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Editors: T.J. Burnhill and M.M. Hewitt

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P.O.Box 6101, 184a Fa Ngoum Road
Ban Sithane Neua, Sikhottabong
Vientiane, Lao PDR
Telephone: (856-21) 263263. Fax: (856-21) 263264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org

Foreword

The Proceedings of the 6th Technical Symposium of the MRC Fisheries Programme have been collated to serve a number of important purposes. They provide a vehicle for young scientists to publish the results of their work; they form a permanent record for future workers to refer to; and they assist in communicating the importance of the fisheries resources in this region to decision makers and the public.

Communication must be considered a key element in any development activity, particularly one dealing with natural resources that are subject to many competing uses. This is the case with the resources of the Mekong. The Mekong's waters are used for hydropower, irrigation, navigation and fisheries; its wetlands are used for production of fish, timber products and agriculture; and its ecosystem supports biodiversity and the livelihoods of millions of people. The fishing industry is just one component of the myriad of uses of the Mekong, but a very important one. To ensure that fisheries are appropriately considered in planning processes, it is essential that fisheries workers make available information on this resource and its role in the lives of riparian people. Such information must take many forms, to ensure that we reach all levels of government and society. In this regard, I appreciate these Proceedings, as they document and present much of the data that underpin arguments on the importance of fisheries in the Lower Mekong Basin.

The range of papers presented in the Proceedings indicates the scope of work being undertaken by the Fisheries Programme, as well as the technical capacity within the region. I am pleased to see in this issue more papers from fisheries researchers not directly associated with the MRC Fisheries Programme. This indicates both the importance of the Symposium within the region, and the growing interaction between agencies associated with management of the natural resources of the Mekong. Such interaction is essential if we are to make the best use of the human and financial resources we have for developing the fisheries of the Mekong.

I hope these Proceedings engender pride among those who have participated in and contributed to the 6th Technical Symposium. Fisheries remain a critical element of any multidisciplinary approach to development in the Mekong. The continued collection, development and distribution of knowledge in the area of fisheries will playa vital role in meeting the needs and keeping the balance of the Mekong River basin, now and in the future.

Dr Olivier Cogels
Chief Executive Officer
Mekong River Commission Secretariat
September 2004

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

D. Khay* and K.G. Hortle

Assessment of Mekong Capture Fisheries Component, MRC Fisheries Programme

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,

* Dept of Fisheries, PO Box 582 Phnom Penh, Cambodia
Email: ifric@online.com.kh

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.

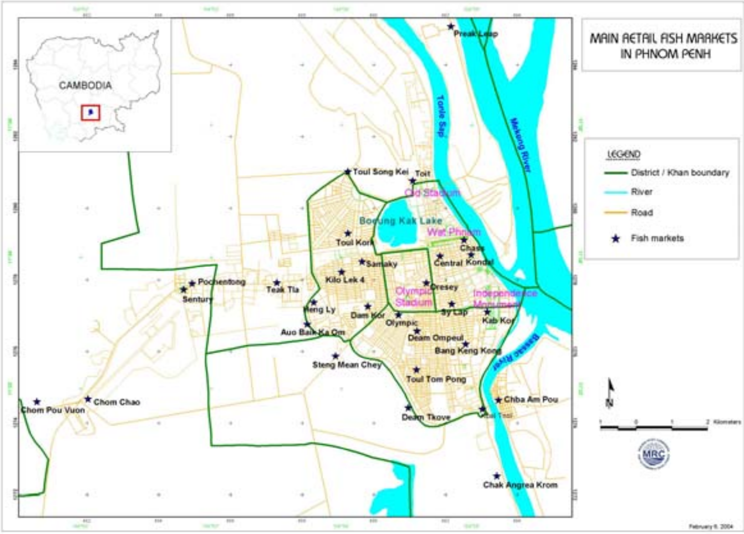

Figure 1. Location of main retail markets in Phnom Penh

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

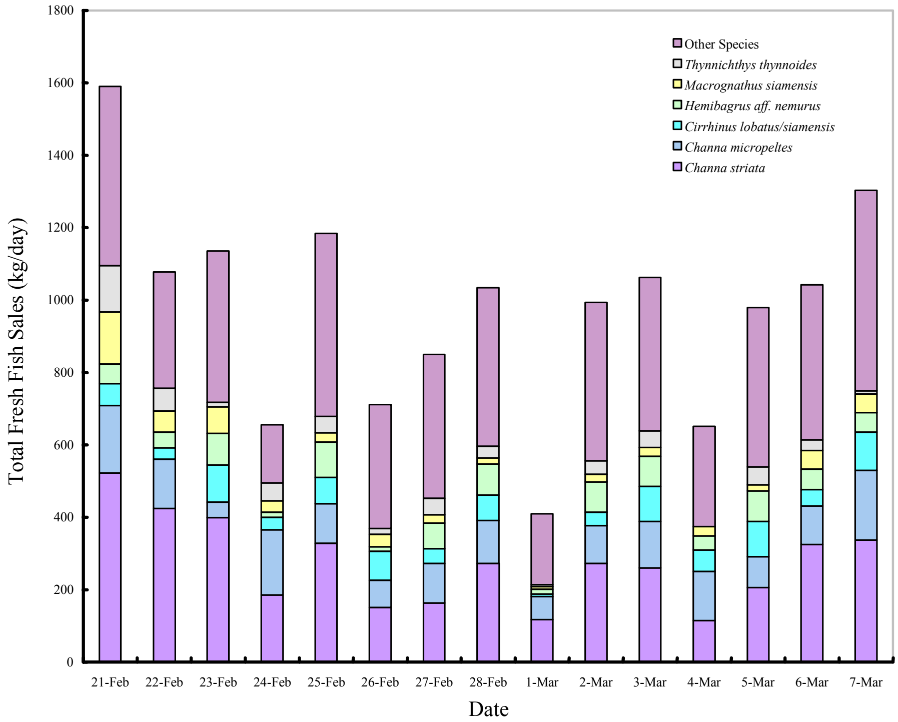

Figure 6. Total sales of inland fish in Bang Keng Kong market over 15 days; showing the six most common species

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.

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

K.G. Hortle,* T. Chea, R. Bun, S. Em and P. Thac

Assessment of Mekong Capture Fisheries Component, MRC Fisheries Programme

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

* Dept of Fisheries, PO Box 582 Phnom Penh, Cambodia
Email: bigcatch@bigpond.com.kh

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^o/1000 m^3) and total numbers of the 13 most abundant fish*

Species	Bottom			Surface			Mean	3-day Total N^o
	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

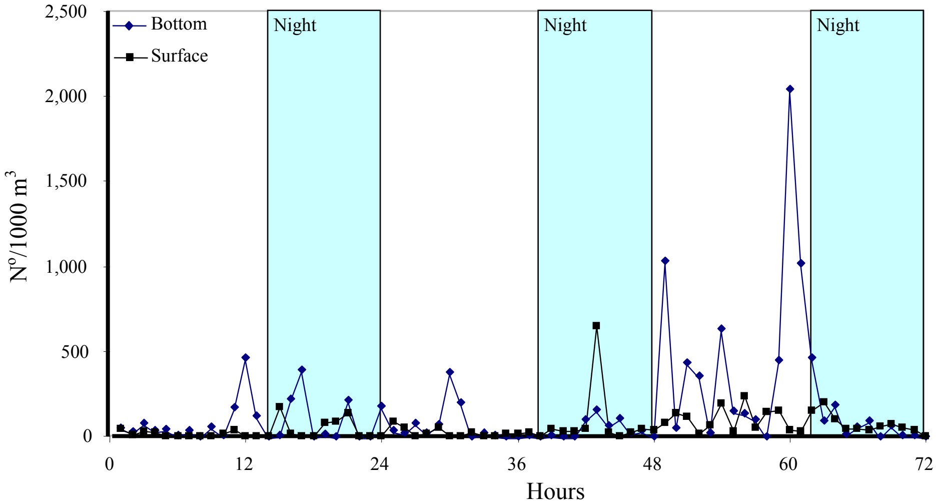

Figure 1. Drift pattern of Cyprinidae larvae

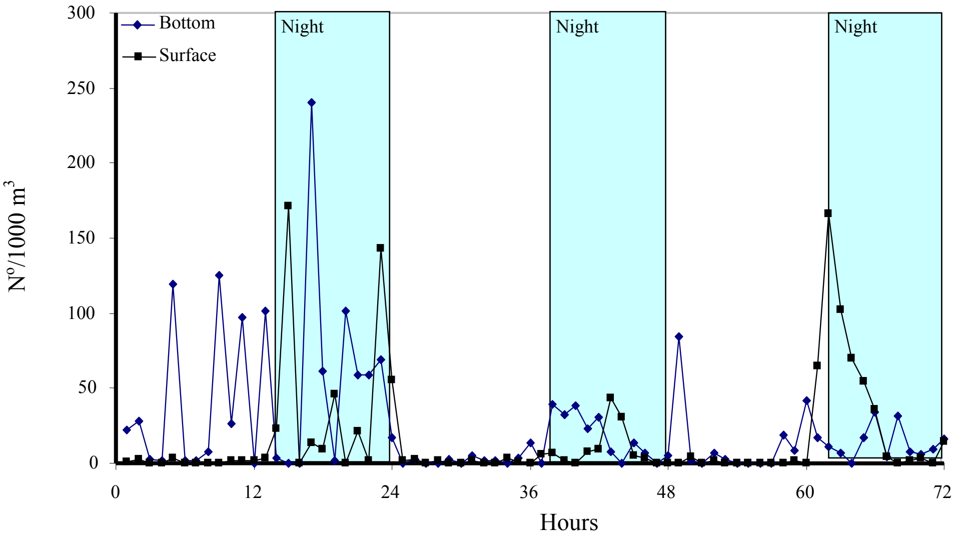

Figure 2. Drift pattern of *P. siamensis*

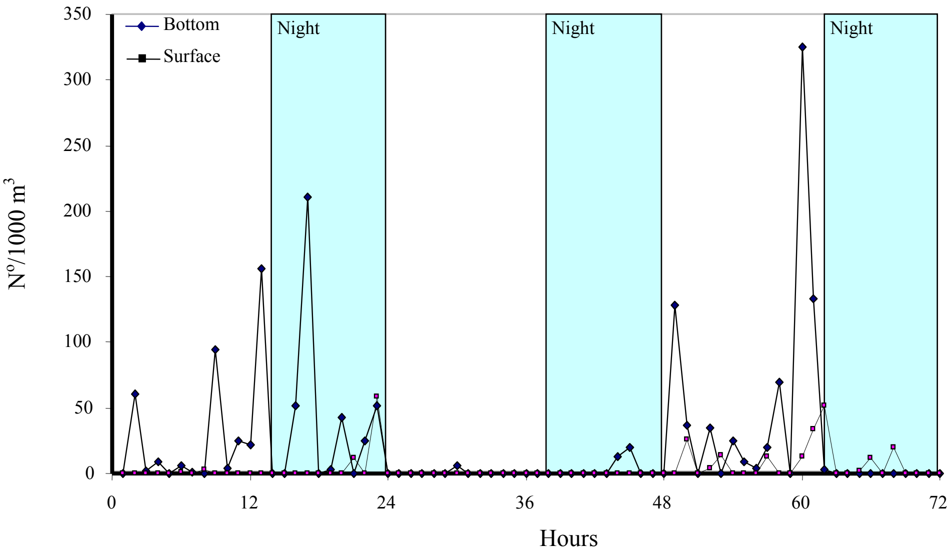

Figure 3. Drift pattern of *P. macronema*

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^o/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

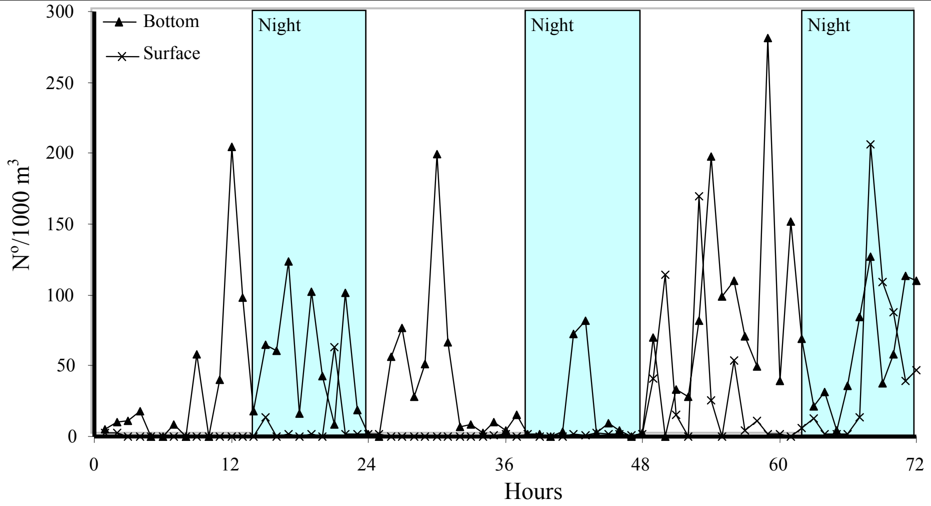

Figure 4. Drift pattern of *Macrobrachium* (shrimp) larvae/post-larvae

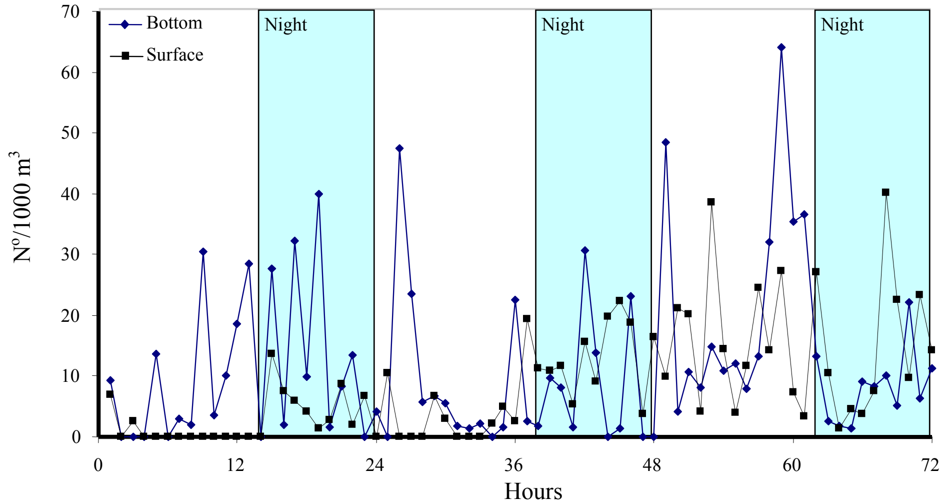

Figure 5. Drift pattern of Hydropsychidae (filter-feeding caddis fly larvae)

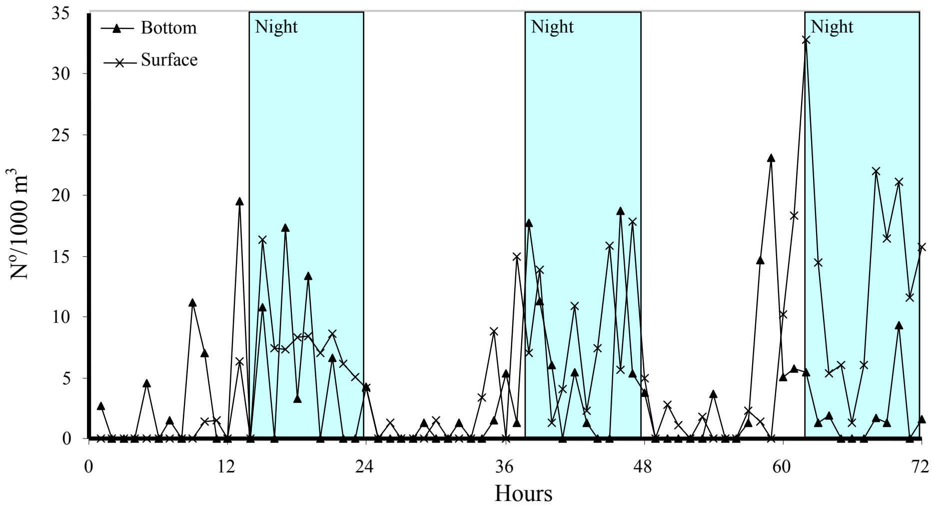

Figure 6. Drift pattern of Gomphidae (predatory dragonfly nymphs)

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°/1000m³)					**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

Ngor, S.*, Aun, L. Deap and K.G. Hortle

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).

* Dept of Fisheries, PO Box 582 Phnom Penh, Cambodia

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

<u>Location</u>

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

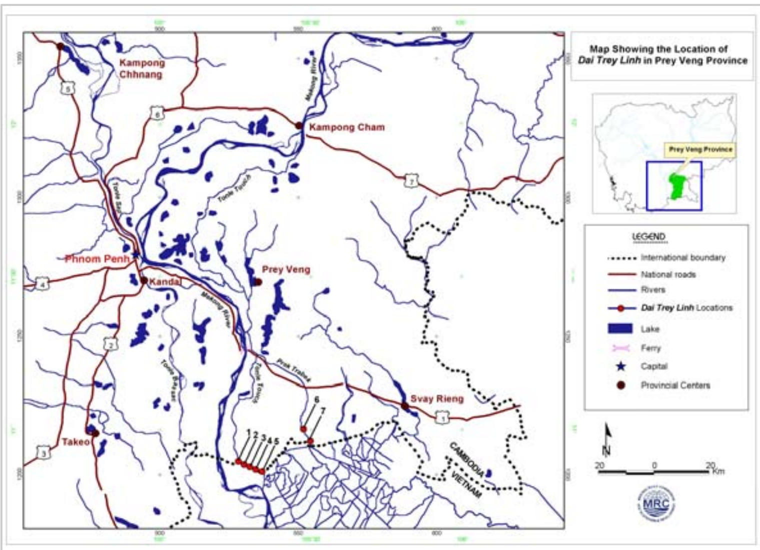

Figure 1. Location of the *dai trey linh*

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.

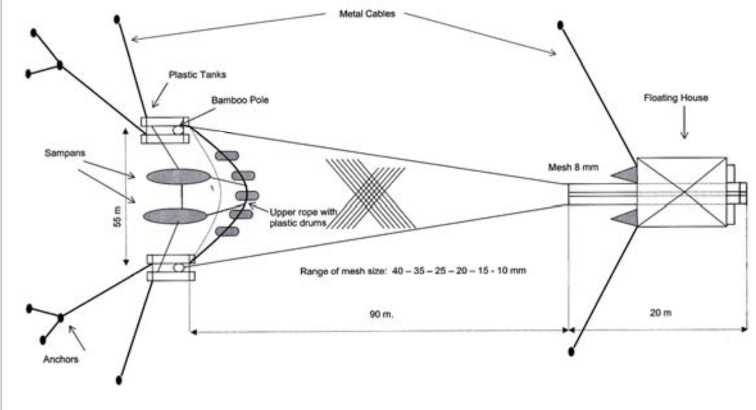

Figure 2. Schematic plan view of *dai trey linh*

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*.

<u>Basis for the fishery</u>

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.

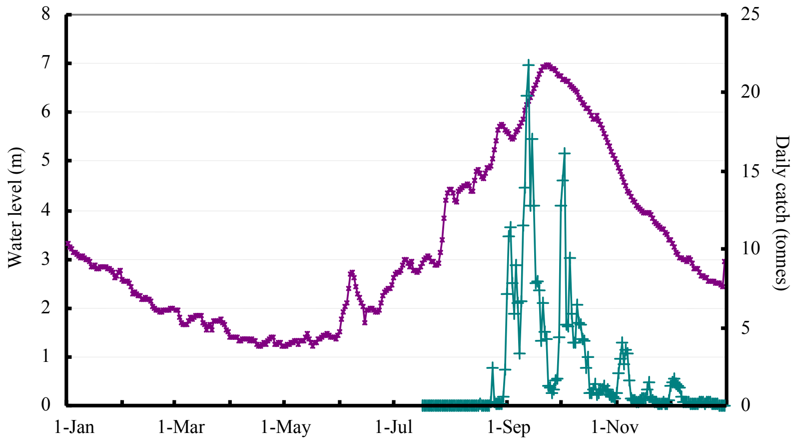

Figure 3a. Weight of catch compared with the level of the Mekong in 2003.

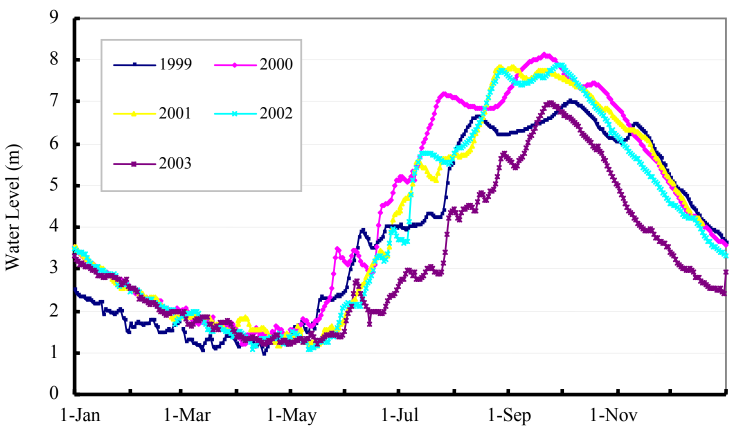

Figure 3b. Level of the Mekong in 2003 compared with the average level during the years 1999 to 2002.

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**	

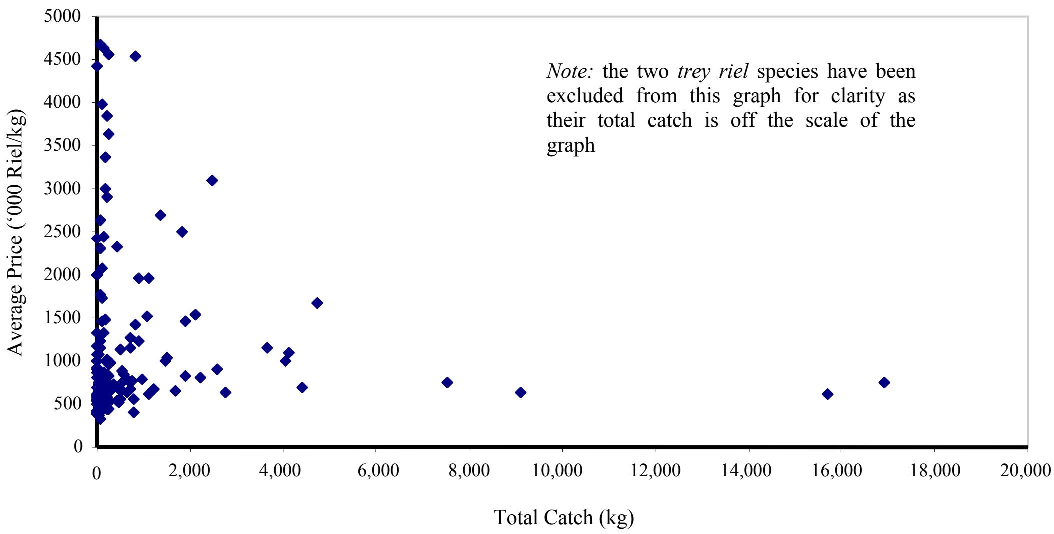

Figure 4. Weighted average price (per kg) of fish species plotted against total catch of each

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

S. Chan[1*], S. Putrea [1], K. Sean [2] and K.G. Hortle[1]

[1]Assessment of Mekong Capture Fisheries Component, MRC Fisheries Programme
[2]Department of Fisheries, Provincial Office, Kratie, Cambodia

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.

* Dept of Fisheries, PO Box 582 Phnom Penh, Cambodia
Email: ifric@online.com.kh

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.

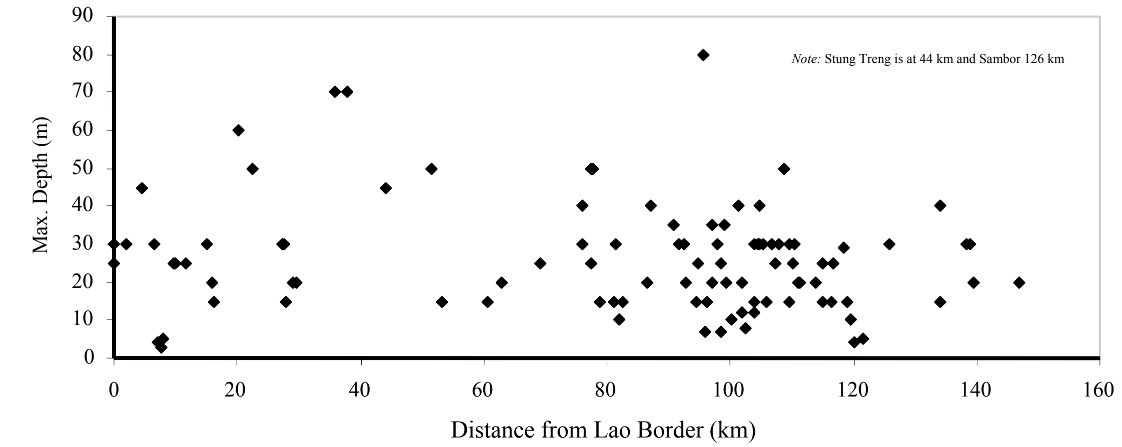

Figure 1. Distribution of pools along the Mekong between the Lao PDR border and Kratie showing their approximate maximum depth during the dry season

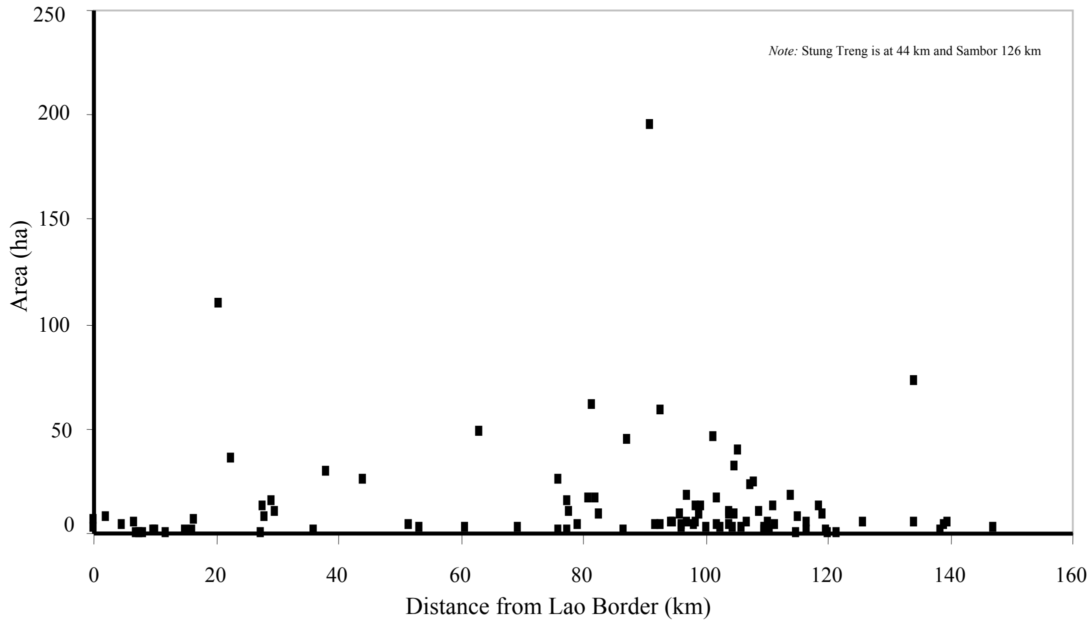

Figure 2. Distribution of pools along the Mekong between the Lao PDR border and Kratie showing their approximate surface area during the dry season

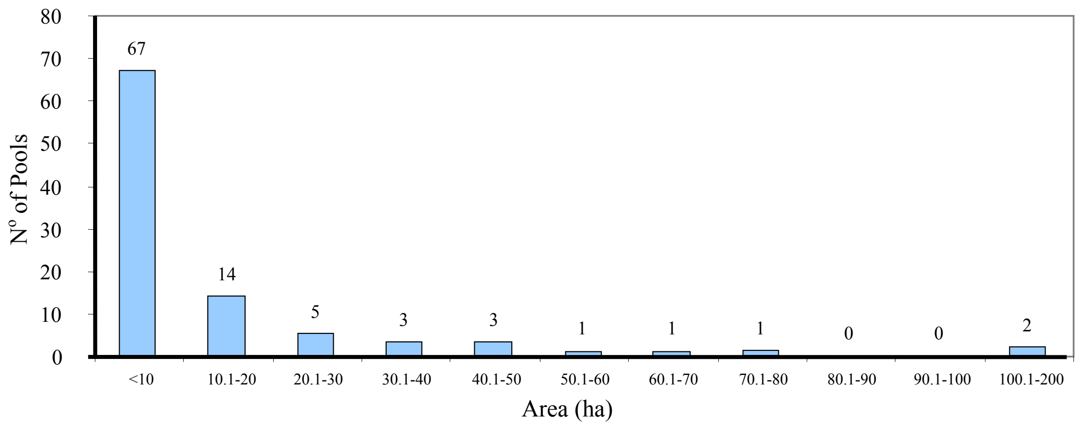

Figure 3. Distribution of deep pools by approximate area

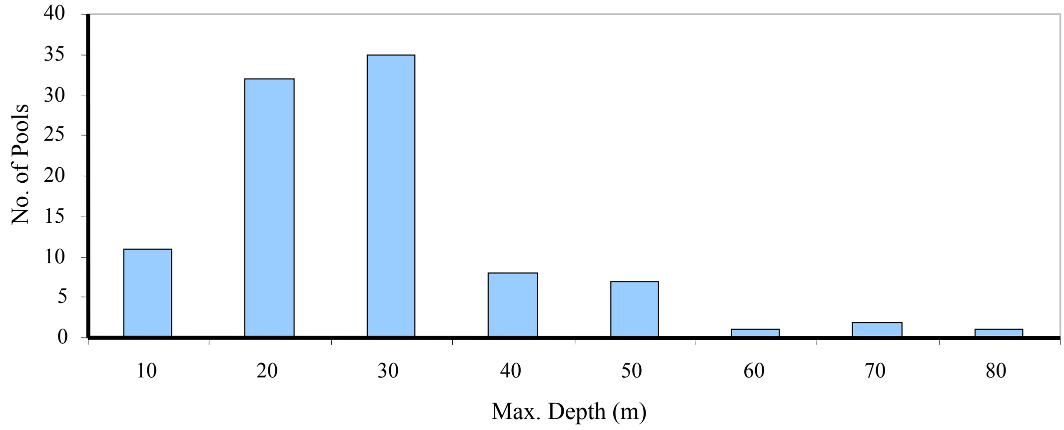

Figure 4. Distribution of deep pools by approximate maximum depth

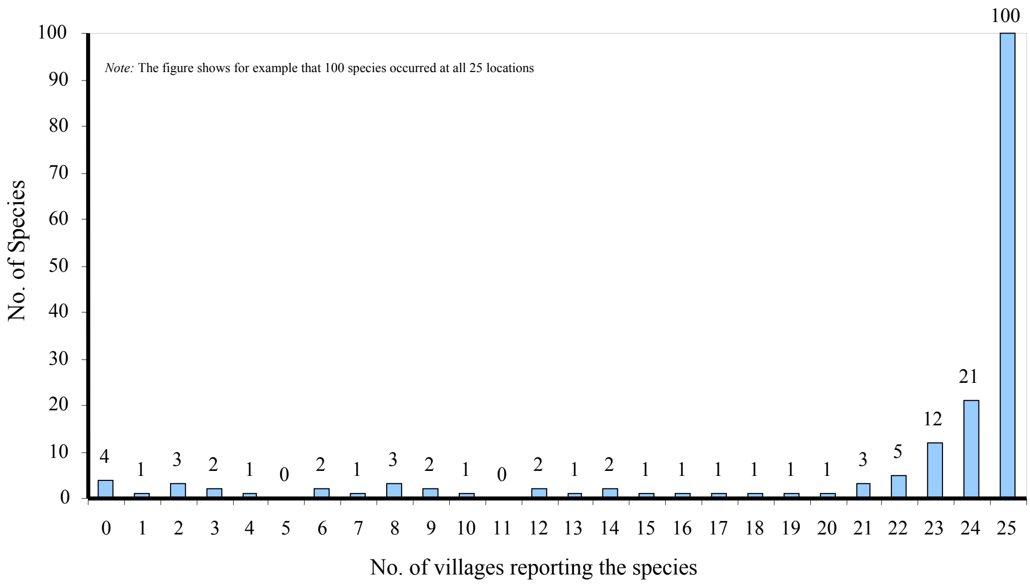

Figure 5. Species reports by location

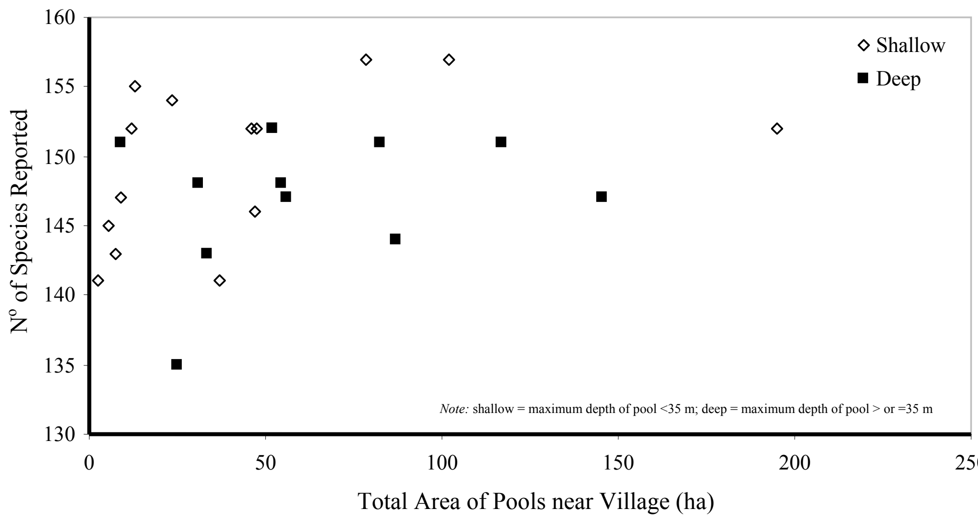

Figure 6. Distribution of species reports by area of pools

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’

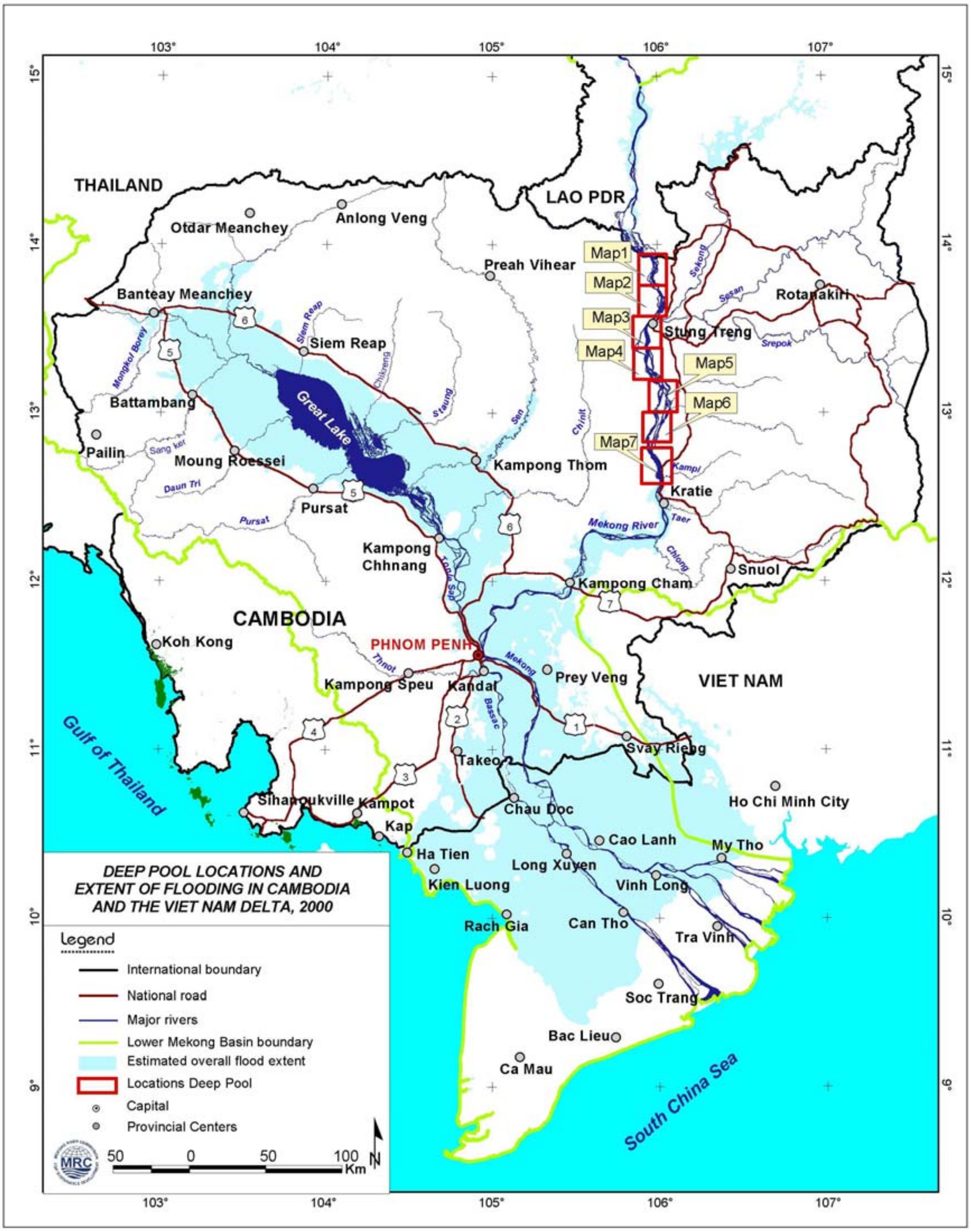
APPENDIX 1

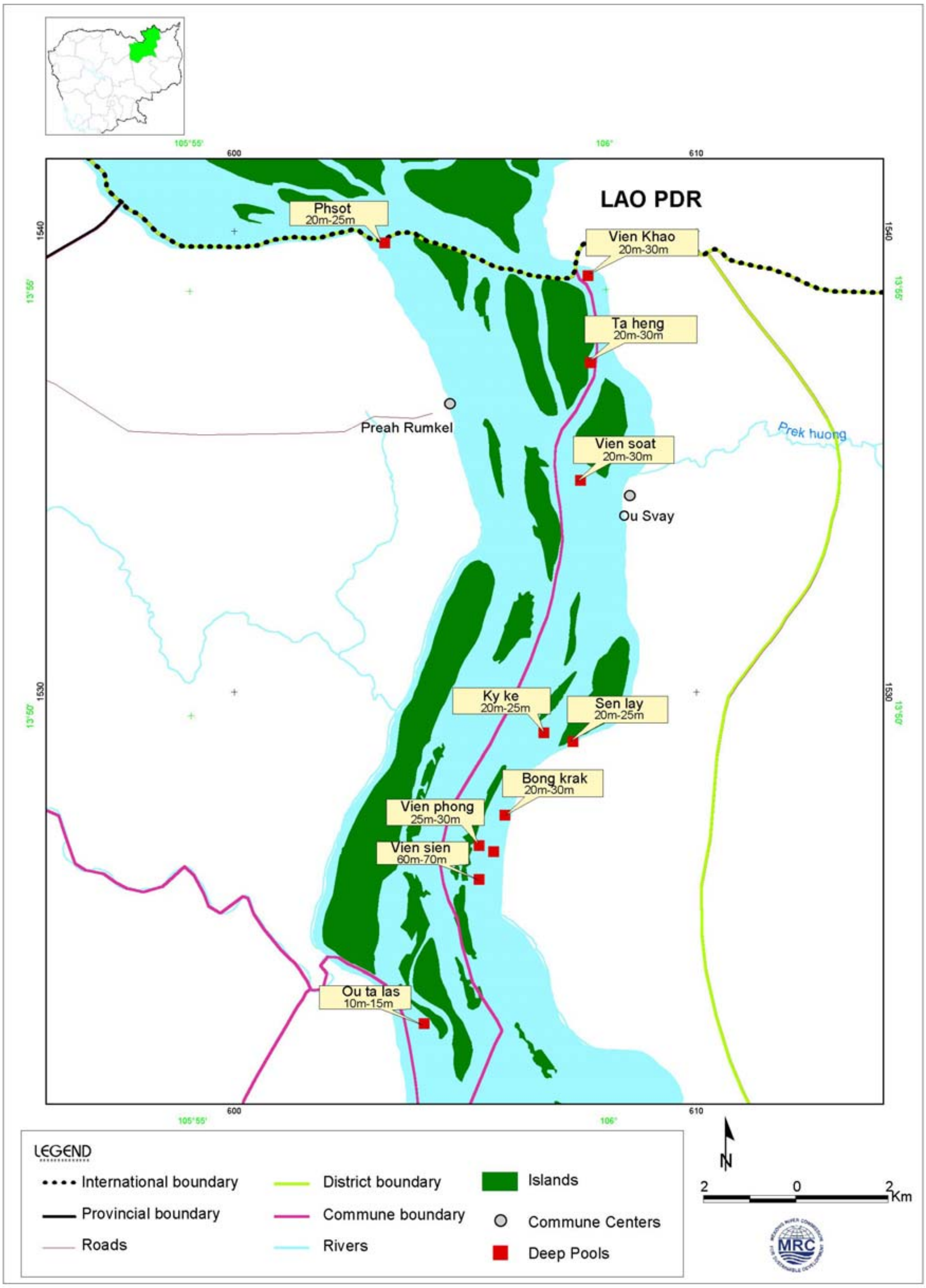
Basic location data on deep pools in northern Cambodia

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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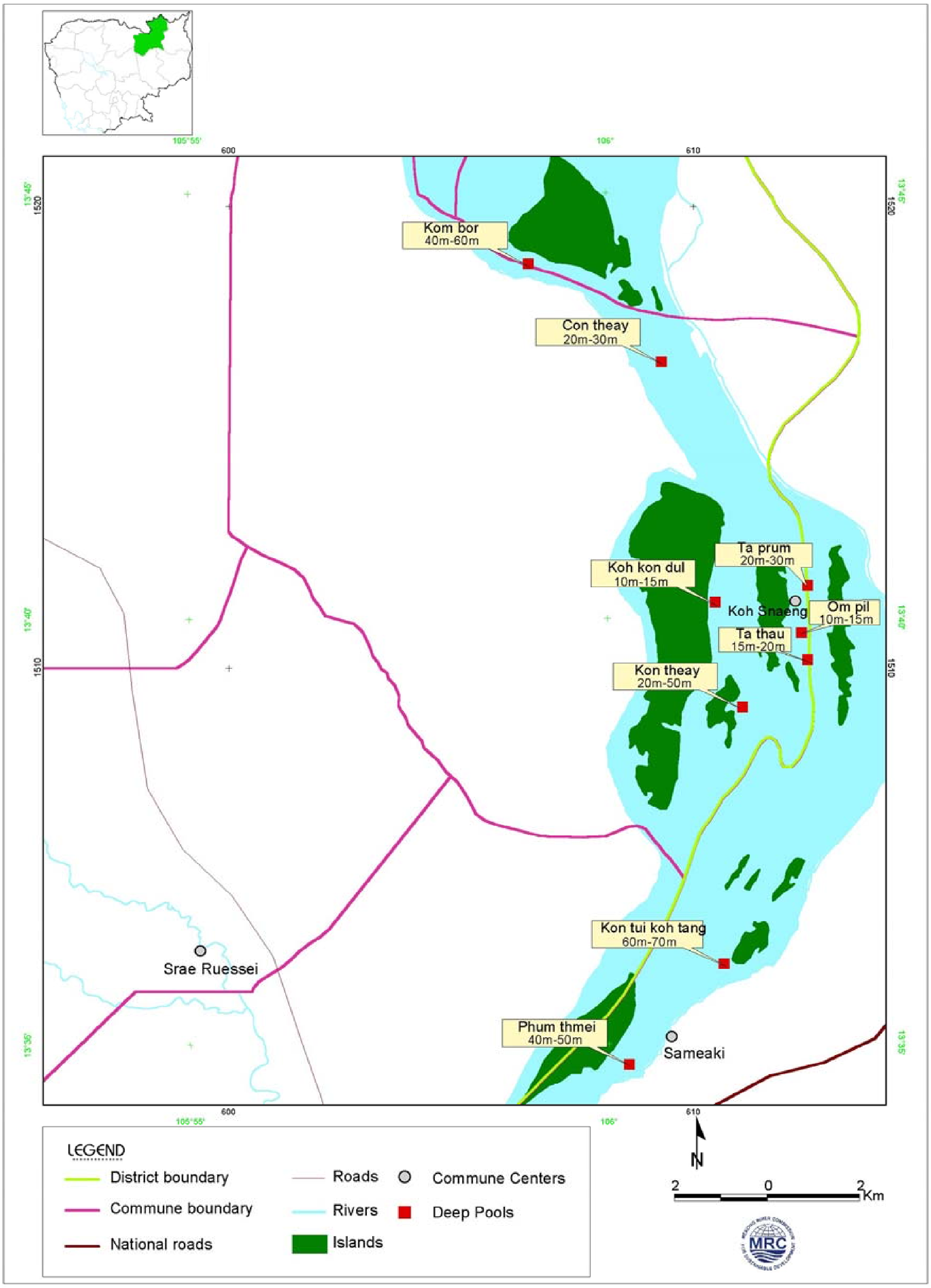
Vien Khao
20m-30m
Ta heng
20m-30m
Preah Rumkel
Prek huong
Vien soat
20m-30m
Ou Svay
Ky ke
20m-25m
Sen lay
20m-25m
Bong krak
20m-30m
Vien phong
25m-30m
Vien sien
60m-70m
Ou ta las
10m-15m
105°55'
106°
600
610
1540
1530
13°55'
13°50'
LEGEND
International boundary
Provincial boundary
Roads
District boundary
Commune boundary
Rivers
Islands
Commune Centers
Deep Pools
N
2
0
2
Km
MRC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Con theay
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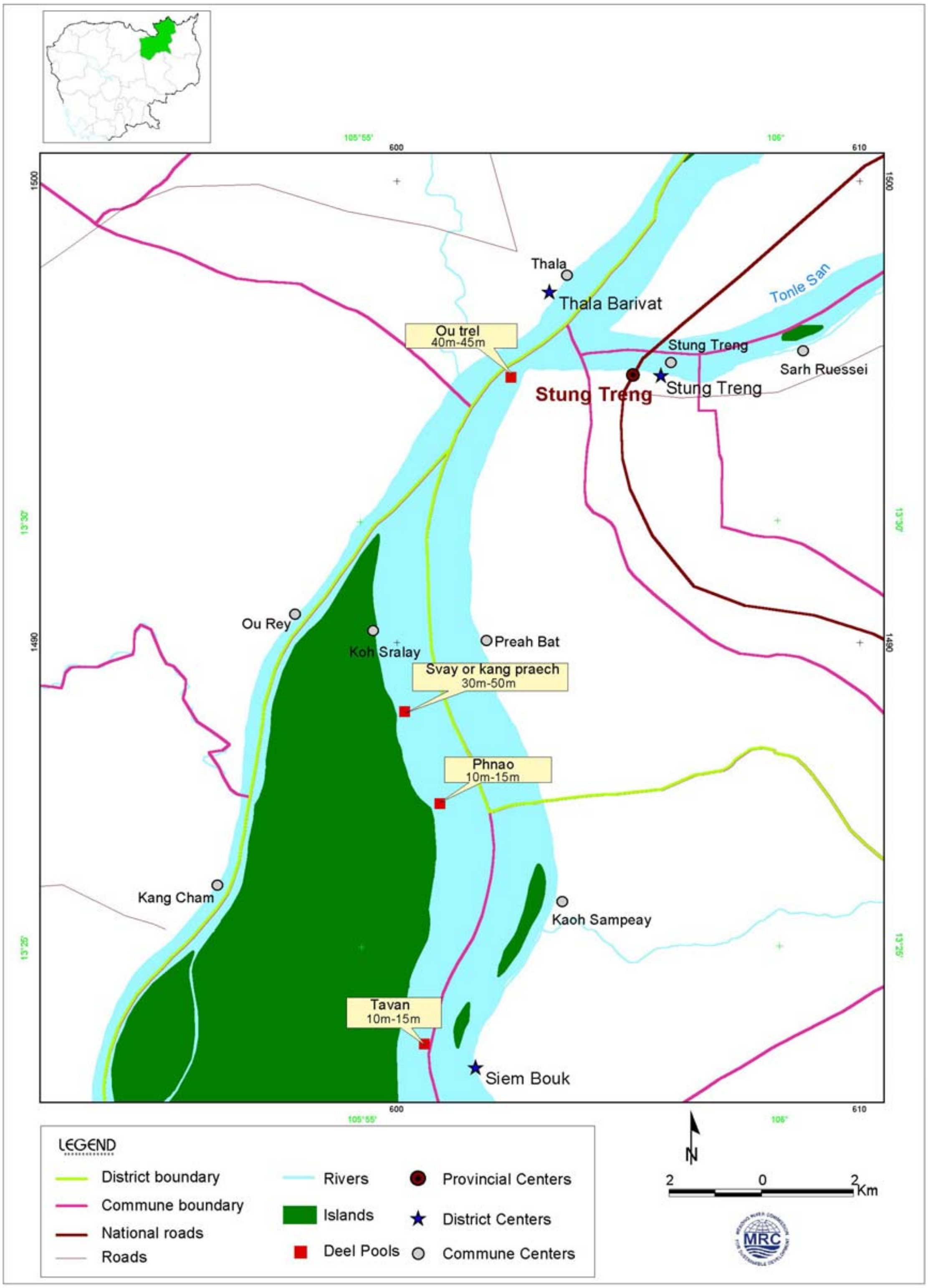
Ta prum
20m-30m
Koh kon dul
10m-15m
Koh Snaeng
Om pil
10m-15m
Ta thau
15m-20m
Kon theay
20m-50m
Kon tui koh tang
60m-70m
Phum thmei
40m-50m
Sameaki
Srae Ruessei
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
Commune Centers
Deep Pools
2 0 2 Km
N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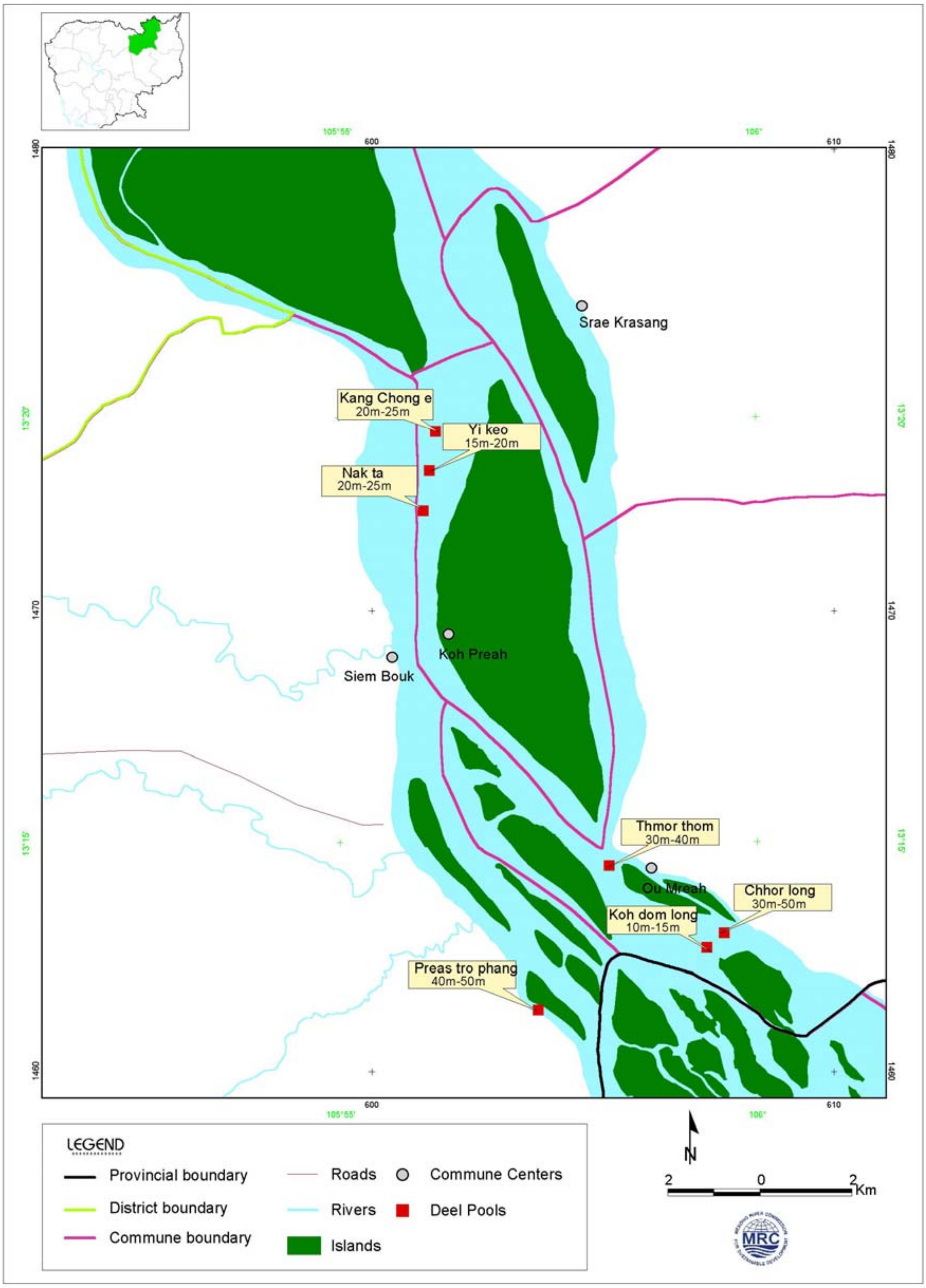
Thala Barivat
Tonle San
Ou trel
40m-45m
Stung Treng
Sarh Ruessei
Stung Treng
Stung Treng
Ou Rey
Koh Sralay
Preah Bat
Svay or kang praech
30m-50m
Phnao
10m-15m
Kang Cham
Kaoh Sampeay
Tavan
10m-15m
Siem Bouk
LEGEND
District boundary
Commune boundary
National roads
Roads
Rivers
Islands
Deel Pools
Provincial Centers
District Centers
Commune Centers
N
2 0 2 Km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Kang Chong e
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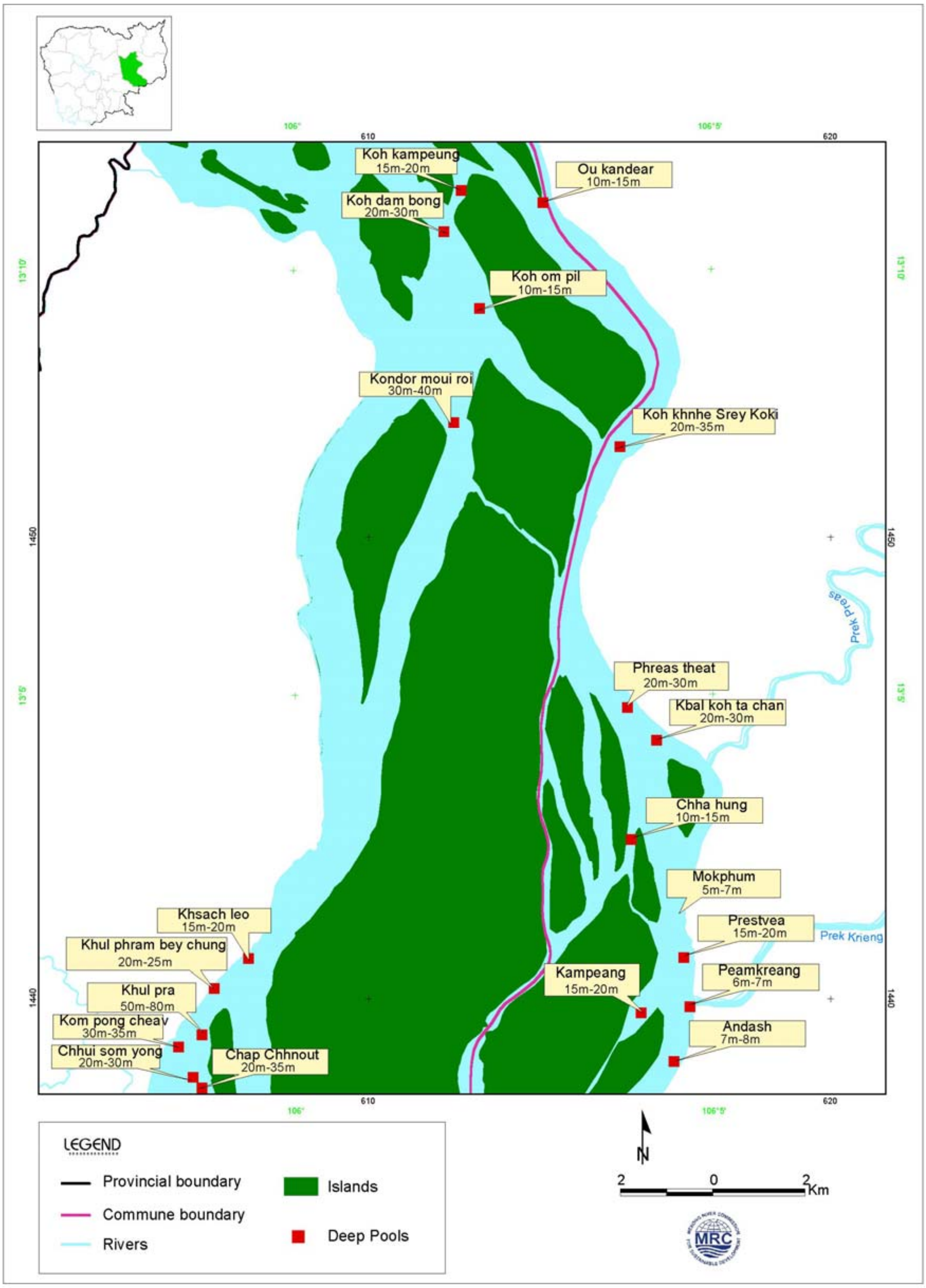
Yi keo
15m-20m
Nak ta
20m-25m
Koh Preah
Siem Bouk
Thmor thom
30m-40m
Ou Mreah
Chhor long
30m-50m
Koh dom long
10m-15m
Preas tro phang
40m-50m
LEGEND
Provincial boundary
District boundary
Commune boundary
Roads
Rivers
Islands
Commune Centers
Deel Pools
N
2 0 2 Km
MRC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Koh dam bong
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Koh om pil
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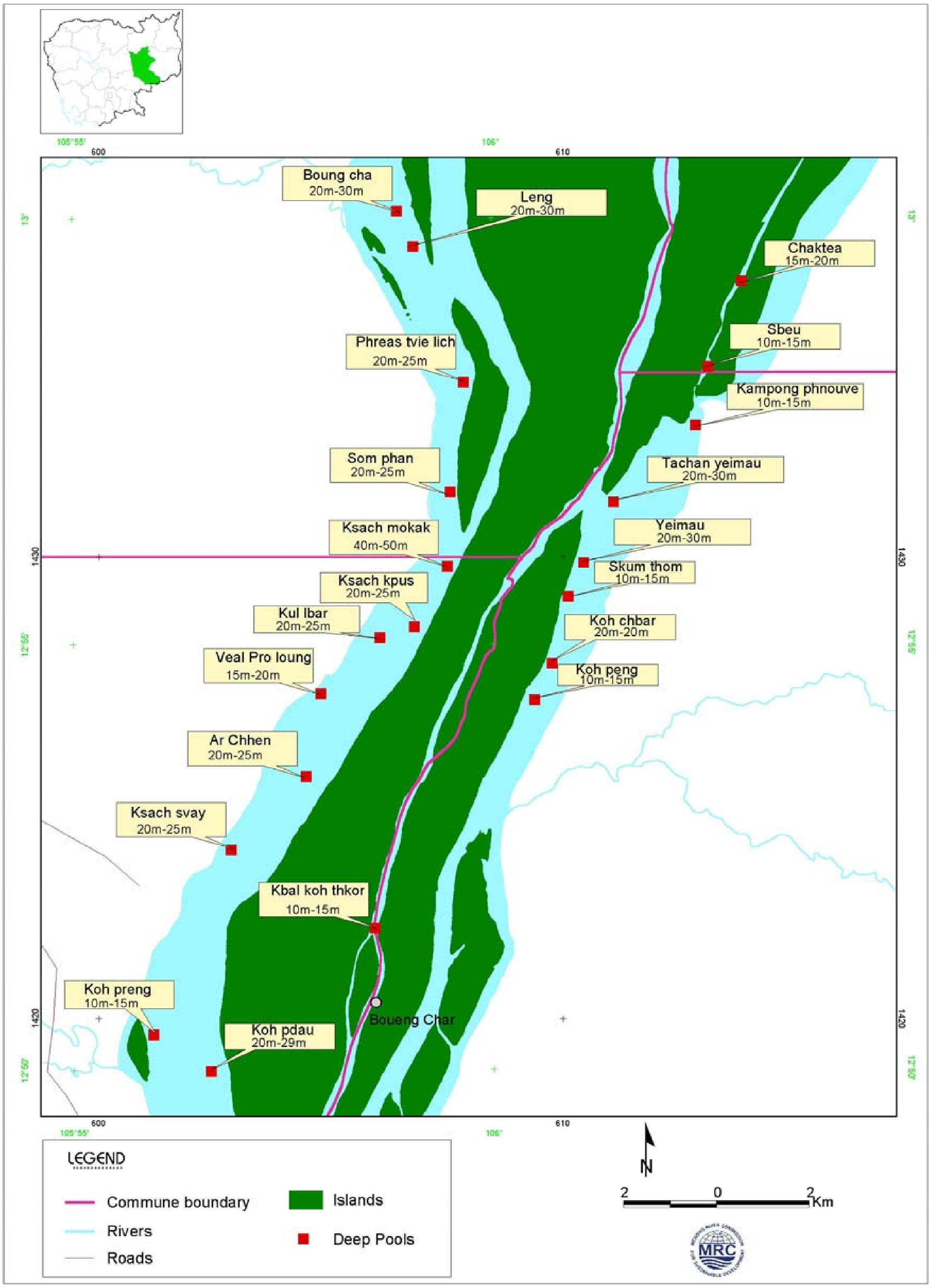
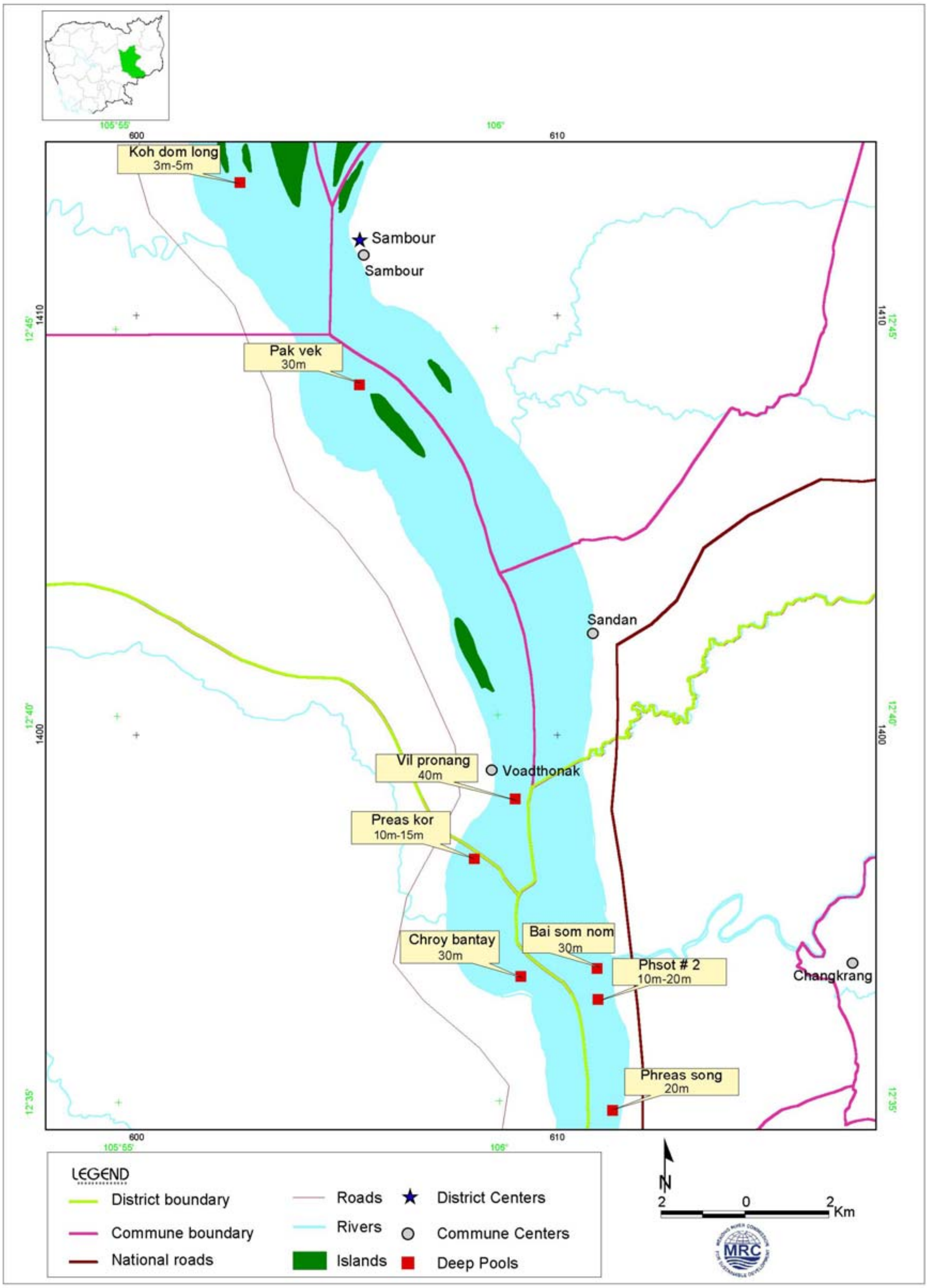
Kondor moui roi
30m-40m
Koh khnhe Srey Koki
20m-35m
Prek Preas
Phreas theat
20m-30m
Kbal koh ta chan
20m-30m
Chha hung
10m-15m
Mokphum
5m-7m
Prestvea
15m-20m
Prek Krieng
Peamkreang
6m-7m
Kampeang
15m-20m
Andash
7m-8m
Khsach leo
15m-20m
Khul phram bey chung
20m-25m
Khul pra
50m-80m
Kom pong cheav
30m-35m
Chhui som yong
20m-30m
Chap Chhnout
20m-35m
LEGEND
Provincial boundary
Commune boundary
Rivers
Islands
Deep Pools
N
2 0 2 Km


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
Boueng Char
Koh pdau
20m-29m
LEGEND
Commune boundary
Rivers
Roads
Islands
Deep Pools
N
2 0 2 Km
MRC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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

Section 2: Aquaculture

Mobile hatchery: a new tool for fisheries extension

Unnop Imsilp*, Sombut Singsee, Pin Polchai, Thanjai Assonjohn and Naruepon Sukumasavin

Aquaculture of Indigenous Mekong Fish Species Component, MRC Fisheries Programme

ABSTRACT

In 2002, staff from the Aquaculture of Indigenous Mekong Fish Species sub-component, Thailand (AIMS-Thailand) developed a mobile hatchery for use in remote rural areas. The performance of the hatchery in the field exceeded expectations. It proved more flexible than anticipated and the percentages of eggs produced, fertilized, and hatched, were comparable with results achieved in a standard hatchery. The hatchery allows artificial wild fish breeding in locations where transportation of these fish from the main hatchery is impossible. Demonstrations of the hatchery have taken place in Nakhonphanom, Udonthani, Mukdahan and Nam Houm (Lao PDR).

A hatching hapa measuring 2x2x0.5 m with flow-through water supply can be used to hatch 3.4×10^6 eggs of *Barbodes gonionotus* (93% fertilization rate and 86% hatching rate), 1.5×10^6 eggs of *Labeo rohita* (74% fertilization rate and 95% hatching rate) or 1×10^6 eggs of *Cirrhinus microlepis* (60% fertilization rate and 30% hatching rate). Funnel-type incubators with 15 L volume can be used to hatch 1.0×10^5 eggs of *Probarbus jullieni* (60% fertilization rate and 40% hatching rate). Demonstrations of the mobile hatchery attracted a lot of interest from local people and helped to raise awareness of issues concerning fish conservation.

KEY WORDS: Thailand, fisheries, mobile hatchery

INTRODUCTION

In many remote rural areas, long distances and poor quality roads hinder access to the fish hatcheries that provide stocks of threatened wild species. In 2002, staff from the Aquaculture of Indigenous Mekong Fish Species sub-component, in Thailand (AIMS-Thailand), designed and built a mobile fish hatchery to help overcome this problem. The mobile hatchery allows aquaculture in the those rural areas where transportation to the main hatchery is difficult if not impossible.

METHODS

The mobile hatchery is assembled from the following materials (see Figures 1 to 7):

- Water pump (Figure 1)
- Electric or engine motor (Figures 2 and 3)
- Material for set machines
- Machines
- Pipe and valve
- Air stone
- Brood stock fish
- Hormone and distilled water
- Hatching hapas (Figure 4 and 4b)
- Blower (Figure 5)
- Funnel-type incubator (Figure 6)
- Water supply in hatchery

Demonstrations of the mobile hatchery took place in Nakhonphanom, Udonthani, Mukdahan and Nam Houm (Lao PDR). When dissembled the hatchery fits on to a pickup truck and it is easy to transport and

* Nakorn Phanom Inland Fisheries Station , 12 Moo, 2 Nongyaat Sub-district, Muang District, Nakorn Phanom Province 48000, Thailand

Figure 1. Water pump

Figure 2. Electric motor

Figure 3. Diesel motor

Figure 4a. Hatching hapa

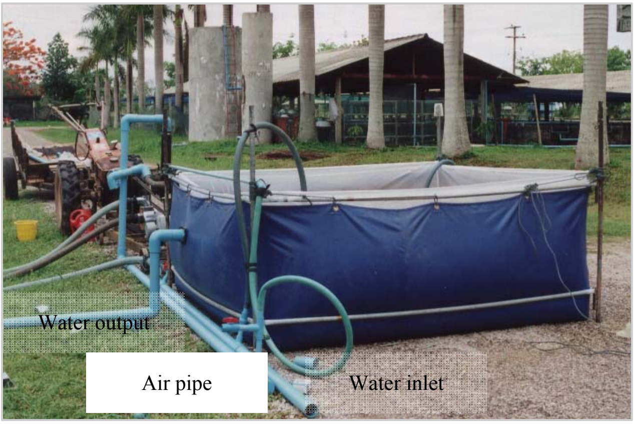

Figure 4b. Hatching hapa

Figure 5. Air Blower

Figure 6. Funnel-type incubator

simple to fabricate. It comes in three parts:

- The first part is a 2x2x0.8 metre hapa used as either a spawning tank or an incubator (Figure 4b). This hapa can hold 4.0×10^6 semi-buoyant eggs. Another type of incubator, a funnel-type incubator can also be connected to the system (Figure 6). The 15 litre funnel type incubator can hold 1.0×10^5 adhesive-demersal eggs.

- The second part, a pump (Figure 1), supplies water to the system.

- The third part is an air blower (Figure 5).

The water pump and air blower run by the 7.5 HP diesel engine (Figure 3) or the 5 HP electric motor (Figure 2). The mobile hatchery was prepared and assembled at a number of rural locations. The performance of the hatchery in terms of egg production, fertilisation, and hatching rates was recorded to compare its performance with that of a standard hatchery. The level of interest and participation by local inhabitants was also monitored.

RESULTS

The results of breeding in the mobile hatchery (Table 1) compare favourably with those of standard hatcheries and the hatchery has proved to be more flexible than was originally expected.

Table 1. *Parameters and performance of the mobile hatchery*

Species	No. of females	Body weight (kg)	No.of males	Body weight (g)	Eggs produced ($\times 10^6$)	Fertilization rate (%)	Hatching rate (%)	remark
	Hatching hapas size 2x2x0.8 meter (1 unit)							
Barbodes gonionotus	14	0.7	21	0.7	3.4	93	86	After injected hormone rearing broodstock for natural spawning.
Labeo rohita	10	1.0	15	1.0	1.5	74	95	After injected hormone rearing broodstock for natural spawning.
Cirrhinus microlepis	4	3.0 - 4.0	10	2.0 – 3.0	1.0	60	30	Artificial breeding and used dry method.
	Funnel- type incubator size 15 liter (8 unit)							
Probarbus jullieni	4	20.0 – 50.0	4	20.0 – 50.0	0.8	60	40	Artificial breeding and used dry method.

Levels of local interest and participation were high. Breeding demonstrations and fish-release activities were held in conjunction with MRRF, Mukdahan Inland Fisheries Station, and Yasothon Inland Fisheries Research and Development Centre. Approximately 100 people participated in Udonthani and about 30 at Mukdahan.

DISCUSSION

The results show that the fertilization rate and hatching rate of fish using the mobile hatchery is similar to those obtained in a standard hatchery (Sutanurak and Plodauon, 1992). The mobile hatchery is particularly suitable for work in the field where there is no access to a regular hatchery, or to breed wild fish in the field when transportation of the fish to the main hatchery is impossible. It is a new and useful tool for fisheries extension and fisheries development in Thailand.

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A survey of aquatic animal health problems affecting small-scale aquaculture production and fisheries in Lao PDR

Somphouthone Phimmachak* and Saleumphone Chanthavong

Aquaculture of Indigenous Mekong Fish Species Component, MRC Fisheries Programme

ABSTRACT

This study presents the results of a survey of aquatic animal health conducted in three provinces of Lao PDR. The objectives of the study were to (1) identify problems with fish disease in Lao PDR, (2) investigate the source and cause of disease and, (3) determine its effect on aquaculture systems.

In total, 163 families were interviewed using a questionnaire; 30-40% reported the occurrence of fish disease. The spread of disease depends on many factors associated with culture in hatcheries and nursing and is more of a problem in integrated than in poly-culture systems. In Oudomxay and Vientiane, fish mortality due to disease was high and often associated with imported seed. Disease occurred mainly in the cool months from around December to April and early rainy season from about May to June. Eight major diseases are prevalent: epizootic ulcerative syndrome (EUS) and diseases caused by Lernaea, Epistylis, Trichodinia, Oodinium, Gyrodactylus, Columnaris, and *Edwardsiella tarda*.

KEY WORDS: Aquatic animal health, fish disease, aquaculture

INTRODUCTION

The number of farmers involved in aquaculture in Lao PDR has increased in recent years. Their methods generally employ extensive culture systems though an ever-increasing number of intensive commercial fish farms now operate near large towns and suburban areas and supply local markets and families with fish.

Farmers report that they often find dead fish in their ponds and this study found mortality rates in some nursing ponds were more than 90% in a number of instances.

Many factors cause the spread of disease including, the illegal importation of aquatic animals, poor knowledge of disease prevention and treatment, poor pond management, high stocking densities, and over-fertilisation.

In October 2002, the Living Aquatic Resources Research Centre (LARReC) and the Department of Livestock and Fisheries Veterinary Laboratory (DLF Vet-Lab), both government organisations, designed a questionnaire to aid in the study of fish disease in three provinces in Lao PDR:

- Vientiane municipality (three districts - Sikhottabong, Naxaythong and Xaythany)
- Oudomxay province (three districts - Houn, Beng, and Xay)
- Champassack province (three districts - Pakse, Paksong, and Pathoumphone)

* LARReC, P.O. Box 9108, Vientiane, Lao PDR
Email: larrec@laopdr.com

We believe that these provinces are representative of the whole country.

The objectives of the study were to:

- Identify problems with fish disease in Lao PDR
- Investigate the source and cause of disease
- Determine its effect on aquaculture systems

METHODS

Between January and July 2003, a team of five LARReC staff and two local researchers interviewed small-scale fish farmers from the regions selected for study. These fish farmers were practising fishpond, rice-fishpond, public and private hatchery, community fishpond, nursery and cage, cultures. The survey team interviewed 163 fish farmers and/or their families (between 40 and 60 from each site) and asked them to complete a questionnaire about their farming practices. The questionnaire, which followed the format of an earlier survey conducted in Savannakhet province (NACA 1999), contained questions about culture techniques, water quality and the prevention and treatment fish diseases.

Figure 1. Small silver carp infected with Lernaea

RESULTS

Presence of disease in different culture systems

In Vientiane, parasites, bacteria and fungi that cause disease in tilapia (*Oreochromis niloticus*), silver barb (*Barbonymus gonionotus*), catfish (*Clarias* sp.), common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), big head (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*) and snakehead (*Channa* sp.) were present in samples from hatcheries, nursing and grow-out ponds (Table 1). The samples also contained fish with epizootic ulcerative syndrome (EUS) along with disease caused by the following organisms: *Lernaea* sp., *Epistylis* sp., *Trichodinia* sp., *Gyrodactylus* sp., *Columnaris* sp., and *Edwardsiella tarda*.

Table 1. *Number of infected samples in Vientiane municipality and Oudomxay and Champassack provinces*

Culture	Province							
	Vientiane		Oudomxay		Champassack		All provinces	
	Nº samples	% infected	Nº samples	% infected	Nº samples	% infected	Nº samples	% infected
Fishpond	32	38	48	46	40	35	120	40
Local hatcheries	11	64	6	33	5	80	22	59
Nursing	2	50	1	100	2	0	5	40
Cage culture	5	80	0	0	2	0	7	57
Rice-fishpond	1	0	2	100	3	33	6	50
Community fishpond	0	0	0	0	3	0	3	0
Total	**51**	**45**	**57**	**47**	**55**	**35**	**163**	**42**

Notes: 1. In this, and the tables that follow, 'samples' refer to the number of fish farmers interviewed, and '% infected', to the percentage of fish farmers that reported diseased fish. 2. Fish farmers in Vientiane use imported seed for cage culture; this might explain the very high (80%) levels of infection

In Oudomxay, *Lernaea* sp., *Epistylis* sp., *Columnaris* sp., and *E. tarda* were present in samples from hatcheries and nursing ponds; *Columnaris* sp also infected cage cultures in reservoirs and rivers.

In Champassack, samples from hatcheries and grow-out ponds were found to be infected with *Oodinium* sp., *Epistylis* sp., and *Edwardsiella tarda* which cause disease in common carp, silver barb, tilapia, Indian carp (*Cirrhinus cirrhosus*), rohu (*Labeo rohita*) and silver carp.

Some of the causative factors are briefly discussed below.

Farming systems

Disease rates are significantly higher where integrated fish farming and livestock systems were in operation.

Table 2. *Incidence of disease in integrated and non-integrated farming systems*

	Culture			
	Integrated		Non- integrated	
	Nº samples	% infected	Nº samples	% infected
Vientiane	16	63	35	37
Oudomxay	11	73	46	41
Champassack	2	50	53	34
Total	**29**	**66**	**134**	**37**

Water source

Levels of infection in culture systems using water from irrigation canals were higher in Oudomxay than in any other province. In Vientiane and Champassack, levels were high in those systems that depended on water from the river.

Table 3. *Incidence of disease related to water source*

	Water source					
	Irrigation		Rain		River	
	N° samples	% infected	N° samples	% infected	N° samples	% infected
Vientiane	30	40	16	50	5	60
Oudomxay	13	69	17	41	27	41
Champassack	12	33	18	17	25	48
Total	**55**	**45**	**51**	**35**	**57**	**42**

Seed source

Farmers in each province noted some differences. In Oudomxay, fish fed on seed imported from China and Viet Nam were twice as prone to infection as those fed seed from the local hatchery.

Table 4. *Incidence of disease related to seed source*

	Seed source					
	Imported		Home-produced		Local hatchery	
	N° samples	% infected	N° samples	% infected	N° samples	% infected
Vientiane	7	71	7	43	37	41
Oudomxay	8	88	11	36	38	42
Champassack	11	27	9	67	35	29
All provinces	**26**	**58**	**27**	**48**	**110**	**37**

Pond preparation

Disease appears to occur most commonly in areas where pond preparation is poor.

Table 5. *Incidence of disease related to pond preparation*

	Pond preparation techniques employed			
	Yes		No	
	Infection rate			
	N° samples	% infected	N° samples	% infected
Vientiane	48	44	3	67
Oudomxay	30	40	27	56
Champassack	39	28	16	50
All provinces	**117**	**38**	**46**	**54**

Use of disease prevention techniques

Farmers who employed disease prevention techniques had a lower incidence of disease

Table 6. *ncidence of disease related to prevention techniques*

	Prevention techniques employed			
	Yes		No	
	Infection rate			
	N° samples	% infected	N° samples	% infected
Vientiane	41	37	10	80
Oudomxay	26	39	31	55
Champassack	36	31	19	42
Total	**103**	**35**	**60**	**55**

Water exchange

The level of disease levels in fish in Vientiane and Oudomxay reared in systems that do not employ water exchange mechanisms were significantly higher than in systems in areas that do. .

Table 7. *Incidence of disease related to water exchange practices*

	Water exchanged			
	Yes		No	
	Infection rate			
	N° samples	% infected	N° samples	% infected
Vientiane	37	38	14	64
Oudomxay	27	33	30	60
Champassack	11	27	44	36
Total	**75**	**34**	**88**	**49**

Seasonality

Respondents from all three localities reported that disease occurred most commonly during the cool months from about December to April and in the early rainy season from about May to June

CONCLUSIONS

Although farmers are developing intensive methods and aquaculture is on the increase in the larger cities and suburbs of Lao PDR, extensive methods are still most common. This study found that disease occurred in all systems. Aquaculture is expensive particularly as the price of feed constantly fluctuates. Some farmers attempt to reduce costs by raising fish with livestock using an integrated method of production. However, fish raised in this way are particularly prone to disease and poor pond preparation techniques, importation of seed, and high stocking densities further compound the problems. Prevention of disease is essential but this fact is not widely appreciated by farmers and consequently the incidence of disease is high. As the industry expands, so too will the problems and costs unless action is taken to reverse the trend.

RECOMMENDATIONS

A number of recommendations follow from the results of this study:

- there is an urgent need for an education and prevention campaign (including quarantine techniques) to teach farmers how to improve their management methods
- seed needs to be of the highest quality and must be disease-free
- educational materials that promote the prevention of disease should be produced and broadcast through extension services and on national television
- capacity-building and development of human resources is required in this field
- riparian countries should continue to share information through seminars, workshops and training courses

REFERENCE

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Artificial propagation of Hoeven's slender carp (*Leptobarbus hoevenii*)

Dang Van Truong*, Nguyen Minh Thanh, Hoang Quang Bao, Thi Thanh Vinh, Pham Dinh Khoi , Nguyen Thi Hong Van and Trinh Quoc Trong

Aquaculture of Indigenous Mekong Fish Species Component, MRC Fisheries Programme

ABSTRACT

The artificial propagation of Hoeven's slender carp (*Leptobarbus hoevenii*) was studied under trial conditions at Research Centre for Aquaculture in the Mekong Delta, Research Institute for Aquaculture No. 2, within the framework of Aquaculture of Indigenous Fish Species (AIMS) component. Trials showed that females required two injections of hormone, preparatory and resolving, to induce spawning; males however required just a single resolving dose. Following injection females and males were kept in spawning tanks with flow-through water. Females were stripped or spawned naturally 5.5 – 8.0 hrs after the resolving injection. Relative fecundity of female ranged between 84,043 and 92,907 eggs/kg. Fertilised eggs were incubated in Zuger jars or aerated fibreglass tanks with flow-through water. Fertilisation and hatching rates ranged from 47.0 to 72.5% and 64.7 to 87.8%, respectively. Hatching period took approximately 13 hrs at water temperature of 28 – 29°C.Two-stage nursing technique in concrete tanks and thereafter in earthen ponds was tested. Survival rate of *L. hoevenii* fingerlings at 50 – 60 days old was found to be at 50 – 60%.

KEY WORDS: Viet Nam, Hoeven's slender carp, artificial propagation

INTRODUCTION

Hoeven's slender carp (*Leptobarbus hoevenii*) is an indigenous freshwater fish found naturally in rivers and springs in Viet Nam, Lao PDR, Thailand and Cambodia. It feeds on larva, worms, and zooplankton during its larval stage and phytoplankton and forest fruits when it reaches maturity (Rainboth 1996). The species is economically important to fisheries in the Mekong Delta where it is native. Here production is mainly through natural capture as efforts to culture it by artificial means to date have been relatively unsuccessful due to a lack of seed and ineffective culture techniques. However, the successful production of seed of sufficient quality and quantity for aquaculture needs further research. As well as being commercially beneficial, this seed would help to reduce the demands on the already limited numbers of this species in the wild.

METHODS

Brood-stock conditioning

Study of the artificial propagation of *L. hoevinii* was carried out from June 2001 to October 2003 at the Research Centre for Aquaculture in the Mekong Delta (Cai Be Centre), Research Institute for Aquaculture No. 2 (Cai Be district, Tien Giang province, Vietnam), under AIMS Vietnam Sub-component.

Fish were collected from the wild in June-July 2001. A further 240 individuals were collected in 2003

* Research Centre for Aquaculture in the Mekong Delta, Research Institute for Aquaculture No. 2, An Thai Trung village, Cai Be district, Tien Giang province, Viet Nam.

and stocked at a density of 24 kg/100m^2 in two separate earthen ponds (700 m^2 each) at the Cai Be Centre.

In order to monitor water quality in the brood-stock ponds, temperature and levels of dissolved oxygen (DO) were measured daily at 07:00 and 14:00 and pH and levels of dissolved carbon dioxide (COD) were measured weekly at these same times of day.

Daily aeration of the brood-stock ponds (23:00 to 06:00) maintained DO at minimum 2.5 mg/l. Water level was kept constant at between 1 to 1.2 m and approximately 30-30% of the pond water was exchanged once or twice every month. In order to create a current, water was pumped every morning for two hours during the period from April to October.

Conditioning of the brood stock took place in two stages. During the first, from December to April, fish were fed an equivalent of 4% of their body weight. This was reduced to 2% body weight during the second stage (May to October). Local-made feed consisted of fishmeal, blood powder, rice bran, fish oil and premix (containing approx. 35% of crude protein). In addition, fruits such as guava and plum were given at a rate of 2% of body weight.

Egg samples were periodically collected from the brood stock to determine stage of maturity based on histology. Samples of eggs were also collected before and after the primary hormone injection; these were kept in Davidson solution. The diameter of each egg was measured under microscope to determine egg transformation after injection. Based on this information, technicians decided when would be the best time to apply the resolving injection.

Records of spawning seasons, maturation ratio, maturation coefficient, absolute fecundity, relative fecundity, real relative fecundity, ratio of brooders releasing eggs, fertilization and hatching rates were made.

Induced spawning

Spawning was induced by injecting Luteinising Hormone-Releasing Hormone analogue (LH-RHa) plus

Table 1. *Hormone doses used to stimulate artificial propagation in Hoeven's slender carp.*

Year	Treatment	Hormone	Preparatory dose/kg		Resolving dose/kg	
			Female	Male	Female	Male
2002	1	Pituitary (mg)	2.0		4.0	3.0
		LHRHa (µg)	80.0		200.0	80.0
		DOM (mg)	10.0		20.0	10.0
	2	Pituitary (mg)	2.0	1.0	4.0	2.0
		LHRHa (µg)	50.0	25.0	140.0	50.0
		DOM (mg)	5.0	2.5	15.0	5.0
2003	1	Pituitary(mg)	1.0		1.2	0.6
		LHRHa (µg)			130.0	65.0
		DOM (mg)			13.0	6.5

domperidone (DOM) and carp pituitary gland extract (PG). The doses used were different in 2002 and 2003 (Table 1). In the 2002 spawning season, two treatments were carried out to find the most suitable dosage. This was achieved by gradually reducing the amount of each hormone used.

Dissemination was accomplished using the 'dry' method, i.e. eggs and milt were mixed before adding water. Fertilized eggs were incubated in Zuger jars or in aerated fibre tanks with flow-through water.

Nursing

Once the yolk sac was absorbed, fry were nursed by two separately treatments:

Treatment 1 (two-stage nursing):

Stage 1: fry were nursed in 12.5 m^2 concrete tanks at a density of about 1,000-1,200 indiv/m^2 (in 2002) and 2,000 indiv/m^2 (in 2003) until they were 20 days old.

Stage 2: thereafter fish were moved to 200 m^2 earthen pond. Density reduced to 50-100 indiv/m^2. This stage last to 40 days.

Treatment 2: fry were moved into 700 m^2 earthen ponds after the yolk sac was exhausted. Density was 200-300 indiv/m^2. Nursing period lasted for 60 days.

Table 2. *Type of feed used to nurse fry*

Age (day)	Type of feed
1-10	Milk powder + moina
11-40	Fish meal + rice bran
41-60	Fish meal + rice bran + pellet feed

RESULTS AND DISCUSSION

Environmental parameters of the brood stock ponds

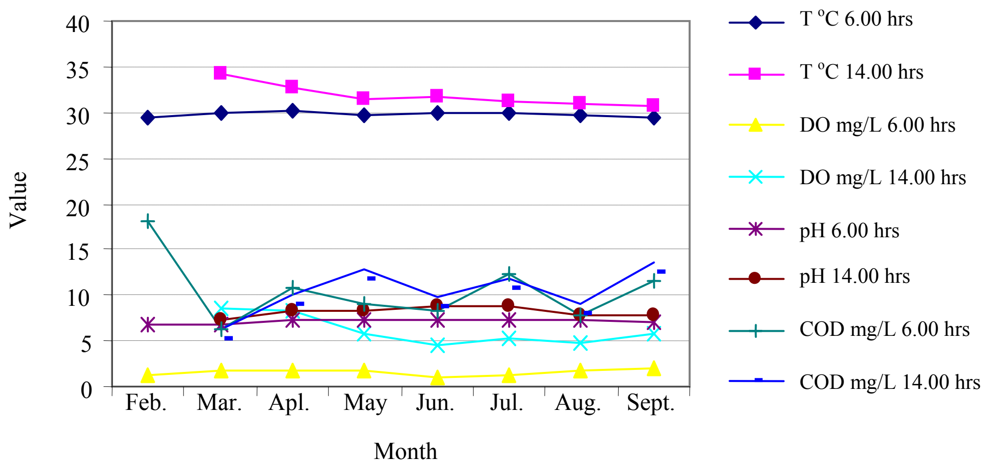

Figure 1. Water quality parameters in brood-stock ponds

Brood-stock maturation

In the wild Hoeven's carp normally take two years to teach maturity. In pond culture, the 34% of brood-stock collected in June and July 2001 reached maturity in 2002. This low percentage may be because the fish had not yet fully adapted to pond environments.

In 2003, the ratio of mature fish increased to 88% (females) and 73% (males), showing that *L. hoevinii*, can thrive well in captivity once they have adapted to artificial feed and the environmental conditions in the brood ponds.

Figure 2 illustrates the maturation ratio of females to males during the spawning season. Males matured earlier than females; while 13% of males were mature by mid-March most females did not reach phases III and IV until April. Some females in phase V could reproduce in May. By June, the maturation ratio had reached 30% in females and 20% in males.

The maturation ratio of both females and males reached a peak in June; thereafter the ratio dropped dramatically in males but remained relatively high in females. Successful spawning requires a large numbers of males to females as males produce only a small amount of sperm. As result, the reproductive season was short. Females are able to reach maturity again 90-120 days after spawning and some of the females in this study were able to reproduce twice in one spawning season.

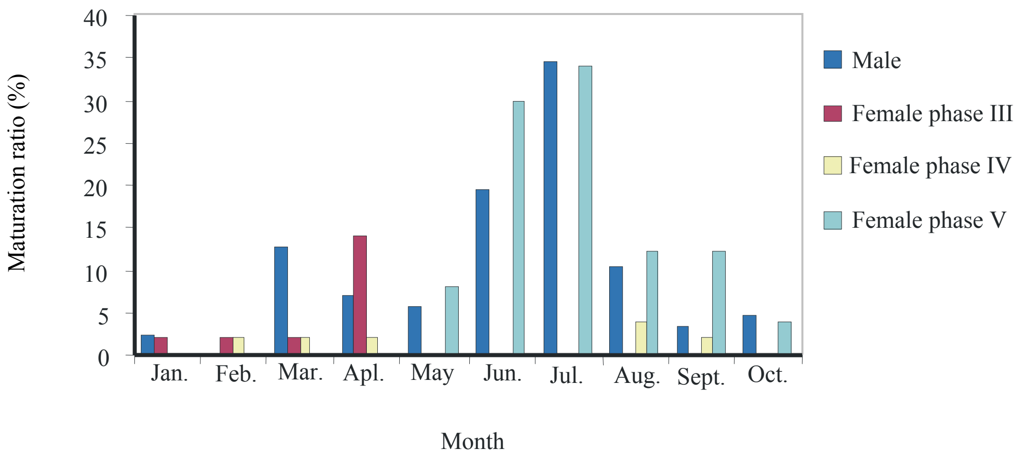

Figure 2. Maturation of brood stock in confined culture conditions

Some reproductive characteristics of L. hoevinii vs. other cyprinids

The reproductive biology of *L. hoevinii* was studied in 2002, along with other three target species (also cyprinids) of AIMS: *O. melanopleura, L. chrysophekadion* and *C. microlepis*. The GSI (Gonadal Somatic Index) of female *L. hoevinii* was 5.3 - 6.7%. Absolute fecundity ranged from 139,360 - 158,000 eggs and relative fecundity from 84,043 - 92,907 eggs/kg. The mean diameter of eggs was 0.98 mm.

L. hoevinii and *O. melanopleura* have similar GSI, which is much higher than that of *L. chrysophekadion* and *C. microlepis*, but much lower than other well-adapted cyprinids like silver barb *Barbodes gonionotus* or red-tail tinfoil barb *Barbodes altus*.

Absolute and relative fecundity of *L. hoevinii* and *O. melanopleura* were similar but were two to three times higher than that of *L. chrysophekadion* or *C. microlepis*. Relative fecundity of *L. hoevinii* was higher than the 50,000 - 70,000 eggs/kg reported by Meanakarn (1985, cited by Leelapatra *et al.*, 2000).

However, the study took place in 2002 after just one year of adaptation and conditioning; at that time, the brood-stock may not have been well matured. Feasibly, GSI, absolute and relative fecundity may be higher in fish fully adapted to artificial conditions.

Table 3. *A comparison of the reproductive characteristics of some indigenous species*

Species	GSI (%)	Fecundity		Diameter of egg (mm)
		Absolute (egg)	Relative (eggs/kg)	
Barbodes gonionotus	15-18	282,377-800,620	250,000-400,000	0.5-0.6
Barbodes altus	15-21	18,250-207,100	228,000-721,000	0.40-0.55
L. hoevinii	5.3-6.7	139,360-158,000	84,043-92,907	0.98 ± 0.03
L. chrysophekadion	1.4-1.7	42,306-51,408	28,204-27,057	1.01 ± 0.12
O. melanopleura	4.3-6.8	106,700-177,975	73,586-114,823	1.07 ± 0.01
C. microlepis	3.1-3.5	30,036-37,592	19,378-22,113	1.30 ± 0.04

Induced spawning

Table 4 gives the results of artificially propagating *L. hoevinii* in the 2002 and 2003 spawning seasons. The results in 2003 show a marked improvement over 2002. The ratio of fully ovulated females increased from 50-75% to 83-100% and fertilization and spawning rates were 47.0-72.5% and 64.1-

Table 4. *Reproductive characteristics Hoeven's slender carp propagated artificially during 2002 and 2003*

Year	Date	No. of females	Ratio of females ovulated completely (%)	Total weight of females[1] (kg)	Real relative fecundity[2] (eggs/kg)	Fertilization rates (%)	Spawning ratio (%)
2002	02/04/02	4	50	5.2	84,663	5.0	63.8
	06/05/02	4	75	4.1	30,366	16.5	64.1
	17/06/02	7	57	7.7	41,208	67.3	61.8
2003	12/05/03	4	100	6.75	41,760	10.0	23.0
	04/06/03	5	80	4.8	104,244	59.0	80.0
	05/06/03	2	100	2.5	151,740	60.0	78.5
	23/06/03	7	57	4.3	96,573	10.8	86.5
	07/07/03	7	86	7.0	88,458	72.5	87.8
	21/07/03	6	83	4.35	133,218	69.6	64.1
	11/08/03	5	100	6.7	107,185	47.0	75.2

Notes: [1]Total weight of females ovulated completely (A) (excluding the weight of females ovulated partially)
[2]Real relative fecundity = total number of eggs of females ovulated completely/A (excluding the number of eggs of females ovulated partially)

87.8% respectively. This improvement is a consequence of more *L. hoevinii* reaching maturity following induced spawning.

In 2003, the brood stock matured well considerably reducing the need for hormone injection. A consequential reduction the amount of hormone used (PG alone for the primary dose, PG and LH-RHa+DOM for the resolving dose) improved the economics of induced spawning.

Average size of eggs before and after resolving injection was 0.94-1.02 mm and 1.01-1.04 mm, respectively. The eggs did not show significant increase in size (only 0.04-0.08 mm) after the primary dose, though this varied in each spawning. The results show that the resolving injection can be given once eggs reach 1 mm in diameter. Latency time is 5-7 hrs after the resolving injection. Eggs began to hatch after 13 hours at water temperature of 29°C -30°C. The rate of hatching rate depends largely on water quality in incubation medium.

L. hoevinii spawn from April to August but mainly in June and July. According to Meanakarn (1985) and Watanadirokul and Kongship (1987) (cited by Leelapatra *et al.*, 2000) the natural spawning season of *L. hoevinii* is from May to November and for the most part from May to September. Although females in phase V were still fertile in September and October, gonad development in most of the males had declined by this time, as had the quantity and quality of sperm. Males usually mature earlier than females but deteriorate quickly making the spawning season short.

In this study, while the quality of ovulation was good, in some cycles fertilization rates were low because of a shortage of milt to fertilize the available eggs. Males matured in ponds produced little sperm and therefore successful spawning required more males than females. According to Leelapatra *et al.* (2000), the ideal spawning ratio of females to males is 1:3 although a ratio 1:2 may be adequate.

Fingerlings

Fingerlings reared under a two-stage regime reached an average weight of 2.54 g and an average length of 6.26 cm by day 60 (Table 5). This growth rate was lower than that seen in the greater bony lipped barb (weight 2.82 g and length of 6.86 cm) and the greater black shark (weight 3.91 g and length of 6.86 cm) at 60 days (Khanh *et al.* 2000).

Table 5. *Results of fingerling nursing in cement tanks and earthen ponds*

Growth rate			Survival rate (%)	
Age (day)	**Weight (g)**	**Length (cm)**	**2002**	**2003**
10	0.02 ± 0.01	1.33 ± 0.04		
20	0.15 ± 0.09	2.02 ± 0.21	70.2-91.4	72.0-76.8
30	0.74 ± 0.20	4.06 ± 0.35		
40	1.39 ± 0.47	5.10 ± 0.49		
50	1.56 ± 0.42	5.41 ± 0.83		
60	2.54 ± 0.56	6.26 ± 0.41	64.1-86.6	53.8-66.7

Two-stage nursing technology produced a high and stable survival rate in Hoeven's slender carp. Survival rates for juveniles at 20 and 60 days were 70.2-91.4% and 64.1-86.6% respectively in 2002 and 72.0-76.8% and 53.8-66.7% in 2003. The results in both these years compared favourably with rates achieved employing one-stage nursing technology. Rearing under this later regime achieved survival rates of only 58.7%.

Maintenance of water quality in the confines of the cement tank more efficient and moreover fry are able to find prey in addition to their regular feed. A clean, predator-free environment and a plentiful supply of feed at this earlier stage in the fish's life cycle promoted survival through to the next stage and beyond.

CONCLUSIONS

1. Nursing *L. hoevinii* in captivity realised maturation rates of 88% in females and 73% in males. Brood stock took two years to mature and three years to spawn efficiently. Females re-matured 90-120 days after the first reproduction of the spawning season.

2. The spawning season of *L. hoevinii* is from April to August and mainly between June and July. The spawning season is short because males and females do not mature synchronously. Males usually mature earlier and decline faster than females.

3. The maturation rate of females ranged from 5.3 to 6.7%. Absolute fecundity ranged from 139,360 to 158,000 eggs and relative fecundity 84,043 to 92,907 eggs/kg. The mean diameter of eggs was 0.98 mm.

4. Induced spawning of *L. hoevinii* using PG, LH-RHa+DOM gave good results. The ratio of females that fully ovulated was 83 to 100%. Real relative fecundity ranged from 88,458 to 51,740 eggs/kg. Fertilization and spawning rates for the 2003 spawning season were 47.0 to 72.5% and 64.1 to 87.8%, respectively. Results of induced spawning depend largely on quality of sperm.

5. *L. hoevinii* fingerlings reached 2.54 g in weight and 6.26 cm in length after nursing for 60 days. Two-stage nursing achieved a high and stable survival rate, between 53.8 and 86.6% fingerlings survived to 60 days.

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Comparison of the effects of buserelin in combination with various forms of domperidone and pituitary gland on the induction of spawning and gonadal development in the Thai carp, *Barbonymus gonionotus*

Naruepon Sukumasavin*, Pongsai Chansri and Mali Lamanthieng

Inland Fisheries Research and Development Bureau, Thailand and Aquaculture of Indigenous Mekong Fish Species Component, MRC Fisheries Programme

ABSTRACT

This study set compares the effects of buserelin (BUS) in combination with various forms of domperidone (DOM) to the effects of extract of pituitary gland (PG) on the induction of spawning and gonadal development in the Thai carp, *Barbonymus gonionotus.* The results indicated that injection of 10 mg/kg BUS in combination with 10 mg/kg DOM (in the form of the human preparation, Motilium) dissolved in distilled water, dimethylsulfoxide (DMSO) or N,N-dimethylformamide (DMFM) had similar effects on the number of fish spawned, fertilization, hatching and survival rates of seven-day-old fry ($p>0.05$) to those seen after the injection of one dose of pituitary gland. Repeated treatments with BUS in combination with all forms of DOM used in this study had no negative effect on gonad development in females, which was completed within three weeks of each spawning. Fish were induced to spawn at least three times during the season and the same was true of fish that were induced to spawn by repeated use of pituitary gland.

KEY WORDS: *Barbonymus gonionotus*, *Puntius gonionotus*, induced spawning, buserelin, domperidone

INTRODUCTION

In most teleost fish, including the Thai carp (*Barbonymus gonionotus*), a surge of gonadotropin (GtH II) secreted by the pituitary initiates the final maturation of gonads and ovulation, and triggers the onset of spawning. The hypothalamus regulates this surge through the interaction of two other hormones, gonadotropin-releasing hormone (GnRH) and dopamine (an agent that inhibits the release of GtH).

Fish reared artificially, will spawn if dosed with GnRH, or its one of its analogues (GnRHa), in combination with a dopamine antagonist (DA) (Peter *et al*. 1988). In Thailand, this proved a very effective, and reliable, way of inducing several freshwater fish species to spawn (Sukumasavin and Leelapatra 1988). Sukumasavin and Leelapatra (1993) also found that buserelin (BUS), a mammalian luteinising hormone, is the most effective of the several forms of GnRHa.

To date, domperidone (DOM) is the only DA used in spawning experiments. DOM is insoluble in water but dissolves in organic solvents such as DMSO (Gissis *et al*. 1991) and DMFM (Gissis *et al*. 1991). It is also partly soluble in propylene glycol (PROP). However, the most common practice is to use Motilium suspension (MOT), a DOM preparation designed for use in humans. However, the effect of repeated use of a BUS-DOM combination on the development the Thai carp's gonads is unknown. In this study, therefore, we set out to investigate the consequences of using BUS-DOM (in various

* Inland Fisheries Research and Development Bureau, DoF, Chatuchak, Bangkok, Thailand, 10900. Email: naruepos@fisheries.go.th

preparations), and extract of pituitary gland (PG), over several spawning cycles.

MATERIALS AND METHODS

The study was carried out at Surin Inland Fisheries Station from February to September 2001.

Experimental fish

Thai carp were reared in earthen ponds at a stocking density of 1 kg/4 m^2 and fed once daily with pellets containing 30% protein at 1.5% body weight. The fish used in this experiment were ripe to spawn, i.e. females with 80% of their oocytes at the germinal vesicle migration stage and males that produced milt when gentle pressure is applied to the abdomen.

Hormone and drug preparation

BUS: Buserelin (Hoechst) was diluted in distilled water at a concentration of 100µg/ml.

DOM: Two types of DOM were used i.e. the pure chemical (Sigma) and the human drug, MOT (Jenssen Pharmaceutica). Pure DOM was dissolved in:

- DMSO (Sigma) at a concentration of 25 mg/ml (DMSO-DOM)
- DMFM (Sigma) at a concentration of 25 mg/ml (DMFM-DOM)
- PROP (Sigma) at a concentration of 25 mg/ml (PROP-DOM)

MOT: MOT was ground and dissolved in distilled water at a concentration of 25 mg/ml (MOT-DOM).

PG: PG, collected from mature common carp (average body weight 500 g) about one hour prior to injection was homogenised and mixed with distilled water. The injection volume was adjusted to 0.5 ml/ kg of fish. The dosage was determined using the following formula:

- 1 dose = weight of donor/weight of recipient

Experiments

Experiment 1: Effects of various forms of DOM in combination with BUS on inducing Thai carp to spawn.

Sexually mature female Thai carp weighing an average of 300 g were divided into five groups of 80 fish each. Fish in each group were identified using spaghetti tags. Each group received an intra-peritoneal injection of BUS and DOM as follows:

Group 1: 1 dose of PG

Group 2: 10µg/kg BUS in combination with 10 mg/kg MOT-DOM

Group 3: 10µg/kg BUS in combination with 10 mg/kg DMSO-DOM

Group 4: 10µg/kg BUS in combination with 10 mg/kg DMFM-DOM

Group 5: 10µg/kg BUS in combination with 10 mg/kg PROP-DOM

Following this treatment, the groups of female fish were transferred to 10 m^3 cement tanks containing the same number of untreated males. The fish then spawned naturally. The resultant eggs incubated in hatching jars and the rates of fertilisation and hatching were counted. Newly hatched larvae were moved to cement tanks. The following data were collected:

- spawning time
- number of fish that spawning during the 8 hr induction period
- fertilization rate
- hatching rate
- survival rate of larvae at seven days old

Experiment 2: Effects of various forms of DOM in combination with BUS on gonadal development in the Thai carp.

The fish resulting from the spawning during Experiment 1 were reared together in a 400 m^2 earthen pond. Every day each fish was fed with 30% protein pellets equivalent to 1.5% its body weight. On the first day, five fish were taken from each group; these were weighed, killed and their gonads removed. This procedure was repeated every seven days. The gonadosomatic index (GSI = gonad weight*100/ body weight) was calculated for each fish. After four weeks, the surviving fish were used to repeat Experiment 1. After the fish had spawned, Experiment 2 was repeated for another cycle.

RESULTS

Experiment 1: Effects of various forms of DOM in combination with BUS on the induction of spawning of the Thai carp (Appendix I, Tables 1, 2 and 3).

The form of DOM is not a critical factor in determining the number of fish that spawn (Table 1). The difference in the number of fish that spawned following injections of PG, of DOM in the form of MOT, or various preparations of DOM, is not statistically significant. This is true for all three induction-cycles. In each cycle, latency periods were all between 4.15 - 6.15 hours and there is no significant difference

($p>0.05$) in the rates of fertilisation and hatching, and the proportion of larvae that survived to seven days old.

Experiment 2: Effects of various forms of DOM in combination with BUS on gonad development in the Thai carp (Appendix I, Table 4)

Within spawning cycles, the GCI varied little between groups of fish that had been injected with PG, different preparations of DOM and DOM in the form of MOT. At the time of injection, the index varied within the range 17.02±0.42% (MOT-DOM) and 21.13±3.99% (PG). In all instances the index fell sharply after spawning (to within the range 5.56±0.68% (PG) to 7.8±1.8% (DMSO-DOM)); thereafter it increased until, by week three, the index returned to the levels recorded at the time of the first injection. This pattern repeated during the second and third spawning cycles. Overall, there was no statistically significant variation in the levels of the GSI within, or between, induction-cycles.

DISCUSSION

The results of this study show that BUS in combination with DOM is as efficient in inducing spawning in the Thai carp as PG (c.f. Sukumasavin and Leelapatra, 1988). Furthermore, BUS in combination with DOM dissolved in DMSO, DMFM or PROP did not affect the number of fish that spawned, fertilisation rate, hatching rate or survival rate of seven-day-old larvae when compared with PG or DOM in the form of the human preparation, MOT (Sukumasavin 1994).

Sirikul (1987) demonstrated that Thai carp induced to spawn with PG would, if induced again, spawn for a second time one month later and three or more times in a spawning season. In this study, Thai carp induced to spawn with BUS in combination with DOM, if induced again, also spawned at least three times in the spawning season at intervals of one month.

This study uses GSI as an indicator of gonadal development because in the Thai carp GSI is highly correlated with mature oocytes ($r=0.9$, $p<0.01$) (Sukumasavin and Leelapatra 1994). GSI has been used as an indicator for gonadal development in several cyprinids, including goldfish (Clemens and Reed 1967; Munkittrick and Leatherland 1984). The peak GSI at the beginning of the study was between 17% and 21%, similar to that of fish reared in earthen ponds reported by Sukumasavin (1992). Furthermore, three weeks after spawning the GSI of fish treated with all forms of DOM in combination with BUS were not significantly different. This indicates that the gonadal development in the Thai carp can complete within three weeks under culture conditions. In addition, there were no significant differences in GSI between the two reproductive cycles ($p>0.05$). The two sets experiments demonstrate repeated use of DOM in combination with BUS has no negative effect on the induction of spawning or gonadal development in the Thai carp.

Table 5 (Appendix I) gives the costs of using PG and BUS in all forms of DOM to induce spawning of 1 kg Thai carp. PG is the most expensive at 10 baht/kg. BUS and MOT-DOM cost 4.65 baht/kg while the costs for DMSO-DOM, DMFM-DOM or PROP-DOM are lower. PROP-DOM is the cheapest overall at

2.27 baht/kg. These results show that PROP-DOM is the most cost effective method of inducing the Thai carp to spawn.

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APPENDIX 1

Table 1. *Effects of using 1 dose of PG and 10 µg/kg BUS in combination with 10 mg/kg DOM as MOT-DOM, DMSO-DOM, PROP-DOM, and DMFM-DOM on spawning induction in Thai carp at first spawning induction*

Hormone	**Nº of fish**	**Mean body weight (g±SD)**	**Latency period (hr)**	**Nº of fish spawned**	**Fertilization rate (%)**	**Hatching rate (%)**	**Survival rate of 7-day-old fry (%)**
PG	80	*294.63±23.38*	4.15	75	98.57±0.91	97.58±2.26	39.27±14.66
BUS+MOT-DOM	80	*315.11±07.15*	4.45	80	99.17±0.85	97.85±1.71	34.97±09.64
BUS+DMSO-DOM	80	*343.23±00.64*	4.45	80	98.42±1.39	97.83±1.14	52.33±12.79
BUS+PROP-DOM	80	*336.36±37.67*	4.45	80	98.65±0.35	96.65±2.05	35.50±09.99
BUS+DMFM-DOM	80	*341.47±02.08*	4.45	80	99.26±0.72	98.80±3.03	33.67±08.75

Table 2. *Effects of using 1 dose of PG and 10 µg/kg BUS in combination with 10 mg/kg DOM as MOT-DOM, DMSO-DOM, PROP-DOM and DMFM-DOM on spawning induction in Thai carp at second spawning induction*

Hormone	**Nº of fish**	**Mean body weight (g±SD)**	**Latency period (hr)**	**Nº of fish spawned**	**Fertilization rate (%)**	**Hatching rate (%)**	**Survival rate of 7-day-old fry (%)**
PG	40	367.47±53.41	4.15	35	95.01±1.06	91.88±2.75	37.60±05.34
BUS+MOT-DOM	40	382.03±59.78	4.50	40	96.59±2.48	92.59±2.38	37.30±10.08
BUS+DMSO-DOM	40	326.80±33.33	4.55	40	96.98±0.30	91.28±1.90	35.07±16.10
BUS+PROP-DOM	40	402.18±15.57	5.30	39	98.30±0.66	95.84±2.64	28.77±03.46
BUS+DMFM-DOM	40	359.84±37.37	4.50	39	95.01±3.79	94.89±3.03	33.77±04.31

Table 3. *Effects of using 1 dose of PG and 10 µg/kg BUS in combination with 10 mg/kg DOM as MOT-DOM, DMSO-DOM, PROP-DOM and DMFM-DOM on spawning induction in Thai carp at third spawning induction*

Hormone	**Nº of fish h**	**Mean body weight (g±SD)**	**Latency period (hr)**	**Nº of fish spawned**	**Fertilization rate (%)**	**Hatching rate (%)**	**Survival rate of 7-day-old fry (%)**
PG	5	373.49±73.45	5.50	4	95.67±1.15	99.67±0.58	42.03±16.10
BUS+MOT-DOM	5	371.03±40.79	5.55	5	96.59±2.48	99.17±1.04	35.40±05.01
BUS+DMSO-DOM	5	399.91±45.57	5.40	5	96.98±0.30	99.50±0.50	35.30±06.55
BUS+PROP-DOM	5	366.17±20.73	6.15	5	97.50±0.87	100.00±0.00	37.00±03.63
BUS+DMFM-DOM	5	410.91±50.62	6.15	5	98.80±0.34	100.00±0.00	30.83±01.26

Table 4. *Effects of using 1 dose of PG and 10 µg/kg BUS in combination with 10 mg/kg DOM as MOT-DOM, DMSO-DOM, PROP-DOM and DMFM-DOM on weekly changes in GSI during the three spawning cycles*

Time	PG	MOT-DOM	DMSO-DOM	PROP-DOM	DMFM-DOM
At 1st spawning induction	21.13 ± 3.99^{d}	17.21 ± 0.42^{def}	20.01 ± 0.18^{e}	19.99 ± 3.32^{ef}	18.10±0.82b
After 1st spawning	5.56 ± 0.68^{a}	5.84 ± 0.72^{a}	7.48 ± 1.76^{a}	6.43 ± 1.51^{ab}	7.33±1.17a
1 week after 1st spawning	8.29 ± 1.09^{a}	7.00 ± 1.47^{ab}	9.46 ± 1.07^{ab}	9.17 ± 1.85^{bc}	8.34±2.02a
2 weeks after 1st spawning	13.78 ± 1.27^{b}	12.06 ± 1.94^{c}	13.17 ± 1.68^{bc}	13.60 ± 1.96^{d}	14.50±2.10b
3 weeks after 1st spawning	19.77 ± 5.46^{cd}	17.67 ± 2.75^{def}	18.52 ± 2.22^{de}	16.68 ± 2.00^{de}	14.79±4.19b
4 weeks after 1st spawning	20.84 ± 3.25^{d}	20.71 ± 2.44^{f}	20.60 ± 4.80^{e}	18.93 ± 2.09^{ef}	19.60±3.09b
At 2nd spawning induction					
After 2nd spawning	5.64 ± 0.38^{a}	5.65 ± 0.59^{a}	7.29 ± 1.89^{a}	4.94 ± 0.03^{a}	4.86±0.04a
1 week after 2nd spawning	8.80 ± 2.19^{a}	8.47 ± 1.38^{b}	10.06 ± 1.47^{ab}	9.80 ± 2.40^{c}	7.14±0.42a
2 weeks after 2nd spawning	17.13 ± 2.30^{bcd}	15.83 ± 1.35^{de}	14.47 ± 2.72^{cd}	14.06 ± 2.64^{d}	14.42±6.53b
3 weeks after 2nd spawning	14.58 ± 4.36^{bc}	15.54 ± 1.21^{d}	15.25 ± 3.63^{cd}	19.08 ± 4.19^{ef}	14.83±1.71b
4 weeks after 2nd spawning	21.55 ± 2.78^{d}	19.28 ± 4.02^{ef}	20.78 ± 1.29^{e}	22.15 ± 2.64^{f}	19.56±5.45b
At 3rd spawning induction					
After 3rd spawning	7.22 ± 3.60^{a}	5.60 ± 0.59^{a}	7.02 ± 2.53^{a}	7.64 ± 1.99^{abc}	8.51±2.58a

Table 5. *Cost of induced spawning 1 kg of female Thai carp*

Hormone	Cost (baht/kg)
PG	10.00
BUS+MOT-DOM	4.65
BUS+DMSO-DOM	2.41
BUS+PROP-DOM	2.27
BUS+DMFM-DOM	2.30

Experiments on seed production and commercial culture of the freshwater prawn (*Macrobrachium nipponense*)

Nguyen Quoc An*, Phan Dinh Phuc, Phan Thi Le Anh, Nguyen Thi Tu, Ly Ngoc Tuyen, and Le Phuoc Binh.

Management of Reservoir and River Fisheries Component, MRC Fisheries Programme

ABSTRACT

Aquaculture of the freshwater prawn *Macrobrachium nipponense* has potential to develop into a high value enterprise. However, this commercial development faces the constraints of insufficient stocking material and a lack of suitable culture technology. This paper presents preliminary results of experiments designed to address these two problems.

The experiments on prawn seed production used eight small (each 2 m^2 in area) and two large hapas (each 20 m^2 in area) placed in ponds. The experiments in the small hapas gave uneven overall survival rates ranging from 8.36 to 43.82%. The yields obtained are also low and uneven, ranging from 167 to 1525 PL10/hapa. Experiment on large hapas gave reasonable overall survival rates (32.95% and 31.85%) and significantly higher yields (20,973 PL10 and 20,319 PL10). Therefore, the use large hapas is recommended for producing large number of prawn seed for aquaculture purposes.

Experiments on commercial monoculture in ponds were also conducted. Stocking material consisted of fingerlings caught from nearby reservoirs. Fingerling size varied from 0.18 to 0.28 g/ind or 5555 to 3571 ind/kg. Stocking density was 60-70 ind/m^2. All environmental parameters (DO, pH, water temperature etc) were maintained at optimum levels. After 135 – 140 days of cultivation, the highest yield was 444kg/ha with 82.6% of the harvested prawns having a body weight of more than 2g (marketable size). However, prawns in the 2g weight range dominated (50.6%) the stock resulting in a low market price. This experiment shows the potential to improve culture management, achieve high production, and increase the number of crops in a year.

KEY WORDS: Freshwater prawn, *Macrobrachium nipponense,* seed production, hapa, commercial culture.

INTRODUCTION

The freshwater prawn, *Macrobrachium nipponense*, is distributed in brackish and fresh waters and can be found in various parts of China (Yu 1931, Cai and Dai 1999, Wang and Qianhong 1999, Miao and Ge 2002), Japan (Kamita 1970 and Uno, 1971), Taiwan (Shy *et al*. 1987), Korea (Holthuis 1980), Indo – West Pacific, Iran (Holthuis 1980 and Wrong and McAndrew 1994) and Vietnam (Dang 1980, Nguyen *et al.* 2002).

The species is commercially the most important freshwater prawn in China, Korea and Japan (Kwon and Uno 1969 and Wrong and McAndrew 1994). Estimates for the production of this species in 2000 were about 100,000 tonnes and accounted for about 50% of total prawn culture production in China (Miao and Ge 2002). In Vietnam, the species has an important role in capture fisheries (Nguyen 2002) but not in aquaculture. *M. nipponense* has potential for aquaculture because it is able to reproduce easily and grows very well in natural conditions, its market price is acceptable, and the prawn can be cultured in ponds, cages, and paddy fields under intensive, semi-intensive, or poly-cultural regimes (Wang and

* Research Institute for Aquaculture No3, 33 Dang Tat Street, Nha Trang City, Viet Nam
Email: an@mrcmekong.org

Qianhong 1999, Kutty *et al*. 2000, Miao and Ge 2002).

In the Central Highland Region, the living standards of communities are usually lower than in other regions of Viet Nam and protein is in shorter supply. Small-scale aquaculture could provide a source of protein and increase the income of the region's poor people. However, the income from aquaculture in the region is still low. The sale price of the main cultured species, including grass carp (*Ctenopharyngodon idellus*), silver carp (*Hypophthalamichthys molitrix*), bighead carp (*Aristichthys nobilis*), rohu (*Labeo rohita*), and tilapia (*Oreochromis niloticus*) is not high (under 1USD/kg for local consumption). Thus, finding species with good economic potential for freshwater aquaculture in the Central Highlands of Vietnam is very important. Research conducted to evaluate the potential *M. nipponense* as a candidate for aquaculture in this region began in 2001. Nguyen *et al*. (2002) have already presented the results of research into the biology of the species and this current paper presents the results of experiments on seed production and commercial culture.

MATERIALS AND METHODS

Seed production

The experiments presented in this paper follow on from a series of successful breeding experiments on *M. nipponense* conducted in the laboratory during 2001 and 2002. Based on the results of the laboratory experiments, the current experiments were field trials aimed to produce larger numbers of seed in hapas located in ponds. The advantages of producing prawn seed in hapas are that the technology is simple for farmers to use and that the price of seed is low.

Hapas for breeding

In order to find out optimum hapa size, experiments were conducted small hapas and bigger hapas as follows:

Eight small hapas size: 1m x 2m x 1m (area of 2 m^2)

Two large hapas size: 6.7m x 3m x 1m (area of 20.1m^2)

The mesh size of hapas: 625 meshes/cm^2

Brood stock

Berried females, collected from commercial catches in lakes and reservoirs, were conditioned in hapas placed in ponds for convenient checking. Only females that were healthy, active, well pigmented, with no missing appendages, were taken. Gravid females carrying uniformly developed eggs (dark brown or grey eggs with visible eyes), were chosen and transferred from conditioning to breeding hapas. The females were removed once the larvae were released completely.

Nursing

Feed for larvae consisted of both natural foods (plankton) and soybean milk. Soybean milk was fed to the prawns twice daily, at 07:00 and 17:00. Bundles of aquatic and nylon fibre provided substrate and shelter for the larvae. Every three days samples of larvae were collected to determine the growth-stage of the prawns. The number of larvae was determined by random sampling conducted every two weeks. Dissolved oxygen (DO), temperature, and pH were measured every 15 days at 06:00, 13:00 and 16:00. The vertical sides of hapas were cleaned daily to ensure water circulation.

Grow-out culture

Pond preparation

The experiment on prawn grow-out culture was carried out in three earthen ponds. The ponds were drained and left to dry in the sun for seven days. Prior to stocking with juveniles, lime (7 kg/100m^2) and cow manure (7.5 kg/100m^2) were broadcast over the floor of the ponds that were then filled with water to a depth of 30 cm. After one week, the level of water in ponds was raised to 1 m and stocked with juvenile prawns.

Stocking

The ponds were stocked with juveniles from breeding hapas and wild-caught from reservoirs and lakes. The density of prawns stocked ranged from 2500 to 4000 ind./kg.

Rearing

Prawns reared in ponds 1 and 2 were given unprocessed feed comprised of rice bran, fish, fishmeal, and oil cake. For the first ten days, prawns reared in pond 3 were fed 1kg/day of uncooked soybean milk. From the eleventh day until harvesting, they were fed processed feed containing rice bran (40%), soybean meal (20%), fishmeal (30%), oyster meal (2%), alga (8%) and a mixture of vitamins.

The daily amount of feed required for prawn in each pond was approximately 7-10% of estimated biomass of prawn in the pond. Feeding took place twice daily, in the morning and afternoon. In addition, feeding trays were placed at the ponds' four corners to check food consumption.

Every 15 days, lime (7 kg/100 m^2), cow manure (7.5 kg/100 m^2), super-phosphate (0.6 kg/100m^2) and urea (0.2kg/100m^2) were added to each pond.

DO, temperature, and pH were measured every 15 days at 06:00, 13:00 and 16:00.

Each month, samples of at least 40 prawns were collected to determine the growth rate.

Harvesting

Harvesting began from the third month using hand lift-nets and traps. Finally, after draining the ponds to 50 cm the remaining prawns were harvested with seines.

Treatment of data

Daily weight gain (DWG) was calculated using the following formula

$$\text{DWG (g/day)} = \frac{\text{Mean final weight (g) - Mean initial final weight (g)}}{\text{Time (days)}}$$

RESULTS

Seed production in small hapas

Table 1 gives the results of the experiment on seed production in small hapas. The results show that the environmental regimes employed through the duration of the experiment (from September to December 2002) were suitable for raising prawn larvae.

Table 1. *Results of experiment on producing* M. nipponense *seed in small hapas*

Parameter	**Hapa Number**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Rearing duration (days)	29	30	31	31	30	30	33	30
Water temperature (^{o}C)	29.7	29.0	29.8	29.5	30.1	30.2	27.3	23.2
pH	8.45	8.44	8.48	8.45	8.45	8.51	8.41	8.40
Dissolved oxygen (mg/l)	4.86	4.81	5.09	4.48	4.73	4.72	4.33	4.60
N^{o} of gravid females	45	50	50	24	46	40	27	28
N^{o} of L1 produced	1992	3600	3750	2760	6072	2280	3480	1820
No L1 produced by 1 female	44	72	75	115	132	57	129	65
N^{o} PL 10 harvested	167	1006	433	272	947	211	1525	658
Survival rate L1 – PL10 (%)	8.36	27.94	11.55	9.86	15.60	9.25	43.82	36.15
Length of PL10 (cm)	1.2 – 1.4							
Total number of PL10 harvested	5219							

Notes: Average water depth in these hapas was 0.4 – 0.5m. Number L1 was a combination of larvae stage I, II and III

The number of stage I larvae (L1) produced depends not only on the number of gravid females in the stock but also their fertility and other, environmental, factors. Normally the more females the stock contains the more L1 produced. This is indeed the case in hapas 2 and 3; these contained 50 gravid females each and produced 3,600 and 3,650 L1 respectively. By comparison, hapas 4 and 8, stocked with 24 and 28 individuals, produced only 2,760 and 1,820 L1.

Occasionally, however, smaller stocks can produce relatively high numbers of L1. In hapa 7, for example, only 27 females produced 3,480 L1. In this instance, the hapa had half the number of females as hapas 2 and 3 but produced similar numbers of L1.

There is no obvious relationship between initial L1 density and their survival rate to post-larval stage 10 (PL10). The overall survival rate from L1 to PL10 reached a maximum of 43.82% in hapa 7, followed by 36.15% in hapa 8. The high survival rate of prawns in these hapas may relate to the special care to given them during the experiment. The poorest survival rates were in hapas 1 (8.36%) 6 (9.25%) and 4 (9.86%). These hapa were found subsequently to contain some predators (adult prawns, fish).

The results from these experiments show that rearing prawns in small hapa produces only small number of juveniles. Accordingly, these hapa are unsuitable for farmers, who require large numbers of prawn fingerlings to stock their 'grow-out' ponds.

Seed production in large hapas

Table 2 gives the results of experiments on seed production in large hapas. The results show that the environmental regimes of both large hapas were better-suited (higher DO levels, greater water depth) for seed production than the small hapas, resulting in better productivity.

Table 2. *Results of experiment producing M. nipponense seed in large hapas*

Parameter	Hapa 1	Hapa 2
Rearing duration (day)	31	35
Metamorphosis days from L1 – PL1 (day)	13.5 – 24.5	12.5 – 25.0
Water temperature (^{0}C)	29.3	30.7
pH	8.4	8.0
Dissolved oxygen (mg/l)	5.8	5.9
Average water level (cm)	60	50
Transparency (cm)	44	38
Number of larvae at stage I,II,III (L1)	63,648	63,800
Amount of PL10 harvested (PL10)	20,973	20,319
Yield per m^2 (PL10/m^2)	1043	1011
Overall survival rate L1 – PL10 (%)	32.95	31.85
Length of PL 10 (cm)	1.37 (1.2-1.6)	

The number of larvae stage I-III (L1) produced in large hapas 1 and 2 were almost the same (63,648 and 63,800 respectively). The initial density of L1 in large hapas was similar to the highest density of L1 in the experiments on small hapas (hapa 5) but the overall survival rates of larvae were much higher (32.95% in large hapa 1 and 31.85% in large hapa 2, compared with 15.60% in small hapa 5).

Interestingly, the amount of PL10 harvested per square metre of large hapa (1043 PL10/m^2 in hapa 1 and 1011 PL10/m^2 in hapa 2) was much greater than the best results achieved in the experiments on small hapas (763 PL10/m^2 in hapa 7).

When comparing the results of the two sets of experiments the advantages of using large hapas for producing prawn seed becomes clear; these are a stable high yield and high survival rate, maintenance requiring less manpower and the greater production of prawn juveniles etc. Unfortunately, due to shortages of finance and labour we were unable to conduct the experiments using greater numbers of large hapas. Repeating the experiments using more large hapas may provide more confidence in the benefits gained by using hapas of this size.

Grow-out culture in ponds

Table 3 gives the results of experiments on growing-out *M. nipponense* in earthen ponds. The table shows that the environmental factors in all three ponds were appropriate for the growth of this species of prawn.

The initial weight of prawns stocked in pond 1 was 0.25g/ind., 0.28g/ind. in pond 2 and only 0.18g/ind. in pond 3. After 135 – 140 culture days, the final weight of prawn in the experimental ponds was 2.8 g/ ind., 3.5 g/ind. and 2.5 g/ind., respectively. The results show that the final weight of prawns correlates closely with the initial weight. The same relationship also found between initial weight and daily weight gain. Quality of feed seems to make little difference. Accordingly, prawns in pond 3 fed with higher quality feed recorded the lowest daily weight gain (0.017 g/day) because their initial weight was also the lowest (0.18 g/ind.). Likewise, prawns in pond 2, which had the heaviest initial weight (0.28 g/ind.), recorded both the largest daily weight gain (0.023 g/day) and the greatest final weight (3.5 g/ind.). As daily weight gain correlates only with initial weight and apparently is unaffected by type of feed proved (the environmental regimes in all three ponds were also suitable for culturing prawns), increasing stocking density may well be the best way to achieve higher yields.

Table 3. *Results of experiments on grow-out of* M. nipponense *in earthen ponds*

Parameter	Pond 1	Pond 2	Pond 3
Area (m^2)	450	350	640
Stocking density (prawns/m^2)	60	70	60
Initial day	25/1/03	16/03/2003	21/02/03
Terminal day	11/6/03	02/08/2003	10/07/03
Duration (days)	135	140	140
Average water level (cm)	85	80	85.78
Transparency (cm)	45	50	51.11
Water temperature (^{0}C)	28.9	29	29.4
pH	8.9	8.7	8.4
Dissolved oxygen (mg/l)	5.5	5.8	6.1
Types of feed	Rice bran, fish meal, fish, oil-cake.	Rice bran, fish meal, oil-cake	Soybean milk, processed feed
Initial weight (g)	0.25 ± 0.14	0.28 ± 0.28	0.18 ± 0.18
Final weight (g)	2.8 ± 1.2	3.5 ± 1.3	2.5 ± 1.2
Daily weight gain (g/day)	0.019	0.023	0.017
Total yield (kg)	17.0	8.4	28.4

Figure 1 illustrates an analysis of the weight distribution of prawns in pond 3. The modal body weight of harvested prawns is 2g (50.6% of the total population). The heaviest prawns (6.0g) account for only 3.4% of the population. The dominance of small prawns, and the resultant low market price, is the main constraint on using this species for aquaculture purposes.

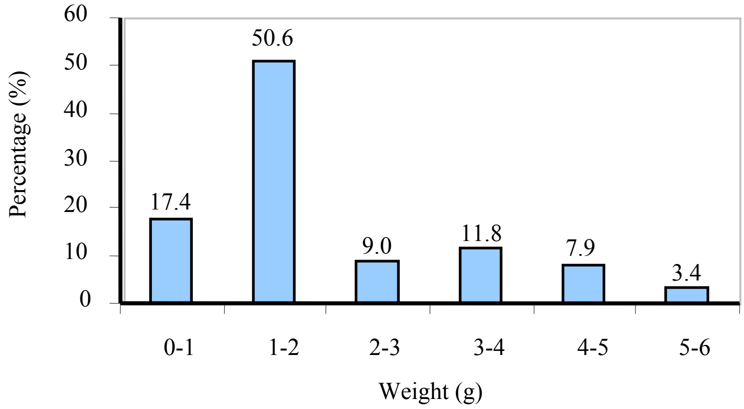

Figure 1. Weight distribution of harvested prawns in pond 3

Table 4 provides some information on the economics of culturing in ponds. The yields obtained after 135 – 140 days cultivation ranged from 240 kg/ha/crop (pond 2) to 444 kg/ha/crop (pond 1). Wang and Qianhong (1999) reported that annual production of *M. nipponense* ranged from 390 to 1,875 kg/ha in China. While the production in ponds 1 and 3 were comparable to these figures, the profit for farmers was poor.

Table 4. *Yield and economic effectiveness of three grow-out culture ponds*

	Pond 1	**Pond 2**	**Pond 3**
		Investment (US$)	
Seed	5.20	4.50	6.50
Feed	29.00	23.20	33.10
Fertilization	4.00	2.10	5.50
Total cost	**38.20**	**29.80**	**45.1**
		Yield	
Total yield (kg)	17.0	8.4	28.4
Yield (kg/ha)	378.0	240.0	443.8
		Profit and Loss (US$)	
Total income	32.98	13.30	551.0
Profit/Loss	5.30	13.50	9.90

However, increasing yields (by increasing stocking density, using suitable feed combination, etc), improving the harvested size of prawns (rotation harvesting) and applying poly-culture (with fish or other aquatic animals) may improve these slim economic benefits.

The recent low market prices fetched by this prawn in Central Highlands (US$1.94/kg) hits the economics of its cultivation. However, prices are much higher in Ho Chi Minh City and other large Vietnamese cities (upwards of US$3/kg) and therefore extending the cultivation this species more widely through the country is, potentially, an excellent commercial prospect.

CONCLUSIONS

- Using small hapas ($2m^2$) for producing fresh water prawn seed results in uneven overall survival rates (ranging from 8.36% to 43.82%) and low producing capacity (maximum 1,525 PL10/hapa or 763 PL10/m^2). Therefore using small hapas for producing mass numbers of prawn seed cannot be recommended.

- Large hapas (20.1 m^2) give good production results. The overall survival rate is stable (ranging between 31.85% and 32.95%). The yield of PL10 obtained from large hapas ranged between 20,973 PL10/hapa and 20,319 PL10/hapa, or 1,049 PL10/m^2 and 1,016 PL10/m^2. This size of hapa is suitable for producing the large amounts of prawn seed required for aquaculture.

- Grow-out culture in ponds generates acceptable productivities (444 kg/ha/crop). However, farmer's profits are low. Enhancing yield in ponds and improving the modal weight of the prawn population will help to increase the farmer's profit. Developing the cultivation of this species throughout Viet Nam may be a commercially viable proposition.

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Section 3: Fisheries Management

Stock enhancement as a major element of reservoir fisheries management

Ouk Vibol[1*], Kaing Khim[2], Heng Samay[3], and Lim Ngeth[1]

[1]Aquaculture of Indigenous Mekong Fish Species Component, MRC Fisheries Programme
[2]Management of River and Reservoir Fisheries Component, MRC Fisheries Programme
[3]Inland Institute of Fresh Water, Department of Fisheries, Cambodia

ABSTRACT

For poor local communities throughout the riparian countries, reservoir fisheries are an important source of food and family income. The Management of River and Reservoir Fisheries (MRRF) and Aquaculture of Indigenous Mekong Fish Species (AIMS) components of the Mekong River Commission (MRC) Fisheries Programme play an important role in augmenting these natural resources by restocking them with species of fish indigenous to the Mekong. The stocking supports government policy to regenerate those species that have been lost and to increase the catch in this important ecosystem.

This paper reports the findings of a study carried out in northern Cambodia in November 2002 on the effects on local food supply and family income of stocking the Thmorda reservoir. Stocking is widely accepted by fishers as one of the most practical ways of strengthening community fisheries management and improving the livelihoods of local people. With the support of the Department of Fisheries (DoF), MRRF and AIMS, local inhabitants of the Thmorda reservoir formed community fishery (CF), drew up a reservoir-wide management plan that included restocking as a priority activity. The community then participated in restocking the reservoir with 21,500 fingerlings of native species (*Barbonymus gonionotus, Barbonymus altus, Pangasianodon hypophthalmu*s and *Trichogaster pectoralis*) produced at Bati and Chrang Chamres, and monitoring the results of their activities.

During the seven months following restocking, the reintroduced fish grew five to six times faster than fish in pond-based aquaculture systems. Up to 30-40% of reintroduced *B. gonionotus* and *B. altus* were recaptured within seven months and had reached a total weight of about 1,180 kg, with an estimated value of about US$1,700.

Whilst these results are encouraging, the ecological effects of stocking on the reservoir and the socio-economic effects on people living in the area need to be investigated further .

KEY WORDS: Reservoir, stock enhancement, livelihood, CF participation

INTRODUCTION

Literature on Cambodia's inland fisheries makes frequent reference to the abundance of fish in the Tonle Sap and Mekong river systems, and to the expertise of the fishers who exploit these resources. Fish, together with rice, forms the stable diet of most Cambodians. Inland fisheries provide three quarters of the animal protein consumed by the population. In addition, fishing is a major source of income providing full or part-time employment for around two million people. Fishing is the principle livelihood for many rural families, who comprise almost 90% of the country's poor. Inland fisheries produce between 290,000 - 430,000 tonnes of fish each year; and the value of the landing is in the order US$150 to US$200 million (DoF 2002). The contribution of freshwater capture fisheries to national food security, and to the larger Cambodian economy, is probably higher than in any other country in Southeast Asia.

* Department of Fisheries, 186 Preah Norodom Blvd., Phnom Penh, Cambodia.
Email: aims1@online.com.kh

Cambodia has a vast fresh water system that extends over nearly two million hectares. This system contains over 600 reservoirs, in addition to rivers lakes, flooded forest, grassland, rice fields, and swamps. Reservoir fisheries in this system are an important source of food and income for poor local communities.

Whilst these reservoirs may adversely affect existing fish habitats and stocks, they can also provide new environments well suited for fish aquaculture and fisheries. The government of Cambodia acknowledges the importance of reservoir fisheries and emphasises the need for appropriate management to promote and develop their existing use and to ensure the fisheries sustainability into the future.

The ecological issues relating to the reservoir fisheries draw increasing attention. These issues include, the consequences of over-fishing and the impacts of destructive practices such as, electro-fishing and fishing with homemade bombs, dynamite, and fine-mesh nets. Although Cambodian law prohibits these practices, they are still commonplace and cause great damage to fish populations and other aquatic fauna.

However, effective fisheries management, with the involvement of local communities, has been able to reduce the incidence of two of these illegal practices (bombs and dynamite) countrywide. This kind of cooperation, together with active stock enhancement, may pave the way for rehabilitation and preservation of the country’s aquatic resources.

This paper documents the results of restocking the Thmorda reservoir, in northern Cambodia, with species of fish that were under threat of becoming extinct locally. The exercise, which required the cooperation of the local community and local fisheries authorities, shows that effective management can enhance food supplies and family incomes.

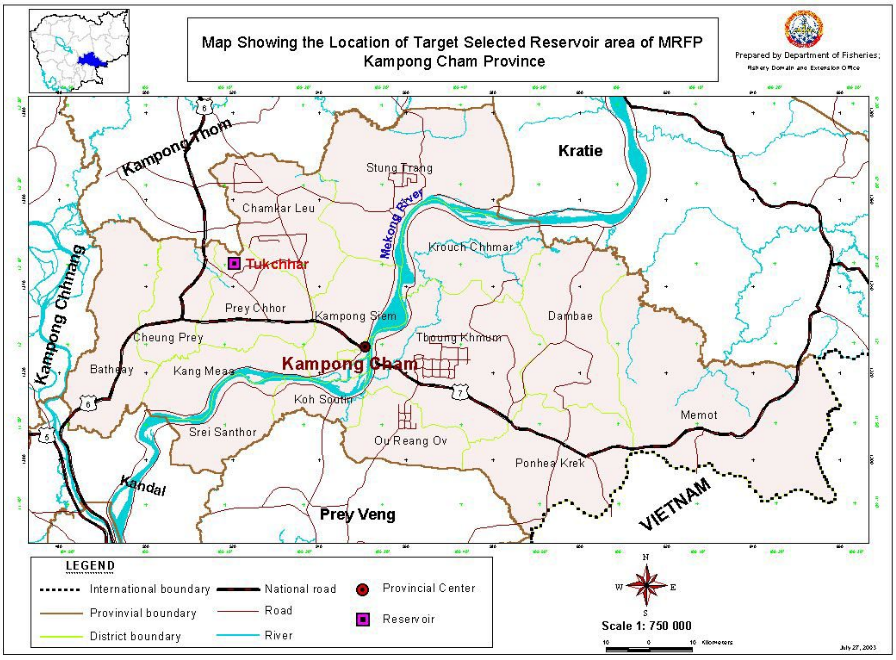

Figure 1. Location Map

THMORDA RESERVOIR

Characteristics and ecology

The Thmorda reservoir in Kampong Cham province of northern Cambodia is located 17 km from the provincial capital and 135 km north of Phnom Penh. Originally built during the Pol Pot era (1976 to 1977), the reservoir was refurbished in 1996 with the aid of a US$1,543,000 Royal Government Loan from the Asian Development Bank (ADB).

The designated area of the reservoir covers 200 ha, the surface area of water is approximately 70 ha and it has a maximum depth of four metres. With storage capacity of nearly 2.5 million m^3, the reservoir can provide enough water to irrigate 2,000 ha of rice fields. During the rainy season, the excess outflow from the reservoir flows into the Tonle Sap river via a canal. In the dry season, even though isolated from this outlet, the reservoir can still supply enough water for irrigation purposes.

Fishing activities

The four villages nearest to the reservoir house 749 families. While rice cultivation provides the main livelihood for the villagers, fishing accounts for about 30% of their income. About 15 families, who do not own a paddy field or garden, depend solely on fishing the reservoir for their living.

The Thmorda reservoir is rich in natural aquatic fauna including many species of fish and snails. Estimated fish production in 2001 and 2002 was between 13,000-15,000 kg. Most local fishers use small-scale fishing gear including cast nets, gillnets, seine, hooks, long lines, and spear guns and some collect snails by hand. Using this gear, fishers can expect to catch between 8-10 kg of fish per day during the rainy season and 2-3 kg per day during the dry season. The most common species in their catch are: *Hampala dispar, Pristolepis fasciata, Oxyeleotris marmorata, Channa striata, Clarias batrachus, Clarias macrocephalus, Notopterus notopterus, Henicorhynchus caudimaculatus, Anabas testudineus, Pseudabassis notatus, Mystus nemurus, Monopterus albus, Tilapia nilotica, Macrognathus siamensis,* and *Macrognathus maculates.*

The catch of some species has declined sharply over the past five years because of over-fishing and illegal fishing. These species include *Barbonymus gonionotus, Cyclocheilicthys repasson, Cyclocheilicthys armatus*, *Osteochilus hasseltii* and *Wallago attu.*

Despite the efforts of the community and local authorities to stop it, illegal fishing, usually electro fishing or fishing with very fine mesh nets, continues to be a problem.

Community fisheries management

Residents of the local four villages formed a community fishery (CF) and, with technical support from the Department of Fisheries (DoF) and financial assistance from the Management of River and River Fisheries component (MRRF), drew up a reservoir-wide management plan. The main aims of the plan

Figure 2. Fishing with cast net

Figure 3. Illegal practices, electro-fishing (left) and fine mesh nets (right)

Figure 4. Local people help re-stock the Thmorda reservoir

are to encourage sustainable management of the fisheries and to develop the resources of reservoir in a way that ensures security of food supplies and helps alleviate poverty. The villagers elected a committee that, together with the local authority and technical support from DoF, devised a plan to regulate internal fisheries. The chief of committee and the local authorities endorsed the regulations and distributed them to people living in and around the reservoir. Since the introduction of these regulations, illegal fishing has declined and fish stocks are recovering.

An example of stock enhancement as a major component of reservoir fisheries management

Why stock?

Re-stocking indigenous fish species also has high priority in the community fisheries' reservoir-wide management plan, the members saw as it another means to increase the catch and improve the livelihood of local people. They also see it as a very effective way of regenerating fish stocks depleted by over fishing and legal fishing. The Prime Minister of the Royal Government of Cambodia officially signed a sub-decree on 25th August 2002, and with immediate effect, declaring July 1st of every year National Fish Day.

METHODS

In support of this proclamation, the Thmorda reservoir was targeted as a site for restocking. The community fishery selected fish species that were in danger of becoming locally extinct to restock the reservoir (Table 1). These species, which include *B. gonionotus*, *Barbonymus altus, Pangasianodon hypophthalmus,* and *Trichigaster pectoralis,* are known to thrive in the type of habitats provided by the reservoir.

Table 1. *Number and weight of fish species restocked in the Thmorda reservoir*

Species	**N° of seeds stocked**	**Average weight (g)**
B. gonionotus	10,000	2.60
B. altus	10,000	1.60
P. hypophthalmus	1,000	1.30
T. pectoralis	500	2.50
Total	**21,500**	

Brood stock were collected from the Tonle Sap River and bred at the Chrang Chamres station. Fish seed from the station was transferred and stocked in the reservoir on 6th November 2002. A stocking ceremony, organised by the community fishery, and attended by local authorities, department and provincial fisheries officers, presented an opportunity to advise local people how to manage stocked fish and urge them to stop using prohibited fishing gear.

Monitoring and data collection

Regular monitoring began immediately after stocking and continues today. Forty local fishers, provided with special record sheets to ensure accuracy, give monthly accounts of the type of fishing equipment they use and the number, species, weight, and market price of fish they catch. Every month a district facilitator collates these data. The data provide a record of the recapture of restocked fish.

At the same time, informal discussions with the community fishery and fishermen provide feed back on the progress of the fish stocking programme and promote information sharing. These discussions take in the yearly catch assessment in order to evaluate the catch since the formation of the community fishery and the restocking of the reservoir.

RESULTS

Restocking took place in November 2002. By May 2003, seven months after stocking, the average weight of recaptured specimens of *B. gonionotus* and *B. altus*, were 0.8 kg and 0.4 kg respectively. Figure 5 (opposite) gives the average daily growth rate of the re-introduced fish. Low stocking density and the high productivity of the reservoir probably contributed to growth rates significantly higher than those of the same fish reared in other culturing regimes. As an example, on average *B. gonionotus* gained 3.77 g per day, some five or six times that of the same species reared in a the pond-based culture system. The same is true for the growth rates of *B. altus*, *T. pectoralis* and *P. hypophthalmus,* even though only a small number of the last two species were recaptured.

The numbers of re-introduced fish recaptured reached a peak in December 2002 before decreasing sharply from January to May 2003 (Figure 6-opposite). By May, the proportions of recaptured re-introduced fish were *B. gonionotus* (30%)*, B. altus* (22%)*, T. pectoralis* (15%) and *P. hypophthalmus* (1%).

In contrast, the weight of recaptured re-introduced fish reached a peak in January 2003, remained at a high level through to March, and declined gradually in April and May (Table 2). *B, gonionotus* (72%) and *B. altus* (26%) account for the bulk of the 972.7 kg catch.

Yearly assessment records show that the fish catch increased from 15,000 kg in 2002 to 18,720 kg in 2003, a 20% increase since the formation of the community fishery and re-stocking the reservoir. Re-introduced fish, which accounted for up to 26% of this increase and for about 5.4% of the total 2003 catch, generated an income of about US$1,470.

Table 2. *Total weight (Kg) of stocked fish species recaptured by month*

Species	**Month (Nov 2002 – May 2003)**							
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Total**
B. gonionotus	65.0	150.0	155.0	95.0	120.0	70.0	50.0	705,0
B. altus	25.0	50.0	55.0	40.0	50.0	20.0	18.0	258,0
T. pectoralis		1.8	0.5	0.3			4.5	7.1
P. hypophthalmus		0.6		2.0				2.6
Total weight	**90.0**	**202.4**	**210.5**	**137.3**	**170.0**	**90.0**	**72.5**	**972.7**

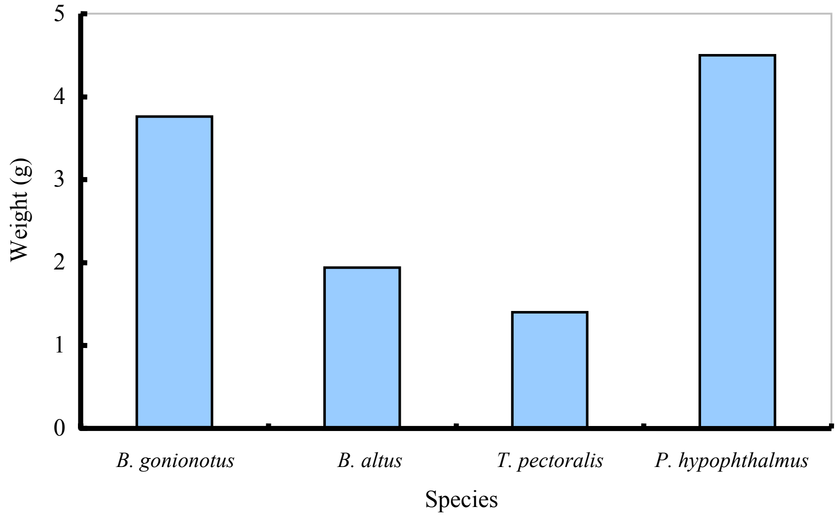

Figure 5. Average daily increase in weight of restocked fish

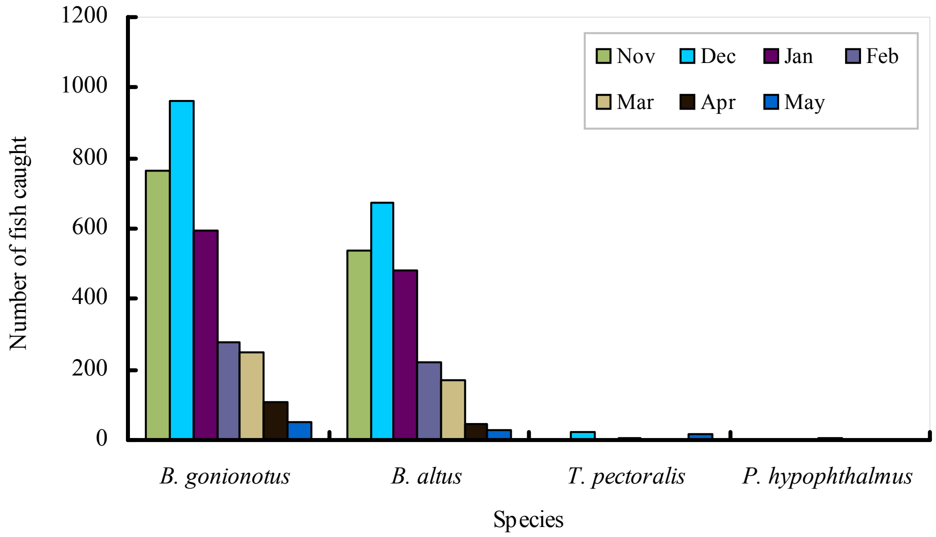

Figure 6. Number of restocked fish recaptured per month

Over 95% of the recaptured re-introduced fish were caught with either gillnets (80%) or cast nets (15%). In order to catch *B. gonionotus* the mesh size of gillnets size was increased monthly. The relationship between the weight of recaptured *B. gonionotus* and the effective mesh size of gillnets is given in Figure 7. Mesh size was increased from 4-5 cm to 9-10 cm in May 2003 when the average weight of this species reached about 800 g (from 2.6 g at stocking).

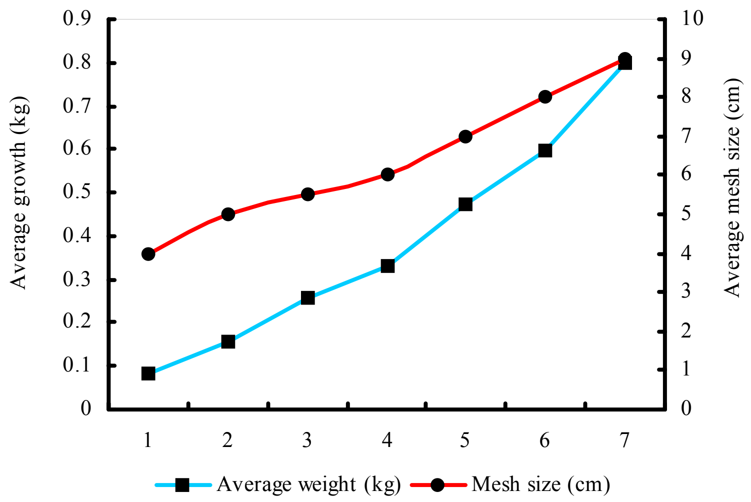

Figure 7. The relationship between weight of *B. gonionotus* and effective mesh size of gillnet mesh size

ATTITUDE OF THE FISHING COMMUNITY TO RESTOCKING

In general, the local villagers were pleased to take part in the restocking programme because the expected increase in their income and the security of their food supply would greatly improve the quality of their lives. The fishers sold about 60% of catch in their local market and kept the remainder for their own families.

Some fishers suggested the community fishery should bring in rules to regulate the mesh size of gillnets and introduce 'fishing seasons'. However, others complained that some fishers were unable to catch re-stocked fish because they could not afford to buy the appropriate fishing tackle.

CONCLUSIONS AND LESSONS LEARNED

Stocking is now widely accepted as one of the most practical and effective ways of improving the fish catch and preserving aquatic resources in reservoir fisheries.

Fish released into the Thmorda reservoir grew quickly and recapture rates were high, up to 30%. *B. gonionotus* and *B. altus* were particularly well suited to the reservoir environment and this factor should be borne in mind when fish species are selected for re-stocking.

Fishers were pleased to participate in restocking because they could see the potential benefits, i.e. more food, increased income, and a better livelihood. Following the formation of the community fishery and restocking, the total catch increased by about 20% per year. Restocked fish accounted for about 26% of this increase. These realised a sales price of US$ 1,470.

The community fishery must now decide how it wants to control fish stocks and catches. It has two options:

1. The community fishery could regulate fishing activities by restricting mesh size and introducing fishing seasons. If these regulations are applied, the fish catch will increase and fish stocks will be recruited through natural reproduction, removing the need to stock the reservoir artificially. However, long-established fishing practices are difficult to change and these measures may meet some resistance.

2. The second option involves the community fishery nominating an individual to act as fish seed producer. This person could take on the responsibility of producing and stocking the reservoir with fingerlings. In this case, fishers who use the reservoir will pay the wages and costs of the nominated person.

We recommend prolonging the restocking of the Thmorda reservoir and extending the practice to other reservoirs in Cambodia. However, careful selection of the reintroduced species is essential, as they must be compatible with the ecology, productivity and physiology of the reservoir.

Future studies should include the social impact of restocking, constraints faced by fishers, and ecological change in reservoirs caused by this practice.

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Inland fisheries co-management: what next for Viet Nam?

Truong Ha Phuong*, Phan Thuong Huy, and J.D. Sollows

Management of River and Reservoir Fisheries Component, MRC Fisheries Programme

ABSTRACT

Natural resources co-management by local users, concerned local governments, and other stakeholders that pays particular attention to the role of the users in resource management has been strongly encouraged by many projects in Viet Nam in recent years. There are many reasons for this, although in general, various socio-economic and environmental problems make the need for resource management clear. However, users must accept the proposed management measures if they are to be legitimate and effective.

This paper focuses on the experiences of the Management of River and Reservoir Fisheries (MRRF) Viet Nam sub-component and makes recommendations to decision-makers on whether or not to promote fisheries co-management, to promote more systematically, and how to carry out this promotion. These recommendations are based on:

- an examination of the economics of co-management and other management systems at selected reservoirs,
- other less measurable but very important costs and benefits, which enter comparative economics equations with difficulty, and
- other lessons learned from efforts to establish co-management in six reservoirs in Dak Lak province, in the Central Highlands of Viet Nam.

In general, participation of fishers in the management of resources on which they depend should be promoted. However, there is great local variation in fishery resources and fishing communities and no single model will apply to all. Local, not just central government support is needed for any co-management effort to succeed and policy guidelines are needed to encourage local governments to support co-management. This should be combined with developing among local officials an increased awareness in the need for user participation.

Finally, the people who use these resources have very little money and limited free time. They usually cannot afford to invest the time and effort needed to achieve successful co-management. However, some modest compensation usually helps to encourage their participation.

KEY WORDS: Natural resources, reservoir, stakeholders, co-management

INTRODUCTION

Definition of co-management

The working definition of co-management used by the Management of River and Reservoir Fisheries (MRRF) sub-component in Viet Nam is:

> '…an increase in broad-based participation of the user community in managing the resource, which gets formal agreement.'

* 180 Phan Chu Trinh St, Ban Me Thout City, Dac Lak Province, Viet Nam

This fitted the objectives of the component. However, participants at the First Regional Training Course in Inland Fisheries Co-Management in 2001 came up with the following alternative definition:

'A systematic process of participation by

affected resource user groups, concerned levels of government, and any other concerned agencies	in	Planning, making decisions about regulating and controlling, monitoring and evaluating and/or distributing

benefits from the use of a resource in a way which gets agreement, if possible formalised, from all concerned. It requires a sharing and definition of both the power and responsibility for managing the resource' (Cowling 2001).

Reasons for co-management

If a resource is sufficiently abundant to meet the needs of the community using it, there tends to be little perceived need to manage the use of the resource. When the resource becomes insufficient because of decreased abundance or increased needs of the community, the need to manage it becomes more widely appreciated.

We define as stakeholder as, 'any individual or group who depends on, or has control, over management of a resource'. Co-management by its very name means management by agreement between, or among, more than one stakeholder. This makes management more complicated, so why is it needed?

One fundamental point, and is it the key to successful co-management, is that fishers, the people who live by, and depend on these resources, are inevitably involved in managing them. They decide whether they will exploit the resource and how and when to exploit it. Fishers' knowledge of the resource is considerable. After all, it is their livelihood; they work with it daily, and have done so for many years and for many generations. No other stakeholder is so intimately involved with resource management and wise policy makers do not discount this intimate source of knowledge. The challenge for other stakeholders is to recognise this, and work with it.

So, when we ask, 'why co-management?' we are asking, 'why should all concerned stakeholders actively cooperate to manage the resource?'

Participants on the First Regional Training Course in Inland Fisheries Co-Management gave a long list of reasons, including:

- it is the cheapest way to manage resources (in the long run)
- sharing responsibilities should lead to better management since stakeholders can complement one

another (no single stakeholder can manage the fishery in a sustainable way)

- the government does not have the capacity, budget, or resources to manage it and needs the help of communities in monitoring, patrolling, and conservation
- reducing government responsibility for managing the resources (to a more manageable level). Communities are often capable of thinking and managing on their own
- strengthening local ownership (responsibility and problem-solving) and local empowerment. People who depend on the resource are involved in decision-making and enforcement. This should lead to better compliance, and more effective management
- helping solve shared social problems. Appropriate for management of common property
- supporting sustainable development if long-term and all concerned are involved in coming to agreements
- resolving conflicts and improves understanding between government officers and fishers. This improvement in communications should lead to more effective management
- increasing community understanding and consideration of the resource. Users learn how to solve problems on their own. Their knowledge is used and their thinking is stimulated
- organisation of local fishers and fishing activities strengthens the community
- more effective resource conservation if level of agreement is high
- user participation is needed to improve or restore resources
- optimal resource utilisation, with minimal disturbance to environment, society, and culture
- conflicts among users are reduced and benefits are shared more equitably leading to reduced gaps among resource users. If all concerned and affected groups participate, none should be seriously affected by management decisions
- hopefully, economic and income improvements
- hopefully, increased yields and size of caught fish
- in reservoirs, which are multipurpose, encourages discussion among all stakeholders
- peace
- fishers' knowledge of the resource is considerable. They are exposed to it over many years on a daily basis. This knowledge needs to be used in managing the fishery

- fishers normally live close to the resource and are in the best position to respond to emergencies if they are free to do so. They can usually adapt management to changing conditions or needs more promptly than agencies which are further-removed from the resource
- it is only fair to have a say in managing the resource on which one depends.

Most of these are reasons for promoting user participation. However, if users can be good managers, then why do other stakeholders need to be involved? The attendees gave following reasons:

- assurance that regulations confirm to government policies and the law of the land
- local resolution of conflicts between locals and outsiders
- co-ordination with other agencies and sectors
- complementation in surveillance and enforcement
- access to technical support and advice
- access to financial support

These are all good reasons why central and local government should promote co-management of fisheries, but how do these ventures work in practice? To answer this we will examine some existing co-managed fisheries located in Dak Lak Province in the Central Highlands of Viet Nam.

History of MRRF Viet Nam

MRRF association with Viet Nam began in August 1995. At this early stage its immediate objective was:

> 'Enhanced capacity of government fisheries agencies to plan and manage reservoir fisheries on a sustainable basis.'

However, as the project development plan makes clear, community based co-management was always the ultimate objective:

> 'Sustained high yields of fish achieved from reservoirs managed under local community agreement with government.'

The aims of Phase I were, therefore, to training project staff and relevant government agencies to conduct baseline biological and socio-economic surveys of selected reservoirs in the Central Highlands of Viet Nam.

The surveys brought to light important variations in the productivity of the reservoirs and their systems of fisheries management. Two of reservoirs were un-stocked and their fisheries managed ineffectively. The other reservoirs were stocked and their management better regulated and more effective. Groups of a few individuals contract two of the reservoirs from local administrative authorities, a cooperative runs one, and an employee of the Dak Lak Aquatic Products Company (DAPCo) manages the forth. Only two of the four stocked reservoirs contained significant numbers of wild species.

The surveys also show that no two reservoirs are a like and, consequently, no single management model is applicable to all. At best, managers will be able work within set of broad guidelines tailoring them to match local circumstances and developing them as they gain experience.

Phase II began in March 2000. Its immediate objective was:

> ‘To develop, implement and disseminate sustainable co-management models for optimal fish production in reservoirs.’

Three of the reservoirs studied in Phase I were dropped from Phase II. One reservoir, managed by a cooperative, was too small. Another, under the management of a provincial company, was already well run, even though the local fishing community did not partake in decision-making. In the instance of third reservoir we felt there was little prospect of establishing a venture under co-management. We selected three new reservoirs to replace the discarded ones.

The first steps towards establishing co-management ventures took place at Ea Soup in June 1998. Lak followed in January 1999 and the other four reservoirs very early in the Phase II.

At the outset, we informed the local authorities of MRRF’s objectives. Having obtained their consent, we then held similar discussions with the appropriate representatives from local communes. Participatory rural appraisal-workshops usually followed these initial meetings. These workshops helped identify the principle stakeholders, bring to light potential problems and discuss possible solutions. The details the work programme were resolved once follow-up discussions with critical stakeholders, training courses, and workshops had taken place.

Following the initial workshops, we gave fishers at each reservoir a training course on environmental awareness. The number of courses depended on the size of the fishing community around the reservoir. These courses allowed participants to consider the need for managing the resource. Fishers realised that some existing fishing methods were not sustainable, but often saw no choice if they were to eat the next day. A common conclusion from every session was that the participants wanted their children to be able to fish. To achieve this needs management; and for the management to be successful, the fishing community had to be involved.

With the co-operation and approval of community and local authorities, informal groups of fishers organized themselves into formal bodies with their own by-laws and elected executive. MRRF staff helped facilitate this work. Generally, the objectives of the fishers-groups’ aims were, assuring sustained fish production, providing mutual help to maintain and improving the living standards of the communities they represented. Facilitating work with concerned officials and other agencies was a third common objective.

To be able to mange the resource effectively, fishers developed regulations to control fishing practices; in many cases these included prohibiting non-sustainable fishing methods, especially use of electro-fishing. Penalties included fines and confiscation of gear. Consistent enforcement against violators of the regulators has been important. In practice, monitoring and enforcement has depended on the fishers' unions, often with some support from local police forces. Some fishers' groups have also stocked their reservoirs, as an additional way of increasing yield.

Table 1. *Reservoirs included in Phase II, showing management systems before and after MRRF involvement.*

Reservoir	Location (District)	Area (ha)	Fishing popn. 1996-2001 (families)	Management system before	Management system after
Ea Soup	Ea Soup	240	74	un-stocked/ open	stocked/union managed
Lak	Lak	658	325	un-stocked/ open	un-stocked/ union managed
Yang Re	Krong Bong	56	47	stocked/ contracted	stocked/ contracted
Krong Buk Ha	Krong Pac	120	30	un-stocked/ contracted	un-stocked/ contracted
Nam Nung	Krong No	52	69	stocked/ contracted	stocked/ contracted
Buon Tria	Lak	141	25	un-stocked/ open	stocked/ union managed

While managing the fisheries was the initial focus for the fishers' groups, the benefit from this was not sufficient to justify the time and money members invested in their organisation; assurance of mutual welfare quickly became an equally important objective. To address this concern all fishers groups received training in credit and savings management, and courses in livelihood alternatives to fishing were provided to most. The courses in credit and savings dealt with all aspects of management of very small-scale financing groups where members could deposit money for later use and borrow money conveniently, at modest interest rates. Most of the livelihood alternatives courses dealt with farming various crops, livestock husbandry, and aquaculture. These courses supported the objectives of the members by encouraging good management (financial and otherwise) and providing fishers with choices so that they could abandon unsustainable practices but still maintain their living standards.

Each month MRRF staff visit each fishers group to monitor their member's activities. During these visits, they attend group meetings, gave advice, and liaised with officials and other agencies as needed.

Finances

The lack of funds to carry out planned activities was one issue that arose in all fishers' group meetings. All the groups had plans to finance their activities through taxation and/or various sorts of contributions from the members; however, these sources alone were insufficient to meet costs. Stocking and patrolling are the two main activities that will help sustain optimal fish production, but these activities are expensive and, to put in place, need more financial contribution from the members and other organisations. The MRRF was not in a position to provide systematic financial assistance to the fishers' groups, and not every group had the resources to do everything it deemed necessary. Neither the Ministry of Fisheries nor the Province of Dak Lak was in a position to help. In 2001 and 2002, the Australian Embassy provided VND 108,100,000 (about US$ 7,000) in assistance. This money was used mainly to purchase inputs for household economic activities supported by the credit and savings programs, fingerlings for stocking in Ea Soup and Buon Tria reservoirs, digging ponds in Nam Nung reservoir and patrolling and other union activities in Lak reservoir. Without this assistance, many fishers' groups would have failed.

The Ea Soup and Lak reservoir fishers' unions, who received support from the Vietnam Fisheries Association, are incorporated formally under provincial regulations. The Buon Tria reservoir group continued to manage its fisheries, but the membership is small and poor, and credit and savings activities did not work well. The Nam Nung reservoir group, while not yet managing its fishery, had a healthy credit and savings programme, and was in a position to manage other community activities, including the fishery, should local decision-makers decide favourably. The Krong Buk Ha reservoir group was progressing in this direction. At Yang Re reservoir, the level of organization declined. Most members, for who fishing was a secondary or tertiary activity, have not managed credit and savings activities efficiently.

Because of inadequate financing, fishers' groups at some locations were unable to participate fully in their fisheries co-management; in these instances, other stakeholders took more control.

The commune at Yang Re awarded a new contact through open tender, giving the contract to bidder who offered the highest price. This left little spare revenue for the new contractor to distribute to the fishing community. However, the contractor still allows poor fishers (mainly indigenous people) to fish in the reservoir with small nets and catch a small amount of fish for their own consumption.

The irrigation manager at Krong Buk Ha felt that any change to the existing fishery management system could lead to conflicts putting a very important dam at risk. The dam, manufactured from inflatable rubber, irrigated a large area, and the manager was concerned that conflicts could lead to sabotage. Ironically, he wanted to prohibit small-scale fishing at certain times and bring in outside fishers to harvest the reservoir. The manager agreed with MRRF's argument that participation by the community would probably reduce conflicts but did not put co-management into practice because he was afraid of the potential risks.

At Nam Nung, the contractor, despite repeated discussions with MRRF, did not agree to share management of the fishery with the local community.

Comparative economics and fishing pressure of co-managed and non-co-managed systems

In this section, we review some reservoir management systems that are already in place. We compare the costs and benefits of the system and comment on the impact the schemes have on fish stocks and the fishery. Unfortunately, the data that allow a more detailed comparison of the performance of individual reservoir fisheries before and after the implementation of a given management scheme are not available.

The various types of reservoir management systems fall into three broad categories:

1. quasi-privatised, where an individual, or small group of individuals, invest in managing the fishery and decides the split of profit between themselves and the fishers

2. government managed, where a government agency regulates the fishery and taxes the fishers

3. co-managed, where the fishing community, and/or its elected representatives, invest in managing the fishery and apportion the share of profits among themselves, in cooperation with concerned local authorities and line agencies

However, before examining four cases in detail we can make some general comparisons between the benefits of the old and new systems. We have chosen two examples, Lak and Ea Soup. Before responsibility for management transferred to a fishers union both reservoirs operated under a system where the District collected taxes. Under this system, many fishers refused to pay taxes because they believed the fishery was under poor management. After transfer of management, however, most fishers willingly joined the scheme because they believed revenue from the taxes would support their own management activities as well as going to the district authorities. In the event, although the tax rate was higher in the old scheme, revenues received from taxes under the new system were twice as large (Table 2). Furthermore, the reduction in destructive practices is roughly four to six times greater under the new management scheme.

Table 2. *Comparison of the tax fee and fishing pressure during two management systems at Ea Soup and Lak reservoirs*

Reservoir	**Management system**	**Tax fee (VND/month)**	**No. of registered fishers**	**Max. fishing fee (VND/year)**	**% of fishers using destructive gear**
Lak	old (1997-2001)	35,000 for Kinh 15,000 for I.P	57	23,900,000	25
	new (2001-2003)	25,000 for Kinh 15,000 for I.P	218	53,760,000	6
Ea Soup	old (1980-1999)	10% of total catch	20	8,000,000	30
	new (2000-2003)	A = VND 30,000 B = VND 20,000 C = VND 10,000	20 20 35	16,200,000	5

Notes: The tax fees, A, B, and C account for differing types of gear and number of full and part-time fishers. Kihn are ethnic Vietnamese, IP indigenous people.

We will now examine four reservoirs in more detail, Ea Soup and Lak lake, which are co-managed, and Ho 31 and Ea Kao that are run under quasi-privatised management (Tables 3, 4, 5 and 6 - over page).

The quasi-privatised reservoirs, Ho 31 and Ea Kao achieved higher yield values per hectare because management had stocked them already. The situation at Ea Soup (Table 3) is particularity interesting because the survey covers a period immediately following stocking. Most of the species restocked were declining before stocking and total yields continued to decline afterwards. However, subsequent data from Ea Soup recorded in 2003 suggests that production was stable but stocked species made up about 10% of its total income (about VND 50.4 million in 2002). Therefore, we suspect that stocking may be responsible for maintaining the yields and income of this fishery.

These trends reflect in the figures for profit per hectare, which is greater in small reservoirs than large reservoirs, and in stocked reservoirs than un-stocked reservoirs even under the same management system. Profit to management cost ratios are considerably higher in government managed and co-managed reservoirs because management costs are lower. Fishers assume management costs directly in un-privatised reservoirs. Net profits per fisher (their share of gross income minus their management costs) were higher in the privatised reservoirs and this was mainly because of stocking.

Also, the number of fishers in Ea Soup and Lak is considerably higher than in the quasi-privatised reservoirs so benefits are more widely but thinly distributed. Hence, the profit per fisher (co-operative member) in Ho 31 is actually lower for each of the 30 members than in Lak and Ea Soup. However, the contractor (a member of the co-operative) gets higher benefits. The profits of this reservoir under a contractor is much higher than it was under the old management system (from 1996-2000). The benefit contribution of the present contractor was 17 million as tax to Tan An co-operative, while annual profit from 1996 to 2000 was only about 11 million. This was because management and fingerling costs were relatively high and management methods were ineffective under the old scheme.

An employee of DAPCo manages Ea Kao reservoir. Thirty fishers operated in this reservoir and 12 people form the fishing team and patrolling group. The fishers pay these people 30% of the total value of the catch and the cost of their yearly insurance premiums. The benefit per fisher (including fishing and patrolling team) is relatively high but about 50% of net benefit goes to the contractor.

The current management systems at Ea Kao and Ho 31 have been very successful in terms of achieving high production and smooth co-operation with the local authorities. However, the managers decide how benefits are distributed, and as a result managers get greater proportion of the revenues (50%) than do the fishers.

The advantages of co-management, based on these data, appear to lie mainly in saved management costs and reduced use of destructive fishing methods. This is valid to some extent, but the whole question of cost and benefits of co-management is considerably more complicated than the simple numbers given here.

Finally, co-management of the water bodies as discussed here is a new activity and this analysis may therefore underestimate the benefits that could result from older, more established co-management systems.

Table 3. *Ea Soup: a medium-sized reservoir co-managed by the fishers union and restocked with fish*

Annual costs (2002)	**Amount (million VND)**
Meetings	12.3
Guarding	3.6
Communicating	1.1
Training	2.6
Stocking	12.0
Other	1.2
Total costs	32.8
Income (landed value 2002)	504.5
Profit to management group	471.7
Profit/ha.	2.0
Profit/cost ratio	14.8
Profit to fishers	471.7
Number of fishers	100.0
Profit/fisher	4.7

Table 4. *Lak lake: a lake co-managed by fishers union and not stocked*

Annual Costs (2002)	**Amount (million VND)**
Taxes	6.5
Meetings	17.1
Communicating	3.0
Guarding and boat maintenance	5.6
Allowance for collectors and board members	15.0
Training	5.5
Total costs	52.7
Income (landed value 1997-2001)	740.0
Profit to management group	687.3
Profit/ha.	1.0
Profit/cost ratio	13.0
Profit to fishers	687.3
Number of fishers	218.0
Profit/fisher	3.2

Table 5. *Ea Kao: a medium-sized reservoir managed by DAPCo. employees*

Annual Costs (2000-2002)	**Amount (million VND)**
Fingerlings	35.0
Insurance for team	12.0
Guards' wages	36.0
Taxes and fees	18.0
Repairs to gear	25.0
Total costs	126.0
Income (landed value 2000-2002) (ca.74% stocked)	475.0
Profit to management group	349.0
Profit/ha.	1.2
Profit/cost ratio	2.8
Profit to fishers	173.0
Number of fishers (including fishing and patrolling team)	42.0
Profit to contractor (1)	176.0
Profit/fisher (42 fishers)	4.1

Table 6. *Ho 31 a small reservoir managed by a co-operative member*

Annual Costs (2000-2002)	**Amount (million VND)**
Fingerlings	5.3
Taxes to tan and co-operative	17.0
Feeding	9.0
Fertiliser	0.6
Labour (fishing and patrolling)	9.2
Total costs	41.1
Income (landed value 2000-2002) (ca.99% stocked)	69.6
Profit to management group	28.5
Profit/ha.	5.4
Profit/cost ratio	0.7
Profit to co-operative members (30)	17.0
Profit to contractor (1)	28.5

Note: This reservoir was at the time stocked under ACIAR fund

OTHER PROBLEMS AND BENEFITS OF CO-MANAGEMENT

Problems

Co-management costs are low in financial terms partly because poor fishers assume them and the cost of their labour is very low. These people are poor and have little time to spare. This means that while they are willing to volunteer the time needed to help manage their fisheries, they are not always able to do so unless some modest compensation is available. Successful co-management depends on the active participation of the resource users. If they cannot afford to participate and invest the apparently modest costs needed, the effort will fail. Therefore, if public agencies wish to promote co-management, they need to be ready to devolve reasonable funding, as well as responsibility, to the users. In addition, participation in managing the resources does not always run smoothly and conflicts arise among users. At present, there are no effective, and timely, procedures in place with which to arbitrate and resolve these conflicts.

Benefits

All the fishers' groups have adopted additional objectives relating to mutual support for the welfare of the community and liaising with local agencies and authorities. They could clearly see that the benefits from managing the fishery alone might not be enough to justify the investment they need to make. Therefore, these groups have all established credit and savings activities and invited support from other agencies, notably those involved in training in alternative livelihoods.

Although the benefits from these activities are difficult to measure, they certainly exist. Nam Nung is a good case in point. Nhung (2002) points to additional, equally intangible benefits that may be of even greater importance; community groups that develop their management skills may be able to manage an increasing number of other different activities more competently and to the benefit of the community. This can increase the prosperity of the community, reduce the workload of over-worked officials, provide instructive examples for other communities and local governments, and ultimately lead to a stronger, more resilient society.

These benefits deserve serious consideration by decision makers responsible for determining the level of support and strong arguments can be made for co-management and community participation in resource management. However, decision-makers must also keep in mind the need for sufficient (and usually financially modest) support for the efforts of the community.

In fact even though co-management looks inexpensive (because fishers' labour is cheap), this does not mean that fishers can afford the investment. Since their participation in management is central, the whole process may fail unless financial assistance (or similar support) is sufficient to allow them to afford to invest their scare free time.

LESSONS LEARNED BY MRRF VIET NAM

In Viet Nam, co-management will not take place unless local authorities give it adequate support. The extent to which MRRF (Phase II) has been able to establish co-management has depended entirely on the attitudes of local stakeholders. In all cases but one (Nam Nung), it was local authorities who permitted, or prevented, the participation of the fishing community in managing the fishery.

It does not always follow that an initial agreement by critical stakeholders will result in the establishment of a co-management scheme. Some stakeholders can change their minds when the implications of devolving responsibility become clear.

The economic and social importance of the fishery may affect the local authorities' attitude to fisheries co-management; their willingness to sacrifice immediate revenue in favour of community participation and prosperity and past their experiences of managing fisheries may influence their position.

Resource users are very quick to understand the need for sustainable management and clearly see their role in this as crucial. They need training, facilitation, and time in order to achieve successful participation in resource management.

As we have said previously, users need some modest financial support, at least initially, if they are to make time available to participate in resource management.

We want to emphasise that it takes time to establish a successful co-management venture. Resource users have a limited amount of money, time, official contacts, and formal education. For co-management to become well-established prolonged, continuous communication and related support is essential.

Organising users to manage the resources on which they depend for their livelihood, in a sustainable manner, cannot be divorced from efforts to maintain and raise their standard of living. Most users exploit resources in an unsustainable way because they feel they have no choice. They are willing to control their efforts if other users do and if they can afford to do so.

Besides incentives, such as training in alternative livelihoods, discouraging violation of rules and regulations needs a system of penalties. Consistent enforcement of these penalties is essential. The wider community must understand and appreciate lenience in individual cases for the regulations to succeed.

Resource users can identify objectives around which they can organise themselves but the means of achieving these objectives need flexible and responsive planning. Poor economic circumstances force users to focus on short term, urgent issues, and unforeseeable, uncontrollable external factors can make more elaborate or longer-term plans inoperable.

The level of government directly involved with a given fishers' group should reflect the geographic area in which the fishery is important. In general the more local the crucial stakeholders, the faster and more responsive the communication, and the more effective the management will be.

RECOMMENDATIONS

Participation of users in managing the resources on which they depend should be encouraged more actively by higher levels of government.

Since management of fisheries, or any other resource, carries implications for various sectors of the economy, and of society, this support should have the agreement of the Central Committee. Policies of particular ministries, while helpful and sometimes crucial, will be limited in their effectiveness without this support.

Encourage local governments to support resource co-management. Higher government levels may accomplish this in different ways such as, campaigns to promote awareness of the need for co-management, related training courses, and favourable publicity for local officials who conscientiously support co-management initiatives.

Public agencies that decide to promote co-management must be ready to support user groups with training, advice, liaison with other agencies and officials, and, at least initially, modest financing. They must be ready to invest the necessary effort and communication, and realise that successful establishment of a co-management mechanism takes a few years rather than a few months.

Efforts to establish co-management, if they are to succeed, must be combined and coordinated with efforts to maintain or improve the resource users' living standards.

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Participation in fisheries co-management in Kandal Province, Cambodia

Kaing Khim*, Sung Sokunthea and Un Kanika

Management of River and Reservoir Fisheries Component, MRC Fisheries Programme

ABSTRACT

Policy reform of fisheries management provides a good opportunity for local users to participate in the running of fisheries and to achieve the goals of protection, conservation, development and sustainable use of this resource. Policy reform in Cambodia has led to the establishment of over 300 community fisheries (CF). This number includes 22 in Kandal province, 12 of which have received support from the Management of River and Reservoir Fisheries component (MRRF) since 2000. Establishing community management and development presents many challenges, especially where participation is concerned. Therefore, it is useful to study the factors that influence this aspect of fisheries co-management. This paper presents the results of such a study carried out in the MRRF target areas of Boeung Chunlen reservoir, Kandal province.

During interviews and discussions, more than 90% of CF members stated that they participated in CF activities, particularly those relating to elections. The legal entitlements that participation offered are a major motivating factor in promoting voluntary participation. Understanding attitudes, practices, beliefs and knowledge is also a key factor.

The interviewees also suggested a number of ways to improve the process of instituting and managing the CF. These form the basis of a number of recommendations concerning the way CF are setup in the future.

KEY WORDS: Community fisheries, community participation, Kandal, Cambodia

INTRODUCTION

Although rice is the staple food for most Cambodians, fish closely follows it in importance. Fish is traditionally the main source of animal protein, especially for the rural poor. The current population growth rate of 2.49% (Ministry of Planning 1998) means that there is a need to produce more fish and to increase access to fishing grounds. However, powerful leaseholders are progressively limiting access to fishing grounds and the number of unresolved conflicts between large-scale commercial fishers and small-scale subsistence fishers is on the increase.

The situation is becoming increasingly difficult for subsistence fishers who depend on natural resources for their livelihood. Furthermore, abuse of power, unequal distribution of benefits and denial of access to fishing grounds is leading to dissatisfaction and serious conflict amongst the thousands of inhabitants in the area around the Tonle Sap Great Lake and the Mekong river floodplain. Conflicts, such as those between owners of fishing lots and local fishers, drove the Government to reform the management of fisheries.

On 24th October 2000, during a visit to distribute emergency aid to flood victims in Siem Reap province, Prime Minister Samdach Hun Sen announced countrywide reforms to Cambodia's fisheries. The aims of

* Department of Fisheries, 186 Preah Norodom Blvd., Phnom Phen, Cambodia.
Email: kaingkhim@online.com.kh

the reforms were to provide more fishing grounds for subsistence fishing and to help alleviate poverty among rural farmers and fishing communities.

In line with this policy, the Government has closed about 56% of the area previously given over to fishing lots and allocated it to the establishment of community fisheries (CF). CF are formed by groups of people living in or near fishing grounds who, in order to relieve poverty and improve their standard of living, want to manage their fisheries in a way that optimises catches but is also sustainable (CF sub-decree 2003).

The policy gives local people an opportunity to participate actively in the co-management of natural fisheries resources in order to achieve the goals of protection, conservation, development and sustainable use of resources. Since introduction of the policy, local communities have established more than 300 CF. This number includes 22 CF in Kandal province, 12 of which have received support from the Management of River and Reservoir Fisheries component (MRRF) since 2000.

Establishing community management and development presents many challenges, especially where participation is concerned. Therefore, it is useful to study the factors that influence this aspect of fisheries co-management. This paper presents the results of such a study carried out in the MRRF target areas of Boeung Chunlen reservoir, Mok Campul, Kandal province (Figure 1).

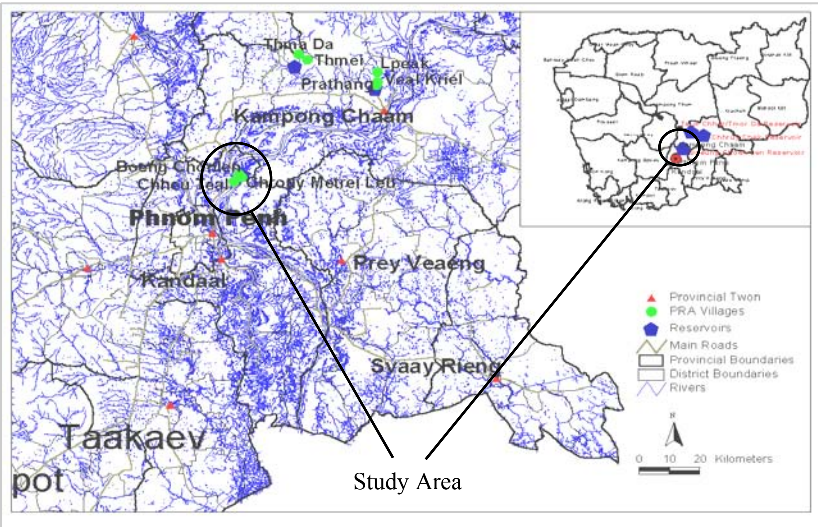

Figure 1. Location map.

METHODS

The CF Federation of Boeung Chunlen Reservoir is comprised of five CF from five villages and has a total membership of 477. Seventy-two of its members (34 female, 38 male), selected at random, participated in this study. Interviews of the participants used a standard questionnaire designed specifically for this study. Discussions in focus group helped to obtain general and supplementary information for later analysis and evaluation.

RESULTS AND DISCUSSION

Respondents' background

Ethnicity

The respondents included both people from both Cham (26%) and Khmer (74%) ethnic groups (see Figure 2). They live in the same communities and formed, and manage, the CF without any oblivious ethnic, or religious (the Cham are Muslims), discrimination or conflict.

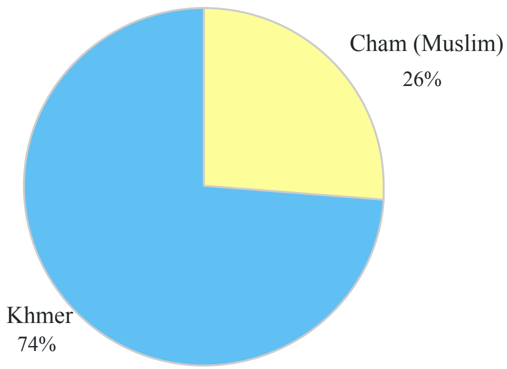

Figure 2. Ethnicity of respondents

Occupation

The primary occupations of the respondents were subsistence rice farming (48.6%), fishing (26.6%) and wage labour (6.9%).

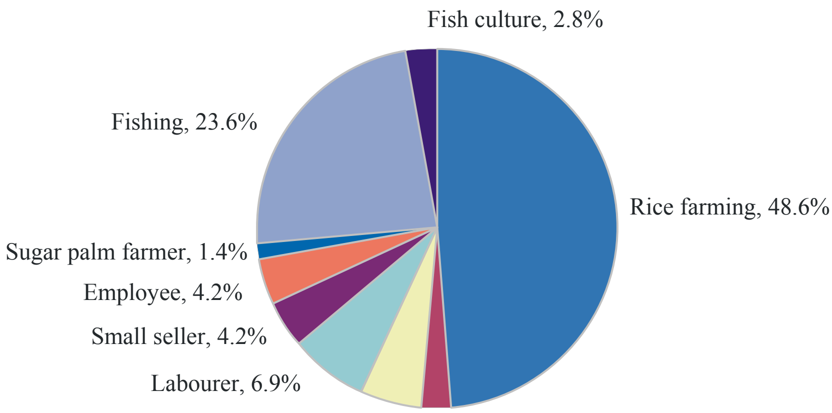

Figure 3. Primary occupation of respondents

However, fish are a very important element food in most villagers' diets and they provide additional source of income for some families. Many respondents gave fishing (40%) or fish culture (21%) as their main secondary occupation. Most villagers (over 87%), said they were engaged in fishing activity of some sort, usually when slack periods in rice cultivation permits.

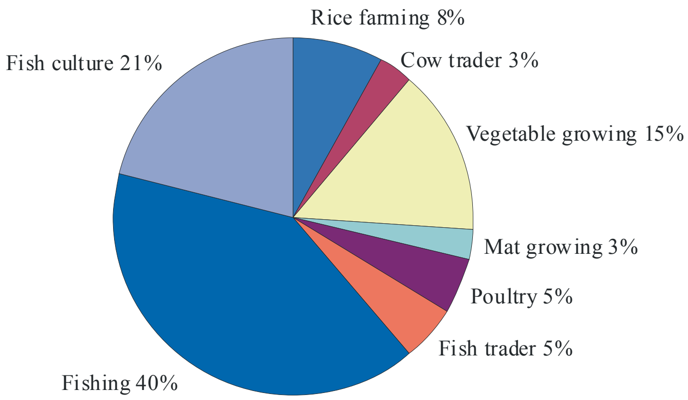

Figure 4. Secondary occupation of respondents

Participation in the CF process

Who participates?

There are two types of participant in the CF process: direct and indirect users. Direct users are members of the CF who fish for a living. These direct users are most closely involved in CF management and development. Indirect users include provincial fisheries officers, representatives of local authorities, local police officers and other related agencies.

Level of participation in the planning, management and implementation process

The survey shows that nearly all members of the CF (95.8%) are willing to participate in elections, probably because they do not wish to miss the opportunity of electing their own team leader onto the CF management team. The next most popular activity was drafting by-laws and regulations. CF members see the importance of these activities because they assign committee members roles, tasks, and responsibilities and establish rules and regulations for running the fishery.

The level of participation was very low in activities related to implementation (16.5%), planning (14.7%) and plan review (11.4%), as can be seen in Figure 6. This is probably because poorer CF members had to attend to their daily jobs in order to provide food for their families and had little time to spare. However, these people said that they were willing to support CF, abide by the rules and regulations, and report any illegal fishing activity.

Figure 5. People participating in drafting by-laws and regulations

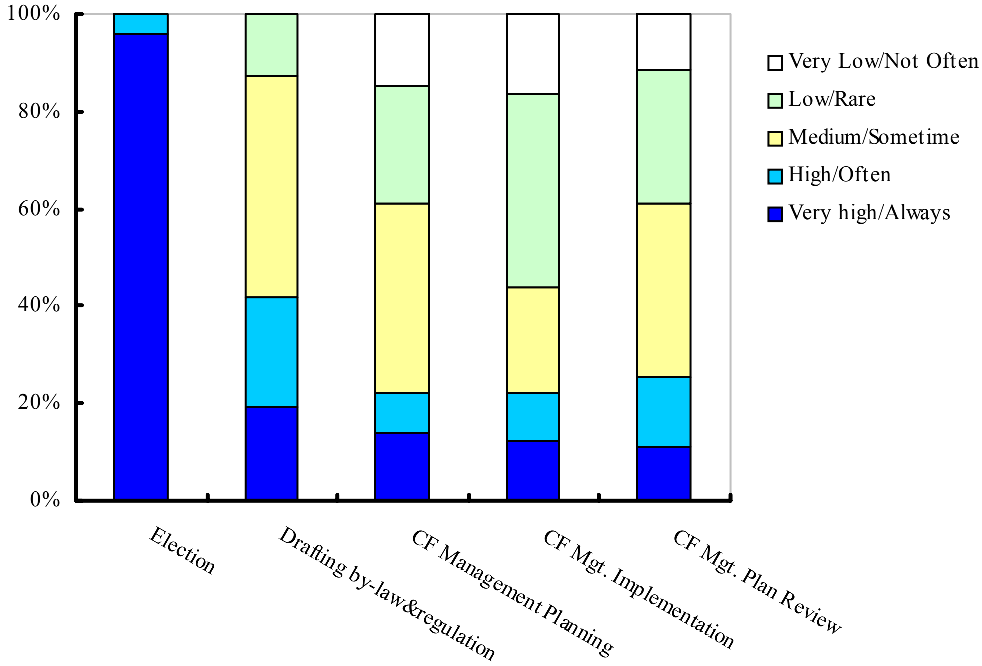

Figure 6. Participation in the CF planning, management and implementation process

Factors influencing participation

The factors that influenced local peoples participation in CF management and development included; national policy on fisheries management, people's knowledge and understanding of the importance and value of CF management, people's attitude/behaviour, and the perceived benefits of participating.

National policy on fisheries management

Almost all respondents (97.2%) said they were highly satisfied with the new national policy reform of fisheries management. They said that they are willing to support it because they believe it encourages user participation and is a better way of managing the natural fisheries resources, which they live close to and maintain.

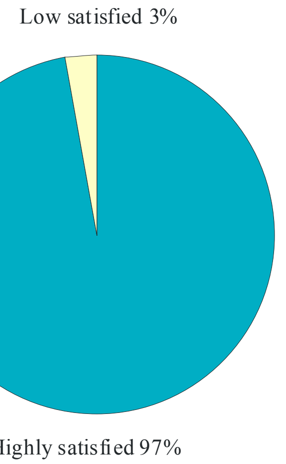

Figure 7. Level of satisfaction with national fisheries policy reform

Other reasons for satisfaction were:

- local users understood the value of their participation in natural resource conservation, protection, management and development
- it encourages co-operation and coordination amongst local users, stakeholders, and government
- no tax collection from middle-scale fishing
- illegal fishing is not permitted
- recently fish catch has increased in the study area and this has contributed to an increase in household income, food security, and poverty reduction
- the fisheries will be sustained for future generations

The very small proportion (2.8%) of participants dissatisfied with the national policy reform had largely misunderstood of the principles involved; some likened it to the idea of solidarity groups (*Krum Samaki*) formed during the Pol Pot era. Therefore, there is still a need to raise awareness of the aims of CF among some stakeholders.

Knowledge and understanding of the importance and value of CF management

Willingness to participate often relates to an individuals' level of knowledge, awareness and understanding of the concepts, importance and value of CF management and development, especially the concept of fisheries co-management and development, and natural resource ownership.

Once people have a clear grasp of these aims, they expressed a willingness to participate and voluntarily support CF. Therefore, in the early stages of establishing a CF, the most important activities are, building trust and understanding, raising awareness, and disseminating information to all stakeholders in the new CF.

Attitudes

Attitudes are an important factor influencing levels of participation. The idea of working together in groups is much easier to promote in villages where people traditionally help each other and share responsibilities. Khmer people, especially in rural areas, tend to live and work together as a community. Therefore, villagers, including the 36% of the CF who are not active fishers, willingly participate in setting up and managing CF in order to develop their communities. They see a communal need to manage their resources in a sustainable way so that future supplies of food are secure, that their own standard of living will increase, and that future generations will benefit from the fishery.

Perceived benefits of participation

Almost half (40%) of all respondents said that they benefited from the CF within two years its establishment, (Table 1). The more than half (60%) of the respondents who claim to have seen no benefit were fishers who did not participate in CF activities and development or were not involved in fishing or active fishers.

Table 1. *Benefits received*

	Khmer		**Cham**		**Total**	
	Count	**%**	**Count**	**%**	**Count**	**%**
Yes	46	28.8	40	72.7	86	40.0
No	114	71.3	15	27.3	129	60.0
Total	**160**	**100**	**55**	**100**	**215**	**100**

Those who saw no benefit believed the fish catch had increased but that this mostly benefited those who fished on a regular basis. Many felt that the CF in their areas, some only launched only within the past two years, and had not developed in accordance with the needs of members because of lack of funds and capacity.

There are many activities involved in organising a CF that need to be carried out systematically (according to the CF management plan and with facilitation, help and guidance from technical agencies) in order to promote self sufficient and effective CF management in the future. All members of CF must receive a fair and proportional share of the benefits if the community as a whole is to increase its standard of living.

The respondents most intimately involved in the CF, active fishers, saw the principle benefits as:

- an increase in fish catch
- increased knowledge and awareness of the value and importance of local and other stakeholders participation in natural fisheries resource management and development
- increased understanding, co-operation and co-ordination both within and between villages; and an alternative livelihood strategy.

Most respondents (79.2%) felt that fish catch had increased since the formation of CF, especially since the establishment of fish conservation zones or fish sanctuaries and the clamp down on illegal fishing practices. This perception held across the community, regardless of the member's gender or ethnic group (see Table 2 and Figure 8).

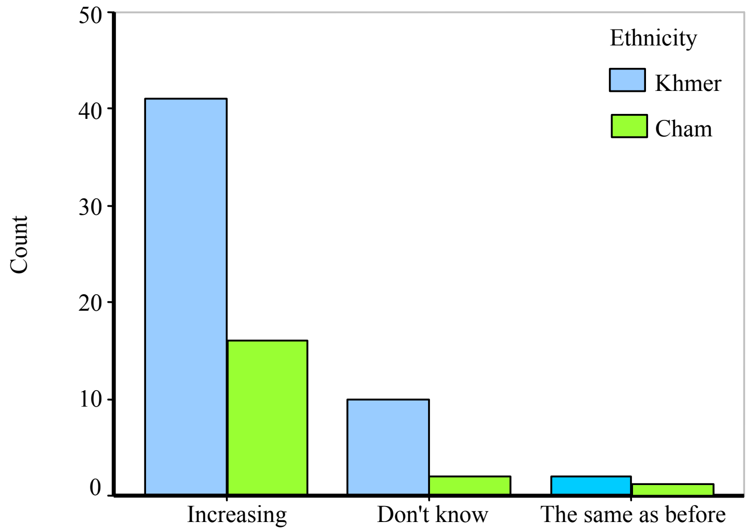

Figure 8. Ethnicity and perception of fish catch since the establishment of CF

Table 2. *Perception of the size of the fish catch since the establishment of CF*

	Male		**Female**		**Total**	
	Count	**%**	**Count**	**%**	**Count**	**%**
Increasing	32	84.2	25	73.5	57	79.2
Don't know	6	15.8	6	17.6	12	16.7
Same as before	0	0	3	8.8	3	4.2
Total	**38**	**100**	**34**	**100**	**72**	**100**

Effects of CF participation

Nearly all respondents (90.3%) said they experienced no negative effects from participating in CF activities (see Table 3) and, on the contrary, felt satisfied with the positive outcomes that they have seen. Only 9.7% respondents felt that their participation interfered with their daily work; most of these were committee members who spend most of their time on CF activities but do not receive any additional incentives or compensation.

Table 3. *Perception of negative effects of CF participation*

	Male		**Female**		**Total**	
	Count	**%**	**Count**	**%**	**Count**	**%**
Yes	4	10.5	3	8.8	7	9.7
No	34	89.5	31	91.2	65	90.3
Total	**38**	**100**	**34**	**100**	**72**	**100**

Members of the CF committee clearly need some form of additional incentives if they are to stay motivated. Providing training for alternative livelihoods or other activities that generate additional income may be one of the best incentives, especially if money generated from these activities helps to finance CF administrative work.

Problems and constrains

Although CF brings many benefits, they also face some problems and limitations. The following are some of the issues raised by respondents during focus group sessions:

- lack of resources to support the operation, participation, and implementation of CF management plans and administration
- a few illegal fishers still do not want to participate in the CF
- inadequate materials and incentives for CF committee members and patrol groups

CONCLUSIONS

This study has shown that at Beoung Chunlen reservoir CF were well organised with active participation and co-operation by members and other stakeholders.

The national legal framework and guidelines consider the needs of local people and present an opportunity for improving standards of living. Building trust, informing, and increasing awareness and knowledge of all stakeholders in the area, and especially in fishing villages, on the purpose of CF and fisheries co-management is one of the most important ways of promoting participation. It is important for facilitators to understand people’s attitudes, practices and beliefs if facilitation activities are to be appropriate and capable of motivating people to participate actively in all CF activities.

Benefits are one of the most necessary factors in promoting high levels of active participation. Many members of the Beoung Chunlen reservoir CF are already enjoying the benefits that co-management brings. These benefits include an increase in fish catch in the area, raised awareness and understanding of the importance of fisheries resource management, and the creation of livelihood activities supported by MRRF. However, most of the membership preferred to receive immediate benefits because they were from rural communities and generally poor and short of food.

Only a few CF committee members, who were very poor and had to work daily to provide enough food for the household leaving them with little spare time, suffered negative effects of participation**.** Even so, these people were able to manage their time well by incorporating CF activities into their daily work routine.

Lack of resources for operating and running CF activities was the main problem identified by during the study.

RECOMMENDATIONS

During focus group discussions, the respondents identified the following list of recommendations:

1. Trust must be built and awareness and understanding of the purpose and concept of fisheries co-management raised if the level of participation is to be increased amongst users and other stakeholders.

2. External support is needed for facilitation activities and CF operation to run and develop CF and increase the level of participation.

3. High levels of co-operation and co-ordination between local authorities and technical agencies are needed to support CF management and development and generate higher levels of participation amongst CF members and local users.

4. The institutional set-up of CF should be reviewed regularly to ensure that benefits are equally distributed among all member of the community.

5. The creation of income-generating activities should be considered as a way of providing suitable incentives to increase the level of participation and benefit earning for suitable fisheries co-management.

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Hydrology, habitat and livelihoods on the floodplains of southern Lao PDR

Roger Mollot[1*], Chanthone Phothitay[2] and Sonsai Kosy[3]

[1]WWF Lao PDR programme
[2]Living Aquatic Resources Research Centre (LARReC)
[3]Livestock and Fishery Section of Savannakhet Province

ABSTRACT

This paper examines the relationship between hydrology, floodplain habitat and livelihoods of people living in the catchment of the Xe Bang Hieng and Xe Kong rivers of southern Lao PDR. Healthy floodplain environments are a key factor in the food security of riverine communities as these habitats yield a rich fauna and flora on which the inhabitants' livelihoods depend. The hydrologic cycle plays a fundamental role in maintaining the health of the floodplain environment. The natural seasonal variation of flow, that includes periodic inundation of the floodplains, creates and supports a diverse range of habitats and ecological niches.

Rural people, who have lived in these environments for generations, and who are well attuned to making a livelihood on the floodplains, have adopted an impressive variety of artisenal fishing gear to target specific fish species or habitats through the changing seasons. Fish, snails, aquatic insects and plants, bamboo shoots and mushrooms are just some of the natural products, harvested from riverine environments, which form an essential part of the local diet. Therefore, healthy floodplain environments and rich biodiversity resulting from an unimpeded hydrological cycle are essential to the way of life of riverine communities in Lao PDR.

It is, however, a way of life that is under threat. As the countries of the Mekong Basin grow in population and develop their economies there is increasing competition and conflict over water resources. Demand for hydropower, irrigation, road networks, river navigation and flood mitigation are a growing challenge to the natural hydrologic cycle and the health of the floodplains. Considering the significant value of floodplain biodiversity to rural livelihoods, effective management of the hydrologic cycle and conservation of the floodplain environment will be necessary to support socio-economic development and environmental health.

KEY WORDS: Lao PDR, biodiversity, seasonally flooded habitats, rural livelihoods

INTRODUCTION

The expanding populations and growing economies of the countries within the Mekong River Basin are generating intense competition for the tremendous water resources of the region. In Lao PDR, the increasing demand on water resources means development plans must strike a balance between competing users that also protects the ecologically important habitats of the floodplains. These competing interests for water resources arise from fisheries, irrigated agriculture, hydropower and navigation. All of these sectors of the economy are important to the socio-economic development of the region.

The natural resources of capture fisheries, however, are a valuable common property and a significant component in the livelihoods of the rural poor. Regardless of age, gender or socio-economic status, capture fisheries and the collection of non-timber forest products (NTFP) are an important activity that

* WWF Lao Programme, P.O. Box 7871, Vientiane, Lao PDR
Email: roger.mollot@wwflaos.org

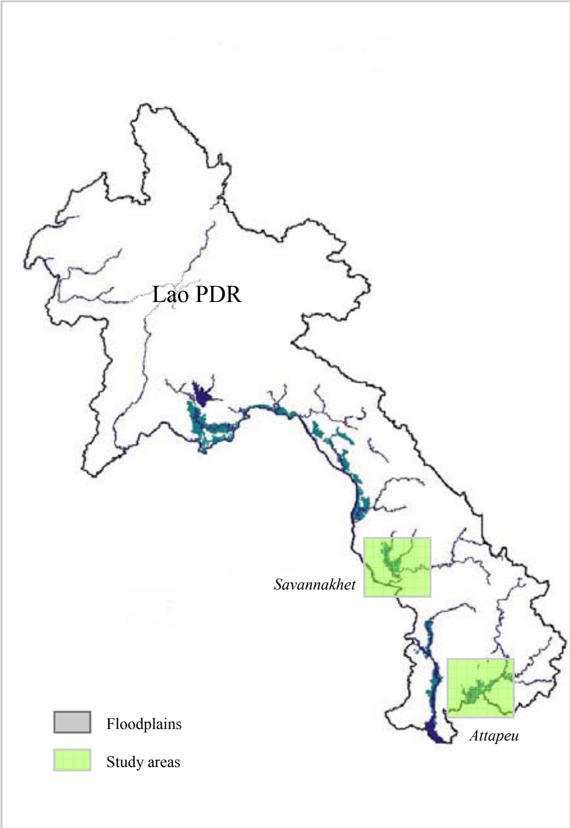


Figure 1. The extent of the floodplains of the Mekong and its major tributaries - Lao PDR

supports household food security and income. Fishing and NTFP collection are especially important to poor people who, if they do not have access to land, may not have other alternatives for food and employment. These people may not benefit directly from hydropower, irrigation and navigation improvement, but they do depend upon fish and NTFP for their livelihoods.

This paper describes one of the issues surrounding the use of these common property resources, the need for careful management of the floodplain environment and the hydrological factors that shape it. The paper illustrates this issue with reference to the extensive floodplains of Mekong and its tributaries in the southern provinces of Savannakhet and Attapeu (Figure 1) using data gathered through participatory assessments carried out by WWF, Living Aquatic Resources Research Centre (LARReC) and the provincial Livestock and Fisheries offices in both provinces.

Lao PDR is predominately a rural population with approximately 80% of people living in the countryside (UNDP 2001). The country is economically under-developed but is rich in aquatic resources from rivers, streams, floodplains and wetlands that provide necessary sustenance in times of rice shortage or crop failure. Rural people regularly collect NTFP for consumption in the home as a supplement to their staple diet of rice and livestock produce (Foppes and Khetphanh, 1997). Aquatic animals (fish, frogs, snails and insects) and plants have been important ingredients in the daily lives of Lao people for generations, providing a food source that is high in protein and rich in fat (Meusch *et al*. 2003).

As a result, the rural livelihoods in southern Lao PDR entwine closely with the seasonal rhythm of the river; the inhabitants' broad knowledge of ecology of their local environment means they are very adept at utilizing the natural resources of this dynamic ecosystem. Men, woman and children are all active in fishing and collecting NTFP, using a variety of gear types that target different fish species or habitat.

In southern Lao PDR, people value a healthy floodplain environment for the ecological role it plays in fish and NTFP production. The hydrologic regime of the river basin shapes this important environment. Alterations to river basin hydrology stemming from hydropower, irrigation development, and flood mitigation schemes potentially cut floodplains off from the mainstream river channel, severely affecting the floodplain environment, fish production and the livelihoods of people who rely upon these common property resources.

FLOODPLAIN ECOLOGY

Floodplains are an important feature of the landscape of southern Lao PDR. Characterized by rich biodiversity they are highly productive areas for agriculture and forestry. These lowland areas adjacent to rivers and streams are an integral component of a river basin and are a key element in the environmental health of a river.

The flow of rivers in southern Lao PDR fluctuates markedly between the wet and dry seasons (Table 1). This fluctuation serves to create critical habitat and food niches that support a diverse fauna and flora (Baran et al. 2001). During the period from August to November, when the flow is at its greatest, the river water inundates the floodplains and fish migrate into these flooded areas to feed and spawn (Baird and Phylavanh 1999).

Table 1. *Xe Bang Hienh and Xe Kong - mean monthly discharge (m^3/sec)*

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Xe Bang Hieng	44.9	24.0	31.2	18.4	111	131	182	194	885	309	377	194
Xe Kong	86.6	62.5	46.1	44.3	80.5	100	137	231	498	304	712	308

Note: Source: Lower Mekong Hydrological Yearbook: 1998. Mekong River Commission

The Mekong's abundant floodplain habitat is one of the key factors accounting for the river system's impressive fish productivity and diversity (Welcomme 1995) and conserving this habitat is essential not only to protect biodiversity but also to provide food security for many rural households. Floodplains are unquestionably the engine of high fish production and rich biodiversity, and serve an important ecological role for the entire river basin.

In southern Lao PDR, the floodplains of the Xe Kong and Xe Bang Hieng (Figure 2 - over page) are typical of the seasonal variation these environments display. The floodplain habitat of these rivers consists of seasonal and permanent wetlands, streams, forests, grasslands and rice paddies. High water levels during the rainy season serve to transport sediment and nutrients onto the floodplain, providing a

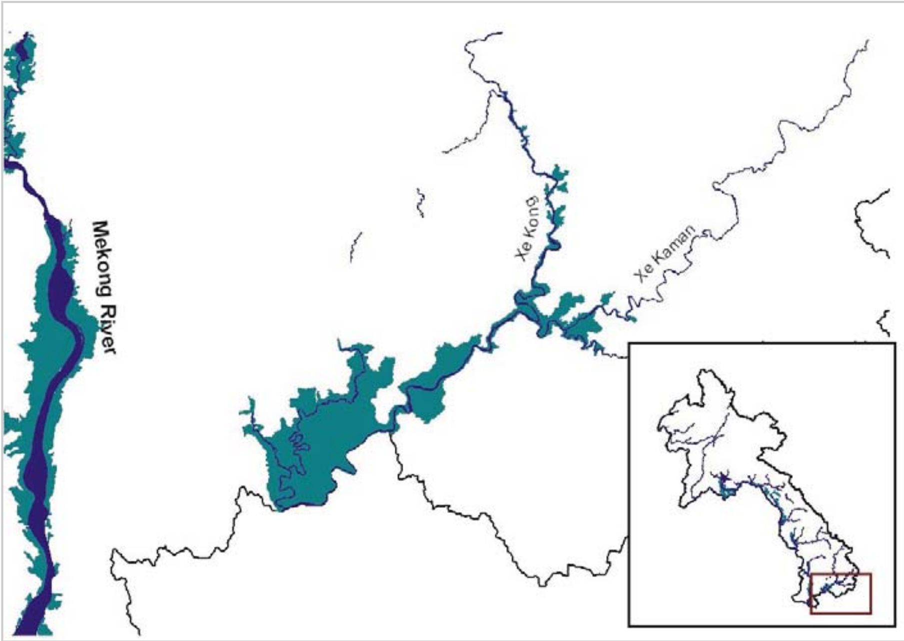


Figure 2. The floodplains of the Xe Kong and Xe Kaman river - Attapeu Province

food-rich environment for spawning fish as well as productive soil for the cultivation of rice and other cash crops. For the people living on floodplains the seasonal variations offer both inconvenience and opportunity. People rely on the rich biodiversity to provide food, income, medicine and construction materials, but seasonal floods can also damage infrastructure and hinder road transportation and livestock production.

Moreover, a healthy floodplain environment is beneficial to the entire river basin. Many fish species that spawn on the floodplain undergo long-distance seasonal migrations into the headwaters of the river system (Poulsen and Viravong 2001), suggesting that vigorous floodplain habitat has biological and socio-economic benefits for both upstream and downstream communities.

While floodplains represent a range of habitats, the type of habitat inundated by floodwaters has a direct effect on the production and diversity of fish and NTFP (Baran et al. 2001). Floodplain communities understand fully the relationship between quality floodplain habitat and high fish production and diversity and are willing to exert greater effort fishing in habitats like seasonally flooded forests than rice paddies or grasslands (Table 2).

Table 2. *Flooded habitats, effort invested and value of produce - Phouvong district, Attapeu province*

Flooded habitat	Effort per month (days)	Harvest rate (kg/day)	Market price (kip/kg)
Rice paddy	12	0.5	3,000
Flooded forest	22	3.0	6,000

The table shows how highly rural people value the high quality habitat of seasonally flooded forests for fish production. In this environment, they are not only able to catch more fish, but the species they catch fetch a higher price market.

This seasonally flooded forest environment is a complex ecosystem, rich in food resources and shelter for spawning fish and juveniles, and is an essential factor in the high fish production and diversity in the Mekong Basin (Baran et al. 2001).

THE ROLE OF THE HYDROLOGIC CYCLE

The seasonal flux of the Mekong is greater than that of any other large river in the world (Welcomme, 1979). The seasonal fluctuation in both the depth of the river and the velocity of its flow and the periodic inundation of its floodplains are key elements of the Mekong's natural hydrologic cycle. In southern Lao PDR, this flooding typically occurs during the wet season months of July to October, with the duration and timing of the flood varying from year to year. However to regard this natural phenomenon of seasonal floods solely as a threat to infrastructure, transportation and health is a mistake; rather it should be understood for the important role it plays in the environment of the river basin and the livelihoods of people who depend upon its abundant riverine natural resources.

Other hydrological factors such as water discharge, flood duration and timing, in addition to the quality of floodplain habitat, also play a role in determining fish production and supporting high biodiversity (Baran *et al.* 2001). Any development that affects the quality of floodplain habitat or alters the hydrologic cycle will have an impact on the production and diversity of fish and NTFP and the way of life of people who rely upon these natural resources.

Threats to this natural cycle occur primarily from the development of infrastructure for irrigation, hydropower and flood mitigation. These types of infrastructure can alter the natural flow of a river, block long-distance fish migrations, and create reservoirs out of free flowing rivers. The cumulative impact of water resources infrastructure will lead to a dampening effect on peak flow as reservoirs holdback water during the rainy season (MRC 2003). This reduction of wet season discharge will lead to a shorter flood period that inundates a smaller area of the floodplain, thereby reducing the habitat available for fish to spawn and nurse in. The reduction, or loss, of seasonal flood events therefore is a threat to the floodplain environment that will lead to a decline in fish production and the aquatic biodiversity of the river basin.

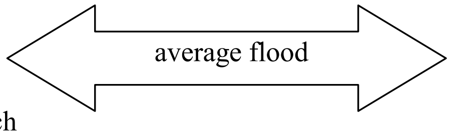
LIVING WITH THE FLOOD

In addition to the benefits for fish production, the seasonal floods maintain the water table of the floodplain and carry sediments and nutrients onto these low-lying areas. For this reason, the people who live on the floodplains of southern Lao PDR recognize the benefits of seasonal floods to fisheries, agriculture and agro-forestry. However, they also recognize that large floods can damage infrastructure, interrupt transportation and lead to livestock disease and loss of rice crops. The box over page illustrates how people see the benefits of small to medium size floods to their overall livelihood, while recognising that large floods that may cause damage to rice crops can lead to higher fish production.

Local perception of seasonal floods

Small to average size floods are regarded as beneficial by flood plain communities. These communities have adopted livelihood strategies to cope with seasonal floods such as planting traditional varieties of flood 'tolerant' rice and utilising capture fisheries. Benefits from floods include high fish yield in the numerous rivers, streams, paddy fields, ponds and wetlands. Fish are an important food resource, high in protein and fat, thereby forming a vital component of rural food security.

Small flood
(2-3 days)
- Good rice crop
- Decreased fish catch



Large flood
(9-12 days)
- Loss of rice
- Livestock disease
- Increased fish catch

Each flood is unique in terms of timing, water level, duration, and characteristics of the flooded habitat. The perception of flood benefits however may depend upon whether the person is a farmer or fisherman, land owner or landless, urban or rural, rich or poor. A good flood for fish production and capture fisheries may cause crop damage and interfere with road transportation. Rural development plans that invest in flood mitigation infrastructure in order to prevent seasonal floods altogether may benefit one sector of the economy at the expense of another.

However, from the perspective of rural villagers, many of who are dependant upon fish and NTFP for household income and food security, seasonal floods are a necessary event that supports fish production and agricultural productivity on the floodplain. These people understand 'living with the flood' is a balance between the ecological function of floodplain hydrology and the need for securing agricultural production. The development of floodplain areas and water resources infrastructure must attempt to balance the necessary role of seasonal flooding and river basin health and household economy. Promoting the concept of 'living with the flood' will improve our understanding of the benefits of floods and maintain these valuable ecosystems. Effective policy and planning will ensure that design of transportation and water resources infrastructure (roads and dams) minimises the impact on the hydrologic cycle of a river basin.

METHODOLOGY

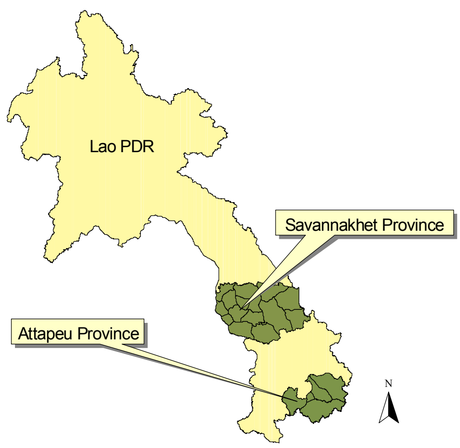
Planning for this study involved cooperation with the Lao National Mekong Committee, LARReC, Regional Development Coordination, and the Provincial Agriculture and Forestry Office and Livestock and Fisheries sections of Savannakhet and Attapeu provinces. The objective was to investigate the relationship between the hydrologic cycle, biodiversity, fish migrations and local livelihoods. To examine these themes in communities that experience different degrees of seasonal flooding this study included communities living on floodplains and in upper catchment areas.

Participatory Assessments

This study used participatory methods to analyse the local use of both habitat and biological diversity in the daily lives of rural communities. Participatory methods explore local knowledge of natural resources by inviting local communities to discuss their daily use and management. For this study, the participatory techniques used Participatory Rural Appraisal (PRA) methods to gain insight of local knowledge and encourage open discussion of the use of biodiversity. This involved asking key respondents to describe seasonal farming and capture fishery activities, compile lists of important fauna, flora and habitat as defined by local knowledge, and perform comparative ranking exercises where participants grade the importance of various types of NTFP and habitat relative to one another. Both women and men were included in the group of key informants and open-ended discussion was encouraged throughout the survey.

Site selection

The provinces of Attapeu and Savannakhet were chosen for the large flood plain areas from the Xe Kong and Xe Bang Hieng river systems respectively (see Annex 1 & 2). These rivers are two of the largest tributaries of the Mekong and serve an important ecological role in the capture fisheries of the Mekong Basin. While both rivers experience seasonal flooding during the rainy season, the size, timing and duration of floods will vary from year to year. Criteria used to select target villages were developed in cooperation with provincial and district authorities based on the socio-economic status of the village, propensity to flood and food self-sufficiency. This allowed for an analysis of the factors contributing to rural livelihoods in communities adapted to living with seasonal floods.



Attapeu province

The participatory assessments in Attapeu aimed to understand local perception of the impact and benefits of seasonal floods on biodiversity and their livelihoods. The survey included assessments in Sombpoi, Songkhon and Ta Ngao villages of Sanamxay district (Figure 3 over page). These villages located along the Xe Kong River suffer extensive seasonal flooding from the Xe Kong and Xe Pian river systems. The surveys, conducted at the household level, endeavoured to quantify household reliance on the system's rich biodiversity. On this extensive floodplain, fishing activities are not restricted to the Xe Kong, but extend across a mosaic of floodplain habitats.

Further participatory assessments, conducted in Phouvong district, examined the local perception of the quality of various floodplain habitats for capture fisheries. As an initial study into the quality of habitat, this survey compared two distinct types of floodplain habitat, rice paddies and flooded forests, to find out the value to livelihoods people attributed to each habitat with regard to capture fisheries.

Figure 3. Targeted districts - Attapeu province

The floodplain in Sanamxay and Phouvong districts possesses a complex ecosystem of both seasonal and permanently flooded habitat that is important to local communities for fishing and harvesting NTFP. Typically, the NTFP collected in flooded areas are fish, bamboo shoots and mushrooms, with some households collecting frogs, snails, rattan, grasses and various traditional medicine (Table 3)

Table 3. *Total quantity (kg/year) and habitat of important NTFP collected in Sombpoi village of Sanamxay district*

NTFP	Habitat	Average household collection (kg/yr)	% of surveyed household collecting this NTFP
Bamboo shoots	floodplain	238	100
Mushrooms	flood plain, evergreen forest, hills, dry forest	100	100
Fish	flood plain, rivers	704	88
Ke se resin	flood plain, dry forest	67	75
Frogs	flood plain, dry forest	27	63
Yang oil	flood plain, dry forest	158	63
Monitor lizard	flood plain, dry forest	25	50
Traditional medicines (*strychnos nux vomica*)	flood plain, dry forest	118	50
Turtle	flood plain	21	50
Snails	flood plain	49	38
Bong bark	flood plain	356	25
Traditional medicine	flood plain	29	25
Yang bong	flood plain, dry forest	463	25
Fruit	flood plain	40	13

Flooding in Sanamxay predominately occurs when the Xe Pian and Xe Kong rivers overtop their banks. Villagers generally see small to average size floods as beneficial and regard flooded soil to be more productive for growing rice. Large floods, that restrict transportation, bring livestock diseases and cause the loss of rice crops, are more of a problem. However, the local rice farmers in the villages surveyed see the benefits of the floods as a trade-off between rice and fish, where large flood years damage the rice crops but result in high fish yields and small floods produce good rice but less fish. Households with little or no access to paddy land put more effort in other activities such as capture fisheries and the collection of NTFP. These households place higher value on the benefits of flooding because consequences, such as increased fish production, are a more significant component of their livelihoods.

Savannakhet province

Surveys in Savannakhet sought to compare the importance of rich biodiversity and the hydrologic cycle to the livelihoods of communities in the upper catchment and on the floodplain. The participatory assessments in Savannakhet did not focus on the household level, but rather sought a broad overview of biodiversity and livelihoods across a wider geographical range of the river. In each village, a single group of key respondents ranked the relative importance of household food resources.

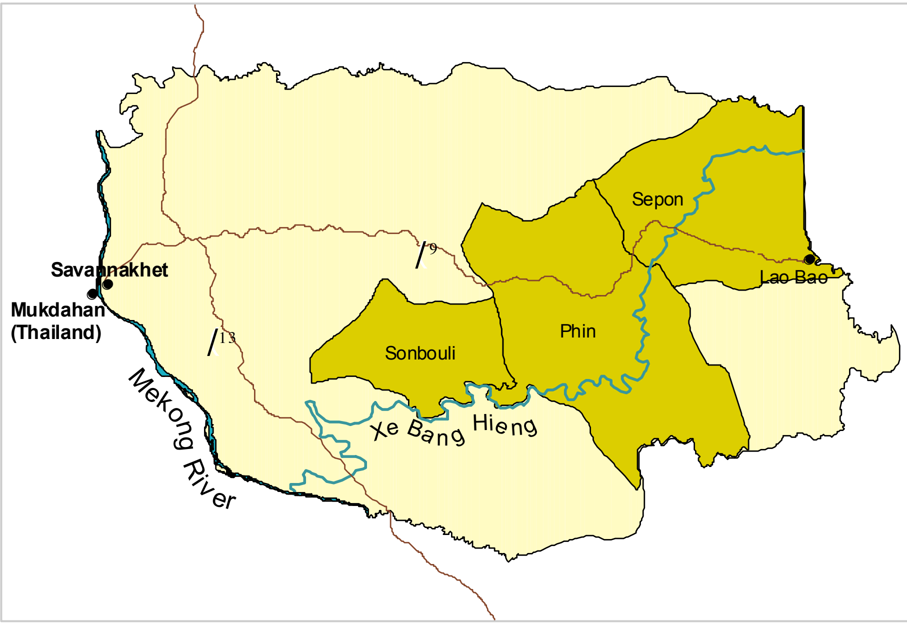


Figure 4. Targeted districts - Savannakhet province

Two field surveys collected data along the Xe Bang Hieng in the provincial districts of Sepon, Phin and Sonbouli. Sepon and Phin are located in the upper catchment where the low hills of the Annamite Mountains along the Lao-Vietnam border dominate the landscape. In these areas, the steeper gradient of the riverbanks limit the extent of seasonal floods. Conversely, in the lowland district of Sonbouli the large wet season flow in the Xe Bang Hieng causes large tributaries like the Xe Champhon and Xe Xang Xoy to back up and flood large areas (see Appendix 1). This extensive floodplain includes large forested areas, predominately bamboo and shrub forests, which, when seasonally inundated by floodwaters, create important habitat for fish.

The first survey focused on the upper catchment area of Sepon and Phin Districts, and included participatory assessments in the villages of Kengkame, Na Huanam, Kengky, Vangkhot, Pai, Sawier, Pasiah and Nyang. The survey's objective was to determine the relative importance of capture fisheries and NTFP to the livelihoods of communities in localities subject to less severe seasonal flooding. This area does experience seasonal fluctuations in discharge, but steeper slopes limit the area of flooding. The habitats suitable for capture fisheries are therefore more restricted. Consequently, most fishing activity focuses on rivers and streams, where seasonal fish migrations triggered by hydrologic changes play a vital role in the local way of life. Because these fish migrate between the floodplains and the higher catchment, the way of life of communities living on this resource entwine intimately, even though they are geographically disconnected.

The floodplain villages of Dong Boun, Na Horlouang and Toum Nyae in the Sonbouli district were surveyed in a similar manner. Here, in contrast to the Attapeu villagers who can fish both the Xe Kong and its extensive floodplain, these communities, because of the high productivity wetlands and seasonally flooded forest habitat, invest more effort fishing on the floodplain. A single group of key respondents provided a general overview of how households value capture fisheries. The objective was to examine the relationship between seasonally flooded forests and capture fisheries and how these communities use these habitats to support their livelihoods. While floodplain communities often have access to rich aquatic resources, this study sought to highlight the importance of this diversity to livelihoods on both the floodplains and upper catchment communities and the pivotal role of an unhindered hydrologic cycle.

In each village, a group of key informants listed and then ranked the importance of floodplain habitats according to their contribution to household income and ease of catching fish. This list of aquatic habitats was grouped according to utilisation by gender. Each group then compiled a list of fish species regularly caught near their village and provided information about the habitat, migration and the importance of each species to villagers' livelihood.

LIVELIHOODS AND FLOODPLAIN BIODIVERSITY

The surveys in both provinces show how critical healthy floodplains are in shaping the environment and hence the way of life and the culture of rural people throughout southern Lao PDR. The high fish diversity and productivity of the floodplains provides an abundant food source for Lao people, accounting for the high rates of fish consumption in lowland communities of the Mekong Basin (see Table 3, also Baran and Baird, 2003; Singhanouvong and Phoutavong 2002).

For generations Lao households have consumed these riverine resources as the principle source of their protein and fat. Furthermore, these fish and NTFP resources are the 'natural capital' that rural villages rely on during periods of rice deficit or when crops fail. However, there is no similar source to rely upon during periods when fish and NTFP are limited (Meusch *et al.* 2003). The security of the food supply and rural health therefore depends on the seasonal flooding and the vigour of floodplain habitat. Disruption of this seasonal flood pulse threatens the floodplain environment and livelihoods of the people who regularly consume fish and NTFP.

Table 4 gives a partial list of fish species regarded as important by people in three villages in the Sonbouli district of Savannakhet province. (Appendix 2 gives a complete list of fish species found near these villages.) This list, which uses local knowledge of capture fisheries rather than direct field sampling, shows just how important the diversity of habitat and aquatic organisms is to rural livelihoods.

Table 4. *List of important fish species from three villages in Sonbouli district*

Scientific name	Market price	Habitat
Belodontichthys dinema	18,000	River, deep pools
Channa spp.	8,000	River, pond, flooded area
Chitala ornata	8,000	River, pond, flooded area
Cyclocheilichthys enoplos	17,000	River, pond, flooded area
Cyprinus carpio	10,000	River, rapid, pond
Hypsibarbus malcolmi	8,000	River, flooded area
Kryptopterus cryptopterus	10,000	River, pond, flooded area
Micronema apogon	15,000	River, pond, flooded area
Morulius chrysophekadion	14,000	River, pond, flooded area
Mystus spp.	15,000	River, pond, flooded area
Notopterus notopterus	8,000	River, deep pool, flooded area
Pangasius macronema	10,000	River, pond, flooded area
Puntioplites falcifer	5,000	River, pond, flooded area
Thynnichthys thynnoides	6,000	River, pond, flooded area
Wallago attu	15,000	River, pond, flooded area

Table 5. *Factors determining the importance of fish species to local livelihoods*

Scientific Name	Fishing	Eating
Wallago attu	Difficult	Good taste
Micronema apogon	Difficult	Good taste
Belodontichthys dinema	Difficult	Good taste
Cyloscheilichthys enoplos	Difficult	Moderate
Kryptopterus cryptopterus	Moderate	Moderate
Mystus mysticetus	Difficult	Moderate
Hemibagrus filamentus	Moderate	Good taste
Chitala ornate	Easy	Moderate
Puntioplites falcifer	Easy	Good taste
Mystus mysticetus	Easy	Moderate
Pangasius macronema	Difficult	Good taste
Clarias batrachus	Easy	Good taste
Morulius chrysophekadion	Difficult	Good taste
Anabas testudineus	Easy	Good taste

A variety of factors influences the villager's perception of which fish species are important to their livelihoods (see Table 5). Fish are important for both subsistence and value their market value. Sold to traders, a large fish will provide household income, and is therefore valued for its potential to generate cash. Small fish, that are abundant and easy to catch, are valued for their regular contribution to food security. Other fish species are valued simply because of their good taste.

Strength in diversity

All the households interviewed for this study collect fish and NTFP from both permanent and seasonally flooded habitat. Permanently flooded habitat includes perennial rivers and streams, wetlands and natural ponds. Seasonally flooded habitat includes a wide range of habitat inundated by floodwaters for periods during the rainy season. This inundation may last as little as one week to several months. Examples of this habitat include the river banks and seasonal streams that are inundated as the rivers rise during the rainy season (May-October), wetlands and natural depressions on the floodplains that are inundated by floodwaters but dry out during the dry-season months, and forests on the floodplain that are flooded for varying periods of time each year. Rice fields also represent important aquatic habitat for collecting non-rice food items such as fish, frogs, molluscs and aquatic insects.

Each household relies on capture fisheries and NTFP for food and income to a different degree depending on factors such as age and gender of household members, number of individuals per household, the wealth of the family and their sufficiency of livestock and rice. While most community members are involved in the collection of fish and NTFP, the age, gender and wealth of an individual will determine the habitat they use, the gear type they employ and fish species they target. To fish in the main rivers often requires a considerable investment, in boats, motors and monofilament nets, while in habitats like flooded forests, wetlands and streams poorer people can use smaller-scale gear for collecting fish and other aquatic organisms such as frogs, snails and insects.

This diversity of habitat ensures a range of households have access to aquatic resources on a regular basis. Women and children may forage the wetland habitat nearby the village to collect plants, snails and fish for their families to eat. The men often fish the mainstream channels of the river where they can catch larger fish; they normally sell these to a trader to provide income for their household. As a rule, in rural villages the poorer the household the smaller the fish they will consume because they will sell large fish to markets in order generate some income.

Rice paddies are a multi-purpose resource utilised for both rice production and capture fisheries. Agricultural development that focuses on rice paddy production must also recognise the value of rice paddy fisheries in household food security. The loss of high quality habitat for capture fisheries, such as seasonally flooded forests and wetlands, for conversion into rice paddy may do little to strengthen food security. On the contrary, it may serve to undermine the considerable resources of food provided by healthy floodplain ecosystems.

FACTORS INFLUENCING USE OF AQUATIC RESOURCES

So far, this paper has explained how of the high biodiversity of wetland habitats support the way of life of rural communities throughout southern Lao PDR. However, how individual communities use and value these aquatic resources depends on a host of factors including their location in the basin and the hydrological regime (upper catchment or lowland floodplain), gender, household wealth and ethnicity.

Hydrological regime – upper catchment and lowland floodplains

The hydrology of the upper catchment differs in a number of significant ways from that of the lowland areas of the floodplain. In the headwaters of a river system the steeper gradient of the river banks restrict seasonal flooding, which creates different riverine habitat; as a result communities in different hydrological regimes place different emphasis on fishing.

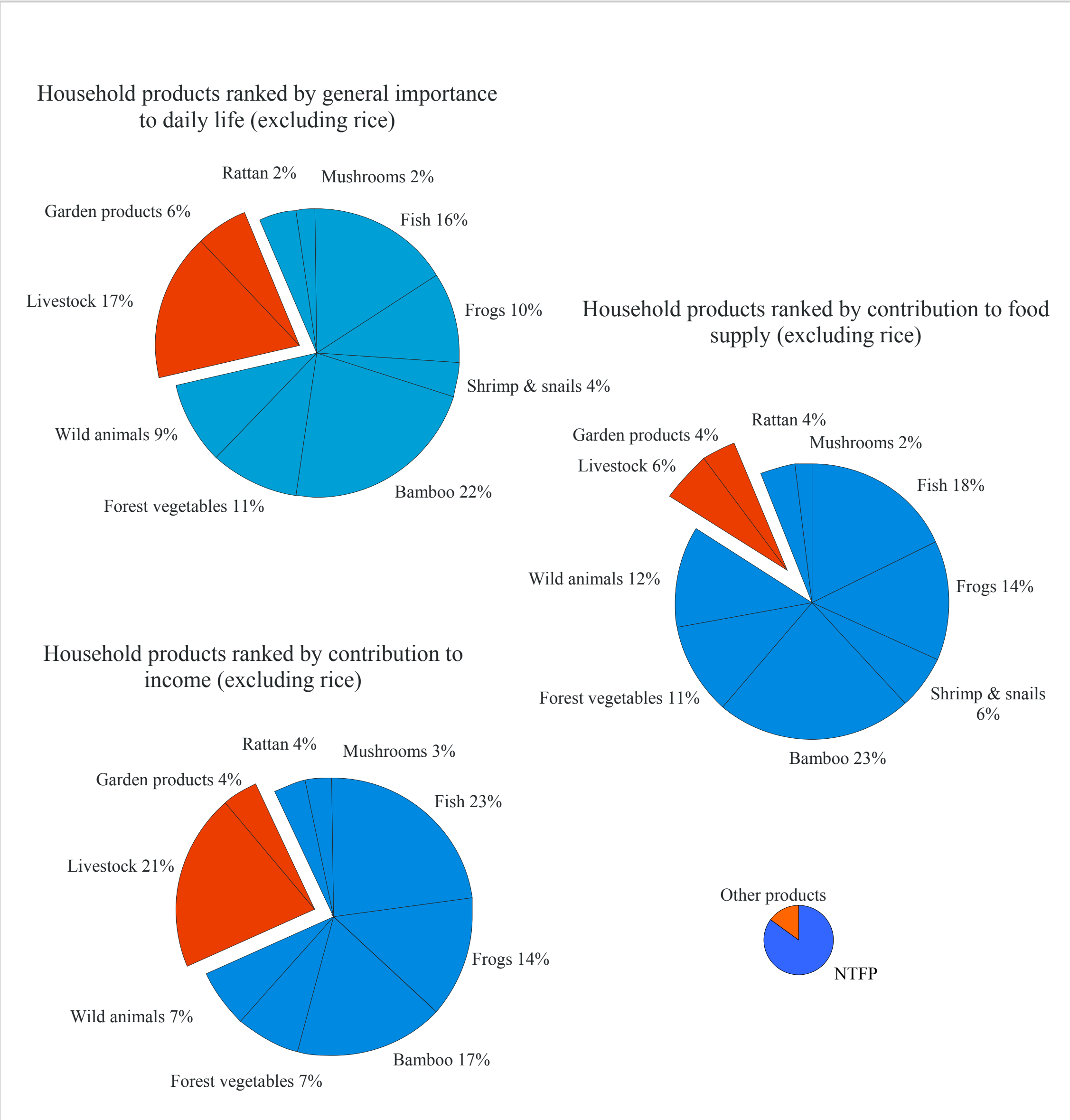


Figure 4. Ranked importance of household products in eight villages in Sepon and Phin districts, Savannakhet province

Despite a lack of floodplain habitat, fish represent a significant portion of the food and income of households in the upper catchment of a river. This lack of seasonally flooded habitat in the headwaters restricts the fishing effort to the mainstream river channels and streams. Seasonal fish migrations triggered by fluctuations in the flow remain a crucial part of the fishery. Many of the fish species that undergo these long distance migrations are dependant upon healthy floodplain habitat for spawning and feeding. In this way, the villages in the headwaters of the river to some extent rely on the same ecosystems and habitats as lowland villages from the floodplain. The hydrologic cycle is important to both maintaining critical floodplain habitat for fisheries as well as providing the environmental cue necessary to trigger seasonal fish migrations.

Table 5. *Water resources in three target villages in Sonbouli district*

	Dong Boun village	Na Horlouang village	Toum Nyae village
Perennial fishing habitat	Deep pools in river Tacham pond Tapone pond Kor swamp Xe champhone Xe Xang Xoy	Sim pond Huali wooden weir	Sim pond Xe Xang Xoy Deep pools in river
Seasonal fishing habitat	Khitha pond Khe pond Khone peung pond Khaman pond Kack het pond Edone pond Chakhe stream Lali stream	Khea pond Flood area Thomneung pond Thomleung pond	Pave pond Veun pond Sim channel Lamtheuck channel Channel small Chakhea channel

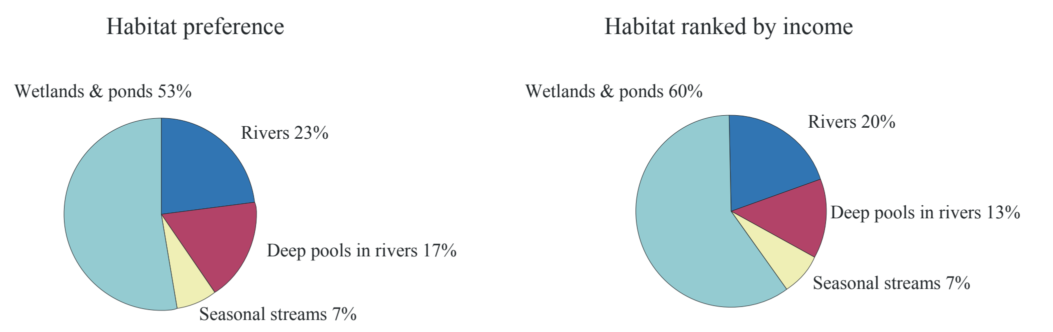


Figure 5. Preferred fishing location in Dong Boun village ranked according to habitat type

In lowland areas on the floodplain, there is more area of aquatic habitat available for fisheries. These communities are not limited to fishing mainstream rivers and streams, but have a range of floodplain habitat available (Table 5).

Table 6. *Usage of water bodies in Songkhon village, Sanamsai district*

Water Resource	Fishing Access	Purpose
Xe Pian	Year round	Income/subsistence
Xe Kong	Year round	Income/subsistence
Ta Ngao stream	Year round	Income/subsistence
Cheua stream	Rainy season	Subsistence
Ahlai stream	Year round	Subsistence
Talao stream	Year round	Subsistence
Rice paddy	Rainy season	Subsistence

Perennial and seasonal wetlands, streams, and flooded forests all offer important habitat for fisheries and livelihoods (Figure 5). These lowland communities are active participants in the fishery, targeting specific habitat for to provide subsistence or to generate income (Table 6).

Communities from the headwaters down to the floodplain regard the seasonal fluctuations in flow as positive factors in the fishery, creating seasonal habitat and triggering fish migrations. People will exert more fishing effort during the wet season months as the amount of habitat increases with the flood. Despite the larger area of habitat available, fishermen are able to catch more fish during wet season months as fish migrate across the floodplain, rice paddies, rivers and streams (Table 7).

Table 7. *Seasonal variation in capture fisheries habitat and average daily catch (kg) from three villages in Sanamsai district, Attapeu province*

Water resource	Fishing season	Dry season average daily catch (kg)	Wet season average daily catch (kg)
Xe Kong river	Year round	1.5	3.0
Seasonal stream	Rainy season		0.5
Rice paddy	Rainy season		0.4

Gender and Fisheries

Men and women will differ in their preference of habitat for capture fisheries (see Figure 6a and b over page). The gear type chosen by men compared with that used by women reflects this. Typically, the men will be fishing in the large rivers and ponds using boats and large-scale gear like monofilament gillnets. Women are responsible for many of the household duties other than fishing, and will often stay within close proximity of the village to collect fish and other NTFP using smaller gear. While this limits them in their choice of habitat, the contribution of wetland fish, molluscs, aquatic insects and plants to household food security is still significant.

Household Wealth

The wealth of the household may also determine how people value aquatic resources. To fish in the mainstream river channels often requires an investment in boats, motors, and monofilament gillnets. This may prevent some poorer households from fishing this habitat. Because fishing in wetlands and

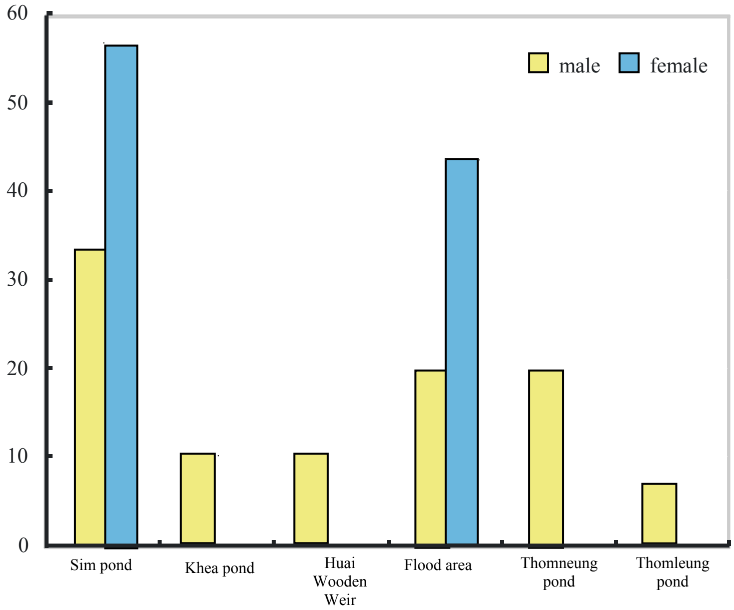


Figure 6a. Preferred fishing location in Na Horlouang village ranked by gender

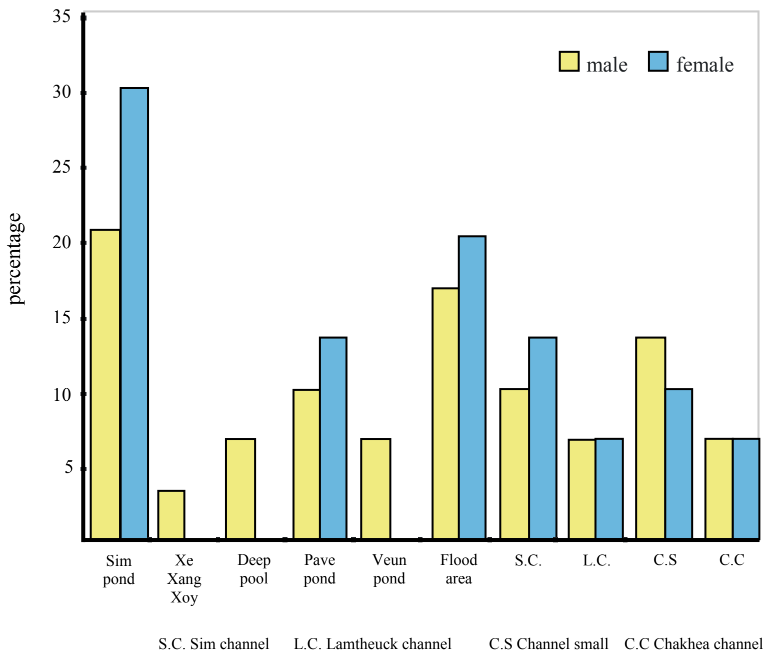


Figure 6b. Preferred fishing location Toum Nyae village ranked by gender

streams needs only inexpensive gear these habitats are available to all members of the community. To the poor and landless members of the village, a healthy fishery and floodplain environment is crucial to their household food security and income.

The type of fishing habitat may also determine the use of the fish and NTFP. Larger fish that are caught in the mainstream rivers are often sold to traders for income. Smaller fish as well as frogs, insects and wetland plants are often for consumption in the home. Rural communities will regard specific habitat as providing food for subsistence purposes or as opportunities to generate income (Table 6).

Ethnicity

Lao PDR's numerous ethnic groups may regard aquatic resources differently according to their own cultural values. The floodplains in upland areas are not extensive and ethnic groups living in these regions may not invest as much effort in fishing as do floodplain communities. However, despite having less of this habitat to fish in, upland villagers still rely on other aquatic animals such as fish and frogs to contribute a significant proportion of the protein in their diet (Figure 4).

In contrast, lowland ethnic groups living on the floodplains can access good fishing grounds and are quite skilled in capture fisheries. These communities exert greater effort on fishing and consume more fish (Table 8). Never the less many of the ethnic minorities living in these areas are very poor and are unable to buy the large-scale gear needed to fish in large rivers; poverty thus excludes some households from the fishery and they must rely instead on other NTFP.

Table 8. *Total quantity (kg/year) and habitat of important NTFP collected in Sombpoi village of Sanamxay district*

NTFP	**Habitat**	**Average household collection (kg/yr)**	**% of surveyed household collecting this NTFP**
Bamboo shoots	floodplain	238	100
Mushrooms	flood plain, evergreen forest, hills, dry forest	100	100
Fish	flood plain, rivers	704	88
Ke se resin	flood plain, dry forest	67	75
Frogs	flood plain, dry forest	27	63
Yang oil	flood plain, dry forest	158	63
Monitor lizard	flood plain, dry forest	25	50
Traditional medicines (*strychnos nux vomica*)	flood plain, dry forest	118	50
Turtle	flood plain	21	50
Snails	flood plain	49	38
Bong bark	flood plain	356	25
Traditional medicine	flood plain	29	25
Yang bong	flood plain, dry forest	463	25
Fruit	flood plain	40	13

Table 8 illustrates the importance of NTFP to households in Sombpoi village. This gives just a partial list of important NTFP collected by households showing the importance villagers consider items like fish, bamboo shoots, mushrooms and rattan to their way of life.

The target villages in Sanamsai district are on the floodplain of the Xe Kong, one of the largest tributaries of the Mekong and an important river system for capture fisheries. These villagers are active in the fishery, utilizing a multitude of gear in various habitats throughout the year, targeting a diverse range of aquatic organisms. Singhanouvong and Phoutavong (2002) estimate the average consumption of living aquatic resources per capita in the neighbouring Champassack province is currently 50 kg per anum. This is the average consumption across the entire province; lowland villages on the floodplain with access to an abundance of aquatic habitat are capable of harvesting a larger fish catch than average.

Floods and Capture Fisheries

The abundance of aquatic habitat on the floodplain supports a wealth of aquatic biodiversity targeted by local fishermen (see Appendix 2). Seasonal flooding plays an important role in generating and maintaining this biological diversity. This study, on the Xe Bang Hieng and Xe Kong rivers, shows the critical role of seasonal floods has on ecology of the floodplains and socio-economic benefits people living within the watershed derive from the diverse fauna and flora these habitats support.

The fishermen their families are fully attuned to the hydrologic cycle of these rivers. They can see that there are more fish in the wetlands and flooded forests than in the main river channels such as the Xe Xang Xoy and they know in years of large floods from the Xe Bang Hieng more fish migrate up the Xe Xang Xoy to the floodplains in their area. They understand the link between floods and capture fisheries. One fisherman explains, “if there is not a lot of water in the Xe Bang Hieng, there will not be fish here in our village.”

CONCLUSION

The study of the livelihoods of rural people in the wetlands of southern Lao PDR illustrates the close relationship between the hydrological cycle, the rich biodiversity of floodplain habitats and the way of life of the communities who depend on the abundance of fish and NTFP these habitats support.

However, it is a way of life that is increasingly under threat. Activities that originate outside of the influence of rural communities are challenging the riparian habitat that supports capture fisheries and NTFP production. Competition for the water resources of the Mekong Basin is putting this rich biodiversity at risk and thereby threatening the livelihoods of communities who rely on these natural resources. These threats stem from hydropower development, irrigated agriculture, flood mitigation and transportation infrastructure that may alter the hydrological cycle, as well as land conversion for agricultural development. Although development in these sectors of the economy is necessary to improve the living standards of rural people, these issues symbolise the growing conflict between urban and rural areas, rich and poor, landowners and landless people. Rural development strategies must incorporate preservation of these ecosystems into their plans since it is these natural resources that play such a significant role in the culture and livelihoods of the very people whose standard of living these strategies aim to improve.

While clearly, there are many legitimate uses of the water resources of the Mekong Basin, development plans must find a balance between the competing demands of hydropower, irrigated agriculture, and flood mitigation and preserving the aquatic biodiversity essential to the livelihoods of the rural poor. Seasonal floods are a natural phenomenon that supports the high fish production and rich biodiversity of the Mekong Basin. An integrated approach to river basin management must understand the relationship between hydrology, biodiversity, and rural livelihoods.

ACKNOWLEDGEMENTS

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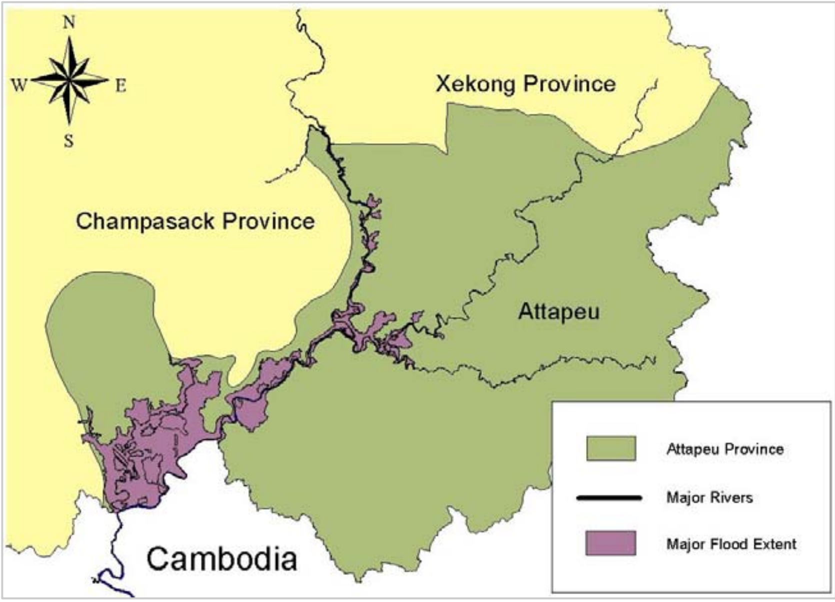
APPENDIX 1: Major flood extent, Attapeu province (Source: Mekong River Commission)



APPENDIX 2. List of fish species reported in three villages of Sonbouli district, Savannakhet province

Local name	Scientific name	Fishing season	Habitat
Pa kheng	*Anabas testudineus*	all year	Stay all area
Pa khea	*Bagarius yarrelli*	Sep-Nov	River
Pa vientfai	*Barbodes altus*	May-Jun	River
Pa khop	*Belodontichthys dinema*	Jul-Aug	River, deep pools
Pa khaman	*Catlocarpio siamensis*	Jul-Sep	River
Pa do	*Channa micropeltes*	all year	River, pond and flood
Pa khay	*Channa grandinosa*	all year	River, pond and flood
Pa khaotom	*Channa marulioides*	all year	Channel, weir
Pa khao tom	*Channa melasoma*	Apr-May	Stream, channel
Pa khor	*Channa striata*	all year	Stay all area
Pa tongdao	*Chitala ornata*	stay all area	Stay all area
Pa tasai	*Cirrhinus jullieni*	all year	River, pond, flood
Pa douck	*Clarias batrachus*	all year	River, pond
Pa chok	*Cyclocheilichthys enoplos*	Aug-Sep	River, pond, flood
Pa nai	*Cyprinus carpio*	all year	River, pond
Pa khealam	*Labiobarbus lineata*	all year	River, pond
Pa south	*Hampala dispar*	all year	River, pond, flood
Pa hoy	*Helicophagus waandersi*	Aug-Nov	River, pond and flood
Pa pak	*Hypsibarbus malcolmi*	all year	Stay all area
Pa pikkai	*Kryptopterus cryptopterus*	Sep-Oct	River, flood
Pa nang	*Micronema apogon*	Mar-May	River, pond, flood
Pa pia	*Morulius chrysophekadion*	Jun-Oct	River, pond, flood
Pa khayeng	*Mystus mysticetus*	all year	River, pond, flood
Pa koth	*Hemibagrus filamentus*	all year	River, pond, flood
Pa kheung	*Mystus wyckioides*	Sep-Nov	River, flood
Pa tong	*Notopterus notopterus*	all year	River, pond and flood
Pa seuam	*Ompok spp*	all year	River, pond, flood
Pa kapouck	*Osteochilus hasseltii*	all year	River, pond and flood
Pa nockkhao	*Osteochilus melanopleurus*	all year	River, pond
Pa bou	*Oxyeleotris marmorata*	all year	Stay all area
Payone	*Pangasius macronema*	Sep-Oct	River, pond and flood
Pa souay	*Pangasius bocourti*	Aug-Nov	River
Pa houakheng	*Poropuntius spp*	all year	River, pond, flood
Pa kar	*Pristolepis fasciata*	all year	Stay all area
Pa sakang	*Puntioplites falcifer*	all year	River, pond, flood
Pa koum	*Thynnichthys thynnoides*	all year	River, pond and flood
Pa nin	*Oreochromis nilotica*	Mar-Apr	River, pond
Pa salith	*Trichogaster pectoralis*	all year	Only pond
Pa khao	*Wallago attu*	Mar-June	River, pond, flood

ABSTRACT TITLES

A fish catch monitoring study using local fishers in Cambodia's rivers.
Chan Sokheng, Putrea Solyda, and Kent G. Hortle

Using local knowledge to inventory deep pools, an important habitat for river fish in Cambodia.
Chan Sokheng, Putrea Solyda, Sean Kin and Kent G. Hortle

Long-term monitoring of trends in catch of the *dai* fishery in the Tonle Sap River, Cambodia.
Hem Rady, Lieng Sopha, and Deap Loeung

A study of the fishery for a migratory species, Trey Kes (Kryptopterus apogon) in Stung Pursat, Tonle Sap Lake, Cambodia.
Phem Sea, Lieng Sopha, Sam Nuov and Kent G. Hortle

The *dai trey linh* fisheries in Tonle Touch River, Prey Veng Province.
Ngor Pengbun, Aun Sinath, Deap Leoung and Kent G. Hortle

Trial food consumption monitoring in Vinh Long Province, Viet Nam.
Phan Thanh Lam, Joe Garrison and Kent G. Hortle

Fish catch monitoring study using local fishers in the Mekong near Vientiane, Lao PDR.
Bouakhamvongsa Kong Pheng; Singhanouvong, Douangkham and Kent G. Hortle

Participatory catch monitoring in the Songkhram River, upper northeast Thailand.
Ubolratana Suntornratana

External and internal characteristics of Schilbeidae and Pangasiidae, found in the Mekong River in Nongkhai and Nakornphanom province.
Anupong Sanitchon

Implementation of co-management plan Choy Check reservoir, Kampong Cham Province, Cambodia.
Kaing Khim and Prach Sokunth

Facilitation of community fisheries management planning in former fishing lots #13, 14 and 15, Kampong Chhnang Province, Cambodia.
Yin Dara, Chuon Kim Chhea, Kaing Khin, Chap Piseth, Lieng Sareoun

Asset-based community fisheries development: an approach to strengthening management capacities in the Mekong Basin.

Thomas Augustinus, Wolf Hartmann, and Kesone Sayasane

Evaluation of giant freshwater prawn (*Macrobrachium rosenbergii* de Man) stocked in Huai Luang Reservoir, Udon Thani, Thailand.
Boontariga Siri, Benjamas Musikaew, and Napaporn Sriputtinibondh

The use of conservation volunteers in fisheries co-management: lessons learned from Nam Oon reservoir, Sakon Nakhorn, Thailand.
Sutee Sinunthorn, Wiratham Tongphan, Kanokporn Deeburee

Fishery status in public waters in Kanchanaburi Province, Thailand.
Amphorn Sakset

Status of using destructive gears in Lak lake, and Ea Soup and Buon Tria reservoirs.
Hoang Tuong Tien,Truong Ha Phuong,Phan Thuong Huy, and Nguyen Ngoc Vinh

Experiments on seed production and commercial culture of freshwater prawns (*Macrobrachium nippononense*).
Nguyen Quoc An, Phan Dinh Phuc,Le Thi Le Anh, Nguyen Thi Tu. Ly Ngoc Tuyen, Le Phuoc Binh

Artificial propagation of *Osteochilus melanopleura*.
Huynh Huu Ngai, Nguyen Minh Thanh, Pham Dinh Khoi, Thi Thanh Vinh, Dang Van Truong, Hoang Quang Bao, and Nguyen Thi Hong Van

Artificial propagation of greater black carp (*Labeo chrysophekadion*).
Thi Thanh Vinh, Nguyen Minh Thanh, Dang Van Truon, Hoang Quang Bao, Pham Dinh Khoi, and Nguyen Thi Hong Van

Biological characteristics, domestication and artificial propagation of beardless barb *(Cyclocheilichthys enoplos* Bleeker, 1850).
Pham Van Khanh, Dang Van Truong, Thi Thanh Vinh, Hoang Quang Bao, Nguyen Thi Hong Van, and Huynh Huu Ngai

Breeding of yellow mystus, *Hemibagrus filamentus* using brooders from Huai Luang Reservoir, Udornthani.

Decha Rodrarung, Noppanun Yoorong

A Study on the influence of characteristics of pond bottom and turbidity on yield of Lanchester's freshwater prawn.
Suriya Jongyotha, Wirat Jiwyam

Incubation of adhesive demersal eggs in plastic funnel.
Ratana Insiripong and Rungrudee Intachote

Rearing *Cirrhinus microlepis* (Sauvage, 1878) brood stock in earthen ponds.
Nongyao Manee, Aruna Maungmut and Prangthip Prasertwattana

Comparison of maturity of *Cirrhinus microlepis* brood stock from the wild and from hatchery condition.
Somboon, Phunsay Phitsanoukan, Voradet Duangboupha, Khunbualom Vonghachack and Vilath Mankhong

The comparison of growth performances of *Osphronemus exodon* with different stocking densities in cages.
Somboon, Khantheo Keodara and Nantha Phandavong

MRC Fisheries Programme language and communication coaching programme
Terry Clayton

Community-based natural resource management research project in Lower Mekong Basin, southern Champassack Province.
Thongchanh Sengsourivong

Dominant species in Cambodian commercial fisheries and the issue of names fishes.
Eric Baran and Chheng Phen

AGENDA

26 November 2003		
All	Registration	08:00 - 08:30
	Opening ceremony	
Chris Barlow	Welcome address	08:30 - 08:35
Governor Champassack	Opening remarks	08:35 - 08:40
	Poster presentations	
Mr. Wolf Hartmann	Introduction	08:40 - 08:45
All	Presentation of posters. Author(s) will be available to discuss (see appendix for titles)	08:45 - 10:00
	Coffee break	09:30 - 10:00
	Fisheries assessment Chairperson: Mr. Xaypladeth Choulamany, Director of LARReC, Lao PDR	
	Chairperson's introductory remarks	10:00 - 10:05
1 Troeun Roth	The yield of fish and other aquatic animals from rice fields in Battambang province, near the Tonle Sap Lake. Troeun Roth, Lieng Sopha, Sam Nuov and Kent G. Hortle	10:05 - 10:25
2 Apichart Termvidchakorn	Fish larvae of the Lower Songkham River Basin. Dr. Apichart Termvidchakorn	10:25 - 10:45
3 Vu Vi An	A fish catch monitoring study in the Mekong Delta, Viet Nam. Vu Vi An, Doan Van Tien and Kent G. Hortle	10:45 - 11:05
4 Khay Dany	Monitoring fish sales at Phnom Penh's retail markets. Dany Khay and Kent G. Hortle	11:05 - 11:25
5 Chea Tharith	Drift of fish juveniles and larvae and invertebrates over 24-hour periods in the Mekong River at Phnom Penh, Cambodia. Chea Tharith, Bun Racy, Em Samy, Thac Phanara and Kent G. Hortle	11:25 – 11:50
	Lunch	11:50 – 13:15
6 Wirathum Thongpun	Fish ecology and catch in the Songkhram River described by stationary trawl net fishery. Wirathum Thongpun, Siranee Ngoichansri, Boonsong Sricharoendham and Wirawan Rayan	13:15 - 13:35
7 Tiwarat Thalerngkieatleela	Taxonomy of freshwater prawn of *Kud Ting Yai*. Nong Khai province, northeast Thailand. Tiwarat Thalerngkieatleela	13:35 – 13:55
	Film: "Big fish - small fry: globalisation of Lake Victoria fisheries". Introduction by Mr. Wolf Hartmann, Component coordinator, MRRF	13:55 – 14:20
	Coffee break	14:20 – 14:40
	Mini workshop Introduction by Khamtanh Vatthanatham The MRC has initiated discussions with Danida regarding a second phase of the Fisheries Programme to begin after July 2005. In this mini-workshop, we would like counterpart staff to identify which issues they think should be covered in Phase 2. We expect country groups to work together to identify: major research and development topics to be addressed in FP Phase 2; and any personnel or administrative issues to be considered in planning a FP Phase 2	14:40 – 17:00
	Reception dinner at Pakse Hotel	19:00 – 22:00

AGENDA (cont.)

27 November 2003		
Group representative	Mini workshop group presentations	08:15 – 09:00
	Fisheries management Chairperson: Mr. Sam Nuov, Deputy Director, DoF, Cambodia	
8 Kanokporn Deeburee	'Women' are more than a group: women's participation in fisheries resources management, Thailand. Kanokporn Deeburee	09:00 - 09:20
9 Kesone Sayasane	Community and intra-household dynamics of food security in Lao PDR, Nam Houm reservoir, Lao PDR. Kesone Sayasane and Thomas Augustinus	09:20 - 09:40
10 Kaing Khim	Participation in fisheries co-management, Kampong Cham and Kandal Province, Cambodia. Kaing Khim; Prach Sokunthy; Soun Southea	09:40 - 10:10
	Coffee Break	10:10 - 10:30
11 Ouk Vibol	Stock enhancement as a major element of reservoir fisheries management. Ouk Vibol, Kaing Khim, Heng Samay, Lim Ngeth	10:30 - 10:50
12 Chanthone Photithay	Seasonally flooded habitat and non-timber forest products: supporting biodiversity and local livelihoods in Southern Lao PDR Roger Mollot,Chanthone Photithay	10:50 - 11:10
13 Malasri Khumsri	Possible causes of decreased catch in Nam Oon Reservoir, Thailand. Malasri Khumsri;Narongsak Sirichaipan; Wason Taruwan; Jaruk Nachaiperm	11:10 - 11:30
14 Phan Tuong Huy	Inland fisheries co-management: what next for Viet Nam? Truong Ha Phuong, John Sollows, Phan Tuong Huy	11:30 - 11:50
	Conclusion - Chairperson	11:50 - 11:55
	Lunch	11:55 - 13:20
	Aquaculture Chairperson: Mr. Naruepon Sukumasavin, DoF, Thailand	
15 Hor Chanlim	Comparison of the growth and total production of indigenous fish species using different stocking composition rates in grow-out polyculture system. Hor Chanlim, Ouk Vibol, Hang Savin and Lim Ngeth	13:20 - 13:40
16 Latsmy Phounevisouk	Survival, feeding and growth of juvenile Mekong prawn (*Macrobrachium* sp.) in aquariums, hapas and pond environments	13:40 - 14:00
17 Unnop Imsilp	Mobile hatchery: a new tool for fisheries extension. Unnop Imsilp, Sombut Singsee, Pin Polchai, Thanjai Assonjohn and Naruepon Sukumasavin	14:00 - 14:20
18 Somphouthone Phimmachack	A survey on aquatic animal health problems affecting small-scale aquaculture production and fisheries in Lao PDR. Somphouthone Phimmachack, Saleumphone Chanthavong	14:20 - 14:40
	Coffee break	14:40 - 15:00
	Aquaculture Chairperson: Dr. Nguyen Van Hao, Director of RIA.2, Viet Nam	
19 Chavalith Vidthayanon	Non-fish biodiversity as food security in Mekong Basinwide. Chavalith Vidthayanon, Apichart Termvidchakorn	15:00 - 15:20
20 Bounsong Vongvichit	Raising frog in cages using different feeds. Bounsong Vongvichit	15:20 - 15:40
21 Sombut Singsee	Effect of various types of hormone on induced ovulation of snail eater (*Pangasius conchophilus* Roberts & Vidthayanon, 1991). Sombut Singsee, Unnop Imsilp, Pin	15:40 - 16:00

AGENDA (cont.)

28th November 2003: Field Trip	
Field trip programme	Time
Departure from Pakse Hotel	08:15
Visit to KM 8 Fisheries Station and demonstration of AIMS activities	08:40 - 09:30
Visit to Khone Falls and lunch	11:30 - 13:00
Visit to Ban Hat Fisheries sub-centre, LARReC	13:30 - 15:00
Arrive Pakse Hotel	17:00

LIST OF PARTICIPANTS

Guest of honour

H. E. Thongvang Sihachack
Central Party Committee Member
Governor of Campassack Province
Pakse City
Champassack Province
Lao PDR

Assessment of Mekong Capture Fisheries Component

Mr. Kent Hortle
Component Coordinator
c/o Department of Fisheries
186 Norodom Blvd
Phnom Penh, Cambodia
Tel: 855 (0)23 211 494
Fax: 855 (0)23 211 494
Email: bigcatch@bigpond.com.kh

Cambodia

Mr. Lieng Sopha
National Component Coordinator
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23) 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

Mr. Troeung Rot
Provincial Supervisor
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

Mr. Hem Rady
Counterpart
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Fax: 855 (0)23 221 485
Mobile: 855 (0)12-936 070
Email: hemrady@yahoo.com

Mr. Aun Sinath
Provincial Supervisor
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel/Fax: 855 (0)23 427 048
Email: aoun_sinath@yahoo.com

Mr. Chan Sok Heng
Counterpart, Biologist
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

Mr. Putrea Solida
Socio Economist
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

Ms. Khay Dany
Socio Economist
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

Mr. Deap Loeung
Project Counterpart
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel/Fax: 855 (0)23 427 048
Mobile: 855 (0)16-828 820
Email: ifric@online.com.kh

Mr. Phem Sea
Provincial Supervisor
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

Mr. Chea Tharith
PhD Candidate, Counterpart
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Fax: 855 (0)23 221 485
Mobile: 855 (0)11 970 587
Email: ifric@online.com.kh

Mr. Sean Kin
Provincial Counterpart
c/o Department of Fisheries
186 Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 221 486
Fax: 855 (0)23 221 485
Email: ifric@online.com.kh

LIST OF PARTICIPANTS

Lao PDR

Mr. Doungkham Singhanouvong
Acting National Component Director
P.O. Box 9108
Vientiane, Lao PDR
Tel: (856-21) 223 436

Mr. Kongpheng Bouakhamvongsa
Counterpart
P.O. Box 9108
Vientiane, Lao PDR
Tel: (856-21) 223 610

Mr. Sisomut Sichanh
P.O. Box 9108
Vientiane, Lao PDR
Tel: (856-21) 215-015
Fax: (856-21) 214 855
Email: larrec.capture@laopdr.com

Thailand

Mrs. Renu Wongsongsarn
National Component Director
Director, Udonthani Inland Fisheries Research and Development Centre
100 Supakij Road, Muang District; Udonthani, Thailand
Tel: 66-42-221 167
Fax: 66-42
Email: udon_fish@yahoo.com

Ms. Siranee Ngoychansri
Fish Biologist
Sakolnakorn Inland Fisheries Research and Development Centre
Mueng District, Sakolnakorn Province Thailand 43130
Tel: 66-1042716220
Fax: 66-1042716220
Email: siranee_ngoychansri@yahoo.com

Mrs. Wirawan Rayan
Fish Biologist
Sakolnakorn Inland Fisheries Research and Development Centre
Mueng District, Sakolnakorn Province, Thailand 43130
Tel: 66-1042716220
Fax: 66-1042716220
Email: wirawan_rayan@hotmail.com

Ms. Tiwarat Thalerngkietleela
Fish biologist
Nongkhai Inland Fisheries Research and Development Centre
Srichiengmai District, Nongkhai Province, Thailand 43130
Tel: 66-1042452050
Fax: 66-1042451195
Email: nkfish2000@yahoo.com; nkfish2000@hotmail.com

Mr. Anupong Sanitchon
Fish Biologist
Nongkhai Inland Fisheries Reserch and Development Centre
Srichiengmai District, Nongkhai Province, Thailand 43130
Tell: 66-1042452050
Fax: 66-1042451195
Email: dong_kku@hotmail.com

Ms. Ubolratana Suntonratana
PhD student
c/o. Inland Fisheries Research and Development Bureau
Department of Fisheries
Bangkok, Thailand
Email: ubolrana@hotmail.com

Mr. Aphichart Temvidchakorn
Senior Fisheries Biologist
c/o. Inland Fisheries Research and Development Bureau
Department of Fisheries
Bangkok, Thailand

Viet Nam

Mr. Nguyen Thanh Tung
National Component Director
c/o Research Institute for Aquaculture No. 2, 116 Nguyen Dinh Chieu St.
Ho Chi Minh City, Viet Nam
Tel: ((84-8) 823 0676
Fax: (84-8) 822 6807
Email: amfcvn@hcm.fpt.vn

Mr. Vu Vi An
Biologist
c/o Research Institute for Aquaculture No. 2, 116 Nguyen Dinh Chieu St.
Ho Chi Minh City, Viet Nam
Tel: ((84-8) 823 0676
Fax: (84-8) 822 6807
Email: amfcvn@hcm.fpt.vn

Mrs. Tran Kim Hang
Socio Economist
c/o Research Institute for Aquaculture
No. 2, 116 Nguyen Dinh Chieu St.
Ho Chi Minh City, Viet Nam
Tel: ((84-8) 823 0676
Fax: (84-8) 822 6807
Email: amfcvn@hcm.fpt.vn

Mr. Phan Thanh Lam
Socio Economist
c/o Research Institute for Aquaculture No. 2,
116 Nguyen Dinh Chieu St.
Ho Chi Minh City, Viet Nam
Tel: ((84-8) 823 0676
Fax: (84-8) 822 6807
Email: amfcvn@hcm.fpt.vn

Mr. Doan Van Tien
Biologist
c/o Research Institute for Aquaculture
No. 2, 116 Nguyen Dinh Chieu St.
Ho Chi Minh City, Viet Nam
Tel: ((84-8) 823 0676
Fax: (84-8) 822 6807
Email: amfcvn@hcm.fpt.vn

Aquaculture of Indigenous Mekong Fish Species Component

Mr. Niklas Mattson
Component Coordinator
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-610
Email: mattson@laonet.net

Cambodia

Mr. Ouk Vibol
National Component Director
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 216 244
Email: aims1@online.com.kh

Mr. Lim Ngeth
Field Coordinator (FC)
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 216 244
Email: aims1@online.com.kh

Mr. Hang Savin
Technical Officer
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 219 857
Fax: 855 (0)23 428 047
Email: aims2@online.com.kh

Lao PDR

Mr. Lieng Khamsivilay
National Component Director
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 723 436
Fax: (856-21) 22 3610
Email: larrec@laopdr.com

Mr. Somboon
Deputy National Component Director
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 723436
Fax: (856-21) 22 3610
Email: larrec.aqua@laopdr.com

Mr. Boonthong Sapakdy
DLF Coordinator
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223 436
Fax: (856-21) 22 3610
Email: eulaodlf.laotel.com

Ms. Somphouthone Phimmachak
LARReC,
P.O. Box 9108
Vientiane, Lao PDR
Tel: 856-21-215 015
Fax: 856-21-214 855
Email: larrec@laopdr.com

Ms. Latsamy Phounevisouk
Biologist
LARReC, P.O. Box 9108
Vientiane, Lao PDR
Tel: 856-21-215 015
Fax: 856-21-214 855
Email: larrec@laopdr.com

Mr. Bounsong Vongvichith
LARReC,
P.O. Box 9108
Vientiane, Lao PDR
Tel: 856-21-215 015
Fax: 856-21-214 855
Email: larrec.aqua@laopdr.com

Mr. Khantheo Keodala
Chief of Nam Houm Hatchery Station, AIMS
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223436
Fax: (856-21) 22 3610

Mr. Pany Sourignamath
Nam Luang Hatchery Station, AIMS
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 723436
Fax: (856-21) 22 3610

Mr. Phounsay Phitsanoukam
Chief of KM8 Hatchery Station, AIMS
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 723436
Fax: (856-21) 22 3610

Thailand

Mr. Charoen Udomkarn
National Component Director
Yasothon Inland Fishereis Research and Development Centre
Yasothon IFRDC,
Mahachanachai yasothon 35130
DoF, Thailand
Tel: 66-45-738 355
Fax: 66-45-738 354
Email: yasofish@yahoo.com

Mr. Sombut Singsee
Khon Kaen
Thailand
Tel: (66-043) 336 024
Fax: (66-043) 242 232
Email: aims@ji-net.com

Mr. Unnop Imsilp
Nakorn Phanom

Mr. Decha Rodrarung
Udornthani Inland Fisheries Reasearch and Development Centre
Supakitijanya Rd, Muang District, Udornthani Province, Thailand
Tel: (66-42) 221 167
Fax: (66-42) 23 223

Mr. Suriya Jongyotha
Counterpart
Khon Kaen Inland Fisheries Research and Development Centre
Khon Kaen, Thailand
Tel: 66-43-246 654
Fax: 66-43-242 232
Email: suriyakai@yahaoo.com

Ms. Pongsai Chansri
Surian Inland Fisheries Research and Development Centre
Muang District, Surin Province,
Thailand
Tel: 66-44-511 335
Fax: 66-44-518 866
Email: pongs55@hotmail.com

Ms. Ratana Insiripong
Fish Biologist
Inland Fisheries Research and Development Centre
Khon Kaen Province 400000
Thailand
Tel: 66-43-246 654
Fax: 66-43-242 232
Email: insratana@yahoo.com

Ms. Nongyao Manee
Yasothon Inland Fishereis Research and Development Centre
Yasothon IFRDC, Mahachanachai yasothon 35130
DoF, Thailand
Tel: 66-45-738 355
Fax: 66-45-738 354
Email: nongyoam@yahoo.com

Dr. Chavalit Vidthayanon
Taxonomist/Senior Fisheries Biologist
Freshwater Biodiversity Unit
Inland Fisheries Research and Development Bureau
Kaset-Klang, Chatuchak;
Bangkok 10900, Thailand
Tel: 66-2-9406 538-9
Email: chavaliv@fisheries.go.th
chavaliv@hotmail.com

Ms. Prangthip Prasertwattana
Yasothon Inland Fishereis Research and Development Centre
Yasothon IFRDC
Mahachanachai yasothon 35130
DoF, Thailand
Tel: 66-45-738 355
Fax: 66-45-738 354
Email: nongyoam@yahoo.com

Viet Nam

Mr. Nguyen Minh Thanh
National Component Director
116 Nguyen Dinh Chieu, District 1
Ho Chi Minh City, Viet Nam
Tel: (84-8) 823 0676
Fax: (84-8) 822 6807
Email: mrccaibe@hcm.fpt.vn

Mr. Hoang Quang Bao
Fish Biologist
116 Nguyen Dinh Chieu St., District 1
Ho Chi Minh City, Viet Nam
Tel: (84-8) 823 0676
Fax: (84-8) 822 6807
Email: mrccaibe@hcm.fpt.vn

Mr. Thi Thanh Vinh
Fish Biologist
116 Nguyen Dinh Chieu St., District 1
Ho Chi Minh City, Viet Nam
Tel: (84-8) 823 0676
Fax: (84-8) 822 6807
Email: mrccaibe@hcm.fpt.vn

Mr. Huynh Huu Ngai
116 Nguyen Dinh Chieu St., District 1
Ho Chi Minh City, Viet Nam
Tel: (84-8) 823 0676
Fax: (84-8) 822 6807
Email: mrccaibe@hcm.fpt.vn

Management of River and Reservoir Fisheries Component

Mr. Wolf D. Hartmann
Component Coordinator
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-610
Email: merops@laopdr.com

Mr. Thomas Augustinus
JPO
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-610
Email: thomas@laopdr.com

Cambodia

Ms. Kaing Khim
National Component Director
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Fax: 855 (0)23 210 154
Mobile: 855 (0)12 506 199
Email: kaingkhim@online.com.kh

Ms. Sung Sokhunthea
Counterpart
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Tel: 855 (0)23 213 026
Mobile: 855 (0)12 668 310
Fax: 855 (0)23 210 154

Mr. Lieng Sareoun
Counterpart
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Fax: 855 (0)23 210 154

Mr. Soun Sothea
Counterpart
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Mobile: 855 (0)16 890 555
Fax: 855 (0)23 210 154

Ms. Prach Sokunthy
Counterpart
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Mobile: 855 (0)12 733 932
Fax: 855 (0)23 210 154

Mr. Chhuon Kim Chhea
Natural Resource Planer
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Mobile: 855 (0)16 886 509
Fax: 855 (0)23 210 154
Email: cfdo@camnet.com.kh

Mr. Yin Dara
Counterpart
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Fax: 855 (0)23 210 154
Mobile: 855 (0)12 895 403
Email: cfdo@camnet.com.kh

Lao PDR

Mr. Sommano Phounsavath
National Component Director
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-436
Email: sommano@laopdr.com

Mr. Khamla Phommachan
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-436
Email: fip@laopdr.com

Mrs. Kosene Sayasane
Natural Resource Planner
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-436
Email: ksayasane@laopdr.com

Mr. Saleumphone Chantavong
P.O. Box 7035
Vientiane, Lao PDR
Tel: (856-21) 223-436
Fax: (856-21) 223-436
Email: fip@laopdr.com

Thailand

Mr. Naruepon Sukhumasavin
National Programme Coordinator
Inland Fisheries Research and Development Bureau
Department of Fisheries
Chatuchak, Bangkok, Thailand, 10900
Tel: 66-2-579 7231
Fax: 66-2-940 5622
Email: naruepos@fisheries.go.th

Ms. Kanokporn Deeburee
Natural Resources Planner
100 Suppakitchany Rd.,
Tambon Hmarkkaeng, Muang District,
Udonthani 41000
Thailand
Tel: 66-42-213 020
Fax: 66-42-249 689
Email: thaimrf@ji-net.com

Ms. Boontariga Siri
Fish Biologist
Udonthani Inland Fisheries & Development Centre
Suphakitjanya road, Muang District, Udonthani, Thailand
Tel: 66-42-221 167
Fax: 66-42-223 233
Email: boontariga_siri@yahoo.com
boontariga_siri@hotmail.com

Mr. Amphorn Sakset
Fish Biologist
Department of Fisheries
Kanchanaburi Inland Fisheries Research and Development Centre
Tha-Maung District, Kanchanaburi Province, Thailand 70110
Tel: 66-34-611 144
Fax: 66-34-611 144
Email: phornfresh@hotmail.com

Mr. Sutee Sinunthorn
Chief of Nam Oon Patrolling Unit
Nam Oon Inland Fisheries Patrolling Unit
Tambon Rae, Pangkhorn District;
Sakon Nakhorn 47160, Thailand
Tel/Fax: 66-42- 981 171

Mr. Wiratham Tongphan
Director of Sakon Nakhorn Inland Fisheries Development Centre
Muang District; Sakon Nakhorn
Thailand 47000
Tel: 66-42-711 447
Fax: 66-42-716 220
Email: wirawan_rayan@hotmail.com

Ms. Malasri Khumsri
Fish Biologist
Amantcharoen Inland Fisheries Station Maung District,
Amantcharoen Province Thailand
Tel: 66-45-517 095
Fax: 66-45-517 095
Email: malasrik@hotmail.com

Viet Nam

Mr. Phan Dinh Phuc
PhD Candidate
180 Phan Chu Trinh St., Ban Me Thuot, Dac Lak Province,
Viet Nam
Tel: 84-50-953 889
Fax: 84-50-953 870
Email: phucdinhphan@yahoo.com

Mr. Phan Thuong Huy
Senior Scientist
180 Phan Chu Trinh St.
Ban Me Thuot City, Dac Lak Province Viet Nam
Tel: 84-50-953 889
Fax: 84-50-953 870
Email:thuonghuy@yahoo.com

Mr. Hoang Trong Tien
Junior Biologist
180 Phan Chu Trinh St.
Ban Me Thuot City
Dac Lak Province, Viet Nam
Tel: 84-50-953 889
Fax: 84-50-953 870
Email: leanhbmt@yahoo.com

Fisheries Line Agencies

Department of fisheries, Cambodia

Mr. Sam Nuov
Deputy Director
Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Mobile: 855 (0)12 853 747
Fax: 855 (0)23 211 485
Email: nuov@mobitel.com.kh

Mr. Mong Leng
Chief of Planning, Accounting and International Cooperation
TAB member
c/o Department of Fisheries
186 Preah Norodom Blvd.
Phnom Penh, Cambodia
Mobile: 855 (0)12-624 803
Fax: 855 (0)23 215 470
Email: catfish@camnet.com.kh

Line Agencies for Fisheries, Lao PDR

Mr. Soulivanthong Kingkeo
Deputy Director,
National Agriculture and Forestry Research Institue (NAFRI)
Vientiane, Lao PDR
Tel: (856-21) 732 047
Fax.: (856-21) 732 047
Email:

Mr. Mahanakhone Souriya
Deputy Director
Department of Livestock and Fisheries
Vientiane, Lao PDR
Tel: 856-21-416932
Fax: 856-21-415674
Email: eulaodlf@laotel.com

Mr. Xaypladeth Choulamany
Director, LARReC
Ministry of Agriculture and Forestry
P.O. Box 9108, Vientiane, Lao PDR
Tel: (856-21) 215-015, Fax: (856-21) 214 855, Email: Larrec@laonet.net

Mr. Prachith Noraseng
Deputy Director
Provincial Agriculture and Forestry Office
Champassack Province, Pakse, Lao PDR
Fax: (856-31) 212 259

Department of Fisheries, Thailand

Mr. Wattana Leelapatra
Fishing Information Technology Centre
Department of Fisheries
Kasetsart Campus, Jatuchak, Bangkok 10900, Thailand
Tel: 66-2-558 0190
Fax: 66-2-558 0190
Email: it@dof.thaigov.net

Mr. Keeree Kohanantakul
Inland Fisheries Research and Development Bureau
Department of Fisheries
Kasetsart Campus, Jatuchak, Bangkok 10900, Thailand
Tel: 66-2-579 2151
Fax: 66-2-579 6439
Email: freshwater@dof.thaigov.net

Mr. Sontipan Pasugdee
Director, Inland Aquaenltuer Research Institure Bureau
Department of Fisheries
Kasetsart Campus, Jatuchak, Bangkok 10900, Thailand
Tel: 66-3-536 6745
Fax: 66-3-536 6882

Ministry of Fisheries, Viet Nam

Mr. Nguyen Xuan Ly
Dierctor, Department of Science and Technology, Ministry of Fisheries
10 Nguyen Cong Hoan St.
Badinh District Hanoi, Viet Nam
Tel: 84-4-835 4516
Fax: 84-4-771 6702
Email: khcn@mofi.gov.vn

Mr. Nguyen Viet Manh
Deputy Director, Department of International Cooperation
Ministry of Fisheries
10 Nguyen Cong Hoan St.
Badinh District, Hanoi, Viet Nam
Tel: (84-4) 832-5608
Fax: (84-4) 832-702
Email: htqt@mofi.gov.vn

Mr. Nguyen Van Hao
National Programme Coordinator
Acting Director, RIA No. 2
116 Nguyen Dinh Chieu Street, District 1
Ho Chi Minh City, Viet Nam
Tel: (84-8) 823 0676
Fax: (84-8) 822-6807
Email: haoria2@hcm.vnn.vn

National Mekong Committees

Mr. So Sophort
Deputy Director of Projects Department
Cambodia National Mekong Committee
23 Mao Tse Toung Road, P.O. Box 2214 Phnom Penh, Cambodia
Tel/Fax: (855-23) 218 727
Email: sophort@cnmc.gov.kh

Cambodia National Mekong Committee

Mr. So Sophort
Deputy Director of Projects Department
Cambodia National Mekong Committee
23 Mao Tse Toung Road, P.O. Box 2214 Phnom Penh, Cambodia
Tel/Fax: (855-23) 218 727
Email: sophort@cnmc.gov.kh

Lao PDR National Mekong Committee Secretariat

Mr. Sourasay Phoumavong
Deputy Director General
Lao National Mekong Committee Secretariat
Prime Minister's Office
Vientiane, Lao PDR
Tel/Fax: (856-21) 216984
Email: sourasay@yahoo.com

Mr. Chanthachith Amphaychith
Lao National Mekong Committee
Prime Minister's Office
Tel/Fax: (856-21) 216984

Thai National Mekong Committee

Ms. Surat Thawachwiboon
Senior Policy and Planning Analyst
Department of Water Resources Bureau of International Cooperation
3/12 U-Thong Road, Dusit, Bangkok 10300,Thailand
Tel: 66-2-244 8028
Fax: 66-2-243 0036
Email: surat@tnmcmekong.org

Vietnam National Mekong Committee

Mr. Le Thanh Bac
Programme Officer
Viet Nam National Mekong Committee
23 Hang Tre St., Hanoi, Viet Nam
Tel No.: (84-4) 825-4785
Fax No.: (84-4) 825-6929
Email: vnmc@hn.vnn.vn

External guests

DANIDA

Mr. Jørgen G. Jensen
Senior Technical Adviser-Fisheries
Danida BFT.1, Ministry of Foreign Affairs
DK-1448 Copenhagen, Denmark
Tel: 45-3-3920 218
Fax: 45-3-3920 790
Email: jojens@um.dk

FAO

Dr. Derek Staples
Senior Fishery Officer
Food and Agriculture Oganisation of the United Nations,
Regional Officer for Asia and the Pacific,
39 Phra Athit Road, Bangkok 10200, Thailand
Tel: 66-2-697 4119
Fax: 66-2-697 445
Email: derek.staples@fao.org

NACA

Mr. Simon Wilkinson
Communications Manager and Editor of Aquaculture Asia,
NACA Secretariat
Bangkok, Thailand
Tel: 66-2-561 1728 ext. 113
Fax: 66-2-561 1727
Email: simon.wilkinson@enaca.org

OXFAM US

Ms. Rebecca Kinakin
MLI Coordinator, Mekong Learning Initiative-Oxfam America
East Asia Regional Office,
#41, ST 352,
P.O. Box 883, Phnom Penh, Cambodia
Tel/Fax: 855-23-210 357
Email: rkinakin@online.com.kh

Mr. Thongchanh Sengsourivong
Director
Pakse Southern Agricultural College
Lao PDR (MLI partner)
Tel: 856-21-212 258

World Fish Centre

Dr. Danny Israel
Project Scientist
World Fish Centre
186 Norodom Blvd.
P.O. Box 582, Phnom Penh, Cambodia
Tel/fax: 855-23-993 558
Email: d.israel@cgiar.org

WWF

Mr. Roger Mollot
Freshwater Officer
WWF Lao Programme
P.O. Box 7871, Vientiane, Lao PDR
Tel: (856 21) 216 080
Fax: (856 21) 251 883
email: roger.mollot@wwflaos.org

Mr. Chanthone Photithay
WWF Lao Programme
P.O. Box 7871
Vientiane
Lao PDR
Tel: (856 21) 216 080
Fax: (856 21) 251 883

Mekong River Commission Secretariat, Fisheries Programme

Dr. Chris Barlow
Programme Manager, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong, P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720 979 ext. 4013
Fax: 855 (0)23 720972
Email : barlow@mrcmekong.org

Mr. Khamtanh Vatthanatham
Programme Officer, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong, P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
E-mail: khamtanh@mrcmekong.org

Dr. Nguyen Quoc An
Programme Officer, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong, P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
Email: an@mrcmekong.org

Mr. Sophat Chun
ROS, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong, P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979,
Fax: 855(0)23 720972
Email: chunsophat@mrcmekong.org

Ms. Nguyen Thi Bich
ROS, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong; P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
Email: bich@mrcmekong.org

Ms. Arounna Vongsakhamphouy
Junior Riparian Professional (JRP, Lao)
Mekong River Commission Secretariat
364 M.V. Preah Monivong; P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
Email: arounna@mrcmekong.org

Mr. Sokhom Ngauv
Secretary, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong, P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979 ext. 4010
Fax: 855 (0)23 720972
Email: sokhom@mrcmekong.org

Ms. Dongdavanh Sibounthong
ROS, Fisheries Programme
Mekong River Commission Secretariat
364 M.V. Preah Monivong; P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
Email: dongdavanh@mrcmekong.org

Mr. Thim Ly
Junior Riparian Professional (JRP, Cambodian)
Mekong River Commission Secretariat
364 M.V. Preah Monivong; P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
Email: thimly@mrcmekong.org

Ms. Worawan Sukraroek
Junior Riparian Professional (JRP, Thai)
Mekong River Commission Secretariat
364 M.V. Preah Monivong; P.O. Box 1112 Phnom Penh, Cambodia
Tel: 855 (0)23 720979
Fax: 855 (0)23 720972
Email: worawan@mrcmekong.org

Consultants

Mr. Terry Clayton
Consultant
Email: clayton@loxinfo.co.th

Mr. John Valbo Jorgensen

Mr. Sten Sverdrup Jensen
IFReDI and LARReC consultant
Email: ssj@ifm.dk