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Mekong River Commission

Hydro-acoustic Survey of Deep Pools in the Mekong River in Southern Lao PDR and Northern Cambodia

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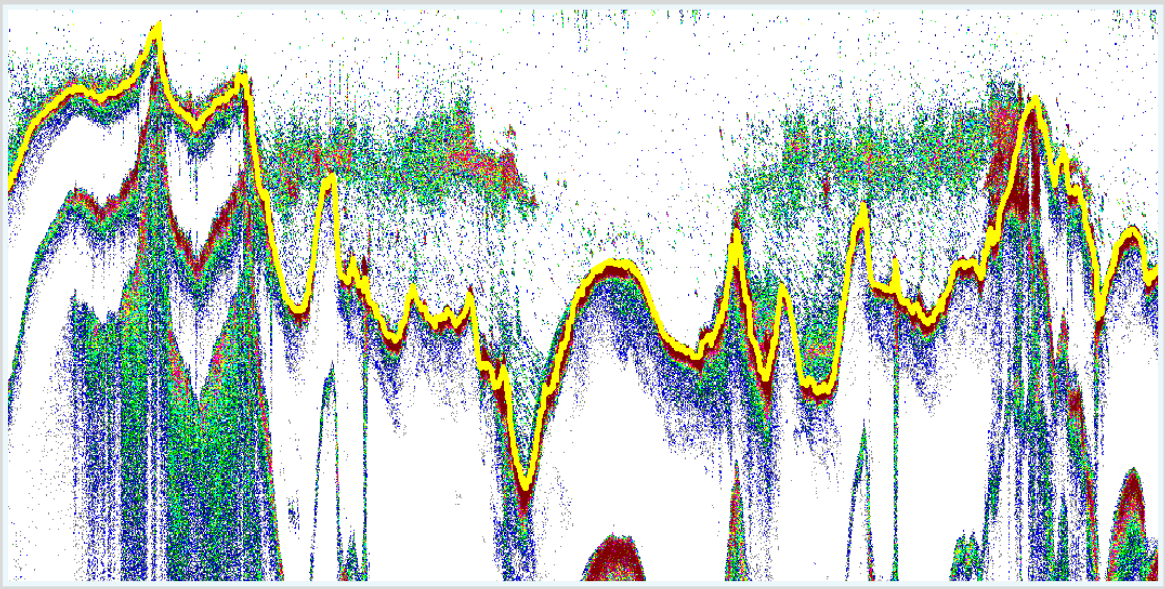

Meeting the Needs, Keeping the Balance

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Acknowledgments

This Technical Paper documents the results of a joint LARReC/IFReDI research project that was supported financially by the EU (INCO DEV) KNOWFISH PROJECT, the National Aquatic Research Institute (NARI) and the MRC Fisheries Programme. The University of Bergen, Norway, provided the hydro-acoustic equipment used in the pilot survey without cost. NARI provided the hydro-acoustic and other equipment used in follow-up survey that is described in this report. The Institute for Fisheries Management and Costal Community Development (IFM), Denmark, and Dr Sten Sverdrup-Jensen, Chief Technical Adviser, NARI, oversaw and managed the project. The authors wish to thank Dr Chavalit Vidthayanon, WWF Thailand, for his advice on aspects of fish behaviour and fish biology.

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Summary

Deep pools in the mainstream of Mekong are important habitats in the life cycle of many commercially important fish. In addition to supporting a sedentary fauna of their own, the pools offer a dry season refuge for many of the migratory species that provide the recruitment for the large-scale fisheries further downstream. Despite their commercial importance, little detail is known of the ecology and biology of these habitats and the fauna they support. Much of what is known comes from interviews with local fishers and surveys of their catches. These provide a lot of information about the type and number of fish living in the pools, but little data on the distribution of fish in the pools, especially data on the micro-habitats preferred by many fish.

Hydro-acoustic surveys, which work on the same principles as sonar, provide a means of acquiring spacial data to complement the information gathered from fishers. It is a relatively untried technique in tropical rivers such as the Mekong. However, a pilot survey conducted in the Siphandone area of southern Lao PDR during early 2003 demonstrated the method worked well in pools greater than 10 m deep and in conditions of laminar flow.

This paper documents the results of a follow-up survey conducted by IFReDI (Inland Fisheries Research and Development Institute, Phnom Penh), LARReC (Living Aquatic Resources Research Centre, Vientiane) and the University of Bergen, Norway, in late 2003 and early 2004. The survey, which was planned and located based on information provided by local fishers, acquired hydro-acoustic data from 69 deep pools located in the Mekong River in Stung Treng province, northern Cambodia and Champassack province, southern Lao PDR. During the same period, catch per unit effort (CPUE) surveys were conducted with Lao fishers who target deep pools.

Echograms produced from the hydro-acoustic data clearly showed individual fish and shoals of fish both in the open water and congregating near topographic features such as crevices and steep banks in the riverbed. Statistical aggregation of data from all the pools was used to map biomass and fish density. This revealed that fishes showed preference for particular water depths. In general, both biomass and fish density increase until a depth of about 30 m below which these measures fall-off reaching a minimum at around 50 to 60 m. At greater depths, both biomass and fish density increase once more and there is some evidence of larger fish (greater than 1-2 m) living in the deepest pools. The data also showed that while biomass was greater during the wet season, fish density was lower, suggesting more larger fish live in the pools during these times. Other observations, such as the greater biomass and fish density in Cambodian pools than in the pools in Lao PDR, remain unexplained, but probably relate to the preference of particular species (or communities of fishes) for particular micro-habitats within individual deep pools.

The CPUE data broadly supported the information provided by the hydro-acoustic surveys, showing similar variations with depth and season. These sources of data are complementary, hydro-acoustic data provide information on the location, distribution and size of fish and CPUE give data on the type and number of fish. Together, these survey methods could provide a set of tools with which to monitor fish populations and abundance in the deep pools. Many fisheries experts believe these factors are indicative of the health of the whole river system and the fisheries it supports. However, more sustained and complete surveys are required before this possibility can be realised.

KEY WORDS: Mekong, deep pools, hydro-acoustics, CPUE, fisheries, environment, habitats, Cambodia, Lao PDR.

1. Introduction

Recent surveys of 'deep pools' in the mainstream of the Mekong River have brought attention to the vital role these habitats play in the life-cycle of many species of commercially important fish (Bouakhamvonsga and Poulsen, 2001; Heng *et al.*, 2001; Poulsen *et al*., 2002; Chan *et al*., 2005). However, fisheries biologists still know surprisingly little about the detailed ecology of the pools, particularly the factors that control the distribution and behaviour of particular species of fish (Poulsen *et al*., 2002).

A lot of what fisheries scientists have learnt about the fish living in the pools comes from interviews with local fishers and surveys of their catches. These provide a lot of good information on the composition, diversity and abundance of the fauna, but little about the location or distribution of populations of fishes between and within individual pools. Furthermore, many of the important deep pools are now the sites of Fish Conservations Zones (FCZs) in which fishing is prohibited or severely curtailed. This places additional constraints on the amount of information that conventional surveying methods can generate.

Hydro-acoustics, which work on the same echolocation principles as sonar, open the possibility of acquiring spatial data to complement the information provided by local fishers. Because they can be repeated easily and quickly, hydro-acoustic surveys can also be used to observe changes in the distribution of fish through time. Furthermore, as sonic pulses do not harm fish, hydro-acoustic equipment can be deployed in ecologically sensitive locations and FCZs, that are otherwise inaccessible.

Although elsewhere in the world hydro-acoustic equipment is used to monitor marine and temperate freshwater fisheries, the method is largely untested in tropical rivers such as the Mekong. Therefore, prior to committing to a large-scale survey, fisheries biologists from the Living Aquatic Resources Research Center (LARReC) in Vientiane and from the University of Bergen, Norway, ran a series of pilot surveys in deep pools in the stretch of the river in the Siphandone area of southern Lao PDR (Kolding, 2002). The surveys, which tested the equipment in a range of pools with different hydrographic characteristics, produced encouraging results in pools deeper than 10 metres and in conditions where the river flow was laminar.

This report documents the results of a more extensive follow-up survey conducted jointly by LARReC, IFReDI (Inland Fisheries Research and Development Institute, Phnom Penh,) and the University of Bergen, during late 2003 (wet season) and early 2004 (dry season). The objectives of the survey were:

- To conduct hydro-acoustic and catch per unit effort (CPUE) surveys over a suite of deep pools that are representative of the dry season refuges of important migratory Mekong fish species;
- To improve the understanding of the ecology and importance of deep pools to Mekong fish — including the relationship between the type of pool and the type and quantity of the fish these habitats support;
- To provide knowledge on fish species composition, abundance and migratory habits in a sample of deep pools during both the dry and the wet seasons;
- To develop a suitable system to monitor fish abundance and distribution that may serve as an indicator of the environmental health of the Mekong River and its stocks of fish.

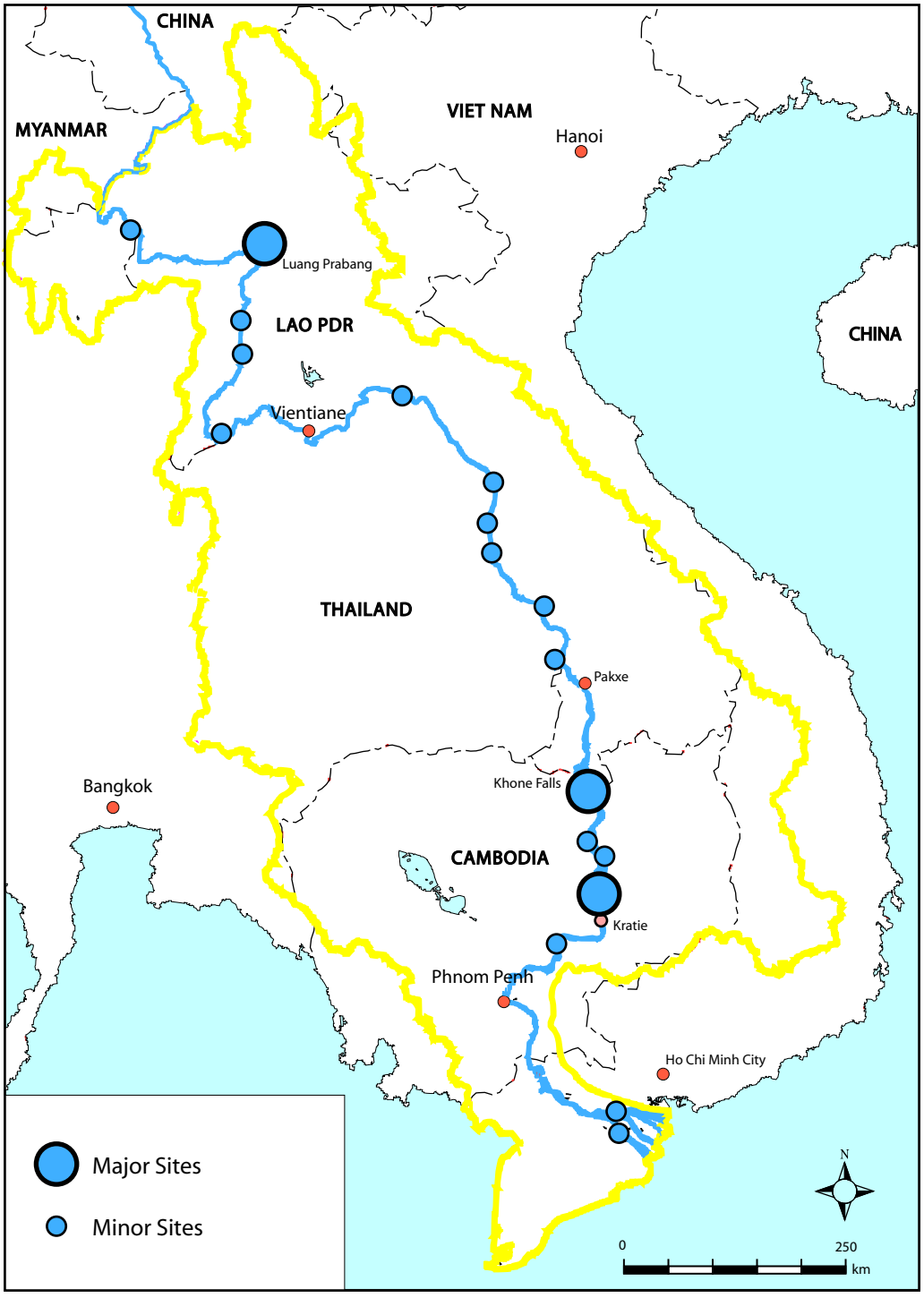


Figure 1. Location of known deep pools in the mainstream of the Mekong.

2. Background

Deep pools in the lower Mekong River system

Deep pools provide a dry-season refuge for many of the migratory species of fish that form the basis of the large capture fishery the Mekong River supports[1]. Poulsen *et al.* (2002b), for example, estimate that at least 75 per cent of the catch taken at the Tonle Sap *dai* fishery in Cambodia, originates from fish that take refuge in the deep pools in the stretch of the Mekong between Kratie and the Khone falls and the catchment of the Sesan, Srepok and Sekong rivers.

Conserving these habitats is, therefore, critically important not only for wellbeing of the local fishing communities, who target both sedentary and migratory species, but also for the large-scale commercial fisheries located hundreds of kilometres further downstream.

At the onset of the annual flood, fish taking refuge in the deep pools may travel several hundreds of kilometres (and across international borders) to spawning and feeding grounds on freshly inundated floodplains. For this reason, conserving these habitats has local, regional and trans-boundary significance (Poulsen *et al.*, 2002a).

However, while they are important in their own right, deep pools are contiguous with the rest of the river and their habitats are an integral part of the river's broader ecosystem. Many fish biologists believe the health of the deep pools is indicative of the wellbeing of the river as a whole. Because they function as 'sink habitats' during the dry season, '[deep pools] are good sites for future surveys into the health of the environment and the state of the fisheries' (Poulsen *et al*., 2002, pg. 15).

Although most fisheries experts have a clear image of what a deep pool is, the definition is somewhat arbitrary. So, according to Chan *et al*. (2005) a deep pool is:

> 'Significantly deeper than surrounding areas and holds water in the dry season, during which it may become disconnected from the main river. A deep pool is also defined ecologically as being of significance for the conservation of a number of fish species.' (pg. 58).

While this definition places greater emphasis on the ecological importance of the pool rather than its bathometric or hydrographic characteristics, the deep pools in the mainstream of the Mekong are found in discrete, geographically separated, clusters. From the perspective of fisheries, the most important clusters are located:

- From the border between Cambodia and Lao PDR downstream to the town of Kratie;
- In the area around the Khone waterfalls;
- In northern Lao PDR, especially in Luang Prabang province (Figure 1).

1 The most recent published estimates, by van Zalinge *et al.* (2004), put the annual capture fishery catch at over 2.6 million tonnes.

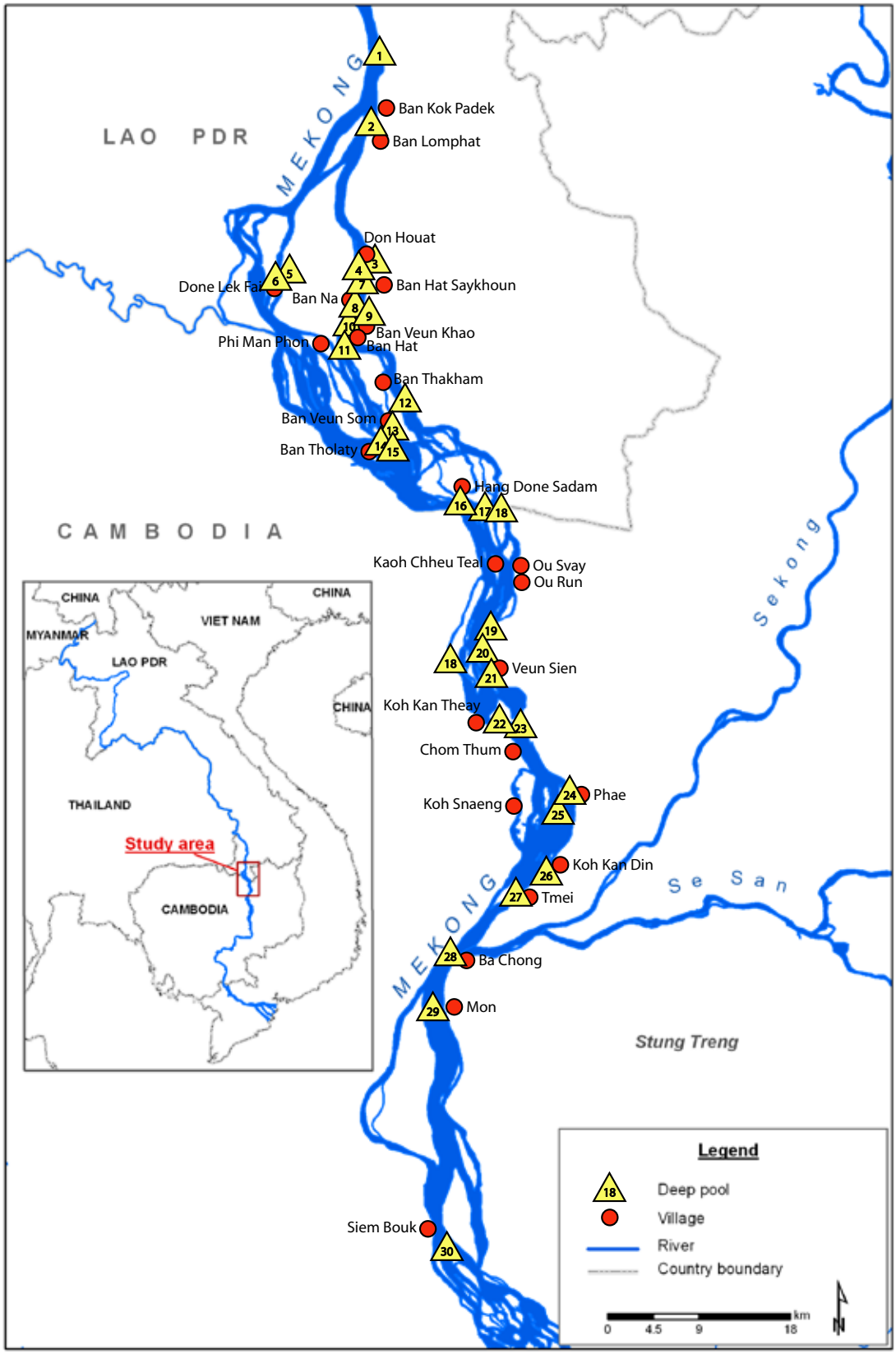


Figure 2. Location of villages and deep pools in northern Cambodia and southern Lao PDR

Table 1. *The most important locations and deep pools covered by the survey*

ID	Country	Village name	Deep pool name	Max. depth (m)	FCZ
1	Lao PDR	Ban Kok Padek	Veun Wa	40	FCZ
2	Lao PDR	Ban Lomphat	Vang Lomphat	23	
3	Lao PDR	Don Houat	Vang Nong Hai	8	FCZ
4	Lao PDR	Ban Hat Saykhoun	Vang Done Samlanh	24	FCZ
5	Lao PDR	Done Lek Fai	Veun Pa Duk	20	
6	Lao PDR	Done Lek Fai	Bung Pa Kouang	23	FCZ
7	Lao PDR	Ban Hat Saykhoun	Khoum Done Phii	21	
8	Lao PDR	Ban Na	Veun Ta Kong	24	
9	Lao PDR	Ban Veun Khao	Vang Khan Fuan	34	
10	Lao PDR	Ban Hat	Veun Songkham	38	FCZ
11	Lao PDR	Phi Man Phone	Vang Thawat	7	FCZ
12	Lao PDR	Ban Thakham	Vang Sahong	4	FCZ
13	Lao PDR	Ban Veun Som	Veun Som	34	
14	Lao PDR	Ban Tholaty	Vang Tholathy	20	
15	Lao PDR	Ban Tholaty	Vang Done Xang	11	
16	Cambodia	Kaoh Chheu Teal	Un Loong Phsot	35	
17	Lao PDR	Hang Done Sadam	Vang Hang Sadam	10	
18	Cambodia	Ou Svay	Veun Khao	29	
19	Cambodia	Ou Run	Un Loong Ky Ke	21	
20	Cambodia	Ou Svay	Bung Krak	20	
21	Cambodia	Veun Sien	Veun Sen (Veun Phong)	30	
22	Cambodia	Koh kan theay	Un Loong Koh Kan Theay	33	
23	Cambodia	Chom Thum	Un Loong Kambor	60	
24	Cambodia	Phae	Un Loong Ta Prum	35	
25	Cambodia	Koh Snaeng	Un Loong Thmor Thum	18	
26	Cambodia	Koh Kan Din	Un Loong Koh Kaden	77	
27	Cambodia	Tmei	Veun Duc	76	
28	Cambodia	Ba Chong	Un Loong Ou Trel	50	
29	Cambodia	Mon	Un Loong Svay	11	
30	Cambodia	Siem Bouk	Un Loong Siembok	36	

Study area

In this report we describe the findings of hydro-acoustic and CPUE surveys conducted at sites in Stung Treng province (Cambodia) and Champassack province (Lao PDR) during the wet season (October-November) of 2003 and in Champassack province only during the following dry season (February-March 2004) (Figure 2 and Table 1 - preceding pages).

We collected hydro-acoustic data from 69 deep pools identified for us by villagers and experienced fisheries officers. However, due to the limitations of the hydro-acoustic equipment (Kolding, 2002), we concentrated most of our efforts on the 30 pools that are deeper than 10 m. (Data from the shallower pools, that can nevertheless still provide valuable information, was also collected from the local fishers.)

Some of the deep pools in the surveyed area were fish conservation zones (FCZs) where fishing is partly prohibited. Therefore, because we wanted to collect data on catches to complement the hydro-acoustic data we attempted to include as many non-FCZ sites as possible in the survey.

The riverbed in the surveyed part of the Mekong (Figure 2) is mainly rocky and during the dry season numerous islands, rocks and sandbanks emerge, dividing the mainstream into multiple channels. In shallower sections, the channels are characterised by rapids with strong currents. These are important spawning areas for many fish species at the onset of the flood season. Pools of variable depth are often found close to the rapids. These pools offer refuge to many kinds of fish during the dry season and they are among the most important fishing grounds. In Lao PDR the pools are referred to as *Veun*, *Vang* or *Bung* according to their characteristics. The same names are widely used in north-eastern Cambodia although the proper term in Khmer is *Un Loong*.

Previous work

Although the importance of deep pools has been recognised for some time (Welcomme, 1985), they have only recently been surveyed in any detail. In Cambodia, Hill and Hill (1994) listed 28 pools in the stretch of the Mekong in Kratie province. Later, Vannaren and Kin (2000) increased the inventory of Cambodian pools to 58, of which 39 were in Kratie and another 19 upstream in Stung Treng province. In a comprehensive review of deep pools in northern Cambodia, Chan *et al*. (2005) provide details on the location, depth and dimensions of 95 pools in Kartie and Strung Treng provinces. Records of catches by local fishers from these pools list 168 species including a number of rare and exotic taxa. Among the former are the giant catfish (*Pangasianodon gigas*), Jullien's golden carp (*Probarbus jullieni*) and the Laotian shad (*Tenualosa thibaudeaui*).

Surveys of deep pools in Lao PDR, are less complete. Roberts and Baird (1995) give details of seven pools in the area of the Khone Falls. Further work by Baird *et al*. (1998), Baird *et al*. (1999), Baird and Phylavanh (1999), in Champassak province and Sjorslev (2000) in Luang Prabang province has provided much information on the fish faunas found in these pools and their importance to the livelihoods of local communities.

In June 2000, the Technical Advisory Body for Fisheries Management (TAB), recognising the importance of deep pools to the Mekong's fisheries, commissioned a review of the status of knowledge on these habitats. The resulting report (Poulsen *et al*., 2002), recommends further studies and monitoring. The pilot hydro-acoustic surveys described in this report are partly a consequence of their recommendations.

Fish conservations zones

Local fishing communities recognise the importance of particular riverine habitats to their livelihoods; in Lao PDR, in particular, there is a long tradition for establishing fish sanctuaries or FCZs. Although these can be established in many different types of aquatic habitats, they are most often associated with deep pools (Baird, 2004). The regulations imposed by each community vary from a total ban on fishing, to seasonal restrictions or prohibitions of certain gears (Chomchanta *et al*., 2000a; Baird, 2004). Most villagers are convinced that the FCZs have a positive impact on their fishery (Baird *et al*., 1998, Chomchanta *et al*., 2000a; Baird, 2004). Catch per unit effort (CPUE) studies into the effectiveness of FCZs have been inconclusive (Terry Warren *pers. comm*.), but the voluntary establishment and maintenance of the FCZs clearly demonstrate the fishers' awareness of the importance of the deep pools in the life-cycles of the fish. The pools in this survey that are designated FCZs are given in Table 1.

Figure 3. Collecting local knowledge - a fisher draws a map of a deep pool.

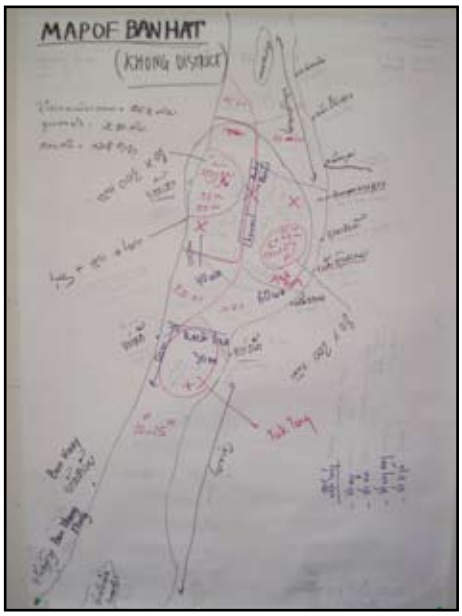


Figure 4. An example of a map (Ban Hat) drawn by local fishers showing the location of deep pools and other geographic features.

3. Methods

During the survey we collected data from three sources:

- Local knowledge about the pools and their fish from fishers;
- Hydro-acoustic data;
- CPUE information collected by selected local fishers in Champassak province, Lao PDR.

Local knowledge

Local fishing communities, who for generations have made a living from deep pools, possess a wealth of knowledge about the ecology of the pools, their fish fauna and fish behaviour. The fishers usually know the precise location of deep pools, their depth and size.

In order to 'tap' this knowledge we prepared a questionnaire to gather information on:

- Physical characteristics of the river;
- Fishing activities by season;
- The number of people fishing in the area;
- Fish species caught and information about their habits.

We notified the villagers well in advance of the survey so the head of the village and several deep-pool fishers were available to be interviewed. The interviews began with the villagers selecting one person to draw a map of the stretch of the river where they normally fish (Figure 3). The fishers then annotated maps with the location of deep pools and other important physical and hydrographic features such as rapids and streams. They also provided additional information about the deep pools such as their size and depth and the physical nature and condition of the riverbed (Figure 4).

We asked the fishers about the fish species present in the deep pools at different times of the year and whether any of these species spawned in the deep pools. However, we found it very difficult to get the fishers to focus on the deep pool, and they often included information from surrounding areas as well. The advantages, limitations and pitfalls of using local knowledge in fisheries surveys have been thoroughly discussed by Valbo-Jørgensen and Poulsen (2000).

We attempted to assess the importance villagers attached to the deep pools as fishing grounds by gathering information about the number of people, both villagers and outsiders, fishing the pools. We also obtained information on the gear used during different seasons and at different localities with particular emphasis on those used in deep pools. Finally we asked if the deep pools in their locality were designated FCZs and, if so, what rules apply to them.

After each interview the villagers were invited to ask questions. Their questions usually related to why we needed the data and what we were going to do with the information they provided. Some villagers expressed concern that fishing in certain areas would be prohibited or restricted as a consequence of our research.

At the end of each meeting we asked selected fishers to take part in the follow-up CPUE survey.

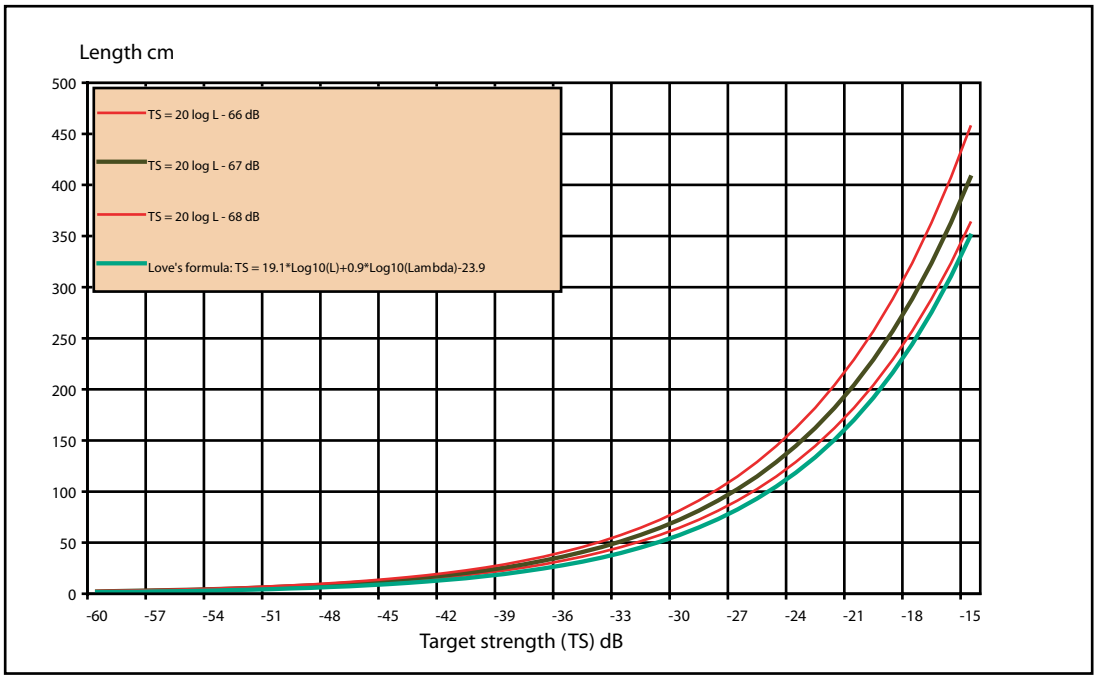


Figure 5. Generalised relationship between target strength (TS) and fish length (updated from Kolding, 2002).

The size of the swim bladder determines a fish's target strength. Consequently, species without swim bladders, or with small swim bladders, have a lower target strength than fish of the same length with larger swim bladders. This factor leads to the underestimation of the size of some fish species, and is a particular problem with several species of catfish (see Appendix 3 for a list of species and the condition of their swimbladder).

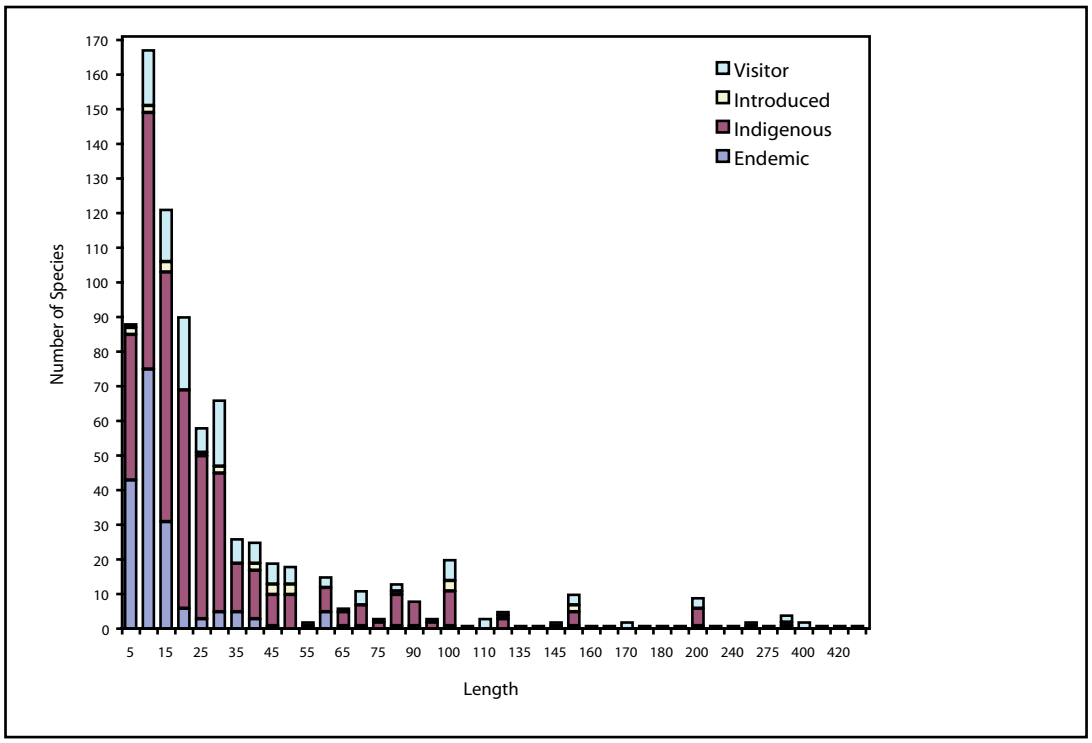


Figure 6. The composition of the fish fauna in the Mekong - ordered by length (source, MRC 2003).

The riverine fish fauna supported by the Mekong is one of the most diverse in the world (Sverdrup-Jensen, 2002). However, this diversity means that the interpretation of the relationship between target strength and the length of fish given in Figure 5 is more difficult in the Mekong than in other rivers with fewer species of fish.

Hydro-acoustic surveys

Principles of hydro-acoustic surveying

Hydro-acoustic surveys work on the same basic echo-sounding principles as does the sonar equipment that is used to locate ships and submarines. The method is straightforward; a transmitter emits a powerful acoustic signal (a 'ping') and a receiver records the time and strength of echoes of the signal reflected from the riverbed and from objects in the water column. Modern hydro-acoustic equipment uses a transducer to both propagate and receive the acoustic signal.

As sound waves travel through water at a constant velocity, we can calculate the range (distance) of the object, by multiplying the time elapsed from the emission of the ping to the return of the echo by the speed of sound in water and dividing the result by two. (The time recorded at the transducer is the 'two-way' time, i.e. to the object and back, therefore we divide the 'two-way range' in half to get the true range of the object.)

The contrast between the density of water and the object reflecting the sonic wave governs the strength (target strength) of the echo. Objects with significantly different density than water give a strong echo while objects with density close to water give a weak signal. As a consequence the riverbed usually returns a very strong signal, particularly if it is formed from rock rather than soft sediment. Organic debris, on the other hand, having a density similar to the water is, by and large, transparent to sound waves and returns weak echoes.

Fish, in contrast, return a good echo. This is because even though the density of most of a fish's body tissue is close to that of water, their swim bladders are filled with air. The size of the swim bladder largely determines the target strength of fish. In many species of fish, target strength is roughly proportional to the size of the swim bladder and therefore the size of a fish can be estimated from the strength of its echo (Figure 5).

However, those species of fish with small or no swim bladders return a weaker signal than the fish species of the same size with well developed swim bladders. In these instances, the strength of the signal will greatly underestimate the size of the fish. This is, for example, true for many catfish and can be a problem in rivers, such as the Mekong, that support large and diverse faunas of fish (Figure 6).

The transducer records the range and target strength of objects in the vertical acoustic axis beneath its location. This is a one-dimensional acoustic trace. Two dimensional transects, or echograms, can be obtained by rigging the hydro-acoustic equipment to a boat and recording a succession of pings (usually one a second) as the boat is driven over a deep pool. If the transducer is linked to a GPS (Geographical Positioning System) the exact location of the pings and echoes can be plotted and mapped (Figure 7).

Figure 8 is an example echogram recorded in February 2004 over Veun Wa, a deep pool near Kok Padek village in Siphandone. The geometry of the riverbed and the location of schools of fish are clearly visible.

Data acquisition

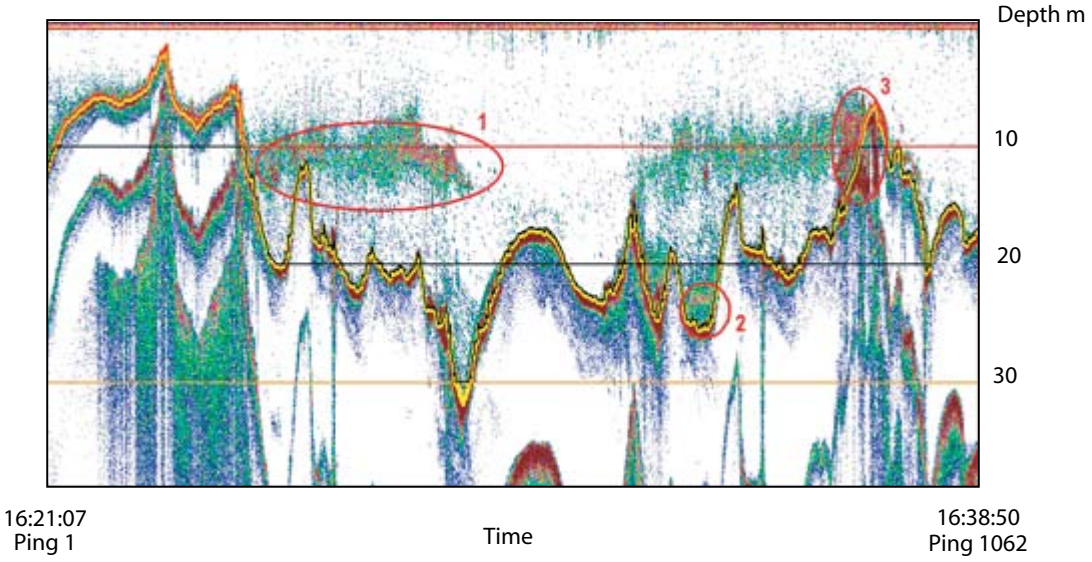
In all, we surveyed 30 deep pools and recorded over 160 transects. The number of transects in individual pools were between 1 and 33 (Table 2). Most of the surveys were recorded during daylight hours because of the danger involved in navigating among rapids after night fall. For these reasons night-time surveys were restricted to Veun Songkham, Veun Wa, Veun Lomphat, Vang Don Samlanh, Khoum Don Phi and Veun Duc. The locations and depths of the pools are given in Figure 2 and Table 1.

Figure 7. Hydro-acoustic equipment.

Top: Collecting hydro-acoustic data from a locally hired boat - here the boat is cruising at about 3 - 5 knots.

Middle: The hydro-acoustic equipment is attached to a GPS allowing accurate location of the ping and the position of fish.

Bottom: A transducer and protective shield (made by a local blacksmith).



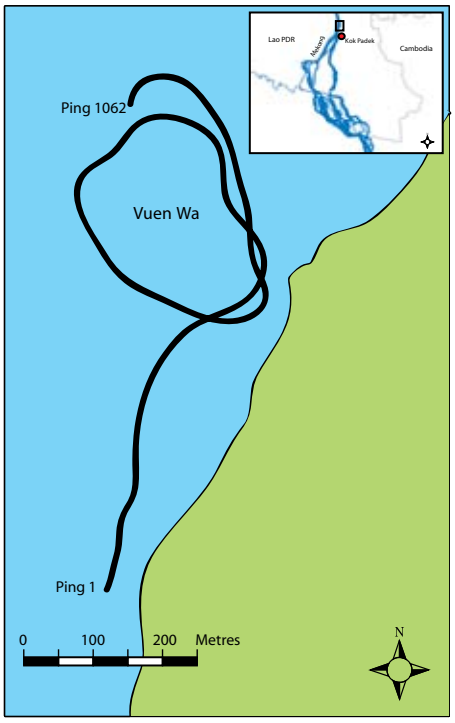


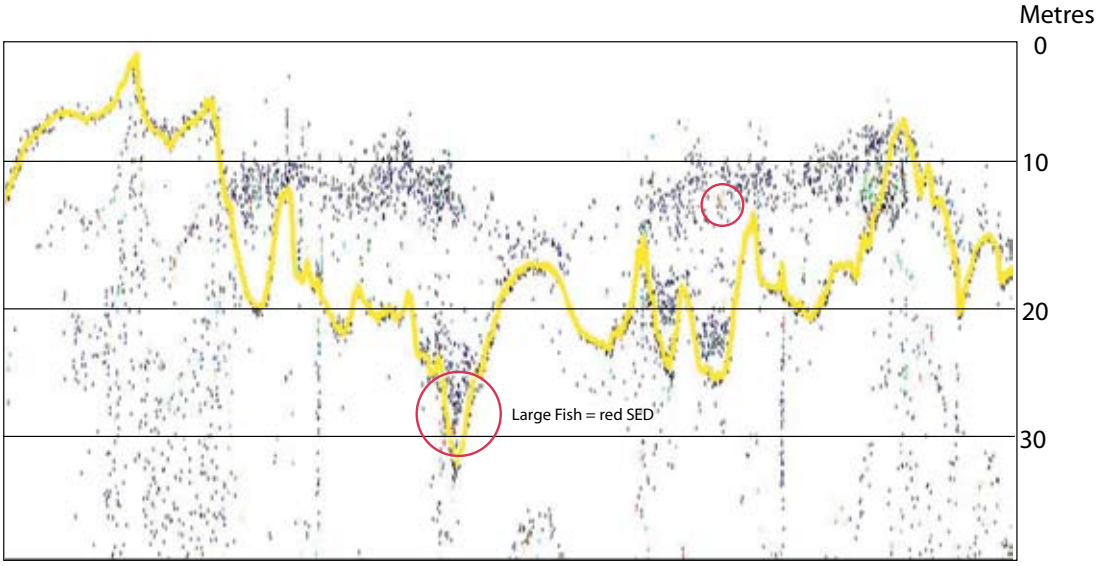
Figure 8. An example echogram (top) recorded in Veun Wa, near the village of Kok Padek in February 2004.

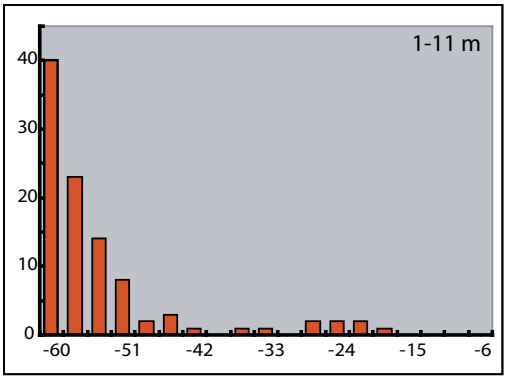
Top: The echogram is displayed using Sonar 4 software. The transect is about 1,922 m long and took nearly 18 minutes to record. The vertical scale is displayed in metres (the maximum recorded depth is just over 30 m) and the horizontal scale, in time. The echogram represents the records of over 1060 pings. The horizontal lines, drawn every 10 m, mark the boundaries of the layers used in processing the data to determine biomass and fish density.

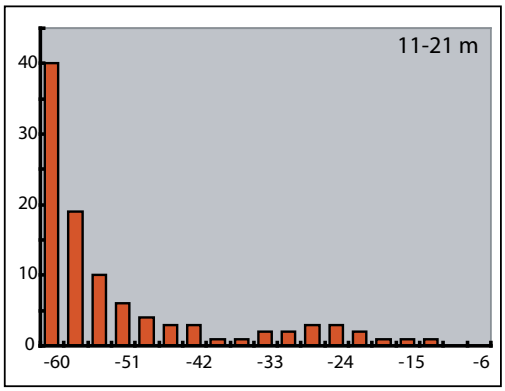
The strong yellow line is the riverbed. However, the topography of the riverbed is greatly exaggerated on this echogram. The horizontal scale is approximately 25 times the vertical scale. What appear to be crevices and very steep banks are more gentle in reality.

Red circles indicate concentrations of fish (the darker the more dense) in 1 open water, 2 near the bottom of a depression and 3 on the side of a bank (perhaps sheltering from the current). These three different behaviours are most likely different species or groups of species.

Bottom: Map showing the course of the boat as it circled around Veun Wa acquiring hydro-acoustic data.







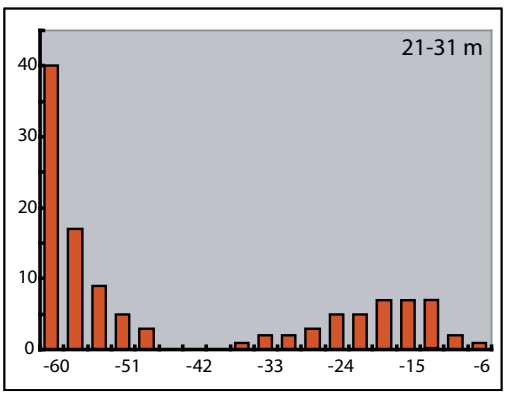


Figure 9. SED (single echoes detected) processing.

Above: The same echogram as illustrated in Figure 8 processed for single echoes. Small organisms with low dB have light colours while large organisms are shown in red to dark colours.

Left: Frequency histograms of the SED in -3bB intervals for each of the three 10 m layers shown in the echogram above. Note the relative increase of the large targets as depth increases. (See Figure 5 for an approximate conversion from dB to length.)

We collected acoustic data from hired local boats cruising at speeds of 3-5 knots, using a scientific echo sounder[1]. A split-beam transducer was mounted on a fixed structure on the fore-port side of the boat at a depth of 0.1 - 0.3 m below the water surface. Echo-recording started 1 m from the transducer, i.e. 1.3 m below the surface. The echo sounder was connected to a laptop computer running the ER 60 software in Windows XP. The computer was also linked to a Garmin GPS (Figure 7).

At each pool the boat driver was asked to manoeuvre the boat around within the borders of the pool until we had collected sufficient data (see Figure 8 as an example). We recorded three files of approximately 10 minutes each at each site, however due to noise on some files, we were unable to analyse all of the transects. Most often, the boat driver was so familiar with the area that he did not need any guidance to cover the pool; on the occasions when the pools had a very irregular shape we were able to guide the driver of the boat using the displays on our computer's monitor.

Data processing

In addition to recording echograms - which give a visual image of the location and size of fish and shoals of fish - we also processed the echo-sounding data to determine biomass (Sa/ha) and fish density (fish/ha).

To do this we used SONAR 4 software (Balk and Lindem, 2005). The general principles on the transmission of acoustic energy, reception of the echo, measurement of target strength and echo integration follow Kolding (2002).

We processed the data in the following sequence:

1. Visually examine the echograms and reject those with too much noise. (The background of the echogram in open water should be clear except where fish are present. However whirls, debris, air bubbles and other artifacts can generate 'noise' that degrades the quality of the echogram.)
2. Carefully define the riverbed using the bottom detection control in Sonar 4, save this and set the offset margin to 0.1 m above bottom.
3. Divide the water column on the echogram into 10 m depth strata (the top of the first strata stratum is defined 1 m below surface).
4. Set analysis in SONAR 4 to 'all pings and whole depth range'.
5. Analysis 1: Record total Sa/ha and total single echo detection (SED) in each stratum.
6. Analysis 2: Set the number of sub-layers to 'X' (X = number of 10 m strata). Record Sa/ha and fish/ha of each layer.

Total Sa/ha is the average total energy (with a lower limit threshold of –60 dB) reflected per hectare within the stratum defined above and is proportional to the combined size of the air cavities, such as swim bladders, in all organisms more than around 3-5 cm long (see Figure 5). However, species of fish that do not have a swim bladders, will not return a strong echo and therefore will not be registered by the hydro-acoustic equipment. As a result the calculation of biomass using hydro-acoustics is only a rough estimate and is very likely to be an underestimate of the true value. The single echo detection (SED) algorithm calculates the number and distribution of single echoes (single organisms) detected in the echogram and their respective reflected energy (= target strength) (Figure 9). The relative distribution of SED is raised by the total Sa/ha to estimate of the total number of fish/ha (irrespective of size).

[1] During 2003 we used a SIMRAD EY 500 echo-sounder and a ES70-11 transducer operating at 70 kHz. In 2004 we used a SIMRAD EK60 echo-sounder and a ER60 transducer at 120 kHz

Table 2. *2003–2004 Survey — location, season, mean Sa/ha, number of transects and maximum depth*

	Lao PDR				Cambodia			
Location	Season	Sa/ha (mean)	Nº of transects analysed	Pool depth (m)	Season	Sa/ha (mean)	Nº of transects analysed	Pool depth (m)
Veune Songkham	Wet and dry	496	33	38				
Veun Khao	Wet	94	1	19				
Khoum Done Phi	Wet and dry	600	8	21				
Vang Done Samlanh	Wet and dry	283	11	23				
Bung Pa Kuan	Wet and dry	223	4	24				
Ou trel					Wet	283	3	50
Veun Pa Duc					Wet	258	16	75
Tmei Village to Stung Treng					Wet	135	2	54
Koh kaden					Wet	344	3	77
Koh kaden to Stung Treng					Wet	169	3	78
Kambor					Wet	375	2	60
Kosneng					Wet	361	10	42
Phae					Wet	291	1	36
Koh kan theay					Wet	459	3	33
Svay					Wet	29	1	16
Siembok					Wet	404	3	36
Koh Snolau					Wet	247	3	19
Kanthey deep pool					Wet	446	3	42
Ky Ke deep pool					Wet	238	2	21
Osvay					Wet	285	1	20
Dolphin deep pool					Wet	747	6	36
Vang Lomphat	Wet and dry	340	8	22				
Vang Kathaov	Wet	449	1	15				
Veun Don Tan	Wet	189	2	22				
Veun I Khom	Dry	258	3	17				
Veun Pa Duk	Dry	428	3	19				
Veun Wa	Dry	368	6	38				
Vang Nong Hai	Dry	128	3	8				
V. Tholaty to V. Done Xang	Dry	261	1	16				
Vang Done Xang	Dry	254	2	11				
Vang Tholaty	Dry	262	3	20				
Veun Som	Dry	212	3	34				
Vang Hang Done Sadam	Dry	455	2	11				
Veun Ta Kong	Dry	720	3	24				
Ban Na to Hat Say Khoun	Dry	221	1	20				
Ban Hat to Hat Say Khoun	Dry	537	2	34				
Vang Sahong	Dry	108	1	4				
Total		**397**	**101**			**345**	**62**	

2003–2004 Survey

A total of 252 transects were recorded and analysed in 832 10 m depth strata during the two surveys. Of these 89 transects (35%) with 152 depth strata were later excluded because of excessive noise and/or unrealistic values.

The following results are based on the retained 163 transects as distributed in Tables 2 and 3. All results from Sonar 4 were processed using PasGear II (Kolding and Skalevik, 2004).

Table 3. *Summary of the 2003–2004 Survey*

	Lao PDR			**Cambodia**			**Total**	
Year	Season	Sa/ha	Number of transects	Season	Sa/ha	Number of transects	Sa/ha	Number of transects
2003	Wet (30 Oct–3 Nov)	233	28	Wet (4–14 Nov)	345	62	310	90
2004	Dry (21 Feb–2 Mar)	460	73				460	73
Total		397	101		345	62	377	163

Note: Sa/ha is the total average energy reflected per hectare. Sa is the Total Area Back Scattering Coefficient

Figure 10. Survey team members demonstrate standard measuring procedures to local fishermen

BOX 1. Fishing Gears Used in Deep Pools

Very few gears are used for fishing in deep pools and most of them are not very efficient or only fish well under certain circumstances. For instance, gill nets, which are among the most popular gears, tend to get stuck among the rocks, and consequently fishers avoid the areas with jagged riverbed even though they know that fish are concentrated there.

The only truly efficient gears in the deep pools are explosives and these are outlawed both by national and local laws and regulations, due to their indiscriminate killing of large amounts of fish and destruction of valuable fish habitats.

Teuk Tong is a bag net, which is only used in Lao PDR, and we are not familiar with any similar gear in Cambodia. The Teuk Tong is an active gear which is operated by two people; the gear is fished along the bottom weighed down by large stones. The two fishers stand in the bow and stern of the ship respectively to keep the net open. When one of the fishers notices that a fish has entered the net, he will trigger a device that closes the net and traps the fish inside.

As it requires considerable skill to use the gear without entangling it in rocks and logs, the gear is no longer widely used in Lao PDR and only few people still know how to make Teuk Tong. We therefore asked an experienced fisherman make some Teuk Tong for us, and we later distributed them in the villages where we wished to collect data.

Figure 11. Test fishing with a fyke net brought from Denmark

CPUE survey

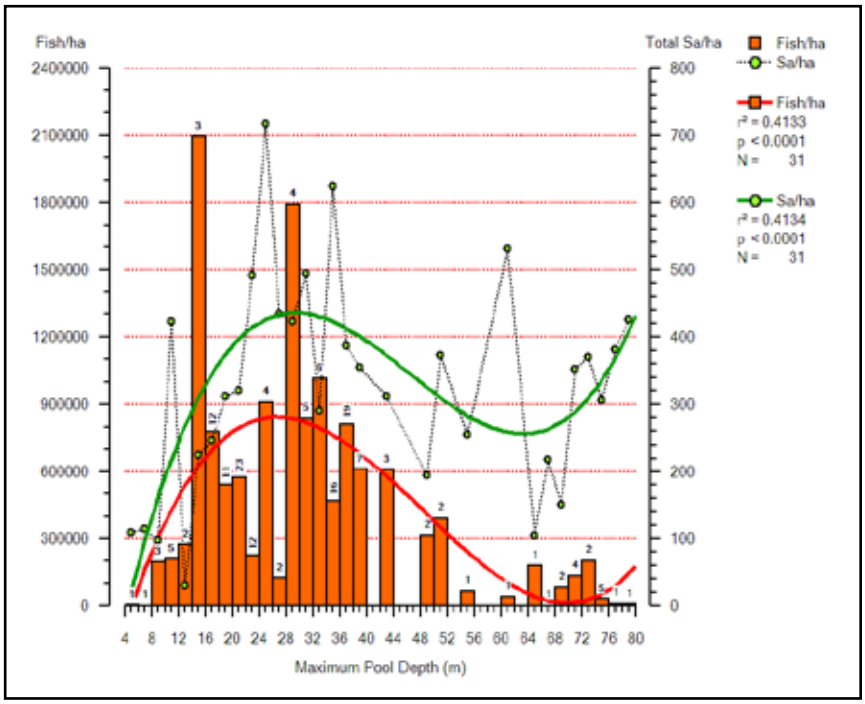
The information hydro-acoustics provides on fish is limited to their position in the water column, their numbers and size. The equipment can only rarely be used to identify fish — even in rivers with fewer species than the Mekong.

However, rigorous and methodical surveys of fishers' catches can provide a lot of information on the composition and abundance of the fauna in deep pools if we assume the various gears they use catch a representative selection of the species and proportions of fish living in the pools.

We therefore undertook a small scale CPUE survey of local fishers' catches to provide data on fish species and abundance. The survey involved three fishermen from each of the four Lao villages, Ban Done Tavantok, Ban Kok Padek, Ban Hat, and Ban Hat Saykhoune (Figure 2). The choice of the fishermen aimed to ensure that the CPUE data included records from catches using all types of gear used in deep pools (Box 1).

The fishermen were asked to keep a logbook of their catches from November 2003 to March 2004 recording the date, location, gear, gear size, number of fish caught by species, and length of all the fish[1] (length was preferred to weight because it is quicker to measure correlates better with target strength). We used a uniform length to weight ratio ($w = 0.01\ l^3$, where w = weight in grams and l = length in centimetres) to estimate the weight of all the fish regardless of their species.

[1] Because fishers were too busy to measure all their catch on days where catches were large, we agreed that, on these days, they need only measure ten randomly selected individuals per species.



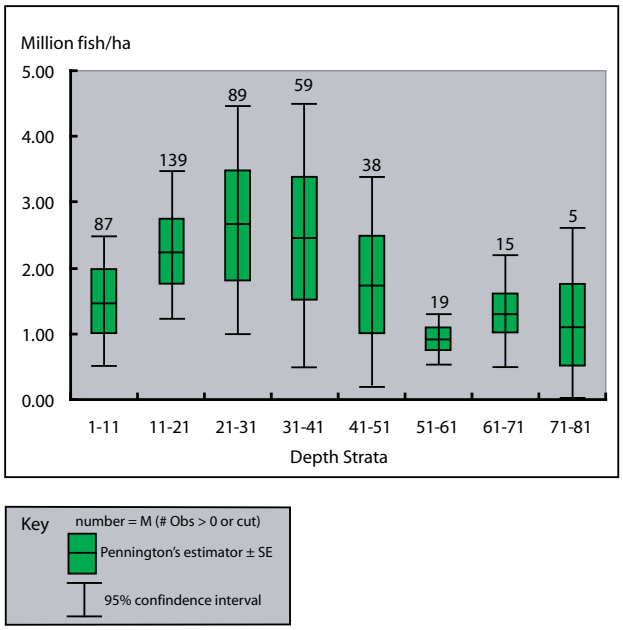


Figure 12. Relationship between pool depth and biomass (Sa/ha) and fish density (fish/ha)

Above: The general relationship between pool depth (2 m depth intervals) and mean 'biomass' (Sa/ha) and mean fish densities. The fitted trend lines are 3rd order polynomials. The number above the bars indicates the number of samples. The trend lines display similar overall shape. Biomass and fish density increase with depth, reaching maxima in pools that are 25 to 30 m. In deeper pools both measures fall-off, reaching minima in pools about 65 m deep. Beneath this depth biomass and fish density increase once more. However, the difference between the fitted trend lines shows that biomass decreases less than the number of individual fish. This suggests a general linear increase in mean size of fish with pool depth.

Below: Overall mean fish densities by 10 m depth strata. This plot shows similar trends to the chart above. The maximum density of fish is found in depth strata between 21 and 41 m. The densities reach a minimum between 51 and 61 m before increasing again the deepest strata (61 - 81 m).

4. Results

Local knowledge

The maps drawn by the local fishers provided excellent background information about the location and depth of the pools near their villages. These were of great help in the detailed design of the hydro-acoustic and CPUE surveys. Unfortunately the information provided by the fishers on the species of fish living in the deep pools was less useful because in some cases they were unable to say whether the fish lived in deep pools or in adjacent stretches of the river.

Hydro-acoustics

Depth relationships

The aggregated results of data from all the pools show a clear relationship between biomass (Sa/ha) and fish density (fish/ha) and depth of pools (Figure 12). This relationship is observed in relation to the maximum pool depth (Figure 12 - top) and the 10 m depth strata (Figure 12 - bottom). Both biomass and fish density increase with depth to depths of about 30 m. Below this depth both measures fall off, reaching a minima at around 65 m. However, at still greater depths both biomass and fish density begin to increase once again, although they do not reach the levels recorded at 30 m.

We observed several individual fishes in the deepest pools, which, according to their target strength, were between 1 and 2 m in length. However most of the fishes in the deep pools (especially during the wet season) are smaller (young of the year or small species) and it is possible that these habitats serve as nurseries to some species.

Geographic variations

Relative fish densities were higher in Cambodia than Lao PDR (Figure 13). The reasons for this are not clear. It does not appear to relate solely to pool depth. Although the section of the Mekong in Stung Treng (northern Cambodia) contains a higher proportion of pools deeper than 40 m (Figure 13), the greatest biomass and density of fish are found at around 30 m, as we have just seen. Pools of this depth are more evenly distributed between Cambodia and Lao PDR.

Seasonal variations

Biomass and fish density showed considerable seasonal variation (Figure 14). Surveys acquired during the dry season (Feb-Mar 2004) recorded higher biomass and lower fish density than those recorded during the wet season (Oct-Nov 2003). This suggests that more large fish live in the pools during the dry season, supporting the contention that the habitats are a refuge for adult fish during these times.

Environmental variations and micro-habitats

At present, because we have little detailed information of the composition of the fish faunas, we cannot account for the difference in biomass and fish densities recorded in the pools in northern Cambodia and southern Lao PDR (Figures 13 and 15). However, the echograms clearly show that fish choose to

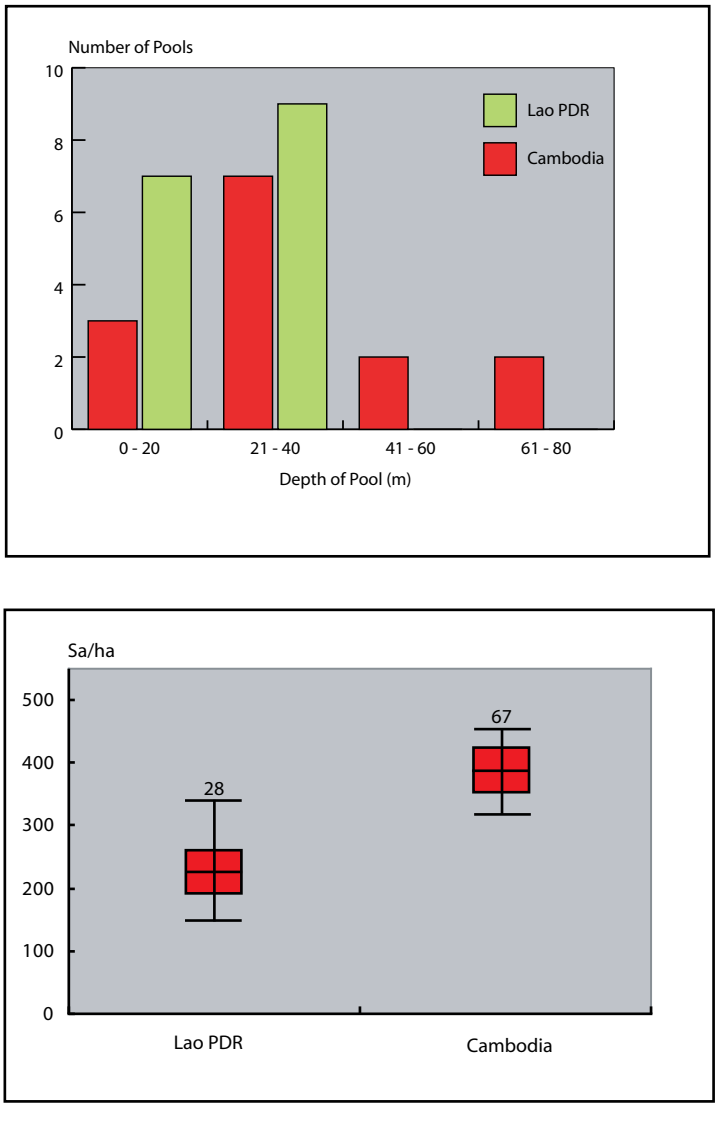
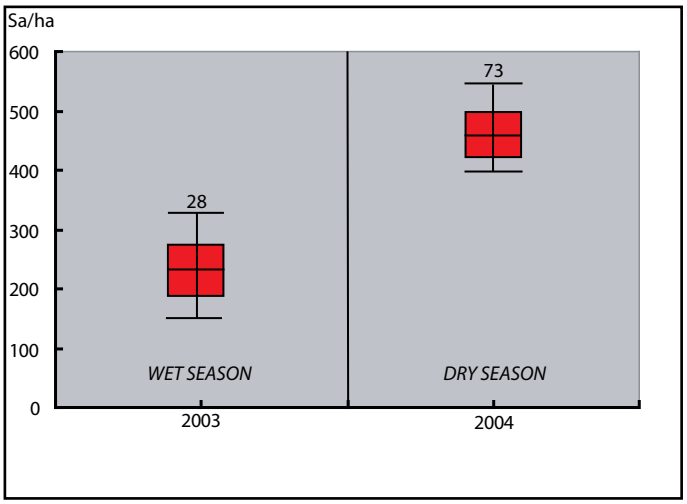
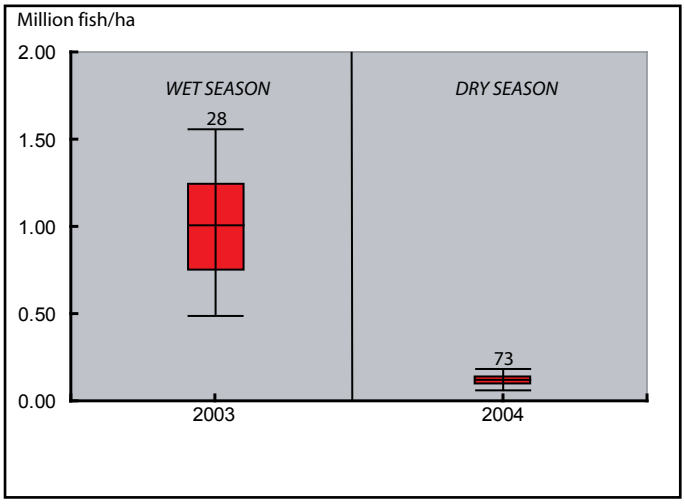


Figure 13. Comparison of biomass and pool depth in Lao PDR and Cambodia.

Above: The distribution of deep pools (grouped by depth) . Note, while the deepest pools are in Cambodia, the distribution of pools in the range 21 - 40 m (which have the largest biomass and fish densities) is more evenly split between the countries.

Below: Comparison of biomass (Sa/ha) of pools in Lao PDR and Cambodia. The biomass is significantly greater in the Cambodian pools. The reasons for this are not fully understood. It does not appear to be a function of the depth of the pools as Lao PDR has more pools in the 21 - 40 m range, which should have the greatest biomass. Other causes, such as certain fishes' preference for particular micro-habitats, are more likely. These require further study.





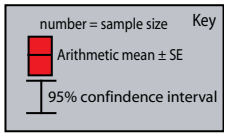


Figure 14. Comparison of biomass and fish densities in the Oct-Nov 2003 (wet season) and Feb-Mar 2004 (dry season) phases of the survey.

These plots include data from Lao PDR only (no data was acquired in Cambodia during 2004). Higher biomass was recorded during the 2004 survey (dry season) while the fish density was significantly lower than in 2003 (wet season). This suggests more large fish were living in the pools during these months supporting the contention that adult fish use the pools as a dry season refuge.

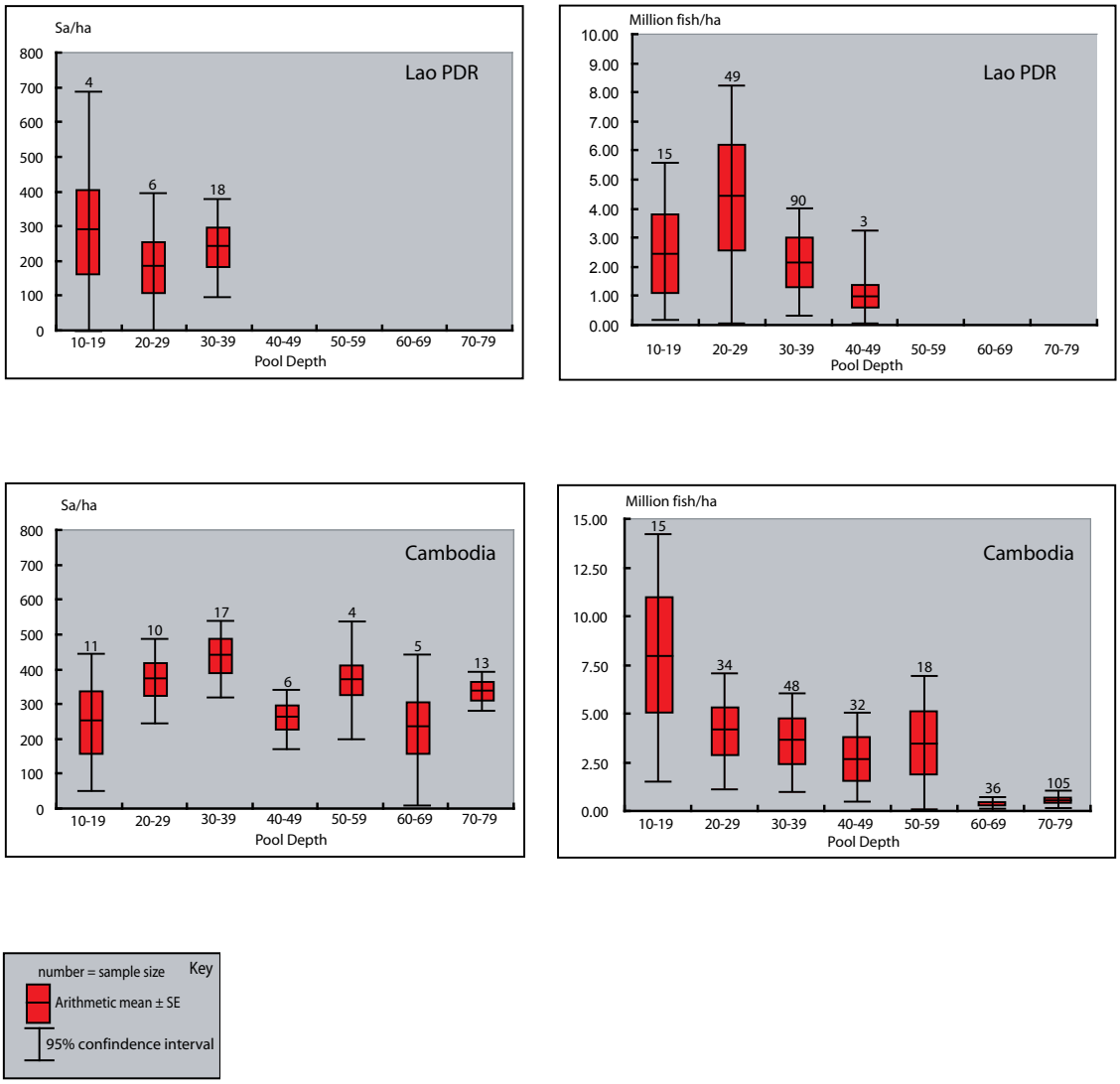


Figure 15. Comparisons of biomass (left) and fish densities (right) in Lao PDR and Cambodia.

congregate in specific positions in the river. We assume, therefore, that the different pools offer different micro-habitats[1].

Most people probably associate the term 'deep pool' with a hole or a regular deepening in the river bottom. However, most of the Mekong deep pools are better described as canyons, fissures or cracks in the bottom, and it is clear from our observations that hydrographic characteristics vary from pool to pool. As yet the hydrology, geomorphology and geology of the pools have not been studied or surveyed in any detail and the reasons behind their origins, location and distribution are poorly understood. This information is needed before their distribution and significance as fish habitats can be explained.

All we can say at present is that the depth, detritus in the river, the nature of the riverbed and the strength and location of currents seem important factors in determining the number of fish seeking shelter in the pools (Chan *et al*., 2005). Some of the fish in the deep pools clearly prefer to position themselves in the vicinity of serrated rocks with steep, almost vertical, sides, where the current is obstructed. Here fish may save a lot of energy in the quiet water and at the same time benefit from drifting food that often concentrates in the whirlpools. Other fish seem to prefer the deepest holes where the recorded densities almost universally were very high, while others again were found in the open water. It is likely that these micro-habitats support different fish assemblages.

CPUE

The 12 fishers who took part in the CPUE survey provided a daily record of where they fished and the type and size of fish in their catch (Table 4). Unfortunately, none of them fished throughout the whole survey period and during the last two months (February and March) only one fisher fished regularly. In addition, one other fisher recorded the type and length, but not the number of fish in his catch (these records were excluded from our analyses). In total the fishers returned 1811 records of their catches. These included 1764 individual fish belonging to 48 taxa.

Composition of the catch

The most common species were Pa Nang Deng (*Hemisilurus mekongensis*), Pa Gnone (*Pangasius* spp.), Pa Nang Khao (*Micronema* spp.) (Figure 17 and Table 5).

However, there were relatively large seasonal variations in the composition of the catch, particularly among the dominant species (Table 6). As the usage of various gears remained relatively stable during the survey period, we believe that these changes are most likely due to seasonal migration patterns.

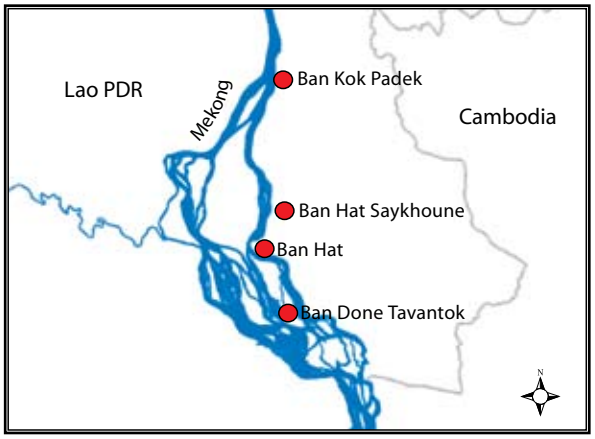
Catch rates and size distributions

Although catch rates (in terms of the number of fish caught per gear set) varied between the different gears, the results of the CPUE survey show a broad correlation between catch-rate and the depth of pools (Figure 17). The only significant deviations from this trend were the catch rates recorded by fishers using gillnets or Teuk Tong in shallow pools (0-9 m). If the results from these very shallow pools are discounted

1 Poulsen *et al.* (2002) document the preference some fish species show for particular pools. Local fishers, recognising these preferences, often name pools after fish that are particularly abundant. *Bung Pa Kouang*, for examples translates as pool of the Boeseman croaker (*Boesemania microplepis*).

Table 4. *CPUE data recorded by 12 local fishers during the survey period*

Fisher Name		Nov 2003	Dec 2003	Jan 2004	Feb 2004	Mar 2004	Total
Mr Boungnong	Catch rate (N°/Set)	3.8	1.0		1.7		1.8
	N° of sets	*5*	*12*		*23*		*40*
Mr Seum	Catch rate (N°/Set)	4.4	1.9	3.9	3.8		3.0
	N° of sets	*3*	*20*	*8*	*13*		*44*
Mr Yongphao	Catch rate (N°/Set)	7.0	3.1	9.1		5.1	5.4
	N° of sets	*2*	*13*	*10*		*29*	*54*
Mr Khambone	Catch rate (N°/Set)	4.0		1.9	1.7	2.0	2.6
	N° of sets	*24*		*23*	*18*	*1*	*66*
Mr Leuam	Catch rate (N°/Set)	9.0		2.9	3.5	4.0	3.5
	N° of sets	*2*		*17*	*13*	*1*	*33*
Mr Pane	Catch rate (N°/Set)			1.4	1.6	2.0	1.5
	N° of sets			*30*	*16*	*1*	*47*
Mr Khambay	Catch rate (N°/Set)	3.2	5.3	3.0			4.0
	N° of sets	*10*	*30*	*27*			*67*
Mr Sithat	Catch rate (N°/Set)	9.0		4.5			4.8
	N° of sets	*2*		*25*			*27*
Mr Sichanh	Catch rate (N°/Set)	2.1	1.9	3.4			2.7
	N° of sets	*10*	*15*	*25*			*50*
Mr Bounlap	Catch rate (N°/Set)	2.0	4.7	6.2			4.6
	N° of sets	*4*	*9*	*6*			*19*
Mr Kamfong	Catch rate (N°/Set)	4.6		8.8	7.0		7.5
	N° of sets	*7*		*18*	*5*		*30*
Mr Somphone	Catch rate (N°/Set)	0.9		1.0	1.0	1.0	1.0
	N° of sets	*7*		*29*	*27*	*1*	*64*
Total	Catch rate (N°/Set)	3.6	3.2	3.5	2.2	4.8	3.3
	N° of sets	*76*	*99*	*218*	*115*	*33*	*541*



Village	Fisher
Ban Kok Padek	Mr Boungnag
	Mr Seum
	Mr Youngphao
Ban Hat Saykhone	Mr Khambone
	Mr Leuam
	Mr Pane
Ban Hat	Mr Khambay
	Mr Sithat
	Mr Sichanh
Ban Done Tavantok	Mr Bounlap
	Mr Khamfong
	Mr Somphone

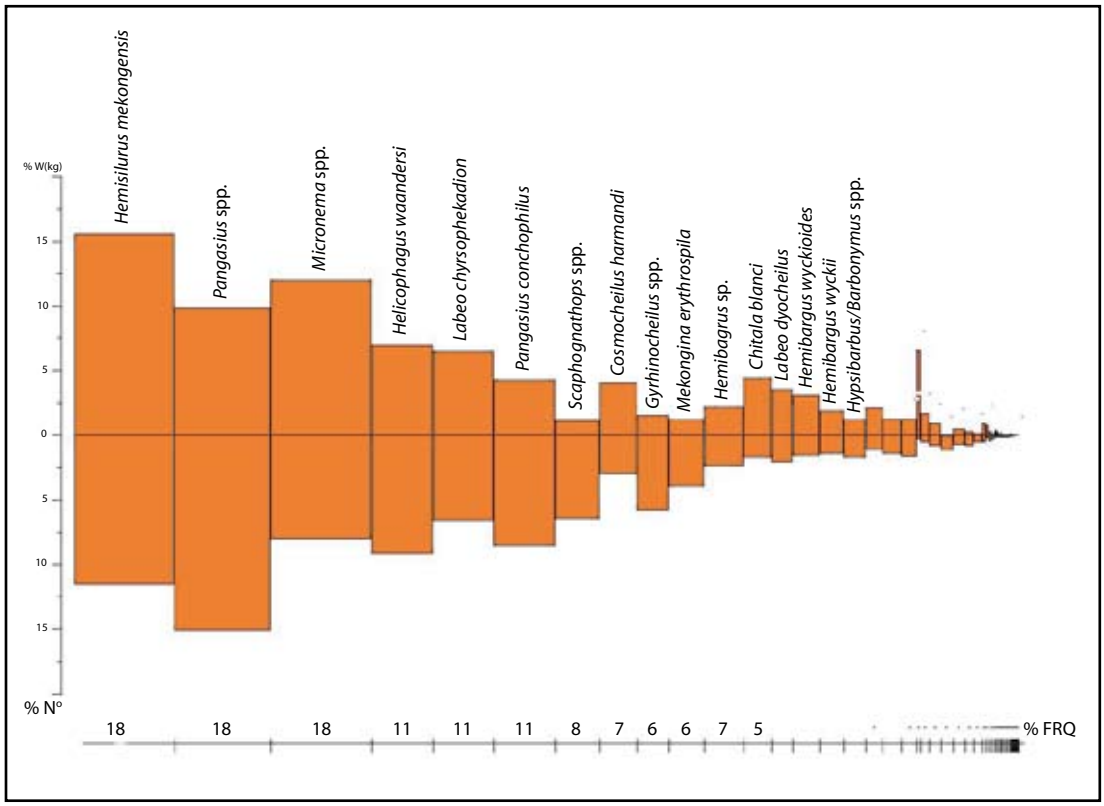


Figure 16. Relative importance and frequency of the 48 species caught by fishermen in the CPUE survey.

Relative importance (% N°+%W) %FRQ (=frequency of occurrence).

Gears: gill nets, long lines and Teuk Tong.

Only the 12 most important species are labelled

Table 5. *CPUE from the Ban Done Tavantok, Ban Kok Padek, Ban Hat and Ban Hat Saykhone, Campassak province, Lao DPR.*

	Gill net		Long line		Teuk Tong	
Number of fish caught	956		336		472	
Number of species caught	31		25		17	
Dominating species 1	Pa Gnone	17%	Pa Nang Khao	16%	Pa Nang Deng	28%
Dominating species 2	Pa Phia	12%	Pa Ke	13%	Pa Gnone	18%
Dominating species 3	Pa Na Nou	12%	Pa Kot Leuang	12%	Pa Nag Khao	14%

Note: Pa Njon (Pa Gnone) = several small pangasiid species

Pa Phia = *Labeo chrysophekadion* and *Labeo barbatulus*

Pa Na Nou = *Helicophagus waandersii* and *Helicophagus leptorhynchus*

Pa Nang Khao = *Micronema* spp.

Pa Ke = *Pangasius conchophilus*

Pa Kot Leuang = *Hemibagrus* sp.

Pa Nang Deng = *H. mekongensis*

Table 6. *Composition of the total catch listing the 23 numerically most abundant species*

	Total		**Nov-Dec**		**Jan-Feb**		**Mar-Apr**	
Species	Nº	% Nº	Nº	% Nº	Nº	% Nº	Nº	% Nº
Pangasius spp.	266	15.10	91	15.20	131	13.00	44	27.80
Hemisilurus mekongensis	203	11.50	39	6.50	163	16.20	1	0.60
Helicophagus waandersi	161	9.10	67	11.20	48	4.80	46	29.10
Pangasius conchophilus	150	8.50	59	9.90	89	8.80	2	1.30
Micronema spp.	141	8.00	48	8.00	91	9.00	2	1.30
Labeo chrysophekadion	116	6.60	34	5.70	82	8.10	0	0.00
Scaphognathops spp.	113	6.40	77	12.90	11	1.10	25	15.80
Gyrhinocheilus spp.	102	5.80	13	2.20	88	8.70	1	0.60
Mekongina erythrospila	69	3.90	22	3.70	39	3.90	8	5.10
Cosmocheilus harmandi	52	2.90	28	4.70	24	2.40	0	0.00
Hemibagrus sp.	42	2.40	14	2.30	27	2.70	1	0.60
Labeo dyocheilus	36	2.00	15	2.50	20	2.00	1	0.60
Hypsibarbus/Barbonymus spp.	29	1.60	11	1.80	16	1.60	2	1.30
Chitala blanci	29	1.60	3	0.50	25	2.50	1	0.60
Cyclocheilichthys enoplos	28	1.60	8	1.30	6	0.60	14	8.90
Hemibagrus wyckioides	27	1.50	13	2.20	14	1.40	0	0.00
No Name	25	1.40	16	2.70	8	0.80	1	0.60
Hemibagrus wyckii	24	1.40	12	2.00	11	1.10	1	0.60
Henicorhynchus spp.	20	1.10	0	0.00	18	1.80	2	1.30
Belodontichthys dinema	18	1.00	1	0.20	17	1.70	0	0.00
Cirrhinus microlepis	13	0.70	0	0.00	13	1.30	0	0.00
Notopterus notopterus	13	0.70	2	0.30	11	1.10	0	0.00
Bagarius spp.	12	0.70	2	0.30	10	1.00	0	0.00
23 Most Abundant Species	1689	95.50	575	96.10	962	95.60	152	96.10
Other Species	75	4.50	23	3.90	44	4.40	6	3.90
Total	1764	100.00	598	100.00	1006	100.00	158	100.00
Nº Gear Set	541		175		333		33	
Catch per Nº Gear Set	3.27		3.42		3.02		4.79	
Month			Nov	Dec	Jan	Feb	Mar	
Nº Gear Set			76	99	218	115	33	
Catch per Nº Gear Set			3.60	3.20	3.50	2.20	4.80	

Note: Nº = number of individuals, % Nº = percentage of the total catch

the overall trends are very similar to results achieved from the hydro-acoustic surveys.

The distribution of sizes of fish was uniform regardless of the depth of the pool. The largest fish (there were few specimens over 50 cm in length) were caught using long line and Teuk Long, gears that are more commonly used in deeper pools (Figures 17 and 18).

Both catch-rate and the distribution of fish sizes showed interesting variations during the survey period (Figure 19). The catch-rate was constant through the first three months of the survey but fell sharply in February before peaking in March. However, the average individual weight rose through December to January (from a high in November), before declining sharply in March.

The CPUE data in March (large numbers and small fish) conflicts with hydro-acoustic records that recorded high biomass and low fish density (small numbers and large fish) during the dry season of months of February and March. The reasons for this discrepancy are not clear; they could be the result of:

- Fishers changing their fishing grounds in March during the low water period to areas with smaller fish;
- Large fish living so deep in the pools that they are out of reach of the fishers;
- The data collected during these months being unrepresentative, as comparatively few gears were set during March (Table 6).

One of the reasons people stopped fishing was the presence of large growth of filamentous algae during the dry-season when the water was clear. These algae are a severe impediment to the fishery and several fishers complained that drifting algae choked their nets at this time of the year.

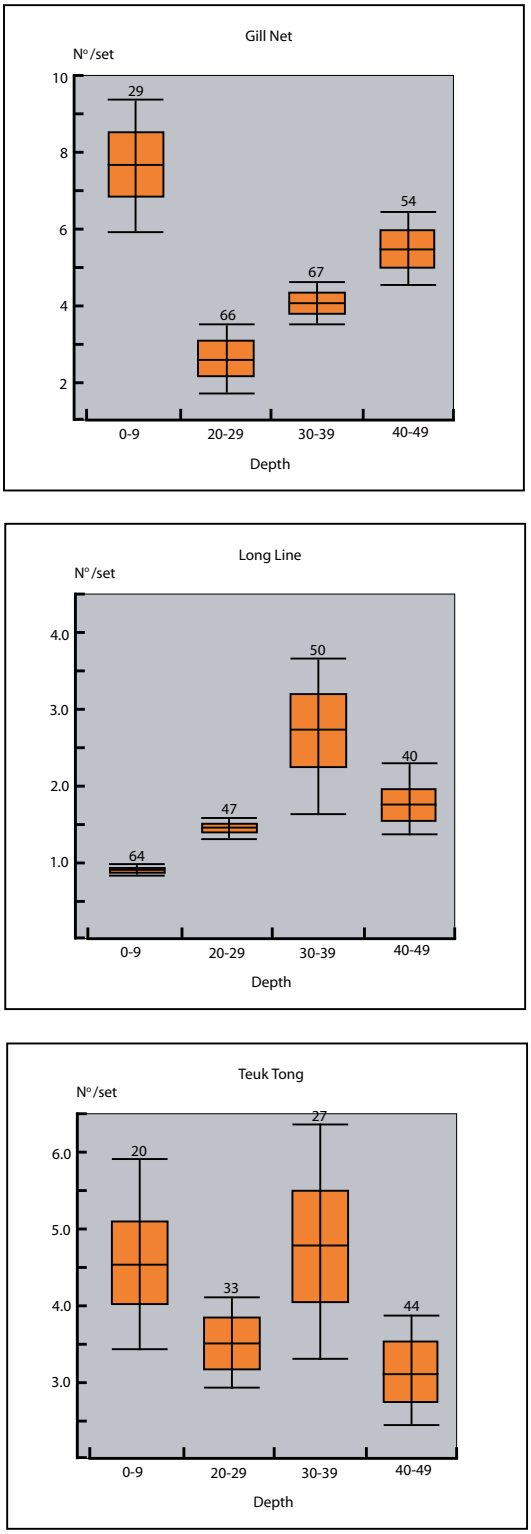


Figure 17. Catch rates (number of gear set) by depth of pool grouped into 10 m intervals.

Boxes = mean ± SE

Bars = mean ± 95% confidence interval (alpha =0.005)

Numbers above bars = sample size

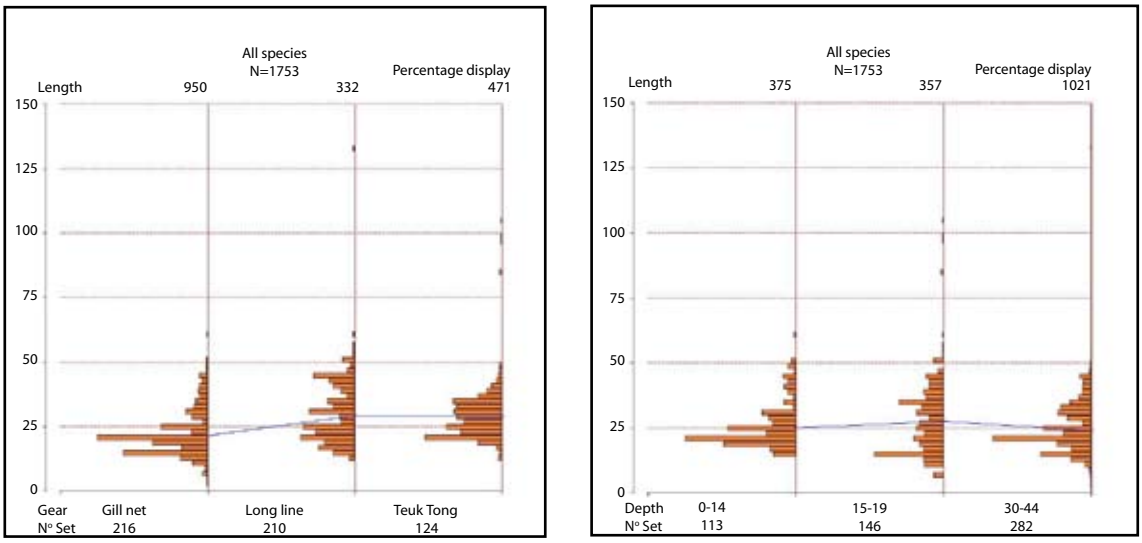


Figure 18. Length frequency distribution by gear type (left) and depth of pool (right) with mean length superimposed (blue lines).

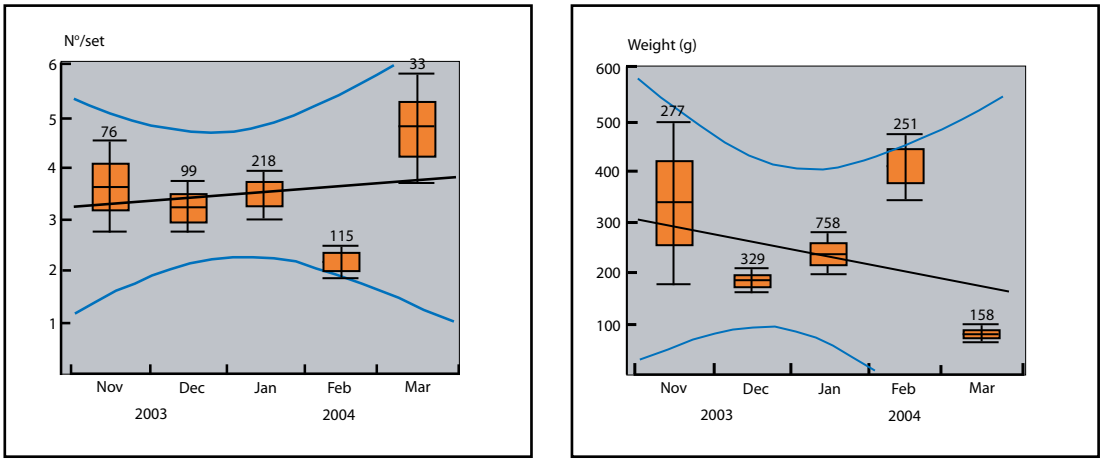


Figure 19. Mean catch rate (left) and individual mean weight (right) by month.

Boxes = mean ± SE

Bars = mean ± 95% confidence interval (alpha =0.005)

Numbers above bars = sample size

Superimposed linear trend line on means (N=5) with 95% confidence intervals (not significantly different from 0 in both panels)

5. Conclusions and recommendations for further work

The results of the 2003–4 survey show that hydro-acoustics can generate valuable information about the distribution and behaviour of fish living in deep pools. Much of this information cannot be obtained from conventional surveys of fishers and their catches. The images provided by echograms show the location of individual fish and shoals of fish in pools and analyses of strength of echoes returned by fish provide information on the size of fish, fish density and the distribution of biomass.

However, the method has limitations. It cannot be used to identify fish species and, because some species have small or no swim bladders, the measures of biomass and fish density derived from hydro-acoustics are qualitative, or comparative, rather than quantitative.

Notwithstanding these limitations, the 2003–4 surveys provide some intriguing insights into the behaviour of the fish living in deep pools. While fishers and fish biologists have long known that some species prefer particular pools, or positions within pools, hydro-acoustics provide the first visual images of fish and shoals of fish congregating in specific riverine habitats. Moreover, GPS siting of the surveys provides the means to map the location of fish and shoals of fish with precision.

The surveys also brought to light interesting geographical and seasonal fluctuations in both biomass and fish density. At present however, the meaning of these fluctuations, in terms of fish behaviour and ecology, is obscure. This is partly because of inadequate coverage (although at least three transects were recorded at each location, many of the files could not be analysed due to noise, and only five pools in Lao PDR were covered in both wet and dry seasons, while the Cambodian pools were only surveyed during the wet season) and partly because information from the hydro-acoustics also needs to be properly integrated with data on other ecological factors, such as vegetation, flow, currents and substrate, that influence fish behaviour.

Given that the hydro-acoustics can provide scientifically valuable data, the broader question arises as to the practical value of this new information in the wider objective of managing the sustainable development of the Mekong's natural water resources in general and its fisheries in particular.

Clearly, as deep pools are important dry season refuges for many of the Mekong's commercially important fish species, any changes in the ecology of these habitats may have serious repercussions for the fisheries further downstream. At present, the pools and the fisheries are in reasonably good health. The diversity of the species and number of large fishes indicates that, as yet, the pools are not over-fished and agricultural or industrial pollutants do not yet seriously threaten the environment of the pools (MRC, 2003). However, the pressures of feeding the basin's expanding population and the need for sustainable development of all the natural resources provided by the Mekong may change this in the future.

Therefore, monitoring the ecological status of the pools and the condition of their aquatic fauna is important, not only for the conservation of local fisheries, but also for the livelihoods and food security of many of the basin's inhabitants. It is a genuine trans-boundary issue that potentially affects people in all four MRC member countries. Moreover, many environmental scientists consider the health of the deep pools is indicative of the health Mekong and its tributaries and recommend monitoring the pools as a check on the condition of the river system as a whole (Poulsen *et al*., 2002).

Hydro-acoustics could provide one practical way to perform this type of monitoring. The technique has many advantages; once purchased the equipment has low operating costs, the surveys are repeatable and data is quickly and easily acquired, they do not harm fish and are suitable for use in ecologically sensitive sites and FCZs, that are off-limits to fishers.

However, environmental monitoring requires detailed knowledge of existing baseline conditions from which to identify and measure changes in the ecology and the faunas of the deep pools. This knowledge does not currently exist, particularly concerning the information provided by hydro-acoustics. Therefore, future work, at least in the short-term, should aim at defining these baseline conditions.

In the case of hydro-acoustics, this involves:

- Compiling a GIS database of deep pools containing hydrographic maps, and data on hydrology, ecology and faunas.
- Evaluating the information echograms provide about the distribution of fish in individual pools in relation to the configuration of the riverbed, the nature of the substrate, local currents and other environmental parameters.
- Analysing biomass and fish density data in 10 metre depth strata rather than by the maximum-recorded pool depth.
- Recording and mapping biomass and fish density in individual pools at varying times of day and during different seasons.

Much of this work can be accomplished using existing hydro-acoustic data; however, the last activity requires acquisition of new data. Ideally, these new surveys should focus on acquiring a denser grid of data over a small number of pools that are easy to access and present few operational problems.

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Appendix 1. Index of fish species with their Lao names

Species code	Lao name	Scientific name
3	ປາຕອງດາວ	*Chitala ornata*
4	ປາຕອງລາຍ	*Chitala blanci*
5	ປາຕອງ	*Notopterus notopterus*
7	ປາໝາກຜາງ	*Tenualosa thibaudeaui*
9	ປາສະນາກນ້ອຍ	*Lycothrissa crocodilus*
11	ປາແຕບ	*Paralaubuca typus*
23	ປາເອິນຕາແດງ	*Probarbus jullieni*
24	ປາເອິນຂາວ	*Probarbus labeamajor*
27	ປາໂຈກ , ປາໝາກບານ	*Cosmochilus harmandi*
29	ປາຈອກຫົວແຫລມ	*Cyclocheilichthys enoplos*
34	ປາສະກາງແຫລ້ , ດຳ	*Puntioplites proctozysron*
35	ປາສະກາງ	*Puntioplites falcifer*
39	ປາປາກນາ	*Barbonymus gonionotus*
44	ປາປາກໝວດ, ປາຂີ້ປູນ	*Hypsibarbus malcolmi*
50	ປາສູດຂ້າງຈຸ້	*Hampala dispar*
51	ປາສູດຂ້າງແຊກ	*Hampala macrolepidota*
52	ປາກະໂຫ, ປາຂະມັນ	*Catlocarpio siamensis*
54	ປາຫວ່າໜ້ານໍ	*Bangana behri*
58	ປາເຟັ້ຍດຳ	*Labeo chrypsophekadion*
59	ປາພອນ	*Cirrhinus microlepis*
63	ປາສ້ອຍຫລັງໝາມ, ປາສ້ອຍທົ່ວໄປ	*Henicorhynchus siamensis*
66	ປາອີ່ໄຫ, ປານິກເຂົາ	*Osteochilus hasselti*
74	ປາສະອີ	*Mekongina erythrospila*
77	ປາໝູ	*Botia modesta*
79	ປາແຂ້ວໄກ້ , ປາໝູລາຍ	*Botia helodes*
84	ປາກົດເຫລືອງ	*Hemibagrus nemurus*
86	ປາກົດໝໍ້ , ປາກົດດຳ	*Hemibagrus wyckii*
90	ປາແຂ້ຄວາຍ	*Bagarius yarrelli*
91	ປາແຂ້ງູ	*Bagarius bagarius*
93	ປານາງແດງ	*Hemisilurus mekongensis*

Species code	Lao name	Scientific name
95	ปาเຊືອม , ปาปີກໄກ່	*Kryptopterus cryptopterus*
96	ปานาๆ , ปาสะงิ้ว, ปาหลังຂຽว	*Micronema apogon*
97	ปานาๆ , ปาสะงิ้ว	*Micronema bleekeri*
99	ปาค้าว	*Wallago attu*
100	ปาลูม	*Wallago leeri*
101	ปาหน้าหนู , ปาหอย	*Helicophagus waandersii*
102	ปาเผะ , ปาแกว	*Pangasius conchophilus*
103	ปาห็อม่อม, ปายาๆ , ปาแกว	*Pangasius bocourti*
104	ปาຊอายแดงๆ , ปาຊอายแຂ้ว	*Pangasianodon hypophthalmus*
105	ปาຊอายขาว , ปาຊอายหมากไม	*Pangasius krempfi*
106	ปาຊอายหางห้ำม	*Pangasius polyuranodon*
107	ปาปึ่ๆ , ปาหูหมาด	*Pangasius larnaudii*
108	ปาเลิม	*Pangasius sanitwongsei*
110	ปายอม	*Pangasius macronema*
111	ปายอมห้องกิม	*Pangasius pleurotaenia*
112	ปายอมหลังก่ๆ	*Pangasius siamensis*
113	ปายอมตาโล้	*Laides hexanema*
118	ปาหลาดดำ	*Mastacembelus armatus*
121	ปากอาๆ	*Boesemania microlepis*
122	ปาก่า	*Pristolepis fasciata*
125	ปากะเดิด	*Trichogaster trichopterus*
126	ปาเໝັ้นสิบหัก	*Osphronemus exodon*
128	ปาຄໍ่	*Channa striata*
142	ปาตองดำ	*Chitala lopis*
175	ปาปีกไก่ , ปาเຊือมขาว	*Micronema cheveyi*
178	ปาห็อม่อม, ปายาๆ, ปาຊอายหางห้ำม, ปาຊอายหางแห้ม	*Pangasius kunyit*

Appendix 2. Information gathered from villagers about the areas covered by the CPUE survey

BAN HAT

Total population: 868

Household: 178

Fishers: 210

Paddle boats: ?

Motor boats: ?

Other villages fishing in the area:

Ban Nok Kok, Ban Veun Khao, Ban Houay, Ban Na and Ban Hang Khong.

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Vang Kong Phou	25 wa/37 m	80 m x 300 m	-	-
Vang Hin Soung (high rock)	15 wa/25 m	80 m x 200 m	-	-
Na Ta Sao deep pool	-	-	-	-
Sand Beach "San Wa"	-	-	-	-
Vang Song Kham	-	-	Rocky with caves	Many fish species live in the deep pool

Other important fish habitats:

Streams: Houay Na

Fishing gears:

Name of Fishing gear	Fishing season	Number of fishers
Stationary gill net	-	-
Long line	-	-
Drift net	-	-
Chan trap	Flood	-
Kha trap	Flood	-
Lanh trap	Flood	-

Important species include:

Pa Noo, Pa Kae, Pa Nang Deng, and Pa Sa Ngua

Pa Nang Deng is known to spawn in the deep pool. The species normally stay in the deep pool during the day and move to shallow water during the night.

Species occurring in the deep pools and the gears with which they are caught:

Species Code	Months	Size (cm)		Other information
		Min.	Max.	
7	3-6	5	20	
20	5-6		15	Catch juveniles from March to June
23	5-6		30	Caught one fish weighing 37 kg in December
44	2-5		10	Max size 2 kg
100	10		10	Juveniles
97	1-12	5	50	
54	2-5	15	40	Max size 5 kg
93	2-5	10	35	1 kg is max weight caught with all gears
105	6		30	Few
103	1-12	20	30	Max size 1.5 kg
121	3-5	-	-	Few app. 5 per year Max size 1 kg
110	1-12	15	25	
107	5-6		25	Max size 1 kg
104	10		35	Caught with cast net
108	10		5	Juveniles

BAN HAT SAY KHOUN

Total population: 1257

Households: 219

Fishers: 219

Motor boats: 40

Paddle boats: 160

Other villages fishing in the area (numbers in brackets refer to number of fishers):
Ban Nang Khuat (5-6), Khong Island (30), Ban Nok Kok (10) and Ban Houay Kaeng (40).

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Don Sam Lan	-	-	-	FCZ established in 1996[1]
Khoum Phi	20 m	100 m * 200 m	Small stones and sand	-
Veun Tong	6-7 m	-	Small stones and sand	-

Other important fish habitats:

Rapids: Kaeng Khan Yang, Kaeng Houa Don Sam Lane, and Kaeng Khan Hin Lack

Streams: Houay Kaeng, Houay Vang Ka Dao and some canals

Fishing gears:

Name of gear	Fishing season	Number of fishers	Other information
Gill net	-	-	-
Longline	-	-	-
Cast net	-	-	-
Lop	-	-	-
Chan	-	-	-
Teuk Tong	-	-	Was previously used in Veun Tong
Spear	-	-	-

Species occurring in the deep pools and the gears with which they are caught:

Code	Few	Many	Month	Size (cm)		Surface	Middle	Bottom	Types of Fishing
				Min	Max				
118	x		5-6	2	60	x			Gill net, long line, cast net
034		x	5-6	2	20	x			Gill net, cast net
007	x		3-4	2	20	x			Gill net
011		x	3-4	2	15	x			Gill net, cast net, Toom trap
003	x		1-12	6	60	x			Gill net, long line , cast net, lift net
004		x	1-12	6	60	x			Gill net, long line, cast net, lift net
005		x	6-9	5	10	x			Gill net, long line, cast net, lift net
142		x							
099	x		3-5	2	100	x			Gill net, long line, cast net
050		x	6-10	3	15			x	Gill net, long line , cast net
051	x		6-10	3	15			x	Gill net, long line , cast net
029	x		1-12	5	20			x	Gill net, long line, cast net
023		x	5-6	5	30			x	Gill net, long line, cast net, Lop trap
024	x		10-12	5	100			x	Gill net, long line
035		x	5-6	5	10	x			Gill net, cast net
044		x	1-4	5	15	x			Gill net, long line, cast net
039		x	3-6	5	15	x			Gill net, long line, cast net, Lane trap
027		x	5-12	5	30	x			Gill net, cast net, Lop trap
126	x		3-4	5	30	x			Hook and line
100	x		3-4	10	100	0		x	long line, lift net (xon)
175		x	6-7	3	15	0		x	Gill net, long line
095	x		6-8	2	5	x	x	x	Gill net, long line, cast net
097		x	6-8	3	10	x			Gill net, long line
096	x		10-2	10	70			x	Gill net, long line, hook line
097 A	x		3-4	10	70			x	Gill net, long line
093		x	3-4	5	40			x	Gill net, long line
121	x		3-4	10	60			x	Gill net, long line, cast net
110		x	1-12	5	20	x			Gill net, long line, cast net

Code	Few	Many	Month	Size (cm)		Surface	Middle	Bottom	Types of Fishing
				Min	Max				
112		x	1-12	5	20	x			Gill net, long line, cast net
111		x	1-12	5	20	x			Gill net, long line, cast net
113									
107	x		6-11	30	50			x	Floating long line
104	x		6-11	5	100	x			Gill net, long line , cast net
106		x							
108		x	6-7	10	20			x	Long line
066	x		3-4	10	20	x			
122	x		1-12	3	12	x			Gill net, cast net
009		x							
125		x							
090		x	1-12	5	100			x	Long line, cast net
091	x		1-12	8	30			x	Long line, cast net
052		x							
128		x							
084		x	1-12	2	60	x		x	Gill net, long line, cast net, hook and line
086	x		1-12	2	60			x	Gill net, long line, cast net, hook and line
079	x		4-5	2	10	x		x	Gill net, long line, cast net, Lane trap
077		x	3-6	2	10			x	Gill net, long line, Toom trap
054	x		3-5	10	40			x	Gill net, cast net, Teuk Tong
058		x	1-12	5	40	x			Gill net, cast net, Kha, Lop, and Chan traps
059		x	1-4	15	60	x			Gill net, cast net
063		x	3-6	5	10	x			Gill net, cast net
102		x	1-12	5	70	x			Gill net, long line, cast net, floating hook
105	x		1-12	2	100	x			Long line, floating hook
101		x	1-12	7	40	x			Gill net, long line
178		x	8-12	8	80	x			Floating long line
103									

BAN PHI MAN PHON

Total Population: 723

Households: 119

Fishers: 400

Paddle boat: 119

Motor boat: 60

Other villages fishing in the area: Ban Deua and Ban Hang Khong (50 fishermen in total).

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Vang Kok Khao	5 m	50 m x 250 m	Rocky	
Vang Tha Wat	8 m	50 m x 250 m		FCZ, established in 1997[2]
Vang Tha Wat Hang Khong	5 m	100 m x 250 m	Rock	

Other important fish habitats:

Rapids: Kaeng Hang Phi Man, Kaeng Phi Man 1, and Kaeng Phi Man 2.

Fishing gears:

Name of gear	Season	Number of people
Gill net	Dry season	400
Long line	-	-
Cast net	Flood season	400

Important fish species in the dry season: Pa Phia, Pa Pak, Pa Tong, Pa Kheung and Pa Mak Ban

Important fish species in the flood season: Pa Kop, Pa Nang, Pa Khae, Pa Kae and Pa Peung.

Species occurring in the deep pools and the gears with which they are caught:

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Min.	Max.			
074			01-06	20	25		x	Hook
118			06-10	0	40		x	Hook
043			09-11	12	0	x		Lop (trap)
011			02-06	10	15	x		Gill net, Cast net
003			01-12	30	70	x		Cast net, Gill net, Lop
004			01-12	30	50	x		Cast net, Gill net, Lop
005			01-12	30	50	x	x	Cast net, Gill net, Lop
142			01-12	20	70	x		Cast net, Gill net, Lop
099			07—12	30	80	x		Cast net, Gill net, Lop
050			01-12	20	60	x	x	Cast net, Gill net
051			01-12	20	60		x	Cast net, Gill net
029			09-12	20	50		x	Cast net, Gill net
023	x		05-06	15	30		x	Long line
024		x	05-06	15	30		x	Cast net, Gill net
035		x	10-12	5	10	x		Lop (trap)
044	x		01-12	20	40		x	Cast net
039		x	01-12	20	40		x	Cast net
027		x	12-06	20	50		x	Cast net
126		x	12-06	20	40	x	x	Cast net
175		x	07-12	10	25	x		Cast net
095	x		07-12	10	25	x		Lop (trap), Hook
097	x		06-12	20	50	x		Hook, Drift net (xon)
096	x		06-12	20	50	x		Hook, Drift net (xon)
097 A	x		06-12	20	50	x		Hook, Drift net (xon)
093	x		06-12	20	50	x		Hook, Drift net (xon)
121	x		01-06	20	50	x		Cast net
110	x		05-12	10	20	x	x	Gill net, Hook, drift net
112	x		05-12	10	20	x		Gill net, Drift net (xon)

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Min.	Max.			
111	x		05-12	10	20	x	x	Gill net, Hook, Drift net
113	x		05-12	10	20	x		Gill net, Drift net (xon)
107	x		06-12	20	40	x		Long line, Tao Hook
104	x		06-12	20	40		x	Tao Hook
108	x		10-12	15	20		x	Long line
066	x		05-06	15	20		x	Gill net
122	x		01-12	15	20		x	Gill net
099	x		03-04	15	20	x		Cast net
090	x		12-06	30	70	x		Long line
091	x		12-06	15	30	x		Long line
128	x		01-12	20	40	x		Lop (trap)
084	x		01-12	15	30	x		Long line
086	x		01-12	15	30	x		Long line
079	x		04-06	10	20		x	Cast net, Long line
077	x		04-06	10	20		x	Cast net, Gill net
054	x		02-06	15	30		x	Cast net, Gill net
058	x		01-12	20	40		x	Cast net, Gill net
059		0	01-06	20	50	0	x	Cast net, Gill net
063		0	04-06	10	15	0	x	Cast net, Gill net
102		0	06-12	15	30	0	x	Long line, Gill net
105		0	06-12	40	80	0	x	Long line
101		0	06-12	15	30	0	x	Long line
178		0	06-12	15	30	0	x	Long line, Tong
103		0	06-12	15	30	0	x	Long line, Tong

BAN NANG KHOUAT, KHONG DISTRICT

Total Population: 537

Household: 86

Fishers: 100

Paddle boat: 86

Motor boat: 37

Other villages fishing in the area (numbers in brackets refer to the estimated number of fishers from the concerned village):

Muang Sene, Ban Hin Siw, Ban Huay Thang Khong, Ban Phi Man Phone, Ban Nop Pak Dy, Ban Deua Tai (70), Ban Tha Pho Tai (111), Ban Done Sang Phai (150), Ban Tha Pao (86), Ban Kaeng Khoum (115), and Ban Don Peuy (10).

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Vang Kon Houat	6 m	100 m x 100 m	-	-
Vang Tha Wat	7-8 m dry season 10 m wet season	300 m x 100 m	Rock and mud	FCZ, established in 1995[3]
Vang Tha Wat Hang Khong	5 m	100 m x 250 m	Rock and mud	-
Vang Euay	2 m	50 m x 50 m	Rock and mud	-
Vang Kaeng Luang	5 m	250 m x 100 m	-	-
Veun Hay	6 m	200 m x 100 m	-	-
Veun Hoy	5 m	(200 m x 100 m)	-	-
Veun Seng	5 m	(200 m x 0 m)	-	-
Veun Sa Nen	5 m	-	Rock + Sand	-

Other important fish habitats:

Rapids: Kaeng Tami, and Kaeng Luang

Fishing gears:

Name of gear	Season	Number of fishers	Other information
Gill net	-	-	-
Cast net	-	-	-
Long line	-	-	-
Spear	-	-	-
Drifting hook	-	-	-
Lop trap	-	-	-
Chan trap	-	-	-

Species occurring in the deep pools and the gears with which they are caught:

Code	Month	Size		Surface	Bottom	Fishing gears
		Min.	Max.			
047	2-5	2	25-30		x	Gill net, cast net
118	1-12	5	40-50			Gill net, long line
011	3-6	0	15	x		Gill net, Xon
003	1-12	0	60	x		Long line, Lop and Chan traps
004	1-12	0	60	x		Lop and Chan traps
005	1-12	0	20	x		Xon
099	6-12	0	100	x		Long line, Lop and Chan traps
050	1-12	10	40	x		Long line, cast net, Lop trap
029	10-5	10	50	x	x	Gill net, long line, Lop trap
023	5-12	10	25	x	x	Gill net, long line, cast net
044	3-12	15	30			Gill net, cast net, Lop trap
027	10-6	0	60		x	Long line, Lop and Chan traps
110	1-12	5	20	x	x	Long line, Xon
112	1-12	5	20	x	x	Xon
111	1-12	5	20	x	x	Xon
104	6-12	10	60		x	Gill net, floating hook
066	3-6	5	20	x		Gill net, cast net
090	9-12	10	50		x	Gill net, long line
084	1-12	0	50		x	Long line, Hook and Line
086	10-2	0	50		x	Gill net, long line, cast net
054	3-6	0	40		x	Gill net, cast net
058	1-12	0	40	x	x	Gill net, cast net
059	3-6	0	50	x	x	Gill net, cast net
102	6-10	0	40		x	Gill net, long line
101	6-11	0	40		x	Gill net, long line

BAN DON HOUAT

Total Population: 615

Household: 97

Fishers: 200

Paddle boats: 104

Motor boats: 40

Other villages fishing in the area:

Ban Boung , Ban Sam Khang, Ban Houa Kaeng, Ban Hat Say Khoun, Ban Nok Kok, Ban Veun Khao, Ban Phon and Ban Sam Khang. The total number of fishers from other villages estimated to 10.

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Vang Tha Wat	5-6 m	-	-	-
Veun Done Ta Pia 1	10 m	80 m x 100 m	-	-
Veun Done Ta Pia 2	7 m	50 m x 100 m	-	-
Veun Nong Hai	15 m	100 m x 200 m	-	FCZ established in 1993[4]
Veun Hang Done Mak Kok	10 m	60 m x 50 m	-	-
Veun Nong Nok Or Hor	15 m	50 m x 70 m	-	-

Other important fish habitats:

Rapids: Kaeng Ton, Kaeng Nang Kai Sone, Kaeng Nang None, Kaeng Ai Kham, Kaeng Noy, Kaeng Done Phai

Streams: Houay Yang

Fishing gears:

Name of gear	Season	Number of fishers	Bottom	Other information
Gill net	All the year	-	-	-
Cast net	All the year	-	-	-
Long line	All the year	-	-	-
Spear	All the year	-	-	-
Drifting hook	All the year	-	-	-
Lop trap	Flood	-	-	-
Chan trap	Flood	-	-	-

Species occurring in the deep pools and the gears with which they are caught:

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Min.	Max.			
003			01-12	5	20	x		
101			01-6	5	10		x	
011			04-07	3	10		x	
099			01-11	3	15	x		
118			02-05	50	70		x	
175			01-01	15	50	x	x	
095			01-01	15	50	x	x	
096			01-01	15	30	x		
097			01-01	15	30	x		
093			01-01	15	30		x	
035			01-01		25		x	
058			01-05		30	x		
090			01-2		30		x	
110		x	01-12		20	x	x	
112		x	01-12		20	x	x	
111			01-12		20	x	x	
023		x	05-09	15	20	x	x	
024		x	05-09	15	20	x	x	
029		x	01-02		40	x	x	
050		x	01-02		30	x	x	
051			01-05		30	x	x	
063			02-05	10	15	x	x	
104			02-05		40		x	
102			01-02		20		x	
105			02-05		50		x	
004			01-01		30		x	
107			06-09		60		x	
039			02-05		20		x	

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Min.	Max.			
005			02-03		20		x	
103	x		02-04		25		x	
121	x		01-05		50		x	
77	x		02-05		15		x	
59	x		02-05		50		x	
27	x		01-06		30		x	
48	x		01-02		30		x	
100	x		01-02		50		x	
044	x		05-07		30		x	
178	x		01-02		40		x	
091	x		01-02		60		x	
79	x		02-05		15		x	
128	x		01-05		35	x	x	
142	x		02-03		70	x	x	
086	x		01-02		40	x	x	
113	x		02-05		10		x	
74	x		02-03		30		x	
066	x		01-05		30		x	
034	x		01-02		15		x	

BAN KOK PA DEK

Total Population: 442

Households: 74

Fishers: 100

Paddle boats: 25

Motor boats: 23

Other villages fishing in the area (numbers in brackets refer to the estimated number of fishers):

Ban Chan (100), Ban Tao Poung (100), Ban Deua Tia (100), Ban Song (10), Ban Sa Phang Neua, Ban Sa Phang Tai and Ban Done San (20).

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Veun Wa	50 m	300 m x 300 m	Rocky	FCZ established in 1998[5]
Veun Lom Phat	15 m	150 m x 300 m	Rocky	-

The main species are:

Pa Nang Daeng, Pa Eun and Pa Kouang (of which they have observed fingerlings)

The giant species Pa Kaho and Pa Leum can be found year round.

Pa Noo, Pa Nang and Pa Nyon stay in the deep pool during the day time and leave to forage in more shallow water during the night.

Fishing gears:

Name of gear	Season	Number of fishers	Other information
Drift net (4-13 cm)	March-July	74	-
Long line	Oct-March	10	-
Lop trap	July- Dec	10	Along shore line
Chan trap	July- Dec	10	Along shore line

Species occurring in the deep pools and the gears with which they are caught:

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Mini	Max			
118			01-12	20	30		x	Hook, Gill net
007			06-02	10	15	x		Gill net
034			01-12	15	20		x	Gill net
011			05-06	10	15	x		Gill net
003			08-11	20	60	x	x	Hook, Lop trap
004			08-11	20	60	x	x	Hook, Lop trap
099			08-11	60	100	x	x	Hook, Lop trap
029			01-12	20	60		x	Hook, Lop trap
023			01-12	15	20		x	Gill net
042			01-12	15	20		x	Gill net
035			01-12	5	20		x	Gill net
044		x	03-06	5	20		x	Gill net
039		x	01-12	10	25	x	x	Gill net
027			01-12	15	30		x	Gill net
175		x	04-06	10	15	x	x	Gill net, Long line
095		x	04-06	10	15	x		Gill net, Long line
096		x	01-12	20	40	x		Gill net, Teuk Tong, Hook
097		x	01-12	20	40		x	Gill net, Teuk Tong, long line
093			01-12	20	30		x	Gill net, Long line, Teuk Tong
121			01-12	15	50		x	Gill net
110			04-06	15	50	x	x	Gill net, Long line
112			04-06	15	20	x	x	Gill net, Long line
111			04-06	15	20	x	x	Gill net
107			06-07	40	50		x	Gill net
104			06-08	40	50	x	x	Gill net
090			10-12	40	50		x	Gill net, Long line
048			01-12	15	40		x	Gill net, Long line
086			10-07	15	30		x	Gill net, Long line

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Mini	Max			
077			02-06	6	15		x	Gill net, Long line
054			03-06	15	40		x	Gill net
058			01-12	15	40		x	Gill net, Cast net, Lop
059			03-06	20	40		x	Gill net
102			10-07	10	60		x	Gill net
101			1-12	15	40	x		Gill net, Lop , Long line
178			03-06	15	40		x	Gill net

BAN DON LEK FAI

Total Population: 600

Households: 95

Fishers: 200

Paddle boats: 95

Motor boats: 35

Other villages fishing in the area (numbers in brackets refer to the estimated number of fishers):

Ban Done Khao Mao (2-3), Ban Done Hee (30), and Muang Sene (2-3).

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Boung Pa Kuang	20 Wa	200 m x 200 m	Rocky	FCZ established in 1996[6]
Vang Mae Ta Bai	-	150 m x 150 m	-	-
Veun Kong Kaeng	8 Wa	50 m x 50 m	-	-
Veun Chan	18 Wa	50 m x 50 m	-	-
Veun Pa Duk	15 wa	50 m x 50 m	-	-

Fishing gears:

Name of gear	Season	Number of fishers	Other information
Drift net		-	-
Stationary gill net	October-May	95	-
Long line	October-May	50	-
Cast net	August-May	50	-
Chan trap	June-November	-	-
Lop trap	June-November	-	-
Hook and line	June-November	-	-
Teuk Tong	February-March	-	-

Other information:

Pa Kae, Pa Mak Ban, Pa Pho, and Pa Nang have fingerlings in October (the last one only few).

A giant catfish weighing 50-60 Kg was caught with a seine net in February-April some years ago.

Pa Kuang (*Boesemania microlepis*), Pa Nai (*Cyprinus carpio*) and Pa Tong (*Chitala* spp.) spawn in Veun Pa Kuang.

Species occurring in the deep pools and the gears with which they are caught:

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Min.	Max.			
096	x		2-5			x	x	Long line, Cast net
097			2-5			x	x	Long line, Cast net
093			10-12			x	x	Long line, Cast net
121			3-4			x	x	Gill net
110	x		3-4			x	x	Gill net, Long line
111	x		1-12			x	x	Gill net, Long line
112	x		1-12			x	x	Gill net, Long line
107		x	9-10			x	x	Long line
104		x	11-2			x	x	Long line, Seine net
085		x	10-6			x	x	Chan trap, Gill net, Long line
090	x		10			x	x	Drift net, Long line
091		x	10			x		Drift net, Long line
084	x		10-6			x	x	Gill net, Long line
086		x	10-6			x	x	Gill net, Long line
079		x	3-6			x	x	Gill net
077	x		3-6			x	x	Gill net, Long line
054		x	4-6			x	x	Cast net, Gill net
058		x	1-12			x	x	Cast net, Gill net
059		x	3-6			x	x	Cast net, Gill net, Lop
063		x	3-6			x		Gill net
102	x		8-10				x	Gill net, Long line
101	x		10-6				x	Gill net, Long line

BAN DON TAN TAVAN TOK

Total Population: 664

Households: 113

Families: 122

Fishers: 20

Paddle boats: 15

Motor boats: 5

Deep pools:

Name of deep pool	Depth	Size	Bottom	Other information
Vang KaThout	-	-	Rocky	-
Vang Tamy	-	-	Rocky	-

Other important fish habitats

Rapids: Kaeng Khi Thout, Kaeng Song Khone and Kaeng Lop.

Fishing Gears:

Name of gear	Season	Number of fishers	Other information
Gill net	-	10	-
Long line	-	10	-
Cast net	-	122	-

The Fish conservation zone has now been abandoned, but the ban on the use of explosives, electricity and poison is still enforced.

Species occurring in the deep pools and the gears with which they are caught:

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Mini	Max			
074	x		01-12	20	60		x	Gill net (Rapid)
118			01-12	15	20		x	Long line
034			11-06	10	15	x	x	Gill net, cast net
007		x	03	10	15	x	x	Gill net, cast net, Long line
011	x		03-04	5	8	x		Cast net, Lee (traps)
003		x	01-12	40	100	x		Cast net, gill net, Long line
004	x		01-12	40	100	x		Cast net, gill net, Long line
005		x	01-12	60	100	x		Cast net, gill net, long line
142		x						
099		x	03-06	40	100	x		Hook line
050	x		01-12	10	40		x	Cast net, gill net
051	x		01-12	10	40	x		Cast net, gill net
029		x	06	15	30	x	x	Cast net, gill net
023		x	11-12	10	80		x	Cast net, gill net, deep pool
024		x	11-12	10	80	x		Gill net, Cast net
035		x	01-12	5	15			Cast net shallow, deep pool
044		x	05-06	5	50			Cast net, gill net shallow
039		x	11-12	5	10		x	Cast net, gill net, deep pool
027	x	x	01-12	10	50	x	x	Gill net, Cast net
126		x	11-06	10	50	x	x	Long line, Hook line
100		x	09-10	15	100		x	Hook line, drifting, deep pool
175		x	09-10	10	20	x		Long line, gill net, cast net
095	x		09-10	9	15	x		Hook line
097	x		11-03	15	100	x		Gill net, Cast net
096								
097 A	x		11-02	15	100	x	x	Gill net, long line, hook
093		x	01-12	15	50	x		Cast net, Long line deep pool
121								

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Mini	Max			
110		x	06-07	10	20	x		Drifting net (xon) deep pool
112	x		11-03	10	20	x		Hook line, gill net
111	x		09-10	10	20	x		Gill net, drifting, hook line
113							x	
107		x	06-07	20	80	x	x	Lop, Tong, Hook deep pool
104	x		06-07	30	100	x	x	Lop, Nam (big net), Gill net
106								
108								
066		x	04-05	5	15	x		Gill net, Cast net deep pool
122	x		11-05	5	15	x		Shallow, gill net, Hook
009	x		04-05	5	20	x		Gill net, cast net, Hook
125								
090		x	01-12	20	100		x	Long line, gill net, Hook
091		x	01-12	15	100		x	Gill net, long line deep pool
052								
128		x	01-12	5	50		x	Lop (trap), hook
084		x	05-06	8	30	x		Gill net, long line deep pool
086		x	05-06	8	30		x	Long line, deep pool
079		x	03	5	10		x	Gill net, Lee (trap), Cast net
077		x	03	5	10		x	Gill net, Lop (trap), Cast net,
054		x	12-06	15	50		x	Gill net, Lee (trap), Cast net,
058		x	01-12	10	50		x	Gill net, cast net deep pool
059		x	03	20	50		x	Gill net, Lop (trap), Cast net,
063		x	03-06	5	10		x	Gill net, Cast net deep pool
102	x		06-07	20	50		x	Gill net, Lop (trap), cast net,
105	x		06-07	20	70		x	Gill net, Lee (trap), hook
101	x		09-10	20	50		x	Long line, (snail, shrimp)
178								

Code	Many	Few	Month	Size (cm)		Surface	Bottom	Fishing gears
				Mini	Max			
103								
103			06-12	15	30		x	Long line, Tong
103			06-12	15	30		x	Long line, Tong
103			06-12	15	30		x	Long line, Tong

Notes

1. The use of explosives and electricity, and fishing in the breeding season is not allowed and it is not permitted to actively scare the fish into the net. Nets are not allowed in small streams and canals and no fishing is allowed in the conservation zone. The village had a meeting with the neighbouring villages to announce the regulations.

Appendix 3. Taxonomic list of fish species known to live in deep pools, and information about their habits and the presence/absence of swimbladder

Family/Species	Swim bladder	Max. size	Habitat	Schooling	Status
Dasyatidae					
Dasyatus laosensis	No	62 cm	Benthic	No	Locally common
Notopteridae					
Notopterus notopterus	Yes		Pelagic	No	Common
Chitala blanci	Yes	90 cm	Pelagic	No	Locally common
Chitala ornata	Yes	100 cm	Pelagic	No	Common
Chitala lopis	Yes	150 cm	Pelagic	No	Rare
Anguillidae					
Anguilla marmorata	Yes	150 cm	Benthic	No	Rare
Clupeidae					
Clupeichthys aesarnensis	Yes	7 cm	Surface/Pelagic	Yes	Common
Tenualosa thibaudeaui	Yes	30 cm	Pelagic	Yes	Rare
Engraulidae					
Lycothrissa crocodilus	Yes	30 cm	Pelagic	Yes?	
Cyprinidae	Yes				
Paralaubuca typus	Yes	18 cm	Pelagic	Yes	Common
Macrochirichthys macrochirus	Yes	70 cm		No?	
Aaptosyax grypus	Yes	100 cm	Pelagic	No	Very rare
Cyprinus carpio	Yes	120 cm	Pelagic/benthic	Yes	Common
Probarbus jullieni	Yes	100 cm	Pelagic/benthic	Yes	Uncommon
Probarbus labeamajor	Yes	150 cm	Pelagic/benthic	Yes	Rare
Probarbus labeaminor	Yes	70 cm	Pelagic/benthic	Yes	Rare
Cosmochilus harmandi	Yes	100 cm	Pelagic/benthic	Yes	Common
Cyclocheilichthys enoplos	Yes	74 cm	Pelagic/benthic	Yes	Common
Puntioplites falcifer	Yes	35 cm	Pelagic/benthic	Yes	Common
Barbonymus gonionotus	Yes	33 cm	Pelagic/benthic	Yes	Common
Hypsibarbus malcolmi	Yes	50 cm	Pelagic/benthic	Yes	Common
Hampala dispar	Yes	35 cm	Pelagic	No	Common
Hampala macrolepidota	Yes	70 cm	Pelagic	No	Common
Catlocarpio siamensis	Yes	300 cm	Pelagic	No	Rare
Thynnichthys thynnoides	Yes	25 cm	Pelagic	Yes	Common
Bangana behri	Yes	40 cm	Benthic	Yes?	Common
Cirrhinus microlepis	Yes	65 cm	Pelagic	Yes	Common
Labiobarbus spp.	Yes	20 cm	Pelagic	Yes	Common
Henicorhynchus spp.	Yes	20 cm	Pelagic	Yes	Common
Labeo erythropterus	Yes	45 cm	Benthic	Yes?	Common
Labeo chrysophekadion	Yes	60 cm	Benthic	Yes	Common
Garra spp.	Yes	18 cm	Benthic	Yes	Locally common
Mekongina erythrospila	Yes	45 cm	Benthic	Yes?	Locally common
Cobitidae					
Botia spp.	Small	25 cm		Yes	Common
Acantopsis spp.	Small	23 cm	Benthic	Yes	Common
Gyrhinocheilidae					
Gyrhinocheilus spp.	Small	28 cm	Benthic	Yes	Locally common
Bagridae					
Mystus albolineatus	Yes	35 cm	Benthic	Small	Locally common

Family/Species	Swim bladder	Max. size	Habitat	Schooling	Status
Hemibagrus filamentus	Yes	60 cm	Benthic	Small	Common
Hemibagrus wyckii	Yes	71 cm	Benthic	No	Common
Hemibagrus wyckioides	Yes	120 cm	Benthic	No?	Common
Siluridae					
Belodontichthys dinema	Yes	80 cm	Benthic	No?	Common
Hemisilurus mekongensis	Small	80 cm	-	Yes?	Common
Micronema apogon	Small	77 cm	Pelagic	Yes	Common
Micronema bleekeri	Small	60 cm	Pelagic	Yes	Common
Wallago attu	Yes	200 cm	Benthic	Yes	Common
Wallago leeri	Yes	145 cm	Benthic	Yes	Common
Schilbeidae					
Clupisoma sinensis	Small	31 cm	-	Yes?	-
Pangasiidae					
Helicophagus waandersii	Yes	79 cm	Pelagic/benthic	Yes?	Common
Pangasianodon gigas	Yes	300 cm	Pelagic/benthic	No?	Very rare
Pangasianodon hypophthalmus	Yes	150 cm	Pelagic/benthic	No?	Locally common
Pangasius bocourti	Yes	100 cm	Pelagic/benthic	Yes?	Common
Pangasius conchophilus	Yes	60 cm	Pelagic/benthic	Yes?	Locally common
Pangasius mekongensis	Yes	90 cm	Pelagic/benthic	Yes?	Uncommon
Pangasius krempfi	Yes	80 cm	Pelagic/benthic	Yes?	Uncommon
Pangasius larnaudii	Yes	150 cm	Pelagic/benthic	Yes?	Uncommon
Pangasius macronema	Yes	35 cm	Pelagic	Yes?	Common
Pteropangasius micronemus	Yes	100 cm	Pelagic/benthic	Yes?	Rare
Pteropangasius pleurotaenia	Yes	30 cm	Pelagic	Yes?	Common
Pangasius elongatus	Yes	100 cm	Pelagic/benthic	Yes?	Locally common
Pangasius sanitwongsei	Yes	250 cm	Pelagic/benthic	No	Rare
Sisoridae					
Bagarius spp.	Small	200 cm	Benthic	No?	Common
Belonidae					
Xenentodon cancila	Yes	40 cm	Surface	Yes	Common
Synbranchidae					
Monopterus albus	No	70 cm	Benthic	No	Common
Mastacembelidae					
Macrognathus spp.	No	45 cm	Benthic	Small	Common
Mastacembelus spp.	-	90 cm	Benthic	No	Common
Datnioididae					
Datnioides spp.	Yes	49 cm	Pelagic	No	-
Scianidae					
Boesemania microlepis	Yes	100 cm	Benthic	No?	Rare
Nandidae					
Pristolepis fasciata	Yes	24 cm	Benthic	Yes?	Common
Eleotridae					
Oxyeleotris marmorata	Yes	50 cm	Benthic	No	Common
Scombridae					
Scomberomorus sinensis	No	200 cm	Pelagic	No	Rare

Family/Species	Swim bladder	Max. size	Habitat	Schooling	Status
Anabantidae					
Anabas testudineus	Yes	23 cm	Surface/pelagic	Small	Common
Osphronemidae					
Trichogaster trichopterus	Yes	15 cm	-	Yes?	Common
Osphronemus exodon	Yes	60 cm	Surface/Pelagic	No?	
Channidae					
Channa spp.	Yes	100 cm	Pelagic	Small	Common
Soleidae					
Brachirus harmandi	Small	10 cm	Benthic	No	Common
Tetraodontidae					
Tetraodon nigroviridis	Yes	17 cm	Pelagic	No	Common

For further information please contact

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