ADB

Technical Assistance Consultant's Report

Project Number: 40514
December 2009

Lao People's Democratic Republic: Preparing the Cumulative Impact Assessment for the Nam Ngum 3 Hydropower Project

(Financed by the Japan Special Fund)

Prepared by Vattenfall Power Consultant AB

in association with Ramboll Natura AB and Earth Systems Lao

Asian Development Bank

VATTENFALL

TA 4921-LAO: Preparing the Cumulative Impact Assessment for the Nam Ngum 3 Hydropower Project Component A, part 2

Final Report from the Monitoring Programme

December, 2009

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1 Introduction

1.1 Background

The primary purpose of this assignment is to prepare for Asian Development Bank (ADB) financing of the proposed Nam Ngum 3 Hydropower Project (NN3) located in the Nam Ngum River Basin (NNRB) in Vientiane Province, in central Lao PDR. The assignment has involved a first phase consisting of the preparation of a "Cumulative Impact Assessment" (CIA) and a second phase - the implementation of a basin monitoring programme over the 2008-2009 period. The first phase was completed in February 2008.

The second phase involves the design and implementation of an environmental monitoring programme for the NNRB, focusing on water-quality and aquatic-ecology monitoring, where fish catch by artisanal fishermen is used as an indicator of the latter. Implementation of the monitoring started in March 2008, and is scheduled to run until the end of October, 2009, with four reports planned. The first bi-annual monitoring report was filed in August, 2008, the second one in February, 2009, a third one in July, 2009 and this final monitoring report is filed at the time of writing this, December, 2009.

1.2 Project Area

The Nam Ngum River is located in north-central Lao PDR, within the Mekong River catchment. The Mekong River is one of the largest in the world and is ranked 8th in terms of average discharge with 15 000 m^3/s (MRC, 2001). The river originates in Tibet at approximately 5 000 m.a.s.l., and then flows south through China, Myanmar, Lao PDR, Thailand, Cambodia and Vietnam before discharging into the South China Sea. The total catchment area of the Mekong River is 795 000 km², out of which approximately 204 000 km² is within Lao PDR (McElwee and Horowitz, 1999).

The Nam Ngum catchment, with a size of 16 841 km^2, is one of the main tributaries of the Mekong River, having the second greatest mean annual discharge among major tributaries originating in Lao PDR (WRCCS, 2007). Rising on the Xiengkhuang plateau of Lao PDR, at the altitude of approximately 1 500 m.a.s.l, it flows in a south-westerly direction. The total length of the river is just over 400 km from its source near Ban Gnot Ngum village in Peak District, Xieng Khouang Province, to where it enters the Mekong River at Ban Pak Ngum, Vientiane Municipality. The mean annual discharge at the confluence with the Mekong is approximately 670 m³/s. The Nam Ngum 1 reservoir, located in the lower part of the catchment, supports a vibrant fishing industry.

2 Water-Quality Monitoring

2.1 Introduction

2.1.1 Purpose of Water-Quality Monitoring Programme

The Water-Quality Monitoring Programme has been designed as a gap-filling programme with the main purpose of monitoring baseline water quality and potential water-quality impacts from the development of hydropower projects in the NNRB. The Government operates seven water-quality monitoring stations in the NNRB. However, these stations only cover the lower part of the basin, in the Vientiane Plain. No station has been established for the upper part of the basin, where access is more difficult.

The development of hydropower projects is expected to alter water quality in the NNRB and consequently affect other water users and environmental values downstream and within project areas. Potential issues relating to water quality during the first few years of reservoir impoundment are likely to include:

- Localised increase in total suspended solids and turbidity in the vicinity of the reservoir banks, where erosion and landslides may be an issue;
- Thermal stratification, resulting in limited mixing of surface and deep-reservoir waters;
- Low dissolved oxygen content, low temperatures, slightly acidic conditions, generation of hydrogen sulphide, elevated metal content and higher salinity in the deep reservoir water;
- Release of phosphorus from decomposing organic matter could result in aquatic weed proliferation. Nutrient concentrations (nitrogen and phosphorus), will generally be higher in the deep reservoir water. Elevated ammonia may be an issue in deeper (anoxic) water.

Maintaining downstream water quality and maximising environmental and social benefits from clean water will need to be a major objective of the development of each hydropower project. Impacts from projects on water quality will have significant effects on a number of downstream and surrounding communities, and consequently on the project itself. Non-hydropower water uses include fishing, irrigated agriculture, domestic water supply, cooking, laundry, bathing and recreation.

The Government, through WREA, are planning on extending its water-quality monitoring programme considerably in the near future. Advanced plans for a “National Integrated Water Resources Management Program” exist in a draft form, which would support WREA in many aspects of water resources management, among them in the water-quality field.

The stated aim for the NNRB is to have around 20 monitoring stations for water quality in the basin, covering all parts. In discussions between our team and the government on how best to utilise our team’s limited resources, it was decided that three sites would complement the existing network and monitoring conducted by hydropower stations under construction (notably Nam Ngum 2 and 3 projects) in the best possible way. These are the sites WQ 1-3, indicated in Figure 1.

2.1.2 Environmental Legislation and Guidelines

2.1.2.1 Ambient Water-Quality Guidelines

Lao PDR Class 2 Ambient Water Quality Standards for Fresh Surface Waters (Lao PDR, draft, 1999): These draft national guidelines are included in the Water Resources and Environmental Agency's (WREA) Draft Regulation for Adoption of Ambient Environmental Standards. They provide ambient water-quality guidelines for fresh surface waters.

USEPA National Recommended Water Quality Criteria (2004): The USEPA criteria have been developed by the United States Environmental Protection Agency and are focused on human and ecosystem health protection.

2.1.2.2 Drinking Water Quality Guidelines

Lao PDR Ministry of Health Drinking Water Quality Guidelines (2004): The Ministry of Health has developed drinking water guidelines for Lao PDR in conjunction with WHO/UNICEF as specified in the Minister's Resolution No. 953/MOH. The Resolution specifies that: "*in specific catchment areas, where mining or industrial activities suggest an increased public health risk due to substances/parameters, those parameters should be tested using the present World Health Organization (WHO) recommended guideline values*".

WHO Guidelines for Drinking Water Quality (2004): The most recent version of the guidelines (3rd edition) was published in 2004. The WHO guidelines are specific to drinking-water quality and are widely used in developing countries.

2.2 Methodologies

2.2.1 Monitoring Techniques

The Monitoring Programme was designed primarily as an ambient monitoring programme with minimal laboratory support. The purpose was to monitor background conditions in the receiving environments that could be affected by the development of planned hydropower projects in the NNRB.

2.2.1.1 Main Content of the Water-Quality Monitoring Programme:

- Monitoring surface water quality of 3 stations – Nam Lik upstream of Nam Lik – Nam Xong confluence, Nam Xong upstream of Nam Lik – Nam Xong confluence, and Nam Ngum upstream of NN3 reservoir;
- Monitoring of 12 water-quality parameters at each monitoring location. These include 9 *in situ* parameters and 3 laboratory parameters;
- Monitoring and sampling of each site is carried out on a monthly basis;
- Ambient water-quality parameters are be monitored and sampled in accordance with Australian EPA guidelines (Environment Protection Authority (EPA) Victoria (2000). *A guide to the sampling and analysis of waters, wastewaters, soils and wastes*. Publication 441, 7th Ed.

2.2.1.2 Field (*in situ)* parameters include:

- **pH** – pH is relatively easy to determine *in situ* and can often be an indicator of general water-quality conditions. Buffering capacity is important to the ability of a water body to resist changes in pH due to addition of acid. Carbonates, bicarbonates and

hydroxides are the major contributors to alkalinity and excessive amounts of these compounds will result in a high pH;

- **Electrical Conductivity (EC)** – Electrical conductivity of water is directly related to the concentration of dissolved ionised solids in the water. Ions from the dissolved solids in water create the ability for that water to conduct an electrical current, which can be measured using a conventional conductivity meter. Electrical conductivity provides an approximate value for the TDS concentration, usually to within ten percent accuracy;
- **Oxidation Reduction Potential (ORP)** – This is a measure of the water system's capacity to either release or gain electrons in chemical reactions. The process of oxidation involves losing electrons while reduction involves gaining electrons. Like the pH measurement, ORP presents an aggregate quantity that may be based on many contributing factors, and therefore can be an indicator of water-quality issues. Unlike the pH measurement, ORP values are affected by all oxidising and reducing agents, not just acids and bases;
- **Dissolved Oxygen (DO), % of DO Saturation**– Dissolved oxygen is one of the most important factors influencing aquatic species. Particularly severe effects can occur when a reservoir is first formed and submerged vegetation and soil decomposes. As it does so, it will deplete oxygen in the reservoir water. Low DO can also result when reservoirs become thermally stratified with temperature changes. Deoxygenated water can be lethal to fish downstream;
- **Turbidity** – This is a measure of the cloudiness or haziness of the water and is caused by suspended sediments and algae. Turbidity in open water is often caused by phytoplankton and the measurement of turbidity is a key test of water quality. A high turbidity increases the risk for residents developing gastrointestinal diseases from water consumption, especially for immune-compromised people, because contaminants like virus or bacteria can become attached to the suspended solid;
- **Temperature** – One of the most common problems in reservoirs and downstream of reservoirs is a changed temperature profile, either cooler or warmer waters than usual for these areas;
- **Total Dissolved Solids (TDS)** – Total dissolved solids consist of organic and inorganic (such as nitrates, sulphates, and carbonates) substances dissolved in water. The most common chemical constituents are calcium, phosphates, nitrates, sodium, potassium and chloride, which are found in nutrient runoff, general storm-water runoff and runoff from areas where pesticides are applied. Naturally occurring total dissolved solids arise from the weathering and dissolution of rocks and soils,

2.2.1.3 Laboratory parameters include:

- **Ammonium** – High nutrient levels characterise reservoirs due to decaying biomass, as previously mentioned, and nitrogen and phosphorus are the two most common in hydropower reservoirs. Nitrogen is an important plant nutrient and may serve as a limiting factor in some waters, especially subtropical lakes;
- **Nitrate** – Refer to 'Ammonium';
- **Total Suspended Solid (TSS)** - Water exiting a turbine usually contains very little suspended sediment, which can lead to increased levels of erosion, scouring of river

beds and loss of riverbanks. Comparing pre- and post-impoundment TSS levels will help predict erosion levels and mitigate future problems.

2.2.2 Monitoring Locations

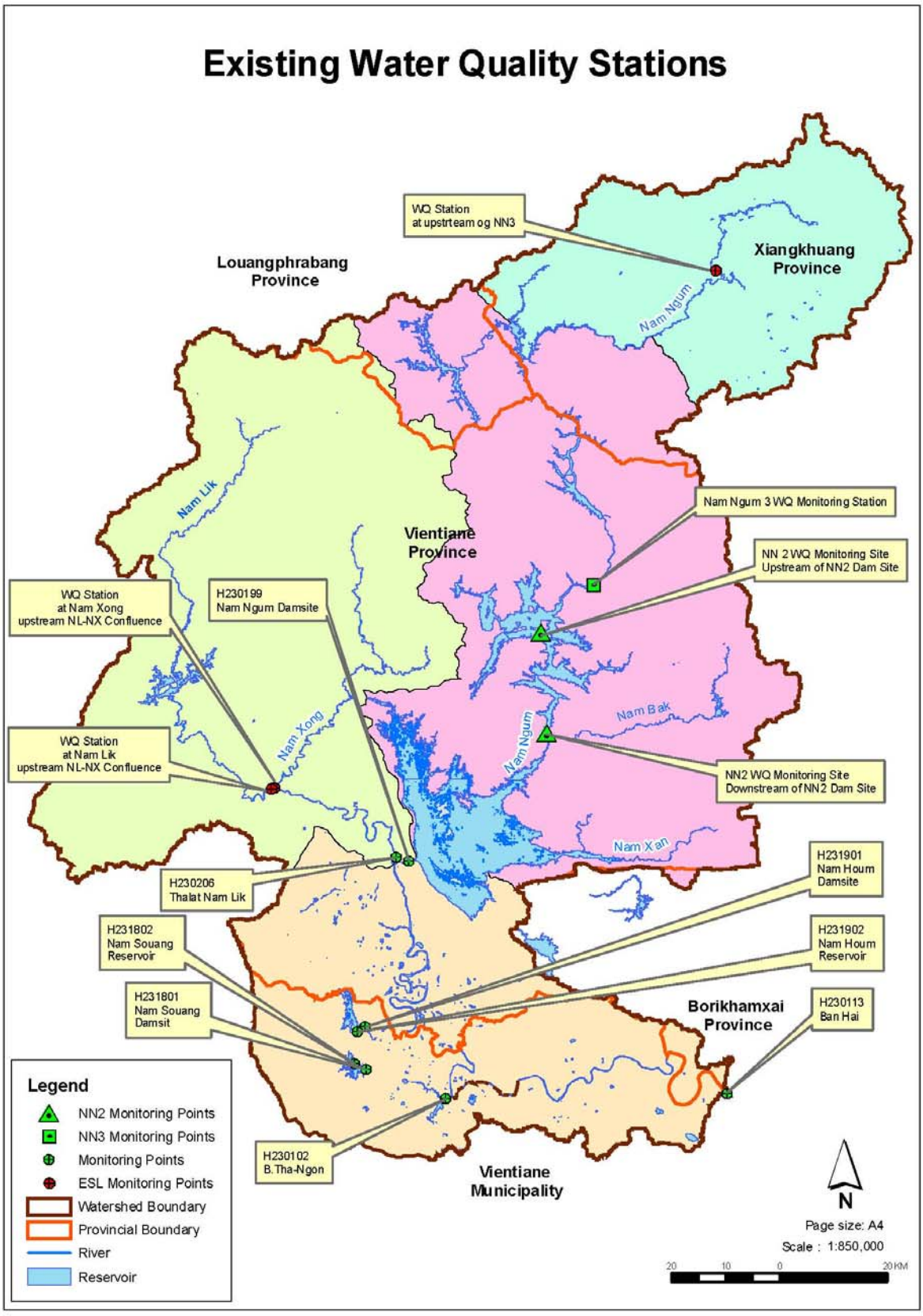
Three monitoring locations (to compliment the pre-existing seven (7), run by the Water Quality Analysis Lab (WQAL) were selected for the Water Quality Monitoring Programme. These locations are listed in Table 1 and shown in Figure 1. As illustrated in Figure 1, the water-quality monitoring stations are located in the middle and upper parts of the NNRB. Together with the existing water-quality monitoring stations, monitored by the WQML and those monitored by the NN2 and NN3 projects, the proposed stations were expected to provide sufficiently dense data in order to observe water-quality behaviour upstream and downstream of reservoirs, and consequently provide a background for future assessment of impacts from the development of hydropower projects on water quality of the main rivers in the basin.

Any potential water-quality impacts from increased agricultural activities in the Vientiane Plain, as well as the cumulative impacts from the series of impoundments that are planned, will be captured by the existing monitoring stations in the lower NNRB.

Table 1: Water-quality monitoring sites in the NNRB monitored by the NN3 CIA Project (see also Figure 1).

Site number	Location	Easting	Northing	Rationale	Frequency
WQ 1	Nam Lik upstream of Nam Lik-Nam Xong confluence	102.29676794	18.64290398	Determine background water quality in the Nam Lik	Monthly
WQ 2	Nam Xong upstream of Nam Lik-Nam Xong confluence	102.30153708	18.64561452	Determine background water quality in the Nam Xong	Monthly
WQ 3	Nam Ngum upstream of NN3	103.06696342	19.52214919	Determine background water quality in the Nam Ngum	Monthly

Figure 1: Water-quality monitoring sites in the NNRB.



2.2.3 Monitoring Equipment

During the planning of the Water-Quality Monitoring Programme, two possible approaches were looked at for the monitoring programme. One involved the use of automated stationary equipment that would analyse water-quality parameters on site, and register the data on a digital device. The other involves the use of portable water-quality monitoring equipment with multi-parameter measurement capability. Ultimately, the selection of equipment was based on two things: 1) the availability of funds; and 2) the ability to use the equipment at other project sites after this project is complete. Since the cost of automated equipment is three to four times higher than portable equipment, and because portability will allow the equipment to be used not only for the sites selected, but also later in other projects implemented by the government of Lao PDR, the team elected to procure portable water-quality monitoring equipment.

A number of different portable monitoring devices were evaluated, and the Hydrolab Multi-parameter Meter was ultimately selected. The Hydrolab meter was selected because it is user-friendly, easy to calibrate and can measure all of the parameters required for the monitoring programme. Photo 1 shows two team members during sampling on the upper Nam Ngum.

Photo 1: Team members working at the WQ3 site, on the upper Nam Ngum river

2.3 Results of the water-quality monitoring

During the monitoring phase of the cumulative impact assessment of the Nam Ngum 3 Hydropower Project (Component A, Part 2), the water-quality monitoring team conducted 21 field monitoring visits each on Nam Lik, Nam Ngum and Nam Xong rivers (March 2008 to November 2009). This report covers all 21 field samplings and observations. The average, maximum, and minimum values of key water quality variables are summarised in Table 2 below.

Table 2: Average, maximum and minimum values of key water quality parameters at the three NN3 CIA Project's water quality monitoring sites.

Parameter	Unit	WQ Guide-lines	Nam Xong			Nam Lik			Nam Ngum		
			Max	Ave	Min	Max	Ave	Min	Max	Ave	Min
Water Temp.	ºC	n/a	30.4	26.6	21.1	28.9	25.8	19.6	25.3	22.4	18.5
Spc Cond.	mS/cm	n/a	0.28	0.16	0.07	0.34	0.20	0.12	0.10	0.06	0.03
DO	mg/L	>4	8.74	7.23	6.01	9.10	7.24	6.43	9.14	7.17	6.14
pH		5-9	8.63	7.37	6.54	8.50	7.69	6.61	8.13	7.12	6.02
TDS	G/L	3500#	3.96	0.30	0.10	0.20	0.13	0.09	34.90	2.13	0.00
% DO Satur.	%	n/a	107	86.1	79.4	100	88.8	82.4	110	90.0	77.2
ORP	mV	n/a	313	238	172	319	233	125	376	259	159
Turbidity	NTU	n/a	141	33.3	1.00	290	77.9	3.40	310	74.0	9.40
Salinity		n/a	0.14	0.08	0.04	0.16	0.10	0.06	0.05	0.03	0.02
Ammonia pH < 7.5 pH > 7.5	mg/L	0.05 0.40	1.86	0.19	0.01	13.00	0.78	0.01	3.50	0.56	0.01
Nitrate	mg/L	10	1.16	0.35	0.01	1.98	0.45	0.00	2.43	0.41	0.001
TSS	mg/L	50* (30#)	87.0	19.0	2.00	135	46.5	1.00	164	37.9	1.00

Industrial Waste Discharge Regulation (Ministry of Industry and Handicrafts, 1994)

* Pollution Prevention and Abatement Handbook (WB, 1998)

Based on the results of the monitoring, it can be concluded that Nam Ngum River and its tributaries still show good water quality, with Nam Ngum, Nam Lik and Nam Xong rivers having average pH values of 7.12, 7.69, and 7.73, respectively. The average dissolved oxygen (DO) values also remain high, and well above the required guideline (7.17, 7.24, and 7.23 mg/L respectively for Nam Ngum, Nam Lik, and Nam Xong). The results for each monitoring station are presented in tables 3-5, and in figures 2-19.

2.3.1 Nam Lik river

With a catchment area of 2 060 km^2 and an average annual discharge of 2.2 x 10^9 m^3 per year, Nam Lik has provided a major dilution factor to water discharged from the Nam Ngum 1 Reservoir. During the NN3 CIA Project's monitoring period, the Nam Lik River was monitored 21 times by the water-quality monitoring team. Of the 21 field samplings and observations, the last six included in this report are previously unreported.

Based on the results of the water-quality monitoring for the past 21 months, it can be concluded that the Nam Lik still has good water quality. Water-quality monitoring data for Nam Lik River upstream of the Nam Xong confluence are presented in Table 3. The key results can be summarised as follow:

- The results of the monitoring revealed that the Nam Lik is slightly alkaline with an average pH value of 7.24. During the monitoring period, the pH values were observed to be ranging from 6.61 to 8.50. No exceedance of recommended levels (pH 5-9) was observed during the 21-months monitoring period.
- The Nam Lik is characterised by its low electrical conductivity. The conductivity levels were observed to be low, with values measured during 21-month monitoring

period to be ranging from 0.120 mS/cm (120 µS/cm) to 0.340 mS/cm (340 µS/cm). The lowest conductivity values were observed during the wet season, likely due to the effects of dilution.

- Dissolved oxygen (DO) values measured during the 21-month monitoring period were all higher than the minimum requirement of 4 mg/L, with the lowest value observed in October 2009 (6.43 mg/L).
- During the 21-months monitoring period, the average ammonium level (0.78 mg/L) was considerably higher than the average nitrate value (0.45 mg/L). Ammonia levels were observed to be higher than the allowable guideline in August 2008, May 2009, September 2009, and October 2009. Nitrate levels were well below the allowable guideline of 10 mg/L during the 21-months monitoring period.
- During the 21-months monitoring period, Total Suspended Solid (TSS) levels were observed to be in the range of 1 mg/L to 135 mg/L. Expectedly, the highest values were observed during the wet season while lowest values were observed during the dry season. TSS were observed to be higher than the allowable guidelines for 9 of the sampled months, all falling during the two sampled wet seasons. Turbidity values were also expectedly highest in the wet season, with the highest value observed in July 2008 (290 NTU).

Figure 2: pH values for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

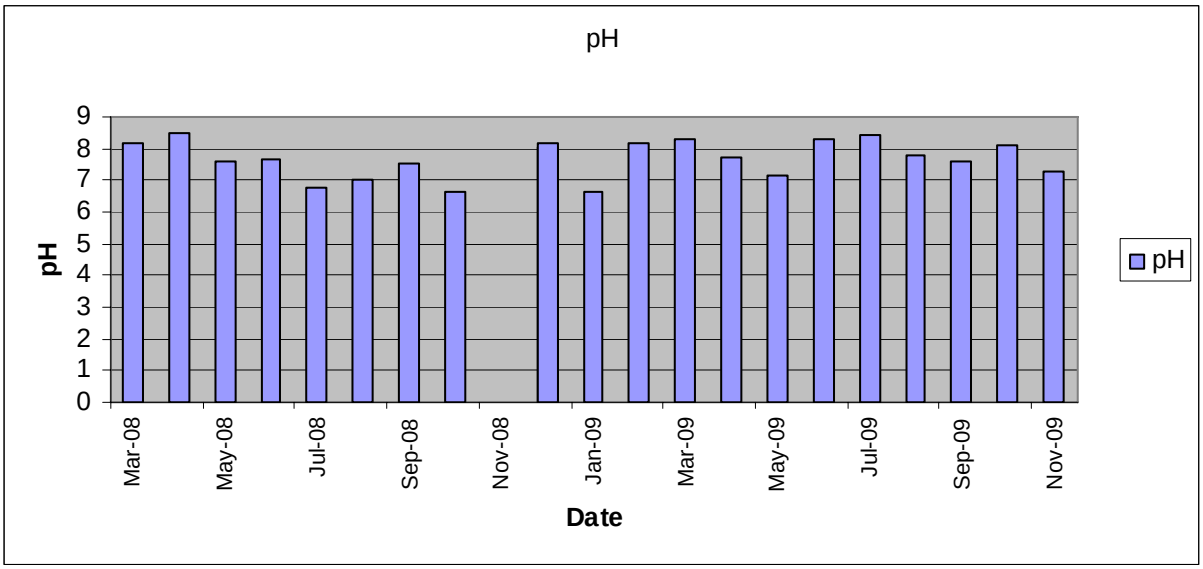


Figure 3: Electrical Conductivity (in mS/cm) values for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

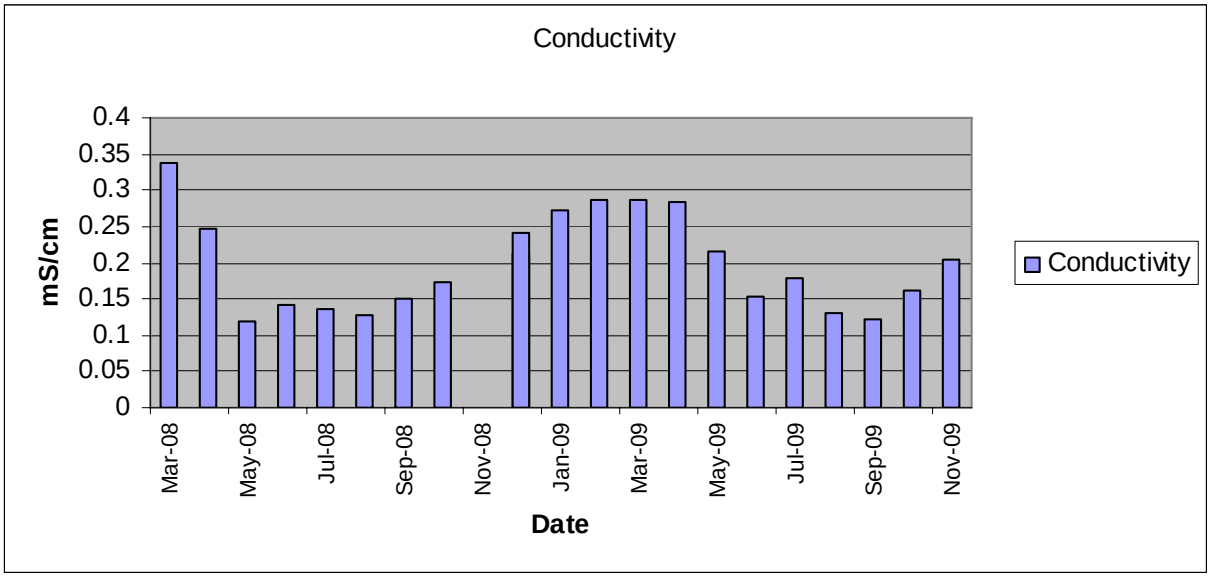


Figure 4: Total Suspended Solids (in mg/L) values for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

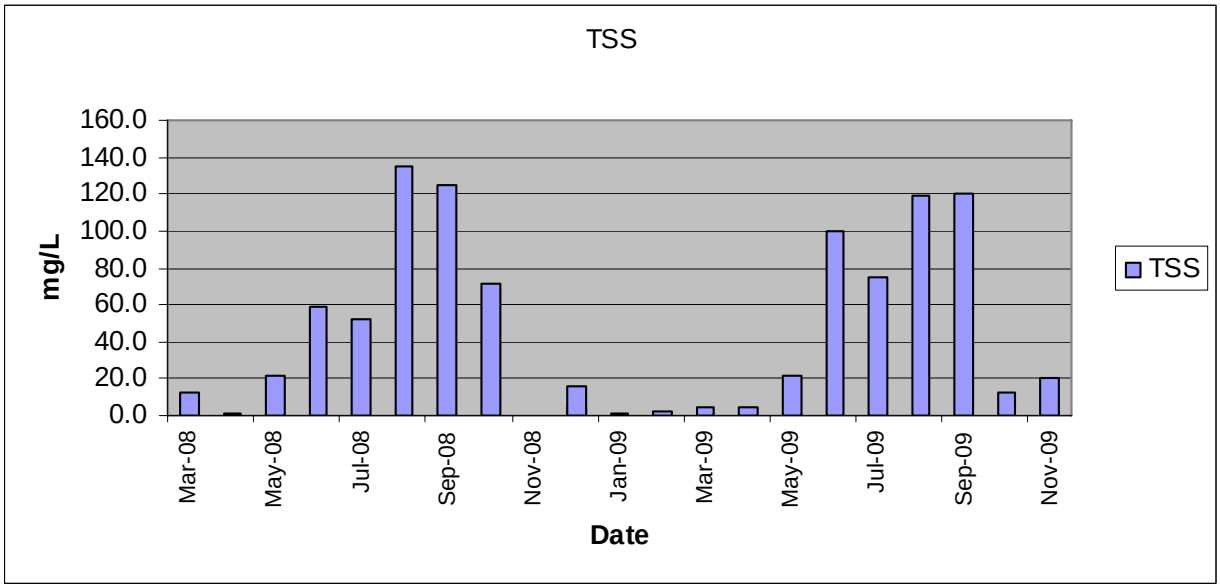


Figure 5: Turbidity (in NTU) values for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

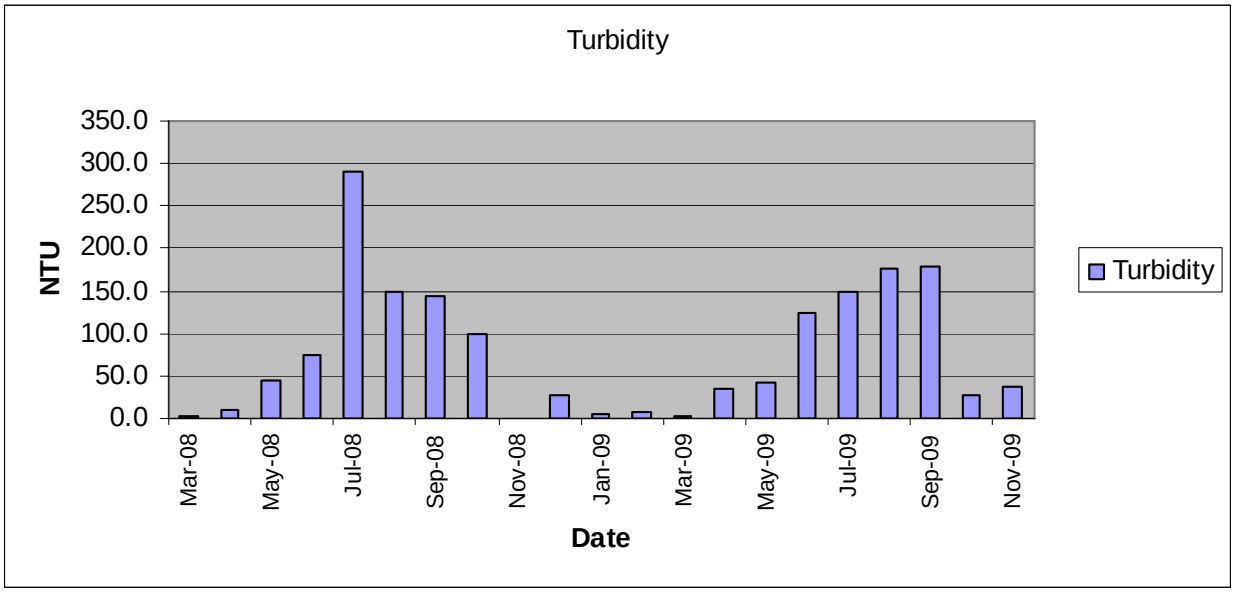


Figure 6: Nitrate (in mg/L) values for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

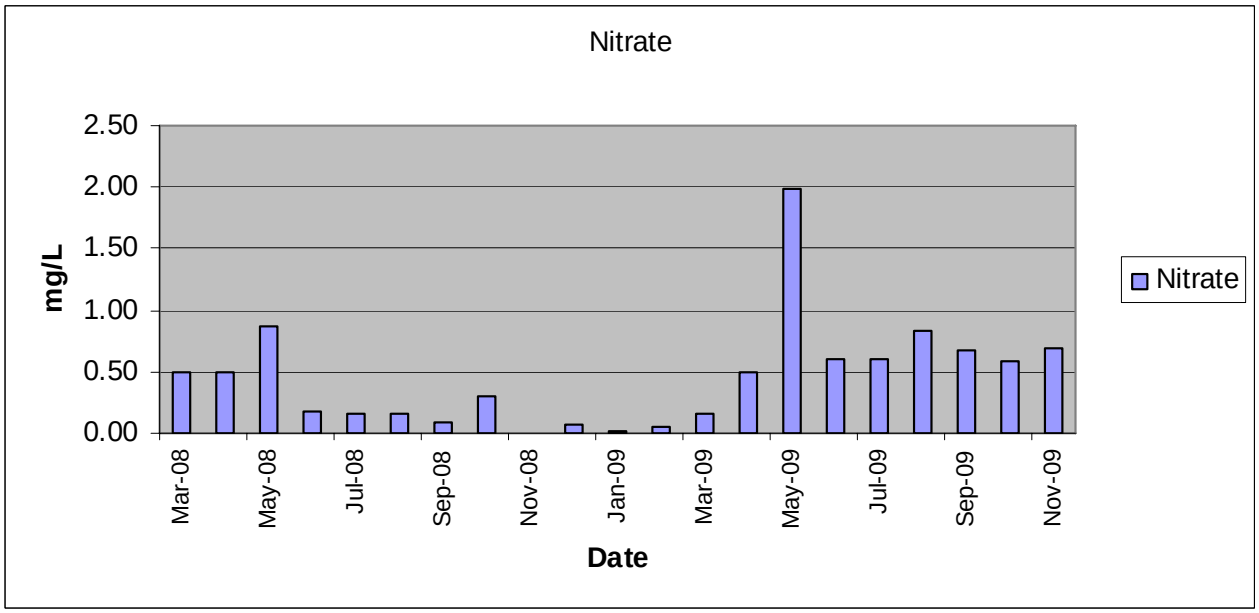


Figure 7: Ammonia (in mg/L) values for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

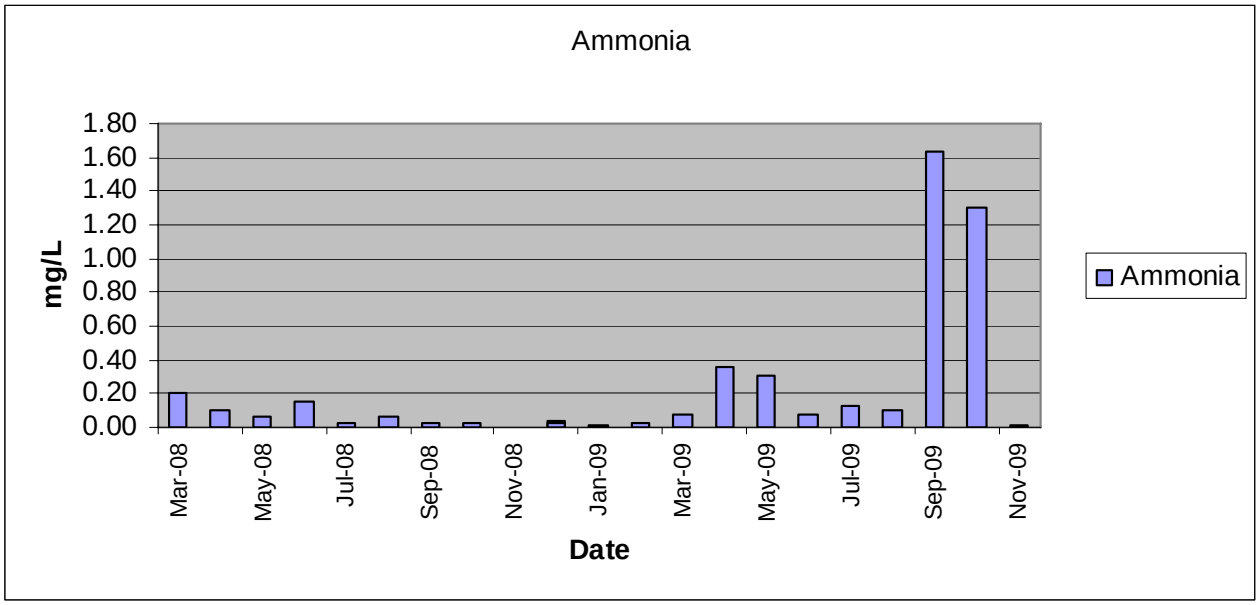


Table 3: Monthly water quality data for Nam Lik upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009). Yellow-marked boxes denote values outside those permitted by the standards.

Sampling Date	Water Depth	Water Temperature	pH	Conductivity (Spc)	DO	% DO Saturation	ORP	Turbidity	Ammonia	Nitrate	Total Suspended Solids
Unit	m	ºC	-	mS/cm	mg/L	%	mV	NTU	mg/L	mg/L	mg/L
Guidelines	n/a	n/a	5-9	n/a	>4	n/a	n/a	n/a	0.05 pH < 7.5 0.40 pH > 7.5	10	50* (30#)
27-Mar-08	0.43	27.25	8.17	0.338	-	-	309	3.4	0.20	0.50	12.0
28-Apr-08	0.34	28.9	8.5	0.247	8.73	97.9	243	10.4	0.10	0.50	1.0
23-May-08	0.189	27.65	7.61	0.119	7.85	95.3	283	44.3	0.06	0.87	21.0
17-Jun-08	0.194	24.95	7.67	0.142	8.12	98.9	286	75.3	0.16	0.18	59.0
29-Jul-08	0.171	25.57	6.75	0.136	-	-	305	290.0	0.03	0.17	52.0
27-Aug-08	0.237	25.06	7.01	0.128	8.02	100.5	319	150.0	0.07	0.15	135.0
30-Sep-08	0.067	25.87	7.56	0.149	7.45	92.5	276	145.0	0.03	0.10	125.0
23-Oct-08	0.314	26.33	6.61	0.173	7.54	91.5	273	98.6	0.03	0.30	72.0
5-Dec-08	0.303	19.58	8.06	0.212	9.1	100.04	287	9.1	0.03	0.00	5.0
31-Dec-08	0.087	22.09	8.17	0.240	8.03	93.3	201	26.5	0.03	0.07	16.0
30-Jan-09	0.983	24.29	6.65	0.271	7.99	95.1	254	4.8	0.01	0.01	1.0
27-Feb-09	0.442	28.38	8.16	0.287	6.97	91.7	228	7.8	0.02	0.05	2.0
30-Mar-09	0.242	27.82	8.28	0.287	7.18	93.3	197	3.7	0.08	0.16	4.0
28-Apr-09	0.135	27.12	7.75	0.283	7.33	90.6	197	35.2	0.35	0.50	4.1
28-May-09	1.563	28.15	7.13	0.215	7.55	97.9	216	43.4	0.31	1.98	21.0
29-Jun-09	0.65	26.21	8.29	0.154	7.72	97.9	173	123.0	0.07	0.61	100.0
28-Jul-09	0.147	25.79	8.42	0.178	7.52	94.4	189	148.0	0.13	0.61	75.0
31-Aug-09	0.764	26.37	7.80	0.131	6.81	84.2	187	176.0	0.11	0.82	119.0
23-Sep-09	0.454	25.28	7.58	0.121	6.77	83.7	211	178.0	1.64	0.68	120.0
29-Oct-09	2.118	26.41	8.13	0.163	6.43	82.4	134	27.8	1.30	0.58	13.0
19-Nov-09	0.288	23.45	7.26	0.204	7.19	87.5	125	36.2	0.02	0.69	20.0

Industrial Waste Discharge Regulation (Ministry of Industry and Handicrafts, 1994)

* Pollution Prevention and Abatement Handbook (WB, 1998)

2.3.2 Nam Xong river

The results of field monitoring and observations of Nam Xong River during the 21-months monitoring period revealed that a majority of the key water-quality variables for the Nam Xong River fall within water-quality guidelines. The key results can be summarised as follow:

- The pH levels (6.54 – 8.63) were observed to be within acceptable limits (5-9). The average pH value was observed to be slightly alkaline (7.37).
- Similar to the Nam Lik River, the Nam Xong River can also be characterised by low salinity with conductivity (EC) values varying from 0.07 mS/cm (70 µS/cm) to 0.280 mS/cm (280 µS/cm). Conductivity levels were observed to be lowest during the wet season and highest during the dry season.
- The dissolved oxygen (DO) levels measured during the 21-months monitoring period were all higher than the minimum requirement of 4 mg/L with the lowest value being observed at 6.01 mg/L in March 2009.
- Ammonia levels were observed to be higher than allowed by the guidelines in 7 out of 21 months sampled (see Table 4). During the 21-months monitoring period, ammonia levels varied from 0.01 mg/L to 1.86 mg/L with an average value of 0.19 mg/L. Nitrate levels (0.01 – 1.16 mg/L) fell within the water-quality guideline.
- Total Suspended Solid (TSS) values varied during the 21-months monitoring period, with the highest values, expectedly, being observed during the wet season and lowest values being observed during the dry season. The permissible level was exceeded during five months, four of which were in the 2008 wet season. Turbidity values were also highest during the wet season.

Figure 8: pH values for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

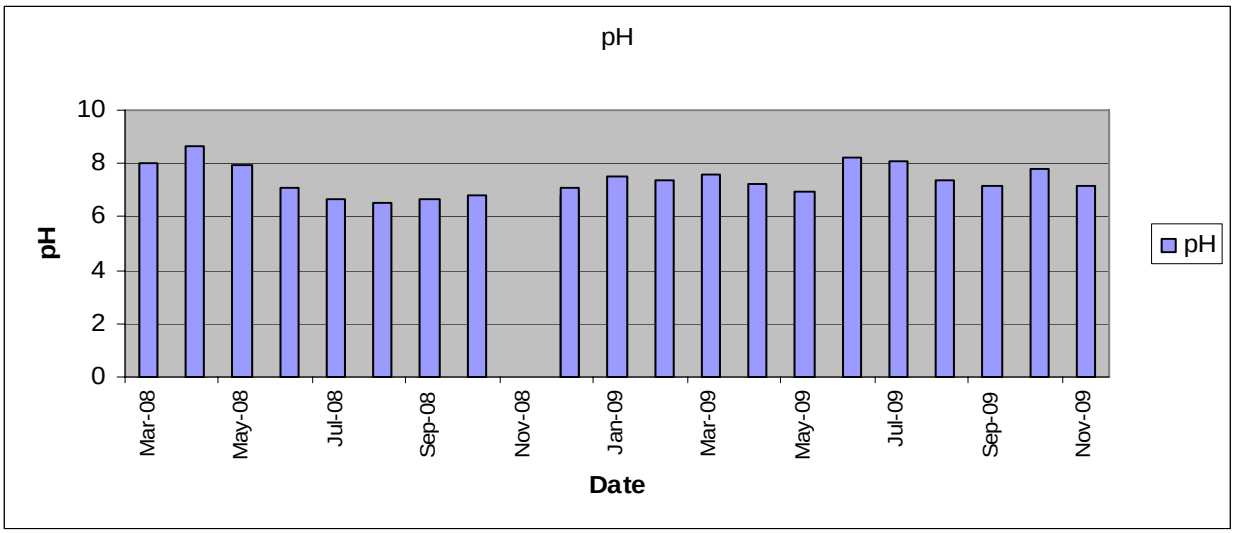


Figure 9: Conductivity values (in mS/cm) for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

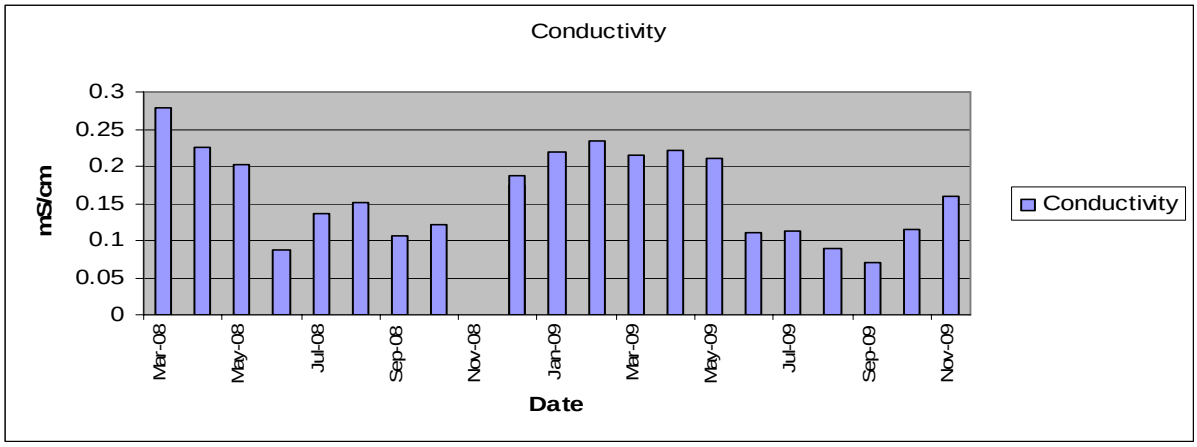


Figure 10: Total Suspended Solid (in mg/L) for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

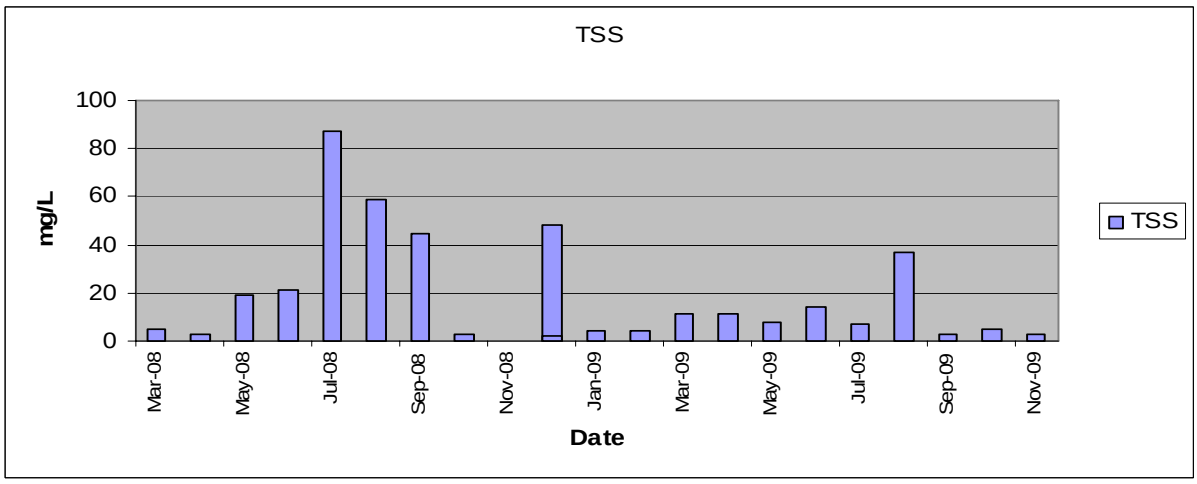


Figure 11: Turbidity (in NTU) for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

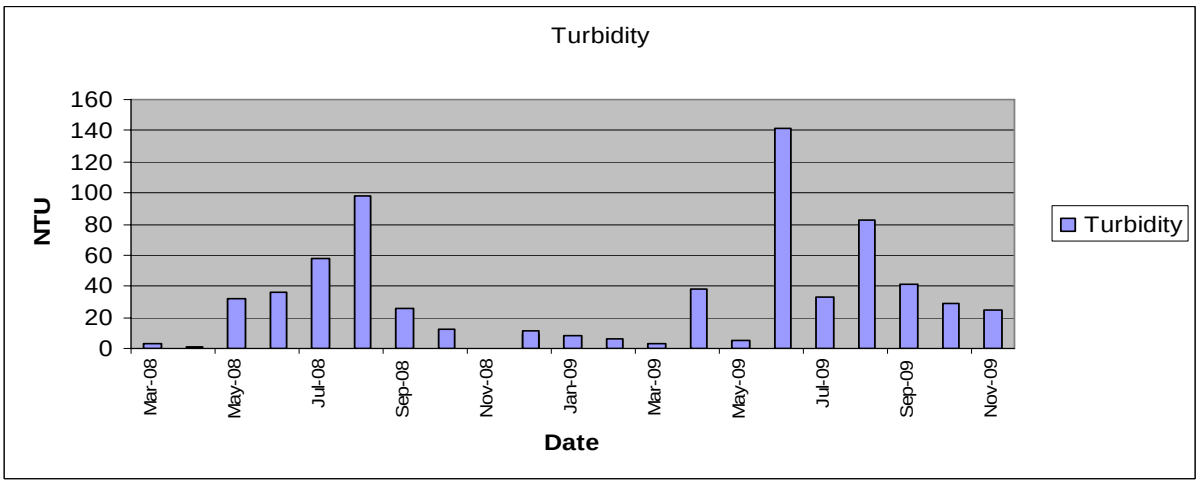


Figure 12: Ammonia (in mg/L) for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

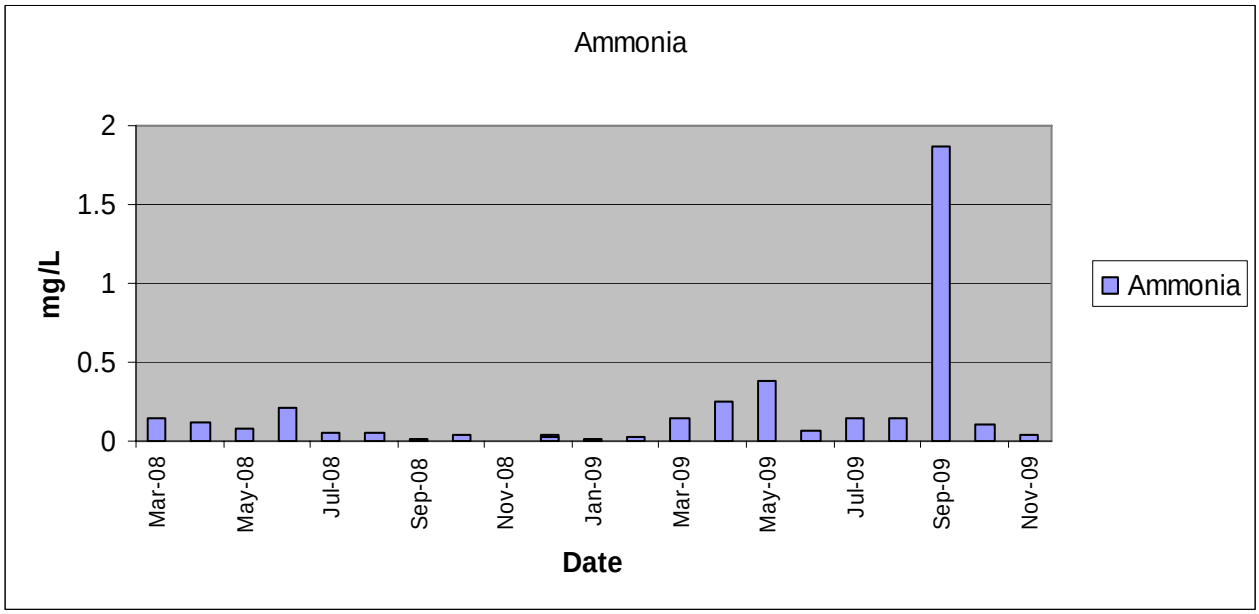


Figure 13: Nitrate (in mg/L) for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009).

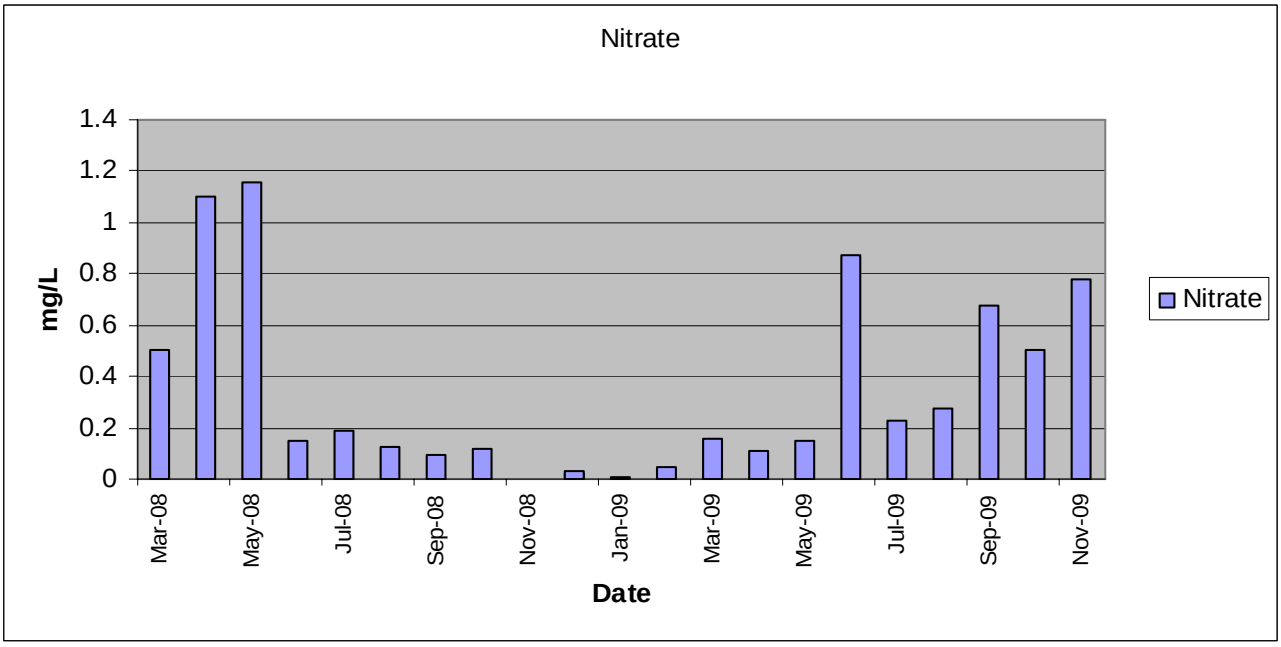


Table 4: Monthly water quality data for Nam Xong upstream of Nam Lik – Nam Xong confluence (March 2008 – November 2009). Yellow-marked boxes denote values outside those permitted by the standards.

Sampling Date	Water Depth	Water Temperature	pH	Conductivity (Spc)	DO	% DO Saturation	ORP	Turbidity	Ammonia	Nitrate	Total Suspended Solids
Unit	m	ºC		mS/cm	mg/L	%	mV	NTU	mg/L	mg/L	mg/L
Guidelines	n/a	n/a	5-9	n/a	>4	n/a	n/a	n/a	0.05 pH < 7.5 0.40 pH > 7.5	10	50* (30#)
27-Mar-08	0.55	28.17	8.01	0.279	-	-	274	3.3	0.14	0.5	5
28-Apr-08	0.21	30.36	8.63	0.226	8.65	98.3	263	1	0.12	1.1	3
23-May-08	0.234	27.13	7.91	0.203	7.95	93.6	271	31.6	0.08	1.16	19
17-Jun-08	0.138	25.19	7.1	0.087	6.19	83.4	306	35.9	0.213	0.15	21
29-Jul-08	0.211	24.86	6.67	0.136	-	-	304	58.3	0.056	0.191	87
26-Aug-08	0.02	25.87	6.54	0.151	8.74	107.1	313	97.7	0.057	0.129	59
30-Sep-08	0.064	26.11	6.69	0.106	6.86	90.4	283	26.1	0.016	0.095	45
23-Oct-08	0.355	28.51	6.78	0.122	7.98	103	303	12	0.044	0.115	3
5-Dec-08	0.158	21.11	6.83	0.174	8.71	98.3	259	9.6	0.036	0.02	48
31-Dec-08	0.398	22.93	7.12	0.187	7.57	87.3	246	11	0.023	0.035	2
30-Jan-09	0.691	25.27	7.5	0.22	8.26	102	251	8.1	0.012	0.008	4
27-Feb-09	0.71	29.1	7.41	0.234	6.10	79.4	234	6	0.020	0.05	4.3
30-Mar-09	0.373	29.02	7.56	0.215	6.01	79.8	181	3.5	0.144	0.1543	11.02
28-Apr-09	0.515	28.8	7.26	0.222	6.02	80.8	195	38.2	0.244	0.1072	11.0885
28-May-09	1.2	29.83	6.96	0.211	7.60	97.6	178	5.2	0.383	0.1498	8.0134
29-Jun-09	0.44	26.24	8.26	0.111	7.38	92.6	188	141	0.061	0.875	14
28-Jul-09	0.479	26.39	8.05	0.113	6.77	85.4	191	33.1	0.149	0.230	7
31-Aug-09	0.801	26.38	7.4	0.089	6.75	85.8	199	82.8	0.139	0.272	37
23-Sep-09	0.772	25.84	7.14	0.071	6.53	81.7	217	41.8	1.864	0.677	3
29-Oct-09	1.447	27.34	7.8	0.115	6.62	85	172	28.8	0.103	0.501	5
19-Nov-09	0.187	24.61	7.17	0.159	6.67	81.4	175	24.5	0.043	0.777	3

Industrial Waste Discharge Regulation (Ministry of Industry and Handicrafts, 1994)

* Pollution Prevention and Abatement Handbook (WB, 1998)

2.3.3 Nam Ngum River

Field monitoring and observations of the Nam Ngum River during the 21-months monitoring period revealed that a majority of the water-quality variables for Nam Ngum River fall within water-quality guidelines. The key results can be summarised as follow:

- Nam Ngum is slightly alkaline with an average pH value of 7.12. Results of the 21-months monitoring period revealed that pH values fall within the acceptable range (5 to 9), with values ranging from 6.02 to 8.13.
- Similar to the Nam Lik and the Nam Xong, the Nam Ngum River upstream of NN3 Reservoir is characterised by low salinity with conductivity (EC) values varying from 0.03 mS/cm (30 µS/cm) to 0.10 mS/cm (100 µS/cm) for the 21-months monitoring period (March 2008 to November 2009).
- Dissolved oxygen (DO) values measured during the monitoring period (March 2008 to November 2009) were higher than the minimum requirement of 4 mg/L, with an average value of 7.17 mg/L.
- Nitrate levels (0.001– 2.43 mg/L) measured during monitoring period were considerably lower than minimum requirements of 10 mg/L.
- Ammonia levels exceeded minimum requirement 10 out of 21 months sampled. The values of ammonia varied from 0.01 mg/L to 3.6 mg/L, with the average value of 0.56 mg/L.
- Total Suspended Solid (TSS) value generally exceeded the Ministry of Industry and Handicraft's Industrial Waste Discharge Regulation and the World Bank's Pollution Prevention and Abatement Handbook during the wet season (May to September). Highest value was observed in August 2008 (164 mg/L). Similarly, highest turbidity values were also observed during the wet season, with the highest being observed in July 2008 (310 NTU).

Figure 14: pH for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009).

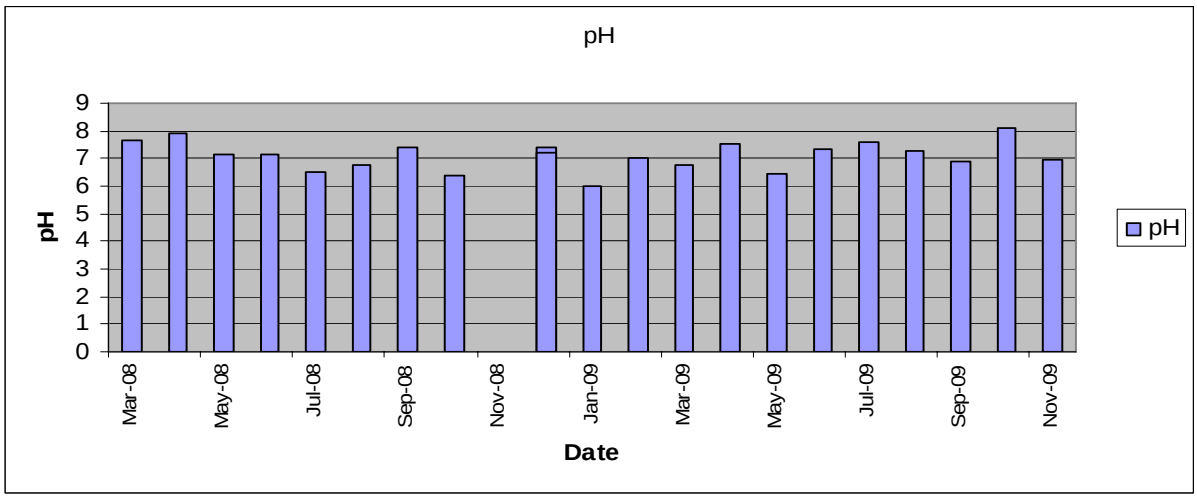


Figure 15: Electrical Conductivity (in mS/cm) for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009).

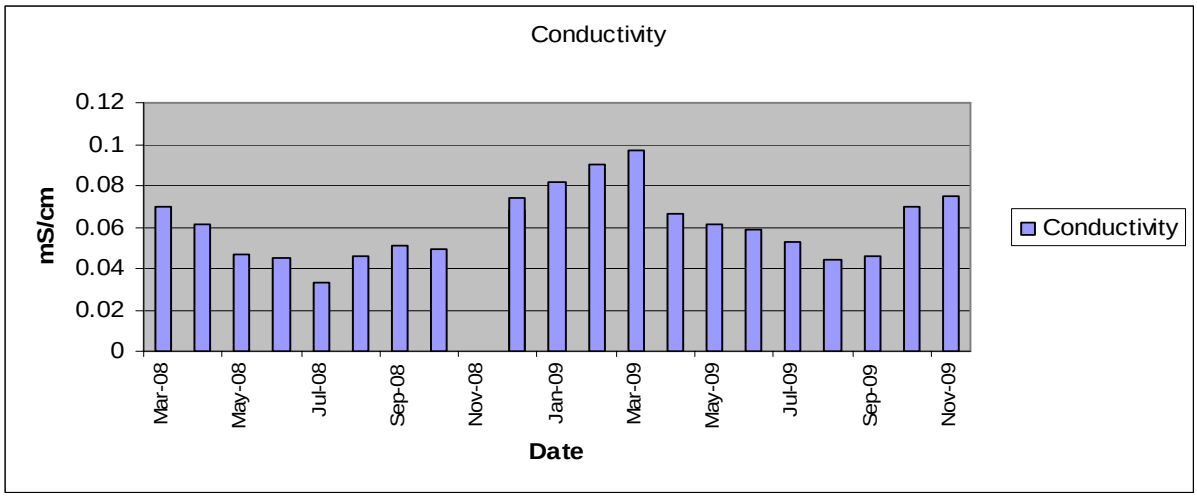


Figure 16: Total Suspended Solid (in mg/L) for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009).

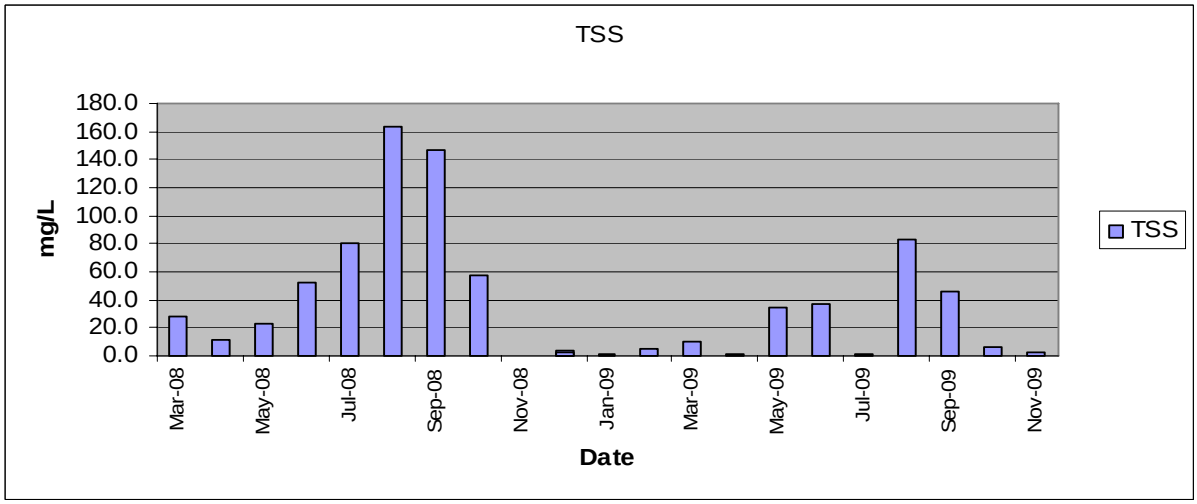


Figure 17: Turbidity (in NTU) for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009).

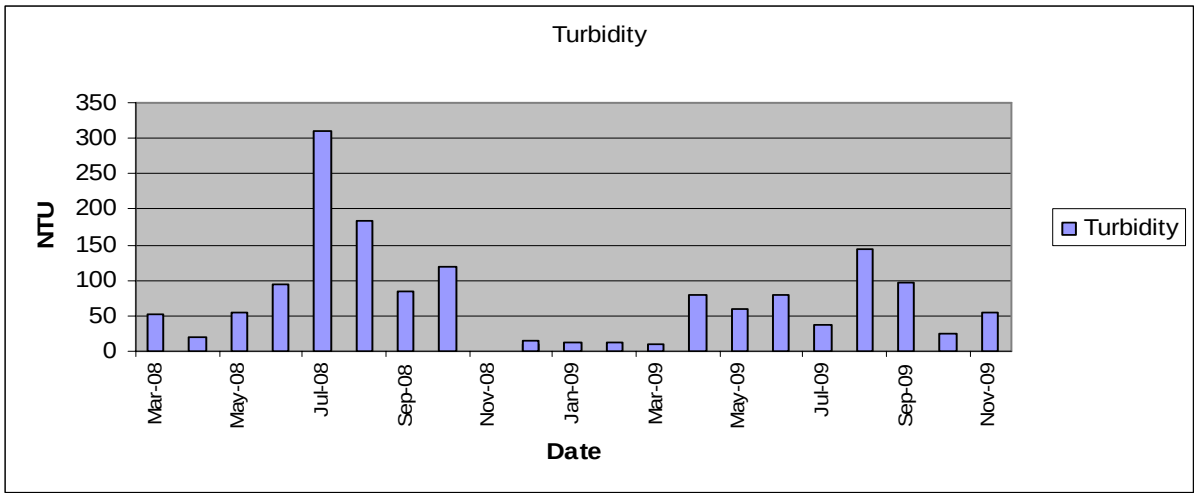


Figure 18: Ammonia (in mg/L) for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009).

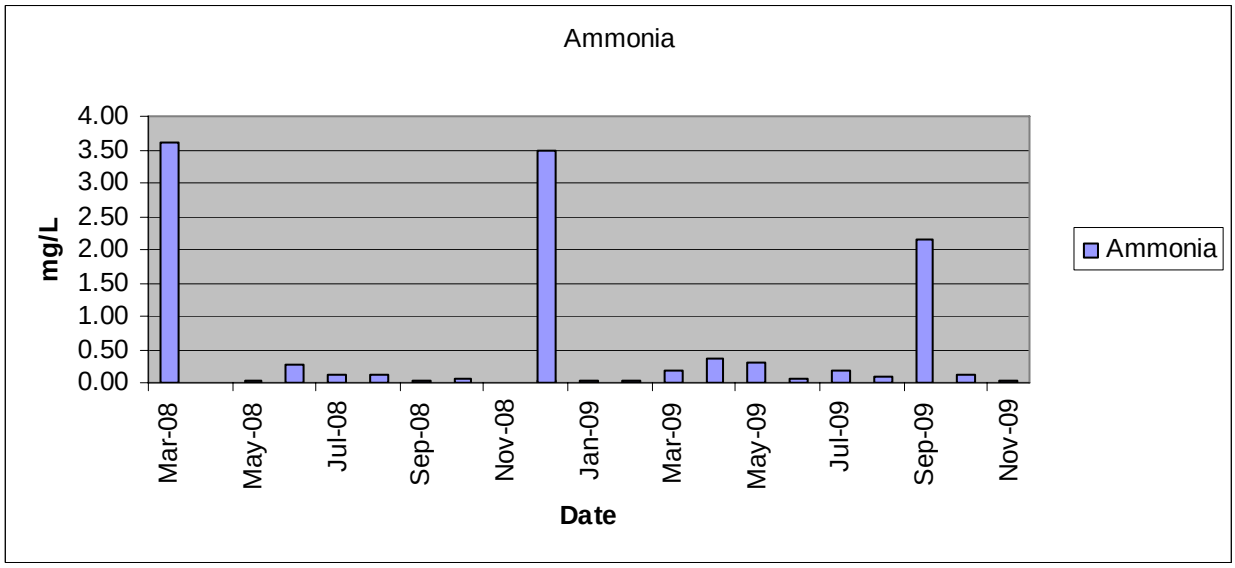


Figure 19: Nitrate (in mg/L) for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009).

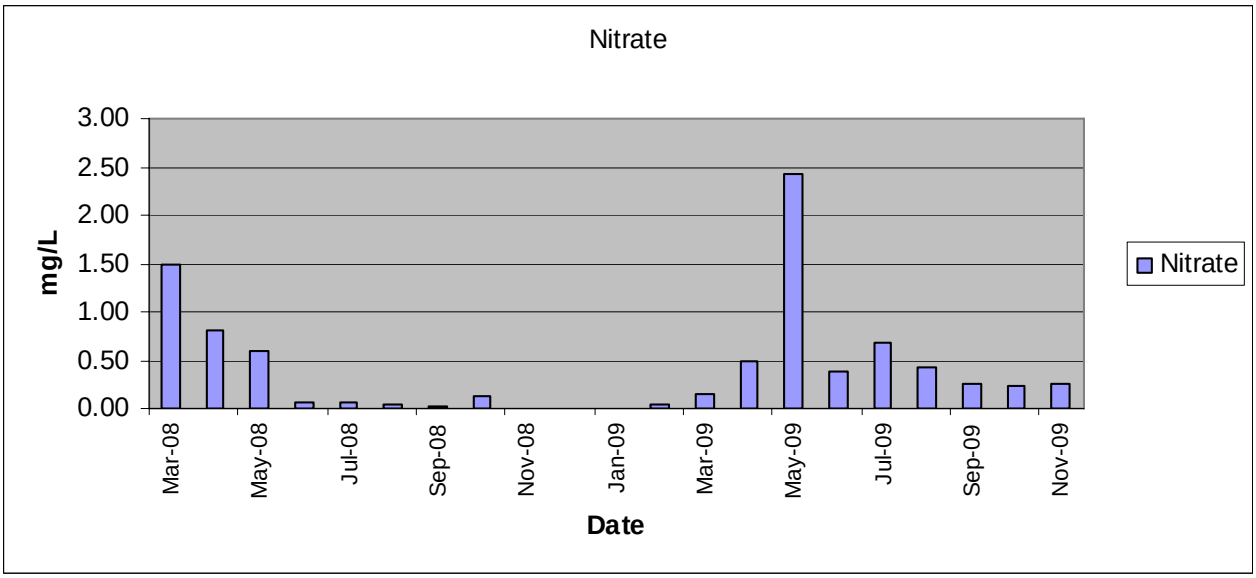


Table 5: Monthly water quality data for Nam Ngum upstream of Nam Ngum 3 Reservoir (March 2008 – November 2009). Yellow-marked boxes denote values outside those permitted by the standards.

Sampling Date	Water Depth	Temperature	Conductivity (Spc)	pH	DO	% DO Saturation	ORP	Turbidity	Ammonia	Nitrate	Total Suspended Solids
Unit	m	ºC	mS/cm		mg/L	%	MV	NTU	mg/L	mg/L	mg/L
Guidelines	n/a	n/a	n/a	5-9	>4	n/a	n/a	n/a	0.05 pH < 7.5 0.40 pH > 7.5	10	50* (30#)
26-Mar-08	0.187	21.97	0.07	7.63	-	-	376	53.3	3.60	1.50	28.0
29-Apr-08	0.19	23.53	0.061	7.94	9.14	99.1	286	20.7	0.01	0.80	11.0
22-May-08	0.218	24.5	0.047	7.12	8.01	97.3	298	55.7	0.03	0.60	23.0
18-Jun-08	0.135	24.04	0.045	7.14	7.91	86.1	307	93.2	0.28	0.06	52.0
29-Jul-08	0.248	22.6	0.033	6.5	-	-	337	310	0.12	0.06	81.0
26-Aug-08	0.016	22.76	0.046	6.75	8.31	107.5	308	184	0.11	0.04	164.0
30-Sep-08	0.004	22.84	0.051	7.43	8.2	110.2	280	85	0.03	0.03	147.0
24-Oct-08	0.092	23	0.049	6.4	7.73	89.9	341	118	0.06	0.12	57.0
06-Dec-08	-	-	0.068	7.41	-	-	-	9.4	0.02	0.00	4.0
30-Dec-08	0.69	18.54	0.074	7.19	8.14	97.4	269	16	3.50	0.00	3.0
29-Jan-09	0.246	18.52	0.082	6.02	8.42	100.3	285	12	0.02	0.01	1.0
26-Feb-09	0.2	20.89	0.090	7.00	6.14	77.2	253	13.1	0.02	0.05	4.7
28-Mar-09	0.186	22.39	0.097	6.78	6.96	89.6	260	10.0	0.17	0.15	10.0
27-Apr-09	0.081	22.89	0.066	7.52	7.53	98.1	239	80.3	0.35	0.48	1.1
27-May-09	0.136	25.27	0.061	6.44	7.48	102.0	221	59.8	0.30	2.43	35.0
30-Jun-09	0.181	23.87	0.059	7.32	7.70	102.6	186	78.2	0.06	0.39	37.0
29-Jul-09	0.006	23.68	0.053	7.57	6.48	85.8	201	36.2	0.19	0.68	1.0
09-Aug-09	0.054	23.24	0.044	7.29	6.71	88.1	194	144	0.08	0.43	83.0
24-Sep-09	0.044	23.14	0.046	6.91	6.77	88.9	185	96	2.14	0.25	46.0
30-Oct-09	0.149	21.83	0.070	8.13	6.95	88.2	159	23.9	0.12	0.24	6.0
18-Nov-09	0.052	19.42	0.075	6.96	7.21	88.3	194	54.5	0.02	0.25	2.0

Industrial Waste Discharge Regulation (Ministry of Industry and Handicrafts, 1994)

* Pollution Prevention and Abatement Handbook (WB, 1998)

2.4 Nam Ngum 2 Water-Quality Monitoring Programme

The Nam Ngum 2 Water-Quality Monitoring Programme has been set up as part of the Environmental Management and Resettlement Action Plan of the Nam Ngum 2 Hydroelectric Power Project. The aim of the programme is to monitor baseline water quality of the Nam Ngum River and its tributaries upstream and downstream of the Nam Ngum 2 Reservoir.

Nam Ngum 2 Water-Quality Monitoring Programme comprises of the following aspects:

- 9 water-quality monitoring stations within, upstream and downstream of the NN2 Reservoir. All but two stations are located on the Nam Ngum River mainstream.
- 6 in-situ water-quality monitoring parameters, including pH, conductivity, dissolved oxygen, total dissolved solids, water temperature and air temperature.
- 14 laboratory-analysis parameters, including major ions and ligands, as well as nutrients (ammonium, nitrate, and nitrite), total suspended solids and chemical oxygen demands (COD).

Coordination with Nam Ngum 2 Hydroelectric Power Project has been difficult during the monitoring period. As a result, the monitoring team was able to obtain only monitoring results for May 2008 and January 2009. The results of these monitoring campaigns are presented in Table 6. We report the data for two of the sampled stations here. The key outcomes of the Nam Ngum 2 water-quality monitoring program can be summarised as follow:

- pH values of Nam Ngum for both upstream and downstream of NN2 Dam Site were slightly alkaline but within the recommended guidelines.
- Conductivity values for both sites were low, with the upstream site having values of 0.0854 mS/cm and 0.120 mS/cm while the downstream site had values of 0.091 mS/cm and 0.114 mS/cm.
- Dissolved oxygen values for both sites were well above the requirement guideline of 4 mg/L.
- Total suspended solids values for the upstream site were well below the required guidelines. However, the total suspended solids value (412 mg/L) for the downstream site exceeded the maximum permissible value by a considerable margin, likely due to construction disturbance.
- Nitrate values for both sites were well below the required guideline (10 mg/L).
- Similarly, ammonia values for both sites were also below the required guidelines.

Table 6: NN2's water quality data for May and January 2009. Yellow-marked boxes denote values outside those permitted by the standards.

Parameter	Unit	Water Quality Guideline	Upstream of NN2 Dam Site		Downstream of NN2 Dam Site	
Sampling Date	-	-	May-08	Jan-09	May-08	Jan-09
Ca	mg/l	n/a	-	12.5	-	19.8
Mg	mg/l	n/a	-	4.12	-	2.336
Cl	mg/l	n/a	-	1.251	-	1.451
SO_4	mg/l	n/a	-	5.43	-	1.15
Total - Fe	mg/l	n/a	-	0.022	-	0.128
Nitrite - Nitrogen (NO_2 - N)	mg/l	n/a	-	0.008	-	0.002
Nitrate - Nitrogen (NO_3 - N)	mg/l	10	0.156	0.044	0.143	0.411
NH4 - N	mg/l	0.05 pH < 7.5 0.40 pH > 7.5	0.089	0.017	0.044	0.122
PO4 - P	mg/l	n/a	-	0.015	-	0.81
Total - P	mg/l	n/a	-	0.021	-	0.112
TDS	mg/l	3500#	-	50	-	51
TSS	mg/l	50* (30#)	7	2	412	5
COD_{mn}	mg/l	n/a	-	2.322	-	1.02
Water Temperature	ºC	n/a	26.2	20.1	27	21.2
Conductivity	mS/cm	n/a	0.0854	0.12	0.091	0.114
DO	mg/l	> 4	6.44	9.54	6.91	9.11
pH		5 - 9	8.14	8.52	8.42	8.37

Industrial Waste Discharge Regulation (Ministry of Industry and Handicrafts, 1994)
* Pollution Prevention and Abatement Handbook (WB, 1998)

2.5 Nam Ngum 3 Water-Quality Monitoring Programme

The Nam Ngum 3's Water-Quality Monitoring Programme was set up as part of the Nam Ngum 3 Hydroelectric Project's environmental commitment, aiming at monitoring the impact of its development on the Nam Ngum River and its tributaries.

Coordination between the monitoring team and the Nam Ngum 3 Hydroelectric Project has been difficult. During the monitoring phase, the monitoring team was able to obtain only two water-quality results from GMS Lao Company Limited, the developer of the Nam Ngum 3 Hydroelectric Project. At the moment development work on the project is slow or at a stand-still, following problems with land slides at the site. These results we were able to share were for the months of February and April 2009 which were also reported in the 3rd Bi-Annual Report. The results are presented in Table 7 with key results summarised as follows:

- pH values measured in February and April 2009 were slightly alkaline (8.04 and 7.64 respectively) which are consistent with the values measured by our water-quality monitoring team (refer to Table 5), up-stream in the same river.
- Electrical conductivity values were low for both February (0.184 mS/cm) and April (0.203 mS/cm).
- Nitrate levels were well below maximum permissible guidelines of 10 mg/L.

- Total Suspended Solids were below both Ministry of Industry and Handicrafts and World Bank guidelines.

Table 7: NN3's water quality data for January 2009

Parameters	Unit	Water Quality Guideline	Jan-09	Feb-09	Mar-09	Apr-09	May-09
Sampling Date		-	-	4-Feb-09	-	3-Apr-09	-
Electrical Conductivity	mS/cm	n/a	-	0.184	-	0.203	-
Turbidity	NTU	n/a	-	9.31	-	22.1	-
pH	NA	5-9	-	8.04	-	7.64	-
Total Dissolved Solids	mg/L	3500#	-	112	-	75	-
Total Suspended Solids	mg/L	50* (30#)	-	14	-	18	-
Iron	mg/L	n/a	-	0.11	-	0.09	-
Zinc	mg/L	n/a	-	0.02	-	0	-
Total Alkalinity	mg/L	n/a	-	84	-	92	-
Total Hardness	mg/L	n/a	-	76	-	97	-
Calcium	mg/L	n/a	-	27	-	23	-
Magnesium	mg/L	n/a	-	2	-	10	-
Sulfate	mg/L	n/a	-	0.8	-	3	-
Chloride	mg/L	n/a	-	2	-	9	-
Nitrate	mg/L	10	-	1	-	2	-

Industrial Waste Discharge Regulation (Ministry of Industry and Handicrafts, 1994)
* Pollution Prevention and Abatement Handbook (WB, 1998)

2.6 Department of Irrigation's Water-Quality Monitoring Data

The Lao PDR Water Quality Analysis Laboratory (WQAL) in the Department of Irrigation (DOI), MAF, currently monitors water quality of the Nam Ngum River downstream of the Nam Ngum 1 Reservoir. The WQAL was initiated by the Mekong River Commission as part of the Water-Quality Monitoring Network for the Lower Mekong Basin in 1985, to assess trans-boundary loadings of various chemicals and sedimentation in the Mekong and its tributaries. The WQAL's water-quality monitoring stations are shown indicated on the map in Figure 1.

For this report, water-quality data was obtained for Nam Ngum River immediately downstream of Nam Ngum 1 Dam site, Nam Lik upstream of the Nam Ngum confluence and Nam Ngum at Ban Pakhai.

Water-quality parameters monitored at these locations include pH, electrical conductivity (EC), alkalinity, total suspended solids, dissolved oxygen (DO), chemical oxygen demand (COD), major ions and ligands (Ca, Mg, Na, K, Cl, SO4), nitrogen (NO3, NH4), phosphorus (PO4) and iron (Fe).

Water quality data for 2009 have not been made available to the public by the Department of Irrigation and the Mekong River Commission. Therefore, in this report, only data from 2008 are reported. The average, maximum and minimum values of water quality parameters measured at the DOI's three water-quality monitoring stations are presented in Table 8 and the comparisons of key water-quality variables are presented in Figures 20-25 below.

Table 8: Average, maximum and minimum values of water-quality parameters measured at the three DOI's water quality monitoring sites.

Parameters	Unit	Nam Lik @ Ban Thalat			Nam Ngum @ NN1 Dam Site			Nam Ngum River @ Ban Pakhai		
		Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
Temperature	**°C**	29.80	26.52	24.00	26.90	25.65	22.60	29.40	26.89	21.60
pH	**-**	8.27	7.28	6.25	7.35	7.03	6.67	7.44	7.06	6.31
TSS	**mg/L**	168.00	63.85	1.00	19.00	8.00	1.00	280.00	101.23	7.00
Conductivity	**mS/m**	0.30	0.20	0.12	0.12	0.10	0.08	0.13	0.11	0.09
Ca	**meq/L**	1.89	1.23	0.64	0.90	0.70	0.55	0.83	0.72	0.61
Manganese	**meq/L**	1.23	0.51	0.23	0.29	0.19	0.13	0.28	0.23	0.17
Sodium	**meq/L**	0.33	0.17	0.09	0.09	0.06	0.02	0.29	0.13	0.04
Potassium	**meq/L**	0.04	0.02	0.01	0.03	0.02	0.01	0.11	0.03	0.01
Alkalinity	**meq/L**	2.16	1.53	0.88	1.15	0.86	0.71	1.02	0.91	0.77
Chloride	**meq/L**	0.31	0.13	0.03	0.08	0.04	0.03	0.15	0.08	0.03
Sulfate	**meq/L**	0.54	0.24	0.11	0.20	0.08	0.03	0.21	0.10	0.05
Nitrate	**mg/L**	0.30	0.11	0.01	0.19	0.10	0.03	0.24	0.11	0.04
Ammonia	**mg/L**	0.13	0.03	0.01	0.08	0.03	0.01	0.05	0.03	0.01
Total Nitrogen	**mg/L**	0.54	0.24	0.03	0.65	0.28	0.17	0.50	0.27	0.07
Total Phosphorus	**mg/L**	0.07	0.02	0.01	0.02	0.01	0.00	0.14	0.03	0.01
Dissolved Oxygen	**mg/L**	8.85	7.47	6.20	6.57	4.45	2.40	7.59	6.34	5.30
COD	**mg/L**	2.41	1.41	0.40	2.78	1.14	0.40	3.31	1.53	0.60

Figure 20: pH profile of the Nam Ngum and Nam Lik River (2008) monitored by DOI, MAF. With due permission from MRC July 2009.

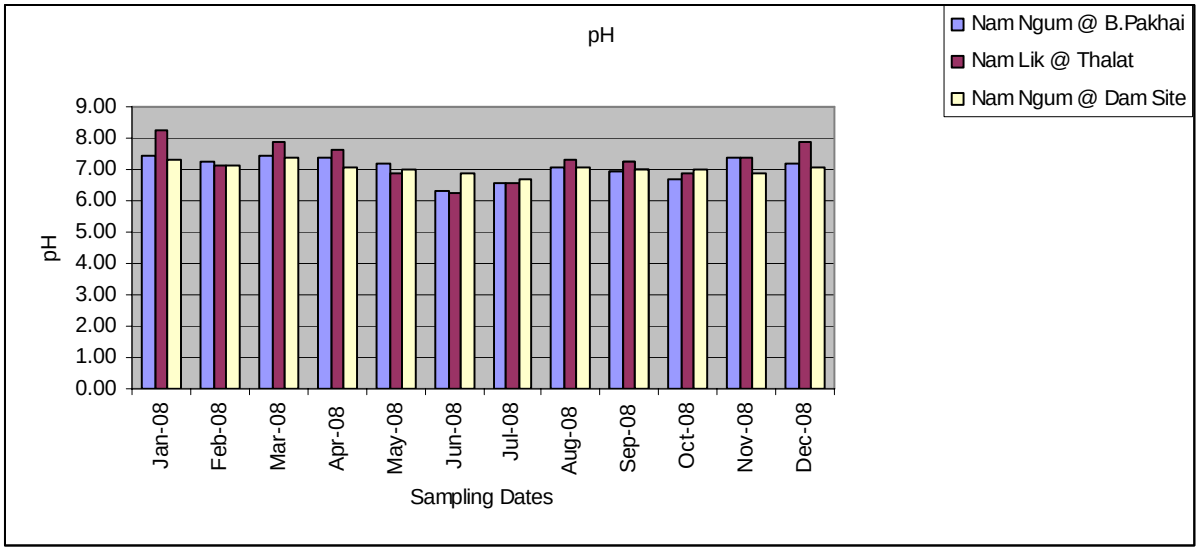


Figure 21: Conductivity profile of the Nam Ngum and Nam Like River (2008) monitored by DOI, MAF. With due permission from MRC July 2009.

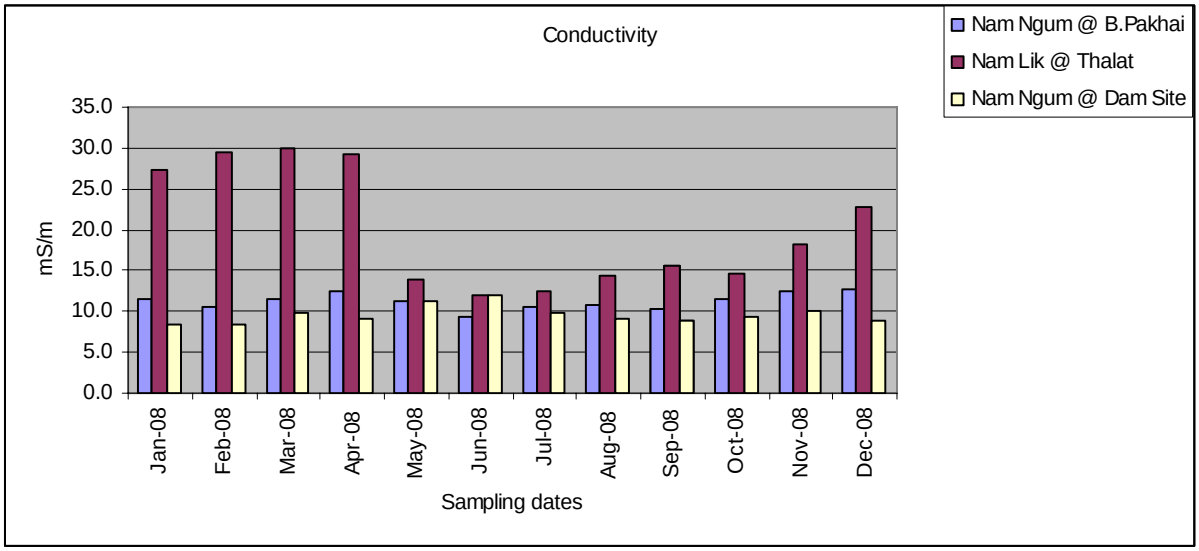


Figure 22: Total Suspended Solids profile of the Nam Ngum and Nam Like River (2008) monitored by DOI, MAF. With due permission from MRC July 2009.

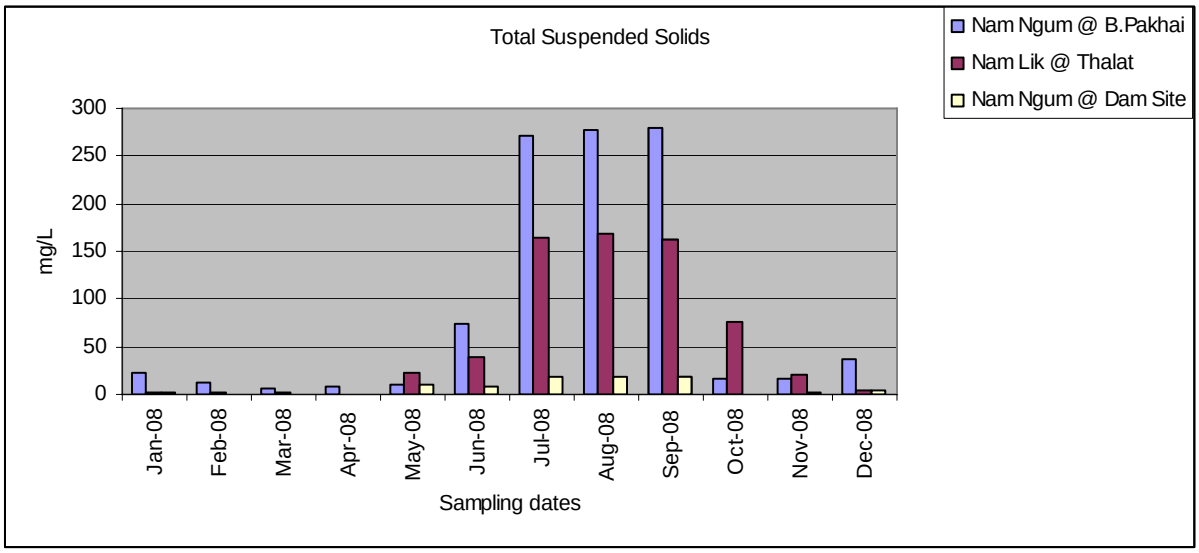


Figure 23: Dissolved oxygen profile of the Nam Ngum and Nam Like River (2008) monitored by DOI, MAF. With due permission from MRC July 2009.

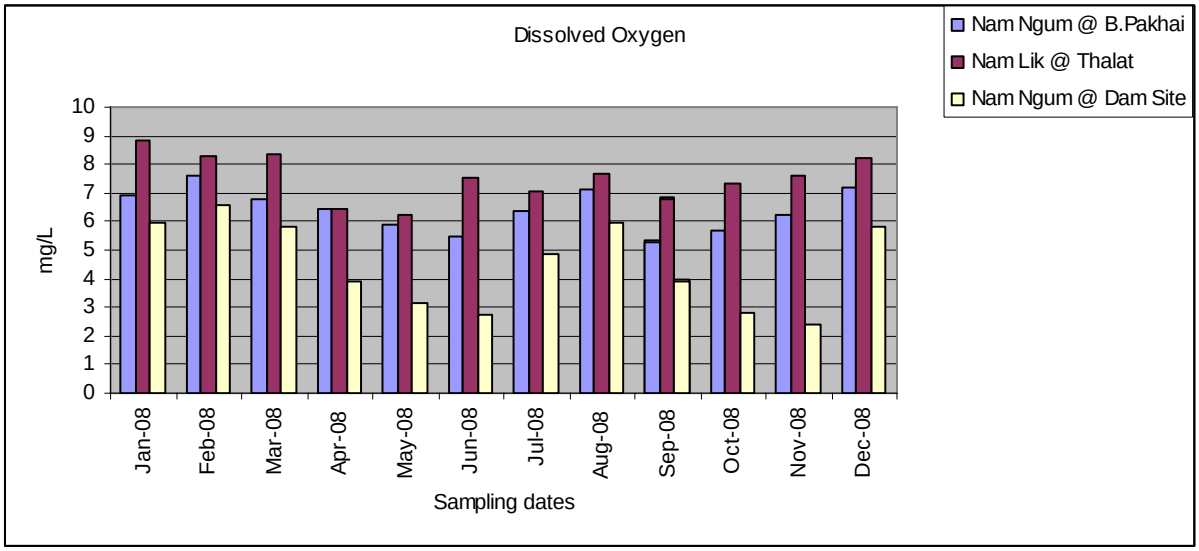


Figure 24: Ammonia profile of the Nam Ngum and Nam Like River (2008) monitored by DOI, MAF. With due permission from MRC July 2009.

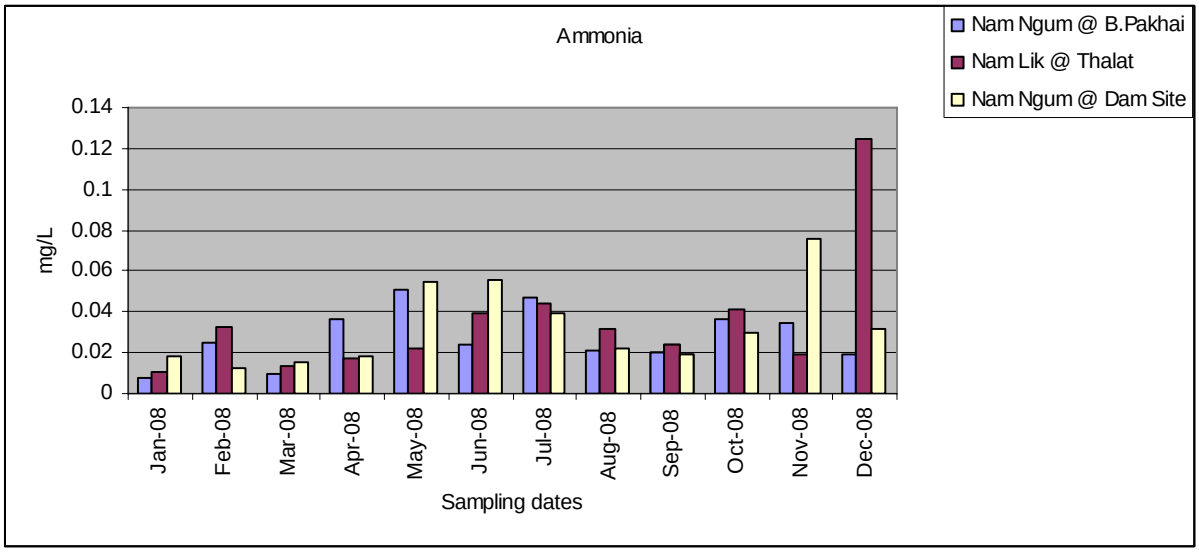
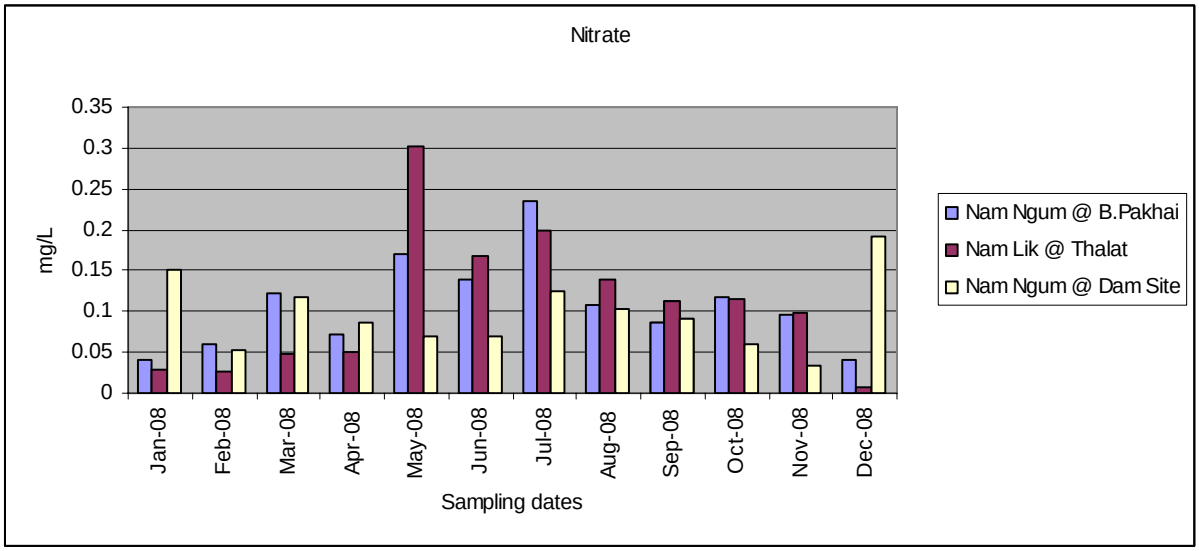


Figure 25: Nitrate profile of the Nam Ngum and Nam Like River (2008) monitored by DOI, MAF. With due permission from MRC July 2009.



2.7 Discussion, Conclusions and Recommendations

During the NN3 CIA Project's Monitoring Programme, the team conducted 21 monthly field campaigns for the Nam Ngum, Nam Lik and Nam Xong rivers. The results of these samplings revealed that the water quality of the Nam Ngum, Nam Lik and Nam Xong rivers are still of good quality. With the exception of a few elevated values of ammonia and total suspended solids, the results revealed that most water-quality variables fall within acceptable guidelines for both drinking-water and ambient surface-water quality. It should be noted that elevated values of total suspended solids were only observed during the wet season. Consistent with the elevated total suspended solids, turbidity values were also elevated during the wet season.

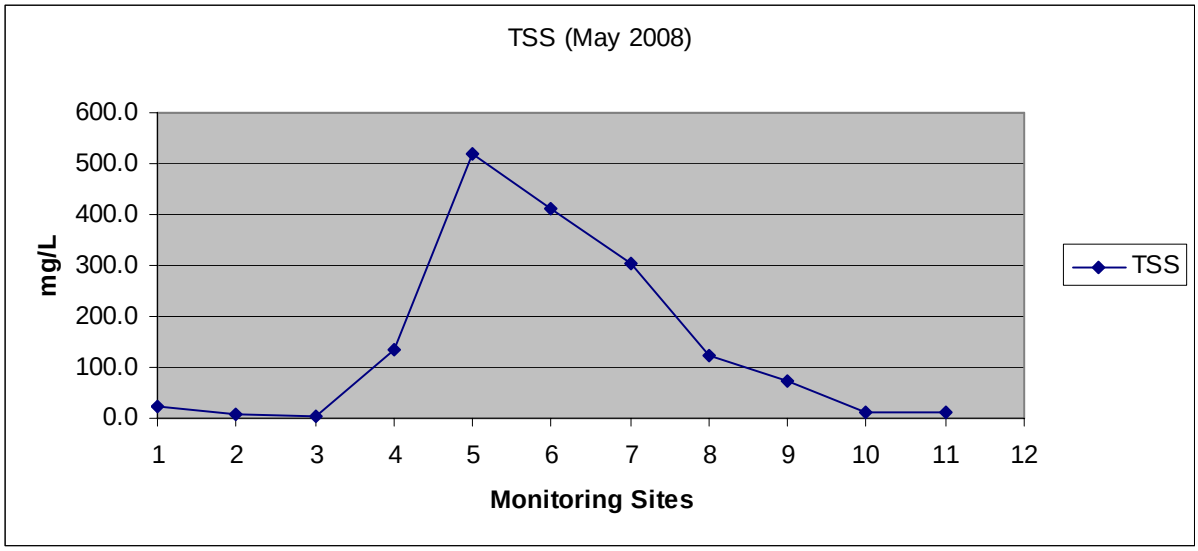
During the last field visit of the monitoring programme, the team members were surprised and dismayed to note the extent of artisanal mining occurring on the Nam Ngum river banks and even right in the river (and its tributaries) in the stretch between the future NN3 reservoir and the NN2 dam site. Photos 2-4 show some of this activity. It is highly likely that mercury is used for extraction of the gold being mined, resulting in severe direct pollution of the river. This is an issue that the WREA needs to address urgently.

Photos 2, 3: Small-scale commercial and artisanal mining operations along the Nam Ngum river.

Photo 4: Small-scale commercial and artisanal mining operations on a Nam Ngum tributary.

It is unclear whether the construction of the Nam Ngum 2 and Nam Ngum 3 hydropower projects has any affect on the water quality of the Nam Ngum River, since the team has not been able to fully assess water quality monitoring results of the Nam Ngum 2 and Nam Ngum 3 Projects. During the Monitoring Programme, the team was only able to obtain two water-quality monitoring results each from Nam Ngum 2 and Nam Ngum 3 Hydroelectric Projects. These results indicated that water quality of the Nam Ngum River has not been severely affected by the construction. With the exception of elevated level of total suspended solid downstream of the Nam Ngum 2 dam site in May 2008, all water-quality variables fall within acceptable guideline. The effects of elevated TSS levels were likely localised, possibly extending to the upper zone of the Nam Ngum 1 Reservoir. Results of the DOI's water-quality monitoring data at the Nam Ngum 1 Dam Site continued to show low level of TSS (no exceedance was observed in 2008). Figure 26 shows the spatial distribution of TSS of the Nam Ngum River, starting from the NN3 CIA Project's monitoring point (Nam Ngum upstream of Nam Ngum 3 Reservoir) to the DOI's monitoring point at Ban Pakhai.

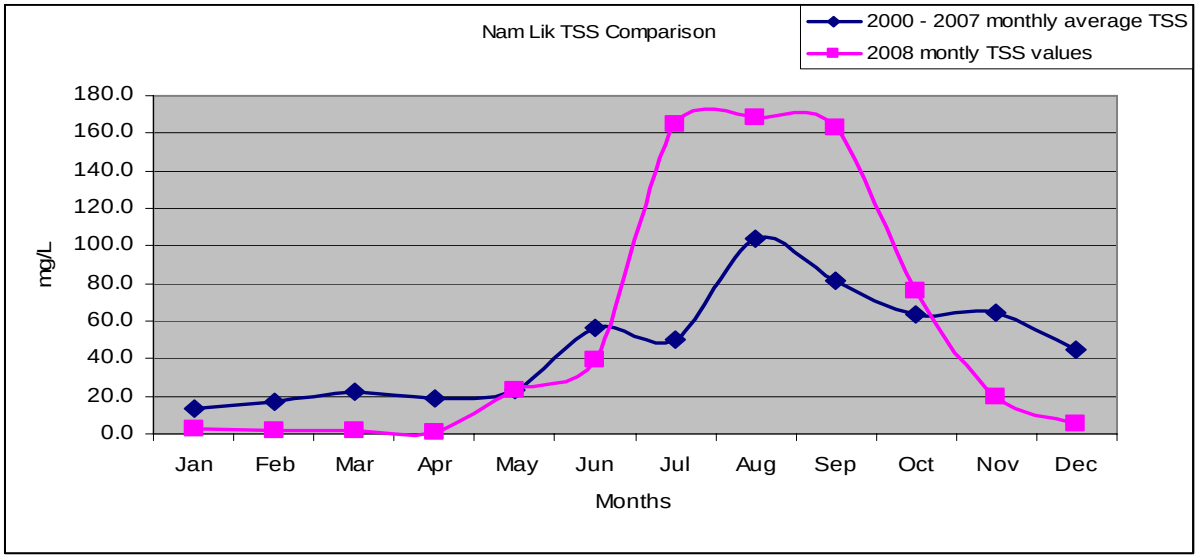
Figure 26: Spatial distribution of total suspended solid in Nam Ngum River in May 2008.



Monitoring Sites:
1 – NN3 CIA Project's WQ Site Nam Ngum upstream of NN3 Reservoir
2 – ST-02 NN2's WQ Site upstream of NN2 Dam Site
3 – ST-03 NN2's WQ Site within the future NN2 Reservoir
4 – ST-04 NN2's WQ Site within the future NN2 Reservoir
5 – ST-05 NN2's WQ Site within the future NN2 Reservoir
6 – ST-06 NN2's WQ Site downstream of the future NN2 Reservoir
7 – ST-07 NN2's WQ Site downstream of Nam Bak
8 – ST-08 NN2's WQ Site upstream of NN1 Reservoir
9 – ST-09 NN2's WQ Site upper zone of NN1 Reservoir
10 – DOI's WQ Site downstream of NN1 Reservoir
11 – DOI's WQ Site Nam Ngum @ Ban Pakhai

Based on monitoring results of the NN3 CIA Project's Monitoring Programme, the construction of hydropower upstream of Nam Lik and Nam Xong confluence has not affected the water quality of the Nam Lik. These results are in conflict with the reported impact on the fisheries in e.g. Nam Lik, but the monitoring period is likely too short to draw any far-reaching conclusions on this issue. TSS level were low during the dry season, but high during the wet season, which is likely due to surface sediment runoff in the wet season. This is also supported by results of the Department of Irrigation's water-quality monitoring data. The DOI's water-quality monitoring results for Nam Lik at Thalat in 2008, showed that the dry-season monthly TSS values were lower than the average monthly TSS values from 2000 to 2007. However, it should be noted that the monthly wet-season TSS values in 2008 were significantly higher than the average monthly TSS values from 2000 to 2007. It is unclear whether the elevated wet season TSS values were the result of the construction of hydropower projects upstream of the DOI's monitoring site or a result of increased surface runoff or other unidentified (erosion) sources of material. The comparison between monthly TSS values measured in 2008 and average monthly TSS values from 2000 to 2007 can be seen in Figure 27.

Figure 27: Nam Lik TSS comparison between 2008 monthly values and historical monthly values (2000 – 2007).



Coordination between the NN3 CIA team's water-quality monitoring team and the Department of Irrigation and the Mekong River Commission has been challenging. The team has not been able to obtain water-quality data for 2009 from either the Department of Irrigation or the Mekong River Commission. The team was informed that water-quality data for 2009 have not been reviewed and therefore, are not yet available to the public. As a result, only data from 2008 is reported in this report.

The team believes that in order to timely identify any adverse effects that can potentially occur as a result of hydropower development in the Nam Ngum River Basin, it is important for project developers to coordinate with the Lao government, allowing individual projects' water-quality monitoring data to be accessed by responsible government agencies, as well as by projects working on behalf of the Government of Lao PDR.

During the preparation of each bi-annual report, the team has had to coordinate with several entities when collecting water-quality data. For the water-quality programme in Laos to be effective, it is important that the government of Laos establishes a central organisation that oversees the compilation of water quality. Having all water-quality data reported to one Government entity will allow data to be easily accessed and utilised. Further, it will allow the government to easily identify and remedy any potential problems with its water-quality monitoring programme, as well as sources of water pollution, in a timely manner.

As we recommended already in our CIA report in early 2008, it is our opinion that the newly formed agency, **WREA**, Water Resources and Environment Administration, should take the leading role in the co-ordination of the water-quality monitoring and management of the data base.

3 Aquatic Ecology, Fish-Catch Monitoring

3.1 Study objective

The overall objective of the aquatic-ecology monitoring programme is to use an indicator, in this instance fish catch, to establish a quantitative baseline against which later comparative analyses may be undertaken. The aim is to assess the change, if any, in relative abundance as a result of infrastructure development (particularly hydropower) at key sites across the basin. It should be noted that "baseline" conditions are already likely to be subject to impacts from the construction of a number of built structures already underway as well as other habitat changes and fishing pressures.

Associated process-related milestones during the design and implementation of the monitoring programme include:

- Secondary data review (done);
- Site reconnaissance and rapid assessment of local fish diversity (done);
- Village and volunteer identification (done);
- Development of a local fish identification guide for the NNRB (done, see Appendix 1);
- Training in recording and documenting fish catch (on-going throughout the programme);
- Periodic and ongoing analyses (on-going through the programme);
- Feed-back of results to the fishermen, with discussions about trends and impacts (done in November 2009).

3.2 Study timeframe

This monitoring programme covers the period from April, 2008 to September, 2009. This will cover the pre-impoundment period of a number of large dams, and it is hoped that it can continue under different management from 2010.

This fourth and final bi-annual report presents the quantitative Catch Per Unit Effort (CPUE) and biodiversity data for the months of April, 2008 to September, 2009. It also includes the results of feedback discussions held with the fishermen researchers in November 2009.

3.3 Methodology

3.3.1 Secondary data review

A review of secondary data was conducted as part of the 1st phase of the TA, in order to determine the level and type of fisheries related data in the basin. Whilst there is a reasonable amount of data on the Nam Ngum 1 reservoir fisheries, the fisheries of the Nam Ngum basin, its fish biodiversity, abundance and ecology is much less well documented. In conjunction with the preliminary data review, a map-based assessment of potential monitoring sites was undertaken to highlight areas of interest.

3.3.2 Sampling site selection

Once this had been done, maps with villages overlaid upon them were developed by the project GIS unit to narrow down possible monitoring locations. Following on from this, a series of meetings were set up with provincial and district authorities from both the fisheries

and energy sectors, to further refine the search for suitable sites based upon more local information. Issues for consideration included security, fishing practices, planned resettlement, proximity to planned hydropower and other infrastructure and transport/road conditions.

Initially six sites were selected across the basin in pursuance of a basin-wide coverage with close attention to existing and planned hydropower projects. A site visit was undertaken to villages in each area to ensure suitability and interest. Owing to security and access reason, one site had to be dropped (downstream of NN3). One village was selected for each of the remaining five sites, refer to Figure 28. Detailed maps for each site are found in Figures 29-32. The monitoring significance of each site is described in Table 9.

3.3.3 Village and researcher selection

At the start, discussions were held with village administration in order to develop the data-collection methods. A full day was spent with focus groups of fishers by first introducing the purpose and aims for the monitoring programme, then moving on to brainstorming lists of fish species currently being caught in the area. Once this had been done, fishers were asked to identify which of the species they considered to be most important and those which are rare. Photographic identification guides were then passed around the group in order for confirmation and crosschecking of species names with photographs. Local names were recorded along with their scientific equivalents. In this way, lists of all species were compiled, cross-referenced and codified. An identification guide was then put together by the project team. This identification guide is attached at Annex 1.

Villagers were chosen based upon their knowledge, interest and availability. Fishers only needed to fish fairly regularly, have a good understanding and ability to identify catch (additional support was provided through training and ongoing support through backstopping and feedback events), and have a basic level of numeracy/literacy. Three individuals were selected from each village based on this criteria and a very small stipend provided to cover their time.

3.4 Quantitative data collection and storage

A basic recording sheet was developed by the project team, detailing basic village and recorder information, date, time, gear used and size, time in and out, species caught, weight, contribution to nutrition and income, presence of eggs and whether species are known to be migrating. Fishers were asked to record catch data on any fishing event, even when no fish were caught. A recording sheet providing a standard format for recording this information was translated into Lao language.

CPUE data (see section 3.5.1. below) was collected for fixed gill nets in all villages in addition to cast nets, long line and various seasonal gears as per methods employed by Baird (2005).

During the period April, 2008 to November, 2009 the national consultant visited the selected villages every 2 months and collected the data sheets from the village researchers. In doing so, he tried to ensure that the data was collected in the agreed format, discussing the results with the village researchers and reporting on any changes occurring in the basin that might affect the fish catches and provide any back-stopping support required.

The data was then transferred to Excel spreadsheets for further analysis and storage. The full set of this primary data from April 2008 to November 2009 will be made available on the CD provided to ADB and Lao Government as part of the final TA report.

Figure 28: Nam Ngum River basin showing location of fish monitoring sites, with proposed dams/dams under construction included.

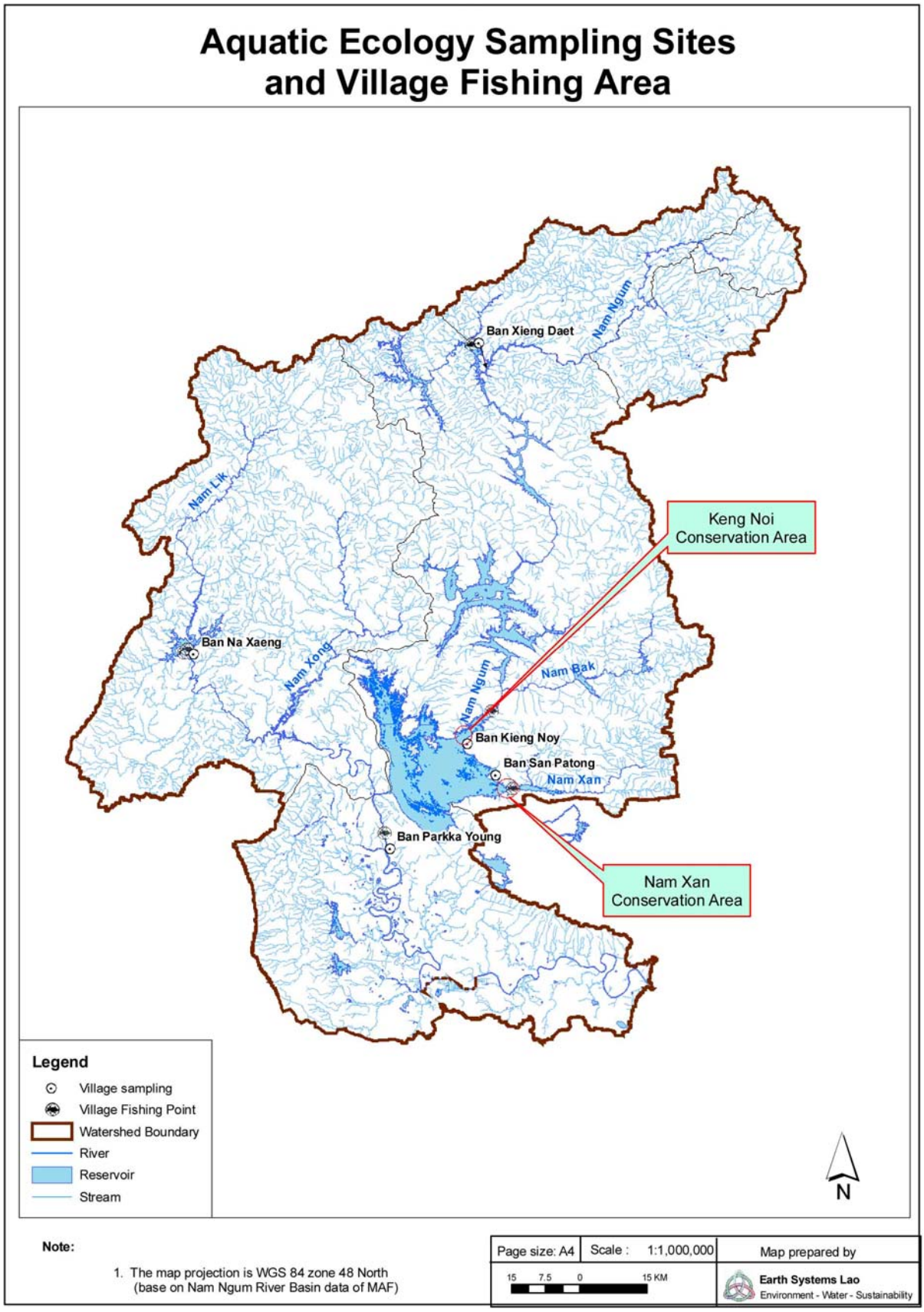


Table 9: Fish monitoring sites in the NNRB

Site #	Village name	Location	Monitoring significance
1	Ban Pakanyeung	D/S of the confluence of the Nam Neun-Nam Lik	This site is downstream of the NN1 dam and shows the effects of existing dam operation. It is also the site which is on the fish migration route from Mekong mainstream up the Nam Lik. In the future it will be only site with direct connection to the Mekong
2	Ban Na Xaeng	D/S of Nam Lik 2	Although the village lies downstream of Nam Lik 2, the main fishing area lies immediately upstream of the dam construction works which started in 2008. The results show the influence of construction works on the fishery upstream and will be useful for comparison after impoundment starts
3	Ban Sanphatong	NN1 reservoir - Nam Xan confluence	This fishing area receives water from the Nam Leuk dam (basin transfer), but should not be subject to any further changes. The fishing area also has the Nam Xan fish conservation zone, which is important for spawning
4	Ban Keng Noi (Phonsavaat)	D/S NN2	This fishing area lies at the confluence of the Nam Ngum 1 reservoir with the main Nam Ngum river. It includes the Kieng Noi fish conservation zone. It lies about 5km downstream of the Nam Ngum 2 dam site, and so illustrates changes due to construction of the dam and in the future dam operation
5	Ban Xieng Det	U/S of NN3	The village area is due to be partly inundated by Nam Ngum 3, and so this site will illustrate changes due to impoundment. However, it is also about 20 km downstream of Nam Ngum 5 which started construction in May 2008. It therefore also illustrates changes in fishery due to construction impacts

3.5 Analysis

3.5.1 Catch Per Unit Effort (CPUE) data

The monitoring programme uses a form of CPUE assessment. CPUE is used internationally and throughout the region, including Laos, to quantify temporally the relative abundance of

fish. In the context of the programme, it will allow for an assessment of the change in relative abundance as a result of planned infrastructure in the NNRB.

The CPUE data can be used to:

- Provide information on the mean CPUE by fisher, village or area;
- Provide information on seasonal variations such as migration peaks;
- Provide information on seasonal intensity of fishing and low seasons, e.g. when the fishermen are planting or harvesting their rice crops.

CPUE has been calculated by summing the total number of kilos caught by all gears over a month and dividing this by the effort (total number of hours the gear is in the water/being used). These mean monthly figures for each village provide a standardised relative index of abundance that can be used to compare across villages and from month to month.

In addition the CPUE for just gill nets has been calculated, since this gives a more uniform measure of exposure of fish to the nets compared to gear such as cast nets, traps, and hook and line.

3.5.2 Gear used

The information provided by the fisher researchers allows an insight into the types and sizes of gears used throughout the year. This obviously varies depending upon the nature of the fishery, the river character and the height of the water. The gear profiles of each village are expressed as a percentage of the total time fished.

3.5.3 Fish and nutrition

The data provided by the fishers indicates how much of the daily catch is sold and how much is consumed by the fishing household. Whilst there is some variation in household size and extent to which they consume the fish, it is possible to get an indication of the importance of fishing as a livelihood activity and contribution to income as well as the average consumption of fish per head in each of the villages.

3.5.4 Biodiversity assessments

The returns provided by the fishers identified which fish species were being caught, the quantities caught and variations in fish species at different times of year. This has enabled the development of a biodiversity index for each location, being the total number of species caught divided by the total number of species recorded for the Nam Ngum basin as a whole (120 species) multiplied by 100.

The data also allows for the identification of the most common fish caught over the period – the 12 most common species by weight have been identified for each site, with a comparison between 2008 and 2009 to bring out inter-annual variations.

3.6 Verification of results

3.6.1 Cross-checking with other fish monitoring/research organisations

The 3rd monitoring report was sent out to a number of projects and organisations, e.g. Nam Ngum river basin project, Nam Theun 2 and Theun Hinboun expansion projects, LARReC, MRCS, World Fish Centre for comment on the results. Several comments were received and suggestions have been incorporated where appropriate.

3.6.2 Feedback to fisher researchers

In November, 2009, the aquatic ecology team visited all five sites and spent 2 – 3 hours discussing the results with the fisher researchers. These feedback sessions provided the team with an opportunity to verify the results, checking whether the fishermen themselves thought that they were appropriate and correct, and then discussing the monthly variations and possible causes for these variations, key events and the most common species caught and the preferred locations for fishing.

Photos 5 and 6. Feedback workshop in Sanphatong/Phonsavaat, November, 2010

3.7 Site descriptions

Table 10 shows the sizes of each of the villages in terms of numbers of households, population and women, and it shows the names of the fishers collecting data on their daily catches.

The following brief descriptions highlight the key features of each site, together with more detailed maps of the areas around them.

Table 10: Village Populations and fisher/researchers

No	Vilage	Houshold	Population	Women	Fisherman	Province
1	**Naxeng**	153	918	587	Mr. Bounhieng	Vientiane
					Mr. Pheng	
					Mr. Eait	
2	**Xiengdet**	111	606	282	Mr. Khamsao	Xiengkhuang
					Mr. Somlith	
					Mr. Vane	
3	**Phonsavaat**	126	1232	686	Mr. Meuat	Vientiane
					Mr. Somphane	
					Mr. Air	
4	**Sanphathong**	46	260	145	Mr. Khamphanh	Vientiane
					Mr. Vanphengphet	
					Mr. Deng	
5	**Pakanyeung**	500	2344	1181	Mr. Intong	Vientiane
					Mr. Laylamphone	
					Mr. Laythong	

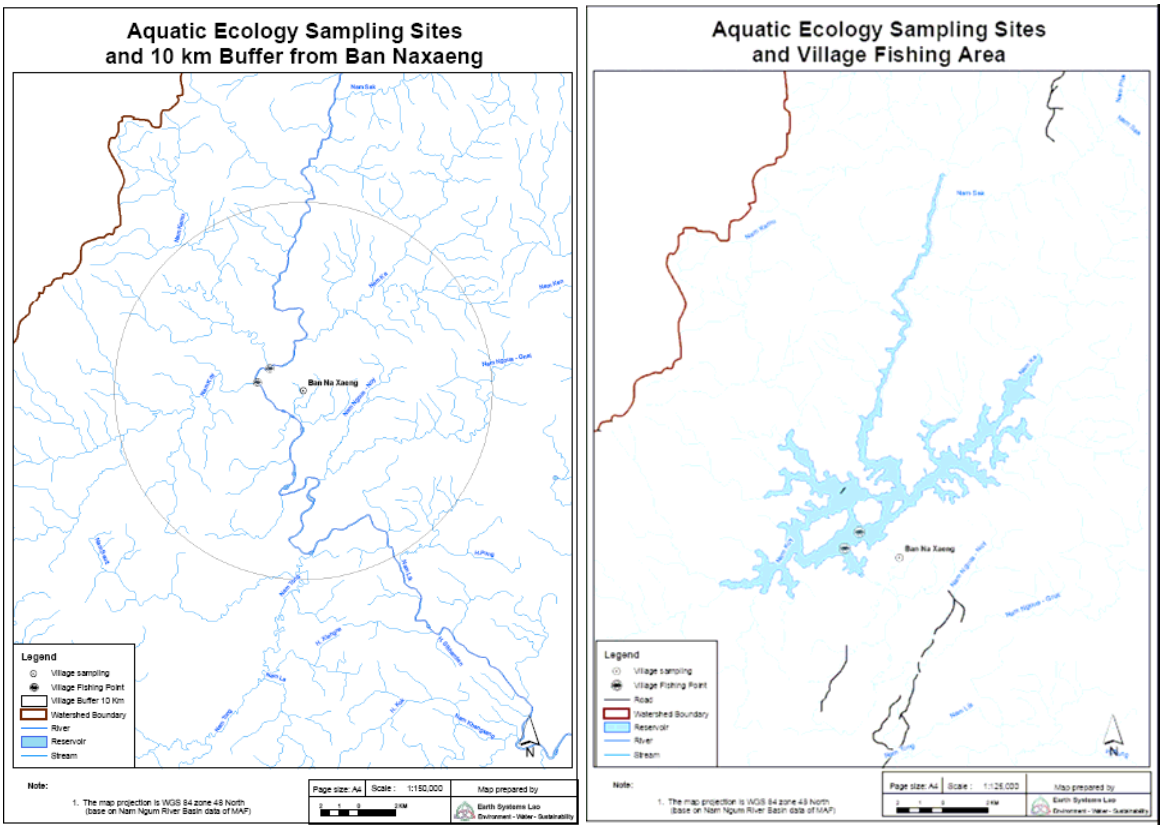
3.7.1 Naxeng

Figure 29 shows the location of Ban Naxeng on the Nam Lik river. The village is located on slightly higher ground overlooking a flat agricultural area to the south. The river flows from the north out of more hilly terrain, through a fairly narrow steep-sided valley. The main fishing area frequented by the fishers lies upstream of the village in this narrow valley. Fishing is carried on downstream of the village, but by other fishers/farmers in the village, although the researchers reported that fishing has declined significantly in the downstream area as a result of overfishing and use of illegal methods.

The researchers generally fish several kilometres upstream, but on occasion may spend several days away fishing as far upstream as Kasi. The researchers are all part-time fishermen, maybe fishing one or two times a week, and otherwise working as farmers, or collecting timber and forest resources.

As can be seen from Figure 29, the Nam Lik 2 dam will create a reservoir upstream of Ban Naxeng, flooding the main fishing areas of the village. Dam construction activities started in January 2008.

Figure 29: Map of area around Naxeng before and after construction of Nam Lik 2 dam

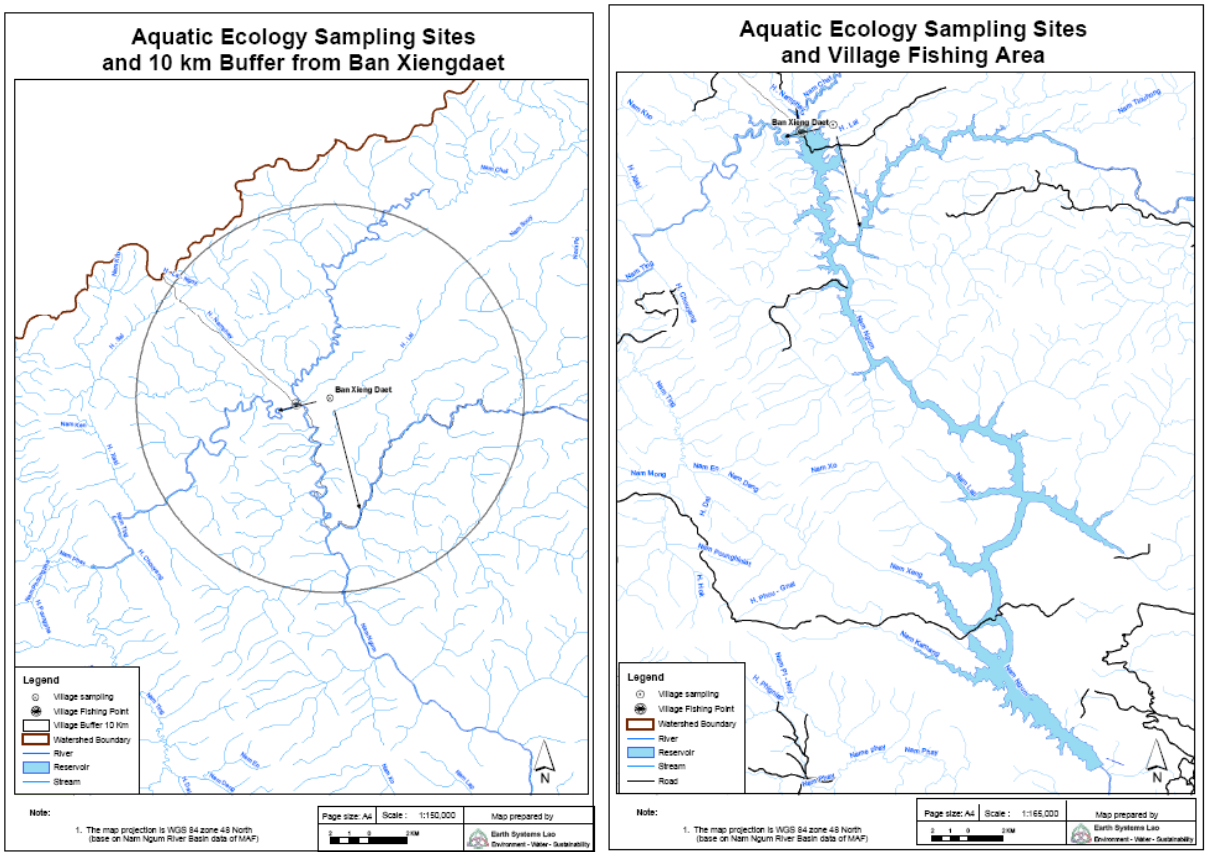


3.7.2 Xiengdet

Figure 30 shows the area around Ban Xiengdet. The village is located about 30 km down a very steep, difficult track which is usually inaccessible during the wet season. This tends to isolate the village. The village lies in a small fertile valley at the junction between the Nam Ting and the Nam Chat, and about 10 km upstream of the confluence with the Nam Ngum. Fishing activities extend both upstream of the Nam Ting and down to the Nam Ngum. The rivers are cool and fast flowing over rocks and gravel. The best time of year for fishing is reported to be April – May, when the water is low and the river less dangerous. Because of its isolation in the wet season, almost all the fish caught is consumed within the village, surpluses being sold to other villagers.

Figure 30 also shows the extent of the reservoir of Nam Ngum 3. Construction of Nam Ngum 3 is temporarily halted and reservoir filling is unlikely to take place until after 2015. Ban Xiengdet lies at the top end of the proposed reservoir. The village also lies about 20 km downstream of Nam Ngum 5 dam; construction of this dam started in May 2008.

Figure 30: Map of area around Xiengdet, before and after construction of Nam Ngum 3 and 5 dams

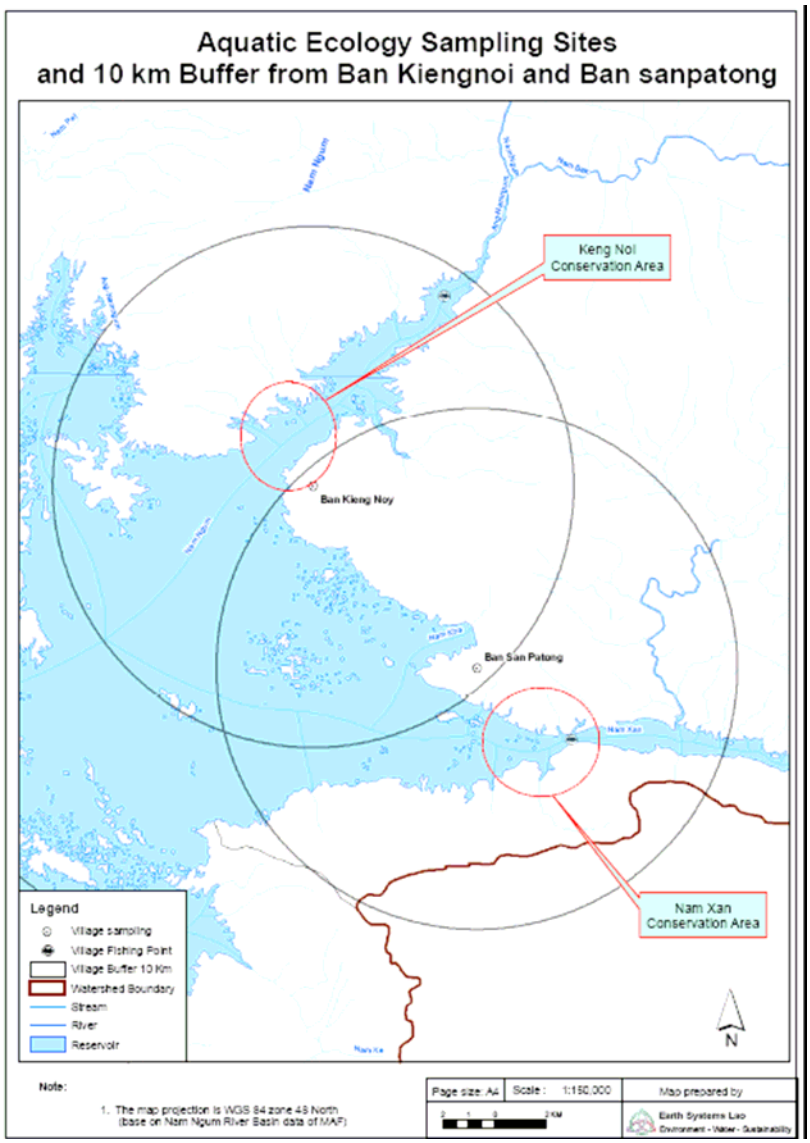


3.7.3 Phonsavaat and Sanphathong

Phonsavaat and Sanphathong are both located on the shores of the Nam Ngum 1 reservoir near the points at which, respectively, the Nam Ngum and the Nam Xan rivers enter the reservoir, see Figure 31. Both rivers are recognised as important areas for fish and Fish Conservation Zones (Keng Noi and Nam Xan FCZ) with fishing restrictions at certain times of year to allow the fish to spawn. At other times of year, fishing is not restricted. The fishermen tend to fish in the areas near the entrance of the rivers rather than in the main body of the reservoir. They are mostly full-time commercial fishermen, taking some time off for harvest. They sell a large proportion of their fish. Fishing is reported to be easiest from March/April to August/September in Sanphathong and slightly later from August to December in Phonesavaat, coinciding when the reservoir is filling.

Nam Ngum 1 reservoir has been long established with a productive reservoir fishery. In 2006 construction started on Nam Ngum 2 dam, which is located about 10 km upstream from Phonsavaat. A provisional date of operation is now 2011 with full commercial operation by 2013.

Figure 31: Map of Phonsavaat and Samphathong, with Nam Ngum 1 reservoir



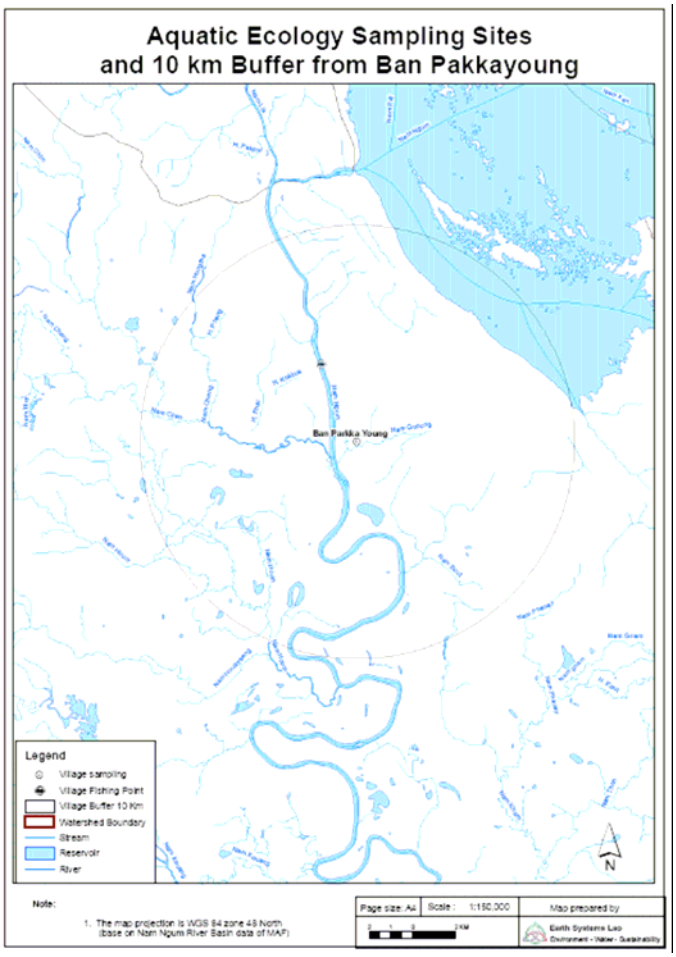
3.7.4 Pakanyeung

Pakanyeung is located about 8 km downstream of the confluence between the Nam Ngum and the Nam Lik rivers, and about 10 km downstream of the Nam Ngum 1 dam, see Figure 32. The village lies on the banks of the Nam Ngum which is about 200 m wide at this point in a wide channel with river-bank gardens. The river is deeper and slower-flowing than the rivers at Xiengdet and Naxeng, although there are some small rocky islands (exposed during low flows, April and May) and gravel beds within the fishing area that are important for spawning, especially for the predominant *Cyprinus carpio.* After Pakanyeung, the river meanders in its own floodplain until it reaches the Mekong, some 100 kms downstream. There is no obstruction to fish migration between Pakanyeung and the Mekong and migrations are reported in October/November and May/June. The main fishing area tends to be upstream of the village, with October and November being the best time of year for fishing.

The researchers are part-time fishermen, also working as farmers, e.g. growing maize in the river bank gardens. The village is located on a good road that provides easy access for sale of fish.

The operation of Nam Ngum 1 hydropower station has an effect upon the flows in the river. Usually the electricity generation starts around 8.00 in the morning and closes at 22.00 in the evening. During the day the water level may be raised about 60 cm.

Figure 32: Map of the area around Pakanyeung showing NamNgum 1 reservoir

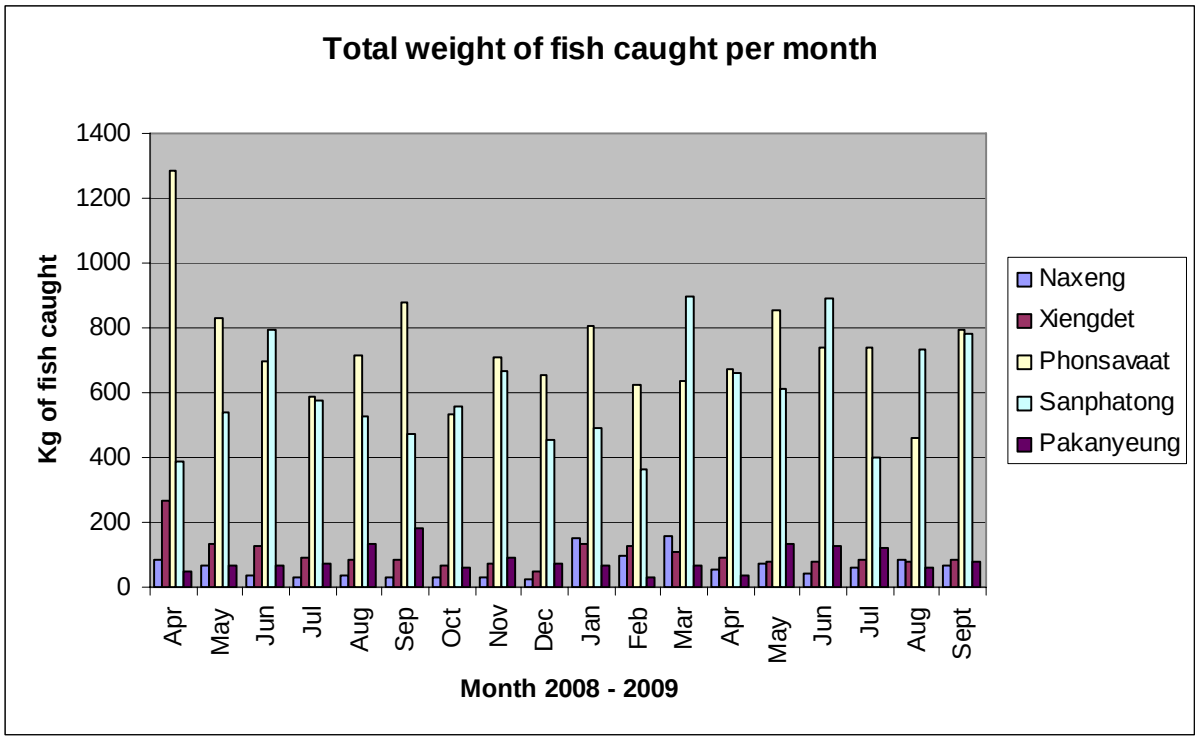


3.8 Results

3.8.1 Total weight of fish caught and hours fished

The quantities of fish caught each month between April 2008 and September 2009 are shown in Table 11 and the number of hours spent in fishing (i.e. the hours to which the gear is exposed to the fish) is shown in Table 12. Figure 33 shows the comparison of the total catch each month in each of the villages.

Figure 33: Monthly catch by village



Figures 34 a-e show the fish catch per month in each village individually together with the hours spent in fishing each month. The latter gives an idea of the intensity of fishing effort, and highlights when the fishermen have been spending less time in fishing activities as they carry out other livelihood activities, such as harvesting.

3.8.2 Gear used

The analysis of the different types of gear used, expressed as a percentage of total time fished is shown in Table 13, which highlights those gears that are used for more than 10% of the time. This analysis shows that gill nets of various sizes were the preferred type of gear in all locations, especially in the two reservoir fisheries of Phonsavaat and Sanphathong, where gill nets were used for over 97% of the time. Here the preferred mesh size was between 7 and 8. In Naxeng, gill nets were used for about 95% of the time, but the mesh sizes were smaller at about 4 – 4.5. In Naxeng, there was also small usage of many other gear types such as cast nets and hooks.

In Xiengdet, gill nets were also preferred, being used for 78% of the time, with similar mesh sizes as at Naxeng, as would be expected in similar size and type of river. Cast nets and handle nets were both used about 10% of the time.

Table 11: Total weight of fish caught per month in each village

	Total catch per month kg																		
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Village mean**
Naxeng	83.9	64.1	38.1	28.0	36.1	33.0	29.5	27.3	22.7	151.2	96.3	156.3	56.3	69.7	41.1	63.1	82.8	67.6	63.7
Xiengdet	263.9	133.1	125.4	88.2	82.3	84.2	67.2	74.4	46.9	134.8	129.8	108.0	88.7	76.5	78.5	87.8	78.5	87.6	102.0
Phonsavaat	1283.6	832.7	699.0	585.3	717.7	880.4	532.4	710.1	656.6	809.0	622.7	635.4	675.4	853.0	738.8	740.2	459.8	795.6	734.9
Sanphatong	387.1	537.5	796.0	572.9	529.3	474.5	556.6	669.5	451.8	491.9	366.5	896.3	660.1	610.7	889.0	399.5	735.4	784.8	600.5
Pakanyeung	49.7	64.5	64.5	71.3	131.9	180.3	63.5	88.0	70.3	63.9	31.9	67.2	34.1	131.3	125.3	120.5	60.1	76.3	83.0

Table 12: Total number of hours fished (Effort)

	Effort (Hours per month)																		
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Village mean**
Naxeng	138	105	129	199	255	187	154	213	130	192	127	192	150	160	91	163	244	173	167
Xiengdet	662	353	390	436	501	292	312	350	390	390	345	291	405	375	242	268	139	229	354
Phonsavaat	2371	2260	1515	1658	1307	1124	987	1103	1104	1269	1379	1354	1089	1198	1372	1378	698	1172	1352
Sanphatong	1824	1644	764	1093	1466	1232	1673	1244	1116	800	774	1184	619	540	792	375	556	516	1012
Pakanyeung	67	123	409	432.5	277	481	300.5	271	211	143	81.5	148	108.5	249	331.5	390.95	192.5	225	247

Table 13: Different types of fishing gear used in each village

Gear		% usage of gear (rounded off)				
Types	**Sizes**	**Naxeng**	**Xiengdet**	**Phonsavaat**	**Sanphathong**	**Pakanyeung**
Gill net	**2**	0				
	3	2		0	1	9
	3.5	2	**17**	2	2	3
	4	**13**	**24**	10	7	7
	4.5	**55**	**28**	0	5	8
	5	9	9			6
	6	**10**	1	0	1	2
	7			3	**40**	4
	8	1		**47**	**26**	**13**
	9			3		
	10			**29**	2	2
	11					
	12	1		1		3
	14			0	4	7
	16	1				1
	20		0	1	9	1
Cast net	**3**		2			
	4	1	2			0
	4.5		7			
	5	1				
	8	0	0			
Hook	**2**	0				
	5	0				
	6			1	2	
	7	2	1	1		1
	8					
	11	1				0
	16				0	
	18					
	0.1		10			
Handle net	**16**					
Net	**8**					
Trap	**8**					3
	10		0			10
	0					**21**
Sabouak						
Gun					0	
Toum	**10**			0		

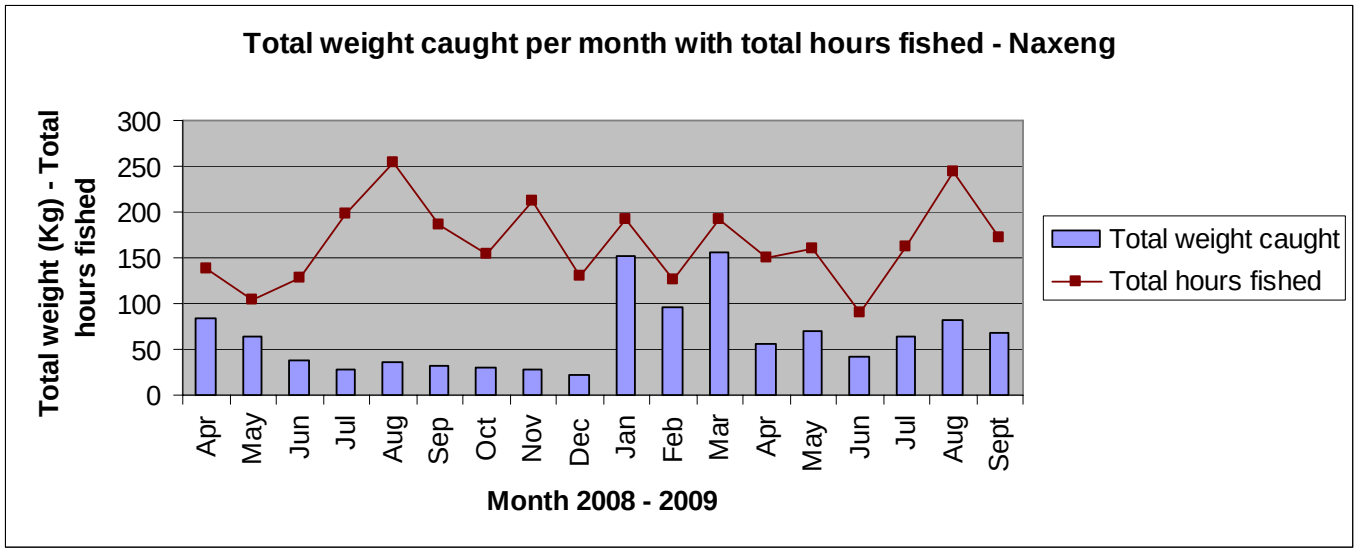
In Pakanyeung, the situation is rather different, with floating gill nets being used for 65% of the time, and traps being used for 34% of the time. The preferred size of gill net is mesh size 8.

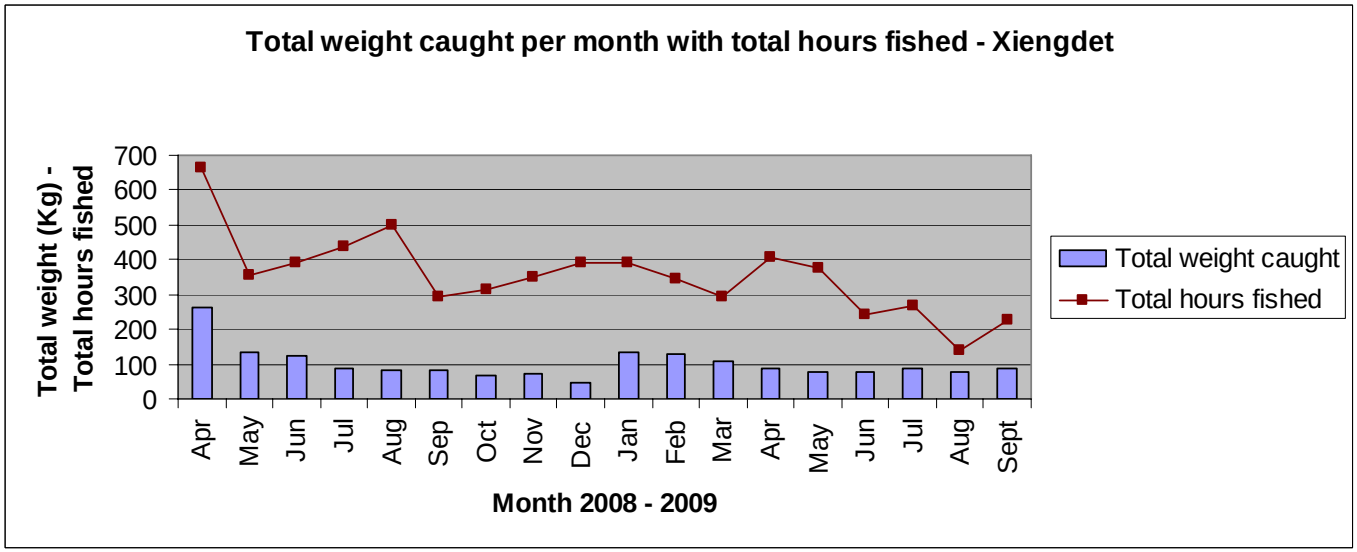
3.8.3 CPUE data

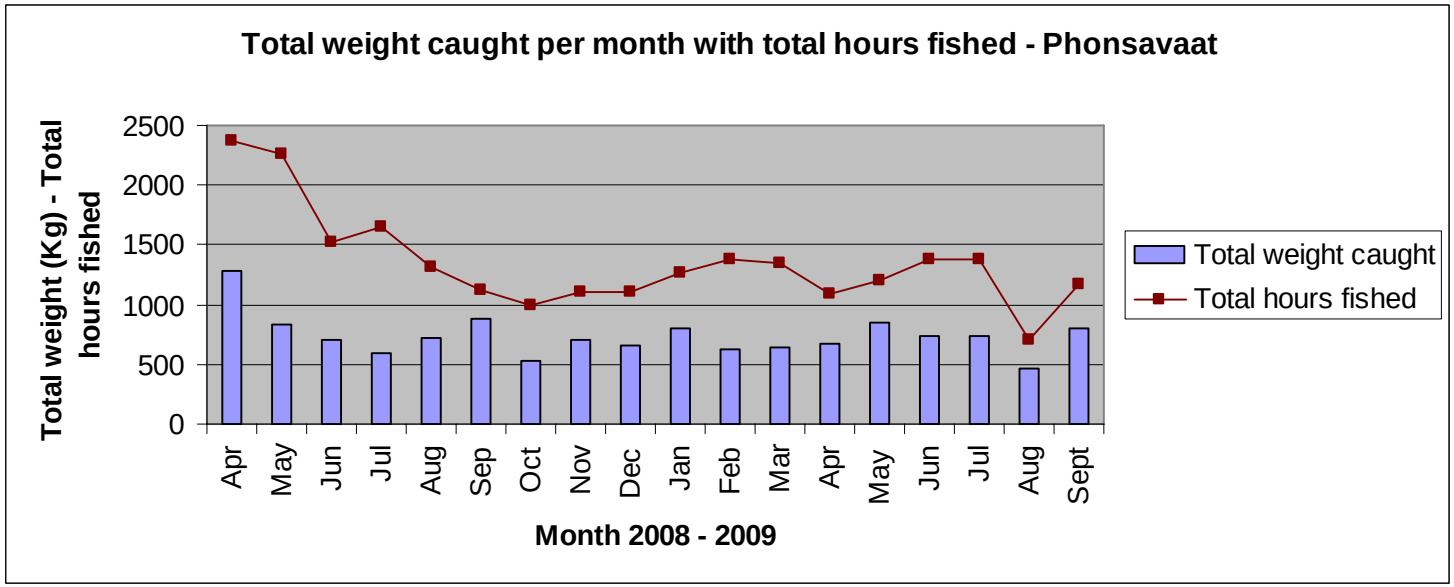
The CPUE data for the whole monitoring period from April 2008 to September 2009 are shown in Table 14. This compares the CPUE for all types of gear, which require different degrees of effort. Thus cast nets and handle nets are more active forms of fishing, whilst gill nets, hook and line and traps involve setting the gear for a longer period – typically overnight. The CPUE is measuring the weight caught per hour of exposure of the gear to the fish. It thus represents the ease with which fish can be caught. Because of the differences in gear, the CPUEs for gill nets have only been calculated as shown in Table 15. It can be seen that the CPUEs for all gear tends to be slightly higher than the CPUEs for gill nets alone, indicating a slightly greater efficiency for other gear. This does not always hold true for some months, especially for the peak season for the reservoir fisheries, where gill nets are used almost exclusively.

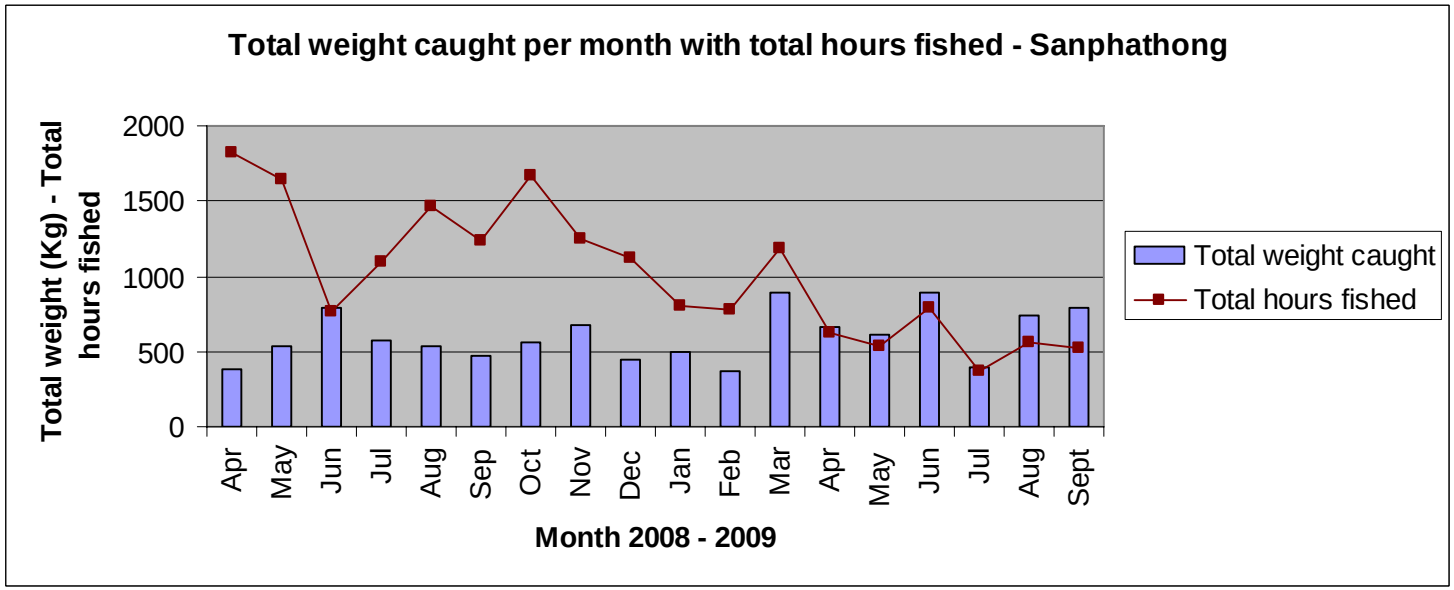
The monthly CPUEs for all gears and in all villages is shown for comparison in Figure 35 and the variation in monthly CPUEs in each village compared with the mean CPUE for the village over the full sampling period is shown in Figures 36 a – e.

Figures 34 a - e: Monthly catches and time spent fishing for each village






Total weight caught per month with total hours fished - Phonsavaat
Total weight (Kg) - Total hours fished
2500
2000
1500
1000
500
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Month 2008 - 2009
Total weight caught
Total hours fished


Total weight caught per month with total hours fished - Sanphathong
Total weight (Kg) - Total hours fished
2000
1500
1000
500
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Month 2008 - 2009
Total weight caught
Total hours fished

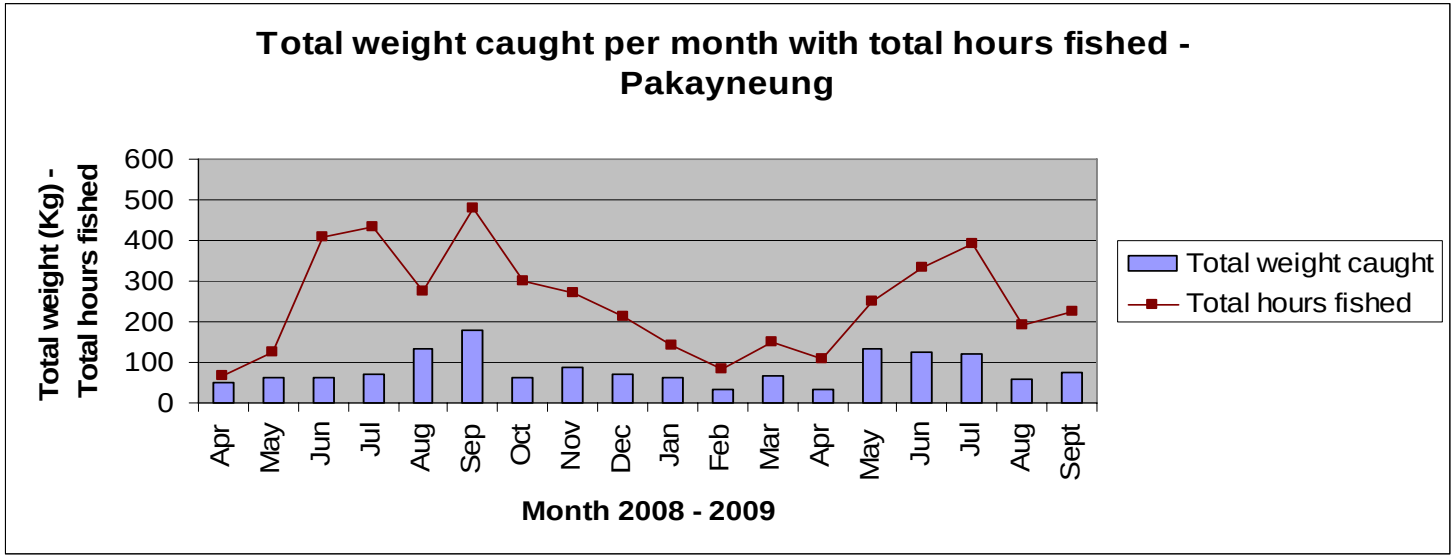

Total weight caught per month with total hours fished - Pakayneung
Total weight (Kg) - Total hours fished
600
500
400
300
200
100
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sept
Month 2008 - 2009
Total weight caught
Total hours fished

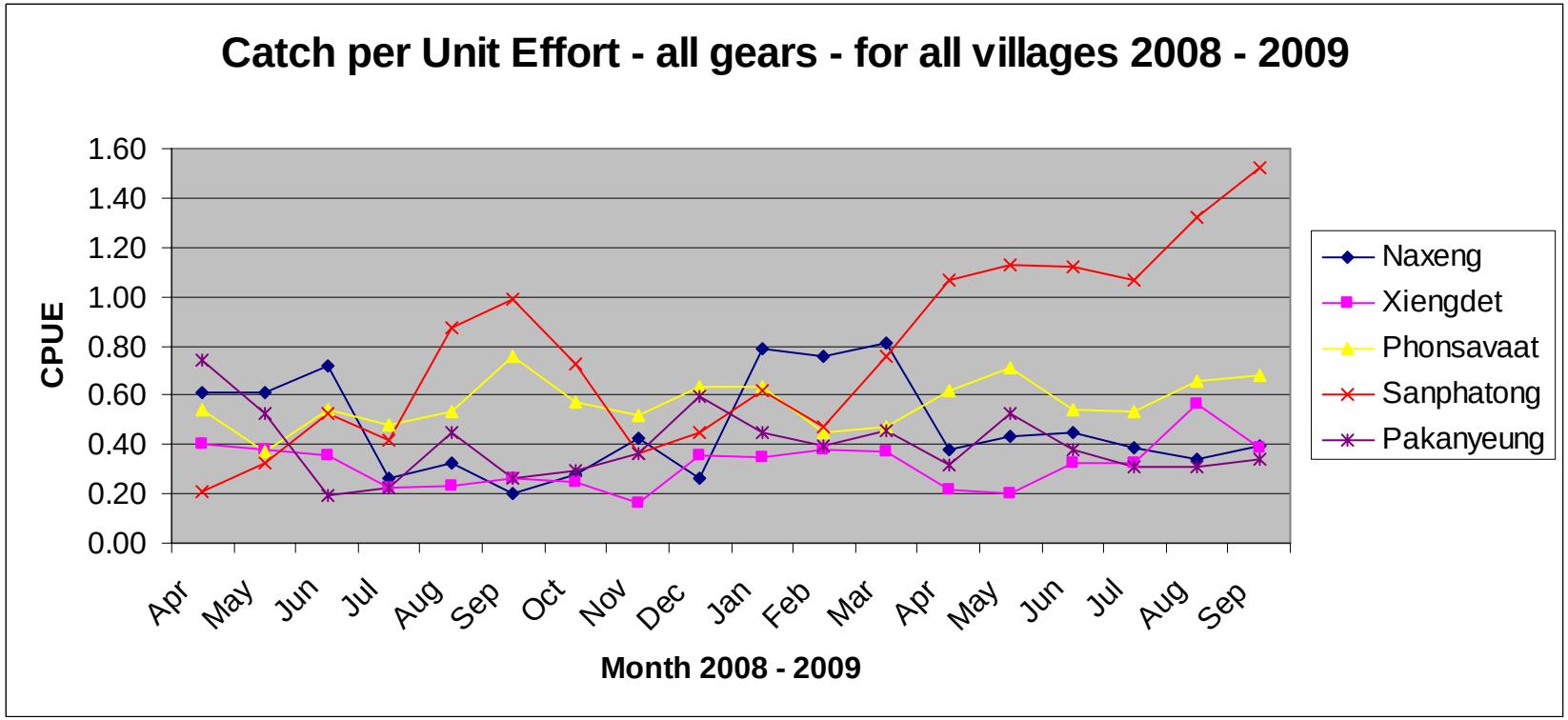
Table 14: Monthly CPUE data from each village for all gears

	Month																		
Village	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Village mean**
Naxeng	0.61	0.61	0.72	0.26	0.33	0.20	0.28	0.43	0.26	0.79	0.76	0.81	0.38	0.44	0.45	0.39	0.34	0.39	**0.47**
Xiengdet	0.40	0.38	0.36	0.22	0.23	0.26	0.24	0.17	0.36	0.35	0.38	0.37	0.22	0.20	0.32	0.33	0.56	0.38	**0.32**
Phonsavaat	0.54	0.37	0.54	0.48	0.54	0.76	0.57	0.51	0.63	0.64	0.45	0.47	0.62	0.71	0.54	0.54	0.66	0.68	**0.57**
Sanphatong	0.21	0.33	0.52	0.41	0.87	0.99	0.73	0.36	0.45	0.61	0.47	0.76	1.07	1.13	1.12	1.07	1.32	1.52	**0.78**
Pakanyeung	0.74	0.52	0.19	0.22	0.45	0.26	0.30	0.36	0.60	0.45	0.39	0.45	0.31	0.53	0.38	0.31	0.31	0.34	**0.40**
Mean all villages	**0.50**	**0.44**	**0.47**	**0.32**	**0.48**	**0.50**	**0.42**	**0.37**	**0.46**	**0.57**	**0.49**	**0.57**	**0.52**	**0.60**	**0.56**	**0.53**	**0.64**	**0.66**	**0.51**

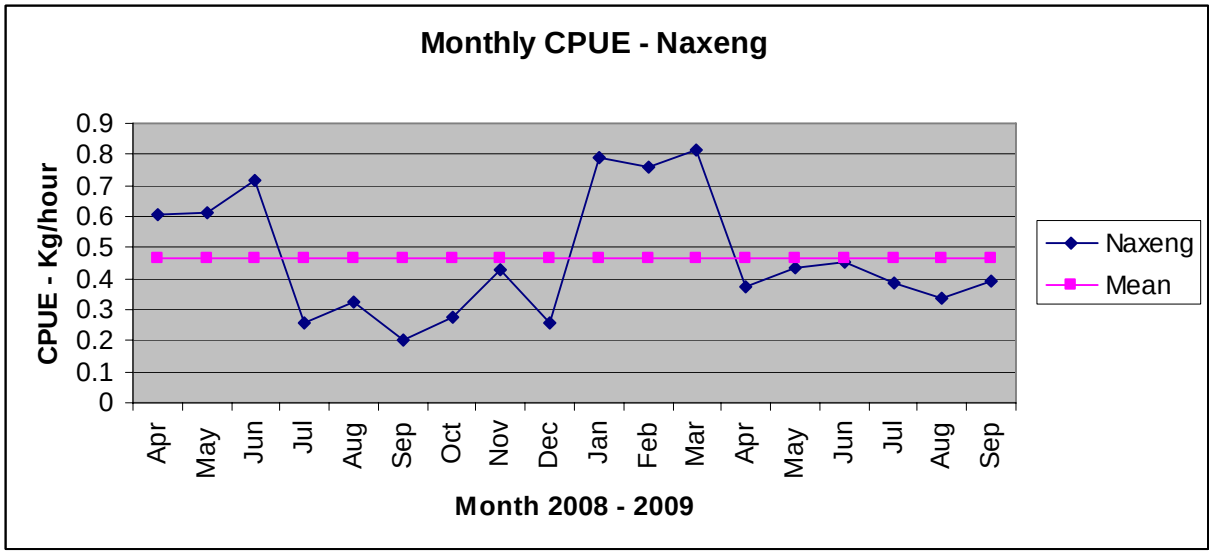
Table 15: Monthly CPUE data for each village for gill net catches only

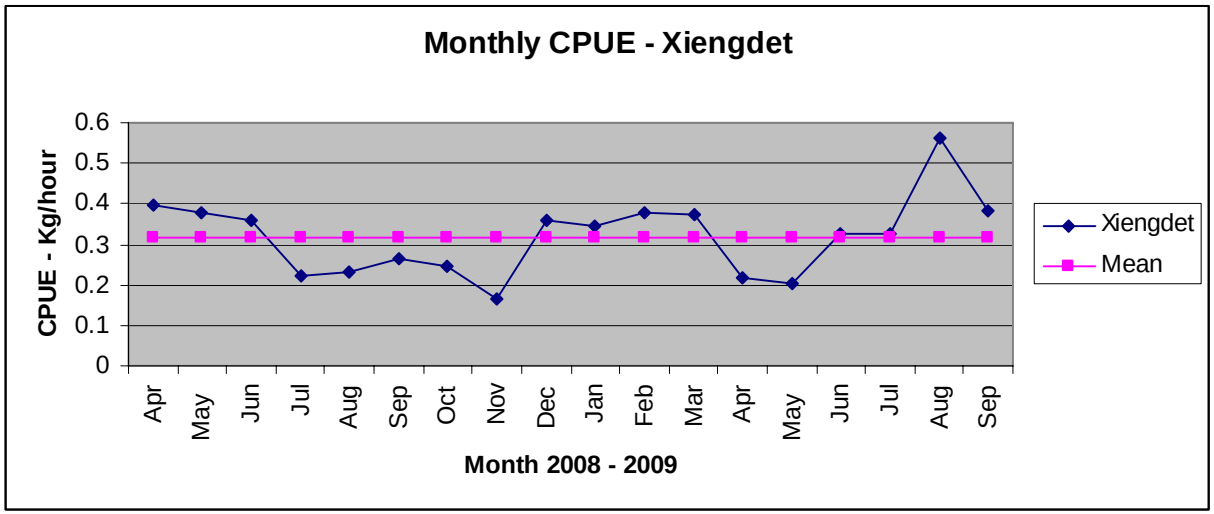
	2008									2009									
Village	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Village mean**
Naxaeng	0.61	0.55	0.18	0.16	0.16	0.18	0.17	0.18	0.14	0.76	0.65	0.77	0.38	0.42	0.45	0.41	0.32	0.31	**0.38**
Xiengdet	0.32	0.34	0.34	0.27	0.36	0.32	0.16	0.18	0.12	0.31	0.34	0.37	0.20	0.19	0.15	0.19	0.40	0.22	**0.27**
Phonsavaat	0.58	0.38	0.58	0.57	0.57	0.87	0.64	0.57	0.66	0.66	0.45	0.47	0.63	0.71	0.55	0.54	0.51	0.61	**0.59**
Sanphatong	0.21	0.32	0.62	0.55	0.55	0.54	0.51	0.71	0.70	0.62	0.47	0.76	1.09	1.17	1.13	1.07	1.32	1.53	**0.77**
Pakanyeung	0.74	0.52	0.51	0.58	0.52	0.41	0.62	0.62	0.60	0.45	0.39	0.44	0.31	0.62	0.55	0.40	0.39	0.36	**0.50**
Mean all villages	**0.49**	**0.42**	**0.45**	**0.43**	**0.43**	**0.46**	**0.42**	**0.45**	**0.44**	**0.56**	**0.46**	**0.56**	**0.52**	**0.62**	**0.57**	**0.52**	**0.59**	**0.61**	**0.50**

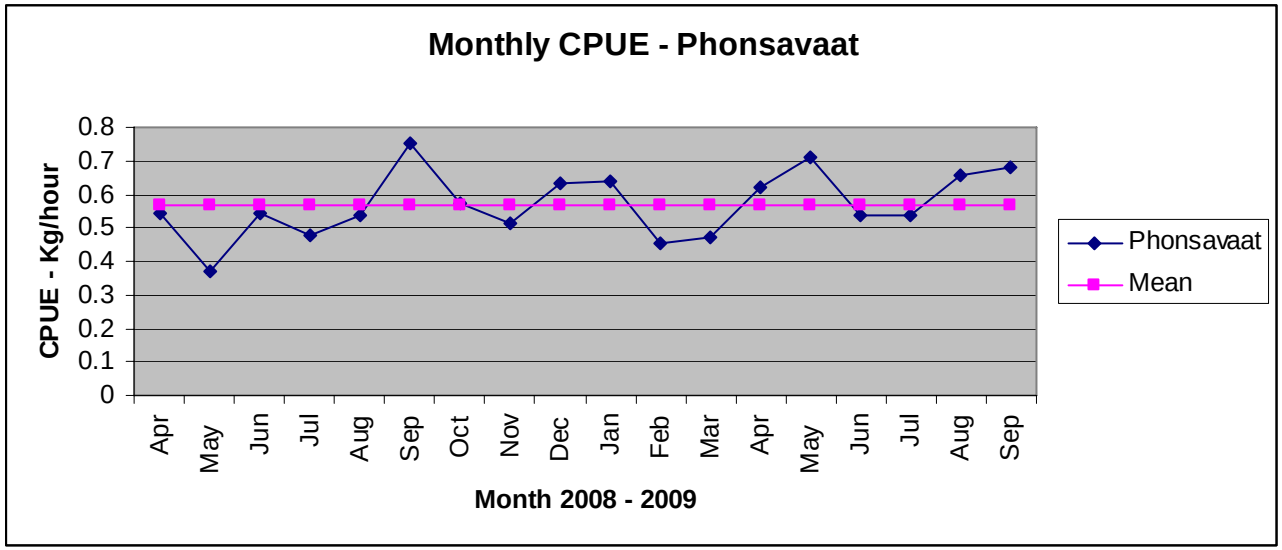
Figure 35: Monthly variation in CPUE for each village

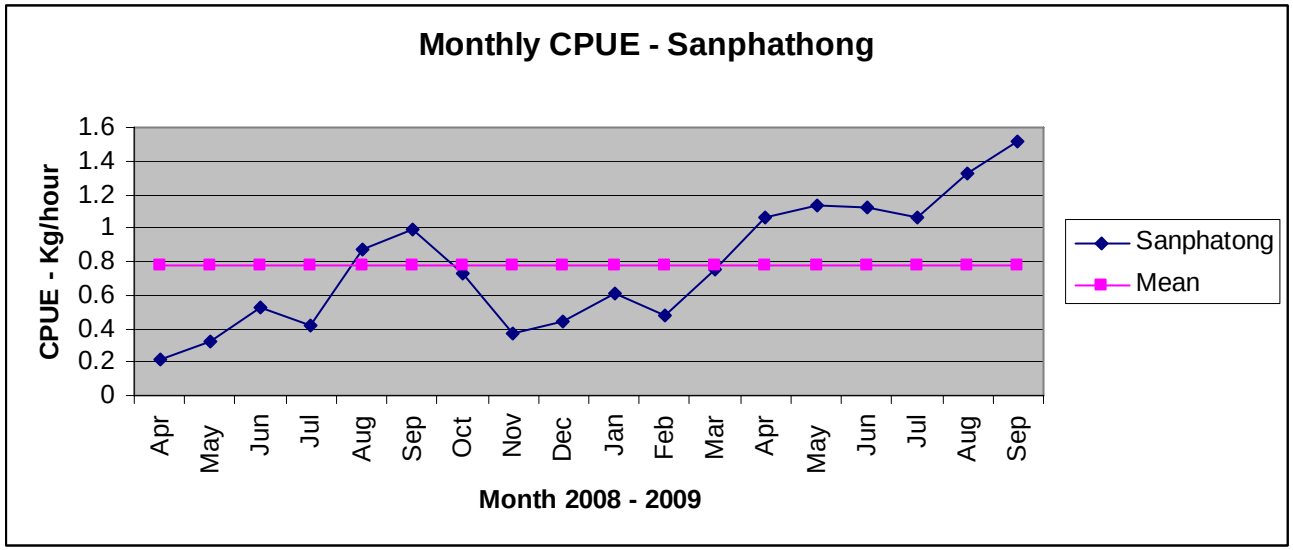


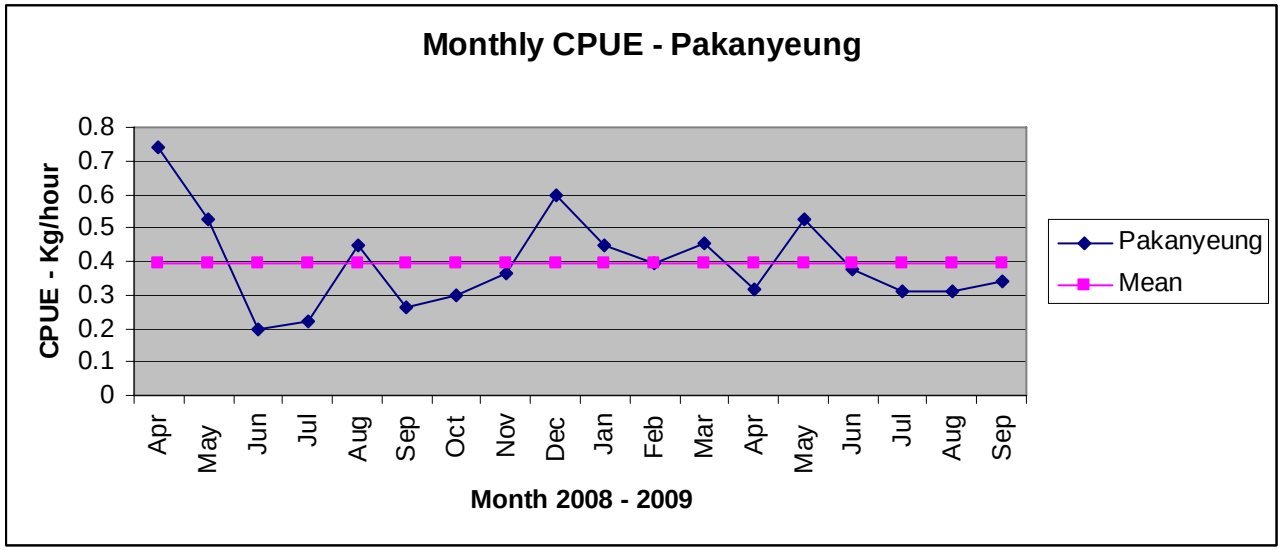
Figures 36 a - e: Monthly and mean CPUEs (all gears) for each village






Monthly CPUE - Phonsavaat
CPUE - Kg/hour
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month 2008 - 2009
Phonsavaat
Mean

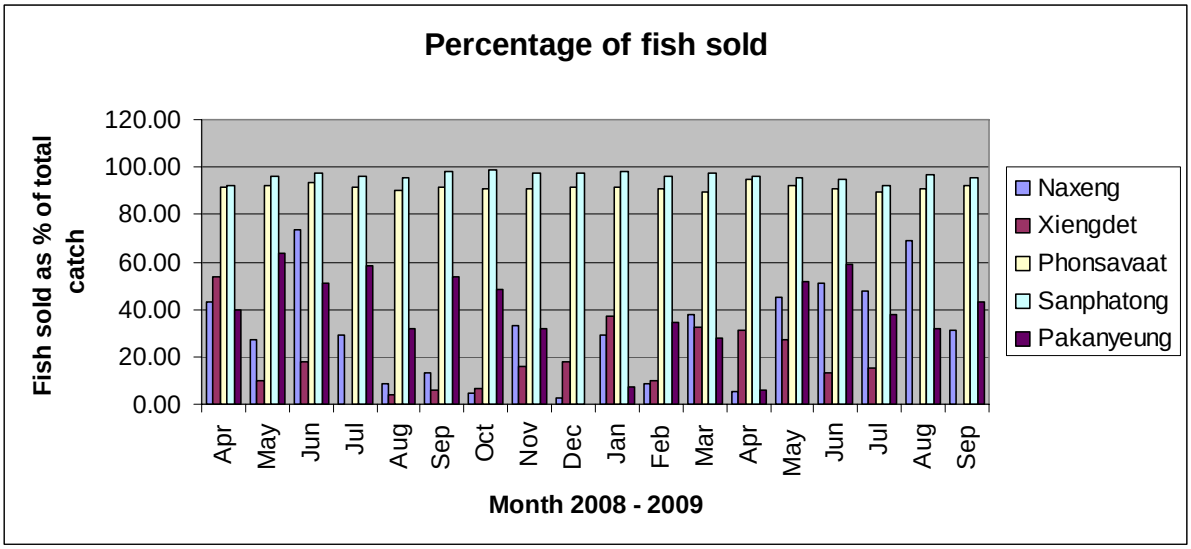

Monthly CPUE - Sanphathong
CPUE - Kg/hour
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month 2008 - 2009
Sanphatong
Mean


Monthly CPUE - Pakanyeung
CPUE - Kg/hour
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month 2008 - 2009
Pakanyeung
Mean

3.8.4 Fish catches as a contribution to income and nutrition

The quantities of fish consumed within the households of the researchers and the proportion sold each month are shown in Table 16 and the proportion of the catch that is sold each month in each village is illustrated in Figure 37. Table 17 takes the average monthly consumption of fish by the researchers in each village and divides by the number of people in the three households. This gives an average monthly and yearly consumption of fish per person.

Figure 37: Fish sold as percentage of total catch



3.8.5 Fish Biodiversity data

The twelve most caught species at each village are identified and placed in order of predominance in Table 18, while the complete species list of all types of fish caught in the Nam Ngum basin is shown in Table 19. This table compares the total weights of each fish species caught in 2008 and in 2009 and then estimates the percentage for each species of the total catch for each village. Photographic species lists were shown to the fishermen and their families to encourage discussion about the fish they catch most during the feedback sessions. This table also shows the total numbers of fish species caught in 2008 and 2009 and the overall Biodiversity Index for each site.

The numbers of species caught each month for each village are shown in Figures 38 a - e. These figures also show the variation in the Biodiversity Index with each month.

Table 16: Monthly weight of fish sold and eaten in each village:

Kg sold

Village	Naxeng	Xiengdet	Phonsavaat	Sanphatong	Pakanyeung
Apr	36.4	141.8	1 174.0	357.2	19.6
May	17.5	13.3	766.8	518.2	40.9
Jun	68.0	24.7	770.3	389.9	40.7
Jul	15.0	0.0	726.9	434.6	55.8
Aug	7.0	4.4	630.5	1 223.0	39.5
Sep	5.0	4.6	775.7	1 201.0	67.5
Oct	2.0	5.0	513.4	1 206.0	43.2
Nov	30.4	9.2	516.1	442.1	31.2
Dec	1.0	24.7	639.4	484.3	0.0
Jan	43.8	49.6	737.7	482.5	4.6
Feb	8.0	13.3	564.6	351.4	11.0
Mar	59.5	35.0	566.8	873.5	18.8
Apr	3.0	27.5	640.2	635.5	2.0
May	31.5	21.0	785.3	582.9	67.5
Jun	21.0	10.3	671.6	842.4	73.6
Jul	30.0	13.4	664.9	367.7	45.6
Aug	57.0	0.0	419.1	712.9	19.2
Sep	21.0	0.0	734.7	750.5	32.7
Monthly mean	**25.4**	**22.1**	**683.2**	**658.6**	**34.1**

Kg eaten

Village	Naxeng	Xiengdet	Phonsavaat	Sanphatong	Pakanyeung
Apr	47.5	122.1	109.7	29.9	30.1
May	46.6	119.8	65.9	19.3	23.6
Jun	24.5	115.3	54.9	10.9	38.7
Jul	36.6	96.5	66.8	17.6	39.7
Aug	76.5	111.5	71.1	58.6	83.9
Sep	33.1	72.4	73.2	22.6	57.6
Oct	40.8	71.0	49.8	15.1	46.2
Nov	60.5	48.7	51.5	11.9	67.0
Dec	32.7	115.3	61.6	14.2	42.2
Jan	107.4	85.2	71.3	9.4	59.3
Feb	88.3	116.5	58.1	15.1	20.9
Mar	96.8	73.0	68.6	22.8	48.4
Apr	53.3	61.2	35.2	24.6	32.1
May	38.2	55.5	67.7	27.8	63.8
Jun	20.1	68.2	67.2	46.6	51.7
Jul	33.1	74.4	75.3	31.8	74.9
Aug	25.8	78.5	40.7	22.5	40.9
Sep	46.6	87.6	60.9	34.3	43.6
Monthly mean	**50.5**	**87.4**	**63.9**	**24.2**	**48.0**

Table 17: Estimates of fish consumption per person in each village

Village	Average weight of fish eaten per month	Number of family members	Average monthly consumption	Average yearly consumption
	kg/mo		kg/head/mo	kg/head/yr
Naxeng	50.46	19	2.66	31.87
Xiengdet	87.37	20	4.37	52.42
Phonsavaat	63.86	16	3.99	47.90
Sanphatong	24.17	18	1.34	16.11
Pakanyeung	48.02	19	2.53	30.33

Table 18: Twelve most caught fish species at each of the villages

No.	12 most caught species in Naxeng	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch
60	Lobocheilos melanotaenia(20cm SL) “Pa Khing, Pa Khiang”	67.68	111.12	178.80	13.31
90	Poropuntius laoensis(20 cm SL) “Pa chat”	88.57	87.61	176.18	13.12
33	Esomus longimana “pa mout”	53.4	75	128.40	9.56
50	Homaloptera smithi (pa mut, pa dit hin)	48.58	50.3	98.88	7.36
64	Mystacoleucus greenwayi (7 cm) “pa lang nam, pa lang koh, pa kee tid”	27.67	25.8	53.47	3.98
9	Barbonymus gonionotus (33 cm TL)“Pa pak, pa pak na”	7.6	41.85	49.45	3.68
5	Baganrius Yerelli 200 cm “Pa Kae”	6.1	39.62	45.72	3.40
48	Henicorhynchus siamensis “pa goum”	14.2	30.39	44.59	3.32
39	Hampala macrolepidota 70cm “pa soot noi”	18.7	23.15	41.85	3.12
42	Hemibagrus filamentus	24.6	17.08	41.68	3.10
15	Channa gachua, ca. 200mm SL (pa kuan, pa kung)	16	16	32.00	2.38
62	Mastacembelus armatus (Pa lat)	16.75	12.86	29.61	2.20
	Total numbers of species	62	62	77	
	Biodiversity Index	52	52	64	
No.	**12 most caught species in Xiengdet**	**2008 (Kg)**	**2009 (Kg)**	**Total caught (Kg)**	**% of catch**
90	Poropuntius laoensis(20 cm SL) “Pa chat”	205.78	160.42	366.20	18.85
57	Labeo dyocheilus (50cm) “pa wa khaii, pa sa ii, pa wa sa ii, pa wa, pa phaow”	149.15	153.12	302.27	15.56
37	Garra theunensis “pa phee”	122.06	132.31	254.37	13.09
78	Osteochilus lini(15 cm) “Pa mawm, Pa na mong, Pa ii thai, Pa pohk”	127.47	95.14	222.61	11.46
103	Tor tambroides(80 cm) “Pa Pohng, Pa Tone, pa xong”	90.10	58.54	148.64	7.65
69	Neolissochilus blanci (40 cm) Pa deng	70.49	71.89	142.38	7.33
22	Clarias batrachus “Pa duk”	60.33	63.44	123.77	6.37
89	Poropuntius carinatus “pa kom”	52.00	34.48	86.48	4.45
119	(Pa dam)	21.64	19.01	40.65	2.09
120	Luciocyprinus striolatus (Pa yoi)	31.08		31.08	1.60
17	Channa striata (Pa cau)	8.60	20.83	29.43	1.51
20	Cirrhinus cirrhosus “pa kin ya, pa nouan chan”	20.84	1.32	22.16	1.14
	Total numbers of species	*44*	*38*	*52*	
	Biodiversity Index	*37*	*32*	*43*	
No.	**12 most caught species in Phonsavaat**	**2008 (Kg)**	**2009 (Kg)**	**Total caught (Kg)**	**% of catch**
93	Puntioplites falcifer(35 cm) “pa sa kaang”	2226.50	1730.50	3957.00	28.84
8	Barbonymus altus “Pa lien fai hang deng”	579.97	694.40	1274.37	9.29
58	Labiobarbus kuhli(20cm) “Pa lang kohn, Pa pood, Pa khui lam”	661.20	508.90	1170.10	8.53
21	Cirrhinus molitorella (50 cm) “Pa gkeng”	479.20	720.30	1199.50	8.74
9	Barbonymus gonionotus (33 cm TL)“Pa pak, pa pak na”	364.70	370.90	735.60	5.36
39	Hampala macrolepidota 70cm “pa soot noi”	167.90	428.00	595.90	4.34
63	Micronema bleekeri (pa nang)	240.90	266.00	506.90	3.70
56	Labeo chrysophekadion 90cm “pa pia, pa pia dham, pa ii tou”	330.40	130.90	461.30	3.36
44	Hemibagrus wyckioides (pa cuang)	379.20	67.70	446.90	3.26
42	Hemibagrus filamentus	220.40	207.40	427.80	3.12
10	Barbonymus schwanenfeldii (35cm) “Pa lien fai, Pa dok Chaan’	180.90	230.90	411.80	3.00
3	Amblyrhynchichthys truncates (Pa Jok Ta Dum, pa ta po)	100.40	239.20	339.60	2.48
	Total numbers of species	*60*	*45*	*65*	
	Biodiversity Index	*50*	*48*	*54*	

No.	12 most caught species in Sanphathong	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch
93	Puntioplites falcifer(35 cm) “pa sa kaang”	1597.50	774.39	2371.89	17.68
9	Barbonymus gonionotus (33 cm TL)“Pa pak, pa pak na”	808.70	766.70	1575.40	11.74
8	Barbonymus altus “Pa lien fai hang deng”	651.50	453.30	1104.80	8.24
21	Cirrhinus molitorella (50 cm) “Pa gkeng”	439.20	539.30	978.50	7.29
52	Hypophthalmichthys molitrix (pa ket lab)	527.20	316.10	843.30	6.29
39	Hampala macrolepidota 70cm “pa soot noi”	402.10	357.80	759.90	5.66
63	Micronema bleekeri (pa nang)	275.20	368.10	643.30	4.80
10	Barbonymus schwanenfeldii (35cm) “Pa lien fai, Pa dok Chaan’	371.90	153.70	525.60	3.92
40	Hampala dispar 35 cm “pa soot” “pa soot gai, pa soot thong”	259.70	193.90	453.60	3.38
44	Hemibagrus wyckioides (pa cuang)	293.10	158.90	452.00	3.37
18	Chitala blanci (pa dong lai)	197.70	239.10	436.80	3.26
58	Labiobarbus kuhli(20cm) “Pa lang kohn, Pa pood, Pa khui lam”	270.00	84.20	354.20	2.64
74	Oreochromis niloticus(pa nin)	307.30	40.60	347.90	2.59
	Total numbers of species	*56*	*48*	*58*	
	Biodiversity Index	*47*	*40*	*48*	

No.	12 most caught species in Pakanyeung	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch
30	Cyprinus carpio (pa nai)	215.00	152.10	367.10	24.07
47	Henicorhynchus lobatus “pa bok”	66.70	106.81	173.51	11.37
44	Hemibagrus wyckioides (pa cuang)	67.60	19.20	86.80	5.69
93	Puntioplites falcifer(35 cm) “pa sa kaang”	21.75	48.52	70.27	4.61
24	Cosmochilus harmandi, 113 “pa mang”	30.60	36.70	67.30	4.41
9	Barbonymus gonionotus (33 cm TL)“Pa pak, pa pak na”	15.10	46.43	61.53	4.03
42	Hemibagrus filamentus	33.75	27.10	60.85	3.99
105	Wallago attu (pa khao)	14.70	34.40	49.10	3.22
98	Scaphonathops theunensis “pa pian”	10.00	33.73	43.73	2.87
72	Ompok bimaculatus(pa seum)	39.00	2.30	41.30	2.71
41	Helicophagus leptorhynchus “pa yone na mou”	12.90	27.50	40.40	2.65
76	Osteochilus hasseltii(30 cm SL) “Pa ii thai”	21.30	17.80	39.10	2.56
	Total numbers of species	*58*	*54*	*73*	
	Biodiversity Index	*48*	*45*	*61*	

Table 19: Nam Ngum fish species list with weights caught and proportions of catch in each village

					Naxeng				Xiengdet				Phonsavaat				Sanphathong				Pakayneung			
No.	Species	Reservoir only	River only	Guild number	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch
1	Acanthopsoides gracilentus (Pa hok guay)				0.4		0.40	0.03														1.5	1.50	0.10
2	Akysis leucorhynchus, 28.7mm SL “pa ki hia”																				0.40		0.40	0.03
3	Amblyrhynchichthys truncates (Pa Jok Ta Dum, pa ta po)			3									100.40	239.20	339.60	2.48	122.70	124.50	247.20	1.84				
4	Anabas testudineus (Pa Keng)			RB	0.5	1.9	2.40	0.18									8.00		8.00	0.06	4.00	8.4	12.40	0.81
5	Bagarius yarrelli 200 cm “Pa Kae”			2*	6.1	39.62	45.72	3.40	8.00		8.00	0.41	25.00	10.00	35.00	0.26	9.00		9.00	0.07	23.00	0.5	23.50	1.54
6	Bangana berhri “pa va thong na nai thow”			2														2.00	2.00	0.01				
7	Bangana lippus “pa va pone”			2																				
8	Barbonymus altus “Pa lien fai hang deng”			2		0.4	0.40	0.03					579.97	694.40	1274.37	9.29	651.50	453.30	1104.80	8.24	4.90	1.6	6.50	0.43
9	Barbonymus gonionotus (33 cm TL)“Pa pak, pa pak na”			RB	7.6	41.85	49.45	3.68	0.14	1.50	1.64	0.08	364.70	370.90	735.60	5.36	808.70	766.70	1575.40	11.74	15.10	46.43	61.53	4.03
10	Barbonymus schwanenfeldii (35cm) “Pa lien fai, Pa dok Chaan’				0.6		0.60	0.04	1.00	0.00	1.00	0.05	180.90	230.90	411.80	3.00	371.90	153.70	525.60	3.92				
11	Belodontichthys dinema (pa khob)								2.50	1.00	3.50	0.18	0.60	0.60	1.20	0.01		1.40	1.40	0.01		1.7	1.70	0.11
12	Botia beauforti “pa kheo kai lai”			2*	0.58	11.8	12.38	0.92	0.50	7.30	7.80	0.40	0.10		0.10	0.00					3.80		3.80	0.25
13	Brachirus harmandi (pa ta diew)			2	2.06	2.82	4.88	0.36													0.40		0.40	0.03
14	Ceratoglanis scleronema, 242 mm SL “pa kab oy”									0.20	0.20	0.01	15.00	5.00	20.00	0.15	3.20	0.00	3.20	0.02				
15	Channa gachua, ca. 200mm SL (pa kuan, pa kung)				16	16	32.00	2.38	4.38	8.60	12.98	0.67												
16	Channa marulius, 81.5mm SL “pa do”									0.40	0.40	0.02	0.30		0.30	0.00	2.70	32.80	35.50	0.26				
17	Channa striata (Pa cau)			RB	8	8.5	16.50	1.23	8.60	20.83	29.43	1.51					1.80	1.00	2.80	0.02	1.10	2.5	3.60	0.24
18	Chitala blanci (pa dong lai)								3.06	1.50	4.56	0.23	152.10	109.40	261.50	1.91	197.70	239.10	436.80	3.26	0.20	3.3	3.50	0.23
19	Chitala ornate (pa dong kao)				5	0.3	5.30	0.39	5.23	1.49	6.72	0.35	3.00	2.00	5.00	0.04	31.00	90.40	121.40	0.90	0.70		0.70	0.05
20	Cirrhinus cirrhosus “pa kin ya, pa nouan chan”	exotic		3*	1.1		1.10	0.08	20.84	1.32	22.16	1.14	1.30	0.60	1.90	0.01	1.90	0.00	1.90	0.01	9.80	10.5	20.30	1.33
21	Cirrhinus molitorella (50 cm) “Pa gkeng”			3/RB	10.85	17.21	28.06	2.09	4.11	1.60	5.71	0.29	479.20	720.30	1199.50	8.74	439.20	539.30	978.50	7.29	15.50	12.6	28.10	1.84
22	Clarias batrachus “Pa duk”			RB	11.9	3.5	15.40	1.15	60.33	63.44	123.77	6.37	1.00		1.00	0.01	4.83	12.00	16.83	0.13	14.10	1	15.10	0.99
23	Clupeichthys aesarnensis “Pa Keo”			RB					4.80	0.60	5.40	0.28												
24	Cosmochilus harmandi, 113 “pa mang”			3*	0.7		0.70	0.05	2.00	2.00	4.00	0.21									30.60	36.7	67.30	4.41
25	Crossocheilus reticulates “pa mun hang dum”				1.5	2.1	3.60	0.27	1.16	1.40	2.56	0.13		2.50	2.50	0.02								
26	Ctenopharyngodon idellus (pa pok meuk)	exotic			13.8	4.07	17.87	1.33									7.30	2.90	10.20	0.08	2.00	1.5	3.50	0.23
27	Cyclocheilichthys apogon (pa dok ngiew hang deng)			RB	0.7		0.70	0.05	1.40	1.00	2.40	0.12	19.30	16.10	35.40	0.26	47.50	59.00	106.50	0.79	2.00	2.4	4.40	0.29
28	Cyclocheilichthys enoplos (pa jok), 102 mm SL			3	0.2		0.20	0.01	2.60		2.60	0.13					10.50	23.40	33.90	0.25		1.4	1.40	0.09
29	Cyclocheilichthys repasson(pa dok ngiew, pa sai tun, pa lai kai)				0.8	4	4.80	0.36					13.50	72.90	86.40	0.63	19.10	68.40	87.50	0.65	5.30	1.74	7.04	0.46
30	Cyprinus carpio (pa nai)	exotic			0.4	4	4.40	0.33	3.38	6.48	9.86	0.51	3.50	2.80	6.30	0.05	10.20	17.80	28.00	0.21	215.00	152.1	367.10	24.07
31	Discherodontus ashmeadi “pa dok ngiew, pa hang deng, pa sai tun”					1.6	1.60	0.12					13.40	34.40	47.80	0.35	1.60	4.80	6.40	0.05	1.80		1.80	0.12
32	Epalzeorhynchos munense 12 cm (pa doot hin)					8	8.00	0.60	0.00	2.80	2.80	0.14	3.60		3.60	0.03								
33	Esomus longimana “pa mout”				53.4	75	128.40	9.56					3.00		3.00	0.02						1.7	1.70	0.11
34	Esomus metallicus “pa bin”					0.8	0.80	0.06		0.20	0.20	0.01					0.60		0.60	0.00		1.3	1.30	0.09
35	Esomus metallicus (pa siew)					10	10.00	0.74	0.50		0.50	0.03	0.60	0.50	1.10	0.01					10.80	1	11.80	0.77
36	Garra cambodgiensis “pa mun, pa kang lai”			2*	0.5	0.3	0.80	0.06					0.50		0.50	0.00					1.80		1.80	0.12
37	Garra theunensis “pa phee”			2*					122.06	132.31	254.37	13.09		0.70	0.70	0.01								
38	Glyptothorax interspinalum “pa kae thong”				11.4	2.2	13.60	1.01	3.97	0.07	4.04	0.21	0.60		0.60	0.00	5.70		5.70	0.04				
39	Hampala macrolepidota 70cm “pa soot noi”			RB	18.7	23.15	41.85	3.12					167.90	428.00	595.90	4.34	402.10	357.80	759.90	5.66	21.20	4.7	25.90	1.70
40	Hampala dispar 35 cm “pa soot” “pa soot gai, pa soot thong”			RB	7.8	17.13	24.93	1.86					186.80	57.50	244.30	1.78	259.70	193.90	453.60	3.38	2.40	8	10.40	0.68
41	Helicophagus leptorhynchus “pa yone na mou”			2	3.4	0.2	3.60	0.27					2.90		2.90	0.02	3.60	0.00	3.60	0.03	12.90	27.5	40.40	2.65
42	Hemibagrus filamentus				24.6	17.08	41.68	3.10					220.40	207.40	427.80	3.12	115.90	48.30	164.20	1.22	33.75	27.1	60.85	3.99
43	Hemibagrus wyckii (pa gote dam)				4.6	3	7.60	0.57					30.00	7.00	37.00	0.27	57.10	4.30	61.40	0.46		21.1	21.10	1.38
44	Hemibagrus wyckioides (pa cuang)				12.8	6	18.80	1.40					379.20	67.70	446.90	3.26	293.10	158.90	452.00	3.37	67.60	19.2	86.80	5.69
45	Hemimyzon confluens “pa paem, pa tid hin” -			endemic						6.10	6.10	0.31												
46	Hemimyzon confluens (pa ee pae)								3.14	1.30	4.44	0.23												
47	Henicorhynchus lobatus “pa bok”			3		0.1	0.10	0.01		6.40	6.40	0.33	3.30	0.00	3.30	0.02					66.70	106.81	173.51	11.37
48	Henicorhynchus siamensis “pa goum”			3	14.2	30.39	44.59	3.32													1.40	0.8	2.20	0.14
49	Homaloptera leonardi (pa bitu)					2.5	2.50	0.19													0.40		0.40	0.03
50	Homaloptera smithi (pa mut, pa dit hin)				48.58	50.3	98.88	7.36														1	1.00	0.07

	Nam Ngum Species				Naxeng				Xiengdet				Phonsavaat				Sanphathong				Pakayneung			
No.	Species	Reservoir only	River only	Guild number	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch
51	Homaloptera smithi (pa pou)																							
52	Hypophthalmichthys molitrix (pa ket lab)	exotic		RB									4.90	12.60	17.50	0.13	527.20	316.10	843.30	6.29				
53	Hypophthalmichthys nobilis (pa huao ngai)												78.00	26.20	104.20	0.76	171.20	120.40	291.60	2.17	1.00		1.00	0.07
54	Homaloptera leonardi“pa dit hin”																							
55	Kryptopterus crytopterus “pa pik kai”			2*									121.10	82.30	203.40	1.48	52.10	52.50	104.60	0.78				
56	Labeo chrysophekadion 90cm “pa pia, pa pia dham, pa ii tou”			RB									330.40	130.90	461.30	3.36	133.70	71.60	205.30	1.53	13.30	8.9	22.20	1.46
57	Labeo dyocheilus (50cm) “pa wa khaii, pa sa ii, pa wa sa ii, pa wa, pa phaow”				3.4	3.5	6.90	0.51	149.15	153.12	302.27	15.56	21.90	4.00	25.90	0.19						2	2.00	0.13
58	Labiobarbus kuhli(20cm) “Pa lang kohn, Pa pood, Pa khui lam”			3*	12.3	11.02	23.32	1.74	0.08	0.08	0.16	0.01	661.20	508.90	1170.10	8.53	270.00	84.20	354.20	2.64	16.15	15.5	31.65	2.07
59	Lepidocephalichthys hasselti (Pa eet)								0.80	1.30	2.10	0.11												
60	Lobocheilos melanotaenia(20cm SL) “Pa Khing, Pa Khiang”				67.68	111.12	178.80	13.31	2.40	0.00	2.40	0.12										3.2	3.20	0.21
61	Macrognathus siamensis (Pa lote)				0.6	0.3	0.90	0.07										1.70	1.70	0.01	3.00		3.00	0.20
62	Mastacembelus armatus (Pa lat)				16.75	12.86	29.61	2.20					4.20		4.20	0.03	2.00	9.30	11.30	0.08	0.30	3	3.30	0.22
63	Micronema bleekeri (pa nang)				0.25		0.25	0.02					240.90	266.00	506.90	3.70	275.20	368.10	643.30	4.80	3.40	5.6	9.00	0.59
64	Mystacoleucus greenwayi (7 cm) “pa lang nam, pa lang koh, pa kee tid”				27.67	25.8	53.47	3.98	2.08	0.00	2.08	0.11	4.60	0.50	5.10	0.04	2.80	8.90	11.70	0.09	4.80	4.4	9.20	0.60
65	Mystus albolineatus “pa ka yaeng kho”												66.90	36.40	103.30	0.75	152.90	6.80	159.70	1.19	0.60		0.60	0.04
66	Mystus atrifasciatus (pa kha yang noi)				0.1	0.6	0.70	0.05					181.70	62.10	243.80	1.78	141.30	0.00	141.30	1.05	4.20	2.4	6.60	0.43
67	Nemacheilus pallidus (pa pun sai)																	1.10	1.10	0.01				
68	Nemacheilus platiceps “pa pun”					0.3	0.30	0.02	4.28	2.00	6.28	0.32												
69	Neolissochilus blanci (40 cm) Pa deng				1.3	18.5	19.80	1.47	70.49	71.89	142.38	7.33												
70	Neolissochilus stracheyi (80 cm) “pa tone”				5.8	16.9	22.70	1.69	17.59	0.00	17.59	0.91					12.00	12.00	24.00	0.18				
71	Notopterus notopterus(pa dong)				1	0.22	1.22	0.09					107.35	96.90	204.25	1.49	62.90	132.40	195.30	1.46	4.60	0.8	5.40	0.35
72	Ompok bimaculatus(pa seum)				4.5	0.1	4.60	0.34					10.30	1.30	11.60	0.08	2.30	1.50	3.80	0.03	39.00	2.3	41.30	2.71
73	Opsarius pulchellus “pa kam”								2.14	0.00	2.14	0.11	0.30		0.30	0.00								
74	Oreochromis niloticus(pa nin)	exotic		RB		1	1.00	0.07	3.70	1.80	5.50	0.28	76.70	54.90	131.60	0.96	307.30	40.60	347.90	2.59	16.50	4.8	21.30	1.40
75	Osphronemus exodon(pa men)					2.5	2.50	0.19	0.37	0.60	0.97	0.05						3.60	3.60	0.03		2.2	2.20	0.14
76	Osteochilus hasseltii(30 cm SL) “Pa ii thai”				4.8	0.62	5.42	0.40					86.30	50.10	136.40	0.99	26.60	21.20	47.80	0.36	21.30	17.8	39.10	2.56
77	Osteochilus lini “pa nok tou”				1		1.00	0.07					5.30	0.00	5.30	0.04					0.50		0.50	0.03
78	Osteochilus lini(15 cm) “Pa mawm, Pa na mong, Pa ii thai, Pa pohk”				1.7	0.44	2.14	0.16	127.47	95.14	222.61	11.46	44.50	13.20	57.70	0.42	72.30	128.80	201.10	1.50	1.70		1.70	0.11
79	Osteochilus melanopleura(40 cm) “Pa nok khao”				2.1	3	5.10	0.38	3.00		3.00	0.15	50.30	30.10	80.40	0.59	21.00	27.50	48.50	0.36				
80	Osteochilus waandersii “pa dok thong”			2	0.6	11.47	12.07	0.90	0.60		0.60	0.03	1.10	0.00	1.10	0.01	5.00	5.00	10.00	0.07	14.30	2	16.30	1.07
81	Pangasianodon hypophthalmus“pa yone lang kiew”			2		0.8	0.80	0.06					0.60	0.60	1.20	0.01						5.3	5.30	0.35
82	Pangasius conchophilus, 127 mm SL(pa yang)			2		0.4	0.40	0.03													1.50	3.3	4.80	0.31
83	Pangasius macronema, 122mm SL “pa yon”			2																	1.50		1.50	0.10
84	Pangasius pleurotaenia“pa souy”			2	3.6		3.60	0.27									0.50	18.00	18.50	0.14		2	2.00	0.13
85	Pangasius pleurotaenia, 139mm SL “pa yon”			2	4.7		4.70	0.35									3.00	3.00	6.00	0.04				
86	Pangio fusca “pa lad meo”					6	6.00	0.45																
87	Parachella maculicauda, 42.2mm SL (pa khab kong)																							
88	Parachela siamensis (pa tab)												2.00	0.00	2.00	0.01					18.30		18.30	1.20
89	Poropuntius carinatus “pa kom”								52.00	34.48	86.48	4.45												
90	Poropuntius laoensis(20 cm SL) “Pa chat”				88.57	87.61	176.18	13.12	205.78	160.42	366.20	18.85	0.60	0.60	1.20	0.01								
91	Pristolepis fasciata(pa ga)			RB	0.6	1.8	2.40	0.18					15.50	5.70	21.20	0.15	15.70	1.30	17.00	0.13				
92	Probarbus labeamajor “pa eurn”			2																		7.2	7.20	0.47
93	Puntioplites falcifer(35 cm) “pa sa kaang”			RB		3	3.00	0.22					2226.50	1730.50	3957.00	28.84	1597.50	774.39	2371.89	17.68	21.75	48.52	70.27	4.61
94	Puntius aurotaeniatus “pa ta dum”			2*					0.46	2.52	2.98	0.15					3.00		3.00	0.02	2.80		2.80	0.18
95	Puntius brevis“pa bi”			2*										3.50	3.50	0.03								
96	Rasbora atridorsalis (pa siew aow)				7.6	3.2	10.80	0.80													0.80		0.80	0.05
97	Rasbora palustris (pa siew kao)																				11.00	4.1	15.10	0.99
98	Scaphonathops theunensis “pa pian”				13.4	2.6	16.00	1.19						2.10	2.10	0.02					10.00	33.73	43.73	2.87
99	Schistura sigillata “pa khun dieng”																				1.20		1.20	0.08
100	Tetradon fangi, 34.5, 62.9 and 75.5mm SL “pa paow”				1.8		1.80	0.13					0.50		0.50	0.00								

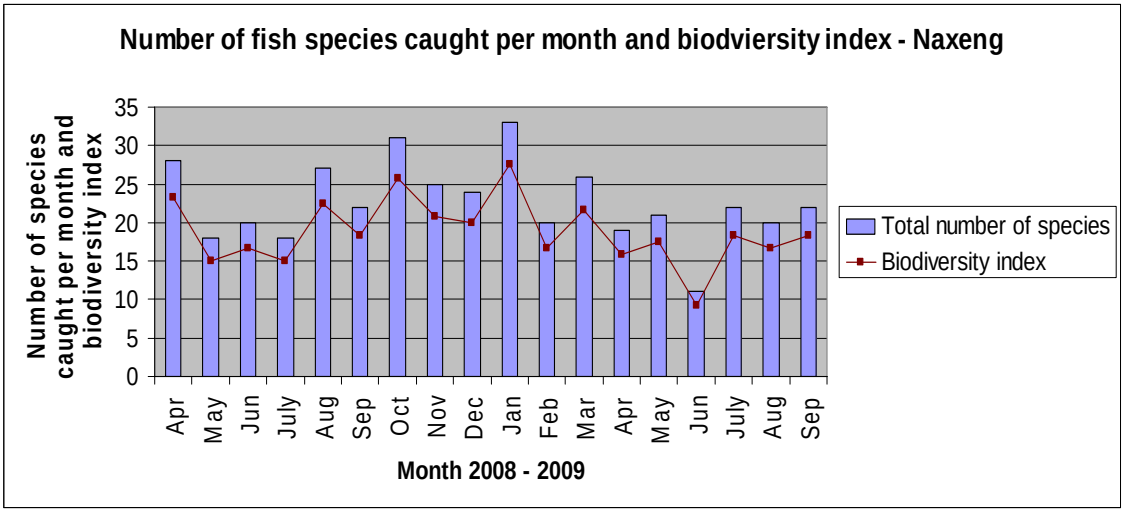
No.	Nam Ngum Species Species	Reservoir only	River only	Guild number	Naxeng 2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	Xiengdet 2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	Phonsavaat 2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	Sanphathong 2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch	Pakayneung 2008 (Kg)	2009 (Kg)	Total caught (Kg)	% of catch
101	Tetraodon baileyi, 45.7 and 69.4mm SL “pa pao”				0.4		0.40	0.03					1.00		1.00	0.01					0.10		0.10	0.01
102	Tor tambroides “pa tone”				2.7	4.2	6.90	0.51																
103	Tor tambroides(80 cm) “Pa Pohng, Pa Tone, pa xong”				3	15	18.00	1.34	90.10	58.54	148.64	7.65												
104	Trichogaster trichopterus (pa ga deut)			RB																	0.40	1	1.40	0.09
105	Wallago attu (pa khao)												14.50		14.50	0.11		12.00	12.00	0.09	14.70	34.4	49.10	3.22
106	Wallago leerii (pa khun)				0.5		0.50	0.04					2.00		2.00	0.01	19.20		19.20	0.14				
107	Xenentodon cancila(pa ga tong)				6.5	1.9	8.40	0.63					4.80		4.80	0.03					4.50		4.50	0.30
108	Nemacheilus pallidus (Pa keo kaie)																					1.3	1.30	0.09
109	Botia caudipunctata (Pa mou man)																					1.7	1.70	0.11
110	Osteocheilus sp 1 (Pa pok)																							
111	(Pa man khanlai)																							
112	Gyrinocheilus aymonieri (Pa kor)																							
113	Amyda cartilagena (Pa fa ong) (Turtle)																							
114	Labeo erythropterus (Pa va souang)																							
115	Chaudhuria cf.caudata (Eel)																							
116	Synaptera aenae (Pa pea song ta)																							
117	(Pa leo)									2.00	2.00	0.10												
118	(Pa song)				6.6		6.60	0.49		20.23	20.23	1.04												
119	(Pa dam)								21.64	19.01	40.65	2.09												
120	Luciocyprinus striolatus (Pa yoi)								31.08		31.08	1.60												
	pa khame								1.10		1.10	0.06												
	King soy				6.2		6.20	0.46																
	Other unidentified					3.8	3.80	0.28									73.20		73.20	0.55				
	TOTAL Weight of fish caught in 18 months				586	756	1343	100	1050	893	1943	100	7318	6400	13718	100	7838	5578	13416	100	802	724	1525	100
	AVERAGE weight of fish caught per month				65	84	75		117	99	108		813	711	762		871	620	745		89	80	85	
	Total number of species caught in 18 months - 110 species				62	62	77		44	38	52		60	45	65		56	48	58		58	54	73	
	Biodiversity index (no. of species/120%)				52	52	64		37	32	43		50	38	54		47	40	48		48	45	61	

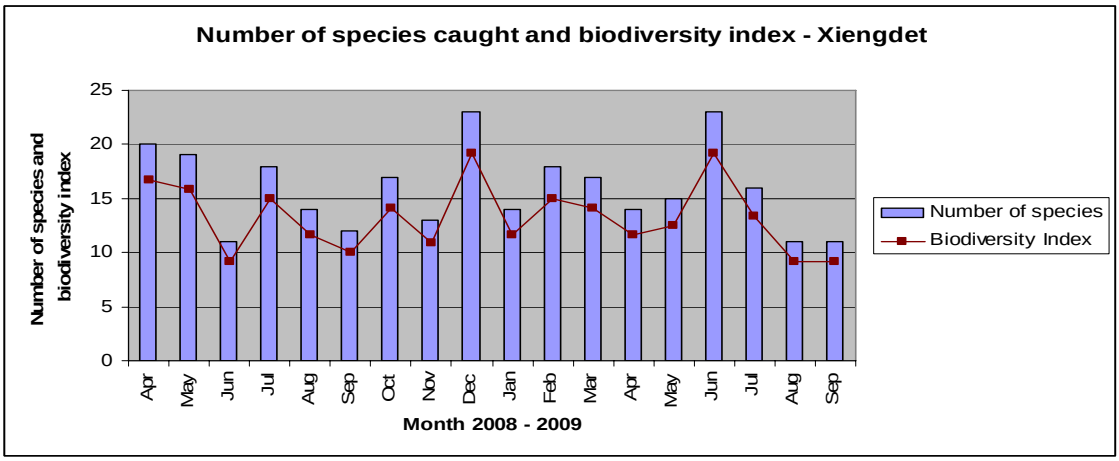
Key

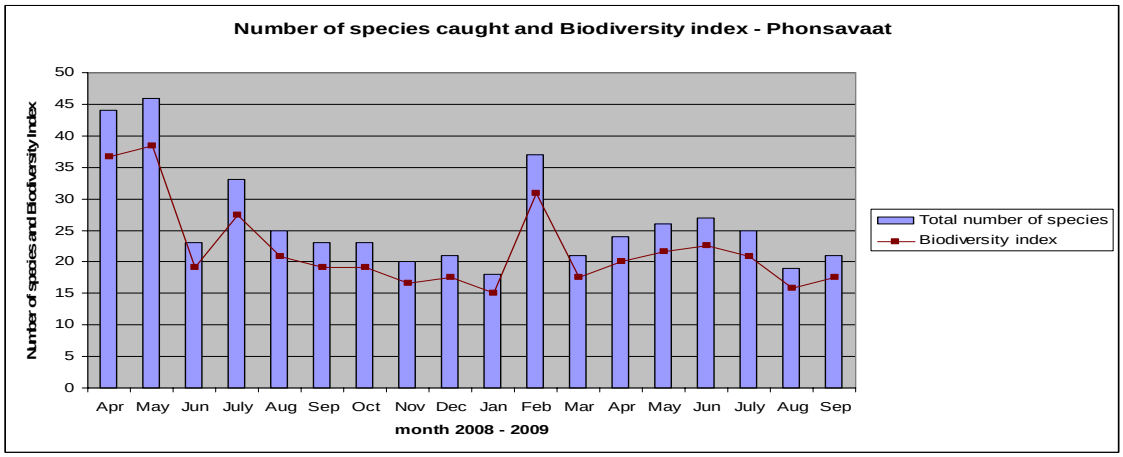
1-5% of catch	
5-10% of catch	
10 - 20% of catch	
20 - 30% of catch	
Reservoir only	
River only	
Reservoir breeder	RB
Migratory guild 2	2
Migratory guild 3	3

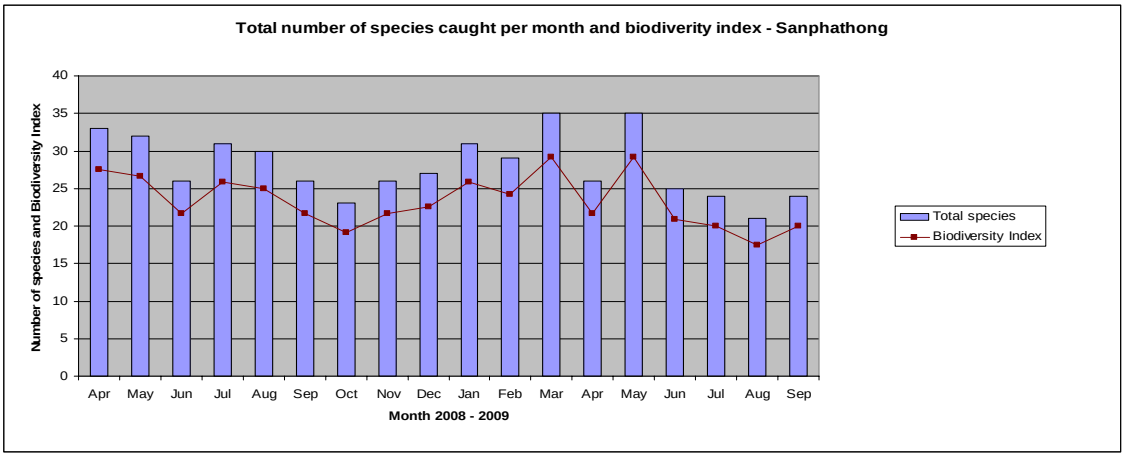
Notes: Reservoir breeders are identified from MFD 2002 and Baran et al (2007); Migratory Guild 2 – Migratory main channel and tributary resident guild (2* indicates similar species); Migratory Guild 3 – Migratory main channel spawner guild (3* indicates similar species) (from Halls and Kshatriya (2009)

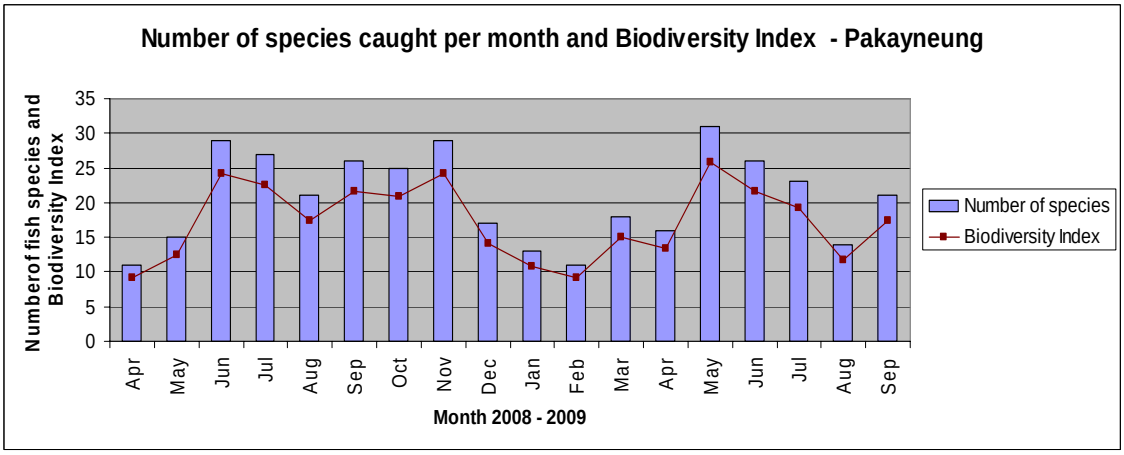
Figures 38 a - e: Number of species caught each month and monthly biodiversity index for each village











3.9 Discussion

3.9.1 Total catch and fishing effort

Table 11 and Table 12 show the total weight of fish caught each month by the three fishers in each village, and the total number of hours fished. It is clear that the mean yield in the two reservoir fisheries is up to 10 times more per month than the riverine fisheries, and the fishermen put in up to 5 times more hours fished. This highlights the difference that the fishermen in Phonsavaat and Sanphathong are full-time fishermen, whilst the others are part-time. The differences in the total catch per month is illustrated in Figure 33. Figures 34 a - e shows the total weight of fish caught each month and the corresponding number of hours fished.

In **Naxeng** they catch an average of 64 kg per month, or about 21 kg per fishermen, and they put in an average of 167 hours in fishing, or about 55 hours per month each (i.e. about 5 days per month using gill nets over night). They caught the most fish in January – March of 2009, with generally lower catches than average in June – December. However, they appear to put in the most effort into fishing in August both in 2008 and 2009.The very low catch between October and December 2008 was attributed to harvest activities (different strains of rice mature at different times). The lower effort and slightly lower peak in weight caught in February 2009 was attributed to the cold and presence of weed. The lower results in June 2009, may be due to the loss of 5 gill nets by one of the fishermen in a flash flood in May.

In **Xiengdet,** the fishers started off the sampling period with high catches in April to June 2008, which were almost double the catches recorded in the same months in 2009. These high catches raised the average catch to 102 kg per month, the highest of the riverine fisheries, or

about 30 kg per fishermen per month. From June 2008, the catches ranged around a mean of 87 kg per month, and whilst it can not be shown statistically, because not enough records were taken earlier, this fall in the average catch may be a result of the construction on Nam Ngum 5 dam which started in May 2008. The fishermen confirmed that in early 2008 the water was less turbid than later, and catches were reduced after the start of the construction work. Nevertheless the months with the highest catches were the low flow season of January – April, the fishers confirm that catches are reduced when the water levels rise. In terms of effort, the fishers of Xiengdet spend the most time fishing of the riverine fisheries, on average 354 hours per month, or 118 hours each, or about 10 days per month with gill nets set overnight. There would appear to be a trend towards fewer hours being fished over the 18 month period, with a low in August 2009 of only 139 hours or 46 hours per fisher.

In **Phonsavaat**, the fishers catch on average 735 kg per month, or 245 kg per fisher per month. Peak months have been in April 2008, with 1284 kg, but thereafter the catches vary around the mean only slightly with the season, with slightly lower catches in the dry season and higher catches in the wetter months. In terms of effort, the fishers of Phonsavaat spend the most time fishing, with an average 1 352 hours, or 351 hours per month each, or about 30 days per month, i.e. full time. The late wet season months of August to October appear to have lower fishing effort, probably because of the fishers would also be spending time in harvesting. In February 2009, the fishers joined the work party for vegetation clearance of the Nam Ngum 2 transmission line, although they continued to set their nets, with average effort; they commented that this vegetation clearance work was hard work for little return, and that they could make more money from fishing. The construction of the Nam Ngum 2 dam started in 2006, so it is not possible to see the impacts of the construction work on the fishery, although the fishermen report that the water quality has deteriorated, and there has been considerable disturbance, soil erosion and soil slide into the deep pools used by the fish, so that fish have migrated to other areas.

In **Sanphathong,** the fishers catch about 600 kg on average per month or about 200 kg of fish each, with about 1 012 hours of fishing per month, or 337 hours per month each, or 28 days per month. However in contrast to the Phonesavaat fishery, there is greater seasonal variation, with peaks in the late dry and early wet season. The fishermen report that it is easier to catch fish between March/April to August/September and more difficult in January and February. In terms of fishing effort there appears to be a decline in the number of hours fished, whilst the catches have been higher in recent months (March to September 2009).

In **Pakanyeung**, the three fishers catch about 83 kg per month, or 28 kg each. They put in a total of about 247 hours or 82 hours each per month. The method of fishing is slightly different in that they are using floating gill nets rather than set nets, because of the risk of their nets being stolen at night. So the hours fished are lower with gill nets, but they also fish with traps, which are set overnight. There is quite a marked seasonal variation in catches, with the wet season tending to be more productive than the dry season. The fishermen confirm that fishing is better when the water level is higher. There is also considerable variation in effort, with more time spent in fishing during the wet season, but with a reduction in August for the harvest.

3.9.2 CPUE data

Table 14 shows monthly CPUE data from each village for all gears and these are shown graphically in Figure 35. Figures 36 a-e show the monthly variation in CPUE for each village individually. All this data is discussed below.

Naxeng has quite high seasonal variation in CPUE, with a mean of 0.47. Undoubtedly the best months for fishing are January, February and March, (with CPUEs around 0.8) and with lows in the wet season months (between 0.2 and 0.4), through to December. In part this is due to the clarity of the water in the dry season, and the flow is lower and safer. However, during these colder months, the fishermen also note the presence of weed, which prevents easy fishing. In February 2009, they also noted a problem of water quality which they attributed to road and bridge construction activities upstream in Kasi District.

Xiengdet has the lowest CPUE of the five villages with a mean of 0.32 with less marked seasonal variation. Nevertheless it would appear that fishing is less easy in the wet season as reflected by lower CPUEs. The fishermen reported growth of weed in the colder months when the water is low. They indicated that the months of March to May are the best times for fishing when the water is low, and just before the wet season starts. The fishing is poor when the water level is rising. However, there is a distinct change when the average CPUE for April and May 2008 (0.39) is compared to the same months in 2009, when the average CPUE is about half (0.21). This may indicate the influence of the construction activities of Nam Ngum 5, about 20 km upstream. The fishermen reported this in January 2009 (see monitoring report no. 3) noting that water quality was a priority problem both for fishing and for their daily lives. There appears to be a peak in August 2009 with similar quantities of fish being caught for much fewer hours fished.

Phonsavaat shows a higher CPUE than the river fisheries with an average of 0.57. There is a regular variation between just below 0.5 and above 0.7. There are better fishing months in August to December, with perhaps less easy fishing in January and February. These are the months in which they reported weed problems.

Sanphathong has the highest mean CPUE for all 18 months with quite significant increases over the most recent months from April to September 2009. No clear explanation for this was made by the fishermen, but there is a significant pattern of increasing CPUE in both wet seasons of 2008 and 2009. The fishermen indicated that after the end of the wet season the fish become more difficult to catch, with lows in January and February, also associated with weed problems.

Pakanyeung has a slightly lower CPUE than Naxeng at 0.40. The CPUEs in early 2008 were significantly high, but then fluctuated about the mean throughout the rest of the sampling period. The fishermen reported the wet season as the best for fishing, although the CPUEs between June to October in both 2008 and 2009 were lower than the mean. As with all the other sites they reported weed problems in January and February.

3.9.3 Contribution of fish to livelihoods and nutrition

Table 16 shows the monthly weight of the catch which is eaten by the household or sold. On average the highest weight of fish eaten per month is in Xiengdet, and the lowest in Sanphathong. The total fish consumption per head per annum in Laos is about 42.2 kg/head/yr (Van Zalinge et al. 2004). This compares with the LECS 3 survey (Lao Expenditure and Consumption Survey, 2002/3) which found 28 kg/head/yr in the south of the country. These consumption figures include processed and dried fish products, so need to be converted to Fresh Whole Animal Equivalents (FWAE) and Hortle, K. (2008) on the basis of such corrections, concluded that the FWAE consumption is 38.3 kg/head/yr.

When the figures from this monitoring are converted to quantities of fish consumed per person per year as shown Table 17 in Xiengdet the average yearly consumption per person is a very high 52 kg/head/year, while in Phonsavaat it is also high at 48 kg/head/year. In Naxeng

and Pakanyeung the consumption rate is slightly lower than the national average at about 32 and 30 kg/head/year respectively. However, in Sanphathong, the rate is very low at 16 kg/head/year. When this was discussed with the fishers, in Xiengdet they confirmed that they ate fish with most meals and because of their isolation they were not able to sell fish to an outside market. In Sanphathong the fishers confirmed that they preferred to sell most of their fish and buy other protein foods such as chicken, rather than eat fish all the time.

Both Phonsavaat and Sanphathong sell about 660 – 680 kg of fish per month in comparison to the 22 – 34 kg per month sold from each of the other villages. Figure 37 shows the proportion of the catch sold, and it is clear that the two reservoir fisheries are selling 90 – 95% of their catch. In the other villages, there is a much greater seasonal variation, with minimal wet season sales in Naxeng and Xiengdet, and these mostly to other households within the same village, and only when there is a surplus of fish to sell. In Pakanyeung, about 30 – 60 % of the fish is sold throughout the year, with lows in the dry season when fish are scarce.

The price of fish in the riverine villages was generally about 15 000 kip per kg ($1.76 per kg) for the common smaller species. When larger fish were caught, such as catfish, the price can be 30 000 – 50 000 kip per kg ($3.50 – 5.88 per kg). However, when there is a glut of fish, as there was in May 2009 at Phonsavaat, when large quantities of *Puntioplites falcifer*, 'pa sa kaang' were being caught, the price fell to as low as 5 000 Kip/Kg, whereas normally they sell for 10 000 Kip/Kg.

Assuming the average price, the fishers at Phonsavaat and Sanphathong are making almost $1 200 per month, whilst the fishers in the other villages are making about $50 per month from fishing. They eat fish worth at least the same amount or more each month.

3.9.4 Biodiversity data

92% of the 120 species in the Nam Ngum list have been caught during the 18 month survey. The most diverse location is at Naxeng on the Nam Lik with 77 species and a biodiversity index of 64. This is followed by Pakanyeung with 73 species (downstream of the confluence between the Nam Lik and Nam Ngum) and a Biodiversity Index of 61. The two reservoir fisheries are less diverse with 65 and 58 species each for Phonesavaat and Sanphathong, and the least diverse is Xiengdet with 52 species and a Biodiversity Index of 43. Xiengdet is on a more isolated river, high up in the catchment with fewer species being caught regularly.

The variation in species numbers being caught at **Naxeng**, shown in Figure 38a, ranges between about 12 and 33 species per month. The low number of species caught in June 2009 also coincides with a low catch due to loss of nets the previous month. The high number of species caught in January 2009 probably can be accounted for by a more extensive fishing expedition over several days towards Kasi (for a celebration), so that a wider variety of habitats were sampled. The catch is dominated by two species *Lobocheilus melanotaenia* and *Poropuntius lobatus* which make up 26% of the total catch. In 2008 *P. lobatus* was dominant, and in 2009 *L. melanotaenia* was caught more. The two preferred species are the catfish *Hemibagrus filamentus* and *Bagarius yarelli,* which feature on the list of 12 most caught species. It is also interesting that the migratory *Henichorhynchus siamensis* is caught here at 3.32% of the catch. 2009 was a better year for this fish than 2008. The fishermen recognise that this fish is the most likely to disappear when the Nam Lik 2 dam is completed. It is also interesting that *H. lobatus* (a similar migratory species) is an important fish caught in Pakanyeung, but relatively little of this fish is caught in Naxeng. Other migratory species caught at Naxeng are *Labiobarbus kuhli* and *Cirrhinus molitorella.* Some of the migratory Pangasid catfish are caught at Naxeng, but in relatively few numbers. 2009 was a much better year for some of the lower-order species such a *Barbonymus goniontus*, *Bagarius yerrelli* and

H. siamensis. The fishermen report that *Poropuntius laoensis* spawns in many places in the Nam Lik, especially in the tributary Nam Ka, which will be flooded by the Nam Lik 2 dam. They also reported that before construction of this dam, the *P. laoensis* spawned downstream of the construction site near the village, but with the silt from the construction and the abstraction of gravel from the river bed, the spawning grounds have been destroyed.

In **Xiengdet,** the range varies between 11 and 23 species caught. Peak numbers of species were caught in December 2008 and June 2009. Low species numbers are generally caught in wet season months, when fishing effort is lower due to high water levels. The most caught species here is again *Poropuntius lobatus*, which makes up 19% of the catch, followed by *Labeo dyocheilus, Garra theunensis* and *Osteocheilus lini* – together these species make up about 58% of the catch. *O. lini* is considered the preferred species for eating. Of the lower-order fish there are several interesting species – *Luciocyprinus striolatus* is a restricted range species occurring in upper reaches of Mekong tributaries in both China and Laos. In 2008, the fishers caught 31 kg of this fish, but in 2009 did not catch any fish at all. The fishermen considered that the disappearance of this fish may be due to the construction works of the Nam Ngum 5 dam and increase in turbidity. Similarly there has been a marked reduction in the catches of *Cirrhinus cirrhosus* between 2008 and 2009, which the fishermen also attributed to the increase in turbidity. *C. cirrhosus* is also interesting in that it is an introduced exotic species, its presence in an isolated upper tributary, and the fact that it is one of the twelve most caught species in that location. The fishermen also noted that they had not seen fish spawning or caught many fish with eggs from November 2008 and in 2009. Another interesting species is *Hemimyzon confluens,* an endemic species to the Nam Ngum basin and only recorded in Xiengdet but in relatively low quantities.

In **Phonsavaat,** initial catches of different species was high in April and May 2008, but settled to an average of around 20 species each month. Another peak was recorded in February 2009, but no clear explanations for these peaks are available. The predominant species is *Puntioplites falcifer* which makes up 29% of the catch. The next four species - *Barbonymus altus, Labiobarbus kuhli, Cirrhinus molitorella, Barbonymus gonionotus* – together make up 32% of the catch. These four are interesting for several reasons. First *B. altus* and *L. kuhli* are both considered Mekong migratory species spawning in the main channel. Their presence in the Nam Ngum river in and above the Nam Ngum reservoir indicates that separate populations have been successfully maintained, after the creation of Nam Ngum 1 dam. They probably breed in the main Nam Ngum river, but this will now be threatened by the construction of the Nam Ngum 2 dam. Little changes in the catch between 2008 and 2009 are recorded. *C. molitorella* and *B. gonionotus* are both recognised reservoir breeders capable of spending their complete life cycle in the reservoir. Two other species in the list are also recognised reservoir breeders – *Hampala macrolepidota* and *Labeo chrysophekadion.* The bottom of the list of twelve - *Amblyrhynchichthys truncates* – is also recognised as in the guild of migratory main channel spawners, as *Labeo kuhli.*

In **Sanphathong**, there is a more steady variation in the numbers of species caught, with an average of between 25 and 30 species throughout the period. Two peaks of 35 species caught were recorded in March and May 2009. In the months of June to September 2009 there was a fall in the species numbers caught coinciding with high CPUEs and higher total weights. This would indicate that greater weights of fewer species are being caught. Possibly this coincides also with the glut in *Puntioplites falcifer* which was reported by the fishermen in May 2009. As with Phonsavaat the most predominant species caught is *Puntioplites falcifer*, but at 18% of the catch. Second place is taken by the reservoir breeder, *Barbonymus gonionotus* at 12% of the catch. *B. altus* and *Cirrhinus molitorella* are both migratory main-channel and tributary

spawners as is *Labiobarbus kuhli.* *Hampala dispar* is a recognised reservoir breeder. In this list a thirteenth species has been included – *Oreochromis niloticus,* the exotic Tilapia escaped from aquaculture and now breeding in the reservoir.

In **Pakanyeung,** there is a strong variability in the numbers of species caught each month, ranging from lows of about 11 species in the dry season months of January to April, to highs of up to 30 species per month between June and November 2008, and May to September 2009. This would also coincide with the higher catches generally recorded in the wet season with higher water levels at Pakanyeung. It also coincides with the reports of fish migrations occurring at the start of the rains between June to August, when *Henichorynchus lobatus* and *Osteocheilus lini* are migrating. The predominant species is the exotic *Cyprinus carpio,* which makes up 24% of the catch. The fishermen indicated that this species spawns locally and has been the predominant species for many years. The second most caught species is the migratory *Henicorhynchus lobatus,* making up 11% of the catch. The fishermen consider this to be the "security catch", i.e. they catch it every day, but the main migration occurs in May/June at the start of the rains. This is followed by the popular catfish species, *Hemibagrus wyckioides* at about 6% of the catch (which can fetch up to 50 000 Kip per kg). This is a species that is mostly caught in the traps. The relatively low catches in 2009 are due to the fact that only one of the three fishers went fishing for this species compared to 2 in 2008. The predominant reservoir species *Puntioplites falcifer* is also found here, making up just under 5% of the catch. *Cosmocheilus harmandi* is also an every-day fish, but the fishermen recognise this as a riverine fish only, which would not survive in a reservoir. *Hemibagrus filamentus* and *Wallago attu* are both valuable catfish generally caught in the traps. *Helicophagus leptorhynchus* is caught all the year round, but *Osteochilus hasseltii* is only caught in the rainy season. A bit further down the order, the exotic Tilapia, *Oreochromis niloticus* is also caught regularly here, making up 1.4% of the catch.

One other comparison that can be made between the sites is for the fish that were only caught in the reservoir fisheries and for those that were only caught in the river fisheries. This comparison, shown in Table 20, begins to address the issue of which fish will survive in the reservoirs created by the dams, and which fish will move or die out when the rivers are impounded. There are some anomalies, such as the presence of *Bangana behri* in the reservoir only column, when this is a noted migratory species.

Table 20: Comparison of fish that were caught in the reservoir only with those caught in rivers only

No.	Species	Reservoir only	River only
1	Acanthopsoides gracilentus (Pa hok guay)		
2	Akysis leucorhynchus, 28.7mm SL “pa ki hia”		
6	Bangana berhri “pa va thong na nai thow”		
13	Brachirus harmandi (pa ta diew)		
15	Channa gachua, ca. 200mm SL (pa kuan, pa kung)		
23	Clupeichthys aesarnensis “Pa Keo”		
24	Cosmochilus harmandi, 113 “pa mang”		
45	Hemimyzon confluens “pa paem, pa tid hin” -		**endemic**
46	Hemimyzon confluens (pa ee pae)		**endemic**
48	Henicorhynchus siamensis “pa goum”		
49	Homaloptera leonardi (pa bitu)		
52	Hypophthalmichthys molitrix (pa ket lab)	**exotic**	
53	Hypophthalmichthys nobilis (pa huao ngai)		
55	Kryptopterus crytopterus “pa pik kai”		
59	Lepidocephalichthys hasselti (Pa eet)		
60	Lobocheilos melanotaenia(20cm SL) “Pa Khing, Pa Khiang”		
67	Nemacheilus pallidus (pa pun sai)		
68	Nemacheilus platiceps “pa pun”		
69	Neolissochilus blanci (40 cm) Pa deng		
82	Pangasius conchophilus, 127 mm SL(pa yang)		
83	Pangasius macronema, 122mm SL “pa yon”		
86	Pangio fusca “pa lad meo”		
89	Poropuntius carinatus “pa kom”		
92	Probarbus labeamajor “pa eurn”		
95	Puntius brevis“pa bi”		
96	Rasbora atridorsalis (pa siew aow)		
102	Tor tambroides “pa tone”		
103	Tor tambroides(80 cm) “Pa Pohng, Pa Tone, pa xong”		
104	Trichogaster trichopterus (pa ga deut)		
108	Nemacheilus pallidus (Pa keo kaie)		
109	Botia caudipunctata (Pa mou man)		
117	(Pa leo)		
118	(Pa song)		
119	(Pa dam)		
120	Luciocyprinus striolatus (Pa yoi)		
	pa khame		
	King soy		

3.10 Conclusion

In conclusion, this monitoring study has come up with some very interesting results and comparisons between the different sites, especially as some of the sites are already being affected by the construction of dams. The following points emerge:

- This monitoring programme has been conducted at strategic points within the Nam Ngum basin, However, the duration of the monitoring (only 18 months) is inadequate for a full statistical analysis. As the variation in catches at each of the sites shows, it is considered that at least four years monitoring is required to establish a baseline. Nevertheless, patterns can be seen to be emerging from these results which clearly illustrate the impacts of dams upon the fisheries;
- The reservoir fisheries found in the Nam Ngum 1 reservoir are productive, generating at least 200 kg of fish per month for each fisherman, and this provides a reasonable full-time livelihood for these fishermen. The fishermen on the rivers catch a much lower weight each month, providing mainly for household needs, with surpluses being sold locally. These are part-time fishermen;

- Estimates are provided for the value of the fisheries at each site in terms of both the average monthly fish production and the quantities sold and consumed, together with estimates of the values of the different fish species;
- The sources of the productivity of the Nam Ngum reservoir lies in the seven tributaries flowing into the reservoir, where there are established fish conservation zones (FCZs) where fishing is restricted in August to October each year to protect the spawning. Keng Noi and Nam Xan FCZs lie in the areas fished by Phonsavaat and Sanphathong villages. The main areas fished by these two villages are where the rivers enter the reservoir, rather than in the main body of the reservoir itself;
- The Keng Noi FCZ lies about 10 km downstream of Nam Ngum 2 dam site and will be threatened by poor water quality releases from that dam;
- Construction impacts of dams have been felt at least 20 – 30 km downstream of dams, e.g. at Phonsavaat (Nam Ngum 2), Xiengdet (Nam Ngum 5) and Naxeng (Nam Lik 2). These construction impacts have resulted in reduced catches, disappearance of some species that prefer clearer waters, and inhibition of spawning, especially of those that spawn in gravel beds;
- Species have been identified that will not survive in the upstream reservoirs created by impoundment of rivers, and a reduced number of species that will survive impoundment, and breed in reservoirs;
- Exotic species have been found in all sites and *Cyprinus carpio* predominates in the catches at one of them (Pakanyeung) and *Oreochromis niloticus* features as a significant species at the reservoir sites and at Pakanyeung.

3.11 Recommendations

The following recommendations are made for the use and continuation of this monitoring programme:

- These results provide a useful starting point for the continued basin-wide fish monitoring, which should complement the monitoring required of all the dams under construction and planned.
- ADB should encourage the Government of Lao PDR to continue this fish monitoring in the Nam Ngum Basin, and the collation of all fish monitoring reports in the basin.
- The results of this monitoring should be shared with developers of all dams under construction, who should in turn share their fish monitoring results with the Nam Ngum River Basin agency currently being established.
- These results should also be shared with interested organisations in the wider Mekong river basin, such as Mekong River Commission, World Fish Centre, Living Aquatic Resources Research Centre (LARReC) and other dam developers in the basin, especially those that have significant fish monitoring programmes such as Theun Hinboun PC and Nam Theun 2.
- The fish monitoring results are interesting enough to warrant a more detailed investigation and could be analysed more extensively as part of a student research thesis at the National University of Lao.
- The Fisheries Programme of the Mekong River Commission is in the best position to collate and analyse all the records of fish monitoring throughout the basin, and publish

regular consolidated reports which could highlight the experience of fisheries impacts of hydropower dams. Funding will be required to maintain such an on-going analysis.

4 References

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