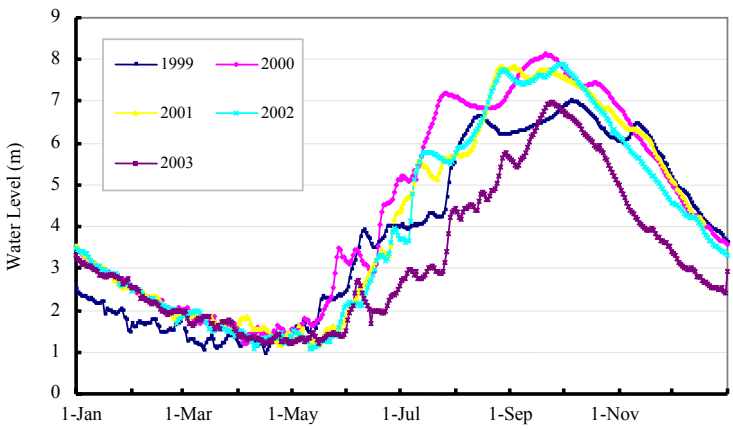

Figure 3b. Level of the Mekong in 2003 compared with the average level during the years 1999 to 2002.

Composition of catch

The survey recorded 161 fish species and one shrimp, *M. rosenbergii*. The ten most abundant species made up 85% of the catch by weight, and the five most abundant species, small cyprinids, comprised about 80% of the catch. (Table 2). Two *trey riel* species together made up about 69% of total catch.

Table 2. *Composition of catch giving total weight (kg) of the ten most abundant species*

Khmer name ***Scientific name***	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**%**
Riel tob *C. siamensis*	1	299	124,897	22,222	591	564	**148,574**	**36.8**
Riel awng kam *C. lobatus*	6	234	62,199	66,200	566	1,300	**130,505**	**32.3**
Arch kok *Labiobarbus siamensis*	0	5	6,923	9,139	539	312	**16,918**	**4.2**
Sloeuk russey *Paralaubuca typus*	0	2	13,164	2,150	285	88	**15,689**	**3.9**
Khnang veng *Labiobarbus kuhli*	1	7	1,184	4,598	2,028	1,277	**9,095**	**2.3**
Pruol kralang *Cirrhinus microlepis*	0	0	5,060	2,147	241	84	**7,532**	**1.9**
Chhpin *Hypsibarbus malcolmi*	0	0	4,068	490	165	24	**4,747**	**1.2**
Kanhchrouk chhnot *Botia helodes*	0	11	2,450	978	796	182	**4,417**	**1.1**
Chra keng *Puntioplites proctozysron*	0	0	1,783	303	1,769	259	**4,114**	**1.0**
Pra *Pangasianodon hypophthalmus*	0	56	3,026	579	235	138	**4,034**	**1.0**
Others (152 species)	110	956	24,358	13,351	12,628	7,046	**58,449**	**14.5**
Total **(all species)**	**118**	**1,570**	**249,112**	**122,157**	**19,843**	**11,274**	**404,074**	

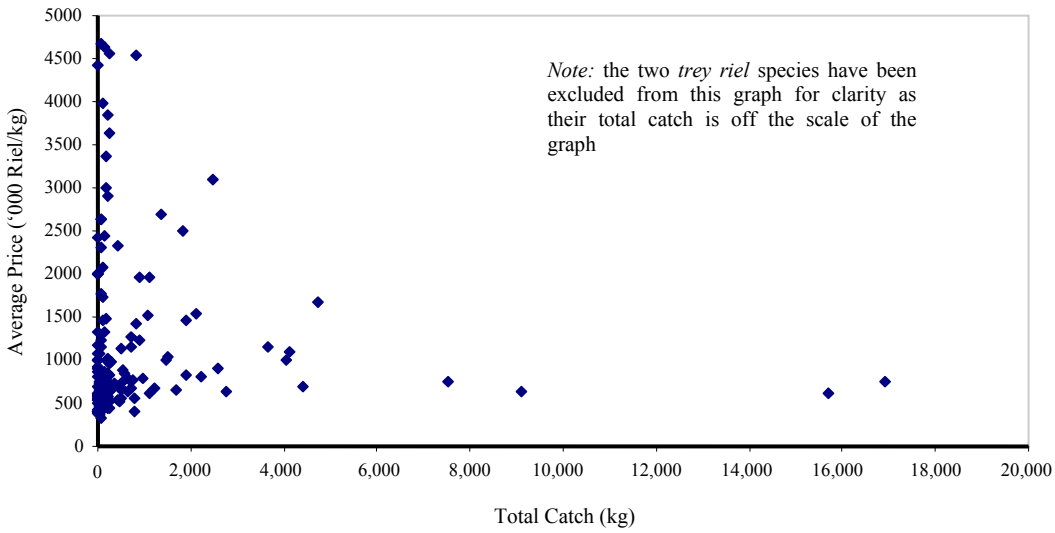

Figure 4. Weighted average price (per kg) of fish species plotted against total catch of each

Table 3. *Total value of catch (R1000s) and the ten most valuable species*

Khmer name ***Scientific name***	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**	**%**	**R/kg**
Riel tob *C. siamensis*	1	123	97,956	14,581	343	307	113,311	33.5	763
Riel awng kam *C. lobatus*	2	90	52,472	43,374	405	670	97,012	28.7	743
Arch kok *Labiobarbus siamensis*	0	2	4,940	6,705	516	620	12,783	3.8	756
Sloeuk russey *Paralaubuca typus*	0	1	8,061	1,332	140	48	9,582	2.8	611
Chhpin *Hypsibarbus malcolmi*	0	0	6,835	855	206	32	7,928	2.3	872
Kes *Micronema apogon*	7	79	3,700	960	2,463	492	7,701	2.3	1,022
Pruol/kralang *Cirrhinus microlepis*	0	0	3,942	1,586	117	49	5,695	1.7	1,200
Khnang veng *Labiobarbus kuhli*	0	2	596	3,960	880	255	5,694	1.7	1,289
Ros/ptuok *Channa striata*	4	24	2,486	941	805	332	4,593	1.4	1,116
Chra keng *Puntioplites proctozysron*	0	0	2,937	555	842	150	4,484	1.3	1,112
Others (152 species)	268	1,080	29,452	18,114	14,482	6,016	69,411	20.5	1,187
Total (all species)	**282**	**1,400**	**213,377**	**92,964**	**21,200**	**8,971**	**338,194**		

Value of catch

The total value of the catch was Riel 338,194, or about US$84,549 (Table 3). The ten most abundant species accounted for nearly 80% of the value of the catch although their unit value (R/kg) was relatively low (Table 3). About 62% of the value came form the sale of *trey riel. Dai* N°1 earned 61% of the total value of fish catch.

The abundance of a species of fish bares little relation to its value; while some of the most expensive fish (R/kg) were among the rarest species; many rarer species fetched lower prices (Figure 4). The most valuable species sold for between Riel 3-4,000/kg (US$0.75-1.00/kg); the most expensive species, the kray (*Chitala blanci*) fetched Riel 4.676/kg (Table 4).

Table 4. *The ten most valuable species (R/kg) in the dai trey linh fishery*

Khmer name	**Species**	**Catch (kg)**	**Price (R/kg)**
Kray	*Chitala blanci*	71	4,676
Khchoueng	*Macrognathus taeniagaster*	144	4,633
Bong kong (shrimp)	*Macrobrachium rosenbergii*	268	4,562
Khchoeung	*Mastacembalus favus*	809	4,539
Prama	*Boesemania microlepis*	8	4,425
Kes	*Micronema bleekeri*	105	3,974
Kes	*Kryptopterus micronema*	218	3,842
Tranel	*Hemibagrus filamentus*	261	3,644
Slat/kray	*Chitala lopis*	196	3,357
Kes	*Micronema apogon*	2,480	3,105

In 2003, the prices of fish reached a peak in September or October depending on the species; for example, sales of *trey riel,* the most commercially important component of the catch, reached a peak in September (Table 5). During these months, the total weight of the catch also reached its peak. Usually prices are low when catches are high but in 2003 the unusually low total catch kept prices buoyant. Buyers, who had planned to buy in the peak months, competed for limited supplies, driving prices upwards.

Discussions with *dai* owners and an appraisal of their limited logbook data shows that catch rates in 2003 were 20-25% of those in 2002 while unit prices were three to four times higher.

Table 5. *Monthly price (R/kg) for the ten species that contributed most to the value of sales*

Khmer name ***Scientific name***	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Mean**
Riel tob *C. siamensis*	500	411	784	656	581	545	763
Riel tob *C. siamensis*	500	411	784	656	581	545	763
Riel awng kam *C. lobatus*	288	383	844	655	715	515	743
Sloeuk russey *Paralaubuca typus*		400	612	620	491	548	611
Chhpin *Hypsibarbus malcolmi*			1,680	1,744	1,248	1,327	1,670
Kes *Micronema apogon*	2,417	3,611	3,439	3,678	3,328	1,300	3,105
Pruol/kralang *Cirrhinus microlepis*			779	739	486	587	756
Khnang veng *Labiobarbus kuhli*		314	503	861	434	200	626
Ros/ptuok *Channa striata*	2,000	747	3,123	1,646	2,615	2,577	2,498
Chra keng *Puntioplites proctozysron*			1,647	1,832	476	578	1,090
Mean price (all species)	**2,400**	**892**	**857**	**761**	**1068**	**796**	**837**

Size of fish caught

In all, the survey recorded the length of 28,589 fish (Table 6); the only exclusions were a few large fish caught in June and July.

The average length of the five common small cyprinid species increased from August through to November. Length-frequency data indicates that almost all the fish of these species were offspring spawned in 2003 (0+), only a very few (<1%) fish were older (1+) suggesting the increase in average size is due, in the main, to rapid growth of juvenile fish. The December catch however, recovered fewer larger fish, perhaps because the smallest fish leave the flooded areas last.

Similarly, fish of other species were also largely the progeny of spawning during 2003. However, the greatest average length of some species occurred in earlier months because samples collected at these times contained some larger, older, fish. For example, in the instance of *Puntioplites falcifer,* while 0+ fish dominated the catch, 1+ fish were more common in September and as a result the average length of individuals in that month was greater.

Table 6. *Weight of catch, mean length (per Month) and total number of the 18 most common fish species caught in the* dai trey linh *fishery from August to December 2003*

Khmer name ***Scientific name***	**Catch (kg)**	**Mean total monthly length (cm)**					**Total number**
		Aug	**Sept**	**Oct**	**Nov**	**Dec**	
Riel top *C. siamensis*	148,574	5.3	6.9	8.4	11.1	9.0	4,617
Riel ong kam *C. lobatus*	130,505	6.1	7.2	8.3	9.5	8.6	7,520
Arch kok *Labiobarbus siamensis*	16,918	7.1	6.8	8.8	9.3	7.4	3,750
Sloeuk russey *Paralaubuca typus*	15,689		7.5	8.0	9.1	8.0	2,442
Khnang veng *Labiobarbus kuhli*	9,095	9.2	7.1	8.3	8.5	8.0	2,503
Pruol/kralang *Cirrhinus microlepis*	7,532		11.6	12.1	11.6	10.8	910
Chhpin *Hypsibarbus* spp.	6,647		13.7	10.5	10.3	9.9	304
Pra *Pangasianodon hypophthalmus*	4,034	7.3	12.2	12.9	11.9	12.5	663
Kes *Micronema* spp.	2,480	23.9	22.9	19.2	15.5	14.4	723
Kaek *Labeo chrysophekadion*	2,235	5.0	7.7	10.4	9.6	9.4	527
Chan teas phluk *Parachela* spp.	2,094		7.0	6.2	8.6	7.9	507
Ampil tum *Puntius orphoides*	1,898		13.6	9.5	12.5	13.1	51
Linh *Thynnichthys thynnoides*	1,700	6.7	7.8			14.4	156
Chhkok *Cyclocheilichthys enoplos*	1,504		13.9	8.4	8.8	9.6	1,031
Chlaing hai *Belodontichthys truncates*	1,081		20.5	22.7	21.0	23.5	88
Chra keng *Puntioplites falcifer*	714	6.8	10.4	8.7	7.6	7.3	2,458
Krom *Osteochilus melanopleura*	705		6.0	12.5	9.4	11.2	252
Khman *Hampala* spp.	217		15.0	13.8	10.4	10.9	87
Total							**28,589**

Stage of maturity

July catches were small, mostly comprising larger whitefish with ripe gonads (i.e. full of eggs) and ready to spawn. The few large fish caught in August and September were in poor condition having already spawned. These general observations confirmed the time of migration and local spawning on the floodplain reported by the *dai* fishers. The catch of spawning fish early in the season shows that some fish move downstream on their spawning migration (the *dais* cannot catch fish swimming upstream).

Conflicts in the dai trey linh fishery

As the fishery operates in the closed fishing season conflicts frequently occur between *dai trey linh* operators, fishing lot lessees, poachers, and villagers. The various fisher's perspectives may be summarised as follows:

1. *Dai trey linh* owners: the *dais* depend on the small cyprinids that migrate down the river and out

of the floodplains back to the river. Illegal fishing on the floodplains and in rivers has a serious impact on *dai trey linh* production. The most common illegal fishing gear used is mosquito-netting fences with traps (locally known as *say yoeun*). Local fishers or villagers in collusion with fishing lot lessees operate these. In an effort to prevent this illegal fishing, *dai* operators cooperate with local fishery inspectors and help to patrol the river or floodplains. *Dais* are permitted to operate only in specific locations, but when the river overtops its banks, downstream-moving fish may not be caught by the *dais*, so they are moved to other more favourable, but non-permitted, areas. This creates conflicts, especially with fishing lot lessees.

2. Fishing lot lessees**:** most floodplain areas along the *Tonle Touch* are fishing lots. Cambodian fisheries law prohibits large-scale fisheries, particularly fishing lots, from operating in the closed season. Lessees have a right to protect their lots from illegal fishing practices. However, some lessees rent parts of their lot to fishers, who use illegal gear such as *say yoeun*, creating conflict amongst *dai trey linh* owners, lot lessees and other fishers. When water starts flowing out of the floodplains back into the river lessees often block streams or canals with bamboo fences to keep fish in their lots. This reduces the production of the *dai* fishery and leads to further conflict.

3. Poachers: poaching often takes place at night upstream of the *dais*, especially during peak catch periods. Poachers can sometimes catch huge amounts of fish in a short period, quickly covering the costs of fishing gear.

4. Villagers: although fishing with *say yoeun* is illegal, these nets are widely used by villagers in the floodplains and river near their homes. Some nets measure hundreds of metres in length and block extensive areas of floodplain. The catch is not just for home consumption; they also sell large quantities of very young fish for snakehead feed. *Dai* operators who buy a legal fishing license want provincial fishery officers to prevent these illegal practices so that they can catch more fish. However, villagers try to protect their fishing gear from confiscation.

DISCUSSION

The *dai trey linh* fishery catch is much smaller than the *dai* Tonle Sap catch, as it has only seven nets (as opposed to 65). The *dai trey linh* fishery reportedly caught 1,600-2,000 tonnes in 2002, and we recorded 404 tonnes in 2003. In the same years, the Tonle Sap *dai* fishery caught 12,427 tons and 6,551 tons respectively (MRC/DOF monitoring data). Low flood levels in 2003 severely affected both fisheries. The *dai trey linh* fishery catch was mostly (69%) very small (0+) *trey riel* and other small cyprinids, whereas the *dai* Tonle Sap catches more large fish, in 2003-4 *trey riel* comprised only about 40% of its catch by weight.

The very high proportion of *trey riel* and other small cyprinids and the preponderance 0+ fish are signs that the fishery is heavily 'fished down', removing larger fish and larger species. Even if the fishery were stable from year-to-year, many very small, young fish are being taken, both by the *dais* and by *say yeoun* when they are even younger, upstream in the floodplains. Because many fishers are in

competition it pays each of them to take any fish of any size and so the total yield of the fishery suffers, as fish are not given time to grow. This is both a local and an international, or trans-boundary, issue as any fish that manage to pass the *dais* would normally pass into Viet Nam, and have time grow more before finally being caught. It also seems likely that the larger fish caught at the start of the season are attempting to return (swimming downstream) to dry-season refuges in Viet Nam. As Viet Nam imports 90% of the catch, Viet Nam should introduce conservation measures (such as protection of brood stock) to improve production in Cambodia, even if purely out of self-interest.

Fishers can take various measures to conserve their fisheries and to reduce conflicts. Firstly, the *dais* owners and operators should observe the stipulations of fishing license and, in particular, should not start operating until August. They would lose little income as they catch relatively few fish before August, and many are larger fish, the local brood stock. *Dais* owners should not move their gear; this practice leads to conflict and damages their credibility when they demand that others comply with fisheries law they themselves transgress. However, the main issue is the extensive and increasing use of *say yeoun,* which not only unselectively catch all species and all small fish, but also create barriers to colonisation across large sections of floodplain, greatly affecting production. Finally, enforcement regulations should take place within a framework where some form of co-management reconciles competing interests, and when fishers agree to forego short-term benefits for general long-term gains.

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APPENDIX 1

Total Catch (kg) by Species by Months for *Dai Trey Linh*

Khmer name	Scientific name	Month						Total	
		Jul	Aug	Sep	Oct	Nov.	Dec.	Catch (kg)	%
RIEL TOB	*Cirrhinus siamensis*	1	299	124897	22222	591	564	148,574	36.77%
RIEL AWNG KAM	*Cirrhinus lobatus*	6	234	62199	66200	566	1300	130,505	32.30%
ARCH KOK	*Labiobarbus siamensis*	0	5	6923	9139	539	312	16,918	4.19%
SLOEUK RUSSEY	*Paralaubuca typus*	0	2	13164	2150	285	88	15,689	3.88%
KHNANG VENG	*Labiobarbus kuhli*	1	7	1184	4598	2028	1277	9,095	2.25%
PRUOL/KRALANG	*Cirrhinus microlepis*	0	0	5060	2147	241	84	7,532	1.86%
CHHPIN	*Hypsibarbus malcolmi*	0	0	4068	490	165	24	4,747	1.17%
KANHCHROUK CHHNOT	*Botia helodes*	0	11	2450	978	796	182	4,417	1.09%
CHRA KENG	*Puntioplites proctozysron*			1783	303	1769	259	4,114	1.02%
PRA	*Pangasianodon hypophthalmus*	0	56	3026	579	235	138	4,034	1.00%
ANDAT CHHKE	*Cynoglossus feldmanni*	3	169	1209	645	817	795	3,638	0.90%
CHRA KENG	*Puntioplites waandersi*	0	33	30	453	1429	823	2,768	0.69%
KRANH	*Anabas testudineus*	10	110	2005	283	133	27	2,568	0.64%
KES	*Micronema apogon*	3	22	1076	261	740	378	2,480	0.61%
KAEK	*Labeo chrysophekadion*	0	1	567	726	516	425	2,235	0.55%
CHHLANHG	*Hemibagrus spilopterus*	2	8	980	446	406	274	2,116	0.52%
CHHPIN	*Hypsibarbus lagleri*	0	0	244	1326	278	52	1,900	0.47%
AMPIL TUM	*Puntius orphoides*	0	0	1761	88	36	13	1,898	0.47%
ROS/PTUOK	*Channa striata*	2	32	796	572	308	129	1,839	0.46%
LINH	*Thynnichthys thynnoides*	1	7	1626	57	4	5	1,700	0.42%
CHHKOK	*Cyclocheilichthys enoplos*	0	0	582	286	474	162	1,504	0.37%
CHANTEAS PHLUK	*Parachela maculicauda*	0	0	985	499	1	0	1,485	0.37%
SANDAY	*Wallago attu*	0	21	1318	5	1	10	1,355	0.34%
KANHCHROUK KRAHORM	*Botia modesta*	0	23	46	570	425	144	1,208	0.30%
BANDOL AMPOAV	*Corica laciniata*	0	0	246	338	450	83	1,117	0.28%
RUSCHEK	*Acanthopsoides spp.*	0	0	26	149	864	77	1,116	0.28%
KHLANG HAI	*Belodontichthys truncatus*	0	0	461	265	315	40	1,081	0.27%
KANTRORB	*Pristolepis fasciata*	0	0	500	223	163	92	978	0.24%
KAHE LOEUNG	*Barbodes schwanenfeldii*	0	0	877	5	17	3	902	0.22%
SLAT	*Notopterus notopterus*	0	0	307	95	291	197	890	0.22%
KHMAN	*Hampala dispar*	0	0	613	60	93	48	814	0.20%
KHCHOEUNG	*Mastacembalus favus*	60	94	89	339	175	52	809	0.20%
KAMPOT	*Tetraodon spp.*	0	3	377	284	92	36	792	0.20%
PHKAR KOR	*Cirrhinus molitorella*	2	0	458	227	57	34	778	0.19%
KANHCHOS CHHNOT	*Mystus atrifasciatus*	2	7	496	80	14	143	742	0.18%
PO	*Pangasius larnaudii*	0	10	72	443	173	31	729	0.18%
CHRA KENG	*Puntioplites falcifer*	0	0	87	43	563	21	714	0.18%
KROM	*Osteochilus melanopleura*	0	0	263	174	231	37	705	0.17%
KANHCHOS CHHNOT	*Mystus mysticetus*	0	36	299	177	164	18	694	0.17%
KANHCHROUK	*Botia morleti*	0	0	55	73	430	71	629	0.16%
CHANTEAS PHLUK	*Parachela siamensis*	0	1	6	431	106	29	573	0.14%
CHHVEAT	*Pangasius macronema*	4	13	207	132	107	78	541	0.13%
CHHLONH	*Macrognathus siamensis*	0	8	390	48	56	24	526	0.13%
KANHCHROUK	*Botia beauforti*	0	0	160	269	72	5	506	0.13%
CHANGWA MOUL	*Rasbora aurotaenia*	0	4	170	217	95	16	502	0.12%
CHANGWA CHUNCHUOK	*Crossocheilus reticulatus*	0	1	42	27	87	342	499	0.12%
KAMPOUL BAY	*Cosmochilus harmandi*	0	0	264	142	48	39	493	0.12%
KAHE KRORHORM	*Barbodes altus*	0	0	428	25	22	18	493	0.12%
PRA KANDOL	*Helicophagus waandersii*	0	4	305	107	50	1	467	0.12%
SRAKA KDAM	*Cyclocheilichthys lagleri*	0	0	37	19	49	359	464	0.11%
CHHKOK PHLEUNG	*Cyclocheilichthys furcatus*	0	0	418	0	6	10	434	0.11%
ANGKAT PRAK	*Puntius aurotaeniatus*	0	4	8	191	4	213	420	0.10%
KANHCHOS BAY	*Mystus albolineatus*	3	0	33	52	181	106	375	0.09%
PAVA MOKMUOY	*Labeo dyocheilus*	0	0	195	97	0	1	293	0.07%
KROS	*Osteochilus hasseltii*	0	0	239	10	23	16	288	0.07%
CHHMAR	*Setipinna melanochir*	0	5	260	15	4	0	284	0.07%
BANG KORNG	*Macrobrabrium rogenbergii*	0	0	64	50	62	92	268	0.07%
TRANEL	*Hemibagrus filamentus*	0	0	0	175	86	0	261	0.06%
KROS	*Osteochilus waandersii*	0	0	51	22	47	136	256	0.06%

APPENDIX 1

Total Catch (kg) by Species by Months for *Dai Trey Linh*

Khmer name	Scientific name	Month						Total	
		Jul	Aug	Sep	Oct	Nov.	Dec.	Catch (kg)	%
KAMPHLIEV KHLANH	*Kryptopterus cryptopterus*	0	54	90	16	75	12	247	0.06%
KANHCHOS	*Mystus singaringan*	2	0	147	45	27	24	245	0.06%
PROR LUNG/CHRAWLANG	*Leptobarbus hoevenii*	0	0	162	62	4	13	241	0.06%
KANHCHROUK LOEUNG	*Botia lecontei*	0	1	14	185	38	2	240	0.06%
KAMPHLIEV	*Kryptopterus hexapterus*	0	0	58	0	98	83	239	0.06%
CHANGWA NONONG	*Lobocheilos quadrilineatus*	0	0	19	0	32	188	239	0.06%
ANGKAT PRAK	*Puntius brevis spp.*	0	6	78	48	27	68	227	0.06%
ANDAT CHHKE	*Synaptura marginata*	0	8	175	19	21	1	224	0.06%
KES	*Kryptopterus micronema*	0	7	0	20	116	75	218	0.05%
KHMAN	*Hampala macrolepidota*	6	1	65	22	83	40	217	0.05%
KROS	*Osteochilus microcephalus*	0	0	49	4	104	60	217	0.05%
KRAY	*Chitala ornata*	0	0	0	215	0	0	215	0.05%
BANDOL AMPOAV	*Clupeichthys aesarnensis*	0	0	0	142	70	0	212	0.05%
KAMPHLEANH SAMREI	*Trichogaster trichopterus*	0	8	122	41	29	12	212	0.05%
KAMPHLIEV	*Kryptopterus schilbeides*	1	3	3	0	25	173	205	0.05%
CHHPIN PRAK	*Barbodes gonionotus*	0	13	180	11	0	0	204	0.05%
KANHCHOS KDAONG	*Heterobagrus bocourti*	0	5	0	22	24	146	197	0.05%
SLAT / KRAY	*Chitala lopis*	0	0	0	11	171	14	196	0.05%
CHHPIN	*Hypsibarbus pierrei*	0	0	13	132	30	17	192	0.05%
KANHCHOS CHHNOT	*Mystus multiradiatus*	0	93	23	41	13	7	177	0.04%
ANDENG TUNLE	*Plotosus canius*	0	0	169	0	0	3	172	0.04%
KHSAN	*Channa gachua*	3	18	95	12	20	2	150	0.04%
KES PRAK	*Kryptopterus limpok*	0	55	89	0	1	0	145	0.04%
CHHKOK TITUY	*Albulichthys albuloides*	0	0	110	2	31	2	145	0.04%
KHCHOUENG	*Macrognathus taeniagaster*	0	0	47	95	2	0	144	0.04%
KAMBOT CHRAMOS	*Amblyrhynchichthys truncatus*	0	0	0	2	104	38	144	0.04%
KAMPHLIEV	*Kryptopterus moorei*	0	0	0	73	54	4	131	0.03%
BANDOL SOK /SMOK	*Gyrinocheilus spp.*	0	2	57	25	39	8	131	0.03%
ANDENG TUN	*Clarias macrocephalus*	0	4	2	8	44	66	124	0.03%
DANG KHTENG	*Macrochirichthys macrochirus*	0	0	57	60	1	2	120	0.03%
ANDAT CHHKE	*Cynoglossus punticeps*	2	1	13	91	1	0	108	0.03%
ANTONG	*Monopterus albus*	0	0	67	37	1	1	106	0.03%
KAMPHLIEV STOEUNG	*Kryptopterus cheveyi*	0	4	17	5	60	20	106	0.03%
KES	*Micronema bleekeri*	0	1	69	31	4	0	105	0.03%
SLOEUK RUSSEY	*Paralaubuca barroni*	0	0	27	73	1	2	103	0.03%
KRORMORM	*Ompok bimaculatus*	0	0	44	28	16	8	96	0.02%
BANG KUOY	*Luciosoma bleekeri*	0	0	92	2	2	0	96	0.02%
ANDENG TUN	*Clarias meladerma*	0	1	2	17	64	4	88	0.02%
KAMPEUS		0	0	2	14	49	17	82	0.02%
CHHVEAT	*Pangasius polyuranodon*	1	7	43	7	5	17	80	0.02%
KANTRANG PRENG	*Parambassis wolffii*	0	0	0	17	58	3	78	0.02%
ANDAT CHHKE	*Achiroides leucorhynchos*	0	0	41	33	1	3	78	0.02%
KRAY	*Chitala blanci*	0	0	0	29	42	0	71	0.02%
KULREANG/KAHOR	*Catlocarpio siamensis*	0	0	10	37	23	0	70	0.02%
KROS	*Osteochilus lini*	0	1	65	0	4	0	70	0.02%
SLOEUK RUSSEY	*Paralaubuca harmandi*	0	0	62	0	0	0	62	0.02%
PHTONG	*Xenentodon cancila spp.*	0	0	0	0	25	35	60	0.01%
SRAKA KDAM	*Cyclocheilichthys repasson*	0	0	4	40	0	15	59	0.01%
DAMREY	*Oxyeleotris marmorata*	0	0	0	38	10	9	57	0.01%
KHCHOUENG	*Macrognathus maculatus*	0	0	20	26	7	2	55	0.01%
TA AUN	*Wallago leerii*	0	0	10	34	8	3	55	0.01%
BANDOL AMPOAV	*Clupeichthys borneensis*	0	0	0	0	53	0	53	0.01%
KE	*Pangasius conchophilus*	0	0	0	46	1	4	51	0.01%
ANDAT CHHKE	*Brachirus harmandi*	0	0	13	29	7	2	51	0.01%
SRAKA KDAM	*Cyclocheilichthys apogon*	0	0	4	15	10	20	49	0.01%
PHKAR KOR	*Cyclocheilichthys armatus*	0	0	7	37	3	0	47	0.01%
BANDOL AMPOAV	*clupeichtys goniognathys*	0	1	0	0	41	0	42	0.01%
KUL CHEK	*Epalzeorhynchos frenatum*	0	1	1	17	4	17	40	0.01%
CHANGWA	*Rasbora myersi*	0	1	25	2	1	10	39	0.01%

APPENDIX 1

Total Catch (kg) by Species by Months for *Dai Trey Linh*

Khmer name	Scientific name	Month						Total	
		Jul	Aug	Sep	Oct	Nov.	Dec.	Catch (kg)	%
CHANTEAS PHLUK	*Parachela williaminae*	0	0	9	16	7	4	36	0.01%
SLOEUK RUSSEY	*Paralaubuca riveroi*	0	0	30	5	0	0	35	0.01%
KANHCHOS THMOR	*Leiocassis siamensis*	0	0	0	10	11	13	34	0.01%
KANHCHOS	*Mystus wolffi*	1	2	14	1	6	8	32	0.01%
KANH CHANH CHRAS THOM	*Parambassis apogonoides*	0	7	15	9	1	0	32	0.01%
KANH CHANH CHRAS TOCH	*Parambassis siamensis*	0	0	14	7	3	7	31	0.01%
KAMPHLEANH PHLUK	*Trichogaster microlepis*	0	11	11	0	1	4	27	0.01%
CHANGWA NONONG	*Lobocheilos melanotaenia*	0	9	3	7	0	8	27	0.0067%
ANDAT CHHKE	*Brachirus orientalis*	0	0	24	1	1	0	26	0.0064%
CHANGWA PHLIENG	*Esomus longimana*	0	0	0	4	5	14	23	0.0057%
SLOEUK RUSSEY	*Oxygaster anomalura*	0	0	7	10	0	0	17	0.0042%
CHANGWA CHHNOT	*Rasbora espei*	0	0	0	14	0	1	15	0.0037%
LOLORK SOR	*Osteochilus schlegeli*	0	0	12	0	2	0	14	0.0035%
CHANGWA	*Rasbora hobelmani*	0	0	7	6	1	0	14	0.0035%
CHANGWA NONONG	*Lobocheilos davisi*	0	0	0	0	5	7	12	0.0030%
CHANLUON MOAN	*Coilia lindmani*	0	2	4	1	3	2	12	0.0030%
CHANGWA CHHNOT	*Boraras urophthalmoides*	0	0	0	8	3	0	11	0.0027%
PRA KHCHOA	*Pangasius bocourti*	2	1	8	0	0	0	11	0.0027%
ANDENG ROEUNG	*Clarias batrachus*	0	0	1	5	0	4	10	0.00%
KANTHOR	*Trichogaster pectoralis*	0	0	3	5	0	1	9	0.0022%
PRAMA	*Boesemania microlepis*	0	1	0	0	7	0	8	0.00%
ANTONG	*Ophisternon bengalense*	0	0	0	7	0	1	8	0.0020%
KAMPREAM	*Polynemus multifilis spp.*	0	0	0	0	6	1	7	0.0017%
CHHDOR/DIEP	*Channa micropeltes*	0	0	0	0	6	0	6	0.0015%
CARP SAMANH	*Cyprinus carpio*	0	0	0	2	1	3	6	0.0015%
CHANLUON MOAN	*Coilia macrognathos*	0	1	0	0	0	5	6	0.0015%
KANHCHORN CHEY	*Channa lucius*	0	0	5	0	0	0	5	0.0012%
CHEK TUM	*Bagrichthys macracanthus*	0	1	0	0	1	2	4	0.0010%
KAOK	*Arius caelatus*	0	0	0	0	2	1	3	0.0007%
KANHCHOS KRAWBEY	*Glyptothorax fuscus*	0	3	0	0	0	0	3	0.0007%
ANDENG AFRIC	*Clarias gariepinus*	0	0	0	0	0	2	2	0.0005%
KRORMORM	*Hemisilurus mekongensis*	0	0	2	0	0	0	2	0.0005%
TRASORK	*Probarbus jullieni*	0	0	0	0	2	0	2	0.0005%
CHANGWA CHHNOT	*Rasbora paviei*	0	0	0	0	2	0	2	0.0005%
KANHCHEAK SLA	*Toxotes chatareus*	0	1	0	1	0	0	2	0.0005%
CHHPIN KRAHORM	*Hypsibarbus wetmorei*	0	0	0	0	2	0	2	0.0005%
KANHCHREA		0	1	0	0	0	0	1	0.0002%
KAOK	*Arius truncatus*	0	0	0	0	0	1	1	0.0002%
CHHKOK POKMOAT BEY	*Cyclocheilichthys heteronema*	0	0	0	0	1	0	1	0.0002%
KHLA /BEY KAMNAT	*Systomus partipentazona*	0	0	0	1	0	0	1	0.0002%
KAOK	*Hemipimelodus bicolor*	0	1	0	0	0	0	1	0.0002%
KAOK	*Hemipimelodus borneensis*	0	1	0	0	0	0	1	0.0002%
PO PRUY	*Pangasius sanitwongsei*	0	1	0	0	0	0	1	0.0002%
ANDAT CHHKE	*Brachirus panoides*	0	1	0	0	0	0	1	0.0002%
		117	1570	249113	122165	19843	11274	404083	100.00%

APPENDIX 2

Total Sale Price by Species by Months for *Dai Trey Linh*

Khmer name	Scientific name	Month						Total	
		Jul	Aug	Sep	Oct	Nov.	Dec.	Value	%
RIEL TOB	*Cirrhinus siamensis*	1	123	97,956	14,581	343	307	113,311	33.5%
RIEL AWNG KAM	*Cirrhinus lobatus*	2	90	52,472	43,374	405	670	97,012	28.7%
ARCH KOK	*Labiobarbus siamensis*	0	2	4,940	6,705	516	620	12,783	3.8%
SLOEUK RUSSEY	*Paralaubuca typus*	0	1	8,061	1,332	140	48	9,582	2.8%
CHHPIN	*Hypsibarbus malcolmi*	0	0	6,835	855	206	32	7,928	2.3%
KES	*Micronema apogon*	7	79	3,700	960	2,463	492	7,701	2.3%
PRUOL/KRALANG	*Cirrhinus microlepis*	0	0	3,942	1,586	117	49	5,695	1.7%
KHNANG VENG	*Labiobarbus kuhli*	0	2	596	3,960	880	255	5,694	1.7%
ROS/PTUOK	*Channa striata*	4	24	2,486	941	805	332	4,593	1.4%
CHRA KENG	*Puntioplites proctozysron*	0	0	2,937	555	842	150	4,484	1.3%
ANDAT CHHKE	*Cynoglossus feldmanni*	2	149	981	1,086	890	1,060	4,167	1.2%
PRA	*Pangasianodon hypophthalmus*	0	20	3,033	519	285	149	4,006	1.2%
KHCHOEUNG	*Mastacembalus favus*	228	362	367	1,861	671	184	3,672	1.1%
SANDAY	*Wallago attu*	0	42	3,577	3	3	26	3,651	1.1%
CHHLANHG	*Hemibagrus spilopterus*	3	6	1,941	622	516	158	3,246	0.96%
KANHCHROUK CHHNOT	*Botia helodes*	0	6	1,819	745	418	106	3,093	0.91%
CHHPIN	*Hypsibarbus lagleri*	0	0	131	2,286	303	57	2,777	0.82%
KRANH	*Anabas testudineus*	4	100	1,770	314	105	21	2,314	0.68%
RUSCHEK	*Acanthopsoides spp.*	0	0	13	285	1,824	70	2,192	0.65%
KAEK	*Labeo chrysophekadion*	0	1	495	784	301	222	1,802	0.53%
CHRA KENG	*Puntioplites waandersi*	0	23	24	398	852	449	1,745	0.52%
SLAT	*Notopterus notopterus*	0	0	349	135	964	290	1,738	0.51%
KHLANG HAI	*Belodontichthys truncatus*	0	0	579	436	578	49	1,643	0.49%
AMPIL TUM	*Puntius orphoides*	0	0	1,484	47	40	13	1,584	0.47%
CHHKOK	*Cyclocheilichthys enoplos*	0	0	944	202	264	141	1,551	0.46%
CHANTEAS PHLUK	*Parachela maculicauda*	0	0	985	499	0	0	1,484	0.44%
BANG KORNG	*Macrobrabrium rogenbergii*	0	0	215	223	319	466	1,223	0.36%
KHMAN	*Hampala dispar*	0	0	678	98	334	45	1,154	0.34%
KAHE LOEUNG	*Barbodes schwanenfeldii*	0	0	1,090	7	11	2	1,110	0.33%
LINH	*Thynnichthys thynnoides*	0	6	1,058	35	3	3	1,105	0.33%
CHHKOK PHLEUNG	*Cyclocheilichthys furcatus*	0	0	991	0	6	17	1,014	0.30%
TRANEL	*Hemibagrus filamentus*	0	0	0	525	426	0	951	0.28%
PO	*Pangasius larnaudii*	0	6	93	496	311	25	931	0.28%
KES	*Kryptopterus micronema*	0	27	0	48	481	281	838	0.25%
KANHCHROUK KRAHORM	*Botia modesta*	0	14	16	520	198	75	822	0.24%
KROM	*Osteochilus melanopleura*	0	0	367	224	123	106	819	0.24%
KANTRORB	*Pristolepis fasciata*	0	0	424	210	84	49	768	0.23%
BANDOL AMPOAV	*Corica laciniata*	0	0	96	256	290	50	693	0.20%
KHCHOUENG	*Macrognathus taeniagaster*	0	0	118	547	2	0	667	0.20%
SLAT / KRAY	*Chitala lopis*	0	0	0	44	599	16	658	0.19%
KRAY	*Chitala ornata*	0	0	0	625	0	0	625	0.18%
KANHCHOS CHHNOT	*Mystus atrifasciatus*	1	5	415	66	7	71	564	0.17%
KAMPOUL BAY	*Cosmochilus harmandi*	0	0	277	217	35	29	558	0.17%
KANHCHOS CHHNOT	*Mystus mysticetus*	0	18	248	147	107	13	534	0.16%
ANDENG TUNLE	*Plotosus canius*	0	0	507	0	0	8	515	0.15%
CHRA KENG	*Puntioplites falcifer*	0	0	123	34	315	11	482	0.14%
CHANTEAS PHLUK	*Parachela siamensis*	0	1	3	379	76	22	481	0.14%
CHHVEAT	*Pangasius macronema*	1	4	186	99	81	108	479	0.14%
KAMPOT	*Tetraodon spp.*	0	1	151	158	102	25	436	0.13%
KES	*Micronema bleekeri*	0	0	252	155	10	0	417	0.12%
KANHCHROUK	*Botia morleti*	0	0	47	124	202	32	405	0.12%
CHHLONH	*Macrognathus siamensis*	0	11	233	55	81	14	394	0.12%
KES PRAK	*Kryptopterus limpok*	0	82	267	0	4	0	353	0.10%
KANHCHROUK	*Botia beauforti*	0	0	76	212	46	5	339	0.10%
KRAY	*Chitala blanci*	0	0	0	29	303	0	332	0.10%
CHANGWA MOUL	*Rasbora aurotaenia*	0	2	113	141	66	8	331	0.10%
KAHE KRORHORM	*Barbodes altus*	0	0	274	31	14	10	329	0.10%
PRA KANDOL	*Helicophagus waandersii*	0	2	166	75	81	1	324	0.10%
PHKAR KOR	*Cirrhinus molitorella*	0	0	151	114	26	19	311	0.09%

APPENDIX 2

Total Sale Price by Species by Months for *Dai Trey Linh*

Khmer name	Scientific name	Month						Total	
		Jul	Aug	Sep	Oct	Nov.	Dec.	Value	%
CHHPIN	*Hypsibarbus pierrei*	0	0	26	223	18	18	285	0.08%
CHHMAR	*Setipinna melanochir*	0	2	260	14	4	0	279	0.08%
CHANGWA CHUNCHUOK	*Crossocheilus reticulatus*	0	0	24	17	58	175	274	0.08%
KANHCHOS BAY	*Mystus albolineatus*	1	0	17	40	134	80	272	0.08%
ANDENG TUN	*Clarias macrocephalus*	0	16	2	16	93	130	257	0.08%
SRAKA KDAM	*Cyclocheilichthys lagleri*	0	0	15	11	42	177	245	0.07%
KANHCHOS	*Mystus singaringan*	1	0	147	45	32	13	237	0.07%
ANDENG TUN	*Clarias meladerma*	0	4	2	23	198	5	232	0.07%
ANGKAT PRAK	*Puntius aurotaeniatus*	0	1	2	99	2	121	225	0.07%
KHMAN	*Hampala macrolepidota*	24	0	96	14	56	31	222	0.07%
ANDAT CHHKE	*Synaptura marginata*	0	9	170	18	22	1	221	0.07%
KAMPHLIEV KHLANH	*Kryptopterus cryptopterus*	0	27	56	16	93	12	202	0.06%
PAVA MOKMUOY	*Labeo dyocheilus*	0	0	119	77	0	1	197	0.06%
CHHKOK TITUY	*Albulichthys albuloides*	0	0	164	1	24	3	192	0.06%
KROS	*Osteochilus hasseltii*	0	0	147	5	22	12	186	0.05%
KAMPHLIEV	*Kryptopterus hexapterus*	0	0	41	0	65	71	177	0.05%
CHHPIN PRAK	*Barbodes gonionotus*	0	13	135	24	0	0	172	0.05%
KRORMORM	*Ompok bimaculatus*	0	0	72	54	33	8	167	0.05%
ANTONG	*Monopterus albus*	0	0	37	111	5	2	155	0.05%
KANHCHROUK LOEUNG	*Botia lecontei*	0	1	8	113	31	1	155	0.05%
PROR LUNG/CHRAWLANG	*Leptobarbus hoevenii*	0	0	111	35	2	6	153	0.05%
DAMREY	*Oxyeleotris marmorata*	0	0	0	105	25	21	151	0.04%
BANDOL AMPOAV	*Clupeichthys aesarnensis*	0	0	0	108	41	0	149	0.04%
KANHCHOS CHHNOT	*Mystus multiradiatus*	0	78	17	30	10	4	139	0.04%
ANGKAT PRAK	*Puntius brevis spp.*	0	2	35	31	20	41	129	0.04%
KHCHOUENG	*Macrognathus maculatus*	0	0	10	101	14	2	127	0.04%
CHANGWA NONONG	*Lobocheilos quadrilineatus*	0	0	11	0	16	97	125	0.04%
KAMPHLEANH SAMREI	*Trichogaster trichopterus*	0	4	69	22	19	7	121	0.04%
KROS	*Osteochilus waandersii*	0	0	15	7	26	67	115	0.03%
KAMPHLIEV	*Kryptopterus schilbeides*	0	1	1	0	18	93	113	0.03%
KHSAN	*Channa gachua*	1	8	76	8	17	1	112	0.03%
KAMPHLIEV	*Kryptopterus moorei*	0	0	0	72	38	3	112	0.03%
KANHCHOS KDAONG	*Heterobagrus bocourti*	0	1	0	22	14	73	110	0.03%
KAMPEUS		0	0	1	9	79	12	101	0.03%
KROS	*Osteochilus microcephalus*	0	0	15	1	52	30	98	0.03%
TA AUN	*Wallago leerii*	0	0	16	66	14	2	97	0.03%
BANDOL SOK /SMOK	*Gyrinocheilus spp.*	0	0	42	20	26	6	95	0.03%
KANTRANG PRENG	*Parambassis wolffii*	0	0	0	13	74	3	90	0.03%
DANG KHTENG	*Macrochirichthys macrochirus*	0	0	38	40	3	2	83	0.02%
SLOEUK RUSSEY	*Paralaubuca barroni*	0	0	8	72	1	1	82	0.02%
KAMBOT CHRAMOS	*Amblyrhynchichthys truncatus*	0	0	0	2	50	23	75	0.02%
BANG KUOY	*Luciosoma bleekeri*	0	0	72	1	1	0	74	0.02%
CHHVEAT	*Pangasius polyuranodon*	0	3	43	5	4	11	66	0.02%
KAMPHLIEV STOEUNG	*Kryptopterus cheveyi*	0	2	8	5	38	11	63	0.02%
ANDAT CHHKE	*Cynoglossus punticeps*	1	0	4	54	1	0	59	0.02%
KULREANG/KAHOR	*Catlocarpio siamensis*	0	0	5	32	20	0	57	0.02%
KE	*Pangasius conchophilus*	0	0	0	48	1	6	55	0.02%
PHTONG	*Xenentodon cancila spp.*	0	0	0	0	19	25	44	0.01%
PRAMA	*Boesemania microlepis*	0	0	0	0	35	0	35	0.01%
CHANGWA	*Rasbora myersi*	0	1	20	1	1	10	33	0.01%
ANDAT CHHKE	*Achiroides leucorhynchos*	0	0	12	17	0	2	31	0.01%
SRAKA KDAM	*Cyclocheilichthys repasson*	0	0	1	20	0	8	30	0.01%
SLOEUK RUSSEY	*Paralaubuca harmandi*	0	0	28	0	0	0	28	0.01%
SRAKA KDAM	*Cyclocheilichthys apogon*	0	0	1	7	8	10	26	0.01%
BANDOL AMPOAV	*Clupeichthys borneensis*	0	0	0	0	26	0	26	0.01%
ANDENG ROEUNG	*Clarias batrachus*	0	0	1	15	0	9	24	0.01%
ANDAT CHHKE	*Brachirus harmandi*	0	0	4	15	4	1	23	0.01%
KANHCHOS THMOR	*Leiocassis siamensis*	0	0	0	7	9	7	23	0.01%
KANHCHOS	*Mystus wolffi*	1	1	14	1	3	4	23	0.01%

APPENDIX 2

Total Sale Price by Species by Months for *Dai Trey Linh*

Khmer name	Scientific name	Month						Total	
		Jul	Aug	Sep	Oct	Nov.	Dec.	Value	%
KROS	*Osteochilus lini*	0	1	20	0	3	0	23	0.01%
KANH CHANH CHRAS THOM	*Parambassis apogonoides*	0	3	9	8	1	0	21	0.01%
KANH CHANH CHRAS TOCH	*Parambassis siamensis*	0	0	8	5	1	6	21	0.01%
KUL CHEK	*Epalzeorhynchos frenatum*	0	0	1	10	2	7	20	0.01%
KAMPHLEANH PHLUK	*Trichogaster microlepis*	0	6	11	0	1	3	20	0.01%
PHKAR KOR	*Cyclocheilichthys armatus*	0	0	2	16	1	0	19	0.01%
BANDOL AMPOAV	*clupeichtys goniognathys*	0	0	0	0	18	0	19	0.01%
CHANTEAS PHLUK	*Parachela williaminae*	0	0	3	8	3	2	15	0.0045%
SLOEUK RUSSEY	*Paralaubuca riveroi*	0	0	10	3	0	0	13	0.0037%
CHANGWA PHLIENG	*Esomus longimana*	0	0	0	2	3	7	12	0.0034%
LOLORK SOR	*Osteochilus schlegeli*	0	0	10	0	2	0	11	0.0034%
CHANGWA NONONG	*Lobocheilos melanotaenia*	0	2	1	4	0	5	11	0.0033%
CHANGWA NONONG	*Lobocheilos davisi*	0	0	0	0	5	6	11	0.0031%
SLOEUK RUSSEY	*Oxygaster anomalura*	0	0	2	8	0	0	10	0.0028%
ANDAT CHHKE	*Brachirus orientalis*	0	0	8	1	1	0	9	0.0028%
ANTONG	*Ophisternon bengalense*	0	0	0	7	0	2	9	0.0028%
KANTHOR	*Trichogaster pectoralis*	0	0	6	3	0	0	9	0.0027%
CHANGWA CHHNOT	*Rasbora espei*	0	0	0	7	0	1	8	0.0024%
KAMPREAM	*Polynemus multifilis spp.*	0	0	0	0	7	1	8	0.0022%
CHANLUON MOAN	*Coilia lindmani*	0	1	2	1	2	2	7	0.0021%
CHANGWA	*Rasbora hobelmani*	0	0	2	3	0	0	6	0.0016%
CHANGWA CHHNOT	*Boraras urophthalmoides*	0	0	0	4	1	0	5	0.0016%
KANHCHORN CHEY	*Channa lucius*	0	0	5	0	0	0	5	0.0015%
PRA KHCHOA	*Pangasius bocourti*	1	0	4	0	0	0	5	0.0014%
ANDENG AFRIC	*Clarias gariepinus*	0	0	0	0	0	4	4	0.0012%
KRORMORM	*Hemisilurus mekongensis*	0	0	4	0	0	0	4	0.0012%
TRASORK	*Probarbus jullieni*	0	0	0	0	4	0	4	0.0012%
CHEK TUM	*Bagrichthys macracanthus*	0	0	0	0	1	2	4	0.0011%
CHHDOR/DIEP	*Channa micropeltes*	0	0	0	0	3	0	3	0.0010%
CARP SAMANH	*Cyprinus carpio*	0	0	0	1	1	1	3	0.0010%
KAOK	*Arius caelatus*	0	0	0	0	2	1	3	0.0009%
CHANLUON MOAN	*Coilia macrognathos*	0	0	0	0	0	2	2	0.0007%
CHANGWA CHHNOT	*Rasbora paviei*	0	0	0	0	2	0	2	0.0005%
KANHCHOS KRAWBEY	*Glyptothorax fuscus*	0	2	0	0	0	0	2	0.0005%
KANHCHREA		0	1	0	0	0	0	1	0.0004%
KANHCHEAK SLA	*Toxotes chatareus*	0	0	0	1	0	0	1	0.0004%
KAOK	*Arius truncatus*	0	0	0	0	0	1	1	0.0003%
CHHKOK POKMOAT BEY	*Cyclocheilichthys heteronema*	0	0	0	0	1	0	1	0.0003%
CHHPIN KRAHORM	*Hypsibarbus wetmorei*	0	0	0	0	1	0	1	0.0002%
KHLA /BEY KAMNAT	*Systomus partipentazona*	0	0	0	1	0	0	1	0.0002%
KAOK	*Hemipimelodus bicolor*	0	0	0	0	0	0	0	0.0001%
KAOK	*Hemipimelodus borneensis*	0	0	0	0	0	0	0	0.0001%
PO PRUY	*Pangasius sanitwongsei*	0	0	0	0	0	0	0	0.0001%
ANDAT CHHKE	*Brachirus panoides*	0	0	0	0	0	0	0	0.0001%
		282	1,400	213,377	92,964	21,200	8,971	**338,194**	100.0%

APPENDIX 3

Monthly average price for each species (Riel/kg)

Khmer name	Scientific name	Month						Weighted Average
		Jul	Aug	Sep	Oct	Nov.	Dec.	
RIEL TOB	*Cirrhinus siamensis*	500	411	784	656	581	545	763
RIEL AWNG KAM	*Cirrhinus lobatus*	288	383	844	655	715	515	743
ARCH KOK	*Labiobarbus siamensis*		400	714	734	957	1,987	756
SLOEUK RUSSEY	*Paralaubuca typus*		400	612	620	491	548	611
CHHPIN	*Hypsibarbus malcolmi*			1,680	1,744	1,248	1,327	1,670
KES	*Micronema apogon*	2,417	3,611	3,439	3,678	3,328	1,300	3,105
PRUOL/KRALANG	*Cirrhinus microlepis*			779	739	486	587	756
KHNANG VENG	*Labiobarbus kuhli*		314	503	861	434	200	626
ROS/PTUOK	*Channa striata*	2,000	747	3,123	1,646	2,615	2,577	2,498
CHRA KENG	*Puntioplites proctozysron*			1,647	1,832	476	578	1,090
ANDAT CHHKE	*Cynoglossus feldmanni*	500	881	811	1,683	1,090	1,334	1,145
PRA	*Pangasianodon hypophthalmus*		361	1,002	896	1,212	1,079	993
KHCHOEUNG	*Mastacembalus favus*	3,801	3,846	4,121	5,489	3,832	3,544	4,539
SANDAY	*Wallago attu*		2,000	2,714	640	2,500	2,610	2,694
CHHLANHG	*Hemibagrus spilopterus*	1,479	790	1,981	1,395	1,271	575	1,534
KANHCHROUK CHHNOT	*Botia helodes*		500	743	762	525	581	700
CHHPIN	*Hypsibarbus lagleri*			535	1,724	1,091	1,100	1,461
KRANH	*Anabas testudineus*	420	912	883	1,108	789	772	901
RUSCHEK	*Acanthopsoides spp.*			518	1,912	2,111	906	1,964
KAEK	*Labeo chrysophekadion*		500	872	1,080	584	522	806
CHRA KENG	*Puntioplites waandersi*			795	878	596	545	630
SLAT	*Notopterus notopterus*			1,137	1,423	3,312	1,470	1,952
KHLANG HAI	*Belodontichthys truncatus*			1,255	1,647	1,835	1,235	1,519
AMPIL TUM	*Puntius orphoides*			843	538	1,120	962	835
CHHKOK	*Cyclocheilichthys enoplos*			1,622	706	557	872	1,031
CHANTEAS PHLUK	*Parachela maculicauda*			1,000	1,000	430		1,000
BANG KORNG	*Macrobrabrium rogenbergii*			3,357	4,455	5,145	5,064	4,562
KHMAN	*Hampala dispar*			1,105	1,629	3,587	930	1,417
KAHE LOEUNG	*Barbodes schwanenfeldii*			1,243	1,345	641	667	1,230
LINH	*Thynnichthys thynnoides*	250	809	651	609	708	660	650
CHHKOK PHLEUNG	*Cyclocheilichthys furcatus*			2,370		990	1,700	2,335
TRANEL	*Hemibagrus filamentus*				3,000	4,955		3,644
PO	*Pangasius larnaudii*		600	1,296	1,119	1,797	822	1,278
KES	*Kryptopterus micronema*		3,857		2,400	4,150	3,750	3,842
KANHCHROUK KRAHORM	*Botia modesta*		598	339	911	466	521	680
KROM	*Osteochilus melanopleura*			1,394	1,288	530	2,862	1,162
KANTRORB	*Pristolepis fasciata*			849	943	518	537	786
BANDOL AMPOAV	*Corica laciniata*			390	758	645	607	620
KHCHOUENG	*Macrognathus taeniagaster*			2,511	5,760	1,000		4,633
SLAT / KRAY	*Chitala lopis*				4,000	3,500	1,109	3,357
KRAY	*Chitala ornata*				2,907			2,907
KANHCHOS CHHNOT	*Mystus atrifasciatus*	250	726	836	820	506	495	760
KAMPOUL BAY	*Cosmochilus harmandi*			1,048	1,528	733	753	1,132
KANHCHOS CHHNOT	*Mystus mysticetus*		502	829	833	654	733	769
ANDENG TUNLE	*Plotosus canius*			3,000			2,600	2,993
CHRA KENG	*Puntioplites falcifer*			1,413	784	560	500	676
CHANTEAS PHLUK	*Parachela siamensis*		500	450	879	717	772	839
CHHVEAT	*Pangasius macronema*	304	290	900	749	754	1,385	885
KAMPOT	*Tetraodon spp.*		267	399	555	1,112	690	551
KES	*Micronema bleekeri*			3,652	5,000	2,575		3,974
KANHCHROUK	*Botia morleti*			859	1,700	469	455	644
CHHLONH	*Macrognathus siamensis*		1,400	598	1,138	1,450	563	748
KES PRAK	*Kryptopterus limpok*		1,488	3,000		4,000		2,433
KANHCHROUK	*Botia beauforti*			473	788	639	1,000	669
KRAY	*Chitala blanci*				1,000	7,214		4,676
CHANGWA MOUL	*Rasbora aurotaenia*		480	665	651	700	521	660
KAHE KRORHORM	*Barbodes altus*			641	1,227	655	538	668
PRA KANDOL	*Helicophagus waandersii*		475	544	698	1,613	1,000	694

APPENDIX 3

Monthly average price for each species (Riel/kg)

Khmer name	Scientific name	Month						Weighted Average
		Jul	Aug	Sep	Oct	Nov.	Dec.	
PHKAR KOR	*Cirrhinus molitorella*	200		330	503	463	564	400
CHHPIN	*Hypsibarbus pierrei*			2,000	1,686	605	1,047	1,482
CHHMAR	*Setipinna melanochir*		440	1,000	907	888		984
CHANGWA CHUNCHUOK	*Crossocheilus reticulatus*		400	564	619	665	513	549
KANHCHOS BAY	*Mystus albolineatus*	268		508	778	741	756	726
ANDENG TUN	*Clarias macrocephalus*		4,000	1,000	2,055	2,102	1,970	2,072
SRAKA KDAM	*Cyclocheilichthys lagleri*			397	588	847	494	527
KANHCHOS	*Mystus singaringan*	357		1,000	990	1,179	542	968
ANDENG TUN	*Clarias meladerma*		4,000	1,000	1,353	3,094	1,270	2,637
ANGKAT PRAK	*Puntius aurotaeniatus*		200	300	517	460	570	536
KHMAN	*Hampala macrolepidota*	4,000	400	1,477	641	678	775	1,022
ANDAT CHHKE	*Synaptura marginata*		1,178	971	944	1,054	1,250	986
KAMPHLIEV KHLANH	*Kryptopterus cryptopterus*		491	619	978	1,240	958	819
PAVA MOKMUOY	*Labeo dyocheilus*			610	797		1,000	674
CHHKOK TITUY	*Albulichthys albuloides*			1,491	712	758	1,300	1,321
KROS	*Osteochilus hasseltii*			615	500	943	750	645
KAMPHLIEV	*Kryptopterus hexapterus*			706		662	852	739
CHHPIN PRAK	*Barbodes gonionotus*		1,000	750	2,200			844
KRORMORM	*Ompok bimaculatus*			1,640	1,930	2,054	975	1,738
ANTONG	*Monopterus albus*			558	3,000	5,000	2,000	1,466
KANHCHROUK LOEUNG	*Botia lecontei*		1,400	605	612	808	500	645
PROR LUNG/CHRAWLANG	*Leptobarbus hoevenii*			683	568	500	435	637
DAMREY	*Oxyeleotris marmorata*				2,757	2,476	2,343	2,642
BANDOL AMPOAV	*Clupeichthys aesarnensis*				761	583		702
KANHCHOS CHHNOT	*Mystus multiradiatus*		837	750	742	754	500	784
ANGKAT PRAK	*Puntius brevis spp.*		282	450	652	729	609	569
KHCHOUENG	*Macrognathus maculatus*			500	3,865	2,000	1,000	2,300
CHANGWA NONONG	*Lobocheilos quadrilineatus*			600		500	518	522
KAMPHLEANH SAMREI	*Trichogaster trichopterus*		475	567	535	643	607	570
KROS	*Osteochilus waandersii*			300	330	543	493	449
KAMPHLIEV	*Kryptopterus schilbeides*	300	260	450		708	539	553
KHSAN	*Channa gachua*	243	463	801	704	860	700	748
KAMPHLIEV	*Kryptopterus moorei*				979	706	625	856
KANHCHOS KDAONG	*Heterobagrus bocourti*		240		1,000	563	500	557
KAMPEUS				450	657	1,607	734	1,235
KROS	*Osteochilus microcephalus*			300	300	500	500	451
TA AUN	*Wallago leerii*			1,590	1,935	1,763	500	1,769
BANDOL SOK /SMOK	*Gyrinocheilus spp.*		200	737	784	674	786	722
KANTRANG PRENG	*Parambassis wolffii*				764	1,270	990	1,149
DANG KHTENG	*Macrochirichthys macrochirus*			660	670	3,240	770	688
SLOEUK RUSSEY	*Paralaubuca barroni*			300	986	1,000	500	797
KAMBOT CHRAMOS	*Amblyrhynchichthys truncatus*				1,000	482	597	520
BANG KUOY	*Luciosoma bleekeri*			784	480	700		776
CHHVEAT	*Pangasius polyuranodon*	260	390	1,000	767	880	629	831
KAMPHLIEV STOEUNG	*Kryptopterus cheveyi*		400	480	900	636	525	593
ANDAT CHHKE	*Cynoglossus punticeps*	459	410	300	588	750		551
KULREANG/KAHOR	*Catlocarpio siamensis*			525	857	883		818
KE	*Pangasius conchophilus*				1,043	1,000	1,375	1,069
PHTONG	*Xenentodon cancila spp.*					744	721	730
PRAMA	*Boesemania microlepis*		400			5,000		4,425
CHANGWA	*Rasbora myersi*		1,000	812	500	1,000	1,000	854
ANDAT CHHKE	*Achiroides leucorhynchos*			300	500	400	667	400
SRAKA KDAM	*Cyclocheilichthys repasson*			300	512		547	506
SLOEUK RUSSEY	*Paralaubuca harmandi*			448				448
SRAKA KDAM	*Cyclocheilichthys apogon*			300	433	834	500	531
BANDOL AMPOAV	*Clupeichthys borneensis*					490		490
ANDENG ROEUNG	*Clarias batrachus*			500	3,000		2,160	2,414
ANDAT CHHKE	*Brachirus harmandi*			330	500	527	500	460

APPENDIX 3

Monthly average price for each species (Riel/kg)

Khmer name	Scientific name	Month						Weighted Average
		Jul	Aug	Sep	Oct	Nov.	Dec.	
KANHCHOS THMOR	*Leiocassis siamensis*				680	860	545	686
KANHCHOS	*Mystus wolffi*	500	405	1,000	800	508	500	724
KROS	*Osteochilus lini*		500	300		760		329
KANH CHANH CHRAS THOM	*Parambassis apogonoides*		431	600	911	1,000		663
KANH CHANH CHRAS TOCH	*Parambassis siamensis*			600	698	430	857	664
KUL CHEK	*Epalzeorhynchos frenatum*		400	800	559	500	440	505
KAMPHLEANH PHLUK	*Trichogaster microlepis*		500	1,000		1,000	650	744
PHKAR KOR	*Cyclocheilichthys armatus*			300	429	400		408
BANDOL AMPOAV	*clupeichtys goniognathys*		300			444		440
CHANTEAS PHLUK	*Parachela williaminae*			300	480	400	500	422
SLOEUK RUSSEY	*Paralaubuca riveroi*			337	500			361
CHANGWA PHLIENG	*Esomus longimana*				500	530	500	507
LOLORK SOR	*Osteochilus schlegeli*			800		920		817
CHANGWA NONONG	*Lobocheilos melanotaenia*		210	300	500		595	409
CHANGWA NONONG	*Lobocheilos davisi*					926	839	875
SLOEUK RUSSEY	*Oxygaster anomalura*			300	750			565
ANDAT CHHKE	*Brachirus orientalis*			330	750	750		362
ANTONG	*Ophisternon bengalense*				1,057		2,000	1,175
KANTHOR	*Trichogaster pectoralis*			2,000	500		480	998
CHANGWA CHHNOT	*Rasbora espei*				500		1,000	533
KAMPREAM	*Polynemus multifilis spp.*					1,120	830	1,079
CHANLUON MOAN	*Coilia lindmani*		400	450	714	767	750	593
CHANGWA	*Rasbora hobelmani*			300	500	400		393
CHANGWA CHHNOT	*Boraras urophthalmoides*				525	400		491
KANHCHORN CHEY	*Channa lucius*			1,000				1,000
PRA KHCHOA	*Pangasius bocourti*	293	200	488				426
ANDENG AFRIC	*Clarias gariepinus*						2,000	2,000
KRORMORM	*Hemisilurus mekongensis*			2,000				2,000
TRASORK	*Probarbus jullieni*					2,000		2,000
CHEK TUM	*Bagrichthys macracanthus*		400			1,000	1,100	900
CHHDOR/DIEP	*Channa micropeltes*					575		575
CARP SAMANH	*Cyprinus carpio*				700	550	430	540
KAOK	*Arius caelatus*					1,000	1,000	1,000
CHANLUON MOAN	*Coilia macrognathos*		370				400	395
CHANGWA CHHNOT	*Rasbora paviei*					900		900
KANHCHOS KRAWBEY	*Glyptothorax fuscus*		600					600
KANHCHREA			1,330					1,330
KANHCHEAK SLA	*Toxotes chatareus*		450		800			625
KAOK	*Arius truncatus*						1,000	1,000
CHHKOK POKMOAT BEY	*Cyclocheilichthys heteronema*					930		930
CHHPIN KRAHORM	*Hypsibarbus wetmorei*					400		400
KHLA /BEY KAMNAT	*Systomus partipentazona*				700			700
KAOK	*Hemipimelodus bicolor*		400					400
KAOK	*Hemipimelodus borneensis*		400					400
PO PRUY	*Pangasius sanitwongsei*		400					400
ANDAT CHHKE	*Brachirus panoides*		390					390

Using local knowledge to inventory deep pools, important fish habitats in Cambodia

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ABSTRACT

The Mekong River is the largest river in Southeast Asia and it supports a major inland fishery. The river flows through Cambodia for about 500 kms, traversing four provinces. Important fisheries habitats include deep pools, rapids, floodplains and associated wetlands. Deep pools (*un loong* in Khmer) have been mentioned by several researchers as important refuge habitats for fish. The definition of a deep pool is somewhat arbitrary; however, a deep pool is significantly deeper than surrounding riverbed and retains water in the dry season when it may be isolated from the main river. Deep pools must also be ecologically significant in the conservation of a number of fish species.

Local fishers from 25 villages along the Mekong from the Lao PDR border to Kratie were asked to identify deep pools based on water depth and importance to the local fishery, so that their location and significance might be accurately documented. Villagers identified 97 deep pools, of which two-thirds measured less than 10 ha during the dry season, and the largest of which measured approximately 200 ha. Most of these pools had a maximum dry season depth of between 20-30 m but some were up to 80 m deep. Most large pools, and the greatest concentration of deep pools, were 80-120 km downstream of the Lao PDR border. There was no apparent relationship between surface area of pools and their depth (i.e. some very small pools are very deep), rather depth depends on local conditions such as bedrock or islands that concentrate wet season flows and create scour holes.

Fishers interviewed for this study said deep pools were important habitats for at least 168 fish species, including six exotic taxa. They said nearly all the deep pools contain most of these species. The number of species they reported bore no apparent relationship to area of pools, villagers who live close to the deeper pools (>=35 m.), on average reported fewer species. The precise effect of habitat variables such as a rocky substrate requires further investigation.

Conservation of large adult fish in deep pools is important not only for maintaining fisheries locally, but also downstream in floodplain areas that depend upon this upstream brood-stock for an annual pulse of larvae and fry during the wet season. According to villagers, the critically endangered giant catfish (*Pangasiandon gigas*) still lives in pools near Kratie, and three other endangered species are widespread, highlighting the importance of this section of the Mekong. Use of gillnets has increased dramatically in the last decade; these are cheap and efficient and have reportedly had a major impact on stocks of fish in deep pools. Conservation of the fishery and the pools themselves will require management measures to limit the harvest of large fish, to control riparian clearing, and to effectively assess and mitigate impacts of dams upstream. Dams on the mainstream in this zone of the Mekong would be disastrous for the fishery. Measures are also needed to control the spread of exotic fish species from the aquarium trade in the region.

KEY WORDS: Cambodia, Mekong, river fisheries, deep pools, conservation

INTRODUCTION

The Mekong River flows through Cambodia for about 500 km traversing four provinces, Stung Treng, Kratie, Kampong Cham and Kandal. This stretch of the river contains a diverse range of important fluvial habitats including deep pools, rapids, floodplains and associated wetlands.

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The deep pools (*un loong* in Khmer) in the mainstream from the Khone Falls to the town of Kratie are important refuge habitats for fish (Poulsen *et al.* 2002). Large fish that live in these pools spawn at the start of the flood season and the rising waters carry the ensuing larvae downstream where they form the basis for recruitment for many of the floodplain fisheries.

However, as discussions with local fishers revealed, the deep pools documented up to now represent only a fraction of those in this stretch of the Mekong. The aim of this study therefore, was to fully document and map the location and general features of deep pools in the Cambodian Mekong as a first step towards developing plans for the management of fisheries in these pools.

The definition of a deep pool is somewhat arbitrary; it must be significantly deeper than the surrounding riverbed, retain water through the dry season (although it may become isolated from the mainstream during these times) and ecologically significant in the conservation of rare or endangered fish. Of course, there is a continuum between deep pools and the rest of the riverbed, but the concept of a deep pool is a useful starting point for prioritising the management of those stretches of the Mekong that are known to be of great importance to fisheries and fish conservation.

METHODS

Surveys were carried out during the 'dry' season (May to June) in 2003 and interviews and discussions held with fishers and provincial officers to gather some basic information about the deep pools and fish along the mainstream of the Mekong. Discussions with village leaders established where people mainly fished and additional discussions with five or six fishers from each village provided more background information. Groups of fishers sketched maps of the river in their vicinity pointing out the location of deep pools. We drew up preliminarily maps of the localities of deep pools by comparing the fishers' maps with information in the Mekong River Commission (MRC) Hydrographic Atlas; this contains accurate maps and partial sounding data. Global positioning system (GPS) readings, taken from local boats, gave accurate locations for the accessible 'corners' of deep pools. The maximum depths of most of the pools were verified using manual sounding or an echo sounder.

During further interviews, fishers were asked to identify the species they had caught in deep pools using a photo flipchart containing 166 common Mekong River species and six exotic species found in the wild in Cambodia as well as another ten exotic species sold in the aquarium trade in Phnom Penh. This is an updated version of the chart used by the Assessment of Mekong Fisheries Component in the four riparian countries: Cambodia, Lao PDR, Thailand and Viet Nam. The charts grouped fish species by family and gave the local as well as the corresponding scientific names. Subsequent reports on the survey use both names. Local fishers, who we asked to monitor and record their catches, provided additional data on fish populations. Villagers also gave other, more general, information about the pools.

Study area

The Mekong drops about 30m over the Khone falls, on the border between Lao PDR and Cambodia, and

another 45m in the 165km stretch between the border and the town of Kartie, which is at 20 m ASL. The adjacent land downstream of Kratie has mainly been converted to farmland (generally rice) so that riverside vegetation comprises mostly of smaller plants, such as swamp grasses, with few large trees. In Cambodia therefore, deep pools are more common in the upper section of the river where bedrock, boulders, islands and vegetation obstruct the flow producing large scour holes, or where large tributaries enter the mainstream and cause erosion of the riverbed.

Downstream from Kartie, the shallower gradient of the river and the soft substratum, together with erosion of the riverbank resulting from intensive farming, has caused the deeper parts of the riverbed to fill with sediment. As a result, there are fewer deep pools in this stretch of the river.

Fishers and villagers from 25 villages along the stretch of Mekong from the Lao PDR border downstream to Kratie town took part in the survey; in all, the survey encompassed twelve communes in five districts of the Stung Treng and Kratie provinces.

RESULTS

Distribution and size of deep pools

Maps giving the location of 95 deep pools identified by the fishers are included in Appendix 2. The maps run sequentially from the Lao PDR border in the north to the town of Kratie in the south. Appendix 1 gives more details on the location of each pool, including its size and geographic co-ordinates.

The location of deep pools in this section of the Mekong distribute in clusters (Figure 1, over page). These often occur where the river splits and flows through narrow channels between rocky islands. During the wet season, the increased flow in these confined channels scours sediment and debris from the bed of the pools. Along this section of the river, there is no obvious correlation between distance from the border with Lao PDR and maximum depth of pools. The section of the river upstream of Sambor (80-120km) contains the largest aggregation of deep pools. This stretch also holds most of the large pools (Figure 2, over page).

The 20 km stretch of the Mekong downstream from the border with Lao PDR has few large pools; most are smaller than ten hectares. These pools are usually confined by hard bedrock which, being more resistant to erosion, limits their size (Figure 2).

During the dry season most of the deep pools are quite small (<10 ha), the largest is about 200 ha (Figure 3, over page).

Although the maximum depth of the most of pools was between 11 and 30 metres (the deepest was about 80 metres), villagers classified some shallow pools, which were only three to five metres deep, as deep pools (*un long*) because they were deep in relation to the surrounding riverbed and because of their importance to the fishery.

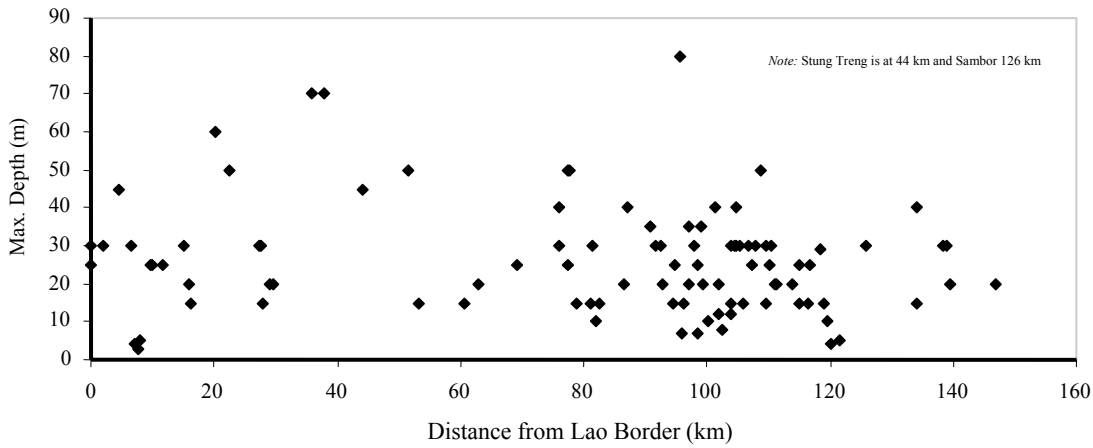

Figure 1. Distribution of pools along the Mekong between the Lao PDR border and Kratie showing their approximate maximum depth during the dry season

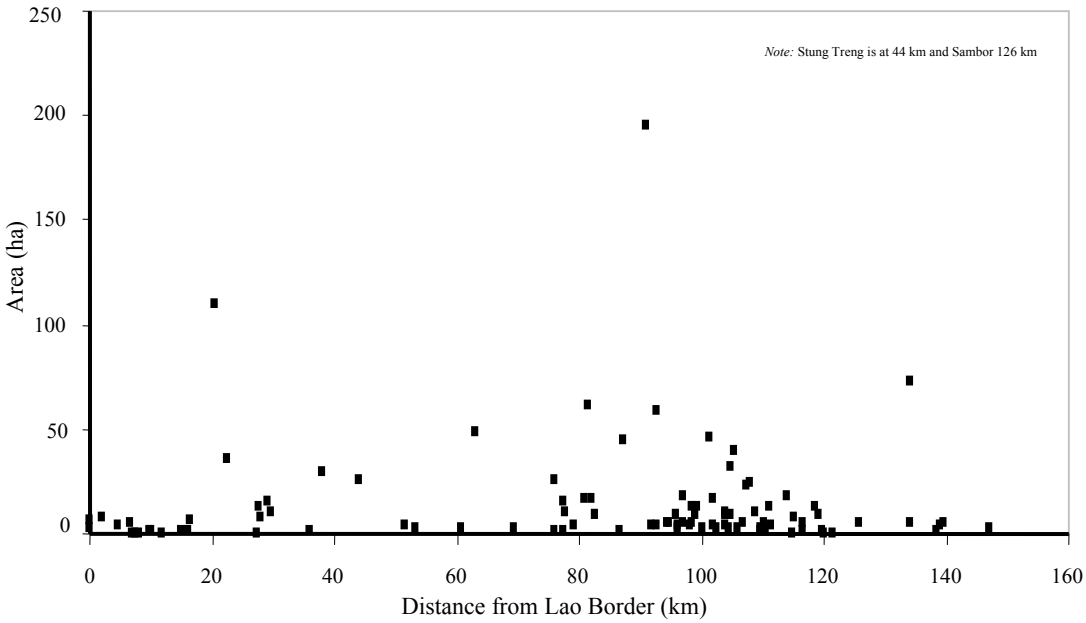

Figure 2. Distribution of pools along the Mekong between the Lao PDR border and Kratie showing their approximate surface area during the dry season

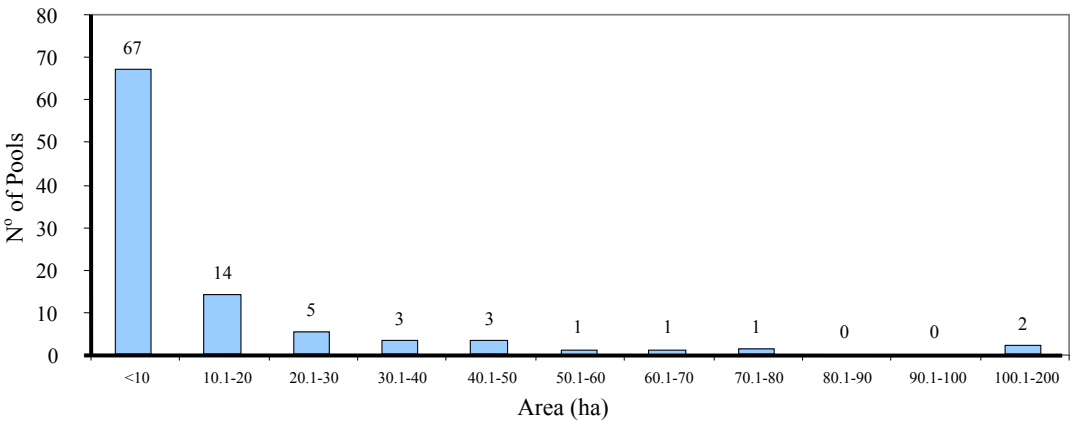

Figure 3. Distribution of deep pools by approximate area

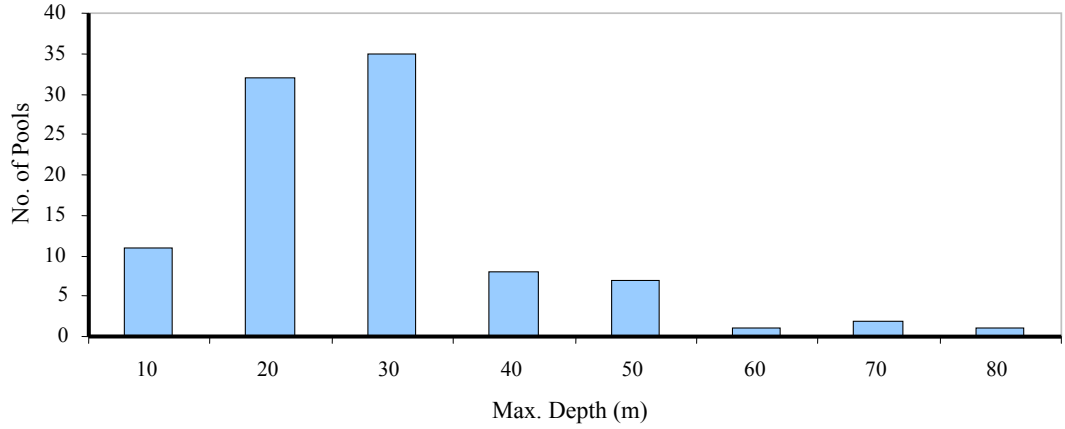

Figure 4. Distribution of deep pools by approximate maximum depth

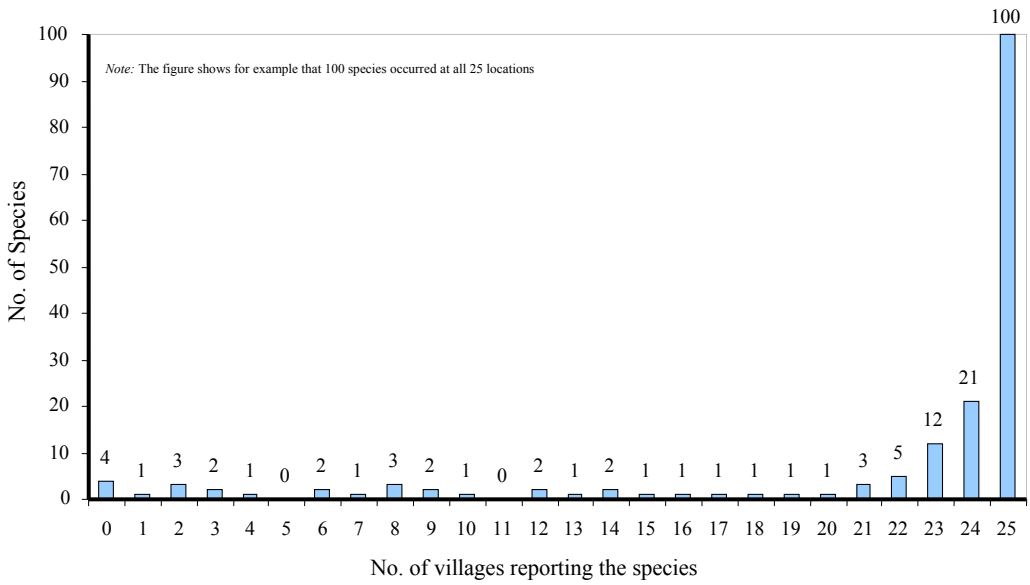

Figure 5. Species reports by location

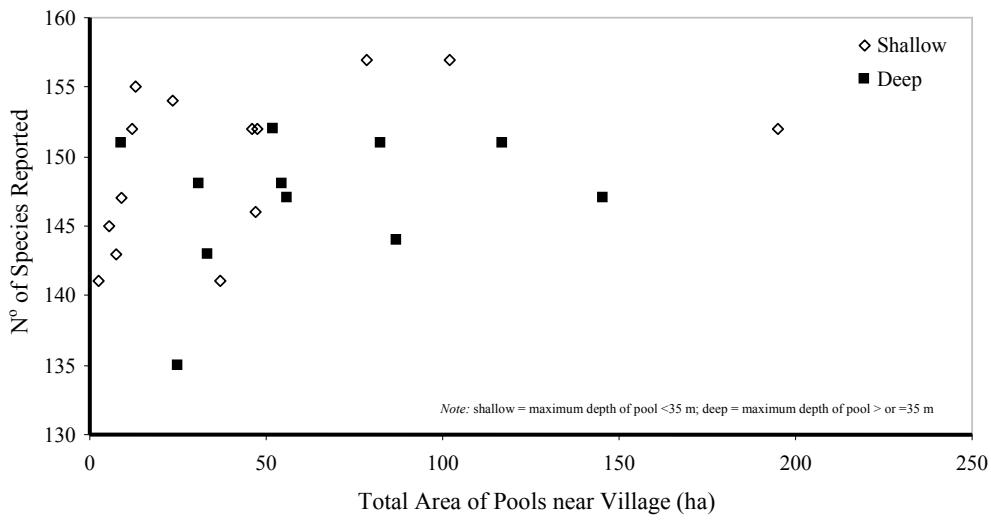

Figure 6. Distribution of species reports by area of pools

Fishing gear

Although a wide variety of fishing gear is available in Cambodia, the trend in recent years has been to use nylon monofilament gillnets as well as cast nets, hook and line, and some specialised nets for the deepest parts of deep pools. Other monitoring of commercial fishers catches along the upper Mekong by the Assessment of Mekong Capture Fisheries Component, shows that the majority of fish are now being caught with gillnets, which are very cheap and readily available. Though fishers did not elaborate on this point, the increasing dominance of gillnets is obvious from the presence of these nets in the villages and local markets and set in pools.

Species identification and location

The fishers, as a group, recorded 168 of the 172 species illustrated in the photo flipcharts. Twenty-two or more villages reported 80% of these species (138) showing that most species inhabit this entire section of the Mekong.

The composition of the fish fauna is broadly similar to that found throughout the Cambodian section of the Mekong. The most common species are, catfishes (Pangasiidae, Bagridae and Sisoridae), river carp (Cyprinidae) and snakeheads (Channidae). Not surprisingly, the fauna lacks many species of fish that normally live in other habitats, such as those found in montane, floodplain and estuarine environments. We could not attach significance to the fauna in any particular pool, as the distribution of most of the species is widespread. Moreover, as the photo flipchart is not representative of the whole fish fauna that has been recorded in the Cambodian section of the Mekong and its lowland tributaries (over 200 species are omitted from the charts), the list of species given in this paper may not be comprehensive.

Based on the current data there is no unequivocal relationship between the diversity of species and the size and depth of pools; although the shallower pools (less than 35m) appear to contain a more diverse fauna. Even so, it seems likely that other local environmental factors, such as substrate, snags or oxygen levels, may be more important. The relationship between the area and depth of pools and fish diversity may be resolved when data from individual pools are available. In the meantime, however, we can make a few interesting observations on the occurrence of introduced, rare indigenous and giant fish species.

<u>Introduced species</u>

The fishers identified only six of the 16 introduced species in the photo flipchart; of these, only three were widespread (Table 1).

This suggests that these species are spreading rapidly through the river system, probably from sites using them for aquaculture. (Note that the African catfish hybridises with the native *Clarias batrachus* and villagers may confuse these two species and their hybrids.) Four sites reported mosquito fish (two in Stung Treng and two in Kratie) and 12 reported swordtails. These escapees from the aquarium trade are apparently becoming widespread. Only two villages reported Nile tilapia (Khohtnot and Trarlork, both in Kratie); this species is apparently still quite rare in the upper Cambodian Mekong, despite its

widespread use in aquaculture along the river upstream in Lao PDR and downstream in Cambodia. Most probably the habitat through much of this section of the river is unsuitable for the species that originates from a lentic environment.

Table 1. *The number of villages reporting introduced species in deep pools*

Species	Common name	Origin	Records
Clarias gariepinus	African walking catfish	Africa	25
Cyprinus carpio	Common carp	West Europe to China	23
Hypophthalmichthys molitrix	Silver carp	China to Eastern Siberia	23
Gambusia affinis	Mosquito fish	North and Central America	4
X*iphophorus* spp	Swordtail	North and Central America	12
Oreochromis niloticus	Nile tilapia	Africa	2

Rare indigenous species

Aaptosyax grypus is an unusual and distinctive large carnivorous cyprinid endemic to the middle Mekong. Although the species has reportedly declined greatly in recent years (Poulsen *et al.* 2004), it was recorded three villages (Kos Sneng, Krohlapies and Chuetealthom); these are all located in section of the river in upper Stung Treng province that has smaller deep pools. These records are consistent with the known distribution of this particularly interesting endemic species, and could form a starting point for work on its conservation.

The giant catfish, *Pangasianodon gigas*, is one of the four 'giant' Mekong species (Coates *et al*. 2003), and is the only Mekong species currently listed by the IUCN as 'critically endangered', the category which denotes the highest risk of extinction (Table 2). Fishers from three villages (Kos Dam Bong, Pontachea and Oukok) recorded this species. All are in a relatively small area in the Sambor district of Kratie province where there is a high density of deep pools, many of which are large.

Table 2. *Locality records of Mekong species listed as endangered or critically endangered on the 2003 IUCN Red List*

Scientific name	Common name	Status	N° of localities
Pangasianodon gigas	Mekong giant catfish	Critically endangered	3
Dasyatis laosensis	Mekong freshwater stingray	Endangered	25
Himantura oxyrhynchus	Marbled freshwater stingray	Endangered	No data
Pristis zijsron	Green sawfish	Endangered	No data
Probarbus jullieni	Jullien's golden carp	Endangered	25
Scleropages formosus	Asian arowana	Endangered	0
Tenualosa thibaudeaui	Laotian shad	Endangered	10

Interestingly, the presence of two other giant species (*Catlocarpio siamensis* and *Probarbus jullieni*) listed by Coates *et al.* (2003) was confirmed by fishers at all 25 villages, suggesting that these species are still reasonably abundant despite increasing fishing pressure. *Pangasius sanitwongsei,* the other giant species, was not in the photo flipchart, and we were unable to confirm if it lives in this section of the Mekong. Two other endangered species featured on the flipchart, the Mekong freshwater stingray and Jullien's golden carp, were apparently still quite widespread, occurring at 25 locations, whereas the

once common Laotian shad is now restricted to only ten locations. The last endangered species, the Asian arowana, is indigenous to south-west Cambodia and may not even inhabit the Mekong.

DISCUSSION AND CONCLUSIONS

Poulsen *et al*. (2002) reviewed previous records of deep pools in northern Cambodia. Hill and Hill (1994) listed 28 deep pools, and Vannaren and Kin (2000) listed 58 deep pools. Most of these are in this study, and we have expanded the list to 97 pools, with data on locations, coordinates, approximate size and maximum depth. Poulsen *et al.* (2002) record 53 species that use the pools as dry season habitats, but during this study, we recorded least 162 native Mekong species, and, given that Cambodia has over 400 freshwater species, we assume that many not featured on the flipcharts also live this in this stretch of the river. Furthermore, a number smaller species that are difficult to identify may have been 'lumped' together in a single species.

In some cases, as some similar species are difficult to differentiate using only photographs, the records of a few individual species require confirmation. Nevertheless, the use of flipcharts provides an efficient way of accessing considerable information about the distribution of fish populations, and is probably reliable for the larger and more distinctive species.

We recorded only six exotic species and only two of these, the common carp and silver carp, were widespread; this suggests that deep pools still support a largely indigenous fauna, a factor that emphasises the need to conserve these special habitats. Exotic species have yet to invade these wild habitats in large numbers despite the burgeoning aquarium trade in Southeast Asia. Local villagers report that *Xiphophorus* spp is becoming widespread even though in a recent review Welcomme and Vidthayanon (2003) did not record the taxa. This demonstrates the value of interviews with local fishers in rapid assessments of the incursion of introduced fish.

The pools identified in this study are important habitats, particularly as they provide dry season refuges for large fish that form the brood-stock supporting local fisheries and floodplain fisheries downstream. Unpublished catch monitoring data collected by the Mekong River Commission (MRC) show that the pools in this part of the Mekong contain many more large adult fish than the river and floodplains further downstream in Cambodia and Viet Nam further highlighting the importance of deep pools to the sub-basin's fisheries.

Two giant species of river barb (*C. siamensis* and *P. jullieni*) previously thought to be in serious decline are apparently still widespread, as evidenced by records from all 25 villages. Unfortunately, the same is not true for the giant catfish, *P. gigas*, considered critically endangered by IUCN and still rare in this stretch of the Mekong. Two other endangered Mekong species are still quite widespread in the deep pools. The presence of giant and endangered species in these pools again demonstrates the importance of these habitats in fish conservation and provides a starting point for the preservation of these species as well as others of special interest such as the Mekong endemic, *A. grypus.*

Deep pool fisheries face two major threats: over-fishing and hydrological change.

Over-fishing of large species is accelerating with improved security, better access, and superior equipment. In the past, fish were relatively safe in the deepest parts of pools as traditional methods of fishing were comparatively inefficient. Nowadays, boats with outboard motors are used to travel long distances from population centres, gillnets line the edges of many of the deep pools so that fish moving to shallower water to feed (especially at night) have become more vulnerable, and specialised nets attached to heavy weights are set in the deepest parts of the water. Large fish are caught and stored in iceboxes then sold on to traders who export them, removing vital brood-stock from Cambodia. While hard data are lacking, all fishers agree that catches, especially of large fish, are increasing. Currently there are no effective measures to control fishing periods or the equipment used in deep pools; the current 'closed season' is during the flood period (June – September) and does not limit the capture of large fish when they are at their most vulnerable (i.e. during the dry season from January-May).

The persistence and quality of deep pools depends on the maintenance of existing hydrology and habitats. If dams upstream attenuate the river's peak flow, the river will lack the force to scour sediments during the wet season. Moreover, if upstream dams trap sediment, the resulting disruption to the equilibrium between deposition and suspension may lead to increased erosion and the pools to infill as the riverbanks slump. Already early feasibility studies include plans for a dam at Sambor (OTCA 1969). Any dam on the Mekong mainstream in this part of Cambodia could be disastrous for fisheries, but this site is the worst possible location from this perspective. Clearing of land adjacent to the river is also likely to cause the riverbank to slump and reduce the depth of pools.

Invasion of the river by exotic species presents a new threat. The Mekong system is species-rich, so it is perhaps less vulnerable to invasion than depauperate systems. Nevertheless, invading species have competitive advantages if the environment is altered to suit them. They, unlike native fish, are isolated from their natural enemies, parasites and pathogens and fishers do not target them because of their small size and poor taste. Furthermore, exotic species escaping from aquaculture supply continuous recruits. Exotic species may continue to establish themselves as has already occurred in the case of at least six species, two of which (mosquito fish and swordtails) have no utility and compete with native fish.

This paper serves as a starting point as we have clearly identified deep pools and summarised their main attributes. Concerted efforts are now needed to develop management plans for the pools in co-operation with fishers, to limit riparian clearing, to ensure that environmental impact assessment of upstream developments takes into account the effects on this important section of the river, and to restrict the spread of exotic species river system.

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APPENDIX 1

Basic location data on deep pools in northern Cambodia

Province	Village	Deep Pool (Eng)	Distance from border (km)	Lth(m)	Wdth (m)	DpthMax	Area (ha)	North Start and East Start	North End and East End
Stung Treng	Chueteal thom	Phsot	0	580	100	25	5.8	N 13^0 55 682' E 105^0 57.225'	N 13^0 55 691' E 105^0 57.544'
Stung Treng	Ourun	Vien khao	0.1	360	70	30	2.5	N 13^0 55 204' E 105^0 59.895'	N 13^0 55 280' E 105^0 59.711'
Stung Treng	Chueteal thom	Ta heng	2	1,050	70	30	7.4	N 13^0 53 668' E 106^0 00.342'	N 13^0 53.782' E 106^0 00.292'
Stung Treng	Ourun	Vien soat	4.5	440	80	45	3.5	N 13^0 50 970' E 105^0 59.023'	N 13^0 50 937' E 105^0 59.267'
Stung Treng	Krolapies	Kro la peas	6.5	**500**	**100**	**30**	5.0		
Stung Treng	Krolapies	Luk	7	**30**	**15**	**4**	0.0		
Stung Treng	Krolapies	Outa pray	7.6	**30**	**15**	**3**	0.0		
Stung Treng	Krolapies	Ou doung	8	**50**	**30**	**5**	0.2		
Stung Treng	Ourun	Ky ke	9.8	280	60	25	1.7	N 13^0 49.513' E 105^0 58.814'	N 13^0 49.626' E 105^0 58.916'
Stung Treng	Ourun	Sen lay	10	180	60	25	1.1	N 13^0 49 353' E 105^0 58.916'	N 13^0 49 430' E 105^0 58.980'
Stung Treng	Veunsien	Bong krak	11.7	**100**	60	25	0.6		
Stung Treng	Veunsien	Vien phong	15	190	50	30	1.0	N 13^0 46.983' E 105^0 58.539'	N 13^0 47.056' E 105^0 58.463'
Stung Treng	Veunsien	Vien sen	16	180	60	20	1.1	N 13^0 46.608' E 105^0 59.068'	N 13^0 46.662' E 105^0 58.988'
Stung Treng	Krolapies	Ou ta las	16.3	**1,000**	70	15	7.0		
Stung Treng	Chom thom	Kom bor	20.3	3,640	300	60	109.2	N 13^0 43.954' E 105^0 59.632'	N 13^0 45.171' E 105^0 58.049'
Stung Treng	Chom thom	Con theay	22.5	3,630	100	50	36.3	N 13^0 43.091' E 106^0 00.665'	N 13^0 41.434' E 106^0 01.739'
Stung Treng	Koh Sneng	Om pil	27.2	100	50	30	0.5		
Stung Treng	Koh Sneng	Ta prum	27.5	1,270	100	30	12.7	N 13^0 41.161' E 106^0 02.609'	N 13^0 40.534' E 106^0 02.892'
Stung Treng	Koh Sneng	Koh kon dul	28	910	90	15	8.2	N 13^0 40.764' E 106^0 01.221'	N 13^0 40.276' E 106^0 01.150'
Stung Treng	Koh Sneng	Ta thau	29	1,000	150	20	15.0	N 13^0 39.121' E 106^0 02.201'	N 13^0 38.606' E 106^0 02.364'
Stung Treng	Koh Sneng	Throm thom	29.5	1,040	100	20	10.4	N 13^0 38.950' E 106^0 01.543'	N 13^0 38.501' E 106^0 01.892'
Stung Treng	Phum thmay	Kan tui koh tang	36	**150**	**80**	**70**	1.2	N 13^0 35.499' E 106^0 00.533'	
Stung Treng	Phum thmay	Phum thmei	38	1,480	200	70	29.6	N13^0 34.763' E 105^0 59.662'	N13^0 35.226' E 105^0 00.333'
Stung Treng	Bachong	Ou trel	44	1,260	200	45	25.2	N 13^0 32.058' E 105^0 56.858'	N 13^0 31.683' E 105^0 56.276'
Stung Treng	Svay	Svay or kang praech	51.5	480	80	50	3.8	N 13^0 27.965' E 105^0 55.460'	N 13^0 27.712' E 105^0 55.503'
Stung Treng	Svay	Phnao	53.3	300	80	15	2.4	N 13^0 26.788' E 105^0 55.853'	N 13^0 26.635' E 105^0 55.905'
Stung Treng	Svay	Tavan	60.7	240	80	15	1.9	N 13^0 22.707' E 105^0 55.675'	N 13^0 22.579' E 105^0 55.709'
Stung Treng	Svay	Beong Kok	62.9	2,400	200	20	48.0	N 13^0 21.342' E 105^0 55.083'	N 13^0 21.831' E 105^0 55.328'
Stung Treng	Siembok	Kang chong e	69.3	290	80	25	2.3	N 13^0 17.842' E 105^0 55.634'	N 13^0 17.990' E 105^0 55.579'
Stung Treng	Siembok	Yi keo	76	190	80	30	1.5	N 13^0 17.653' E 105^0 55.705'	N 13^0 17.749' E 105^0 55.675'
Stung Treng	Siembok	Nak ta	77.5	190	80	25	1.5	N 13^0 17.454' E 105^0 55.722'	N 13^0 17.554' E 105^0 55.715'
Stung Treng	Koh chrum	Thmor thom	76	2,520	100	40	25.2	N 13^0 14.683' E 105^0 58.284'	N 13^0 13.453' E 105^0 58.880'
Stung Treng	Koh chrum	Chhor long	77.5	2,600	60	50	15.6	N 13^0 14.048' E 105^0 59.453'	N 13^0 13.351' E 106^0 00.700'
Stung Treng	Koh chrum	Preas tro phang	77.8	**1,000**	**100**	**50**	10.0		
Stung Treng	Koh chrum	Koh Dom Long	79	500	70	15	3.5	N 13^0 13. 865' E 105^0 59.384'	N 13^0 13.925' E 105^0 59.654'
Kratie	Kohnorung	Koh kampeung	99.3	830	150	20	12.5	N 13^0 11.416' E 106^0 01.821'	N 13^0 11.207' E 106^0 02.229'
Kratie	Koh dam bong	Koh dam bong	81.5	2,040	300	30	61.2	N 13^0 10.957' E 106^0 01.448'	N 13^0 09. 858' E 106^0 01.525'
Kratie	Kohnorung	Ou kandear	81	1,390	120	15	16.7	N 13^0 10.959 ' E 106^0 02.679'	N 13^0 10.422' E 106^0 03.219'
Kratie	Kohnorung	Me dut or phem chrus	82	1,110	150	10	16.7	N 13^0 05. 465' E 106^0 03.420'	N 13^0 04.883' E 106^0 03.570'
Kratie	Koh dam bong	Koh om pil	82.5	880	100	15	8.8	N 13^0 09.885' E 106^0 01.424'	N 13^0 09.411' E 106^0 01.437'
Kratie	Koh dam bong	Cheong Kel or Kampong kbeung	86.6	250	70	20	1.8		
Kratie	Koh dam bong	Kandor moui roi	87.2	2,260	200	40	45.2	N 13^0 08.678' E 106^0 02.001'	N 13^0 07.482' E 106^0 01.761'
Kratie	Khsach leav	Koh khnhe Srey Koki	90.8	4,870	400	35	194.8	N 13^0 07.957' E 106^0 03.914'	N 13^0 05.415' E 106^0 03.232'
Kratie	Trarlok	Phreas theat	91.8	350	100	30	3.5	N 13^0 05.415' E 106^0 03.232'	N 13^0 05.465' E 106^0 3.420'
Kratie	Oukok	kbal koh ta chan	92.6	3,870	150	30	58.1	N 13^0 04.883' E 106^0 03.570'	N 13^0 05.465' E 106^0 03.420'
Kratie	Trarlok	Chha hung	94.5	460	100	15	4.6	N 13^0 03.467' E 106^0 04.030'	N 13^0 03.226' E 106^0 03.980'
Kratie	Trarlok	Lo vear	96.1	**200**	150	15	3.0		
Kratie	Pontachea	Mokphum	96	340	100	7	3.4	N 13^0 04.903' E 106^0 03.970'	N 13^0 04.769' E 106^0 04.095'
Kratie	Kohtnot	Khsach leo	92.8	840	50	20	4.2	N 13^0 04.529' E 106^0 00.937'	N 13^0 04.090' E 106^0 00.822'
Kratie	Pontachea	Prestvea	97	900	200	20	18.0	N 13^0 02.450' E 106^0 04.575'	N 13^0 01.968' E 106^0 04.646'

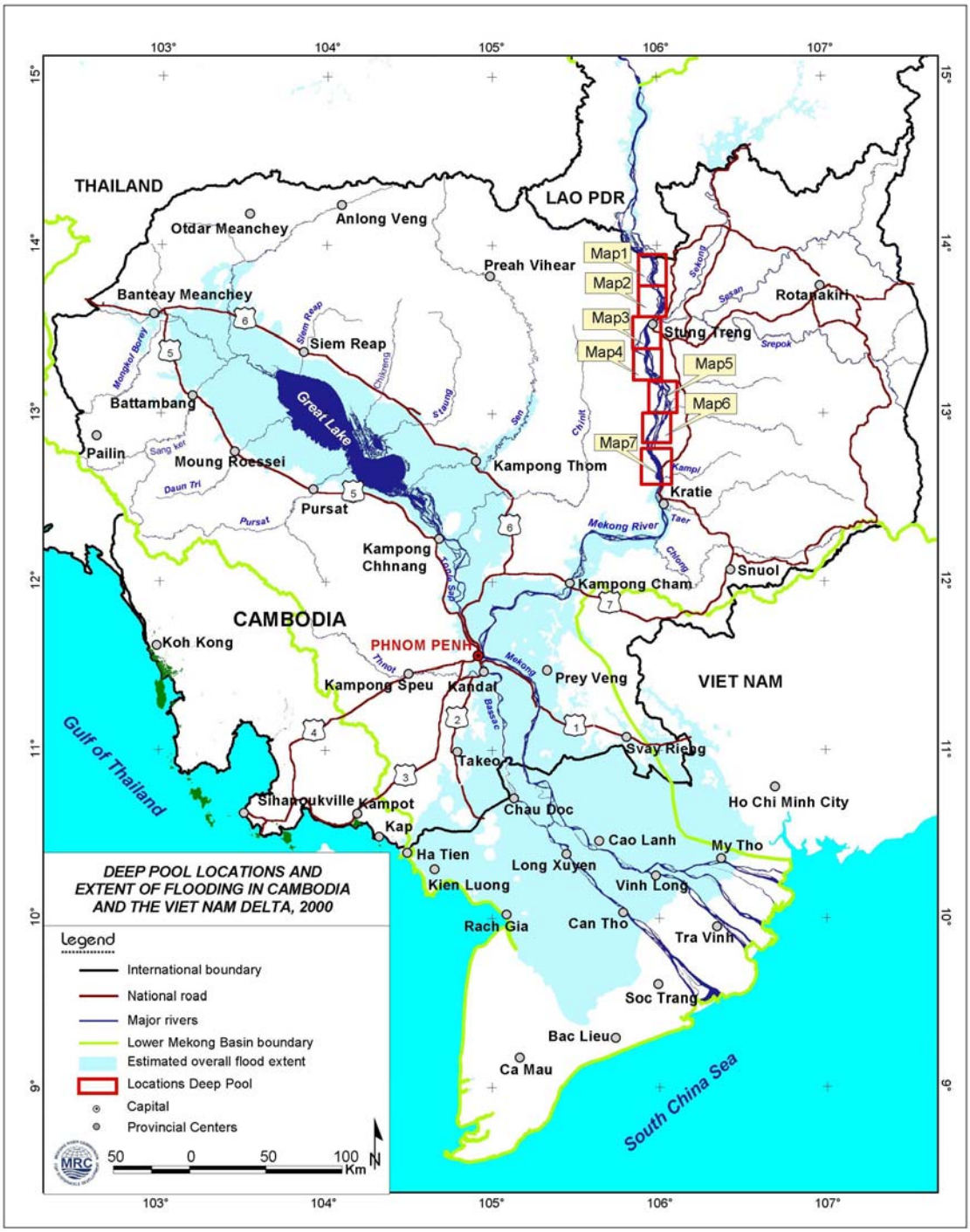
APPENDIX 1

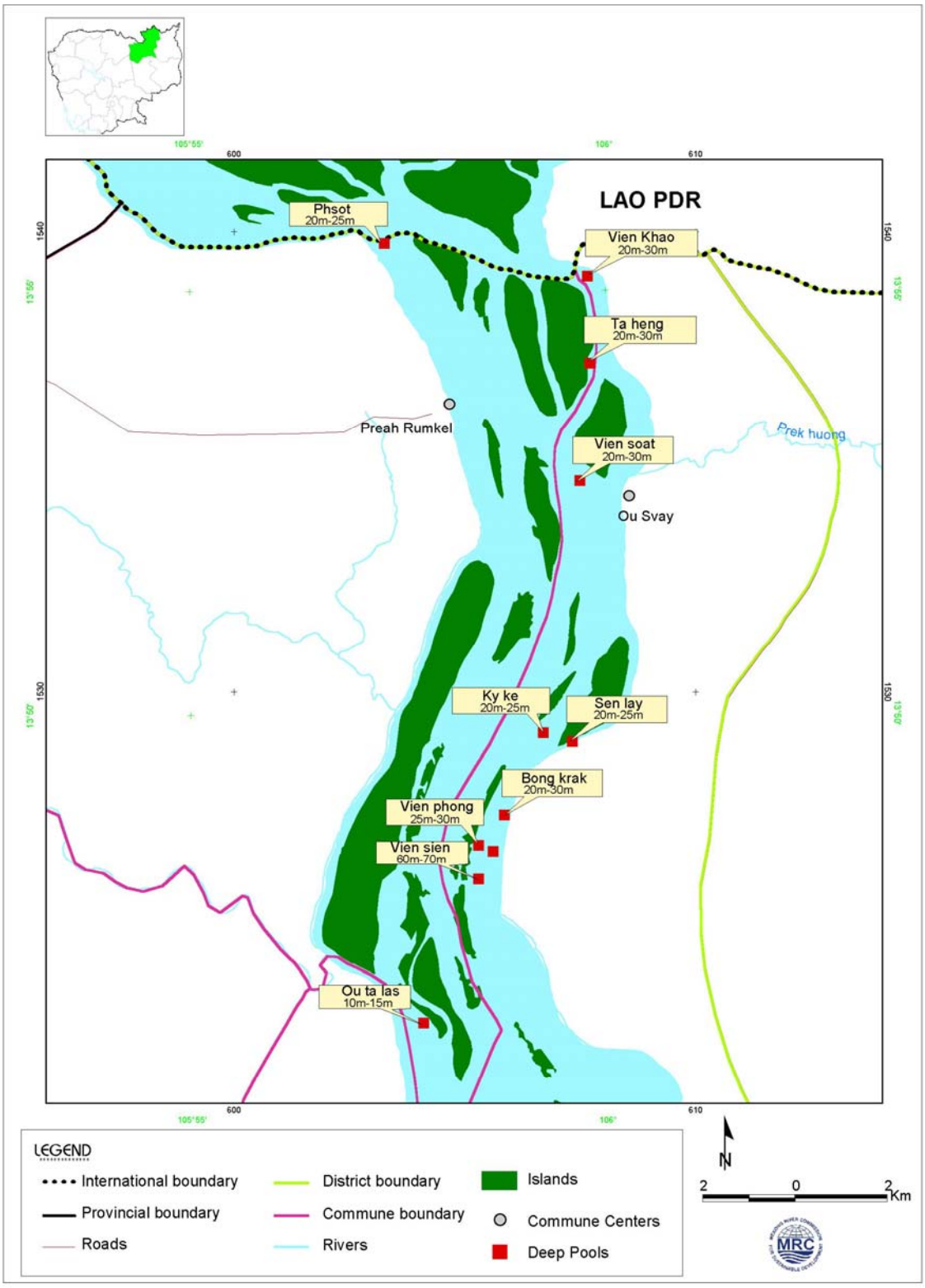
Basic location data on deep pools in northern Cambodia

Province	Village	Deep Pool (Eng)	Distance from border (km)	Lth(m)	Wdth (m)	DpthMax	Area (ha)	North Start and East Start	North End and East End
Kratie	Pontachea	Peamkreang	98.4	1,300	100	7	13.0	N 13^0 01.383' E 106^0 04.740'	N 13^0 00.716' E 106^0 04.513'
Kratie	Damrey	Khul pra or Pra	95.8	1,720	50	**80**	8.6	N 13^0 03.282' E 106^0 00.349'	N 13^0 02.461' E 105^0 59.904'
Kratie	Damre	Kom pong cheav	97	610	80	35	4.9	N 13^0 02.394' E 105^0 59.826'	N 13^0 02.170' E 105^0 59.580'
Kratie	Trarlok	Tro loak	98.5	300	150	25	4.5	N 13^0 02.480' E 106^0 03.499'	N 13^0 02.382' E 106^0 03.368'
Kratie	Damrey	Chhui som yong	98	430	80	30	3.4	N 13^0 02.153' E 105^0 59.565'	N 13^0 01.965' E 105^0 59.429'
Kratie	Damrey	Chap chhnout	99	1,040	80	35	8.3	N 13^0 01.965' E 105^0 59.429'	N 13^0 01.575' E 105^0 59.017'
Kratie	Oukok	Sandan	100.1	580	50	10	2.9	N 12^0 59.565' E 106^0 03.809'	N 12^0 59 272' E 106^0 03 702'
Kratie	Oukok	Andash	102.5	430	50	8	2.2	N 12^0 59.856' E 106^0 03.949'	N 12^0 59.650' E 106^0 03.837'
Kratie	Damrey	Boung cha	103.8	1,270	80	30	10.2	N 13^0 01.575' E 105^0 59.017'	N 13^0 01.035' E 105^0 58.588'
Kratie	Damrey	Kul run teas	101.3	2,270	200	40	45.4	N 13^0 02.046' E 106^0 03.136'	N 13^0 01.140' E 106^0 02.294'
Kratie	Damrey	Leng	104.5	270	80	30	2.2	N 13^0 01.035' E 105^0 58.588'	N 13^0 00.891' E 105^0 58.564'
Kratie	Pontachea	Chaktea	101.8	960	170	20	16.3	N 12^0 59.304' E 106^0 02.994'	N 12^0 59.793' E 106^0 03.174'
Kratie	Oukok	Ancheng	102	870	50	12	4.4	N 12^0 58.898' E 106^0 03.387'	N 12^0 58.464' E 106^0 03.206'
Kratie	Kohtnot	Ver val	105.4	1,580	250	30	39.5	N 13^0 00.095' E 106^0 02.163'	N 12^0 59.278' E 106^0 01.915'
Kratie	Trarlok	Phsa kang kep or val pronang	104.8	2,110	150	40	31.7	N 12^0 58.117' E 106^0 01.550'	N 12^0 57.004' E 106^0 01.319'
Kratie	Oukok	Kampong phnouve	105.9	400	50	15	2.0	N 12^0 57.775' E 106^0 02.489'	N 12^0 57.566' E 106^0 02.435'
Kratie	Pontachea	Sbeu	104	550	170	15	9.4	N 12^0 58.509' E 106^0 02.626'	N 12^0 58.767' E 106^0 02.780'
Kratie	Oukok	Kbalchuortachor	104	640	50	12	3.2	N 12^0 58.031' E 106^0 03.024'	N 12^0 57.948' E 106^0 02.680'
Kratie	Damre	phreas tvie lich	104.8	950	100	30	9.5	N 12^0 58.716' E 105^0 59.030'	N 12^0 58.254' E 105^0 59.252'
Kratie	Trarlok	phreas pon lich	106.9	460	100	30	4.6	N 13^0 03.467' E 106^0 04.030'	N 13^0 03.226' E 106^0 03.980'
Kratie	Damre	som phan	107.2	2,240	100	25	22.4	N12^0 58.134' E 105^0 59.659'	N 12^0 56.829' E 105^0 59.517'
Kratie	Oukok	Tachan yeimau	108	1,200	200	30	24.0	N 12^0 56.720' E 106^0 01.592'	N 12^0 56.088' E 106^0 01.464'
Kratie	Kohtnot	Yeimau	109.6	470	50	30	2.4	N 12^0 55.608' E 106^0 01.168'	N 12^0 55.367' E 106^0 01.094'
Kratie	Ampilteok	Ksach mokak	108.8	1,990	50	50	10.0	N 12^0 56.452' E 105^0 59.754'	N 12^0 55.552' E 105^0 59.151'
Kratie	Vatanak	Skum thom	109.5	180	50	15	0.9	N 12^0 55.705' E 106^0 00.891'	N 12^0 55.617' E 106^0 00.854'
Kratie	Ampilteok	Ksach kpus	110.1	980	50	25	4.9	N 12^0 55.079' E 105^0 58.666'	N 12^0 54.779' E 105^0 58.222'
Kratie	Ampilteok	Kul lbar	110.5	310	50	30	1.6	N 12^0 55.247' E 105^0 59.100'	N 12^0 55.107' E 105^0 59.003'
Kratie	Oukok	Koh chbar	111.4	860	50	20	4.3	N 12^0 54.816' E 106^0 00.624'	N 12^0 54.385' E 106^0 00.442'
Kratie	Ampilteok	Veal Pro Loung	111	2,440	50	20	12.2	N 12^0 58.134' E 105^0 59.659'	N 12^0 56.829' E 105^0 59.517'
Kratie	Pontachea	Kampeang	114	1,070	170	**20**	18.2	N 13^0 00. 490' E 106^0 03.572'	N 13^0 01.000' E 106^0 03.846'
Kratie	Kohpdau	Koh peng	114.9	100	50	15	0.5	N 12^0 50.489' E 105^0 55.898'	N 12^0 50.459' E 105^0 55.944'
Kratie	yey	Ar chhen	115	1,540	50	25	7.7	N 12^0 52.647' E 105^0 56.886'	N 12^0 51.977' E 105^0 56.386'
Kratie	Ampilteok	ksach svay	116.6	1,010	50	25	5.1	N 12^{0}51.977' E 105^0 56.386'	N 12^0 51.497' E 105^0 56.118'
Kratie	Oukok	Kbal koh thkor	116.5	170	50	15	0.9	N 12^0 51.665' E 105^0 58.583'	N 12^0 51.753' E 105^0 58.596'
Kratie	Kohpdau	Koh preng	119	1,860	50	15	9.3	N 12^0 53.169' E 105^0 59.796'	N 12^0 52.218' E 105^0 59.467'
Kratie	Kohtnot	Kon tui koh thkor	119.7	250	50	10	1.3	N 12^0 49.938' E 105^0 58 233'	N 12^0 50.068' E 105^0 58.270'
Kratie	Kohpdau	Koh pdau	118.5	2,620	50	29	13.1	N 12^0 50.705' E 105^0 56.396'	N 12^0 49.405' E 105^0 56.966'
Kratie	Damre	Kon thmor har	120	**50**	**20**	4	0.1		
Kratie	Kohpdau	Koh dom long	121.5	**100**	**50**	5	0.5		
Kratie	Vatanak	Pak vek	125.7	1,000	50	30	5.0	N 12^0 39.570' E 106^0 00.050'	N 12^0 39.037' E 105^0 59.973'
Kratie	Vatanak	Vil pronang	134	2,900	250	40	72.5	N 12^0 41.024' E 106^0 00.692'	N 12^0 39.441' E 106^0 00.576'
Kratie	Vatanak	Preas kor	134.1	1,000	50	15	5.0	N 12^0 39.570' E 106^0 00.050'	N 12^0 39.037' E 105^0 59.973'
Kratie	Kampee	Bai som nom	138.5	300	50	30	1.5	N 12^0 36.685' E 106^0 01.331'	N 12^0 36.523' E 106^0 01.340'
Kratie	Vatanak	Chroy bantay	139	690	50	30	3.5	N 12^0 39.441' E 106^0 00.576'	N 12^0 39.071' E 106^0 00.602'
Kratie	Kampee	Phsot #2	139.5	990	50	20	5.0	N 12^0 36.376' E 106^0 01.315'	N 12^0 35.863' E 106^0 01.458'
Kratie	Kampee	Phreas song	147	500	50	20	2.5	N 12^0 34.913' E 106^0 01.505'	N 12^0 34.648' E 106^0 01.461'

APPENDIX 2

Location of Deep Pools

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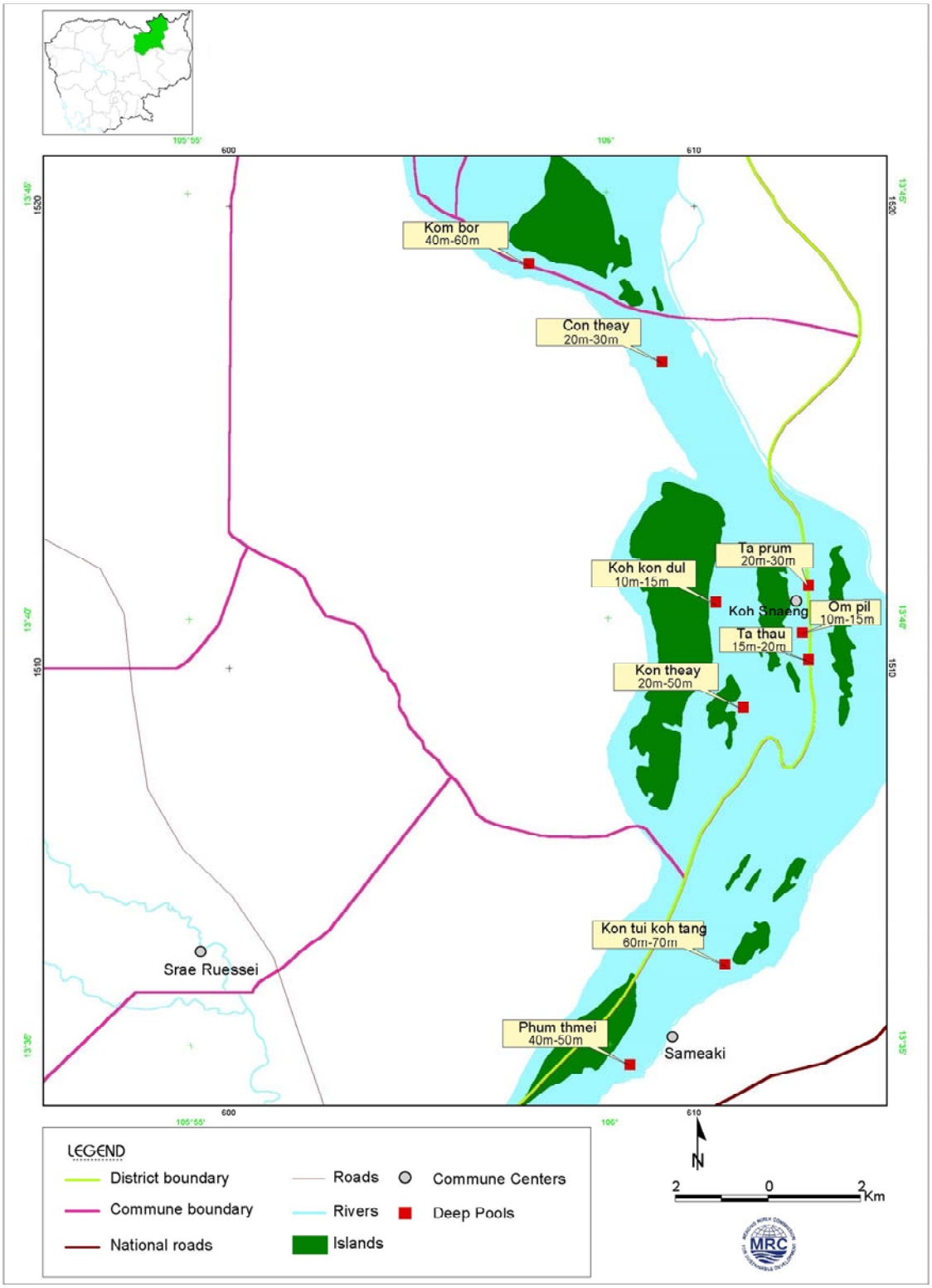
Phsot
20m-25m
Vien Khao
20m-30m
Ta heng
20m-30m
Preah Rumkel
Prek huong
Vien soat
20m-30m
Ou Svay
Ky ke
20m-25m
Sen lay
20m-25m
Bong krak
20m-30m
Vien phong
25m-30m
Vien sien
60m-70m
Ou ta las
10m-15m
600
610
1540
1530
105°55'
106°
13°55'
13°50'
LEGEND
International boundary
Provincial boundary
Roads
District boundary
Commune boundary
Rivers
Islands
Commune Centers
Deep Pools
N
2
0
2
Km
MRC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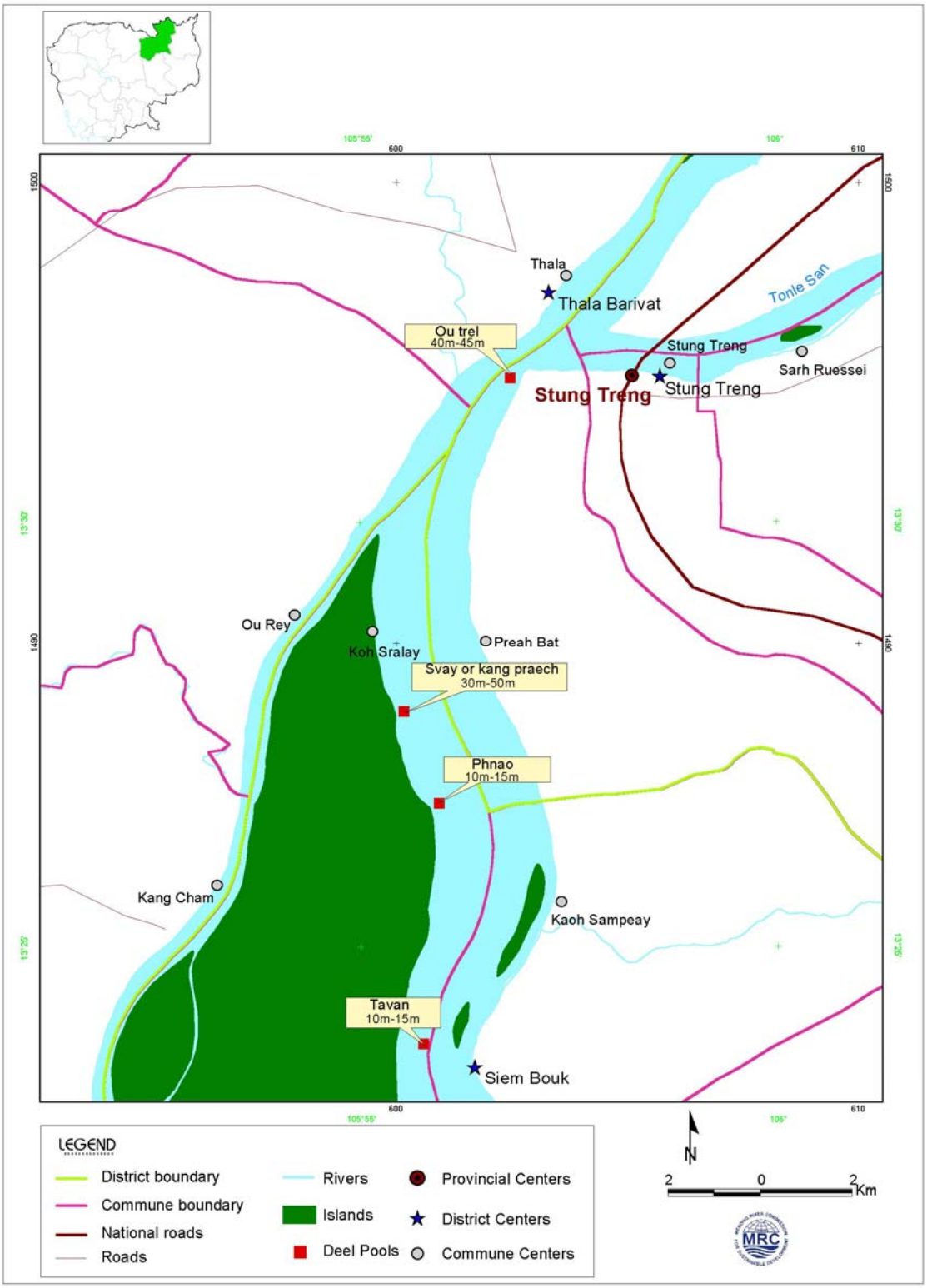
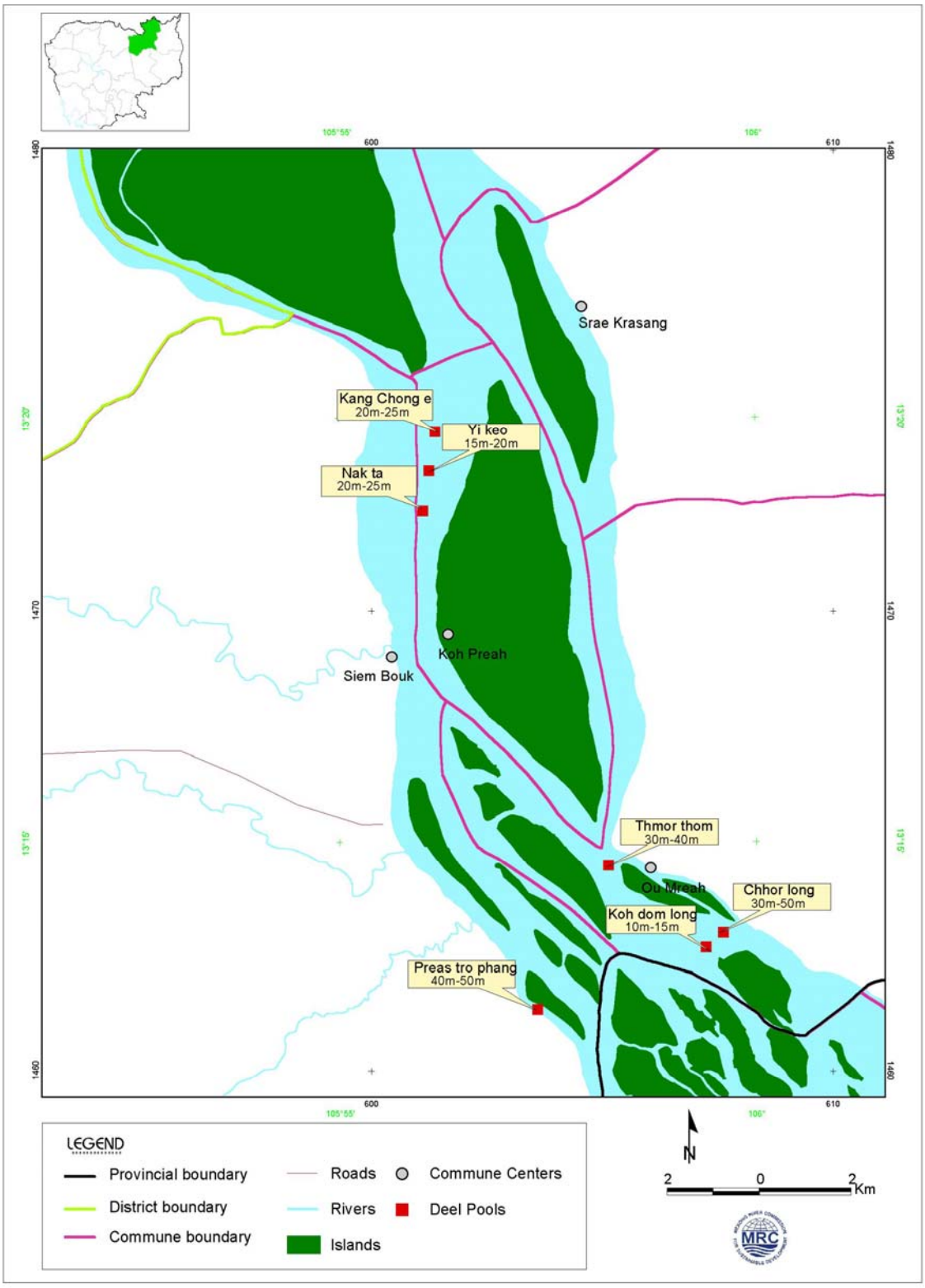
Con theay
20m-30m
Ta prum
20m-30m
Koh kon dul
10m-15m
Koh Snaeng
Om pil
10m-15m
Ta thau
15m-20m
Kon theay
20m-50m
Kon tui koh tang
60m-70m
Srae Ruessei
Phum thmei
40m-50m
Sameaki
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
Commune Centers
Deep Pools
N
2 0 2 Km
MRC


Thala
Thala Barivat
Tonle San
Ou trel
40m-45m
Stung Treng
Stung Treng
Stung Treng
Sarh Ruessei
Ou Rey
Koh Sralay
Preah Bat
Svay or kang praech
30m-50m
Phnao
10m-15m
Kang Cham
Kaoh Sampeay
Tavan
10m-15m
Siem Bouk
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
Deel Pools
Provincial Centers
District Centers
Commune Centers
N
2 0 2 Km
MRC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Kang Chong e
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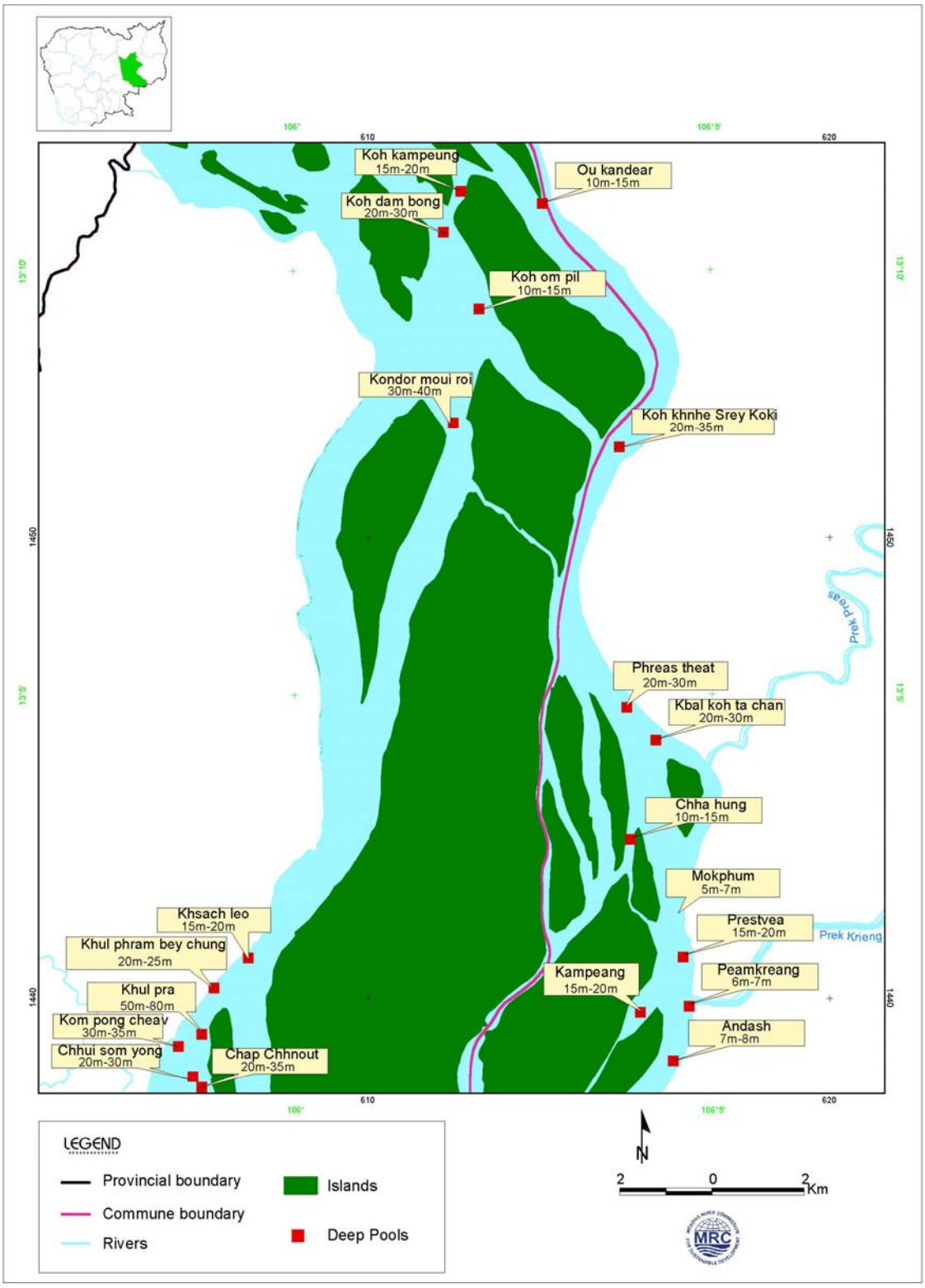
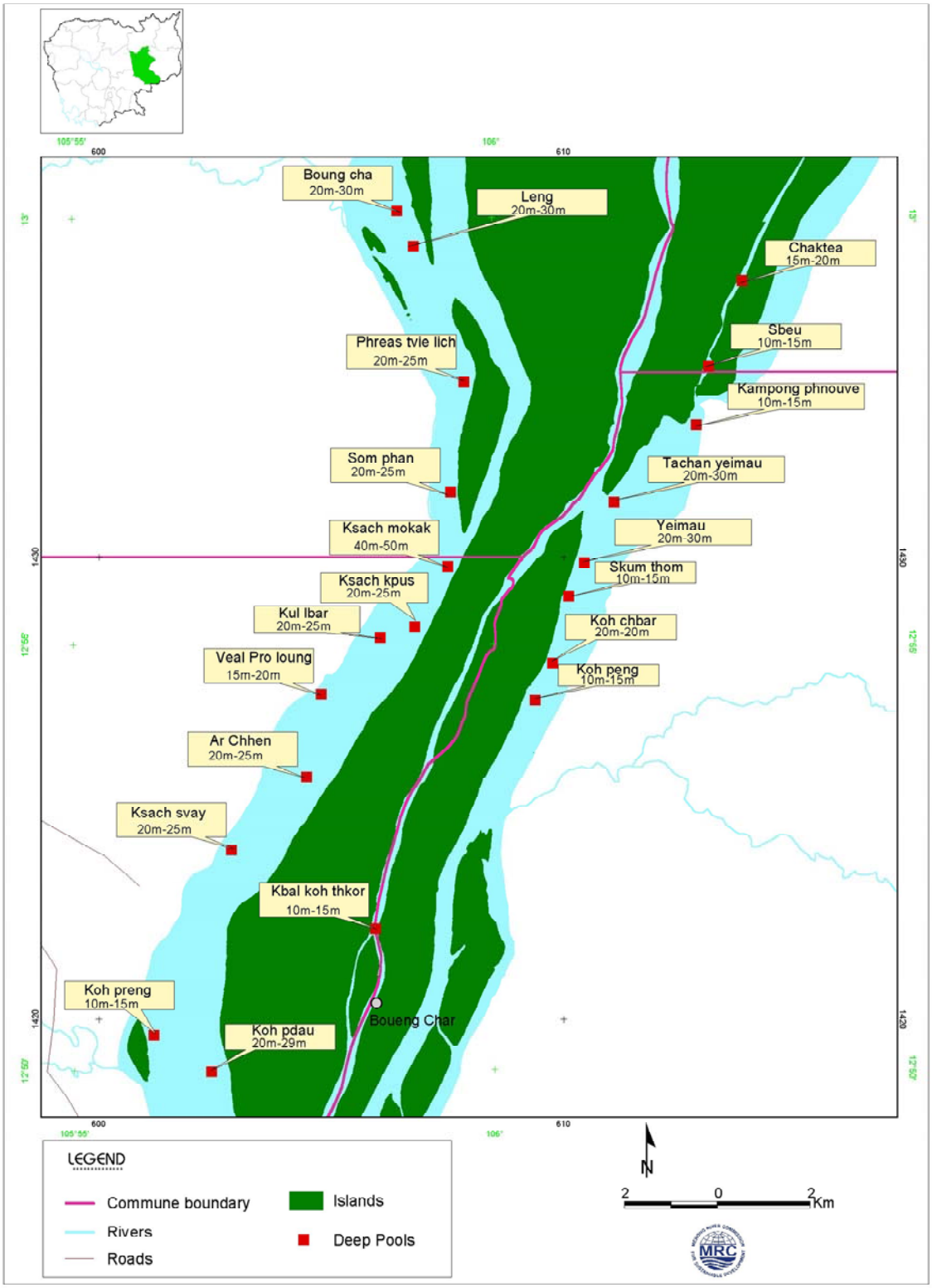
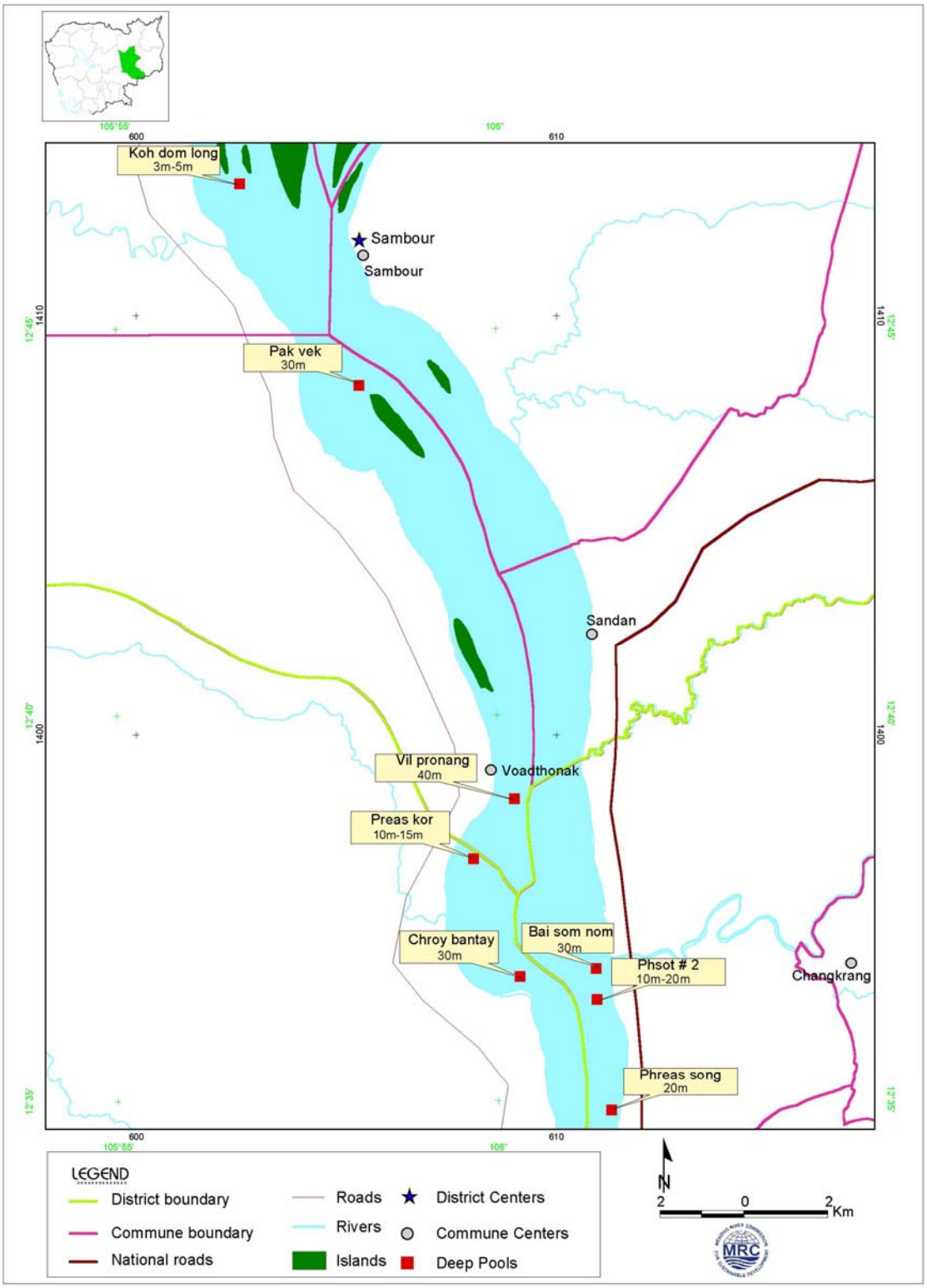
Yi keo
15m-20m
Nak ta
20m-25m
Koh Preah
Siem Bouk
Thmor thom
30m-40m
Ou Mreah
Chhor long
30m-50m
Koh dom long
10m-15m
Preas tro phang
40m-50m
LEGEND
Provincial boundary
District boundary
Commune boundary
Roads
Rivers
Islands
Commune Centers
Deel Pools
N
2 0 2 Km
MRC


Koh kampeung
15m-20m
Ou kandear
10m-15m
Koh dam bong
20m-30m
Koh om pil
10m-15m
Kondor moui roi
30m-40m
Koh khnhe Srey Koki
20m-35m
Prek Preas
Phreas theat
20m-30m
Kbal koh ta chan
20m-30m
Chha hung
10m-15m
Mokphum
5m-7m
Prestvea
15m-20m
Prek Krieng
Peamkreang
6m-7m
Kampeang
15m-20m
Andash
7m-8m
Khsach leo
15m-20m
Khul phram bey chung
20m-25m
Khul pra
50m-80m
Kom pong cheav
30m-35m
Chhui som yong
20m-30m
Chap Chhnout
20m-35m
610
620
106°
106°5'
13°10'
13°5'
1450
1440
LEGEND
Provincial boundary
Commune boundary
Rivers
Islands
Deep Pools
N
2
0
2
Km
MRC


Boung cha
20m-30m
Leng
20m-30m
Chaktea
15m-20m
Sbeu
10m-15m
Phreas tvie lich
20m-25m
Kampong phnouve
10m-15m
Som phan
20m-25m
Tachan yeimau
20m-30m
Ksach mokak
40m-50m
Yeimau
20m-30m
Skum thom
10m-15m
Ksach kpus
20m-25m
Kul lbar
20m-25m
Koh chbar
20m-20m
Veal Pro loung
15m-20m
Koh peng
10m-15m
Ar Chhen
20m-25m
Ksach svay
20m-25m
Kbal koh thkor
10m-15m
Koh preng
10m-15m
Koh pdau
20m-29m
Boueng Char
LEGEND
Commune boundary
Rivers
Roads
Islands
Deep Pools
N
2 0 2 Km


Koh dom long
3m-5m
Sambour
Sambour
Pak vek
30m
Sandan
Vil pronang
40m
Voadthonak
Preas kor
10m-15m
Chroy bantay
30m
Bai som nom
30m
Phsot # 2
10m-20m
Changkrang
Phreas song
20m
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
District Centers
Commune Centers
Deep Pools
N
2 0 2 Km
MRC