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COMMENTARY

JUST ANOTHER DAMMED RIVER? NEGATIVE IMPACTS OF PAK MUN DAM ON FISHES OF THE MEKONG BASIN

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ABSTRACT

Thailand's Mun River is the most important tributary of the Mekong River. The new Pak Mun Dam, just 5 km upstream from the mouth of the Mun into the Mekong mainstream, has profound ecological implications for the ecology of the Mekong River as well as the entire Mun drainage.

Baseline data on fishes and fish ecology of the Mekong basin, including the Mun River and its tributaries such as the Chee, are totally inadequate. Previous environmental impact analyses of Pak Mun underestimate or ignore major negative impacts on fish. The fish ladder to be installed on Pak Mun Dam may be the best design available, but the very rich and highly diverse megapotamic fish fauna of the Mun River cannot possibly be sustained by means of a fish ladder and fisheries stocking programs, no matter how much manpower and money are expended on them. Pak Mun Dam predictably will have significant negative impacts on the ecology and fisheries of the Middle and Lower Mekong basin, not just the Mun River and its tributaries. Pollution from riverside industrialization at Ubol Ratchathani, the mouth of the Mun River, and on the Mekong mainstream based on Pak Mun hydropower will pose direct threats to the mainstream Mekong fisheries of Laos, Cambodia, and Vietnam.

Key words: chemical pollution, defaunation, ecological simplification, environmental impact assessment, fish ladders, hydroelectric dams, migratory delay, multiple chemical sensitivity, rapids, reservoirs.

INTRODUCTION

The dire threat of negative environmental impacts to Thailand's native fishes is now widely known and publicly acknowledged at the highest levels of the Government. Mr. Chuan Leekpai, the Prime Minister, gave the opening address at the Fourth Conference of Indo-Pacific Fish Biologists (Bangkok, 28 November–4 December 1993). In a plea for conservation and environmental protection, Chuan said he was glad that the [endangered] Mekong giant catfish and shark conservation would be discussed at the conference, as well as the systematics and genetics of fishes. In closing, he noted that "the discussion of the classification of fish species may prove ironic if there are no fish species left to classify."

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Dr. Plodprasop Surasvadi, Director General of the Department of Fisheries, recently reported that fisheries surveys of the Chao Phraya showed a decline from 121 fish species in 1967 to 66 in 1981 and only 31 in 1990 (BANGKOK POST, 7 Dec. 1993). One may query the exactness of such figures, but the remarkably rapid recent decline is not in doubt. Dr. Plodaprasop played an important role in the government's reaction to the massive fish kill in the Chee River due to toxic industrial effluents in March 1992. He was one of the first to point out unequivocably the negative impacts of Pak Mun Dam on fishes (*The Nation,* 26 April 1992). The present article goes into the negative impacts in considerably more detail, and includes some topics not mentioned by Plodprasop. Most large dams built in Thailand, and especially those used for hydroelectic power and where there has been extensive destruction of forest cover in the watersheds, have had extremely negative consequences for the fishes of Thailand, in the Gulf of Thailand as well as in the rivers that formerly teemed with fish.

Some people think that large dams and reservoirs help protect Thailand from severe floods and droughts. They point to Laos as an example of a neighboring country that still has most of its forest, and yet suffers from floods and droughts. But this reasoning will not stand up to careful examination. Floods and droughts are normal occurrences in tropical countries with high rainfall, including those covered with forest. In forested countries the duration and effects of wet and dry periods are buffered or softened by the forest. We need not go into details of soil accumulation, water tables, and the complex relationships of forest to the rain cycle in great detail here. Let us simply note that substantial forest destruction in Thailand started long ago, and that all recorded diasastrous floods and droughts in Thailand have occurred since then. With the relatively uniform forest that once blanketed virtually all of Thailand and neighboring countries, the effects of rainfall or of its lack were spread more uniformly over a very wide area. Now that only about 15% of the forest is left, and that distributed very patchily, the effects of heavy rainfall or of drought tend to be concentrated in relatively small areas (that is, small in geographical terms, but large in relation to human problems). Thus it is that for several years now Thailand has been simultaneously afflicted by flood and by drought (as it is at this moment, December 1993).

Although much forest remains in Laos, a very great deal of its magnificent forest has been damaged or destroyed already, especially in the watersheds that are experiencing severe floods and droughts, and the rate of forest destruction in Laos has suddenly increased drastically. The recent moratorium on logging in Thailand has not resulted in a net decrease in the "Thai timber industry". Rather, the loggers and their chain saws have moved into neighboring countries, including Myanmar, Laos, and Cambodia. Unfortunately for Thailand, negative impacts from deforestation do not respect national boundaries. As the Thai timber companies and their collaborators sow forest destruction in neighboring countries, so shall Thailand reap the unwanted consequences, including ever more severe regional droughts and flooding.

For a different perspective on the problem of floods and droughts in Southeast Asia, let us hear a voice from the past. Here is Raymond Barthélemy, A French colonial administrator, writing about Cambodia at the turn of the century (translated from the original French):

> "Cambodia lives, prospers, and owes a great part of its riches to a natural periodic phenomenon, the rising and falling of the Mekong River...this rhythmical movement of the waters, regular as the respiration of a living organism, provides nearly all of the energy necessary to obtain the benefits from the country...In Europe flooding is an unforeseen event, unexpected and feared, often disastrous; in Cambodia it is foreseen, awaited, desirable, and always beneficial [toujours un bienfait] (BARTHÉLEMY, 1913: 363)."

It is particularly noteworthy that when this was written, neither Cambodia nor its upstream neighbors had seriously deforested the Mekong basin, but that in contrast, a great deal of forest destruction had occurred almost everywhere in Europe including France.

Throughout all or almost all of Thailand's earlier history the annual flood cycle probably was highly benevolent, as it still is, or at least was until relatively recently, in Cambodia. It is virtually certain that if upstream degradation of the Mekong basin continues, Cambodia will soon enough be afflicted by irregular and unpredictable floods and droughts of increasing severity, so that the former rhythmical blessings bestowed each year by the wonderful Mekong River will become more and more frequent arhythmical diasasters.

Before considering the likely negative impacts of the new Pak Mun Hydroelectric Dam on fishes, a brief discussion is given of some general topics regarding the susceptibility of fishes to impact from pollution and other human activities.

Chemical Impacts on Fishes: the Double Whammy

"Double whammy" is American slang. It means getting hit from two (or more) different directions simultaneously, like the one-two punch in boxing that results in a KO. In the present instance, I use it to refer to multiple chemical sensitivity. This is a medical term usually referring to human response to dangerous chemicals, but it can be applied readily to fishes.

Before explaining how the double whammy of multiple chemical sensitivity applies to fishes, and particularly to freshwater fishes in Thailand, we need to consider some general aspects of fish reaction to dangerous chemicals. The first point to make is that different kinds of fish differ enormously (by several orders of magnitude) in their sensitivity or susceptibility to chemicals. The hardiest or most resistant freshwater fishes in Thailand include air-breathing species such as the common catfish or pla duk, *Clarias batrachus* and the common snakehead or pla chon, *Channa striata*. Perhaps the most resistant of all Thai fishes is pla mor, *Anabas testudineus:* even more than pla chon and pla duk, it can survive in really foul, badly stinking and heavily polluted water.

At the other extreme are certain extremely active open-water species with high metabolic rates, which can live only in relatively clean water with high levels of dissolved oxygen. This includes a number of freshwater herrings and anchovies, notably the endemic Mekong herring *Tenualosa thibaudeaui*. Such species, although they die very easily, can be extremely abundant and important in the food chains of larger fish species. Within the dominant freshwater fish family Cyprinidae are many species almost as sensitive as the herrings and anchovies. Other cyprinids, especially the introduced common carp or pla nai, *Cyprinus carpio,* and the species used in aquaculture including pla tapien or *Puntius gonionotus,* are very hardy or moderately hardy. Thus in discussing the effects of chemicals on fish, it is necessary to realize that many kinds of fishes are involved, and that their resistance and responses to different kinds of chemicals is not at all identical.

The second point to realize is that fish, unlike humans, absorb most chemicals mainly through their skin and their gills. Gills are far the most sensitive part of the fish when it comes to absorbtion of, and adverse reactions to, all kinds of poisonous chemicals (this is why air-breathing fishes are generally most resistant to chemicals).

The third point is that many chemicals have very significant sublethal effects. Among these generalized sublethal (non-killing) effects are the following:

(a) greatly increased swimming or other avoidance activity, with attendant hyperventilation of gills and loss of energy;

(b) increased permeability of the gills (caused by many pesticides, e.g. paraquat);

(c) decreased disease resistance, due to depression of the immune system or other direct effects; and

(d) interference with the mucus envelope (detergents; mercury and all other heavy metals).

We can now consider the double whammy, or the effects on fish of simultaneous exposure to two or more chemicals. Acting one at a time, neither chemical may kill fish or even seriously effect fish. But a sublethal concentration of a chemical that causes, for example, hyperventilation and/or greatly increased permeability of the gills, could easily have fatal consequences in the presence of extremely low (and normally safe) concentrations of other chemicals.

A very serious threat to fish resulting from Pak Mun Dam will be the establishment of riverside industries, based on cheap hydrolectric power, which use the Mekong River for cheap disposal of a variety of highly toxic (and interactive) waste products. Benefits from industrialization facilitated by the dam will accrue to Thailand, but negative impacts will be felt downstream, in southern Laos, Cambodia, and Vietnam. Serious riverside polluters might include (but not be limited to) sugar refineries, distilleries, breweries, saw mills, paper mills, textile mills, chemical plants, paint and dye factories, and slaughter houses.

Critical Events in the Life of Fish

For mammals and birds the single most dangerous time in the early life is the moment of birth (in the case of most mammals) or of hatching (for birds). The most dangerous time for adults—when they are under the greatest stress, and most susceptible to predation—is the time of reproduction. Much the same applies to fishes, with some important differences related to their biology and aquatic environment.

In nearly all fishes, including the vast majority of those inhabiting the Mekong basin, there are actually two critical stages in the early life history, both of them characterized by far higher loss than ever occurs in the less fecund mammals and birds. This is a natural consequence of the very large numbers of eggs produced by most fish species, and the relatively low amount of parental care or investment devoted to the individual eggs. Thus even in the most "natural" or "best" of circumstances, the early life stages of fish experience extremely high mortality. The first peak of mortality occurs at the very moment of spawning and fertilization, the moment when the life of each new individual fish begins. The percentage of eggs successfully fertilized (i.e., united with a sperm) can range from 0 to 100. In species with very large numbers of eggs, such as the giant Mekong carp *Catlocarpio siamensis* and the giant Mekong catfish *Pangasius gigas*, the percentage of eggs fertilized may be extremely low. If the eggs are not fertilized within moments of the spawning act they die. The proportion of eggs fertilized will vary enormously due to all sorts of influences, including but by no means limited to water temperature, flow, and turbidity. If the males engaged in the spawning act are stressed, as is likely if toxic effluents are present, the quality of the sperm they produce is highly likely to be affected, with resulting poor fertilization success. The same of course applies to quality of the female gametes or eggs.

A second crtical stage in the early life of most fishes is the moment of hatching, when egg-sac larvae (larval fish entirely or almost entirely dependent on yolk from within the egg) have used up the supply of yolk and must begin to forage successfully for all of the food they need. This critical stage, depending upon the biological characteristics of the species such as amount of the original yolk supply and physcial conditions of the environment (particularly water temperature) may occur as soon as 18 hours after fertilization (e.g. in many small species of Cyprinidae) or as late as 4 weeks. The great majority of fledgling fish fail to make this transition, especially in the more fecund species lacking parental care. Any adverse environmental effects, such as sudden change in temperature, decrease in suitable food available for larval fish, or toxic substances may greatly increase the mortality until it approaches or attains 100%.

Such massive mortalities in the early life history of fishes must have occurred already thousands of times in Thailand without any notice being paid. Nevertheless, if they occur often enough, they can be just as fatal to the survival of species as the spectacular die-offs of large adult fish.

Migratory Delay and Related Problems

The most critical stage in the life history (and genetic or reproductive continuity) of adult fish, is of course the moment of reproduction. In most fish species this involves spawning or external fertilization, when eggs and sperm are extruded from mating adults at a suitable time and in a suitable place. For many or most larger and medium sized fish species, including the so-called ecological "keystone species", and many of importance to fishermen, reproduction takes place only after a reproductive migration involving a substantial period of time and lengthy movement upstream or downstream.

The problem of "migratory delay" and its possible relevance to Mekong fishes was brought to my attention by a Canadian fishery biologist in July 1993. Studies of migratory salmon in British Colombia (in streams in western Canada flowing into the Pacific Ocean) revealed that the upstream migrating salmon were able to continue their migration despite dams by utililizing one or more fish ladders. But the downstream or seaward migrating, young-of-the-year salmon, known as smolt, were unsuccessful. The large expanse of stagnant water in reservoirs above the dams fatally slowed the downstream migration. The smolts have a critical period no longer than about 15 days during which they swim strongly downstream and are physiologically capable of switching from freshwater to saltwater life. If they are delayed longer than 15 days, they lose the seaward migratory urge and become incapable of adjusting to sea water. Without returning to the sea, they are incapable to reaching large adult size, maturing sexually, and making the return migration to spawn in fresh water (WHITE, 1992).

While the Mekong and most other large tropical rivers do not have species with seaward migratory juveniles comparable to the smolt of salmon, they do have many strongly migratory species. Mekong fish species may have distinct migrations for reproduction, for feeding, or for dispersal or spreading of the population. All are essential to the continued success of the populations. Most or all of these migratory species may have critical phases during which interference with migration can have fatal consequences. Thus many species actively migrate for only a few days or weeks at most. If they are upset at such times, the migrating fish may disperse and be unable to resume migrating.

In the Mekong River the great reproductive migration of the large cyprinid fish *Probarbus jullieni* (pla yesok or pla uhn in Thai, pa uhn in Lao) occurs every year in the months of November, December, and sometimes January. The duration of the migratory period may last one or two months and occurs over a very large part of the lower and middle Mekong River. But the actual spawning occurs in very limited areas or spawning grounds, and may occur entirely within a very short period, 2 or 3 days only (Terry Warren, pers. commun.). If anything happens to upset the fish, such as a sudden change in water level or quality, they might not spawn at all, or have very poor spawning success. If their spawning grounds are spoiled, as they almost certainly would be by the upstream proximity of a dam, they may or may not move on to other spawning sites.

PAK MUN DAM

The Mun River, which drains a very large area in Thailand's Northeast or Isan, is the largest tributary of the Mekong River, with well-known commercial and subsistence fisheries. In May-June 1993 a World Bank team visited Thailand for a midterm review of the new Pak Mun Dam. A statement on the impact of Pak Mun Dam on fisheries was prepared by a member of the team, Dr. Robert L. Dwyer. This was circulated on 10 August 1993 as part of a World Bank "Office Memorandum" on the "Pak Mun Hydroelectric Project Mid-term Review".

Dwyer's report appears to be the only available environmental impact assessment (EIA) of fisheries impacts of Pak Mun Dam based on a consideration of the dam as it finally has been constructed. They only previous EIA document on Pak Mun Dam and fisheries describes the fishes and other aquatic organisms in some detail but does not go deeply into the matter of negative impacts (CHUAPOEHUK ET AL., 1982). The modified plans for Pak Mun Dam supposedly lessened impacts generally, and made an additional overall EIA unnecessary (WORLD BANK, 1991). But some modifications, including excavation of a deep tailwater channel not called for in original plans, addition of a fish ladder, and revised maximum depth of flooding to an elevation of only 108 m (instead of the originally planned 112 m) should be discussed in the context of environmental impact on the fish and fisheries.

This review has two objectives: (1) to reveal serious shortcomings of the fisheries EIA of Pak Mun Dam; and (2) to serve as a model and stimulus for peer reviews of fisheries EIA on other large dams and infrastructure projects. Since the EIA under review is only a brief midterm assessment, it should be possible for the points raised here to be taken into consideration in any further Pak Mun Dam fisheries EIA.

Some people think EIA is something that only happens once, at the beginning of a project. Most analysts, however, now feel that EIA should be an on-going, continuous process. It must include any and all statements that attempt to address the problem of environmental impacts of any engineering scheme or other large scale human activity, whether before, during, or after completion of the activity. An EIA statement may be global, or it may address one particular kind of impact, or the impacts on any one or more features of the environment, such as villages or fisheries (ROBERTS, 1993). This view of EIA corresponds at least partly to that of the World Bank, as described in the latest version (August 1991) of its operational directive 4.0 on Environmental Assessment or EA (the term the World Bank now prefers instead of EIA). It is also my view that the process of EIA has been pre-empted by powerful organizations with vested interests and their carefully chosen and highly paid consultants, and that one way to rectify this deplorable and dangerous situation is for concerned individuals with special knowledge to write and publish critical reviews of EIA documents. Such reviews should also consider the appropriateness of the qualifications and background of the person or persons responsible for EIA (ROBERTS, 1993).

Much of the important EIA literature is secret ("confidential") and/or of very limited circulation. It is important that EIAs become available for public examination and part of the historical record. Peer-reviewed journals should be established with the primary objective of serving as outlets for readable EIA statements of reasonable length and reviews or commentary based upon them. Until such journals come into existence, it will be necessary to publish articles on EIA in newspapers and in the limited space available in journals normally devoted to science and conservation.

Summary of Dwyer's Fisheries EIA of Pak Mun Dam

Dwyer's 10-page midterm document on fisheries impacts of Pak Mun Dam is well-written, well-organized, and concise. Particular attention is given to the fish ladder to be installed on the dam. The ladder is or will be of nearly identical design to one that has been in operation on the Phayao Dam in northern Thailand (PHOLPRASITH, 1990). Dwyer's statement is based mainly or entirely on his visit to Thailand and on meetings he had with officials and staff of EGAT (Electricity Generating Authority of Thailand), Royal Department of Fisheries, and Faculty of Fisheries of Kasetsart University during the week of 31 May – 5 June 1993.

Some design features of the dam that may have negative impacts on fish and the use of explosives in the building of the dam are discussed briefly. Several modifications of the fish ladder are recommended or suggested. Fisheries research facilities funded by the World Bank intended to assist in long-term monitoring and mitigation measures such as increasing fisheries in the reservoir by introduction of hatchery stock are mentioned.

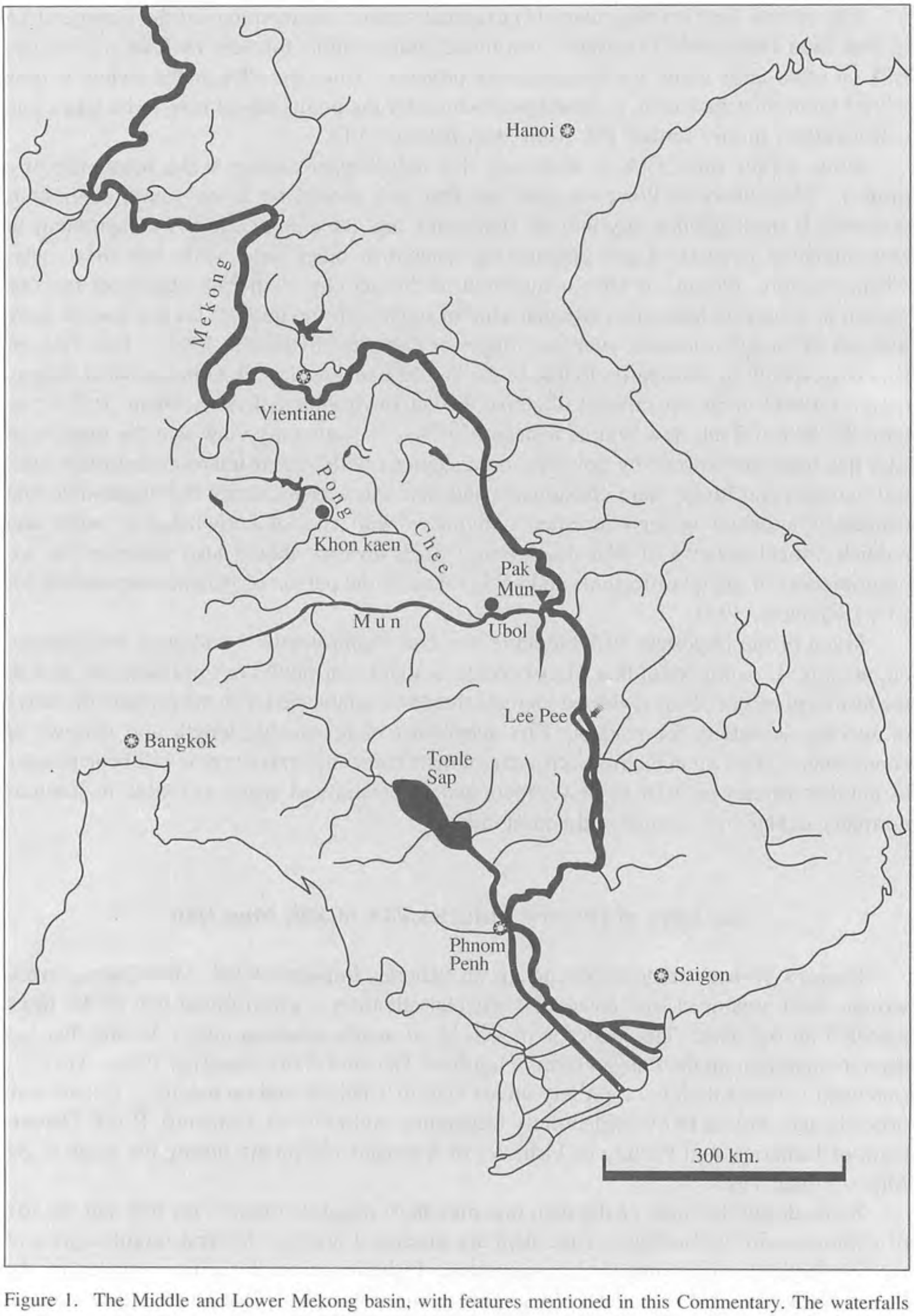

Figure 1. The Middle and Lower Mekong basin, with features mentioned in this Commentary. The waterfalls on the Mekong River at Lee Pee (arrow) separate the Middle and Lower Mekong.

Authorship of EIA

It is the World Bank's duty to engage the most highly qualified consultants available: "a ruler who appoints any man to an office, when there is in his dominions another man better qualified for it, sins against God and against the state" (Koran). World Bank officials should not neglect to engage a consultant just because his views might not coincide with some of their preconceived notions or pet theories. The idea that EIA consultants on dams must be "acceptable to both the World Bank and the local contracting agencies" (World Bank Operational Directive 4.0 on EA or EIA, 1991 version) definitely compromises their function. Consultants must be free to do field surveys, gather data, and express their expert opinion without constraints or censorship imposed by any of the contracting agencies. In effect, consultants should not consider that they represent only the interests of the organization engaging them to do an EIA; rather, their main concern should be to represent, to the very best of their ability, the environment.

Dwyer (Ph.D. in biological oceanography) obviously lacks sufficient knowledge of tropical fishes, and of fishes of the Mekong basin in particular, to be solely responsible for an EIA on fisheries of the Mun River. Evidence of familiarity with the literature on Mekong fishes and fisheries is noticeably absent in his report. Dwyer has useful qualification in some technical aspects of impact assessment, but should have had at least one co-consultant with first hand knowledge of Mekong fishes.

Given the consultant's evident lack of familiarity with Thailand, a single week of on-site inspection and interviews was clearly insufficient preparation for writing up the present EIA. He might have prepared an excellent EIA statement had his terms of reference been limited to technical and operational aspects of the fish ladder on the Pak Mun Dam. In this case, his EIA should have included a review of the operation and present status of the Phayao fish ladder based on a review of the literature, a site-visit, relevant interviews, and photographs and engineering drawings of fish ladder design at Phayao and at Pak Mun.

Overall Critique of Pak Mun EIA

A full new EIA was clearly called for, as inadequacies in the World Bank midterm assessment on fisheries and Pak Mun are substantial. It fails to even mention some of the most important negative impacts of the Pak Mun Dam and its installation, such as the virtual elimination of the rapids of the Mun River. The rapids were an important feature of the ecology of the Mun, as well as an essential habitat for many fish species. Negative impacts of disrupting the linear continuity of the Mun River, disrupting flow seasonality and otherwise simplifying its ecology are not discussed. Industrial waste pollution arising directly as a result of electrification provided by Pak Mun Dam is not mentioned, nor is the potential impact on fisheries in the rest of the Mekong basin.

Bearing in mind that this is an extremely short report, there are a number of naive or unwarranted assumptions about fish biology and about the validity of unsubstantiated or unconfirmed information reported from various sources. Some highly dubious or outright erroneous premises are explicitly or implicitly supported, including a) that exisiting baseline data on fishes on the Mun basin are adequate; b) that satisfactory long-term monitoring and EIA on the fisheries and fish communities of the Mun River and of the Chee River (the Mun's major tributary; officially spelled Chi) are being performed; c) that a fish ladder will enable fish populations to be maintained; and d) that the only fish species living in the Mun River worth being concerned about are the commercially valuable ones.

Specific Criticisms and Commentary

The numbered points in quotation marks are taken directly from Dwyer's EIA, in the order of their appearance in his report.

1. "The lower Mun River supports a diverse, and apparently resilient, fish community that continues to support active commercial and subsistence fisheries."

Mekong fishes may have evolved a wide range of adaptations and tolerances in order to live with seasonal fluctuation, but the idea that because of this they are "better suited than temperate fish to withstand the changes imposed by water projects" is a dubious proposition. This idea was promoted by V.R. Pantulu, formerly Fishery Advisor to the Mekong Committee, and a specialist on fisheries in reservoirs, in several papers published in the 1970's (e.g. PANTULU, 1973; 1975).

Dwyer specifically mentions the resiliency of Mekong fishes in connection with their supposed recovery from a toxic waste spill in the Chee River in March-April 1992. The idea that tropical freshwater fish faunas with large numbers of species are highly resilient is now questioned seriously by many ichthyologists familiar with them (e.g., GREENWOOD, 1992; LOWE-MCCONNELL, 1990). In fact, rich riverine fish faunas throughout the tropics are now seriously threatened by deforestation, dams, pollution, and other negative impacts.

Short term prospects for fisheries in Pak Mun Reservoir are fair. Due to inundation of some 60 square kilometers (9 of farmland, 17 of mixed woodlands, and 44 of river valley), riverine fish populations predictably will have favorable short-term conditions for reproduction and feeding. There should also be a lag time before fishermen unaccustomed to reservoir fishing take full advantage of temporary increases in fish biomass. After a few years, however, the fisheries based on naturally occurring riverine species will decline more or less precipitously, as they have in all or almost all reservoirs on rivers with rich fish faunas.

What happens in a typical or average reservoir behind a large dam in tropical countries with large rivers? This question can be examined in the light of numerous documented instances from Africa and South America as well as Asia. I am not in a position nor shall I try to cite even a portion of the relevant literature. Readers interested in further information and case studies can begin by consulting GOLDSMITH & HILDYARD (1984; 1986). When a dam has been constructed it takes several years for the reservoir to fill. A great deal of highly fertile alluvial and adjacent woodland (sometimes much of it already converted to the most productive farmlands) is flooded. This flooding resembles what happened under the natural riverine regime, except that it is as extensive or more extensive than before, and it does not recede at the end of the rainy season. Fishes respond to the new vast extent of spawning grounds and fertile feeding grounds with an unprecedented burst of population growth, characterized by a superabundance of large fish. Many of the fish are top-level predators with the highest market value.

Local fishermen, unprepared for such abundance, and unaccustomed to as well as unequipped for navigating and fishing on the vast extent of a reservoir, take several years to catch up to the abundance of fish. Some fishermen, often outsiders rather than locals, succeed better than others. The result is a highly productive fisheries concentrated in a relatively small area. This facilitates capitalization of the fisheries, establishment of new and more distant markets, and development of infrastructure such as access roads, fish landings, fish processing plants, fish freezers, and so on. Traditional and artisanal fishermen and small-scale fishing increasingly give way to mechanized large-scale fishing until they disappear entirely or are reduced to subsistence level. What happens next is decline.

Once the reservoir is completely filled, the annual enrichment by alternating flooding and recession of the waters no longer occurs. Vast permanently flooded and stagnant areas become relatively dead or lifeless; fish reproduce and feed in them less and less. In the most extreme cases, a wild, free-flowing river with an aerobic fauna dominated by large numbers of fish species and various submerged higher aquatic plants is turned into an anaerobic habitat with relatively few, mostly air-breathing fish species dominated by bacteria and floating higher aquatic plants, such as the terrible pest *Eichhornia crassipes* (water hyacinth). Water in such a reservoir is unfit for most fish species, for human consumption, or even for irrigation.

In less extreme instances, there is nevertheless usually a marked decline in fisheries after the initial productive period. This is characterized by a great decline in the number of fish species contributing to the fisheries. Migratory fish species especially are lost, but so are many others that are non-migratory or less noticeably migratory. This reduction in fish species usually is accompanied by a marked decline in size and value of catchable species. Fisheries catches in aging reservoirs consists of small numbers of species with early maturation, small body size, and low economic value. Whenever this happens there is a tendency by fisheries departments to try to compensate by introduction of exotic fish species "better adapted to reservoirs", such as the common carp, *Cyprinus carpio,* and the nilotic tilapia, *Tilapia nilotica.* Such introductions invariably spread far upstream and downstream from the reservoir (often throughout the entire river basin) and result in additional negative impacts on the native fishes. A classic example of this in Thailand is provided by Bhumiphol Reservoir, which started filling in 1964. Its fisheries, nowhere near so productive as originally predicted, is dominated today by *Tilapia nilotica* (pla nin).

2. "The past effects of the molasses spill upstream are diminishing, according to unpublished results of a study of that river reach (sponsored by the National Research Council of Thailand; NRCT). Scientists conducting that study [of the effects of the March-April 1992 molasses spill on the Chee River] believe that natural reproduction and immigration from other areas of the basin will complete the recovery by the end of the 1993 rainy season."

This statement is unsubstantiated and erroneous. The Chee River is the largest tributary of the Mun River (Fig. 1), and is noted for its commercial and subsistence fisheries. There has never been an adequate ichthyological survey of the Chee River, either before the molasses spill or after it. It is thus quite impossible to say what portion of the Chee fish fauna has recovered. The spilling of a large amount (variably reported as 700 cubic m or 9000 tons) of molasses was one of the worst single episodes of river pollution in Thailand's history. It occurred toward the end of the dry season, with water levels in the Chee lower than in almost any previous year. Most of its smaller tributaries had dried up, eliminating them as escape routes. Fish were killed from the source of the spill, on the Nam Pong (Pong River) near Khon Kaen just above where it joins the Lam Nam Chee to form the Chee River, and then for the entire length of the Chee, i.e., until it reaches the Mun River. Some fish also died in the Mun for a considerable distance below its confluence with the Chee (Figs. 2-3). The total river reach in which the fish kill occurred was some 420 km (40 km of the Nam Pong, 320 km of the Chee, and 60 km of the Mun).

Rapids can serve as refuges with water sufficiently oxygenated for fish fleeing from poorly oxygenated water to survive. Rapids like those in the lower Mun are notably absent from the Chee. In the Mun the fish kill stopped at Kaeng Saphue, the first rapids, some 40 km downriver of Ubol Ratchatani (now usually spelled Ubon).

The study referred to by Dwyer is being conducted by Prof. Mahn Bhovitchitra, Faculty of Fisheries, Kasetsart University. It emphatically will not provide information on the recovery of fish species in the Chee, because it concerns only the short stretch of the Nam Pong directed effected by the spill during its first few days. The study is limited to determining the duration of the negative effects of the spill (including deoxygenation), and how long it took before fish started reproducing again, only in the Nam Pong (Prof. Mahn Bhovichitra, pers. commun., 20 September 1993). The total length of the Nam Pong being surveyed for the effects of the spill is only some 40 km.

3. "The field work for the EGAT/Department of Fisheries (DOF) assessment study in the lower Mun River was begun in April 1993. The results of the first survey showed the presence of 93 species of fish...Although the beginning of the EGAT/DOF study was delayed, it will result in a full year of baseline (preoperational) data. The sampling design of the study appears sufficient to provide a data set which, when combined with the ongoing NRCT study of the recovery from the [Chee River] molasses spill, will provide a technical basis from which judgments can be made about any future impacts [on the fishes]...".

A collection of voucher specimens of all fish species, with accurate data on locality and date of collection for each sample, is an absolute requirement for baseline data on EIA of rich riverine fish faunas. Ichthyologists competent in ecology and systematics must be involved in the sampling program and in identifying the specimens. Most important, the specimens must be deposited in an institution which maintains a permanent research collection and facilitates their examination by any qualified scientists. In the present instance it seems these steps are not being taken, and that little or no monitoring of Mun fishes is being done.

Neither EGAT nor the Thai Department of Fisheries have baseline data for the great majority of fish species inhabiting the Chee or Mun rivers prior either to the molasses spill or to the beginning of construction work on Pak Mun Dam.

Based upon my field studies on Mun and Chee fishes (begun in 1985) and other sources of information, at least 230 species were present in the basin of the Mun River before construction of cofferdams, blasting, and other work began on the dam. Before the 1992 molasses spill the Chee River was inhabited by about 200 fish species, nearly all of which probably also inhabited the Nam Pong before construction of Ubolrat Dam in 1965.

Figure 2. Villager with *Belodontichthys* sp (predatory catfish) killed by molasses spill of March 1992 (at mouth of Chee River into Mun River).

Figure 3. Fish picked up by villagers after molasses spill of March 1992 (Mun River at Wat Dorn Tat below Ubol, about 400 km downriver from site of spill at Khon Kaen).

Figure 4. Pak Menam Mun, mouth of Mun River, looking downstream into Mekong mainstream of Laos. Traditional drag-net fishery based on migratory fish species (note floats of drag net about 200 m long).

Figure 5. Kaeng Tana Rapids (1992).

Figure 6. Kaeng Tana Rapids (1992).

Figure 7. Rapids of lower Mun River near Pak Mun Dam site (1990).

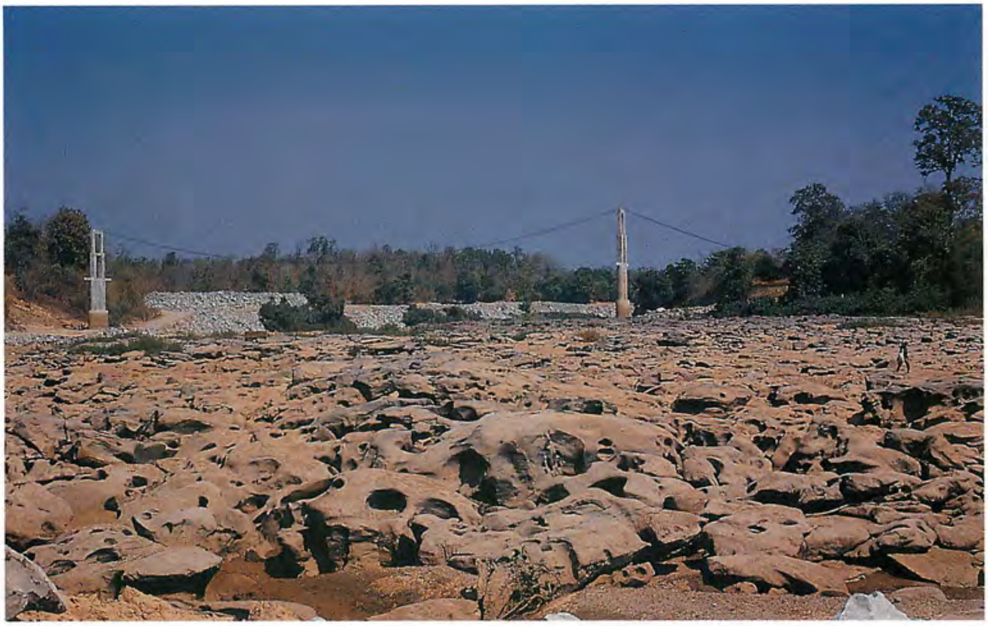

Figure 8. Rapids of lower Mun River, exposed by coffer dam below Pak Mun Dam site.

Figure 9. Pak Mun Dam, with five of its eight turbines. Fish ladder not yet installed. Immediately downstream is a coffer dam within which blasting and excavation was going on (December 1993).

According to Prof. Mahn, his EIA on the Nam Pong fishes cannot serve as baseline data for EIA of the Pak Mun Dam because Nam Pong fishes and fish habitats are not representative of those of the Mun River (pers. commun., 20 September 1993). The portion of the Nam Pong affected by the molasses spill is known to have been populated by at least 75 to 100 fish species before the construction of Ubolrat Dam (SIDTHIMUNKA, ET AL., 1968; BHUKASWAN & PHOLPRASITH, 1976).

Mahn identified three sources for repopulation of the Nam Pong: Ubolrat Reservoir; Khlong Pak Siao; and the Nam Lam Chee. He had been hopeful that Nam Pong fish could be fully recovered by the end of the 1993 wet season, i.e., by November 1993. Before recovery could occur, however, there were two more fish kills in the Nam Pong. The first was in the beginning of August, supposedly due to untreated waste allegedly entering the river from a flour factory (*Bangkok Post*, 12 Aug. 1993). The second, less than one month later, was at the beginning of October, possibly due to illegal waste from a paper mill (*Bangkok Post*, 7 Oct. 1993). It seems unlikely that the Nam Pong will ever again have anything like the fish fauna it had before construction of Ubolrat Dam.

The most important source of fish repopulation of the Nam Pong River presumably will be the Nam Lam Chee, which joins the Nam Pong just above the second dam. The Nam Lam Chee (official spelling Nam Lam Chi) was not affected by molasses in 1992. The Khlong Pak Siao, a small tributary entering the Nam Pong a few km upstream of where the molasses spill occurred, should also contribute to the repopulation. It is unlikely that Ubolrat Reservoir will contribute any additional species.

It is important to realize that the segment of the Nam Pong affected by the spill has been heavily impacted for a long time. It lies between two dams, Ubolrat Dam and a Ministry of Science, Technology, and Environment dam or weir ("fai kooey cheuak") some 50 km downstream. Neither dam has a fish ladder. The Nam Pong is chronically polluted by agricultural pesticides and fertilizers, several kinds of industrial waste, and episodic outflows of deoxygenated and otherwise foul water from Ubolrat Reservoir.

I observed the Nam Pong at the outflow of Ubolrat Dam in 1970 and again in 1973. Immediately below the dam the water was foul-smelling, and there was evidence of severe scouring due to sudden discharge of water from the dam. An hour of collecting with a fine-meshed push-net, which should have yielded 50 specimens of 10–15 species, resulted in collection of only a single small specimen of *Rasbora borapetensis*. Two hour's similar collecting in the Nam Pong several kilometers downstream yielded only a single fish species, *Chaudhuria* cf. *caudata*. This was found in the dense growth of the exotic aquatic plant pest *Eichhornia* (water hyacinth) which heavily infested the Nam Pong shortly after completion of Ubolrat Dam. Gerald Ginnelly, a fishery biologist from University of Michigan then teaching at Khon Kaen University, accompanied me to the Nam Pong. He had collected a new species of *Botia* in rapids near the site of the second dam but was unable to find any additional specimens. I examined the specimen collected by Ginnelly, and it was the species subsequently described as *Botia eos* Taki, 1972. So far as known, this species no longer occurs in the Nam Pong. It is present in the rapids of the Mekong River and (at least until recently) in the rapids of the Mun River.

The Mun River normally would be the single most important source of fish species for repopulation of the Chee River. Since Pak Mun Dam is being built, it is unclear whether the Chee will be repopulated mainly from the Mun, or mainly from the Lam Nam

Chee, Ubolrat Reservoir, and other sources with far fewer species than the Mun. It is saddening that work on Pak Mun Dam was not postponed for one or two years, as requested by the Thai Department of Fisheries and many local people, to allow the fishes of the Chee River a better chance to be repopulated from the Mun River.

Instead of waiting a while and permitting natural repopulation of the Chee, the Department of Fisheries was pressed to restore the fishes immediately by introducing hatchery reared fish. Millions of fry of some 20 fish species, including several exotic species, were introduced in the second half of 1992 and early 1993. Most of these introduced fish presumably died very soon, probably just as well from an ecological standpoint.

4. "If Pak Mun Dam does cause any changes in the fish community, the Department of Fisheries and EGAT have several proven mitigation measures available to respond to any changes."

Deterioration of fish habitats and loss of fish biodiversity of the Chee and Mun Rivers will not be adequately documented, let alone mitigated. Effective mitigation measures do not exist for tropical rivers with rich fish faunas that have been dammed.

Most of the "proven" mitigation measures of EGAT and the Department of Fisheries, including fish ladders and use of hatchery stock to re-introduce fish species, have proven to be failures (see below).

5. "The Department of Fisheries will operate a fish ladder [on Pak Mun Dam] that will be constructed using a design proven at Phayao Dam."

The fish ladder on Phayao Dam is one of the first to be installed on a large dam in Thailand. A study of the use of the Phayao fish ladder by migrating fishes by PHOLPRASITH (1990) has been widely publicized.

Unfortunately, this study was conducted relatively soon after renovations of the fish ladder were completed, and there has been no subsequent follow-up study. Since then Phayao Reservoir suffered two set-backs with severe effects on fish life: a major infestation of *Eichhornia*, followed by drying up of the reservoir. For many months there has been no water flowing out of the fish ladder. Thus all fish migration has been disrupted.

It must be asked, what use is a fish ladder to river fish, if it only permits them to move from one place where they cannot live (i.e., the outflow of a dam) to another place where they cannot live (a reservoir)? But this is only the beginning of the problems with fish ladders.

In the case of the Mun River, the outflow from the Pak Mun Dam is a very short stretch, only 5 km, before it flows into the Mekong. Thus the problem of the outflow as poor fish habitat is not so important as it is with dams in which a biologically impoverished outflow is the only available fish habitat for hundreds of kilometers.

The main barriers to riverine fish will be the turbines, Pak Mun Dam itself, and the reservoir above the dam. Statements to the contrary notwithstanding, the dam will disrupt the downstream flow of organic materials at the base of the food chain, as well as severely inhibit important upstream and downstream fish movements.

It is to be expected that for very long periods (most of the time, perhaps) the only downstream route for fish past Pak Mun Dam will be through the turbines. But we are not to be overly concerned about this: less than 8% of fish passing through the bulb turbines will be killed (WORLD BANK, 1991).

The most effective fish ladders known, including the kind installed at Phayao and now proposed for the Pak Mun Dam, will not be sufficient to permit migratory fish to survive in the Mun River. The observation that a portion of migrating fishes are able to pass a ladder is not sufficient evidence that the fishes will continue to return year after year to pass the ladder, as they must if the populations are to survive. With each passing year the number of fishes, whether of species or of individuals, using the fish ladder on the Pak Mun Dam will decline until finally no naturally occurring migratory species are left.

The strongly migratory fishes of the Mun River include two ecologically and commercially important groups, both of which are certain to be adversely affected by the dam. First of all are the forage fishes, of fundamental importance to the food chain of many other fish species, and often utilized directly by man. These fishes feed very low on the food chain. In the Mun River they are mainly cyprinid fishes such as pla soi, *Cirrhinus* spp (including *C. siamensis*), pla lang khon, *Labiobarbus leptocheilus,* and pla paep, *Paralaubuca typus,* but also the endemic Mekong freshwater herring, pla mak pang, *Tenualosa thibaudeaui.* Then there are the large migratory fishes, all of commercial value. Many of these are cyprinids, such as *Cosmochilus harmandi, Cyclocheilichthys enoplos,* and *Morulius chrysophekadion.* But in the Mun River, as in the mainstream of the Mekong itself, many of the most important larger migratory fishes are catfishes of the families Siluridae and Pangasiidae. Among the more important species are the silurids *Belodontichthys* sp, *Kryptopterus* spp (*K.* cf *apogon* and *K.* cf *bleekeri*), and *Hemisilurus mekongensis,* and the pangasiids *Helicophagus waandersi, Pangasius conchophilus, P. larnaudei,* and *P. macronema.*

Any measure of the success of the fish ladder on the Pak Mun Dam must include its effectiveness in permitting the long-term continued migration of these and other migratory fish species. The Mekong *Tenualosa* herring (already severely declined throughout its range) and the large Siluridae and Pangasiidae are not part of the much smaller fish fauna that utilized the fish ladder on Phayao Dam, which included almost no catfishes. I observed a catch of *T. thibaudeaui* taken in the Mun River near Ubol Ratchathani in June 1993, but doubt that the species will still be there in June 1999. It is doubtful whether any of the catfishes will make effective use of the fish ladder.

6. "The DOF's research center at Ubol over the years has demonstrated that they can culture over 25 species of local fish (all of which were present in the April 1993 samples from the Mun River)...The Fisheries Increment and Development Center to be based near the dam will have hatchery facilities, and should be capable of augmenting the reproduction of any commercially important species that experiences a decrease in abundance in the area."

What can be said of plans to have the Department of Fisheries re-stock Pak Mun Reservoir with fish? Taken to its logical conclusion, it would mean replacement of a highly diverse naturally occurring fish fauna of well over 200 species, with a substantially impoverished artifical one dominated by some 25 species, all or most of which will have to be perpetually renewed by stocking.

7. "All blasting [at Pak Mun] occurs within cofferdams, or when the area in question is dewatered naturally during the dry season. This practice should continue, and will adequately protect any fish from the blast shock wave."

Hundreds or even thousands of tons of dynamite and other explosives, and a lot of heavy earth moving machinery, have been used in constructing Pak Mun Dam and in clearing the channel below the dam. The main channel (or tailrace) is about 2.3 km long, 80 to 100 m wide, and at least 4 m deep. It was formerly occupied entirely by the finest rapids in the Mun River. The channel will divert most of the water that would flow through what little remains of the rapids in Kaeng Tana National Park.

Excavation of this channel has resulted in elimination of rapids as a significant fish habitat in the Mun River below the dam. The rapids in the Mun River above the dam will be effectively eliminated by inundation and siltation.

Fishes cannot totally vacate rocky stretches of river isolated in so-called "dewatered" cofferdams or from rocky areas "naturally dewatered during the dry season." The opportunity to sample rapids-inhabiting fishes killed by explosives has been wasted, and consequently the only knowledge we shall ever have of the rapids-inhabiting fishes of the Mun River is extremely limited. Before Pak Mun Dam was built there were large populations of numerous specialized rheophilic fish species, including but not limited to several species of *Garra*, one or two *Gyrinocheilus*, several homalopterids, and the remarkable endemic Mekong hairy pufferfish, *Tetraodon baileyi*.

Enough remains of the rapids of the Mun River in the 5 km stretch below Pak Mun Dam for visitors to Kaeng Tana National Park to see what rapids look like. But the rapids will certainly not retain anything like the diversity of rapids-inhabiting fish species previously present.

The rest of the rapids of the lower Mun River have been blasted away and/or inundated, and therefore are no longer rapids habitat. Kaeng Saphu, the rapids furthest upstream from the dam, will be flooded most of the time. For three months during the tourist season, water levels will be lowered during the daytime so that tourists will be able to see the rapids. This will have virtually no benefits for rapids-inhabiting fishes which have been subjected to especially heavy siltation and long periods of stagnant or slow moving water and relatively low dissolved oxygen. All statements to the effect that Kaeng Tana or Kaeng Saphu rapids have been preserved refer to the purely cosmetic results achieved for tourists.

Kaeng Tana National Park is perhaps the only place in Southeast Asia, and certainly the only one in Thailand, in which a significant rapids of a large lowland river was officially preserved from destruction. While its total area includes some 80 square kilometers of terrestrial habitat not directly impacted by Pak Mun Dam, the most unique part with the rapids has been ecologically destroyed.

The direct effects of blasting and related activities on the fishes of the lower Mun River also should be documented, if only for the historical record. Darayes Mehta, Senior Power Engineer for the World Bank, was quoted as saying "the blasting does not have an impact on the rapids, although the noise and explosions have scared the villagers" (*The Nation*, 6 June 1993). He is undoubtedly mistaken in this, if he did in fact make such a statement, as is evident from the photographs in Figures 11–13. A channel 80–100 m wide and 4 m deep was excavated straight through Kaeng Haew and Tad Hua Poo rapids in Kaeng Tana National Park.

The main work of excavation was done below the coffer dam near the site of the dam, from the first week of November 1991 until May 1992, a period of 6 or 7 months. According to officials, the extensive and prolonged blasting and excavation had no deleterious effect on fishes. This is doubtful.

There have been reports that after villagers complained about fish kills resulting from blasting during the first week of November 1991, Thai and sometimes foreign construction workers brought pesticides or other chemicals to kill fish so they could be picked up before each blasting. From December 1991 until May 1992 blasting was done three times every day—in the morning around 9 a.m., at noon, and again at 6 p.m. Since then extensive blasting and excavation have been conducted at least intermittently until as recently as the end of December 1993 (date of writing). The same sort of fish poisoning by or for local villagers reportedly continues but results in relatively few fish.

In explanation of the above statements, I am not complaining about the poisoning of fish in the rapids below the coffer dam. Fish remaining in the lowered and barely flowing water would die very soon anyway, either by blasting or excavation, or by heating and deoxygenation of the water. In such circumstances, use of poison is a much more effective and less wasteful means of harvesting the fish than use of explosives. With explosives, most of the fish would be lost, whereas with poisons most can be recovered. My complaints are rather that far more fish have been killed because of the blasting and related activities than was foreseen or has been acknowledged, and that little or no effort was made to make extensive collections and scientific investigation of fishes in the rapids when they would have to die anyway.

DISCUSSION

Pak Mun Dam has effectively extirpated the Mun River from the rest of the Mekong riverine ecosystem. This can only have deleterious effects on the ecology of the Mekong River itself. As to the Mun River, its disrupted and simplified ecology will be subject to steadily increasing pollution (largely resulting from industrialization based on hydroelectric power) and infestation by aquatic pests and disease organisms.

A valuable paper on negative environmental impacts or threats to fishes has been published by BEVERTON (1992). He points out that fishes living in freshwater habitats (especially large tropical rivers) are much more threatened by extinction than those in marine or estuarine habitats. The main threats to freshwater fishes, in order of the "increasing ability of the fish themselves as self-maintaining populations to gain relief" may be identified as follows (modified from BEVERTON):

1. Partial or complete destruction of habitat (including deforestation);
2. Blockage of migration routes;
3. Reduction of water flow and/or volume;
4. Deterioration of water quality (through chronic and episodic toxic effluents, deoxygenation, eutrophication, siltation, nutrient depletion, or thermal pollution);
5. Adverse effects of introduced species; and
6. Excessive depletion by fishing.

As explained by BEVERTON, combinations of two or more threats can be far more dangerous than a single threat. Pak Mun Dam will be the direct or indirect cause of all of these kinds of threats except the last (and least important) one.

The foremost cause of the widespread ecological deterioration (including decline of fishes) in Thailand undoubtedly has been the destruction of the forests. In prehistoric times probably 90–100% of the country was deeply forested. At present, only about 25% is forested, and much of this is degraded forest or rubber plantation. While cutting the forests began hundreds of years ago, most of the loss occurred only in the last 50 years (since World War II). For a detailed account of the destruction of Thailand's forest, and of the cost in terms of human suffering, see LEUNGARAMSRI & RAJESH, 1992. The first large dams in Thailand, built in the 1920's, were for irrigation and flood control. The problem of severe floods, as well as that of water shortage, may always have been due mainly to deforestation. Unfortunately, construction of dams in this country has not always been accompanied by watershed protection; on the contrary, in most places dams have led to increased forest destruction (TUNTAWIROON & SAMOOTSAKORN, 1986). When the forest goes, the main source of natural organic nutrient input to rivers also goes; many small permanent streams dry up completely and larger permanent tributaries dry up seasonally. Fishes living in forested watersheds disappear just as rapidly as do forest birds, mammals, and other organisms.

Migratory salmon do not exist in the Mun River or anywhere else in the Mekong basin. Nor do they exist in any of the other large tropical river basins in Asia, Africa and South America where large dams are destroying highly productive riverine fisheries based mainly on strongly migratory fish species. The absurd notion that since there are no salmon in the Mekong basin there are no "truly migratory fish species" evidently originated in the numerous papers of V.R. Pantulu, former fisheries expert for the Mekong Committee. It subsequently has been standard dogma of World Bank officials and consultants whenever dismissing the impacts of dams on fishes of the Mekong basin.

To say that there is little or no published literature on extensive fish migrations in the Mekong and therefore no evidence that they occur is absurd, as anyone who has the least knowledge of the folklore and fishing traditions of the Mekong riparian peoples (including the fishermen of Pak Mun!) can readily attest. The extremely important migrations of Mekong fishes into and out of Cambodia's Grand Lac was extensively documented by FILY (1962) and in a series of shorter papers by d'Aubenton (e.g. D'AUBENTON, 1963), all of which were or should have been available to Pantulu. All Thai people know about the famous long distance migrations of the Mekong giant catfish or pla beuk, *Pangasius gigas,* formerly also an inhabitant of the Mun River. Everyone who has visited the famous fisheries at Pak Mun (the mouth of the Mun River) knows (or should know) that they are based almost entirely on seasonal fish migrations.

One additional fallacy concerning migrations of tropical riverine fishes should be exorcised. This is that migrations for reasons other than reproduction (i.e. for dispersal or feeding) are somehow of relatively little importance (e.g., WORLD BANK, 1991). In fact, all of their migrations are essential adaptations of the fishes, as self-regulating populations, to the linearity and seasonality of the riverine ecosystem.

Yet another idea of dam proponents concerning fisheries that needs to be debunked is that reservoir fisheries are far more productive than riverine ones. In some instances a reservoir may have more productive fisheries than the portion of river it has flooded, but this only occurs at a greater cost to the riverine fisheries far upstream and far downstream from the dam and its reservoir.

Officials and consultants have made much of the statement that the Pak Mun Dam is

Figure 10. One of the thousands of detonations used in removing the rapids and excavating the streambed for Pak Mun Dam.

Figure 11. Kaeng Tana National Park Rock Quarry.

Figure 12. Completed excavation, with water held back by coffer dams.

Figure 13. The terminal result: the biologically impoverished outflow canal of Pak Mun Dam.

a "run of the river" hydroelectric dam, and that therefore it will have little or no negative environmental impact on fisheries compared to "large storage dams with stagnating masses of water" (WORLD BANK, 1991). It is nice to see dam proponents for once candidly acknowledging the negative environmental impact of stagnant reservoirs created by large dams. "Run of the river" dams are supposed to permit hydroelectric generation based on straight flow through of the river or minimal water storage. In theory, a run of the water installation could offer virtually no obstacle to up- and down- stream fish movements, but this is not the case with Pak Mun Dam. The Pak Mun Dam spillways will be opened from the bottom of the dam, rather than from the top, in order to facilitate fish movements. However, even under the best circumstances, the spillways will be open during only about three months of the year (WORLD BANK, 1991). Even during these three months, they will be closed at night, the only time when migratory activity of catfishes and some large cyprinids occurs. And this is only under the most favorable conditions. In case of drought—highly likely because so much of the catchment area of the Mun River has been deforested—the spillway gates are liable to remain closed regardless of whether fish need them open. For much of the time, therefore, Pak Mun Reservoir will be a large storage reservoir with a mass of stagnating water unfit for most species of riverine fishes.

Although there is virtually no published information on the topic, the lower Mun River provided important spawning grounds for some of the large migratory cyprinids and catfishes important in the commercial fisheries. In June 1985 I collected thousands of very young *Pangasius* spp (probably *P. conchophilus* and *P. macronema*) in the Mun just upstream from the bridge at Ubol Ratchathani. The sample also included young of the silurid catfish *Hemisilurus mekongensis*. The lower Chee River including its mouth in the Mun River a short distance upstream from Ubol probably was an important spawning ground for these and other migratory fishes. The moderately swift flowing and well oxygenated water in deeper water below each of the rapids in the lower Mun River probably were important spawning grounds for *Cosmochilus harmandi, Cyclocheilichthys enoplos,* and other large cyprinids. Young of the year of the rare endemic Mekong predatory cyprinid *Aaptosyax grypus* are known from only three localities, all just below mainstream rapids. One of these localities is just below Kaeng Tana in the lower Mun. I have examined only four adults: all were gravid or ripenning females, nearly lm long and weighing 6–15 kg, and all were caught in or near the mouth of the Mun River.

Only since 1963 have large dams been built to provide domestic and industrial electrification for Thailand. In the past, when electricity consumption was far less, hydroelectric dams contributed up to 50% of the electricity consumed in Thailand, but since 1990 that figure has been less than 10% (ANON., 1992), and further decline is inevitable. Perhaps the only socially and economically valid reason for building more hydroelectric dams is for the creation of secondary industrial centers in places like Khon Kaen and Ubol Ratchathani. The building of Ubolrat Dam facilitated the development of industries that polluted first the Nam Pong and then the Chee River, with devastating impact on fishes and fishermen. This pattern of dams followed by industrial pollution, already established on Thailand's Meklong, Tachin, Chao Phraya, and Tapi rivers, is almost certain to be followed at Ubol Ratchathani and the Mun River.

During almost the entire history of Thailand people have been able to swim, bathe, and play in the rivers, which also provided safe drinking water and fresh fish, prawns, clams, and snails. Only in the last generation have rivers become unfit for humans and fish.

The fishes of the Chee River cannot protest or speak for themselves, so let us hear the voices of the fishermen who depend upon them for a living. Listen to Niang Phusatod, 70:

> "I am a fisherman and earn a living from this river. I could tell my future right away from my first glimpse of the ruined river. My family must hurry to make money by netting as many fish as possible; it will be the last time. Why did a factory discharge poisonous water to kill the river, to take away our resource? It has been a very long time since I have seen fish of such large size. They are the king of each species of fish and they live in their own palace deep in the water. No one can catch them because they are too clever—they have many tricks to survive our fishing gear. Their appearance on the surface means that their palace is in ruins. These large fish have endured much. It is sad to see them die like that. If they have deserted their palace, it must naturally mean that other fish cannot survive in this water" (quoted in *Bangkok Post*, 5 April 1992).

Run Chaiwest, 51:

> "If fish could speak, they would have screamed painfully for help. They would have asked why they were made victims and who had the right to take away their lives. I have been a fisherman all my life. I do not know what I can do except fish" (*The Nation*, 12 April 1992).

Sawat Bunpang, 61:

> "in all my years I have never seen some of the kinds of fish that have been killed. I did not even know that the Chee River had so many fish in it: (*The Nation*, 12 April 1992).

While stocks of some Chee fish species will no doubt reproduce explosively as the molasses disappears, it may be a long time if ever before the rest of the species make a comeback. Recovery of fish stocks has been complicated by introduction of exotic fish species. Under pressure from a previous government, the Department of Fisheries released large numbers of *Tilapia nilotica, Cyprinus carpio,* and other exotic fishes into the Nam Pong and Chee in 1992–93. These are likely to destroy eggs and young of naturally occurring species when they can least withstand any additional predation pressure. Recovery is also complicated by the survival of large numbers of predatory air-breathing fishes which were not killed outright by the molasses spill but are now starving to death. This includes four or five species of the extremely rapacious snakeheads, *Channa,* and the climbing perch, *Anabas testudineus.* Enough of them will survive to devastate stocks of other fishes for years to come.

Tropical rivers which have been deforested and dammed are characterized by loss of entropy, nutrients, habitats, and biodiversity. They become increasingly simplified ecologically and unable to withstand additional impacts such as pollution (of whatever kind) and establishment of exotic pests such as water hyacinth. The latter is the worst aquatic plant pest in the world, and is now a prominent feature not only of nearly all of Thailand's reservoirs and canals, but also of her rivers that have been damaged by deforestation, dams, and defaunation. Evapotranspiration of water by this plant is one of the most important causes of water loss in dams and has contributed to the present water shortage in Thailand. Lack of dams is not the cause of water shortage in Thailand; they are part of the problem, the major causes of which are deforestation and rice cultivation. Additional dams might ease the water shortage in the short run, but in the long run they will only exacerbate it. Water shortage is hard on humans and on fish.

Episodic pollution, such as the 1992 molasses spill into the Nam Pong and Chee rivers, often results in massive fish kills and public attention. Chronic pollution, however, is probably an even more serious problem for riverine fishes. It can inhibit their growth, lower their resistance to disease (including human diseases such as opisthorciasis for which fishes are the intermediate hosts), and interfere with their ability to reproduce. River pollution of all kinds is particularly severe in Thailand, which has had rapid riverside industrialization with very little consideration for the environment, and where regulations on pollution are relatively weak and their enforcement weaker still.

Menam Mun is not a minor tributary of the Mekong River, but rather the Mekong's largest tributary. The Mekong has begun to suffer the death of a thousands cuts; building Pak Mun Dam is a particularly heavy blow, equivalent to cutting off a leg.

Pollution from industries based on Pak Mun electrification will have a direct impact on the mainstream Mekong riverine fisheries of Laos, Cambodia and Vietnam. An extensive and intensive systematic inventory and ecological study on the fishes of the entire Mun and lower Mekong basins should begin at once, concurrently with long term monitoring of all fisheries impacts of Pak Mun Dam.

CONCLUSION

It is time for a moratorium on construction of large hydroclectric dams in Southeast Asia and for a moratorium on industries that release toxic wastes into rivers. Thailand's most pressing development need is not further industrialization but restoration and protection of forests and rivers. The sooner this is recognized and acted upon the better.

Officials of the World Bank, Asian Development Bank, and the Mekong Secretariat should realize that the received truths concerning development that once seemed true are true no longer, or at least not so true as they once seemed. It is time to exercise better judgment and more enlightened conduct. We must not continue on the path of unrelenting environmental degradation.

It is not too late to halt and then reverse ecological destruction and defaunation, but it will require substantial changes in attitudes and in ways of doing things. Deforestation, dams, and pollution are not isolated events but part of a world-wide pattern of politically expedient but unwise and too rapid economic development, unrestrained by adequate environmental protection. It is an open question whether businessmen and politicians can adjust their attitudes and operations sufficiently to safeguard rather than destroy mankind's greatest heritage, the biosphere and its biodiversity.

Make no mistake: Mankind's greatest material heritage is an ecologically healthy planet Earth. Our greatest source of aesthetic, artistic, and intellectual inspiration and material well-being and wealth is Earth's amazing variety of living organisms. Human overpopulation—currently largely ignored and little spoken of in Thailand—is only one of the root causes of environmental destruction. Another is the over-riding materialism of modern "societies" (one might say "anti-societies," really) and the blindness of the unlimited pursuit of material gain in the name of national development and international trade [largely trash] which is unrelentingly linked to increasing environmental and spiritual impoverishment.

In an imaginary world, with infinite untapped resources and infinite ability to dispose of waste products, unregulated capitalism stimulated by capitalistic selfishness might be a workable strategy to provide the best quality of life for the greatest number of people. But the real world is quite finite, especially in its ability to dispose of or recirculate waste products, and it is impossible to maximize the quality of human life (however it might be judged) with the largest number of people the planetary ecosystem can possibly support.

I do not believe that there are or ever will be adequate technological solutions to this dilemma. We must learn to live with the reality of a user-friendly but finite planet Earth. It's life sustaining resources are already being depleted at an unsustainable rate.

A high-ranking but unusually candid and outspoken Thai official recently declared that there will soon be so much development and so many people on the land in Thailand that it will no longer be possible to grow any food there. He foretold that it would be necessary for Thailand to obtain virtually all of its food from the sea. I doubt that he really meant what he was saying. By the time the land of Thailand could no longer grow any food, the marine ecology also will have been seriously impaired. And Thailand would not be the only country competing for her "rightful share of marine territory" for farming.

I hope the world will recover from its present state of ecocidal (really suicidal) capitalistic cupidostupidity in time to avoid destroying the life-sustaining capability of planet Earth. Apart from destroying our planetary ecology entirely, the one crime future generations will regret most will be the loss of biodiversity.

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