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EFFECTS OF DAMS ON DOWNSTREAM RESERVOIR FISHERIES, CASE OF NAM NGUM

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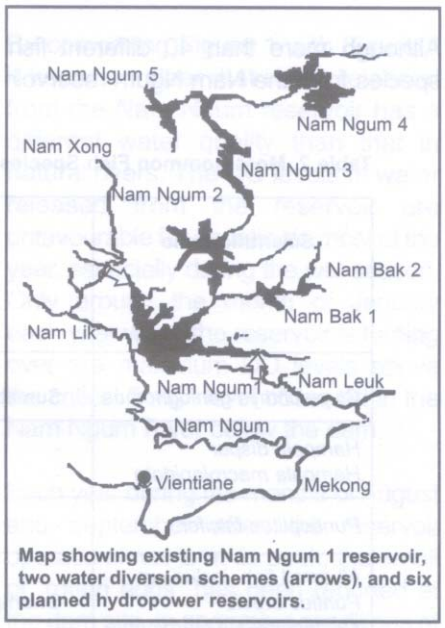
For the sustainable development of the Nam Ngum watershed, it is becoming urgent that hydropower development EIAs and EIAs of any water resource development address downstream issues in a regional context.

Nam Ngum Hydropower



Map showing existing Nam Ngum 1 reservoir, two water diversion schemes (arrows), and six planned hydropower reservoirs.

In 1971 the first hydropower dam in the Lao PDR was completed. The construction of the dam in the Nam Ngum River created a reservoir with an area of 450 km2 at full supply level. Electricity generated at the Narn Ngurn power- house has been the major foreign currency earner for the Lao PDR. The current annual gross power revenues of the Nam Ngum I dam are estimated at approximately US$36 million. The Nam Xong water diversion scheme came on line in 1995. The Nam Leuk hydropower and water diversion project is under construction. Another six hydropower projects upstream of the existing Nam Ngum reservoir are under consideration (see Map). A definite positive impact of hydropower development is the fish production and economic value of fisheries in newly created reservoirs. This article discusses potential impacts of hydropower development on down- stream reservoir fisheries and aquatic diversity. Information used for this paper has been gathered during the Nam Ngum Watershed Management technical assistance project, co-financed by the Asian Development Bank (ADB) and the Government of Denmark.

Existing Reservoir Fisheries in Nam Ngum I

After water quality problems in its initial years due to inadequate removal of vegetation before impoundment, the Nam Ngum I reservoir has seen a proliferation of fisheries activities. Fish caught at the reservoir is consumed by the population of 16,000 people living around the reservoir and also traded, mainly in Vientiane markets. Dried Sumatran River sprat *(Clupeichthys goniognathus)* is traded to the main cities and towns all over the country.

Table 1 shows the consumed and traded quantities of reservoir fish and their estimated value in US dollars for the year 1997.

The trade values in Table 1 are estimated based on prices paid by the Nam Ngum reservoir fish trading monopoly, which has a central landing place near the dam. The value of total reservoir fishing yield is estimated at US$ 0.8 million for 1997. This is a minimum estimate, because there is illegal or unregistered trade of reservoir fish. This estimate was also effected by the devaluation of the Kip, the Lao currency, devalued in 1997 from 993 to 2,083 Kip per US dollar.

Table 1. Quantities and Estimated Value of Fish Consumed and Traded at Nam Ngum Reservoir in 1997.

	WEIGHT OF FISH [kg/year]	ESTIMATED VALUE OF FISH [US $/year]
· Recorded Annual Fresh Fish Trade	562,000	483,000
· Recorded Annual Processed Fish Trade	212,000 [1)]	52,000
· Annual Consumption of Fish by Local Population	695,000	278,000
TOTAL 1997	**1,469,000**	**813,000**

[1)] converted in kg wet weight

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The price per kilogramme of reservoir fish increased only at a factor of 1.2 during 1997. There are strong indications that the same value or more can be given to the Nam Ngum reservoir fishing yield in all the years during the last decade. The annual minimum fishing yield is estimated at 32.6 kg per hectare at full supply level of the reservoir.

Although more than 40 different fish species from the Nam Ngum reservoir are recorded, only 12 species determine the recorded fish trade. Table 2 shows the most common fish species and their percentage in weight and value in 1997.

Oreochromis niloticus is the only non- indigenous species of the regularly introduced fish species, which has been able to establish a population in the reservoir. Some fish species have been recorded from the Nam Ngum River before closure of the dam, but have never been observed in the reservoir. Species belonging to the family Cobitidae (found in habitats with swift currents) and most of the species belonging to the family Pangasiidae (migrating from the Mekong River up into tributaries) have not been able to establish reservoir populations due to modification of habitat and blockage of migration. *Tenualosa thibaudeaui.* recorded in the Nam Ngum River before closure of the dam, is a fish species whose population abundance has declined all over the Mekong Basin since the early seventies.

Fishermen are complaining about the increased effort needed to obtain the same fishing yield as 10 years ago. The fish trading company is of the opinion that the average size of fish has become considerably smaller in the last few years. These are strong indicators that the maximum sustainable reservoir fishing yield has been surpassed. Fishermen have been trying to take it all and losing more in the process. A community -based reservoir fisheries management programme can offer a solution.

Table 2. Most Common Fish Species in 1997 Nam Ngum Reservoir Fish Trade.

ScientificName	FAO Name	Lao Name	Percentage of Weight in 1997 Reservoir Fish Trade	Percentage of Value in 1997 Reservoir Fish Trade
Clupeichthys goniognothus	Sumatran River sprat	Pba Keo	25 %	8 %
Hampala dispar *Hampala macrolepidota*	- -	Pba Sout	24 %	26 %
Puntioplitus falcifer	-	Pba Sa Kang	22 %	30 %
All small fish, including: *Puntius brevis* *Mystacoleucus marginatus* *Dangila sp. cf. cuvieri*	Swamp barb - -	Pba Bee/ Pba Kee Lam	10 %	7 %
Amblyrhynchichthys truncates	-	Pba Dta Po	4 %	4 %
Morulius chrysophekadion	Black sharkminnow	Pba Phia	4 %	7 %
Mystus nemerus	-	Pba Kot	4 %	8 %
Mystus wyckioides	-	Pba Kheung	1 %	4 %
Oreochromis niloticus	Nile tilapia	Pba Nin	1 %	2 %

Reservoir Water Quality

The Nam Ngum reservoir is stratified; a surface water layer (epilimnion) with high water temperature is separated from a bottom water layer (hypolimnion) with low temperature. With differences in water density caused by temperature differences, the two water layers usually do not mix. The surface water layer is continuously in contact with air and therefore contains a lot of dissolved oxygen (DO). Photosynthetic activity of algae and aquatic plants may push DO levels in the surface water layer even to over-saturation. Because of lack of sunlight, no photosynthesis takes place in the bottom water layer. Lacking aeration in the bottom water layer, oxygen consumption by decomposing organic material can create low DO concentrations or even anaerobic conditions in the hypolimnion.

As a result of reservoir stratification, other water quality parameters than temperature and DO also change according to water depth. In the bottom layer, values of hardness, conductivity, alkalinity, turbidity, ammonia and iron are higher than in the surface water layer. Values of pH are decreasing with water depth as well, due to differences in photosynthetic activity.

Each year during December and January, the Nam Ngum reservoir destratifies and turns over. At this time of year dropping air temperatures, increased inflow of cold water from the rivers during the wet season, and increased wind action lead to mixing of the surface and the bottom water layers. The turnover induces high DO concentrations throughout the water column of the reservoir.

Fish distribution in the reservoir is restricted to the surface water layer, the shallow areas, and the reservoir areas of the in-flowing rivers of the Nam Ngum and the Nam Xan, where favourable water quality conditions for fish exist. Water quality conditions of the hypolimnion at deep reservoir areas are generally unfavourable for aquatic life.

Apart from light fishing on pelagic Pba Keo in the surface water layer of the reservoir, existing fisheries activities are mainly concentrated in the valleys where the Nam Ngum River and the Nam Xan River enter the reservoir. In these areas, conditions prevail resembling a slow flowing lowland river rather than conditions found in stratified reservoirs. The Nam Ngum valley in particular is considered a prime fishing area, with a high aquatic bio-diversity. At the beginning of each rainy season fish are assembling for spawning in this area and up in the Nam Ngum River.

Downstream Effects of Nam Ngum I Reservoir

All water in the Nam Ngum River downstream of the reservoir along the 5 km stretch between the dam and the confluence of the Nam Ngum with the Nam Lik is released from the reservoir. Figure 1 shows the monthly measured DO concentrations just below the Nam Ngum dam. It also shows the 5 mg/1 DO level, above which DO conditions are considered optimum for aquatic life. As can be observed, DO concentrations in the Nam Ngum River just below the dam are more often below the crucial DO concentration of 5 mg/1 than above it.

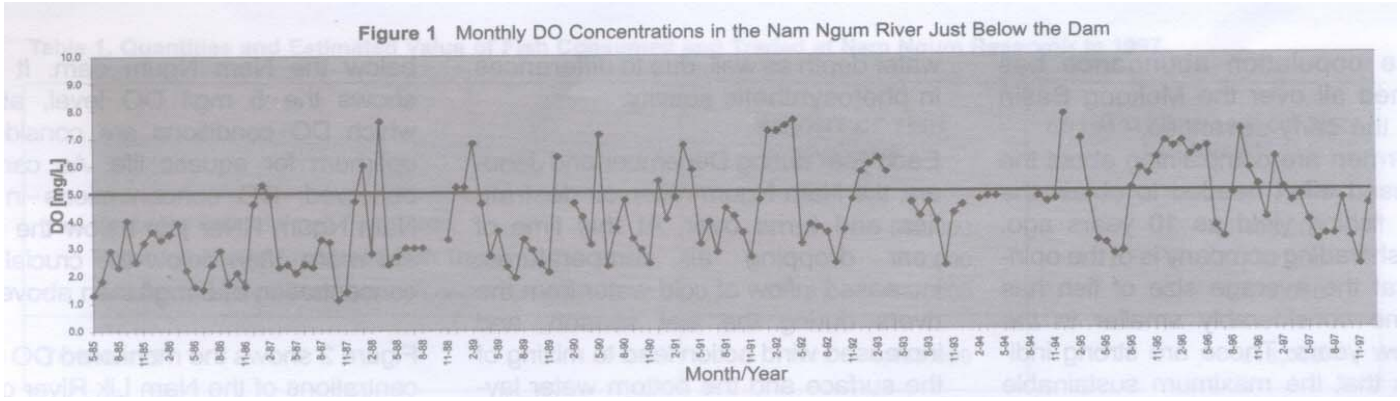

Figure 1 Monthly DO Concentrations in the Nam Ngum River Just Below the Dam

Figure 2 shows the monitored DO concentrations of the Nam Lik River close to its confluence with the Nam Ngum River below the dam. DO fluctuation in the Nam Lik is compatible with the seasonal DO fluctuations of natural rivers in the Lao PDR. Maximum DO levels occur in the dry season and minimum DO levels can be observed in the rainy season. DO levels in natural rivers may dip below the critical level of 5 mg/1 only at times of heavy rainfall after long dry spells, due to organic material run off.

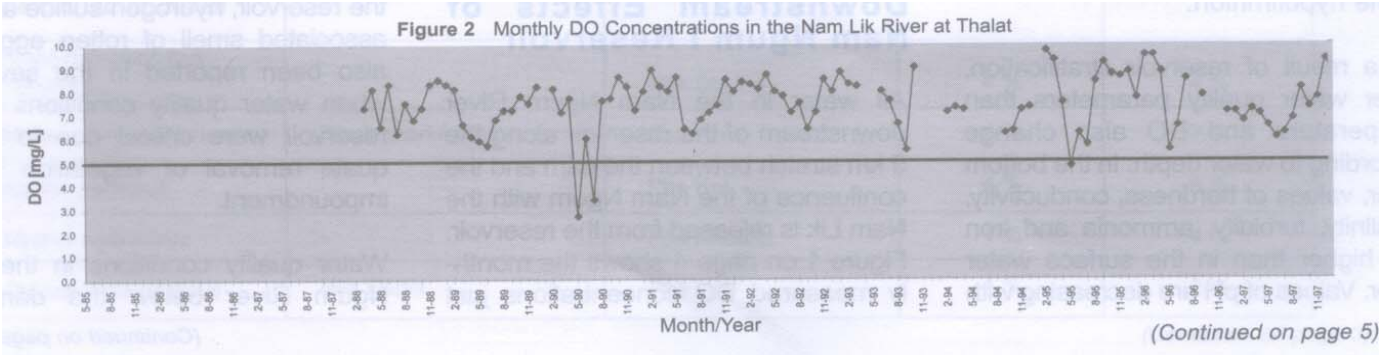

Figure 2 Monthly DO Concentrations in the Nam Lik River at Thalat

(Continued on page 5)

By comparing Figure 1 with Figure 2 it becomes clear that water released from the Nam Ngum reservoir has a different water quality than that in natural rivers. The DO levels of water released from the reservoir are unfavourable for aquatic life most of the year, especially during the wet season. Only around the month of January each year when the reservoir is turning over are maximum DO levels above the critical 5 mg/1 level observed in the Nam Ngum River below the dam.

Each year during the months of August and September when the reservoir operation level is at its peak, the smell of "rotten eggs" has been reported at the dam site. **In** anaerobic conditions of the reservoir, hydrogen sulfide and the associated smell of rotten eggs had also been reported in the seventies when water quality conditions of the reservoir were critical due to inadequate removal of vegetation before impoundment.

Water quality conditions in the Nam Ngum River below the dam are dependent on the reservoir operation level. When the reservoir level rises during the rainy season, the elevation level of the hypolimnion also rises. If the elevation of the hypolimnion is rising above the elevation of the water intake to the powerhouse, water quality conditions in the Nam Ngum River below the dam become unfavourable for aquatic life. However, after closure of the dam no fish surveys have been con- ducted in the Nam Ngum River.

Stratification of reservoir water lead- ing to unfavourable water quality conditions for aquatic life in the hypolimnion can be expected in all reservoirs that have a

depth of more than 12 metres. If reservoir water is released from the top water layer, no other downstream effects can be expected than changes in temperature. If water levels fluctuate more than 10 metres a year (more than 10 metres draw down) significant effects on downstream aquatic life can be expected as a result of the release of water with low water quality from the hypolimnion. There are no fewer than 15 existing hydropower projects in Thailand and Viet Nam, which have a reservoir depth of more than 12 metres and a draw down zone of more than 10 metres (MRC, 1997, *Large Dam Fisheries of the Lower Mekong Countries).* Only one prospective dam in Thailand has been designed (after extensive reservoir water quality modelling) with a variable-level water intake. However, this project has been can- celled because of resettlement issues. A variable-level water intake allows reservoir water to be taken continuously from the surface layer, avoiding release of water from the hypolimnion with low DO levels (IUCN- The World Bank Group, 1997, *Large Dams, Workshop Proceedings).*

The dam blocks off upriver fish migration. In the case of the Nam Ngum River, tributaries down- stream of the dam, such as Nam Lik, can also be affected. Fish migration from the Mekong River through the Nam Ngum up the Nam Lik is likely to be influenced by water quality conditions in the Nam Ngum River.

Effects of Upstream Hydropower Development on Fish Populations

The Nam Xong water diversion project came on line at the end of 1995. Water is diverted from the Nam Xong River to the Nam Ngum reservoir, resulting in increased opportunities for power generation at the Nam Ngum powerhouse. The dam in the Nam Xong creates a relatively small shallow reservoir that is not stratified. The flow of clean water into the Nam Ngum reservoir is believed to have local, positive effects on fisheries in the Nam Ngum reservoir. However, the rise of reservoir operation level, resulting from the diversion flow, increases the time of release of reservoir water from the hypolimnion, thus further aggravating downstream effects in the Nam Ngum River.

The Nam leuk hydropower project, which is under construction, will divert water from the Nam leuk watershed into the Nam Ngum watershed. The reservoir of this project will be permanently stratified. Diverted Nam Leuk water will enter the Nam Ngum watershed in the Nam Xan River a few kilometres upstream of the reservoir. This area is exactly the location where *Wal lago attu* and *Wallago leeri,* reservoir fish species of spectacular size, have their spawning grounds in shallow water. The changes in hydrological regime and water quality in the Nam Xan River most certainly will wipe out *Wallago* sp. It appears that the environmental impact assessment (EIA) of the Nam Leuk hydropower project has completely ignored potential downstream effects.

Upstream of the Nam Ngum reservoir, six more hydropower developments are planned in the Nam Ngum watershed. All of the six hydropower projects will create reservoirs which are expected to be permanently stratified. None of the available EIAs are addressing the potential downstream effects on the annual minimum revenue of US$ 0.8 million generated by existing Nam Ngum reservoir fisheries. None of the existing EIAs are addressing the potential risks of wiping out fish populations. None of the projects are proposing possible mitigation measures that can be defined in the feasibility, design, or operation phase of the projects. None of the EIAs mention the potential downstream effects of stratified reservoirs on aquatic life.

Rare view of the Nam Ngum dam and reservoir from downstream.

Of the six defined hydropower projects, the Nam Ngum II and the Nam Ngum III projects are in the most advanced state of planning. The Nam Ngum II dam is planned close to the location where the Nam Ngum River is entering the reservoir. It is also at this location where the Department of Livestock and Fisheries of the Govemment of the Lao PDR has put in much effort to create a "fish sanctuary" or closed box. It is here where most of the recorded reservoir fish is caught. Since most of the more than 40 described reservoir fish species have been recorded from this location, release of Nam Ngum II reservoir water from the hypolimnion will certainly have significant effects on aquatic diversity and fishing yields in the existing Nam Ngum reservoir. The construction of the Nam Ngum III dam will result in deteriorating water quality of the Nam Ngum II reservoir, increasing the impacts on fisheries and aquatic diversity of the Nam Ngum I reservoir. Dams are physically blocking off reservoir fish from upriver spawning areas. The construction of fishways at the dams will not form a mitigation measure as long as water quality issues are not addressed.

Dam opponents should not try to freeze developing countries in a status quo by neglecting the value of hydropower as the strongest hard currency earner in the Lao PDR, or by trying to defend a policy of saving every distinctive population of aquatic organisms that already exist in broader geographical areas. However, it is a known fact that a broad range of water resource development projects have affected aquatic biodiversity the world over. The effects of water resource development on freshwater biodiversity have been wide in the Unit- ed States and Canada, where 40 % of the estimated 750 freshwater fishes and 72% of the 297 mussels are extinct, endangered or threatened (Kottelat, M. & T. Whitten, 1996, *Fresh- water Biodiversity in Asia,*

World Bank Technical Paper No.343). Much higher aquatic diversity exists in the Mekong Basin with an estimated total number of 2,000 fish species, of which many are Mekong endemic. The impacts of water resource development may be much more severe in the Mekong Basin, in view of the total number of fish species potentially affected, which in turn determines fisheries practices and revenues.

Feasibility and design studies of hydropower projects need to consider variable-level reservoir intakes that allow water to be taken continuously from the reservoir surface water layer. Variable-level intakes avoid release of water from the hypolimnion and associated negative downstream effects. The current EIA piecemeal approach on a project by project basis is largely ignoring downstream effects and cumulative impacts. Hydrological and water quality monitoring and modelling, fish surveys and fisheries monitoring should form a necessary baseline for hydropower development and lead to formulation of mitigation measures and appropriate watershed management planning.