# A MONITORING STUDY TO ASSESS THE LOCALIZED IMPACTS CREATED BY THE NAM THEUN-HINBOUN HYDRO-SCHEME ON FISHERIES AND FISH POPULATIONS

**FINAL REPORT**

**Prepared for the Theun-Hinboun Power Company (THPC), Vientiane, Lao P.D.R.**

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## 1. EXECUTIVE SUMMARY

All electric power generation development, including hydropower, gives rise to contentious issues and hydropower development remains a controversial issue in the few countries that have the potential to develop it. It will always have its advocates and its critics. Topographically Lao PDR appears to be ideally suited to hydropower development and since the country opened up to the global economy in the 1980's, hydropower has emerged as almost its only current saleable commodity (Usher, 1996. Damming the Theun River, Nordic Companies in Laos). Lao PDR has embarked on an extensive hydropower development program that has many implications for its economic future, social structure and environmental integrity. In a country in much need of foreign exchange, the benefits accruing to hydropower development are obvious, but realistic social and environmental costs have to be taken into account during the analysis and decision-making phase.

This report aims to identify major impacts on fish populations and fisheries arising from construction and operation of the Theun-Hinboun hydro-project, and provide direction to THPC and others in finding ways to mitigate or compensate for these impacts. It also aims to identify and recommend further research and monitoring needs. Some difficulties arise in assessing these impacts, or making recommendations to mitigate them, because tropical flood-cycle rivers remain one of the most difficult ecosystems in which to conduct investigations. This is particularly so in ones with large migratory fish populations such as the Theun and Hinboun. As an inter-basin transfer project, the sheer geographical size of the area affected has imposed some constraints on what could be achieved. Gaps in our data and knowledge do exist and several issues remain to be more thoroughly investigated. However, this study is one of the first of its kind in Lao PDR, and should be of some benefit to those responsible for fisheries monitoring at other projects in the future.

The major impacts to fish populations and fisheries identified by the monitoring program, and discussed in this report, have resulted from the following. 1) The blocking of the upstream wet-season spawning migration in the Theun in 1998, 2) The submerging of rapids and the alteration in aquatic environmental conditions in the head-pond area, 3) The temporary reduction in water quality in the Theun head-pond in May 1998, 4) The quantity of dry-season minimum by-pass flows released past the Theun dam, 5) The nutrient-trap effect of the Theun head-pond, 6) The loss of natural hydropower downstream of the dam, 7) The increased dry-season flows in the Hinboun and its associated increased sediment load, and 8) Migratory disorientation in the Nam Hai.

In addition to those above, the following **potential** impacts have been identified and will require monitoring. 1) Possible outbreaks of fish disease (EUS) in the Theun head-pond, 2) Introduction of exotic fish species for aquaculture or release into the Theun head-pond, 3) Vulnerability of fish stocks to over-fishing by conventional or destructive fishing methods, and 4) Damage to riverine ecosystem caused by sediment flushing at the Theun dam.

Mitigation procedures and monitoring activities are suggested wherever possible. With regard to the above identified and potential impacts, the **main recommendations** of this report are hereby summarized under two headings: I) Critical and II) Additional.

**I) Critical recommendations**

**Upstream of the Theun dam**

- Expand the quantitative CPUE monitoring program to include the villages of Sop Ngouang and Katok in addition to Kengbit (Section 7.1).
- Establish if there is a substantial downstream movement of fish through the head-pond waters from October to December each year by CPUE monitoring. Also, if there is a movement, attempt to establish if these fish are able to negotiate the dam on their downward passage (Section 5.2.4).
- Discourage ANY introductions of exotic fish species for release into the head-pond or for aquaculture (Section 6.1.2).

**At the Theun dam (Operation)**

- Fish screens, or acoustic deflectors, should be installed at the turbine intake tunnel in the Theun head-pond (Section 5.5.1).
- Apart from the continual low-level removal of sediments via the sand flushing gates, major sediment flushing should only take place during the wet-season months, preferably in August and September. Flushing should only take place between 07:00 and 09:00hrs and never during the afternoon or at night. Small amounts of material flushed over a number of days may have less impact than large amounts over shorter periods (Section 6.2.2).

**Downstream of the Theun dam**

- Increase the minimum dry-season by-pass flows from 5 to 10 cumecs (Section 5.2.2.).
- Establish an independent study to assess exactly what the minimum dry-season by-pass flows should be at the Theun dam based on more detailed surveys and research (Section 5.2.2).
- Make an independent assessment of the effectiveness of constructing a fish pass at the Theun dam (Section 5.2.4.).
- Establish if the Theun dam prevents the upstream wet-season migration from reaching historical spawning grounds over the next 2 years by direct observation, anecdotal information and CPUE monitoring above the dam (Section 5.2.4).

**II) Additional recommendations**

**Upstream of the Theun dam**

- Attempt to establish a wet-season fish sanctuary in a defined area at the end of the head-pond (Section 5. 1.3).

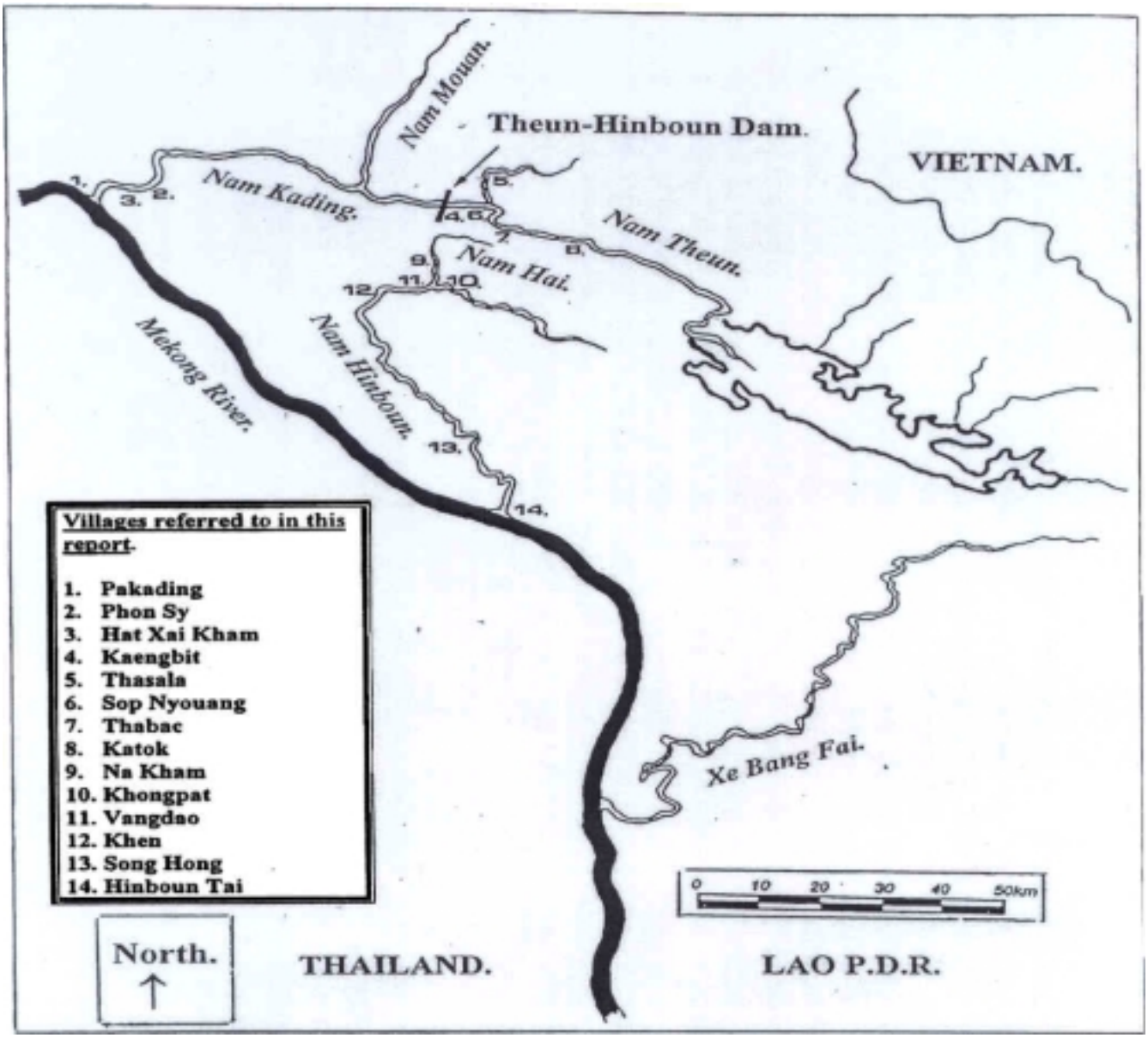
- Carefully document any future fish-kills in any project-defined areas (Section 5.1.4).

**Upstream and downstream of the Hai / Hinboun confluence to the Mekong**

- Expand the CPUE monitoring program to include the village of Song Hong on the Hinboun (Section 7.1).

**General**

- In combination with quantitative records (CPUE), carefully document the disappearance of any typically caught species, and / or the appearance of any new species in fish landings (Section 5.1.2).




**2. (Fig.1) MAP OF THE MAIN STUDY AREA**

## 3. BACKGROUND

To date, several studies, investigations and surveys have attempted to predict what effect the construction and operation of the Nam Theun-Hinboun hydro-scheme will have on fish populations and fisheries of the riverine systems associated with the project (Norconsult, 1994. Summary Environmental Impact Assessment Report. Theun-Hinboun Power Project. Ministry of Industry and Handicraft, Vientiane, Lao PDR; NIVA / NINA-NIKU, 1995. Annex B1. Final Report on Aquatic Ecology, Minimum Release and Water Quality. Water Quality and Aquatic Life Study Final Report. Theun-Hinboun Impact Studies; NORPLAN A.S., 1996. Impact Studies for the Theun-Hinboun Hydropower Project Laos). The NIVA / NINA-NIKU 1995 study provides the only quantitative work on minimum release flows past the Theun dam.

This investigation, carried out between December 1997 and December 1998 and funded by THPC, is based on extensive interviewing of riparian villagers, limited quantitative sampling and monthly observation concerning the impacts the project has had on fish and fisheries following approximately one year of project operation. The objective of the fisheries monitoring program is to assess the impacts of the project on the fish populations within the project-affected area and to reduce the predicted adverse impacts by developing additional mitigation measures (THPC. Terms of Reference for monitoring of fish impacts. Environmental Management Committee Office (EMCO), July 19997). Specifically the main study aims as provided in an Inception Report (A monitoring study to assess the localized impacts created by the Nam Theun-Hinboun hydro-scheme on fisheries and fish populations. Inception Report. January 1998) are:

- To monitor the relative abundance of commercial and semi-commercial fish stocks at selected sites within a localized area adjoining various parts of the Nam Theun-Hinboun hydro-scheme for a period of 3 years after the approximate time of project start-up.
- To identify when the main periods of fish movement occur at the selected sites referred to above and which species are involved.
- To obtain as complete as possible, fish species inventories from areas approximately adjacent to the dam on the Nam Theun including the head-pond and its tributaries, the Nam Hai and sections of the Nam Hinboun.
- To identify the main impacts on fish and fisheries in localized areas affected by the Theun-Hinboun hydro-scheme and to suggest any possible mitigation measures to reduce the magnitude of the identified impacts.
- To assess the effectiveness of the minimum proposed dry-season flows on downstream fish populations.
- To determine if recruitment to the existing fish populations in selected areas adjacent to the Theun-Hinboun hydro-scheme is taking place.
- To identify known spawning or other key fisheries habitat areas, such as tributaries, small creeks etc... and to identify the likely project impacts on these.

### 3.(1) Pre-impoundment situation with respect to fish populations, annual fish migrations and fishing activities

Roberts (1996. Fluvicide: An independent environmental assessment of the Nam Theun 2 Hydropower Project in Laos, with particular reference to aquatic biology and fishes. Unpublished paper.) states that the Nam Theun is the third largest tributary of the Mekong River in Laos with a mean annual flow of some 600 cumecs. and a total catchment area of about 15,590 $km^2$. Mean flows used for the project projections (pers.com. THPC, 1999) are based on hydrological records and flow modeling and amount to 453 cumecs. before Nam Theun II and 212 cumecs. after it. Much of the basin is densely forested with an estimated 2,800mm of annual rainfall. Surveys carried out in 1992 by Burapha Development Consultants (1992. Nam Theun 1-2 study on aquatic life. Nam Theun 1-2 Hydropower Project feasibility study, Norpower) found 98 fish species present in what is now defined as the project area. A NIVA / NINA-NIKU survey in 1995 recorded 70 species in the middle catchment area and Kottelat (1996. Distribution of the fishes previously considered endemic to the Nam Theun and Xe Bangfai basins, Lao PDR. NTEC, Vientiane, Lao PDR) observed 60 species from the Theun basin. Of the 60 species observed by Kottelat, 11 were at that time not known from anywhere else in Laos, but lack of survey data from other catchments currently places the degree of endemism in question. Roberts (1996) describes the Theun as a special tributary of the Mekong, with a fish fauna characteristic of large, clear, cold-water mountain tributaries similar to some of the Mekong tributaries found in Yunnan Province in Southern China.

Although there are some species common to both the Nam Theun and the Nam Hinboun, generally speaking the Nam Hinboun fish fauna is more typically dominated by Mekong lowland species, but can still be described as rich. Roberts (1996) estimates that the Hinboun contains at least 100 species and quite likely over 200. In common with the Theun, a rise in water level at the beginning of the wet-season stimulates a large-scale, upstream movement of fishes in the Hinboun, many of which are in full reproductive condition and destined for spawning grounds up-river. Anecdotal reports and months of quantitative sampling in the dry-season, suggest that many of the fish moving upstream to the areas affected by the project in the wet-season originated from the Mekong mainstream. During the wet-season period, the lower Nam Hai changes from a low flow-volume stream to a channel with full bank to bank flows. Some species moving up the Hinboun at that time turn into the Hai at the confluence point, and move up to spawn in the inundated areas of the Nam Hai plain. Many species are present in the Theun, Hinboun and the upper Nam Hai throughout the dry-season months and are targeted for food by the riparian human populations.

Current knowledge of the detailed life-cycles of almost all Mekong basin species is very limited. A number have only recently been scientifically described. Collectively they thrive in a diverse range of seasonal habitats, have different seasonal dietary preferences, spawn at different times and are targeted using a wide range of fishing gears for commercial, semi-commercial and subsistence purposes by the riparian human population. Whereas local fishers use their indigenous knowledge of native fishes to target almost every type and size of fish in their various habitats, it is usually the periods of fish migration when fishing activities intensify. During these periods, there are often opportunities to exploit migratory stocks for commercial purposes and / or harvest fish in sufficient quantity for preservation by fermenting, smoking or drying. Several reports, based on anecdotal information, make reference to these migratory periods. The Nam Theun 1-2 Study on Aquatic Life (Burapha

Development Consultants 1992) identified three periods of movement in the Theun: March to April, May to June and August to September. During the same study, villagers along the Nam Hai and Hinboun reported on fish movements during the rainy season. Other studies and reports comment on the upstream movement of fishes in the wet-season months in the Theun (Norconsult 1994; NIVA / NINA-NIKU, 1995; Kottelat, 1996; NORPLAN, 1996).

Whereas, there is little doubt that these migrations do exist, our detailed knowledge of them remains fragmentary and incomplete. Three major issues concerning these movements have relevance to the impacts of the Theun-Hinboun hydro-scheme. Firstly, it has yet to be established if the upstream, wet-season movements (and the return) are carried out only by Theun residents, or if migrants also move in from the Mekong. Secondly, if the latter situation is correct, it must be established categorically that the rapids at Keng Vang Fong, approximately 30km upstream from the Mekong confluence, do not represent a natural barrier to fish movement. The implication here is that the project may have little effect on the migratory populations if their passage is blocked anyway. In addition, if the fish were able to pass Keng Vang Fong under pre-impoundment conditions, did they travel the 100 km or so to the current dam-site and beyond ? This last question remains unanswered and would require a considerable separate research effort involving a fish-tagging program.

### 3.(2) Post-impoundment situation regarding altered hydrological regimes

The Theun-Hinboun hydro-scheme is a 210MW trans-basin run-of-river project approximately 100km upstream of the confluence with the Mekong and located in the border area between Bolikhamsay and Khammouane Provinces, some 280 km east of Vientiane. At the project site, a narrow mountain ridge separates the Theun and Hinboun basins with a difference in elevation of about 240m (THPC, 1997). This difference in elevation is used for power generation by diverting up to 110 cumecs. of the Theun's flow via a gated diversion weir and a 5.2km low-pressure head-race tunnel to a surface power house at the base of the Phou Hai mountain range. Turbinated flow volumes enter a 3.5km tailrace and re-regulation pond before discharging into the Nam Hai, a seasonal stream and tributary of the Nam Hinboun. The Nam Hinboun eventually joins the Mekong at a point approximately 30 km upstream of Thakhek, the administrative center for Khammouane Province. The power generated from the project is mainly exported to Thailand, but some output is used for local domestic consumption.

Closure of the Theun dam in December 1997 has created an impounded stretch of water extending some 24 km up the mainstream Theun, 14 km up the Nam Ngouang, and also some 3 km up the Nam Ao, a small stream entering the Theun at the damsite. During dry-season months, the head-pond level is maintained by an inflatable rubber barrage located on the top of a wide concrete structure spanning part of the river width. THPC has agreed with the Government of Lao PDR to discharge a minimum of 5 cumecs. past the dam which, during the dry-season months, passes through the sand-flushing gates. When flows exceed 115 cumecs. during the onset of annual rains in April or May, more water is released past the dam via the sand-flushing gates, whilst still maintaining the head-pond level. When inflows reach 190 cumecs., the sand-flushing gates are fully opened. At inflows exceeding 190 cumecs, the rubber gate begins to deflate automatically in order to maintain a head-pond elevation of 400m a.s.l.. This causes the greater proportion of the excess flow to pass over the deflated rubber/concrete barrage. Although dependent on local rainfall patterns in any one year, this would be the normal situation at the start of the wet-season (pers. com. THPC, 1998). When the inflows to the

head-pond are in excess of 2000 cumecs. during the wet-season months, two hydraulically operated radial gates are raised to sufficient height to allow the increased flows to pass the dam (pers. com. THPC, 1998). When inflows into the head-pond reach 2450 cumecs. (pers. com. THPC, 1999), the radial gates are fully opened and the water level in the head-pond and below the dam reach approximately, or exactly, the same height. At this point the rubber gate/concrete barrage becomes submerged.

During the periods when the project is running at full capacity, 110 cumecs. of turbinated flow volume is discharged from the powerhouse into the 3.5 km tailrace on the Nam Hai plain. Just before entering the Nam Hai, the discharged volume enters a re-regulation pond and passes over a small weir at its furthest point away from the powerhouse. The extra 110 cumecs. then joins whatever seasonal flows are passing down the Nam Hai and together this volume moves down the Nam Hai channel and eventually enters the Nam Hinboun just upstream from Vangdao village. Full capacity operation is dependent on inflow volume to the Theun head-pond, availability of the generation units**,** power demand from Thailand over any one 24hr period. In 1998 at least, discharged flow volume and operational capacity have been variable due to a major drought and some problems with the rubber gates and one generator. Reduced demand in Thailand has also contributed to the irregular power generation. EGAT has attempted to operate the installation as a peaking plant causing many starts and stops in power production. This has increased the rate of bank erosion along the Nam Hai downstream of the tailrace channel.

### 3.(3) Summary of monitoring activities carried out on fish populations and fisheries

In an attempt to monitor the impacts the project has had on fish populations and fisheries, two main approaches have been used. The first has been to establish a quantitative monitoring program in key potential impact areas, and secondly to compile as much anecdotal evidence as possible from local people who have traditionally exploited the fishery resources of the areas now affected by the project. Quantitative monitoring has been carried out in co-operation with local fishers from one village on the Hinboun and one village on the head-pond. Ideally, data from more villages would have been desirable, but human resources, competition with other responsibilities of project staff and, in the case of the Hinboun, difficulty in using gillnets in villages downstream of the Hai / Hinboun confluence has prohibited a more extensive study. However, data are available from which preliminary inferences may be drawn (see section 4. below). Another obvious shortcoming is that pre-impoundment baseline data on standardized catch (CPUE) are not available, and the reader must accept that monitoring has probably taken place on fish populations that have already been impacted to some extent.

## 4. THE QUANTITATIVE FISHERIES MONITORING PROGRAM (C.P.U.E.)

### 4.(1) Introduction

The recording of CPUE (Catch Per Unit Effort) data is a means of obtaining an index of relative abundance of fish populations over a time series. CPUE data can be gathered on a range of different gear types, but fixed gillnets are particularly useful because they sample a wide range of species, of different size classes depending on the mesh sizes used, do not require an attendant operator and are far

less vulnerable to saturation than many other gears. In addition to providing an index of relative abundance, time series CPUE data will identify major periods of fish movement and can be used to detect the duration and species compositions of migrations (Warren *et al*., 1998). For most investigations of fish migratory behaviour in Mekong tributaries, it is usually sufficient to record fish landings in kilogrames, per net, per night. Night-time landings are usually chosen because it is the time when most people set their nets and also when many fish become more active. Migratory activity often intensifies during the hours of darkness. To account for any variation in fish landings between different set nets, CPUE data on any one sampling day are usually expressed as mean values from a number of different nets and operators.

## 4.(2) Materials and Methods

### Study sites

CPUE data have been recorded at two locations within the general Theun-Hinboun project area. One at Kengbit Village just up from the Theun dam-site on the banks of the head-pond, and another at Khongpat Village on the Nam Hinboun, just upstream from the confluence of the Nam Hai and Hinboun.

### Data collection

CPUE data (Kg/Net/Night) were recorded from ten randomly selected fishers at Khongpat, and three from Kengbit at regular intervals each month from December 1997 to November 1998. Monofilament gillnets in a range of mesh sizes were supplied by THPC to fishers as requested. At Khongpat, the mesh sizes used ranged between 2cm and 8cm, with 5cm mesh size used most often. At Kengbit, mesh sizes ranged between 2cm and 20cm, with 7cm used most frequently. Sample specimens from overnight fish landings were preserved in formalin and identified to species level wherever possible. Where this proved too difficult under field conditions, fish specimens were recorded to genus level only.

Catch was standardized to kilograms of fish per net, per night, to provide an index of relative abundance on each sampling day. Mean overall and individual species, or genera CPUE, was estimated by summing all daily CPUE records and dividing by the number of fishers from whom the data were collected. Original field data sheets are held at the THPC offices in Vientiane and copies at site.

### Data analysis

Mean monthly CPUE values for all species together were estimated from field data. These values were transformed to a logarithmic scale using the formula $Y = \ln (Y + 1)$. Mean monthly CPUE was then re-transformed back to the linear scale and reported as such (Fig. 2). Overall mean CPUE values, based on all samplings over the study period for all species together, were also estimated from the two study sites (Table 1).

## 4.(3) Results

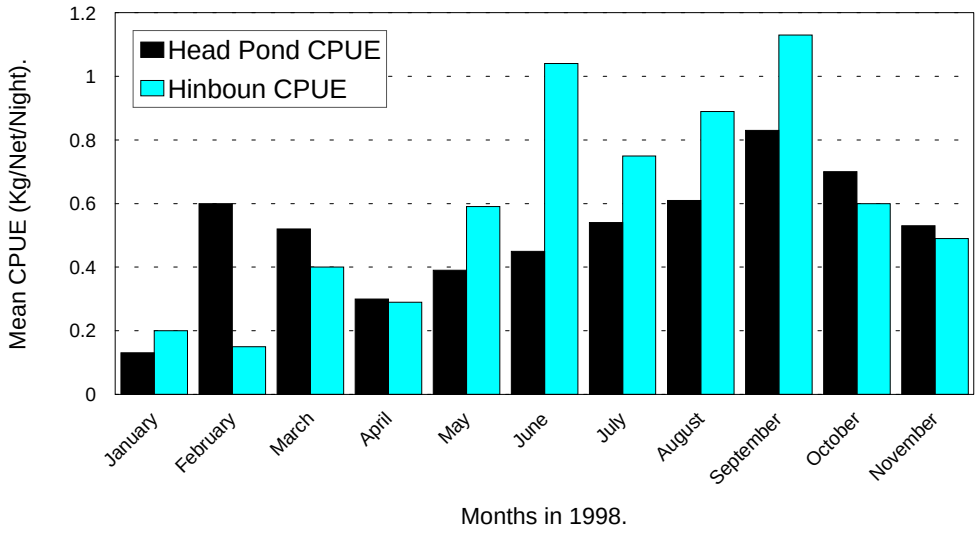



**Fig. 2.** Mean CPUE in 1998 from gillnet fishers at Kengbit village on the Theun head-pond and Khongpat village on the Hinboun river. Significant differences (P = 0.000) were detected between mean monthly CPUE data on the Hinboun river. No significant differences (P = 0.55) in mean monthly CPUE were detected between any months on the Theun head-pond.

**Table 1.** Summary characteristics of fish landings and related statistics at the two study sites based on all sampling days from January to November 1998.

| **Parameter** | **Kengbit, Headpond** | **Khongpat, Hinboun** |
|---|---|---|
| Total number (n) of samplings. | 198 | 334 |
| Mean CPUE (Kg/Net/Night) based on all samplings with 95% CI's in parentheses. | **0.56** (0.47-0.66) | **0.57** (0.53-0.62) |
| Total weight (Kg) of fish landed based on samplings. | 192.6 | 220.9 |

**Table 2.** Homogenous monthly CPUE groups using a LSD multiple range test from samplings carried out at Khongpat village on the Hinboun river in 1998.

| Months in 1998. | Samplings (n). | Mean CPUE (Kg/Net/Night). | Homogenous Groups. |
|---|---|---|---|
| February | 33 | 0.15 | X |
| January | 7 | 0.20 | X X |
| April | 23 | 0.29 | X X |
| March | 50 | 0.40 | X X |
| November | 31 | 0.49 | X X |
| May | 59 | 0.59 | X X |
| October | 17 | 0.60 | X X X |
| July | 24 | 0.75 | X X |
| August | 35 | 0.89 | X X |
| June | 25 | 1.04 | X |
| September | 30 | 1.13 | X |

**Table 3.** Homogenous monthly CPUE groups using a LSD multiple range test from samplings carried out at Kengbit village on the Theun head-pond in 1998.

| Months in 1998. | Samplings (n). | Mean CPUE (Kg/Net/Night). | Homogenous Groups. |
|---|---|---|---|
| January | 4 | 0.13 | X |
| April | 16 | 0.30 | X X |
| May | 7 | 0.39 | X X X |
| June | 10 | 0.45 | X X X |
| March | 10 | 0.52 | X X X |
| November | 31 | 0.53 | X X X |
| July | 18 | 0.54 | X X X |
| February | 17 | 0.60 | X X X |
| August | 24 | 0.61 | X X X |
| October | 28 | 0.70 | X X X |
| September | 27 | 0.83 | X X |

**Table 4**. Fish species, genera or groups, landed by fishers on sampling days at Khongpat village in decreasing order of importance.

| **KHONGPAT, HINBOUN.** | | | |
|---|---|---|---|
| **Species.** | **Local Lao name.** | **Total sample landing weight (Kg).** | **Percent of total sample landings (%).** |
| *Henicorhynchus* spp. | Koum | 36.98 | 16.75 |
| *Mystus nemurus* | Kot | 35.77 | 16.20 |
| *Systomus orphoides* | Pok | 24.57 | 11.13 |
| ----- | Other | 23.36 | 10.58 |
| *Hypsibarbus* spp. | Pak | 21.58 | 9.77 |
| *Poropuntius* spp. | Jat | 13.82 | 6.26 |
| *Hampala macrolepidota* | Sout | 10.14 | 4.59 |
| *Puntioplites falcifer* | Mou | 9.30 | 4.21 |
| *Cyclocheilichthys repasson* | Oub Na | 8.69 | 3.94 |
| *Cirrhinus molitorella* | Geng | 8.13 | 3.68 |
| *Crossocheilus* spp. | Li Ki | 7.68 | 3.48 |
| *Dangila cf. cuveri* | Kee Lam | 4.75 | 2.15 |
| *Osteochilus lini* | Na Mong | 3.51 | 1.59 |
| *Osteochilus waandersi* | Nong | 3.00 | 1.36 |
| *Anabas testudineus* | King | 2.07 | 0.94 |
| *Mystacoleucus atridorsalis* | Kee Dam | 1.89 | 0.86 |
| *Mystacoleucus* spp. | Ka Chi | 1.60 | 0.72 |
| *Ompok bimaculatus* | Seum | 1.29 | 0.58 |
| *Raiamas guttatus* | Sanak | 0.90 | 0.41 |
| *Sikukia* spp. | Khao Si | 0.86 | 0.39 |
| *Acantopsis* spp. | Pun | 0.78 | 0.35 |
| *Lobocheilus quadrilineatus* | Noo Sing | 0.19 | 0.09 |

**Table 5**. Fish species, genera or groups, landed by fishers on sampling days at Kengbit village in decreasing order of importance.

| **KENGBIT, HEADPOND.** | | | |
|---|---|---|---|
| **Species.** | **Local Lao name.** | **Total sample landing weight (Kg).** | **Percent of total sample landings (%).** |
| *Poropuntius* spp. | Jat | 44.68 | 23.20 |
| *Puntioplites falcifer* | Mou | 31.97 | 16.60 |
| *Bagarius yarrelli* | Khe | 22.00 | 11.42 |
| *Barbodes gonionotus* | Pak | 21.30 | 11.06 |
| ---- | Other | 20.05 | 10.41 |
| *Hampala macrolepidota* | Sout | 16.42 | 8.53 |
| *Tor* spp. | Deng | 14.20 | 7.37 |
| *Bangana behri* | Na Nor | 11.50 | 5.97 |
| *Cirrhinus molitorella* | Geng | 4.75 | 2.47 |
| *Mystacoleucus* spp. | Ka Chi | 2.54 | 1.32 |
| *Scaphognathops stejnegeri* | Ma king | 1.62 | 0.84 |
| *Bangana ?lippus* | Ee | 0.80 | 0.42 |
| *Bangana* sp. n. aff. *Sinkleri* | Sa | 0.50 | 0.26 |
| *Oreochromis niloticus* | Nin | 0.14 | 0.07 |
| *Cyclocheilichthys repasson* | Oub Na | 0.12 | 0.06 |

### 4.(4) Inferences

**Above confluence of the Nam Hai and Hinboun**

A one-way ANOVA detected significant differences (P = 0.000) between mean monthly CPUE on the Hinboun river at Khongpat village (Fig.2 and Table 2). Homogenous groupings of CPUE data suggest a migration did take place during the wet-season months in 1998 (Table 2). Data are required during subsequent years to determine if this continues unaffected.

**Head-pond area**

A one-way ANOVA test found no significant differences (P = 0.55) in mean monthly CPUE between any months on the Theun head-pond at Kengbit (Fig.2 and Table 3). There almost certainly would have been significant differences if the wet-season migration had been able to pass the Theun dam, and the statistical evidence supports this study's observations and anecdotal reports that the migration was blocked in 1998. It remains to be seen if, in a year with normal rainfall levels, the migration is able to follow its normal pattern, by passing the dam in May, June and July. However, given the considerable inflows required to submerge the dam and the existing operating rules, it seems unlikely this will occur. The observed step-wise increase in mean monthly CPUE from April to September reflects the generally greater mobility of many species during the wet-season months, but not a migration (Fig.2).

The most important group of species landed in terms of weight in the head-pond belongs to the genus *Poropuntius* (Table 5). This group is known not to tolerate impoundment conditions (Rainboth, 1996), but the second most important species *Puntioplites falcifer* does appear to tolerate reservoir conditions and is one of the most important species currently targeted by fishers at Nam Ngum reservoir north of Vientiane.

Based on our limited sampling program on the Theun head-pond and in the Nam Hinboun, it appears that on average it was possible to land approximately 0.5Kg of fish per set net, per night in 1998 (Table 1). This figure is within the expected range if compared with data from other Mekong tributaries and water bodies (unpublished data from Sedone River and Nam Ngum Reservoir, Lao PDR).

## 5. IMPACTS ON FISH POPULATIONS AND FISHERIES IDENTIFIED BY THE FISHERIES MONITORING PROGRAM

### 5.(1) Upstream of the Theun Dam

#### 5.(1.1) Effects on local ecosystem and changes in aquatic bio-diversity

Prior to dam construction, the stretch of the river now transformed into the head-pond, was characterized by deep pools, separated by sections of rapids and riffle. Under dry-season conditions, much of the rocky hard substrate in the rapids sections were covered in dense growths of filamentous green algae (periphyton), which is a major food item of many Theun species and also forms a secondary habitat for aquatic animals such as crustaceans and insects. This habitat, with its attendant population of aquatic fauna, has now been changed. Current speeds are now much less in the dry-season, which favors deposition of suspended solid material, water depth has increased and with light penetration vastly reduced, seasonal blooms of algae can no longer develop on the hard substrates. Under such conditions, it is highly likely that many species whose normal habitat is rapids (seasonally at least) will move away from the head-pond area. Perhaps they are able to move back up into the more typical riverine sections at the end of the head-pond, as suggested by numerous riparian fishers interviewed in head-pond villages.

With head-pond being maintained at approximately full supply level (400m a.s.l.), bank slumping may have contributed to sediment deposition in some sections of the head-pond. This is currently being monitored and there has been no marked increase since dam construction began (pers.com. EMCO, 1999). In addition, EMCO is now assessing ways of protecting the head-pond banks by replanting vegetation and managing people's access along the banks.

**Mitigation / Monitoring:**

No direct mitigation can be suggested for this except that every attempt should be made to reduce any further deforestation of riparian habitats, which may contribute to more sediment deposition. Control of deforestation in any area in Lao PDR is the responsibility of the government, which issues logging licenses and controls illegal cutting. CPUE monitoring should be able to identify which species have moved away from the head-pond area.

### 5.(1.2) Unstable head-pond environment

Much debate has centered around the possibilities for fishery development in the new head-pond created by the Theun dam. NORPLAN (1996) acknowledge the need for fisheries management in order to minimise any future declines in fisheries. Reservoirs created by hydro-power and irrigation dams often do present conditions for new fishery developments, such as at the Nam Ngum reservoir for example. At Theun-Hinboun the situation is rather different. Run-of-river projects tend to be less environmentally damaging than projects with large water storage areas, but they often create a situation in which the stretches above the dam are neither strictly a reservoir, or strictly a river. This is the case at Theun-Hinboun. During dry-season months, the head-pond comes to resemble a true reservoir with microscopic algal blooms developing and current speeds vastly reduced. At the onset of annual rains, current speeds and water turbidity levels increase to a point that the "reservoir" appears more like a river. Presumably, the primary productivity that developed during the dry-season months in the form of microscopic algae is then flushed away from the system. It is also highly likely that as wet-season conditions establish in the head-pond, any remaining migratory species present will probably move upstream towards the end of the head-pond and beyond. Perhaps some species will be able to tolerate these alternating conditions, and almost certainly there will always be some fish in the head-pond, but the situation may not allow those species that are normally able to adapt to static water conditions to establish sustainable populations.

**Mitigation / Monitoring:**

No direct mitigation suggested but CPUE monitoring should identify which species are able to adapt to the new conditions.

### 5.(1.3) Response by fish to re-establishment of flowing water conditions in the wet-season months

Following closure of the Theun dam in late 1997, some fish species, whether migratory or not, will have either moved away already, or be in the process of doing so, or will have been eliminated in some other way. With such a diverse range of habits and behaviour, some fish species will probably be able to tolerate the conditions longer that others. At the onset of rains in April and May, any remaining migratory species will probably move upstream; some species may have been able to build up sufficient energy reserves for reproductive development and may eventually be able to spawn. Many (not all) of the species of importance to riparian fishers along the Theun, produce buoyant or semi-buoyant eggs. Hatching times for tropical riverine species are relatively quick (2-4 days). Newly emergent fry and/or eggs from fish that are able to spawn upstream of the head-pond, will probably represent the largest potential source of recruits for the head-pond fishery. Unfortunately, as the 1998 upstream wet-season spawning migration was mostly, or completely, blocked by the Theun dam (pers.obs), it's extremely difficult to predict if the head-pond will receive sufficient numbers of recruits from any upstream spawning activities. If there was a large static water storage area below the spawning grounds, some recruits at least may have been able to maintain their position and grow and develop accordingly. Unfortunately, it must be presumed that a portion of new recruits and / or eggs will exit the head-pond during the wet-season months, either past the dam or down the turbine intake tunnel. Either route seems hazardous for delicate fry and/or eggs, but in any event, any juvenile stages exiting the head-pond via either route probably won't be returning.

**Mitigation / Monitoring:**

One mitigation measure suggested is the establishment of a fish sanctuary at the end of the head-pond, extending some distance back up the free-flowing sections of the Theun. This report recommends that the last kilometer of head-pond, and the first 4km of free-flowing water be designated as a fish sanctuary and all fishing methods be prohibited in this area from May 1 to September 30 starting in 1999. Such a system is operated successfully in many Thai reservoirs including Ubolratana, Nong Han, Nam Oon and Sirinthon where effective policing is practiced. Complete villager cooperation will be required if this is to be implemented successfully. It should be stressed that fishing should only be banned in this area alone and that local people should still have access to fishing in all other areas for subsistence purposes. The area might be extended in the light of experience gained in the first year. Monitoring of the effectiveness of the sanctuary will probably have to be based on anecdotal reports.

A "no-fishing" zone has already been declared in the area immediately below the Theun dam. This should be enforced, if at all possible, in order to help protect the large numbers of migratory species that accumulate in this area during the early wet-season, as well of course for safety reasons. It is recommended that no fishing takes place in this area at any time of the year and that the area should extend to at least 500m downstream below the dam. However, it should be noted that despite sign posting, fencing, security guards at the dam-site and discussions between EMCO and village / district authorities, the no-fishing area below the dam is constantly fished and there is not a great hope of success for other no-fishing zones.

**5.(1.4) Reduced water quality in the head-pond and fish kills**

At least one "fish kill" took place in the Theun head-pond during May1998; presumed to have been caused by water quality problems associated with submerged and decaying terrestrial vegetation. In addition to this, the increase in water depth, and reduction in light penetration, almost certainly destroyed the dense growths of algae covering the rocky sections of the head-pond, and this may have contributed to the temporary reduction in water quality. However, as most of the plant material has now presumably decayed and been re-cycled and flushed away, this may not be a recurring problem at Theun-Hinboun.

**Mitigation / Monitoring:**

No direct mitigation suggested, but any future fish kills should be carefully documented in terms of dates and extent of occurrence. Every attempt should be made to collect any dead specimens and preserve them in formalin for future identification. After several weeks in 10% formalin, these fish together with any other specimens collected, should be taken to the Department of Fisheries in Vientiane to await identification by taxonomic experts. Details of location, dates and any other relevant information should accompany the preserved specimens.

### 5.(1.5) Submerging of rapids in the head-pond area and the creation of a seasonal lacustrine environment

The majority of Nam Theun fishes make use of rapids at various times to carry out critical life-cycle events such as reproduction or feeding. Amongst other attributes, rapids serve to increase oxygen levels deep into the pools they pass in to, they break-up and re-suspend organic material washed into the river from riparian forests and their tail-waters represent important sites for spawning for many species. Because of good light penetration and solid substrates, rapids produce large amounts of filamentous green algae (periphyton) upon which many Nam Theun species depend for feeding.

Given that conditions have now totally changed within the head-pond area, it seems highly probable that many of the species, which depend on rapids for various reasons will be eliminated from the head-pond area. Even after only two months of dam closure, we began observing several "rapids" species in very poor condition in fish landings within the head-pond area. Typically their bodies were emaciated and their heads appeared abnormally large. We attribute this to the complete alteration of their dry-season feeding habitat. The time it will take for the near complete disappearance of these "rapids" species from the head-pond area can only be guessed at.

According to local villagers, 13 rapids along the Nam Theun and 5 rapids along the Nam Ngouang were submerged following the closure of the Theun dam in December 1997. At least one rapid, approximately 500m upstream of the Nam Ngouang / Theun confluence was identified by local villagers as a spawning site of the predatory cyprinid species *Luciocyprinus striolatus*. Because of its large size, and the fact that it spawns during the dry-season months (January / February) when water clarity is greatest, its spawning behaviour can be observed relatively easily. Most Nam Theun fishes spawn during the wet-season months, and many species shed their eggs at the surface in open waters. Interviews with riparian fishers suggest that some spawning activity takes place in almost every section of the river, particularly in the vicinity of rapids. However, detailed observation is difficult because of strong flows and high turbidity during the wet-season months. Some species may "home" to certain stretches of Theun for reproduction, but this is unknown at present. Alternatively, some of the species that once used the rapids in what is now the head-pond area may be able make use of unaffected rapids further upstream.

### 5.(1.6) Appearance of new fish species

By May 1997, fishers at Kengbit informed us that they had started catching a new species of fish within the head-pond area which they said they had never caught before in that section of the "river". The species has been identified as *Carassius auratus* (wild goldfish). This species is known from areas of northern Laos where it forms an important component of subsistence capture fisheries. They adapt well to lacustrine habitats and are not usually found in flowing waters. It is not anticipated that this species will impact on native species present in the head-pond if it remains in low numbers.

**Mitigation / Monitoring:**

No direct mitigation can be suggested. The arrival of any new species should be carefully documented.

## 5.(2) Downstream of the Theun dam

### 5.(2.1) Nutrient trap effect of the reservoir

During dry-season months, large amounts of organic material, mostly in the form of leaf litter, accumulate at ground-level in the forested areas of river catchments. During the period of low rainfall, this material remains intact and dehydrated. At the onset of rains, it begins to decay under the action of bacteria and fungal microorganisms, and together with torrential forest downpours, eventually washes into feeder streams and main river channels flowing through the forested areas. The nutrients released from the processes of decay serve to stimulate primary production and fuel important food chains. In reservoirs with large storage areas, this material, and the nutrients released tend to become trapped in the reservoir waters and partly absorbed by base sediments. Although the situation at Theun-Hinboun is somewhat different in that there is no large storage area, and major flow does pass the dam during the wet-season, the diverted flows during both the dry and wet-seasons amount to a net loss of nutrients from the system below the dam.

**Mitigation / Monitoring:**

Limited amounts of material may be restored to the system during sediment flushing operations, but this procedure should be carried out with great care (see section 6 of this report on sediment flushing).

### 5.(2.2) Minimum water release past the Theun dam

Under an Environmental Mitigation agreement signed on October 31 1996 between the Theun-Hinboun Power Company (THPC) and the Lao Government (GOL), the THPC has agreed to release a minimum flow of 5 cumecs. past the Theun dam. Although this is a year-round commitment agreed to by THPC, the minimum release will almost certainly only take place during the dry-season months. That is, on most days during approximately 18 weeks when rainfall and inflows to the Theun head-pond are lowest, and water conservation measures become important.

Below the dam, the Nam Theun (or Nam Kading) passes through a deeply incised, thickly-forested valley where almost no human habitation exists. The closest village (Phol Ngarm) is some 100km downstream of the Theun dam and about 60km below the Kading / Nam Mouan confluence. Typically, the banks of the river are lined with huge rocks that have fallen down from their sedimentary bases higher up the valley slopes. Sandy bays are present is some areas. Under dry-season conditions, the river is divided up into sections of swift rapids and deep pools. Table 6 overpage presents data on dry-season stream flow rates at the dam site prior to dam construction and also from measurements taken in 1998.

**Table 6. Mean monthly stream flows (cumecs.) in the Nam Theun at the present dam site prior to construction and in 1998.** Data sources: ((1) *Impact Studies for the Theun-Hinboun Hydro-Power Project, Laos, NORPLAN A.S., 1996* and (2) *THPC monthly Operation and Maintenance Reports, 1998).*

| Month | (1) Normal year mean inflow (cumecs.) | (1) Estimated mean dry year inflow (1 of 5) (cumecs.) | (2) Mean inflow to head-pond (cumecs.) (1998) | (2) Sum of discharge to Nam Kading via all exits (cumecs.) (1998) |
|---|---|---|---|---|
| Jan. | 111 | 99 | 59 | 34 |
| Feb. | 89 | 74 | 56 | 5 |
| Mar. | 76 | 55 | 51 | 5 |
| Apr. | 57 | 44 | 46 | 5 |
| May | 122 | 60 | 58 | 11 |
| Jun. | 661 | 431 | 257 | 147 |
| Jul. | 1,183 | 978 | 709 | 632 |
| Aug. | 1,430 | 949 | 339 | 278 |
| Sep. | 853 | 796 | 641 | 520 |
| Oct. | 760 | 529 | 234 | 133 |
| Nov. | 265 | 237 | 128 | 53 |
| Dec. | 166 | 139 | 102 | 11 |

Whichever data set is referred to, clearly a minimum release of 5 cumecs. represents a substantial reduction in normal flow volume (NORPLAN, 1996 estimated that flows would only be between 10% and 23% of their normal volumes during the dry-season months). NORPLAN (1996) recommended a minimum by-pass flow of 10 cumecs. for a trial period of 3 years. NIVA/NINA (1995) proposed a minimum release of between 6 – 15 cumecs. and stated that less than 6 cumecs. would more or less completely destroy the fisheries on the river stretch between the dam and the Nam Mouan. They continued by stating that a compensation release of 15 cumecs. would be expected to cause only a small reduction in fisheries production.

Although these above recommendations are not based on long-term fisheries studies, they have been made based on educated judgement and do not simply represent guesswork. A long-term study on fisheries below the dam may, of course, recommend even greater minimum releases. The reader is asked to imagine a situation in which 100% of flow is available (46 to 59 cumecs. inflow to head-pond between January and May 1998, and considerably more in a year with more typical rainfall). Excluding any other complicating factors, this would support 100% of resident fish life in the section of the river that flows past the dam. No flow at all would probably result in extinction for most species of fish. The present minimum release of 5 cumecs. represents 8 to 10% of the available mean monthly flow, based on the 1998 data, and considerably less than 8% during a more typical year with greater inflows (Table 6). The exact effect this is having on riverine fisheries below the dam is unknown, but is certain to be negative.

Although some areas are not accessible for fishing, the section immediately below the Theun dam has until recently been quite heavily targeted by fishers from Kengbit and other villages. This river section

appears to have been affected in two main ways. Firstly, according to local people, fish stocks were very heavily targeted shortly after the closure of the dam in December 1997 when abnormally low water levels in the large pools in the area made the resident fish stocks extremely vulnerable to capture. Secondly, a marked reduction in mean stream flow caused by the closure of the Theun dam has directly impacted fish populations due to a range of factors discussed below.

Based on interviews with local people at the dam site, closure of the dam caused water levels to fall to their lowest dry-season levels ever witnessed. Although this in itself is undesirable, the main impact on resident fish populations comes from the increased water residence times (time taken for the volume of water in a deep pool to be completely replaced by new water) in the deep pools where many species take up dry-season refuge. Fish are at their most vulnerable during the dry-season months when the effects of predation, increased water temperatures, lowered oxygen levels and susceptibility to disease are greatest. Increased water residence time produces three main effects. Firstly, water temperatures increase and, as a consequence of this, oxygen levels decrease. Increased water temperature and lowered oxygen cause stress to fish populations and as such make them more vulnerable to predation and disease. Thirdly, phytoplankton levels increase causing the water colour to appear more green. Many Nam Theun species are not suited to these conditions but are instead are adapted to environments with clear, cool waters with high levels of dissolved oxygen.

**Mitigation / Monitoring:**

NORPLAN (1996), provide recommendations on what should be a minimum release of water after taking into account the interests of the power sector and environmental issues. A minimum of 10 cumecs. was recommended in that report. Any long term decline in fisheries cannot yet be determined, but it is highly likely that the existing minimum flow release is insufficient to maintain the health of the aquatic environment in the Nam Kading downstream of the dam. In the absence of quantitative studies, minimum flow releases of at least 10% of the mean monthly flow have been recommended in maintaining healthy aquatic habitats in Europe, North America and Australia. Given the diverse nature of tropical fish faunas, and the generally higher water temperatures of tropical rivers, it is probable that the figure of 10% of mean monthly flow is insufficient to maintain a healthy aquatic environment in the Nam Kading.

Some species will be able to tolerate the conditions better than others and may come to dominate the species composition. This is likely to have a de-stabilizing effect on the ecosystem in general. Conditions should improve somewhat below the confluence with the Nam Mouan and further down the Kading as feeder streams join the main channel. However, the diverted flow volume for power generation will probably result in some impacts on fish populations, during the dry-season months at least, all the way down to the Mekong. It is therefore recommended that minimum dry-season by-pass flows be increased to 10 cumecs. There is no evidence to suggest that the damage undoubtedly caused by the present minimum release of 5 cumecs. over two dry-seasons in 1998 and 1999 is irreversible. On the contrary, environmental conditions can be expected to improve providing the increased minimum flow is continuous.

Given the economic implications[1] that an increase in the minimum by-pass flow has for the project, it is further recommend that specific studies be initiated to identify, as precisely as possible, what the minimum by-pass flow requirements should be. One approach might be to survey pool perimeters and rapids sections under varying flow releases from the head-pond, and make an assessment of the flows required to drown out rapids and lower the water residence times to an acceptable level in the deeper pools. Water residence times, hydrological data on current speeds in rapids, water depths and water temperatures etc… from other unaffected sections of the Theun would need to be collected and used as baseline data and help formulate guidelines.

### 5.(2.3) Loss of natural hydropower

Rivers can be viewed as machines run by natural hydropower (Roberts, 1996). Natural hydropower is an essential property of any river. It can be regarded as the system's internal energy source and is necessary to create various aquatic habitats, transport sediments and nutrients, and break up organic material for use in primary food chains. The level and type of biological production will change in any river which has had a portion of its internal energy removed. Hence, the "river" which flows beyond the Theun dam has not only been changed because of reduced flow volume, but its quantity of internal energy has also been altered. Some natural hydropower will be returned to the Kading beyond its confluence with the Nam Mouan.

**Mitigation / Monitoring:**

No mitigation suggested.

### 5.(2.4) Migratory delay / failure at the Theun dam in 1998

Disruption to the annual fish migrations past the Theun dam site has been identified as one of the most serious impacts caused by the Theun-Hinboun hydro-project. Fish migration patterns in the Mekong basin are poorly understood generally and in many cases our knowledge of them is limited to anecdotal reports from riparian fishing communities. Only a few studies have attempted to investigate Mekong basin migratory patterns.

Following the first rains in late May and early June1998, we began receiving reports from operators at the dam that under certain conditions, large numbers of fish could be seen circling in the weir pool below the Theun dam. On June 8, I personally witnessed a large number of fish swimming around below the dam and occasionally attempting to leap into the fast currents issuing from the dam's two radial gates. On July 7, a guard at the dam-site explained that on July 3 the water became very clear below the dam and he witnessed hundred's of fish estimated to weigh up to 8 Kg circling below the dam. According to the guard, very heavy overnight rainfall on July 5 caused the water level below the dam to increase to less than one meter from the lip of the concrete / deflated rubber gate barrage. Under these conditions, the guard witnessed several large fish leaping and making it over the dam. By

[1] The approximate loss in electricity sales revenue resulting from an increase in minimum dry-season by-pass flows from 5 to 10 cumecs. is estimated at $1 million per annum (pers.com., THPC 1999).

July 6, the water level below the dam had once again fallen by several meters and the fish could no longer pass at the dam-site.

When inflows to the Theun head-pond are in excess of 2450 cumecs. the Theun dam is completely flooded including the concrete/rubber gate barrage (pers.com. THPC, 1999). In theory, when this occurs, it should be possible for migratory stocks to pass upstream from below the dam to the head-pond area. However, whether or not this intermittent event is actually effective in maintaining the upstream fish movements in the Theun is dependent on two main factors: 1) The frequency with which this actually occurs during any one wet-season, and 2) precisely when it occurs during any one wet-season.

Two main factors control fish migration; external triggers such as flow volume, water temperature, water chemistry, turbidity etc.., and the internal physiological state of the fish. Fish that are delayed on their upstream migration en route to historical spawning grounds will eventually lose their desire to migrate and will probably not be able to spawn in that year. One question that has been asked at site is that if fishes in full spawning condition, and not able to pass the Theun dam, can return downstream again and travel up the Nam Mouan to spawn. It is not known if this would happen or not and it really depends on whether or not Theun migrants "home" to spawn in certain critical habitats, as do many fish species world-wide. Nam Mouan fishers reported unusually high fish landings in certain sections of that tributary in April 1999 (pers.com. THPC, 1999). It is just possible that some fish are using this alternative route for their upstream spawning migration, but equally, the high landings may just be coincidence. Only an extensive tagging experiment could answer this question with certainty. Apart from spawning failure due to natural causes, spawning may be prevented in any one year because the conditions necessary for the fish to pass the dam don't occur at the right time. In addition, spawning may fail because the conditions necessary to facilitate the passage of fish at the dam simply do not occur with such frequency to enable large numbers of fish to move. From a capture fisheries point of view, clearly the blocking of the wet-season migration would mean that fishing conditions would remain poor in the head-pond area during the wet-season months, as appears to have happened in 1998. Only quantitative monitoring will be able to establish if fishing conditions improve in the future.

Assuming that rainfall patterns in any one year are sufficient to allow the upstream movement of fish in the wet-season, there is the additional problem of how the fish will return back downstream again during the period from October to December. It is unlikely that most species will be able to pass through the sand flushing gate exit. Fish tend to swim away from such structures. It also seems unlikely that fish would pass over the concrete / rubber-gate barrage, unless there was a huge volume of water passing over it. This is unlikely to be the case during the period of the downstream migration from October to December. If any fish do enter the turbine intake tunnel they would probably not emerge alive in the tail-race, and would in any case be lost from the Theun system.

**Mitigation / Monitoring:**

During April and May in 1998, much of the flow entering the head-pond in excess of requirements was released from the head-pond under the radial gates. According to THPC, the reason for this was that the cause of a broken rubber gate on the concrete barrage in May 1998 was still under investigation and, understandably, the company did not want to pass water over the broken unit until the matter had

been concluded. Under normal circumstances, the radial gates would remain closed until inflows to the head-pond have reached 2000 cumecs. and excess flow volumes passed over the concrete / rubber gate barrage. This mode of operation is strongly recommended as it would maximize the chances of fish being able to make it past the dam during periods of heavy rainfall and flash-floods in late May and June. Fish certainly cannot pass upstream under the radial gates until such times as the level of water below the dam and above has equalized, due to the immense force of water and current speeds. This can be easily observed by standing on the dam and watching fish trying to negotiate the current. In order for fish to be able to move upstream against a current, the velocity of water passing downstream must be less than a fish's burst speed. A burst speed is defined as a maximum single effort that is not sustainable (Clay, 1995. Design of Fishways and Other Fish Facilities). No data are available on burst speeds for Nam Theun species, and are likely to be highly variable and species specific.

To maximize the chances of post-spawners being able to return downstream to their dry-season habitats, as much flow volume as possible should be passed over the concrete / rubber gate barrage during the months of October to December, and not under the radial gates. Operators at the dam-site state that this is the normal mode of operation.

Fish passes were proposed for the Theun dam by NORPLAN (1996). Such structures have been incorporated into the Pak Mun and Payao projects in Thailand and basically consist of a series of flooded steps that in theory allow the upstream (and downstream) passage of fish. New research and further quantitative data collection at the Pak Mun fish ladder is about to commence this year (pers.com. Sripatrprasite, 1999). As a run-of-river low dam with a head differential of less than 10 meters during periods of high wet-season flows, such a device could have been built on the Theun dam during construction phase. However, its effectiveness in actually maintaining the Theun migratory fish populations was, and still is, in question. Much research is still required to find a specific design structure to cater for the diverse range of tropical fish faunas found in rivers like the Theun. Many designs have been based on the fish passes in use on temperate river systems in North America and Europe, where usually only a limited number of species are involved. Some Salmonid fish species are pre-adapted to use a fish ladder by the fact that they readily leap and jump and often have large energy reserves accumulated from consuming high quality feeds in the marine environment. Many tropical species found in Asia, particularly gravid females swollen with eggs, do not have the ability to jump and would be unlikely to make use of a ladder-type fish pass. However, within the last 10 years, effective fish passage structures have been designed and tested in Australia based on the requirements of warm-water species (pers.com. Michael Holics, 1999).

Some Theun species do leap and jump however, and could be seen doing so below the Theun dam in 1998. At least four different species were observed stranded on a ledge on one of the radial gates in June 1998. They could only have got there by what must have been an impressive leap. Of the species that were observed to leap, several are important commercial capture species. Given the moderate costs involved in construction (perhaps 100,000 to 150,000 USD) this report recommends that this issue be further investigated. What is envisaged is that a small team of experts (biologists and engineers) visit the site during 1999 and make an assessment of the feasibility of constructing a fish pass and provide a prediction of it's likely effectiveness based on experiences elsewhere world-wide. Biologists selected for the team should be familiar with Asian tropical fish faunas and should have first-hand experience of design criteria for fish passes. Similarly, engineers involved should have

direct previous experience in design and construction of fish passes. The team would be required to present their findings to THPC, relevant Lao Government agencies and other groups and institutions for funding considerations. The estimated cost of this investigation is 24,000 USD. Collaborative efforts should be established with the Lao Department of Livestock and Fisheries (DLF) to ensure that any experience gained can be applied elsewhere in Lao PDR. If it is decided to proceed with construction, the DLF should be involved with key monitoring activities after installation, to assess its effectiveness and possible duplication at other sites.

As an alternative to a fish pass, NORPLAN (1996) suggested that the idea of manual trapping and transport of spawners be investigated. Whereas this method is used with success in some situations, and with a limited number of species, it is difficult to appreciate how this would work in practice at the Theun dam. Capturing large fish in the open waters of the Nam Theun below the dam during the wet-season months, when the river is swollen and subject to flash-floods, will likely prove extremely difficult and hazardous to operators. If the operation takes place at night when migratory activity intensifies, it will be even more dangerous. Fish caught by gillnets may well be damaged and be unlikely to continue their migratory journey. A different system might involve the construction of a concrete trapping chamber below the dam that could be emptied by netting the fish. However, getting the fish to enter and remain in these chambers is difficult, and any such structure would have to be able to operate under a very wide range of hydrological conditions. Even if such a structure could be built and operated successfully, there is the problem of how to get the fish back down below the dam again during their return migration at the end of the wet-season. However, such a system could be reviewed during the expert's mission mentioned above.

Monitoring fish landings should be extended to include sections of the Nam Mouan. Given the difficulties involved in accessing this area, monitoring would probably be best carried out using anecdotal evidence from fishers. If it was concluded that fish were making partial use of this alternative route, one option may be to actively discourage fish from continuing up the Nam Theun towards the dam using electro-shocking devices above the Nam Mouan-Theun confluence point.

Monitoring activities in the Nam Theun should involve visual observation of migratory activity below the dam during the wet-season months and also examination of CPUE data gathered in the head-pond. Each date, time and period of duration that the dam and barrage become flooded out and in theory, permit the upstream movement of fish, should be very carefully documented even if it is only anecdotally reported by dam operators.

### 5.(3) Upstream and downstream of the confluence of the Hai and Hinboun to the Mekong

#### 5.(3.1) Increased flow volume in the Nam Hinboun and migratory disorientation

In common with the Nam Theun and most other Mekong tributaries, there is an annual upstream movement of fishes in the wet-season in the Hinboun. The exact triggers that cause this movement are unknown but it is likely that there are a number of factors acting in concert which actually cause the movement. Prominent amongst these is an increase in flow volume and the changes in the physical and chemical properties of the water associated with it. Although turbinated flow volumes have been variable over any one 24hr period since the project began operating in December 1997, when the

project is running at, or near full capacity, near wet-season type flows pass down the Nam Hai and Hinboun continuously. There is no way of knowing what the effect of this has had on the 1998 wet-season migration, or will have on migratory patterns in subsequent years. Whether or not the fish will continue to respond to the additional flows brought about by seasonal rainfall, and migrate as usual, or whether the near constant wet-season type flows will cause migratory disorientation, particularly over time, remains to be observed.

**Mitigation / Monitoring:**

No mitigation can be suggested for the possible adverse effects of the increased flows. Monitoring of fish migratory activity over time, either quantitatively (CPUE) or anecdotally, should be able to establish if the increased flows have caused migratory disorientation or not.

### 5.(3.2) Increased sediment load in Nam Hai and Hinboun

In addition to the possible impacts on migratory and resident fish populations caused by near wet-season type flows, some species have almost certainly been affected by the increased silt and sediment load now passing down the Nam Hai and Hinboun. Although certain species may be found at almost any time of the year in the Hinboun, many species make use of seasonal habitats and as such are mainly found (and caught) during certain times of the year only. One such habitat found extensively along the Hinboun during the dry-season months prior to the project start-up in late 1997 was deep depressions and holes in the river bed. These act as refuges for small, delicate dry-season species and were the places where villagers used to set their gillnets. Villagers at Vangdao just below the confluence of the Hai and Hinboun have commented that a long hole in front of their village, where most of their dry-season fishing operations took place, is now filled up with silt and sediment. In addition to this, many of the dry-season species will not tolerate the increased silt loads carried by the water and will have moved upstream beyond the confluence. This may be one reason why villagers at Khongpat village, above the confluence, reported abnormally high landings during the 1998 dry-season months.

**Mitigation / Monitoring:**

The problem of additional sediment transport is likely to be greatest during the first year of project operation and should diminish over time to some extent. Bank erosion along the Nam Hai is quite severe in some places, but presumably it will eventually redefine its course and establish new bank contours along certain sections. Theun waters from the head-pond carry a very low sediment load, which favours rapid re-suspension of bank deposits. In addition, the banks of the Nam Hai are mainly composed of soft alluvial deposits and are easily eroded. These two factors, together with the sheer quantity and speed of the flow now passing down the Nam Hai have contributed to the erosion problem. THPC is currently preparing to address this problem and is shortly expected to begin rectifying the situation.

## 5.(4) Within the Nam Hai

### 5.(4.1) Unstable environment within the Nam Hai, and the gathering of fish below the re-regulation pond weir

The seasonal Nam Hai stream originates in the Phou Hai mountains and flows down through a rocky, forested catchment before reaching the Nam Hai plain. At the point where it enters the plain, it receives the turbinated flow volume from the Theun-Hinboun power-house. Before the project began operating, very little water passed down the Nam Hai during the dry-season, and fishing activities were mostly restricted to the wet-season months when migratory species moved upstream from the Hinboun and the Mekong. Some fishing also took place in the numerous forest pools in the upper reaches of the Nam Hai, which act as the dry-season refuge habitat for many small fish species.

High current speeds and large amounts of floating debris have effectively prevented any fishing with gillnets in the Nam Hai throughout 1998. In such an environment, it will likely be years before the Nam Hai can support anything like a resident fish fauna, if this ever happens at all. However, based on our direct observations, two things at least do appear to have taken place. Small fish species, typical of the forested pools in the upper catchment, are now being caught regularly by fishers using lift-nets just below the weir at the end of the re-regulation pond. In addition, considerable numbers of larger fish were observed in the waters below the weir in March, April and June. This was particularly noticeable when the turbines were temporarily shut down. Unfortunately, these fish were almost certainly out of place, and should not have been in Nam Hai during these months. Although there is no way to prove it, it appears as though the increased flows down the Hai and the Hinboun stimulated an out-of-season, upstream migration in March and April. Fish are often attracted to the strongest flows at weir pools and below turbine discharges, and this is probably why the fish gathered where they did. Some of the fish examined were in spawning condition, and if they hadn't been attracted by the strong flows passing down the Nam Hai would probably have continued further on up the Hinboun to their normal spawning habitats. It seems unlikely that they would have spawned in the Nam Hai environment.

**Mitigation / Monitoring:**

No mitigation is required for this, and if only a small proportion of the total upstream migration arrives at the re-regulation pond weir, it's probably of no great consequence. If some of the fish can be caught by local villagers along the Nam Hai, it should be regarded as a positive impact. If the same event happens again in 1999, it should be documented as carefully as possible and any anecdotal reports from villagers included.

## 5.(5) Other areas impacted or altered

### 5.(5.1) Possible inter-basin transfer of Nam Theun species to the Hai / Hinboun system

Although there are certain species common to both river systems, much of the Nam Theun fish fauna must be regarded as atypical of many Mekong tributaries, including the Nam Hinboun. In common with all inter-basin water diversion projects, there is some possibility of the transfer of Nam Theun species to the Nam Hai and Hinboun systems. Given the conditions under which adults, juveniles, eggs

and / or larvae of Theun species would need to survive in order to reach the lower catchment areas (i.e. through pressure tunnels and turbines), it seems unlikely that will happen, but certainly should not be ruled out altogether.

**Mitigation / Monitoring:**

Metal mesh fish screens could be fitted to the intake tunnel in the Theun head-pond to discourage larger fish from entering the turbine intake tunnel if necessary. The actual mesh size used will need to be negotiated between project engineers and biologists, and a compromise made. A mesh size of $9cm^2$ would likely be effective, but this may impede flow rates due to blocking. Screens to protect eggs and larvae are almost certainly impractical. I know of no suitable material, nor can I conceive of any structure that would prevent eggs and larvae from entering the intake tunnel without seriously impeding project operation. Given the large amounts of floating debris (whole trees) passing down the Theun during the wet-season, any such structure would likely become blocked and / or damaged very quickly.

As an alternative to a fish screen, acoustic deflectors have been used with success at some hydro-projects to keep fish away from turbine inlets. These have the advantage of having a minimal effect on water flow and therefore do not reduce the productivity of the power station. Their effectiveness of operation relies on the ability of fish to detect sound waves underwater. Research has shown that fish will avoid certain areas where acoustic deflectors are deployed. Typically, an acoustic system will comprise a sound signal generator, power amplifiers which boost signal levels to the required output levels for the sound projectors, and sound projectors which are used to create an underwater sound field (Lambert *et al*., 1997. The use of acoustic fish deflection systems at hydro stations).

Riparian fishers in the lower catchments should be asked regularly about any unusual species appearing in fish landings. Any unusual fish appearing in the tailrace or re-regulation pond should be carefully documented. Voucher specimens should be preserved in formalin for future identification.

## 5.(5.2) Anecdotal information and reports received from local villagers regarding impacts on fish populations and fisheries at Theun-Hinboun

**Construction of small community water bodies for dry-season capture fisheries**

Given that riverine capture fisheries have been impacted by the project, one proposal that may partly alleviate the reduction in available fish catch is to construct small community fish ponds to act as a dry-season fishery resource. These community trap ponds should be clearly distinguished from aquacultural ponds. With the latter type of pond, construction is usually carried out in areas not subject to flooding, wild fish are often eliminated from the system, exotic fish are often stocked and external inputs such as plant leaves, rice-bran, manures are used as inputs to fuel primary food chains and stimulate fish growth. Such small-scale aquaculture is not always appropriate for resource-poor farmers and without effective extension and other back-up services, results often fall short of expectations.

The type of pond being proposed here is usually constructed in an area subject to annual flooding or is connected to some other water body via gullies or channels. Particularly effective are the ones that

permit flood-waters to enter during the wet-season, and can then be sealed off in some way as the flood begins to recede in the dry-season. If positioned correctly, they can intercept migratory pathways of numerous small species and can attract other species that become generally more mobile in the wet-season.

The villagers themselves often know exactly where these ponds will work and where they won't. They're usually very familiar with how flood-waters behave in the areas around their village, and should be consulted as to what they consider would be the most appropriate system in their particular village. It is difficult to imagine how ponds such as those envisaged for the lower catchments will work well along the Theun head-pond, as it's clearly not a floodplain. However, there may be a few appropriate locations and THPC has already constructed two ponds in the head-pond area.

Probably the greatest potential for establishing these ponds is close to the villages in the Nam Hai and Hinboun floodplains. It is recommended that all villages be visited by a survey team to establish if the villagers require ponds, and where and what exactly should be constructed. Where small concrete structures (crude sluice gates) are needed to control water flow, perhaps the villagers themselves can build these if supplied with the necessary materials. A survey of the villages has now been carried out and a report is pending.

**Improved veterinary care and facilities for domestic livestock**

During visits to head-pond villages in August 1998, villagers explained to us that vulnerability to common diseases posed a constraint to raising poultry and pigs. They also considered that much of the disease could be prevented, but vaccines and veterinary advice were not available in the area. At certain locations, entire stocks of poultry and pigs have been lost within a short time period. Many people have apparently just given up trying to raise domestic livestock.

Given that some villagers now have difficulty in catching fish, they probably need assistance to improve their food-security options. Perhaps one way to do this might be to make vaccines and basic veterinary advice available in the villages affected by the project. Although I have not seen any village-level veterinary extension literature in Lao PDR, it likely exists. The Department of Livestock-Fisheries and / or the Veterinary Department in Vientiane / Thakek should be able offer further advice.

**Volunteer services to work with provincial, district and the local communities**

Volunteer services may be able to assist with agricultural, horticultural and livestock improvement schemes in the villages affected by the project. Organizations such as Canadian Universities Service Overseas (CUSO - Canada) and Voluntary Services Overseas (VSO – United Kingdom) and others are operating in Lao PDR and are working in a wide range of fields. Volunteers are often able to bring high levels of expertise to a situation, facilitate rapid dialogue between central authorities and target communities and can often access funding for small projects from a wide range of sources. Both the above organizations would probably be interested to receive a request for a volunteer together with a list of task descriptions.

**Interviews with riparian villagers**

The following text is a summary of my comments on interviews held with Theun-Hinboun riparian fishers and villagers during May 1998 concerning impacts on fish and fisheries. Details of villager responses are provided in Appendix 2 and the end of this report.

**Within the Nam Hai and above and below the confluence of the Nam Hai and Hinboun to the Mekong**

The unusually high fish landings reported from Khongphat have likely been caused by fish moving upstream to get away from turbid waters below confluence. This may not be a sustainable increase. Fishing operations have likely intensified at Khonphat this year due to our policy of supplying fishers with gillnets in order to collect quantitative data on fish landings.

This study was told of quite severe hardships with respect to fisheries at Vangdao when it was visited in February 1998. It is likely that this village, and many other villages like it all the way down to the Mekong, will continue to be impacted by the high-speed turbid flows during the dry-season in the future. Many of the small, delicate dry-season species, which form the mainstay of the dry-season fisheries in these villages, will not tolerate the conditions created by the project.

Traditional fishing gears, such as long-lines and gillnets, are difficult to use in the Nam Hai now due to the strong currents. Fish did move up and down the Nam Hai during the wet-season, but they were migratory species, not residents, and the movement was probably stimulated by the unusually strong flows released from the lower end of the re-regulation pond.

It is likely that many species (not all) would have been attracted to the Hinboun-Mekong confluence area during the dry-season as a result of increased flows caused by the project. This is common behaviour seen in many species. Some species may have continued further on up the Hinboun mistaking the “new water” for the beginning of the wet-season rise in water level. It is difficult to predict exactly what the impact of this event will have / has had on Hinboun migratory fish populations, if it did indeed take place.

It is possible that the normal number of fish, or perhaps even slightly more, have moved up the Hinboun to Song Hong village from the confluence this year. One potential problem is if the more or less constant flows during the whole of the dry-season will cause migratory disorientation and possible failure. Fish, like other living creatures, migrate in order to place themselves in suitable habitats to carry out essential life-cycle events, or to escape seasonally or local adverse conditions. Any disruption to these seasonally regular movements is almost certain to negatively impact on the fish populations. Similarly, although the process is far from fully understood, many Mekong tributary populations rely on hydrological and environmental cues to begin their return downstream migration back to the mainstream at the end of the wet season. Reduced stream flow, and a reduction in water turbidity are thought to be amongst the triggers involved. Some species may fail to make the return journey if riverine conditions still approximately resemble those of the wet-season. Return migratory failure may have equally adverse effects on the fish populations.

**The head-pond area and below the Theun dam to the confluence of the Nam Kading and Mekong**

This study has received widespread reports that many large fish were caught in the deep pools below the dam in the early dry-season after the dam was closed. It remains to be seen if these fish will be at least partly replaced by fishes moving upstream from the lower reaches of the Nam Kading in subsequent years. The observation that fish are in the head-pond, but are difficult to catch, is probably partly true. But there probably aren't quite as many fish in the head-pond as supposed, even though certain species can been observed close to the banks on many stretches of the head-pond. It will take quite some time (years) for the species composition to become anything like stable in the head-pond. Even then, it will be subject to dynamic changes. Many species requiring specific habitats such as rapids in order to complete their life-cycles will disappear much more quickly (perhaps months).

The difficulty in catching fish in the head-pond has been reported by many people, but this study received one report from Katok Village upstream of the Theun bridge that the fish catch had remained the same as before the dam was built. The "fish kill" which took place in the head-pond in May 1998 is alomost certainly not linked to the broken rubber gate and the timing of the two events just coincidence. The price of fresh fish has gone up all over Lao PDR this year and not just at Theun-Hinboun.

It proved very difficult to find people in any village along the lower Kading close to the Mekong confluence on our interview day which were full-time fishers. This study was told that they were either working their fields or elsewhere. The people we interviewed were not particularly knowledgeable about fish and fishing matters.

Further interviews along the lower Kading Villages in subsequent years are probably necessary to establish if there has been a general shortage of fish during the dry-season in recent years, or if the shortage has only occurred as a result of the construction and closure of the Theun dam.

## 6. ADDITIONAL POTENTIAL IMPACTS REQUIRING MONITORING

### 6.(1) Upstream of the Theun dam

#### 6.(1.1) Possible outbreaks of fish disease (Epizootic Ulcerative Syndrome – E.U.S.)

For over 25 years now, research has been continuing into a disease condition (E.U.S) of Asian fish that appears to particularly affect wild fish stocks. Although the investigation is still in progress, most researchers now agree that the primary agent responsible for the disease is *Aphanomyces invadans*; a fungal pathogen (Lilley *et. al.*, 1998. Epizootic Ulcerative Syndrome (EUS) Technical Handbook). Although symptoms do vary between species and in different geographical locations, typically the disease causes large external lesions and ulcers on the body surface. Mortality of affected fish has been high in some outbreaks. Although the disease can affect wild fish in a number of different aquatic ecosystems, it appears to be particularly a problem with fish in enclosed or semi-enclosed water bodies. Outbreaks of the disease in Thailand often coincide with coolest time of the year, and low water temperatures are considered to be associated with the disease. Although this condition has not been

observed by us in any fish species from the Theun in 1998, there remains the possibility of an outbreak in the cool head-pond waters during the early and middle dry-season months.

**Mitigation / Monitoring:**

No mitigation is required, but any diseased fish should be photographed, preserved in formalin and taken to the Fisheries Department in Vientiane for diagnosis.

### 6.(1.2) Introduction of exotic species for release into head-pond waters or for aquaculture in cages

Given that the construction of the Theun dam has certainly had some major impacts on wild fish stocks within the defined project area, there now exists a desire to try to rectify the situation by replacing the fish stocks that have been impacted by something else. Given that research into the propagation and culture of indigenous species in SE Asia is still in its infancy, the possibility of introducing exotic fish presents itself to some as the only viable alternative. However, this may prove to be a major mistake, however well-intentioned, and is definitely not recommended in this report. Biological literature abounds with examples of the dire consequences of releasing exotic species (especially Tilapia and common carp) into water bodies such as the Theun head-pond. In all probability, even if there were no risk of the introduced species impacting on what remains of the native fish populations, any attempt to introduce exotics to the head-pond would likely prove futile because the fish would likely move downstream past the dam with the annual flood-cycle.

The possibility of raising fish in cages has been proposed in some reports. However, this cannot be recommended in this report either. Cages cost time and money to build. They have limited life-spans and are subject to outsider theft. In a river like the Theun, during the wet-season months, they are vulnerable to submerging by flash floods and physical damage from floating debris. Above all, whatever species are stocked, fish require good-quality protein food in order to grow and provide returns on investments. Given the limited resources of riparian villagers along the head-pond, pelleted concentrate feed would probably need to be imported from Thailand, which would almost certainly make the venture unprofitable. Unless the cages are positioned in sheltered areas, fish growth would probably be poor during the wet-season months because of the extra energy demands required by the fish to "hold station" in the cages. With no readily available source of wild seed fish, at the right time, of the correct species, of the right size, there would be a tendency to try to use exotic fish again. This introduces the risk of escapees and also the possibility of disease.

It's quite possible that some villagers will experiment with cages on their own, but this is unlikely to become a sustainable activity in the long-term and should not be actively promoted.

**Mitigation / Monitoring:**

Any attempts to raise fish in cages should be documented. Reports should contain details of which species are being cultured, which feeds are being provided, the source of the fish seed, details of the materials used to construct the cages and whether or not the activity is viable.

## 6.(2) Downstream of the Theun dam

### 6.(2.1) Vulnerability of fish stocks to over-fishing by conventional or destructive fishing methods

In May 1998, we received reports from fishers at Kengbit village that following the closure of the Theun dam in late 1997, fishing activities intensified considerably in the areas below the dam. According to villagers, the abnormally low water levels created by minimum by-pass flows of 5 cumecs. past the Theun dam made catching fish much easier in deep pools and rapids. Although the villagers reported they had used traditional methods for capturing fish at this time, we also received widespread accounts of outsiders using explosives to catch fish, particularly in the deeper pools. I have personally examined the landings of some villagers passing through Kaengbit which appeared to have been caught using explosives.

**Mitigation / Monitoring:**

The only mitigation measure that can be suggested is for local authorities to actively engage in an awareness campaign. Village meetings and posters explaining the long-term adverse effects of using destructive fishing methods may help to enforce the message. (See also comments on Fisheries Management Program regarding illegal fishing methods).

### 6.(2.2) Flushing of sediments

During low and moderate river flows, the reservoir will act as a sedimentation and accumulation basin for suspended material and material transported as bed-load (THPC, 1998). Experience has shown that this material can have deleterious effects on riverine biota when flushed into the old river channel during routine maintenance operations. The extent of the negative impacts caused is dependent on, but not limited to, the exact nature and quantity of the sediment, the seasonal timing and duration of the flushing and the precise time the flushing takes place within one 24hr period. When sediments are flushed downstream, they stimulate a sudden (hours) and massive increase in bacterial and fungal activity and the population of these organisms expands considerably. The extra oxygen requirements of these microorganisms can reduce environmental oxygen to dangerously low levels. Under certain conditions, this can result in large-scale fish kills and other non-lethal negative impacts. The effects are likely to be particularly serious during periods of low seasonal flows where elevated water temperatures and low water residence times may exacerbate the situation.

During the hours of daylight, oxygen levels in almost all aquatic systems are at their highest levels, perhaps peaking in the early to mid- afternoon. This is mainly due to the photosynthetic activity of plants (periphyton and phytoplankton) which use the sun's energy to build up storage compounds and produce oxygen as a by-product. During the hours of darkness, photosynthetic activity all but ceases, but respiration of all living organisms in the system continues. Essentially this causes the dissolved oxygen concentration in the system to fall to it's lowest level just before dawn. It is very important that the extra demand on oxygen created during the flushing and release of sediments does not coincide with the natural period of low oxygen concentration.

At Theun-Hinboun, impacts resulting from sediment flushing will probably be less of a problem than at some hydro-power reservoirs, but great care should still be taken. Future catchment deforestation could substantially increase sediment transport rates and thereby reservoir sedimentation rates (NORPLAN, 1996). Theun-Hinboun reservoir is mostly confined to the old river channel and large areas of vegetation have not been submerged. In addition, it is not a deep reservoir and presumably a good proportion of accumulated sediments are naturally flushed through the system during high wet-season flows or continuously via the sand flushing gates. THPC is monitoring any possible sediment accumulation in the head-pond and results will be known in approximately one year's time. Recommendations regarding flushing of sediments at the Theun dam are provided below.

**Mitigation / Monitoring:**

**Sediment flushing from reservoir**

According to THPC's manual for operation and maintenance, flushing of sediments will take place by operating the radial gates at inflows in the range of 500 – 2,000 cumecs. at the end of the wet-season in September and October. Flushing of large amounts of accumulated sediment should take place during periods of highest flows only (September), and never during the dry-season months. Continuous flushing of light sediments via the sand flushing gates during normal project operation probably has a minimal impact. If possible, the flushing operation should be extended over a wide time scale, with short flushings taking place separated by 4 or 5 days recovery period. Flushing should **never** take place during the afternoon period or during the hours of darkness. Probably the safest time to flush sediments is between 07:00 and 09:00hrs. The areas below the dam should be thoroughly inspected after each flushing to assess any negative effects. THPC is amending its operational manuals to take account of this recommendation.

**Sediment flushing from the intake**

During periods when inflows exceed 115 cumecs., surplus water will be released through the sand flushing ducts until the inflow exceeds approximately 240 cumecs. (THPC, 1998). The four ducts will be opened one by one with increasing flow. Given that flushing sediments through the ducts will take place almost continuously and in comparatively small amounts, any negative effects are likely to be less than flushing sediments from the reservoir via the radial gates. Nothing further can be recommended regarding the proposed method of operation, but the area below the dam should be inspected regularly for signs of any negative effects from sediments.

### 6.(3) Upstream and downstream of the Hai / Hinboun confluence to the Mekong

#### 6.(3.1) Migrations, spawning and recruitment

The most important impacts to be monitored in the above areas are if the upstream wet-season migration still takes place in 1999 and 2000 and, if so, if there is evidence that spawning and recruitment are taking place.

**Monitoring/Mitigation:**

Given the difficulties in establishing quantitative monitoring in these areas, much of the monitoring will probably have to be based on anecdotal reports from riparian villagers. Where quantitative sampling is possible, this should provide the required information.

## 7. FUTURE ACTIVITIES

For details of the future Action Plan at Theun Hinboun, see Appendix 2.

### 7.(1) CPUE Monitoring Program

Monitoring of fisheries using CPUE should be expanded to include more villages (see section 3.3). This should be possible now that EMCO staff numbers have been increased. EMCO staff must attempt to establish (or continue) times-series data collections in the villages of Kengbit, Sop Nyouang, Katok, Khongpat and Song Hong. Village meetings should be held to explain the program and recruit fishers. At least five fishers should be selected. Only data from gillnets should be recorded. Fishers will require a small financial incentive in order to cooperate with the study. Data collection should take place on one agreed day per week. Data to be recorded should include: date, location, fisher name, the mesh size of gillnet (s) used, the number of gillnets used of each mesh size, total numbers and weights of each species (or collective name i.e. "Pba Soi") caught using each mesh size. Data forms have been used at Theun-Hinboun during 1998 and should serve as examples. Data should be entered into EMCO's computer immediately on returning from the field. Any species not already on the computer's CPUE spreadsheet should be entered under the "OTHER" column. Hard copies of all data sheets should be filed in order using a separate ring folder for each village. If the time-series data collection is interrupted for any reason (floods etc…) it should be re-started again as soon as possible and not abandoned at any particular village.

The main constraints to an expansion of the CPUE program are: 1) a disruption to traditional fishing methods in Nam Hai and Hinboun villages, making the recording of data difficult at these sites. 2) Difficulties in accessing some sites either because of time constraints (long boat journeys) or flooding during the wet-season. The objective of recording CPUE is to obtain a set of data on **standardized catch** over a time series, and not simply to record quantity of catch. This is the only way to obtain an index of relative abundance that can be used to: 1) Compare fish populations at the species level between months of any one year, and between the same months of different years. 2) Identify which species have declined and which species have come to dominate species compositions. 3) Detect annual migrations and shifts in habitat and niche.

Gillnets can meet the required gear criteria because, within a certain mesh size, they are comparatively non-selective and not subject to saturation such as some traps and long-lines. The only disadvantage with them is that they often cannot be used under all wet-season conditions. Only a limited number of species can be caught using long-lines, and this itself is dependent on the bait used and hook size. Quite often a fish will take the bait without being caught on the hook, or small species will remove the bait from a large hook thereby rendering the sampling unit (the hook) ineffective. Only certain species, often within a specific size class, will enter a trap. The kinds of traps in use on the Hinboun are subject

to saturation and are not suitable to obtain indices of relative abundance. CPUE data from long-lines and traps will be almost meaningless and difficult to interpret.

Given the situation described above, and having discussed future monitoring activities with EMCO, the following action is now recommended. CPUE monitoring should be continued at Khongpat village on the Hinboun and at Kengbit on the Theun head-pond. EMCO staff should visit and interview fishers at the villages of Sob Nyouang and Katok on the Theun head-pond. If fishers are prepared to cooperate with a CPUE study, an attempt should be made to establish monitoring at these villages using the same methods as at Kengbit. Similar discussions and interviews should be conducted with fishers at the village of Song Hong on the Hinboun and CPUE programs established if suitable. Song Hong is recommended because it can be accessed by good roads all year-round. EMCO staff will have to demonstrate how to fill out forms and record data accurately. CPUE data recording should take place on over-night fish landings once per week on a day agreed by EMCO and villagers. Forms can be collected each week during site visits and entered to EMCO's computer at the project site. Back-ups of all data should made from the start. Anecdotal information should be recorded at all sites on a monthly basis and made available in brief monthly reports. If it proves impossible to record CPUE data from Song Hong village, monitoring may have to rely on anecdotal reports only.

Fishers will almost certainly require an incentive in order to cooperate with data sampling over time. Without sufficient numbers of gillnets in use, and in a range of different mesh sizes, data may be difficult to interpret. THPC has provided gillnets for use in the CPUE sampling program since beginning monitoring, and has agreed to supply more nets as and when required in future. Each fisher that cooperates with the program should be supplied with at least one gillnet. As an approximate guide, data are required from about 10 gillnets on each sampling day. If only five fishers can be recruited to record data, then perhaps each fisher can be supplied with two nets each. These kinds of details should be negotiated during interviews. Every attempt should be made to supply the mesh sizes requested from the fishers during the different seasons. It is recommended that a budget be made available that will allow EMCO to quickly respond to requests from the fishers. In addition to the above, each village that cooperates with the program will require two basic weighing machines. Preferably, 0 – 2Kg (or 0 – 5Kg), and 0 – 10Kg. These are available from Vientiane or Thakek. EMCO staff should provide instructions on how to use the machines.

**7.(2) Construction of wild fish ponds**

Construction of wild fish-ponds has already begun at two villages on the Nam Hai / Hinboun plain. When it is established which villages require a pond, construction should proceed immediately. Anecdotal evidence from villagers will be the best method of monitoring the success of these ponds.

**7.(3) Construction of a fish hatchery close to the head-pond**

Predicting exactly what will happen to the quality of the fisheries in the head-pond over the next five years is quite difficult because of the uncertainties and variables involved. The main issues are: whether or not the wet-season migration will be able to pass the Theun dam in 1999, and in the years that follow, the unstable and alternating seasonal conditions in the head-pond waters, and if there will be major changes in species compositions and, if so, which species may come to dominate.

One idea that has emerged is the possibility of building a fish hatchery with the objective of breeding and releasing certain species currently found in the head-pond. In theory, this is a reasonable proposal, but its effectiveness in actually maintaining fishing quality in the head-pond will be dependent on a number of factors. Firstly, research into breeding indigenous fish species in Lao PDR is in its infancy, and consequently any such program would have to be viewed as at least partly experimental. The technologies that do exist probably could be adapted and extended to a number of new species. Secondly, there are many such hatcheries all over Lao PDR with the capability of producing indigenous fish seed, but relatively few actually do it and are successful. The reasons for this vary from place to place, but poor management can often be identified as the major cause. Thirdly, it will take several years to establish the hatchery, train staff, establish management procedures and actually get the project producing seed fish. Realistically, such a project should not be viewed as immediate solution to the current situation. Fourthly, there's no way to predict if stocking the head-pond will actually improve fishing conditions. The stocked fish may simply move away upstream, or exit the system during the wet-season. Finally, even with a well-managed farm, the artificial propagation of fish cannot even come close to competing with natural reproduction in terms of numbers of recruits produced.

Given the above variables, it is recommended that the proposal to construct a hatchery be placed on hold for at least one year. At the end of 1999, the results of further monitoring should be used to help decide if construction of a hatchery is required or not. If it is still unclear, then a decision should be delayed for a further year. If it is decided to proceed with construction, a detailed survey of suitable sites will be necessary together with detailed plans of the hatchery, pond construction and general farm layout. Such a project could not expect to be economically self-sustaining. It would require operating costs (fuel, feed, staff incomes etc….) to be met by external sources.

### 7.(4) Fisheries Management Program at Theun-Hinboun

Having reviewed the proposed Fisheries Management Program (Burapha Development Consultants, 1997), I have found the plan to be technically feasible overall but disagree on a number of points and approaches. Comments on Part IV of the report regarding the action plan are provided below.

- **Institutional strengthening** (P.23). This should be given a high priority within the overall framework of the program. Wherever possible, training and study tours should be participatory with trainees providing much of the input from their own practical experiences. A study tour to the Pak Mun hydro-power project in Ubonratchatani Province in Thailand may prove useful.

- **Conservation** (P.23). Recommendations on closed seasons and sanctuaries are also provided in Section 5 of this report. Complete villager cooperation with careful explanations of potential benefits will probably work better than imposing penalties for violators as suggested in the Burapha report. Protection of rare and endangered species is an important issue identified by Burapha. Unfortunately, many of the species in need of protection are often caught with comparatively non-selective gears whilst targeting the more common species. This makes their absolute protection and conservation almost impossible. A better approach may be to identify known spawning grounds and protect certain habitats where rare fish and other semi-aquatic animals are known to exist. In

addition, the species in question is often damaged or injured during capture and survival rates are low after release. However, there may be some benefit in encouraging villagers to release rare fish when caught, but this is unlikely to occur. Education and posters may prove to be the most effective method.

- **Elimination of illegal fishing methods.** (P.24). From all that we have heard and witnessed during the first year of fisheries monitoring at Theun-Hinboun, this is a serious problem in some areas, particularly below the Theun dam. It is recommended that all materials for making home made explosives, either assembled or otherwise, be declared illegal and subject to confiscation by relevant authorities. Simply banning their use, as suggested by Burapha, is unlikely to be effective. The main sources of these materials should be identified and every effort made to halt their sale. That is, it should be made illegal to sell the materials as well as own them.

- **Limit on net mesh size.** (P.24). This is a difficult issue. There is no direct evidence that the use of small-mesh nets is having a negative effect on the overall quality of the fishery in the Theun or the Hinboun rivers, but there may be an effect. During certain times of the year, small species form the most important component in fish landings for subsistence purposes. Apart from using some traps and small hooks on a long-line, the only effective way to capture small fish in bulk is to set small-mesh nets. Until such times as it can be proven that the use of small-mesh nets is having a major negative effect on the fishery, it cannot be recommended to ban their use outright as suggested in the Burapha report.

- **Water pollution** (P.25). Any direct source of pollution should be identified and prevented. However, I think it unlikely that any normal activities at Theun-Hinboun would pose a serious risk of pollution. I have not seen evidence of the intensive agriculture mentioned by Burapha.

- **Catchment area and watershed management** (P.25). All possible effort should be directed towards reducing shifting cultivation techniques. But obviously alternatives do have to be identified and extended to villagers in a practical way.

- **Establishment of village fishery networks** (P.26). Very important. This could act as a forum to discuss all matters of concern related to the fishery at Theun-Hinboun and seek cooperation from villagers regarding conservation issues.

- **Experimental fishing** (P.27). Up to a point this has already started. However, unless extensive frame surveys (background data on fishing operations and socio-economics) are also conducted to assess total effort, CPUE data alone will not provide information on annual fish catch or fish production as suggested by Burapha. In a partially open system like Theun-Hinboun, the factors that actually determine annual fish catch and production are probably too complex for any model to be of much practical value.

- **Survey of the head-pond substrata and monitoring alterations in fish ecology** (P.27). Time-series CPUE data gathered at specific locations should provide most of the required information.

- **Relocation of villages** (P.27). Based on all available information to date, it is probably true that Theun-Hinboun head-pond will not become a very important fishery in the future and will probably not support a large fishing community in the same way as at Nam Ngum for example. Evidence suggests that if anything, an out-migration of villagers is taking place rather than the in-migration suggested by Burapha. The reasons for this are apparently complex and may not be related at all to the construction and operation of the project. A bridge constructed by THPC has significantly improved access to and from several head-pond villages.

- **Fish market development** (P.28). There may be some advantages in constructing a simple building for fish traders, high up on the bank. A reliable source of ice and better catch transport facilities may help to improve marketing.

- **Survey of fish seed resources** (P.28). See comments on fish seed and stocking the head-pond in section 5 of this report.

- **Establishment of fishery station and re-stocking** (P.29). As above.

- **The construction of a fish passage and screen** (P.29). See comments on a fish passage and protective screen in section 5 of this report.

- **Small-scale aquaculture development** (P.30). See comments on small-scale aquaculture development in section 5 of this report.

- **Zoning area** (P.30). Zoning the overall project area may be an aid to management.

- **Nam Kading below dam site downstream to mouth of Nam Mouan** (P.31). Some of these important issues are being monitored already, but it must be appreciated that it is extremely difficult to obtain quantitative measurements in this section of the river. Not only is it difficult to access the area, and dangerous in the wet-season, but fishing operations in this section are erratic and intermittent. CPUE data gathered in the head-pond should establish when, and if, migratory stocks are able to pass upstream beyond the Theun dam. See comments on a no-fishing zone below the dam and recommendations on flushing sediments in sections 5 and 6 of this report.

- **Monitoring and evaluation** (P.32). Process is on-going. Fishery specialist will provide assistance with data analysis and interpretation after each 6-month period if requested.

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## 10. APPENDIX 1

**Action Plan For Monitoring Impacts To Fisheries At Theun-Hinboun Hydropower Project**

The following proposed action plan provides a statement of each impact referred to in this report together with any indicators that the impact is, or might be taking place. Some impacts (e.g. impacts 7 and 9) are not possible to isolate from other factors and cannot be monitored separately. Where monitoring activities are required, or mitigation measures can be suggested, these are provided together with estimated costs for a further 2-year period beginning in January 1999 and ending in December 2000. In order to conduct the monitoring program as efficiently as possible, certain monitoring activities have been grouped together and should be carried out at the same time. Where any one impact is only likely to require monitoring over a specific period, this is indicated.

Monitoring activities for the impacts listed below can be coordinated over the 2-year period from January 1999 to December 2000. Given that there are five main sites to be monitored at Kengbit, Sop Nyouang, Katok, Khongpat and Song Hong Villages (one site visited per day), this will require 12 man-months of input per year and therefore 24 man-months input over the 2-year monitoring period. Total costs for monitoring the impacts listed below are estimated at 5,180 USD. Total estimated costs for mitigation and additional studies for these impacts are estimated at 2,075,100 USD.

1. Effects on local ecosystem and changes in aquatic bio-diversity.
2. Unstable head-pond environment.
3. Response by fish to re-establishment of flowing water conditions in the wet season months.
4. Periodic reduced water quality in the head-pond and fish kills.
5. Submerging of rapids in the head-pond area and creation of a seasonal lacustrine environment.
6. Appearance of new species.
8. Reduced dry-season flows passed the Theun dam.
10. Migratory delay / failure at the Theun dam.
11. Increased flow volume in the Nam Hinboun and migratory dis-orientation.
12. Increased sediment load and thermal pollution by Nam Theun waters in the Hai / Hinboun.
13. Unstable environment within the Nam Hai, and the gathering of fish below the re-regulation pond weir.
14. Possible inter-basin transfer of Nam Theun species to the Hai / Hinboun system.
15. Possible outbreaks of fish disease (E.U.S.).
16. Introduction of exotic species for release into head-pond waters for aquaculture in cages.
17. Vulnerability of fish stocks to over-fishing by conventional or destructive fishing methods below the Theun dam.
19. Migrations, spawning and recruitment in the Nam Hai and Hinboun.

The following impacts have also been identified, or thought likely to occur. However, they either are beyond present monitoring capabilities (impacts 7 and 9), or cannot be coordinated easily with other activities and will require a separate monitoring effort over a short period only (impact 18). Total estimated costs for monitoring impact 18 over the 3-year period are estimated at 300 USD. No mitigation costs are involved.

7. Nutrient trap effect of the reservoir.
9. Loss of natural hydropower.
18. Flushing of sediments.

**IMPACT 1:**

Effects on local ecosystem and changes in aquatic bio-diversity (P.17).

**Impact Indicators:**

Disappearance of certain typical species from landings.
River bank collapse.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to monitor changes in species composition. Directly observe damage to banks.
Annual cost for monitoring 5 sites including fuel and fisher payment is 1440 USD.
Annual cost for replacement of gillnets for 25 fishers every 3 months at a cost of 10 USD dollar per net is 1000 USD.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 2, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week in each selected village from January 1999 to December 2000.
Total monitoring cost for 2-year period is 4,880 USD
No mitigation costs.

**IMPACT 2:**

Unstable head-pond environment (P.18).

**Impact Indicators:**

Disappearance of certain typical species from landings.
Possible seasonal appearance of new fish species in fish landings.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to monitor changes in species composition.
Costs already accounted for at impact 1 above.

**Expertise:**

As for impact 1 above.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 3, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week in each selected village from January 1999 to December 2000.
Total costs for monitoring accounted for at impact 1 above.
No mitigation costs.

**IMPACT 3:**

Response by fish to re-establishment of flowing water conditions in the wet-season months (P.18).

**Impact Indicators:**

Disappearance of certain typical species from landings. Information provided by local people on observed spawning activity.

Information from fishers and riparian villagers on sightings of juvenile stages of any species in the head-pond waters.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to monitor changes in species composition and detect spawning migrations. Most important period is the middle to late wet-season. Gather anecdotal information during visits to collect CPUE data.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

Attempt to establish a “no fishing” zone at the end of the head-pond.

Annual cost for erecting signs, village meetings and visiting the area is 300 USD.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 4, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week in each selected village from January 1999 to December 2000.

Total costs for monitoring accounted for at impact 1 above.

Total mitigation cost for 2-year period is 600 USD.

**IMPACT 4:**

Periodic reduced water quality in the head-pond and fish kills (P.19).

**Impact Indicators:**

Unusually dark-coloured water with associated unpleasant odour in the head-pond, the feeder streams or below the turbine discharge point at the top of the tailrace. Dead fish.

**Recommended Monitoring Activities and Estimated Costs:**

Visually check quality of water at all sites visited at all times and continue with water quality monitoring program. Probably the most dangerous period is at the end of the hot-season in April or May when the first rains are arriving. Any fish kills should be carefully documented by location, date, time, duration and an estimate of the numbers of fish killed (i.e. 10's, 100's or 1000's). Preserve as many dead fish as possible in formalin for future identification..

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 5, 6, 8, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week in each selected village from January 1999 to December 2000.

Total costs for monitoring accounted for at impact 1 above.

No mitigation costs.

**IMPACT 5:**

Submerging of rapids in the head-pond area and the creation of a seasonal lacustrine environment (P.20).

**Impact Indicators:**

Disappearance of certain typical species from landings and generally a decrease in the number of fish species.

Possible appearance of a few new species.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to monitor changes in species composition. Gather anecdotal information on the appearance of any new species and a decrease in the number of target species.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 6, 8, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week in head-pond CPUE villages from January 1999 to December 2000.

Total costs for monitoring accounted for at impact 1 above.

No mitigation costs.

**IMPACT 6:**

Appearance of new fish species (P.21).

**Impact Indicators:**

New species appearing in fish landings or anecdotally reported.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to detect appearance of new species. Gather anecdotal information on appearance of new species. Some indication of numbers of the new species, how and where they were caught would also be required.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 8, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week in head-pond CPUE villages from January 1999 to December 2000.

Total costs for monitoring accounted for at impact 1 above.

No mitigation costs.

**IMPACT 7:**

Nutrient trap effect of the reservoir (P.21).

**Impact Indicators:**

Loss of productivity and a reduction in fish bio-mass below the dam.

**Recommended Monitoring Activities and Estimated Costs:**

No direct monitoring required. This impact impossible to separate from effects of other impacts. No monitoring costs.

**Expertise:**

None.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved.

**Coordination, Timing and Total Costs:**

No coordination or costs involved.

**IMPACT 8:**

Minimum water release past the Theun dam (P.21).

**Impact Indicators:**

Reduction in normal water level. Reduction in normal current speeds in rapids and deeper pools. Rapids appearing shallower than normal. Water colour becoming greener in deeper pools below dam. Reduction in standing crop and fish landings.

**Recommended Monitoring Activities and Estimated Costs:**

Direct observation and anecdotal reports from local fishers.

Annual cost for weekly visits to the areas below the dam is 100 USD.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

This report recommends increasing the minimum dry-season by-pass flows from 5 cumecs. to 10 cumecs.

Annual estimated cost is 1,000,000 USD (THPC, 1999).

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 10, 11, 12, 13, 14, 15, 16 and 19. Conduct monitoring activities once per week from November to May each year.

Total monitoring cost for 2-year period is 200 USD.

Total mitigation cost for 2-year period is 2,000,000 USD.

**IMPACT 9:**

Loss of natural hydropower (P.24).

**Impact Indicators:**

Loss of productivity and a reduction in fish bio-mass below the dam.

**Recommended Monitoring Activities and Estimated Costs:**

No direct monitoring required. This impact impossible to separate from effects of other impacts. No monitoring costs.

**Expertise:**

None.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

No Coordination or costs involved.

**IMPACT 10:**

Migratory delay / failure at the Theun dam (P.24).

**Impact Indicators:**

Accumulation of large numbers of fish below the dam during the wet-season months from April to September. Statistical evidence from CPUE data collected in the head-pond villages. Information provided by fishers in head-pond villages.

**Recommended Monitoring Activities and Estimated Costs:**

Direct observation of fish below the dam. Use CPUE to monitor changes in species composition and to detect migratory activity in the head-pond.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

It is recommended that a panel of 3 experts who have experience of tropical fish faunas and fish passes be invited to visit the Theun dam and present a brief report of their findings to THPC. A firm recommendation on whether to construct a fish pass should be based on their findings. The brief report should contain details of design construction.

Cost for carrying out this investigation is estimated at 800 USD per day, per person over a 10-day period. Cost therefore is 24,000 USD plus travel and DSA.

Estimated construction cost of a fish pass is between 100,000 and 150,000 USD.

At this stage, a fish hatchery as an alternative is not recommended.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 11, 12, 13, 14, 15, 16 and 19. Monitoring should take place once per week during CPUE visits to the head-pond area from April to September each year.

Monitoring costs already accounted for at impact 1 above.

Mitigation cost for the investigation is 24,000 USD plus travel and DSA costs. Precise cost of fish pass construction should be an output of the investigation.

**IMPACT 11:**

Increased flow volume in the Nam Hinboun and migratory disorientation (P.27).

**Impact Indicators:**

No sudden arrival of migratory species at the start of, and during the course of the wet-season.

**Recommended Monitoring Activities and Estimated Costs:**

If possible, use CPUE to detect migratory activity in the Hinboun. As much anecdotal information on atypical migratory movements should be gathered as possible from riparian villagers.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

Construction of trap ponds for wild fish is recommended for affected villages.

Total cost of constructing 15 to 20 ponds is estimated at 50,000 USD.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 12, 13, 14, 15, 16 and 19. Conduct monitoring activity once per week during visits to selected CPUE villages from January 1999 to December 2000.

Total monitoring costs already accounted for.

Total mitigation cost is 50,000 USD.

**IMPACT 12:**

Increased sediment load and thermal pollution by Nam Theun waters in the Hai / Hinboun (P.28).

**Impact Indicators:**

Disappearance of certain typical dry-season species from landings downstream of the Hai / Hinboun confluence.

Turbid waters during the dry-season months.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to detect shifts in typical species compositions. Directly observe sediment load carried by Nam Hai and Nam Hinboun. No monitoring required for possible effects of thermal pollution as this is impossible to separate from the effects of other impacts.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 11, 13, 14, 15, 16 and 19. Conduct monitoring activities once per week during visits to selected CPUE villages on the Hinboun from January 1999 to December 2000.

Monitoring costs already accounted for at impact 1 above.

No mitigation costs.

**IMPACT 13:**

Unstable environment within the Nam Hai, and the gathering of fish below the re-regulation pond weir (P.29).

**Impact Indicators:**

Large numbers of fish in full reproductive condition gathering below the re-regulation pond weir.

**Recommended Monitoring Activities and Estimated Costs:**

Directly observe and gather anecdotal information from riparian villagers.
Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 14, 15, 16 and 19. Conduct monitoring activities once per week from January 1999 to December 2000.
Total monitoring costs already accounted for at impact 1 above.
No mitigation costs.

**IMPACT 14:**

Possible inter-basin transfer of Nam Theun species to the Hai / Hinboun system (P.29).

**Impact Indicators:**

Appearance of species only previously found in the Theun in Nam Hinboun landings.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to detect appearance of any Theun species in Nam Hai or Hinboun.
Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 15, 16 and 19. Conduct monitoring activity once per week in selected CPUE villages on the Hinboun from January 1999 to December 2000.
Monitoring costs already accounted for at impact 1 above.
No mitigation costs.

**IMPACT 15:**

Possible outbreaks of fish disease (E.U.S.) (P.33).

**Impact Indicators:**

Fish appearing in landings or markets from the head-pond with large external ulcers or lesions on body surface.

**Recommended Monitoring Activities and Estimated Costs:**

Direct observation.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 14, 16 and 19. Conduct monitoring activities once per week during visits to selected CPUE villages and local fish markets from January 1999 to December 2000.

Monitoring costs already accounted for at impact 1 above.

No mitigation costs.

**IMPACT 16:**

Introduction of exotic species for release into head-pond waters for aquaculture in cages (P.34).

**Impact Indicators:**

Establishment of culture activities using exotic fish. Appearance of exotic species in fish landings or local markets.

**Recommended Monitoring Activities and Estimated Costs:**

Direct observation.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

Riparian villagers should be made aware of the potential dangers exotic species pose to indigenous fish populations. No specific costs involved.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 14, 15 and 19. Conduct monitoring activities once per week in head-pond villages from January 1999 to December 2000.

Total monitoring costs already accounted for at impact 1 above.

No mitigation costs.

**IMPACT 17:**

Vulnerability of fish stocks to over-fishing by conventional or destructive fishing methods below the Theun dam (P.34).

**Impact Indicators:**

Anecdotal evidence from local fishers that stocks are declining or difficult to catch. Direct observation of fish caught by using explosives.

**Recommended Monitoring Activities and Estimated Costs:**

Regular visits should be made to head-pond villages to interview riparian fishers and observe fish landings.

Costs already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures or costs involved.

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 14, 15, 16 and 19. Conduct monitoring activity once per week in selected head-pond villages from January 1999 to December 2000.

Total monitoring costs already accounted for at impact 1 above.

No mitigation costs.

**IMPACT 18:**

Flushing of sediments (P.35).

**Impact Indicators:**

Fine silt deposits covering submerged rocks below the dam. Retarded growths of filamentous algae growing on rocks. In the extreme case, fish gasping for oxygen at the water surface and fish deaths.

**Recommended Monitoring Activities and Estimated Costs:**

As far as possible, inspect the area below the dam after flushings.
Annual cost of monitoring is estimated at 100 USD.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

Only flush sediments during the height of the wet-season. Flush small amounts of material over several days rather that large amounts over shorter periods. Allow 4 or 5 days recovery period between flushings. Never flush sediments during the afternoon or at night. Flush sediments between 07:00 and 09:00hrs.
No known mitigation costs.

**Coordination, Timing and Total Costs:**

No coordination with other monitoring activities but EMCO should make contact with Operation and Maintenance staff at site. Conduct monitoring activity after each flushing
Total annual cost of monitoring is 100 USD.
No known mitigation costs.

**IMPACT 19:**

Migrations, spawning and recruitment in the Nam Hai and Hinboun (P.36).

**Impact Indicators:**

Fish fail to make their annual spawning migration in the wet-season. Spawning failure and poor recruitment to the fishery. Fishing quality gradually diminishing. Perhaps some species disappearing from landings. Few juvenile size-classes appearing in fish landings.

**Recommended Monitoring Activities and Estimated Costs:**

Use CPUE to detect migration failure, disappearance of certain species or shifts in size-classes. Gather anecdotal evidence for any of the above.

Costs for monitoring are already accounted for at impact 1 above.

**Expertise:**

One EMCO staff.

**Recommended Mitigation Measures and Estimated Costs:**

No mitigation measures suggested or costs involved

**Coordination, Timing and Total Costs:**

Coordinate with monitoring activities1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 14, 15, 16 and 17. Conduct monitoring activity once per week during visits to selected CPUE villages on the Nam Hinboun from January 1999 to December 2000.

Total monitoring costs already accounted for at impact 1 above.

No mitigation costs.

## 11. APPENDIX 2

### Anecdotal information and reports received from local villagers regarding impacts on fish populations and fisheries at Theun-Hinboun

After approximately 6 months of project operation, and at the specific request of THPC, a series of interviews were conducted in a number of riparian villages within the project area regarding impacts on fish populations and fisheries (see map). These interviews were conducted by EMCO staff and myself. These interviews are in addition to those made by ADB, IFC, THPC, IRN and certain NGO groups. Where other subjects not directly related to fisheries were mentioned during the interviews, these have been included.

It should be noted that these comments have been provided by local people in a single interview, after only a very short period of project operation, and during a wet-season with below average rainfall. Interviews conducted at other times of the year may, or may not, produce different results.

- ***(1) Interview at Khongphat village with Mr Khamkoume, village chief, just upstream from confluence of Nam Hai and Nam Hinboun. May 12 1998.***

**Mr Khamkoune**:
Fish landings specifically at this village during this dry-season have been better than normal. One problem experienced by villagers occurs when they set gillnets during the night and then the turbines are shut down. This causes water level to drop and current speed to increase above the confluence. This pulls floating bushes and sticks into the nets. Some nets have been damaged like this. Another minor problem, is that villagers from Vangdao have to come to fish above the confluence now because the current flow there is too strong for them to set nets. So far, there has been no real problem and everyone can catch just about enough fish.

- ***(2) Interview at Kaengbit village with Mr Mong, village chief, just upstream from the Theun dam and on the banks of the headpond. May 12 1998.***

**Mr Mong**:
Fish landings now are below normal for the areas above and below the Theun dam. Back last December, January and February, fish landings were exceptionally good. What happened was that after they closed the dam, the water level below the dam went right down. Many people came to fish in the deep pools and sometimes we could catch 200Kg in one day. You could see the fish swimming around and they were easy to catch. Now we don't want to go fishing there because all the good fish have been caught already. We are also worried that the fish will not be able to come up past the dam this wet-season. We also have a problem with people coming to fish with home-made bombs. It's people coming from all over the place. We want the Provincial and District authorities to try to stop this.

Fishing conditions in the head-pond have completely changed now. Before they closed the dam, we could go fishing in many different places and use a number of different methods to catch fish. Now we

can only use gillnets and we need to buy deep-water nets that are expensive (around 700 Thai Baht each). The fish are there, but we can't catch them. I think the fish population will increase in the future because they're so difficult to catch now.

People in Kaengbit village are only part-time fishers and not really that interested in fishing anyway. The decrease in fish catch is no big problem for us because we can go to the forest to collect "kee see" (a kind of resin used in boat making) or cut "san bushes". We can make 3,000K to 5,000K per day doing this. If we cut and sell "san stalks" we can get 300K/Kg for this. Mainly we're rice-farmers and under normal circumstances we can grow enough to keep us in rice for 5 or 6 months of the year. I have a plan to start cow-raising in this village. We need 10 cows to start with which will cost between 1.5 and 2.0 million kip. After 3yrs there should be enough income for each villager.

- ***(3) Interview with Mr Mai-On, village chief, and Mr Bawlert, social community chief at Sop Nyouang village, approximately 9km upstream from the Theun dam and opposite the confluence of the Nam Nyouang and Nam Theun. May 14 1998.***

**Mr Mai-On and Mr Bawlert**:
Before the dam was built we could catch fish all the time using a lot of different methods. Now we can only put gillnets into the water and have to buy new deep-water nets. The numbers of fish are about the same as before, but now they're more difficult to catch. We think the number of fish will increase in the future because people can't catch them now. Also, people can't use bombs to catch the fish now because the deep holes where fish gather are all gone. We have noticed that many of the species that used to eat the green algae on the rocks in the shallow water are getting very thin now when we occasionally catch them. We are worried that even if the fish can come up past the dam, they will continue up to the end of the head-pond and beyond because many like to live in rapids and these are now gone.

The decrease in fish catch is no real big problem and we can catch enough fish to eat. Many families have moved away from here anyway (50 originally, now 18 left). They've gone to Thabac and Lacsao mostly to open shops or do trading activities.

- ***(4) Interview with Mr Khamson, village defense person, at Vangdao village, just below the confluence of the Nam Hai and Nam Hinboun. May 14 1998.***

**Mr Khamson:**
It was very difficult for us to catch fish this last dry-season and we did suffer some hardships. The water currents were too strong and floating bushes and sticks destroyed our gillnets. The fish weren't there anyway and had moved up to the area above the confluence. That's where we mostly go now to catch fish. We also fish around the shallow areas around this village with castnets and catch just about enough fish to eat. Now that the first rains have come, there are a few more fish and it's about the same as a normal year. We can also set our gillnets sometimes around the far bend in the river just below the mountains, about 1km from here. We can only do this when they close the water off. Sometimes we have to run down to the fishing area to gather our nets in quickly when they release the water. If we don't, the current and the sticks damage our nets.

The project has had some bad impacts on the fishing but we do have the communication road and we can now get medical treatment at the hospital. The project has also given us concrete rings to supply us with drinking water.

- ***(5) Interview with Mr Bounmy, village chief, at Thasala village on the Nam Ngouang at road crossing No. 1. Week May 18 to 22 1998.***

**Mr Bounmy:**
I thought the fish had disappeared or gone to another place when the water level came up and the river became bigger and deeper. It was very difficult for us to catch fish. When the water level went down again (we heard about the broken rubber gate) we could catch the fish same as before the dam was built. We also saw many dead fish in the water during the time the rubber gate broke. The price of fish has gone up from 800 Kip/Kg a while ago to 4,000 Kip/Kg now.

- ***(6) Interview with Mr Vanna, village chief at Katok village, upstream of the Theun bridge and on the banks of the head-pond. Week May 18 – 22 1998.***

**Mr Vanna:**
In our village the fish catch has stayed the same even though the water has come up quite high now. But when the water level went down, because of the broken rubber gate, the fishing wasn't so good because the water was not so deep.

- ***(7) Interview with Mr Bounthan, deputy chief of Nakham village, along the Nam Hai. Week May 18 – 22 1998.***

**Mr Bounthan:**
Our fish catch has gone down because of the release of the water from the power plant. The water is turbid and the flow very strong. Our fishing equipment cannot be used in this river any more. If possible, we would like to change the equipment and we would like to have a fish-pond if we have the money.

- ***(8) Interview with Mr Bounmy, village chief of Bankhen village, downstream of the confluence of the Nam Hai and Hinboun. Week May 18 – 22 1998.***

**Mr Bounmy:**
The same as the other village, our fish catch has gone down. The reason is the water from the power plant and dirty water. We would like to change our equipment for longer nets and would like to have a fish-pond to raise fish.

- ***(9) Interview with Mr Khan, an experienced fisher at Hinboun Tai village, at the confluence of the Nam Hinboun and Mekong. June 9 1998.***

**Mr Khan:**
During this last dry-season we had some problems when they released the water. The currents were too strong and we couldn't use our gillnets. Instead, we use long-lines to catch fish. Fish seem more this year, but we can't catch them easily. I think there's more fish this year because they released water in the dry-season which the fish like. I estimate I catch between 2 and 10Kg of fish per day on average. We have enough fish to eat and I sell some fish. Actually, rice is the problem for us; there are enough fish in the river. The idea of a community pond is OK, but it's not really necessary as we have the river.

- ***(10) Interview with Mr Jantong, a regular fisher and former Jaeow Muang and Mr Inpun, deputy governor of Commisio district, at Song Hong village at the bridge-Hinboun crossing along route 13. June 9 1998.***

**Mr Jantong and Mr Inpun:**
We can catch enough fish to eat and sometimes we are able to sell fish if landings are good. The fish numbers are about the same as a normal year but the number of places where we used to fish have been reduced because the water level has increased and generally the fish are more difficult to catch. When the water was really low in a normal dry-season, or when the water is really high in the wet-season, we can catch fish easily. The constant mid-water level created by the project makes it difficult to catch fish. The wet-season migration is about the same as a normal year. Actually, we don't really have any experience of fishing with the project in operation yet. It is too short a time period to be able to tell if there are problems or not. I think a community pond connected to the small stream that enters the Nam Hinboun is a good idea.

- ***(11) Interview with Mr Gaeow, a part-time fisher and six other residents at Hat Xai Kham village, a few kilometers upstream from Pakading on the Nam Kading (Theun). June 9 1998.***

**Mr Gaeow:**
We've stopped putting gillnets in the river now because of the increased flows during the wet season and the floating debris. Instead, we set long-lines in the Nam Kading and catch fish in the feeder streams and can catch enough fish to eat. I suppose we get about 2 or 3Kg of fish per day when we go fishing. The landings were about the same as a normal year this dry-season but the water level was the lowest we have ever seen for the period. For us, the dry-season is the main fishing season and it's not so good in the wet-season. We used to catch Pba Va (*Labeo erythropterus*) with drift gillnets in August and September when they came up to spawn, but the provincial authorities have banned this for several years now.

- ***(12) Interview with Mr Wong, a villager, at Phon Sy village on the Nam Kading, a few kilometers upstream from Hat Xai Kham village. June 9 1998.***

**Mr Wong:**
For 4 or 5 years now landings have been decreasing. This year, the dry season landings were very poor and catching fish was difficult. We had just about enough fish to eat, but we couldn't sell any fish. The water level during the dry season was the lowest we've seen for many years. I think the dam is to blame for the low water.

- ***(13) Interview with Ms Viang, an employee, and Mr Nut, owner's son, at the Nang Ting restaurant at Pakading near to the confluence of the Nam Kading and Mekong. June 9 1998.***

**Ms Viang and Mr Nut:**
Ms Viang: We have had no problem in finding fish for the restaurant from the landing site and local market, but I've only been working here for 2 months and don't know about earlier.

Mr Nut: We've had no problems in finding fish for the restaurant this year, but we get fish from the Mekong as well as the Nam Kading.

- ***(14) Interview with Ms Yom, restaurant owner, at Pakading village close to the confluence of the Nam Kading and Mekong. June 9 1998.***

**Ms Yom:**
We buy fish caught in the Nam Kading and during both last year's dry season and this one, it was difficult to find fish for our restaurant. The shortage was mainly in March, April and May. Now the wet -season has arrived there is enough fish.

- ***(15) Interview with Mr Saengphit, owner of the Silom restaurant, at Pakading close to the confluence of the Nam Kading and Mekong. June 9 1998.***

**Mr Saengphit:**
The water in the Nam Kading was really low this year. I saw several islands appearing in the river that I hadn't seen before when I went to the area on May 9 and 10. There were definitely less fish being caught this year compared to previous years. I only buy fish caught from the Nam Kading. I think the reason is because of the diverted water from the Theun into the Nam Hinboun.

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