A Review of the Nam Theun 2 Environmental Assessment and Management Plan (EAMP) As It Pertains to Impacts on Xe Bang Fai Fisheries

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The majority of this report is based on the EAMP Final Draft released in November, 2004. The principal section referred to is "Aquatic Habitats and Fish Diversity" (pp. 82 - 97). However, occasional reference may be made to information presented in other sections of the EAMP or Volume 3 of the Social Development Plan (SDP). This is because both documents refer to potential environmental impacts caused by the Nam Theun 2 Hydropower Project, but they do not always correspond as to the nature, type and degree of certainty of those impacts.

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EXECUTIVE SUMMARY

The Nam Theun 2 Hydropower Project is likely to have multiple serious, negative impacts on the aquatic resources of the Xe Bang Fai, Nam Phit and other downstream river basins. The probable result will be, as predicted in the project's Social Development Plan, a "collapse in the aquatic food chain" from the Nam Phit down to the Mekong confluence. Despite these dire predictions, the EAMP - the document which should contain a full assessment of the project's likely impacts on downstream aquatic resources - is noticably lacking in detail and rigorous scientific analysis. One of the main reasons for this is that the ichthyological studies that have been carried out by NTPC within the Xe Bang Fai basin have primarily examined the distribution and diversity of fish species in the river, rather than looking at aquatic ecosystems, habitats, fish communities, fish genetics or bioproductivity. Little space in the report is devoted to fish migrations, aquatic ecology and human usage of the aquatic resources. New biological, hydrological and geomorphological information available since 1996 has not been incorporated into the conclusions of likely impacts on Xe Bang Fai fish populations, and so there is a marked disparity in the information provided in the EAMP and predictions of impacts found in the SDP (Chapters 31 and 32).

Where the EAMP does identify serious impacts likely to result from the Project's operations, it expresses an unwarranted faith in mitigation methods to alleviate the impacts, despite a poor record of mitigation attempts at other regional hydropower projects. The EAMP's narrow focus on fish species alone ignores the importance of other aquatic organisms in the riverine ecology and food chain, and correspondingly fails to consider the implications of the loss of these resources for the food security and livelihoods of the people of the Xe Bang Fai basin.

SUMMARY OF FINDINGS

- The EAMP likely underestimates the number of fish species present in the Xe Bang Fai because no studies have been conducted during the wet season, when fish from the Mekong mainstream will migrate into the Xe Bang Fai, its tributaries and floodplain wetlands. Furthermore, the EAMP overlooks the fact that distinct populations of the same species may exist in discrete river basins. These populations may exhibit unique traits and genetic differences, so that biodiversity may still be threatened when a distinct population of a rare fish species is lost or declines greatly due to anthropomorphic ecological disturbances.

- Despite a recommendation from its fisheries consultant in 1996, NTPC has failed to study fish migrations in either the Nam Theun or Xe Bang Fai basins, resulting in a deficiency of knowledge on fisheries. Such a deficiency makes it difficult to accurately predict the impacts of the project on fish populations.

- Construction of the downstream channel, regulating pond and associated infrastructure are likely to result in excessive sedimentation in the Nam Kathang, Nam Gnom, Nam Phit and middle Xe Bang Fai. This sedimentation could cause impacts to fisheries in downstream stretches for many kilometres, including potential mass mortality from clogged gills and smothering of eggs and larvae, as well as chronic shallowing of pools currently acting as dry season fish refuges.

- The EAMP has not been updated to reflect design changes (in particular, greater turbined flows down the Xe Bang Fai river) since the original impact predictions and recommendations were made in 1996. As water levels will be more than twice as high as was assumed in 1996, many of the predictions of potential impacts are now outdated.

- The submergence of rapids, which are an important habitat and spawning ground for fish and many other aquatic organisms, will have a major impact on the ability of these organisms to survive. As a result, villages located nearby rapids sites are likely to suffer heavier falls in catches than those located on slow stretches. Despite this, NTPC has undertaken no specific study of rapids ecology and biodiversity in order to estimate impacts.

- The EAMP fails to assess the project's impacts on the Xe Bang Fai's many non-fish aquatic species - such as gastropods, mussels, shrimps and aquatic weeds - which are important for biodiversity and human consumption. The loss of these species could result in serious nutrient deficiencies for Xe Bang Fai residents.

- The EAMP downplays the impacts that cold water from the reservoir will have on fish in the Nam Phit, Xe Bang Fai and associated rivers. Particularly cold weather on the Nakai Plateau and upper watershed may lead to periodic releases of much colder water than in the Xe Bang Fai river system, potentially killing adult fish as well as eggs, larvae and juveniles.

- The EAMP fails to recognize the ecological, economic and livelihood value of the Nam Phit tributary of the Xe Bang Fai, which stands to be radically altered by the construction of the Downstream Channel.

- The EAMP relies far too much on trying to separate out impacts into discrete factors, rather than recognising and discussing the multiple, cumulative and synergistic effects that the changes to hydrology, water quality and geomorphology are likely to have on the aquatic ecosystems and biota of the Xe Bang Fai River system. These factors will have a profound impact on the ability of many fish species to hunt and forage, spawn and survive in their juvenile stages. The combined impacts of water quality and quantity changes are likely to cause a crash in the aquatic food web, inevitably affecting the human end users of these resources.

INTRODUCTION

Despite the Nam Theun 2 Project's long inception phase, and the scores of studies conducted on the potential environmental impacts of the project, very few have focused on fishery and aquatic ecology impacts. This is readily apparent from an appraisal of the section on "Aquatic Habitats and Fish Diversity" in the EAMP. This section is primarily based on the work of one consultant, which itself was based mainly on three fish collection surveys of the river in the dry seasons of 1996, 2002 and 2003. Rather than admit its own failure to commission sufficient in-depth studies on the fishery and aquatic resource base of the Xe Bang Fai river, NTPC seeks to blame its own lack of knowledge on a perceived general paucity of studies on fish distribution, biology and ecology in the lower Mekong basin. This is simply untrue. Over the past decade, the Mekong

River Commission and many other organizations and individuals have conducted many fishery studies and technical reports in the Xe Bang Fai and other parts of the Mekong Basin. Referring to these studies, coupled with the knowledge gained from experiences with other hydropower projects in the Mekong Basin in both Laos and Thailand, would have helped elucidate many of the areas the EAMP claims to be knowledge or data deficient in, particularly with regards to Mekong fish migration patterns and potential dam impacts.

The present review looks at the EAMP's treatment of potential impacts of the Nam Theun 2 Hydropower Project on the aquatic resources of the Xe Bang Fai and associated downstream river basins. The review follows the same order as the EAMPs section on Aquatic Habitats and Fish Diversity in Chapter 3.

FISH DIVERSITY AND ENDEMICITY

The consultant hired by NTPC to ascertain the potential impacts of the project on aquatic habitats and fish diversity is a Swiss-based fish taxonomist with extensive experience in the region, who conducted fish collection expeditions across the Nam Theun and Xe Bang Fai basins in 1996, 2002 and 2003, and other river sites in Lao PDR in 1997. From the 1997 survey it was concluded that while two species of fish were presently considered as endemic to the Xe Bang Fai basin, neither species could be considered as threatened by Nam Theun 2 Project, as their distribution range lay in areas upstream of the presumed area of direct impacts. However, this fails to recognize that the ecological changes to the Xe Bang Fai will probably affect the entire middle and lower riverine ecosystem due to continuity and connectivity principles (Arthington, 2002), not just the areas downstream of Mahaxai. In addition, distinct populations of the same species may exist in discrete river basins. These populations may exhibit unique traits and genetic differences, highlighting the reality that biodiversity may still be threatened when a distinct population of a rare fish species is lost or declines greatly due to anthropomorphic ecological disturbances.[2]

It is stated that 131 species of fish have been observed in the overall Xe Bang Fai basin, 67 species of which were observed in the lower river. All of these fish were identified during the initial survey in March 1996 (Kottelat, 1996), and subsequent surveys in 2002 and 2003 (also conducted during the dry season) did not reveal any new species. This figure compares with 183 species[3] of fish recorded from the Nam Songkhram river system and 265 species[4] recorded from the Mun – Chee river basin, both middle Mekong tributaries in Northeast Thailand. Given the greater variety of aquatic habitats and relatively undisturbed nature of the Xe Bang Fai basin, this would suggest that only a proportion of the overall fish biodiversity in the Xe Bang Fai basin has actually been identified in these limited surveys. Kottelat (1996) recognised this when stating

[2] It should be noted that the term "biodiversity" implies more than just the amount of visible variability amongst animals and plants, but includes genetic diversity within a species also and the diversity of ecosystems, as stated in the definition of biodiversity included in the Convention on Biological Diversity (1992): "….the variability among living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems."

[3] OEPP (1999) Wetlands of Northeast Thailand. Document of Wetlands in Thailand. Vol. 3. Office of Environmental Policy and Planning, Office of the Prime Minister, Bangkok.

[4] This figure, attributed to Dr Chavalit Vidthayanon of Thailand, is quoted in Roberts (2001)

(p.37), "*The 67 species obtained are certainly far from the total lower Xe Bangfai fauna which could probably amount to over 100 – 150 species once samples can be obtained at other periods of the year.*"

Other authors have also recognised that biodiversity is higher in Mekong tributaries during the rainy season when many species of fish that have taken dry season refuge in the mainstream Mekong move into the tributaries for spawning and feeding migrations (Suntornratana et al., 2002). Hence, it is odd that no fish biodiversity survey of the Xe Bang Fai basin has been conducted during the rainy season, despite ample opportunities over the last eight years to do so.

MIGRATIONS

"*Fish migrations in the Xe Bang Fai River Basin are probably the most important ecological characteristic of the river basin for the livelihood of local people, most obviously in relation to local economies, and as a source of family income, food and nutrition*." (Shoemaker et al., 2001)

Despite recognising the contribution of Shoemaker et al.'s 2001 study to the state of knowledge about fisheries and fish migrations on the Xe Bang Fai river and referring to a few MRC reports (e.g. Poulsen et al., 2000, 2002, 2004), the EAMP still insists that, "*Little reliable data on fish migrations and reproduction in the Mekong basins* (sic) *is available*", citing Taki (1978) and Kottelat (1996) as the source of information. This statement is misleading and factually incorrect. It also does a disservice to the work of many others who have published works since these cited references.

In fact, a large number of papers have been published on Mekong fisheries and fish migrations at various locations in the lower Basin during the past decade or so[5]. These show that, contrary to the EAMP's claims, there is a significant and growing body of literature on Mekong fish migrations both at a basin and local level, using various approaches and research methodologies to derive valid knowledge and information about the resource base. It should be noted that no specific report detailing migratory patterns has been released publicly by NTPC, despite the recommendation made by Kottelat in his 1996 report that "*immediate attention is needed to monitor migrations*" (presumably referring to both the Nam Theun-Kading and Xe Bang Fai river systems). Despite this recommendation being made eight years ago and vast amounts of consultant time and money having been spent on other studies, this recommendation remains unfulfilled.

It is now widely accepted by fishery scientists working with the Mekong River Commission (MRC) that through accessing local knowledge from fishers and others associated with the active fish trade in the Lower Mekong Basin (LMB) "*it is possible to obtain vital information that could not have been revealed using conventional biological techniques*" (Bao et.al., 2001). Using such a methodology, Shoemaker et al., (2001) were able to gather large amounts of relevant information on fish migrations in the Xe Bang Fai system during a two week period in

[5] For example, refer to Roberts, 1993; Roberts and Warren 1994; Roberts and Baird, 1995; Singhanouvong et al., 1996; Warren et al., 1998; Warren, 1999; Chomchantaet. al., 2000; Bao et al., 2001; Noraseng and Warren 2001; Poulsen . et. al., 2002; Ratanachotmanee and Suntornratana, 2002; Suntornratana et al., 2002; Baird, 2003; Hogan et al., 2004

early 2001, including some key species, spawning habitats, periods of migration, fishing methods, key locations of seasonal migration fisheries and some potential environmental triggers of migratory behaviour. Hence, it is surprising that NTPC has not initiated a similar, but longer-term and larger-scale study, using indigenous knowledge to monitor fish migrations. The lack of such a study means that there are huge gaps in data, making it difficult to produce a comprehensive analysis of potential impacts of the project on Xe Bang Fai fisheries.

POTENTIAL IMPACTS ON AQUATIC HABITATS

Below are the main potential impacts and mitigation measures identified by Kottelat that are referred to in the EAMP, separated into two main categories: (i) impacts related to construction and, (ii) impacts related to the permanent changes to the various aquatic habitats. The impacts are listed only where they relate specifically to the Xe Bang Fai river basin, and include the reviewer's own comments on each.

(a) Construction Related Impacts

Work in the Riverbed & Infrastructure Construction

Impacts – Identifies construction of the Downstream Channel as an activity "*that could potentially increase sediment load*" in the streams and rivers, and that this could affect fish populations downstream both directly and indirectly. Presumably the worst affected areas will be the Nam Kathang, Nam Gnom and other small streams in the Gnommalat plain closest to the surface disturbance and the Nam Phit floodplain and its tributaries, down into the middle Xe Bang Fai around Mahaxai.

Suggested Mitigation – A short section reads, "*The HC [Head Contractor] will adhere to the erosion plans set down in HCCEMMP's [Head Construction Contractor's Environmental Management and Monitoring Plan] to help limit sedimentation resulting from construction of the downstream channel. In the Xe Bang Fai, some species are adapted to high levels of suspended solids, to which they are currently subjected in the wet season*". A few paragraphs later in the section (p. 88, Chapter 3) it reads: "*All infrastructure, including temporary constructions, will be stabilised and bridges will be built to respect the existing stream/river bed and bank morphology*".

Reviewer's Comments – It is virtually inconceivable that the construction of the Regulating Pond, Downstream Channel and other associated infrastructure such as road upgrading which will be carried out in, or near, seasonal and permanent watercourses will not lead to large amounts of sediment-laden run-off to enter these rivers, even with the best avoidance measures taken. This is because civil works will be taking place directly in the river bed of the Nam Kathang, Nam Gnom, Huay Khama, Nam Phit and Xe Bang Fai at various points along their lengths.

Most construction work will likely take place in the dry season, when the rivers are normally running at their clearest. It is not unusual for periodic episodes of rainfall to occur even outside the normal rainy season, which in a matter of hours or even minutes, if heavy, could wash large

amounts of exposed soil into the watercourses. This could cause impacts to fisheries in downstream stretches for many kilometres, including mass mortality from clogged gills. However, less spectacular but more likely, is steady chronic sedimentation which can also harm and kill fish, especially eggs, larvae and juveniles, whilst adult fish are put under increasing stress from inefficient respiration, susceptibility to disease and parasites (especially of the gills).

The Nam Kathang, Nam Gnom and Nam Phit all derive a part of their flow from the limestone geology, which provides a number of clear, cave spring pools draining into the rivers. These rivers are likely to clear quickly after rainfall episodes, and the native fish populations would be adapted to these temporarily turbid periods under normal run-off conditions. The degree of adaptation of different fish species to high turbidity or suspended solid loads varies enormously. Hence, on the previously clear Nam Hai river in Bolikhamsay Province, following the construction of the Theun-Hinboun power station, there was a rapid decline in many cyprinid species, but a slight increase noted by villagers in the quantity of *Mystus nemurus* and *Bagarius yarrelli* (both catfish species) in their catches (Schouten et al., in prep. and personal observation).

NTPC's level of commitment to abide by the above statements of intent to mitigate during early construction phases should be monitored closely by independent third parties in the next two years, as it will probably provide a good indication of the Company's overall level of commitment to abiding by other environmental protection safeguards and proposed mitigation measures at later stages of the project.

Limestone Extraction in Karstic Formations

Impacts – The EAMP (p.89) warns that the quarrying of limestone for construction material may threaten biodiversity (often specialised and highly endemic fauna, found in underground streams and water bodies) "*either directly by destruction of the habitat or indirectly by pollution*."

Mitigation – "*The sites where limestone will be quarried and the location where the downstream channel passes through karst* [i.e. in Gnommalat and Mahaxai Districts] *will be surveyed for possible presence of caves and springs. As this is part of a very extensive karstic area, it is very unlikely that limestone extraction will threaten any endemic species. If any caves are present, the opportunity to explore them scientifically should be taken. Particular attention will be given to avoid all types of pollution in karstic areas, as in such places contamination may spread faster and over greater distances than in any other soil types*".

Reviewer's Comments – The above comments were originally made in Kottelat's (1996) report when none of the caves and underground streams in the various karstic formations in the XBF catchment had been scientifically explored. Kottelat recommended surveying and documenting these formations eight years ago, yet it appears from the EAMP that this recommendation has not been followed.

In Kottelat's (2001) book, *Fishes of Laos*, he notes the presence of at least one endemic cyprinid species in the general project area, but its location is not more specific than: "*Khammouan Karst east of Thakek. In caves*." The fish, only one known specimen of which has been caught, was

named *Troglocyclocheilus khammouanensis* and is distinguished by the absence of any externally visible eye. If the exploitation of the limestone karst for construction materials is hastily enacted before thorough studies have been conducted, extinctions of aquatic organisms may occur before they are even recognised as being in existence.

Shoemaker et al. (2001), report that the headwaters of the Nam Phit come from spring-fed pools in caves. These pools are directly connected to the limestone karst formations found in the Phou Hin Poun NBCA and associated geological areas. A variety of fish species are known to use the caves as dry season refuges (Shoemaker et al., 2001 and Baird, 1998). The EAMP fails to mention the importance to local fish populations and aquatic biodiversity of these pools and caves, presumably because no detailed surveys have been carried out.

(b) Operation Related Impacts

Increased Xe Bang Fai Flow

Impact – "*The increased flow in the Xe Bang Fai will result in the increase of the minimum water level in the river. Several habitats will definitively disappear, some may be displaced and others will be altered. Several dry season rapids will be permanently flooded and some extensive rocky outcrops that form permanent rapids will be displaced. Some stretches functioning as rapids only during high discharge may become permanent rapids. It is likely that most rapids-inhabiting species could be able to adjust to these shifts*."

Reviewers Comments

Water Releases Much Greater than Earlier Estimates

When Kottelat wrote his prediction of potential impacts in 1996 it was assumed that the NT2 Project would release an extra 200 m^3/s. Due to subsequent design modifications, the planned water releases are now expected to vary between 240 m^3/s in the dry season to over 300 m^3/s during the wet season (p.4, Chapter 31, Volume 3, SDP). According to the same section in the SDP, "*the addition of the NT2 discharge could more than double the flow in the Xe Bangfai during the nine dryer months of the year, from October through to June*". This will raise dry season water levels at Mahaxai by between 3.3 m in December and 4.9 m in April. By contrast, Kottelat (1996) had assumed that the dry season water level would rise by only 2 meters.

In other words, the present EAMP - which more or less repeats Kottelat's predictions of impacts verbatim - is based on outdated and incorrect assumptions made eight years ago, when in fact water levels will be up to 210 % - 245 % higher than Kottelat had earlier realised. This fact obviously calls into question the accuracy of the impact predictions made by Kottelat. The assumption that *"most rapids inhabiting species could be able to adjust to these shifts*" in water levels and flows is almost certainly wrong, considering the evidence found at other dam-impacted rivers.

The experience at the Theun-Hinboun Hydropower Project in Lao PDR (also a trans-basin diversion scheme) certainly nullifies the claim that fish will be able to adapt to the new

conditions. The EAMP only briefly mentions the Theun-Hinboun as having caused *"a significant diminution of standing crop*". According to an unpublished report commissioned by THPC, declines of up to 80% in fish yields have been experienced in some villages (Schouten et al, in prep.). My own discussions with village fishers at numerous points down the Nam Hinboun river in March, 2004 indicated that there had also been a perceived decline in fish biodiversity along the river, with some rheophilic species greatly diminished in numbers or disappeared from catches altogether since the dam was built.

Importance of Rapids as Fish Habitat

Rapids are considered habitats of high aquatic biodiversity significance in the lower Mekong River and its major tributaries (Roberts, 1993; Baird, 2001). As well as large numbers of specialised fish species congregating at rapids, there may also be large numbers of specialist crustacean, mollusc and insect species adapted almost exclusively to rapids conditions in the Mekong and tributaries, although comprehensive research is still largely lacking. Roberts (2001) estimated that at least 33 species of specialised rapids fishes inhabiting the lower Mun River prior to the Pak Mun Dam "*have probably been extirpated*" since the dam was built. According to Roberts (2001), the rapids in the lower Mun River not only probably had the highest biodiversity of any single fish habitat in the Mun River, but also may have had the highest bioproductivity.

The same generalisation is almost certainly true of the upper and middle Xe Bang Fai River, although no specific study of the rapids ecology and biodiversity appears to have been made to date. The implications of this are that villages located near to rapids sites are likely to suffer more significant falls in catches than those located on slower stretches. This lack of habitat-specific focused study is a weakness that could and should be remedied by NTPC or the World Bank before the rapids are "lost" to the river diversion and other dam-related impacts.

Rapids Submergence will affect Plant Biodiversity and Aquatic Productivity

In addition to faunal biodiversity, rapids in the Mekong basin are important sites of plant biodiversity. Maxwell (2001) documented several species of shrubs, trees, ferns, grasses and amphibious herbs associated only with seasonally inundated rapids in the Siphandone Wetlands of southern Lao PDR. These plants are referred to as "rheophytic". Although they can spend up to six months submerged each year, they are particularly sensitive to long-term changes in hydrological regime, such as when the submergence period is extended well beyond natural levels.

The Theun-Hinboun Dam's diurnal releases of water into the Nam Hinboun have caused large numbers of riparian trees and rapids-associated vegetation to die-off in the downstream inundation zone, including species of the formerly common *dton khai* shrubs (*Phyllanthus* spp.), (personal observation, March 2004). Many of the plants associated with rocky substrates play important ecological roles in providing spawning, nursing and feeding areas for fish at various stages of the life cycle and help to break the current and stabilise banksides from erosion. Some rapids-associated plant species provide food and medicinal herbs for villagers too. An example of an edible plant type, previously commonly harvested at fast-flowing rapid stretches in the

Nam Hinboun and Mun Rivers is the filamentous algae or *tao* . A fishery and water quality consultant employed by THPC noted, "*Before the start of operation of the Theun-Hinboun powerhouse, fishers used to harvest up to 8 kg of "Tao" per household per year for consumption*", but it has since "*disappeared from the Hinboun mainstream*" (THPC internal document, 28-12-2002).

The loss of some or all of these aquatic plant species will have profound effects on the aquatic food chain as they form a significant part of the primary productivity of the aquatic ecosystem.

Loss of Other Aquatic Species

The same internal paper from Theun-Hinboun Power Company also reported the disappearance of gastropods, mussels and shrimps from the Hinboun mainstream, which were formerly harvested by villagers for consumption. Gastropods and mussels were thought to constitute catches of up to 50 kg/household/year each, while up to 5 kg/household/year of shrimp were caught. It can be expected that the same population crash and disappearance of these important food chain links and human food security components will also take place in the Xe Bang Fai downstream of the Nam Phit confluence.

Given that fisheries in the Xe Bang Fai River appear to be considerably more productive than those recorded in other Lao rivers (Shoemaker et al., 2001; Warren, 2003), it could be assumed that the harvest of non-fish aquatic products, like those mentioned above, is also higher. Therefore, it might be useful to briefly consider in rough terms the anticipated impact of a similar disappearance of gastropods, mussels, shrimps and aquatic weeds (*tao* and *kai*) from the Xe Bang Fai. Conservatively taking an average consumption figure per household of 50% of the Nam Hinboun figures above and multiplying by the number of families recorded as relying on the Xe Bang Fai for fishing (figure taken from Table 30-19, p. 27, Chapter 30, Vol. 3, SDP), the table below shows the potential loss of food source that could occur following a disappearance of these "free" aquatic products alone.

TABLE 1 – Aquatic food items and weight consumed, which may disappear from the Xe Bang Fai and hence local people's diets, following water diversion[6].

Aquatic product	Gastropods	Mussels	Shrimp	'*tao*'	TOTAL
Est. mean consumption / household / year (kg)	25	25	2.5	4	56.5
Est. no. of fishing households on XBF mainstream	7,096	7,096	7,096	7,096	7,096
Total consumption per year (kg)	177,400	177,400	17,740	28,384	400,924

While the EAMP does not take into account the potential impacts of NT2 discharges on non-fish aquatic products, the SDP is more honest about these impacts in Chapter 32, stating "*A collapse in the aquatic food chain in Xe Bangfai mainstream is predicted to occur as a result of increased*

[6] NOTE: This table only shows the number of households impacted living in villages on the mainstream XBF, when in fact, there may be many other households potentially impacted too, who live in so-called "hinterland" villages and travel to the XBF to fish temporarily, often in the dry season when food is scarce.

discharges, water depth, river bank erosion, sedimentation, and fluctuation of water levels during the dry season. Households are expected not to be able to collect aquatic vegetation, snails, mussels, and shrimps after COD. The maximum value in losses in household catch of aquatic products from Xe Bangfai mainstream is estimated to be USD 20 per year, assuming an average of USD 0.3 per kilogram harvested aquatic products. These losses are expected to occur all the way to the Mekong River."

The implications for the nutrition and health of villagers without these essentially 'free' items could be very serious indeed and deserve an immediate comprehensive study of impacts and options for replacement.

Loss of fish spawning grounds

Impact – "*More significant* [than the loss of rapids habitat] *is the fact that some of the rapids may be spawning grounds. Some species may need shallow waters in the rapids for spawning and an increased water level may have significant negative impact on their reproductive success. The lack of reliable information on fish reproduction and migration does not allow further discussion of this impact*." (EAMP, p.92)

Reviewer's comments – This latter sentence is rather curious and repeats earlier claims in the EAMP of an inability to make predictions of impacts due to "*a lack of reliable information*". As mentioned elsewhere, substantial amounts of research have been conducted on fish migration and spawning patterns in the Mekong mainstream and in a few tributaries (e.g. Nam Songkhram river: Suntornratana et al., 2002). Again, the problem with the EAMP would appear to be an over-reliance on the comments made by Kottelat in his 1996 paper[7], lack of subsequent focused aquatic ecological investigations or surveys on the Xe Bang Fai, and little attempt to review more recent literature on the subject and triangulate data sources from other river basins.

While there is insufficient space to go through a list of fish species individually and the multiple potential threats to their spawning habitats from inundation of rapids, it may be useful to highlight a couple of issues of particular concern. The first relates to those species which are known to or thought to spawn in the dry season period, when riverine habitats like rapids, riffles, shallows and gravel beds will be most seriously impacted by the Nam Theun 2 releases. As Roberts (1993) notes, even under "natural" circumstances, the early life stages of fish are periods of extremely high mortality. However, as a result of adverse environmental changes in flow rate, water depth, suspended solids, turbidity, bed load material, dissolved oxygen, temperature, other chemical parameters, food availability and presence of toxic substances, natural mortality rates will soar, depending on the severity of the impact. In isolation each factor may be lethal or sub-lethal, but due to multiple, synergistic actions the factors can combine to create 100% mortality of eggs, larvae, fry or adult fish, even when each individual factor is acting at sub-lethal levels.

Although most Mekong fish species reproduce during periods of rising or high water levels near the start of the rainy season, a number of species are known to spawn before the rainy season

[7] It should be mentioned that Kottlelat's field surveys were primarily designed to be fish taxonomic studies with some observations on potential fisheries impacts, but were never intended to be exhaustive fishery or aquatic ecological studies, an area outside the author's primary expertise.

arrives, often in rapids, riffles or well-oxygenated shallows. This survival strategy may be connected to temperature, dissolved oxygen (DO) or turbidity levels at that time of year or it may be connected with feeding preferences of the juveniles and young, which can readily exploit the planktonic food sources available in the dry season. If the rapids and sand/gravel substrate shallows are inundated by an extra 3 – 5 metres of water and flows of up to 20 times the natural discharge in February to April, with turbidity and suspended solid levels at far higher levels than normally found in the dry season, then it would seem highly probable that the individual and multiple impacts arising will preclude spawning success and juvenile recruitment for some important species (see Table 2)

TABLE 2 – Some fish species which normally spawn or are thought to spawn outside of the rainy season and are known to occur in the middle and lower Xe Bang Fai

Fish species	Spawning period	Critical spawning habitat	Notes
Puntioplites spp	March – May/June	Shallows, gravel riffles	Observed spawning by villagers in dry season in Nam Gnouang, Nam Theun and Nam Ngum.
Poropuntius spp. & *Mystacoleucus* spp	"Dry season"	Gravel shallows	Observed spawning at night by villagers.
Raiamas guttatus	Feb – March	?	Mainly found in shallow, fast flowing and clear rivers
Pristolepis fasciata	March - April	Shallows, streams	Important food fish
Probarbus jullieni and Probarbus labeamajor	Dec – Feb	Deep pools for "courtship and shallow areas nearby for spawning"	P. jullieni considered Endangered status in Mekong basin (IUCN Red List species)

Warren (2003 and 2004) reports that cyprinids (e.g. *Puntioplites* spp, *Hypsibarbus* spp., *Barbodes* spp, *Morulius chrysophekadion* and *Systomus orphoides*) form the bulk of catches in the Xe Bang Fai. While Poulsen et al., (2004) have reported that *Puntioplites falcifer* spawns in large Mekong tributaries at the start of the rainy season, this was not the case on the middle Nam Theun system, where *Puntioplites* sp. was observed spawning at night on gravel shallows upstream of the Theun-Hinboun Headpond in mid-March, 2004[8]. If this same pattern of pre-rainy season spawning of certain cyprinid species is also found in the Xe Bang Fai system, then future juvenile recruitment of certain keystone productive food species could be severely reduced by the Nam Theun 2 releases. Similarly, the implications for the reproductive success of the IUCN Red Listed species *Probarbus jullieni* (listed as "Endangered"), known to inhabit the Xe Bang Fai river as far upstream as the Mahaxai area (Terry Warren, personal communication, October 2004), could be equally bleak. Whether *P. jullieni* spawns in the Xe Bang Fai is not known, but spawning grounds have been identified in other lower Mekong tributaries such as the Nam Ou and Nam Lik in Lao PDR, and the observed spawning time is from December to February (Poulsen et al., 2004).

[8] As observed by fishermen and reported to the author.

By contrast, the EAMP paints a confusing picture of which species may or may not be negatively affected by the NT2 Project. It does mention several species of small loach (*Shistura* spp., *Nemacheilus longistriatus* and *Serpenticobitis zonata*) and a torrent catfish (*Amblyceps serratum*), which "*may disappear*" from the stretch of river downstream of the Nam Phit confluence after losing their favoured habitat of shallow water gravel beds, but it fails to mention that some of these loach species are of seasonal importance in catches to fishers (Ian Baird, pers. Comm.). In the very next paragraph it says, "*Apparently, the remaining species and communities may not be affected by the change in water level*." Yet just a few sentences later, the EAMP states, "*It is likely that a significant number of species will not be able to survive locally under these permanent conditions and a lowering of fish diversity and productivity is to be expected*." Apart from the obvious contradictions presented here, it is clear that NTPC has little idea about which species are likely to be threatened by the water diversion.

Changes in Water Temperature

Impact – In the next paragraph on p.92 the EAMP continues: "*The diversion will introduce cooler water into a warm lowland river. This difference will be reduced by passive warming of the water in the 27 km run from the power station to the Xe Bang Fai. Aeration of the water in the Downstream Channel will also assist this warming process. In the dry season, the temperature difference is expected to be less than 3.5 ^{o}C in the Upper Xe Bang Fai. In the wet season, the differential will be less, and will be buffered by greater quantities of water in the Xe Bang Fai. Alone, the change in temperature is possibly not significant (Kottelat, pers. com), but in synergy with other impacts it could significantly increase the stress on the aquatic community*."

Reviewer's Comments – Because of the relative high elevation of the Nakai Reservoir (538 masl) compared to the power station on the Gnommalat Plain and the potential for cool water inputs entering the Reservoir from the tributary rivers arising at elevations of around 1,500 - 2,000 masl, there is potential for water temperature differentials to be much greater than the predicted difference of "*less than 3.5 ^{o}C*" in the dry season. During the cool season (December to February), extremely cold conditions in the Annamite Mountains have been reported in the past as causing massive fish mortalities in the Nam Gnouang river, a Nam Theun tributary which enters the Theun-Hinboun headpond. Roberts (1996) reports this event as having occurred in 1985-86 or 1987-88, while Schouten et al., (in prep) was apparently referring to the same phenomenon, when he wrote "*in January 1975 … air temperatures decreased below 0 ^{o}C at night. The result of this extreme cold in 1975 was a massive fish kill affecting numerous fish species in Nam Gnouang."* Hence, it would be reasonable to expect air and water temperature differentials at the Nakai Reservoir and powerhouse to be greater than 3.5 ^{o}C on occasions during the cool season.

The EAMP makes no mention of the potential effects of a prolonged period of cold weather on the Nakai Plateau and Annamite Mountains during the December - February cool season, when inflowing water temperatures to the reservoir could be as low as 5 ^{o}C at nights for possibly several days, or even weeks on end. This would attenuate the thermal stratification in the reservoir, as presumably there would be little mixing at this time of year, when wind speeds are low and rainfall is rare.

Roberts (1996) thought the potential risk of thermal pollution in the Xe Bang Fai serious enough to declare, "*Cold water diverted from Nam Theun 2 Reservoir will probably be the worst impact of Nam Theun 2 on fish and fisheries of the Xe Bang Fai*." He went on to describe the impacts thus:

> "*Cold water from Nam Theun 2 Reservoir entering the Xe Bang Fai mainstream will have complex negative impacts on all life history stages of Xe Bang Fai fishes. Eggs, larvae and very young juveniles drifting downstream from the upper Xe Bang Fai at all times will be unable to escape from an abrupt temperature drop that will kill them. The same will apply [to] earlier life history stages drifting down the Nam Oula, the major tributary of Xe Bang Fai which enters the mainstream just a few kilometres downriver from Ban Mahaxai. …An episode of very cold water from the Nam Theun would almost certainly cause a massive mortality of Xe Bang Fai fishes, resulting in the temporary or permanent disappearance of a number of species that are of most importance to wild capture fisheries and food security …*"

The differences between the assessments of Roberts' and the EAMP author/s' are too great to be ignored and this aspect requires more study and research by independent, credible fishery biologists and ecologists.

NTPC claims that in the dry season "*sudden temperature changes are not expected*" (p.92), because "*the Xe Bang Fai will be mostly composed of the Power Station discharge and will largely take its characteristics from this discharge*". However, the EAMP makes no effort to explain what will happen to water temperatures in the river each weekend following turbine shut-down on Sundays and resumption of power generation on Monday mornings. Presumably, the river will gradually warm up as levels fall on Sundays and upstream water mixes with the water released from the regulation ponds, and then the temperature will abruptly fall on Monday mornings when the turbines are turned back on and a column of cool water enters the Xe Bang Fai, stressing or killing fish and other aquatic organisms as it moves downstream. This weekly temperature shock regime will probably be more detrimental to aquatic productivity and fish community stress than if the turbines were generating power evenly throughout the week and no shut down occurs. Adaptation by adult fish species will no doubt be highly variable, with some better able to cope than others, but it is unlikely that fry and juveniles will be able to adapt to the new temperature shock regime and will be rapidly killed.

Other Water Quality Impacts

Rather surprisingly, the EAMP section on Water Diversion (p.92) neglects to mention any other water quality parameters that will be altered in the Xe Bang Fai and may impact aquatic communities and fish biodiversity. Instead, the reader is expected to refer back to the section on Water Quality (p.70 – 82), which discusses the water quality parameters in general terms, with only very occasional mentions about the impacts on fish and aquatic life. In this section, the author/s used various computer models to simulate water quality conditions in the Nakai Reservoir under various operating scenarios and compared the situation with some other reservoirs in Lao PDR that have suffered water quality problems in the past. The general

conclusions reached are that the water quality parameters will not reach critical levels for fish survival and any events of anoxic water can be mitigated against through the proposed measures. The parameters of most concern in terms of fish and aquatic ecology are dissolved oxygen (DO), dissolved methane, ammonia and hydrogen sulphide. The most critical period will be the first two or three years, while vegetation left in the reservoir decomposes and emits noxious gases which enter the water column.

Apart from methane and DO, other potentially toxic water quality parameters that the EAMP considers, but basically dismisses as not being a significant threat to fish and aquatic life downstream, are ammonia and hydrogen sulphide (p. 73). This again is due to faith in the efficiency of the outlet device to mix oxygenated epilimnion water and anoxic hypolimnion water during the periods of stratification in the Reservoir (See Fig. D-5, Annex D, EAMP for a technical drawing). If this outlet works as planned and the DO levels are kept above lethal levels for fish downstream (which will vary enormously according to species, life cycle stage and other existing water quality variables), then there may still be sub-lethal levels of DO for many kilometres downstream, due to elevated biological oxygen demand (BOD) levels in the released water. Many warm water pond fish require > 5 mg/l DO to reproduce and grow normally, whereas continuous exposure of 1 – 5 mg/l will cause slow growth and poor reproductive capacity and death < 1mg/l (Boyd, 1982). The majority of riverine fish in the Xe Bang Fai, especially those inhabiting rapids habitats, are likely to require significantly higher DO levels than 5 mg/l. Hence, while the turbinated waters from the NT2 Power Station may not be lethal to fish in the dry season and early rainy season, prolonged exposure to sub-lethal levels of DO and possible traces of methane, ammonia and hydrogen sulphide may cause reproductive stress, and slower than normal growth for fish at all stages of the life cycle. These altered water quality factors are likely to have synergistic adverse effects on not just fish, but other aquatic organisms, thus causing multiple and cumulative impacts on the aquatic food chain.

Nam Phit

On page 94 of the EAMP there is a short section addressing potential impacts on other rivers, specifically mentioning the Nam Phit. This section is basically an abridged version of the section found on page 53 of Kottelat's (1996) report. He describes the Nam Phit as being "*dry most of the year for most of its course*" and "*Only the lowermost stretch (probably less than 4 or 5 kms) has permanent water*." Yet despite this rather dismal picture of "*a sluggish stream*" (he visited in the height of the dry season), Kottelat surprisingly describes the lower Nam Phit and its confluence with the Xe Bang Fai as "*one of the few places along the middle Xe Bang Fai where commercial fishermen (as opposed to occasional, subsistence fishermen) were observed to be operating*."

In the next paragraph, Kottelat (1996) wrote: "*Completion of the project will transform the middle and upper Nam Phit from a temporary stream with dry river bed most of the year into a wide channel with constant flow. As there is no permanent aquatic biodiversity (the stream is repopulated from downstream populations during each wet season), the impact on it will be very limited*."

While the latter sentence is more or less identical in both Kottelat (1996) and the EAMP (2004), there is one significant difference in the EAMP version, notably the phrase *"middle and **upper** Nam Phit*", has been substituted for "the middle and **lower** Nam Phit". In other words, they are referring to different stretches of the same river, which according to Kottelat have greatly different physical characteristics and productivity and economic value as a fishery. The EAMP author/s are patently wrong in stating that "*there is no permanent aquatic biodiversity*" in the lower Nam Phit, when Kottelat's own survey on 8 March, 1996 found 16 fish species in the Nam Phit "*about 500 m from the confluence with the Xe Bang Fai*" (p.11). Kottelat did not even attempt to look at other forms of aquatic biodiversity or survey any points further upstream. He estimates that there is permanent water only in the lower 4 or 5 kms of the Nam Phit and it is "*dry most of the year*" from this point upstream to its source. However, appearances can be deceptive and even in an ephemeral stream with apparently no water on the surface there is often subsurface drainage and a broad assemblage of aquatic biodiversity (including species of air-breathing fish) found beneath the seemingly lifeless surface, in a resting phase of their life-cycles until the next rains come.

The description of the Nam Phit offered by Kottelat and misquoted in the EAMP bears little resemblance to the description provided by Shoemaker et al. (2001) which devotes several pages to the Nam Phit and its associated wetlands (see p. 32 – 34). The authors of this report gathered their data from nearby villagers who shared local ecological knowledge on such topics as fish species, fisheries, living aquatic resources, vegetation and useful terrestrial products gathered by villagers in the seasonally flooded forest located in the middle reaches of the Nam Phit, where the Houay Khama stream enters. It notes the presence of spring-fed pools in caves in the upper catchment of the Nam Phit and how these act as important reservoirs of fish, which take shelter in them during the dry season and then migrate downstream at the start of the rainy season to feed in and repopulate the flooded forest (refer to earlier section on Limestone Extraction in Karstic Formations)

Shoemaker et al. (2001) reported that villagers from up to 21 different communities come to fish and utilise the natural resources in this seasonally flooded forest area of about 70 Ha, some from villages many kilometres away. "*According to villagers, the Nam Pheet flooded forest is the most important fishing grounds in the district*", says the report. Likewise, it is reported that people from Nakai and Mahaxai district flock to the Nam Phit at the start of each rainy season to catch fish from a natural pool in the river during a festival "*celebrating the belief that thousands of fish come to rejuvenate the Phit river*", confirming its status as an important local fishery. (*Vientiane Times*, June 14, 2004). It is perhaps understandable that Kottelat (1996) missed the significance of the fishery and aquatic ecosystem of the Nam Phit, given the brevity and timing of his field visit in the mid-dry season (fishing activity is at its peak during the wet season months) and inability to talk with resource users directly.

Given the apparent ecological importance of the upper, middle and lower Nam Phit to biodiversity, fisheries and other human usage values, it is surprising that it is given such scant attention in the EAMP document, with no direct reference made to Shoemaker et al. (2001) in order to triangulate information with that contained in Kottelat's (1996) report.

The latest draft of the EAMP contains a new section on the Nam Phit (p.94) which makes some vague predictions about potential impacts, but totally downplays the significance of either the fishery or of the impacts to it by adding so much additional, poor quality water to the river. The EAMP states that "*deoxygenation is not likely to become a major problem due to downstream flushing and mixing with well oxygenated water in the Xe Bang Fai*." This is a complete fabrication. So long as water continues to follow the laws of gravity and flow downstream, it is difficult to see how the Nam Phit will benefit from mixing with Xe Bang Fai water. In addition, the EAMP downplays the erosion that is likely to occur along the river channel. For an idea of the expected erosion, NTPC need only visit the Nam Hai – Hinboun river system to see that after six years of operation there has still been no sign of stabilisation of erosion or turbidity and that the process could continue unabated for many decades to come.

It would seem highly likely that due to the size and scale of the Downstream Channel (up to 150 metres wide, with associated levees) and water releases up to 300 m^3/s, the future productivity and functioning of the Nam Phit wetlands area looks bleak. Urgent efforts should therefore be made to accurately document the biodiversity and human values of this wetland and the Nam Phit in entirety, well before any Nam Theun 2 Project-related infrastructure development begins in the area (this may already be too late, as tunnel construction in the Gnommalat area has already commenced in late 2004, according to various field reports).

Mekong Mainstream

Impacts – This is very briefly dealt with on p. 96 of the EAMP, thus: "*Changes in the run-off and probable changes in the water temperature and chemistry of the Nam Kading, Nam Theun and Xe Bang Fai may interfere with the natural stimuli responsible for the start of migration, but the biological data is not available to speculate on this…..Tributaries are of the utmost importance for Mekong mainstream fish; without access to tributaries, most stocks would be negatively affected and some may even disappear. It is likely that the increased discharge in the Xe Bang Fai may instigate spawning migrations into the river. However, this can only be observed once the Project is operating*."

Reviewer's Comments – If there was any substance to the claim that increased flows in the Xe Bang Fai (albeit radically altered in terms of seasonal profile, temperature and bio-chemical profile) may stimulate fish from the Mekong mainstream to swim up the Xe Bang Fai on spawning migrations, then it is likely that this phenomenon would have been noted in the Nam Hinboun following start of operations in early 1998. As it is, all reports from observers who talked with fishermen, fish traders and others living near the river suggested that there was a delay in upstream migrations during 1998 in the Nam Kading and Hinboun Rivers (Shoemaker, 1998; ADB, 1998; Baird, 1998; Anon., 1999; Warren, 1999).

Subsequent studies have found that the fisheries in the Nam Hinboun have declined by up to 80% from the pre-project situation and no mention has been made by fishers of increased discharge inducing or instigating upstream migrations from the Mekong (Schouten et al., in prep.). In fact, the available evidence from fishers' catches would suggest quite the opposite i.e. that migrating fish are running up the Nam Hinboun in far fewer numbers than previously.

Given the recognised importance of large Mekong tributaries like the Xe Bang Fai and Nam Songkhram for seasonal fish feeding, spawning and nursing grounds, then any loss of biodiversity and productivity through gross environmental change is almost bound to have negative impacts on the ecological health of the Mekong mainstream. This in turn will have unknown, but certainly negative repercussions, on the human end-users of the aquatic resources harvested from the Mekong over a wide area, upstream and downstream of the Xe Bang Fai confluence.

An Asian Development Bank-commissioned Cumulative Impact Assessment[9] of Nam Theun 2 Project impacts on the Mekong mainstream estimates that the Project will modify flow regimes in the Mekong River as far downstream as the Great Lake in Cambodia and Delta in Vietnam. There will be an 8% increase in dry season flows in the Mekong at Savannaket/Mukdahan, gradually reducing to a 3% increase between the Tonle Sap at Phnom Penh and the Delta. Simulated modelling of flows in the wet season suggests that there will be a reduced inflow to the Great Lake of 100 m^3/s, or 2% of baseline average inflow. This is equivalent to a 3-4 cm reduction in flood water level, corresponding to a reduction of approximately 50 km^2 in the inundated area. Despite the recognition of the magnitude of the annual flood pulse and the level of fish production in the Great Lake, the CIA concludes, "*It is not likely that either the NT2 alone, or the 5-year perspective will cause any significant negative impacts on the aquatic or near-river terrestrial biodiversity in the Mekong zone. There might be small changes in distribution of some species but there is no indication that the species composition will be changed or that vulnerable species will be endangered*." This opinion by the CIA's consultants tends to ignore evidence of gross changes in fish population composition and biodiversity that have occurred in some Thai rivers following damming, irrigation scheme withdrawal and habitat modification, which could be an indicator of trends to come on the mainstream.

As with Northeast Thailand's Mun River and its former healthy riverine ecology and extensive fisheries supporting thousands of villagers, (Roberts, 1993; Amornsakchai et al., 2000; Roberts, 2001), so the Xe Bang Fai is another major Mekong tributary under threat of following the same route. Hitherto free-flowing and unregulated, with important rapids and wetlands-based fisheries, the Xe Bang Fai undoubtedly plays an important role in maintaining the overall ecological health of the mainstream Mekong and literally millions of people that benefit from its rich fishery resources, both upstream and downstream of its confluence with the Mekong. The diversion of impounded Nam Theun waters from the Nakai reservoir and subsequent altered hydrology will create the pre-conditions for secondary project impacts such as intensification of agriculture, commercialisation and over-harvesting of fish and other natural resources, which will inevitably lead to further degradation of the aquatic environment both within and beyond the immediate Xe Bang Fai mainstream, at the expense of the rural poor and aquatic resource users.

[9] The CIA is presently in draft form (Draft Final Report submitted July, 2004) and was prepared by consultants for NORPLAN and EcoLao companies. According to the Terms of Reference, the Final Report should have been delivered to ADB four weeks after submission of the Draft Final Report and been disclosed to the public by posting on the Project website and also made available in printed form.

CONCLUSION

In summary, the EAMP as it stands is data deficient in terms of fish and fishery impacts. The dam will have potentially major impacts on three, if not four (Nam Theun-Kading, Xe Bang Fai, Nam Hinboun and mainstream Mekong) river systems, and yet no aquatic ecological studies and an inadequate number of in-depth long-term fishery studies have been conducted. The EAMP can not be considered an independent and scientific assessment of the potential impacts of the project on scientific assessment, and far more study and analysis should be done before project construction commences.

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