

ASIAN DEVELOPMENT BANK

**CUMULATIVE IMPACT ANALYSIS
AND NAM THEUN 2 CONTRIBUTIONS**



Annex 4: Fish Biodiversity and Fisheries

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November 2004

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1 INTRODUCTION

Large rivers worldwide play an important role in any single nation's ecology, economic status, social latticework and cultural background. Large rivers must be viewed as a multiple-use resource providing support for a wide and diverse range of industries and activities. These include navigation, fisheries, irrigation water supply, transport, power production, and support to various industries and recreation. By their very nature, not all the above mentioned uses are mutually compatible, and conflicts between "users" and various resource stakeholders are commonplace worldwide.

Large rivers provide important social and economic benefits to the populations of both the "developed" and "developing" nations. The fisheries that large rivers support represent a source of food, employment and income worldwide, often for the poorest sections of the community. Large river fisheries are considered to be universally under-valued, and often are not given the priority they deserve in river basin management planning.

During the past 100 years or so, various endogenous and exogenous factors, together with many different anthropological interventions, have brought about a degradation of many large riverine habitats, and freshwater fisheries in particular. Because of the complexities associated with these changes, solutions in terms of management practices, conservation, restoration and rehabilitation of degraded large river systems dictate that a multi-disciplinary approach be adopted. Experts in the fields of ecology, conservation, fisheries biology, hydrology, limnology, engineering and geology are required to work together to formulate optimum management strategies for large river systems and their respective fisheries.

Large rivers [such as the Mekong], and their associated wetland habitats, support a significant part of the world's aquatic bio-diversity. Sustaining bio-diversity and fisheries in large rivers require that habitat management and exploitation management be considered in parallel.

Given that millions of people living in the LMB that rely on fisheries for one reason or another might be affected by water-related infrastructure development, it is essential that Mekong Basin development be analyzed and assessed from a holistic point of view. Whereas isolated projects require their own EIA's to focus on localized impacts on fisheries, and the problems that these may cause to riparian communities, what is required for a broader view for the entire Mekong Basin is a cumulative impact assessment (CIA study), to which this ADB funded study is a contribution

2 MEKONG FISH BIODIVERSITY AND ECOLOGY

The Mekong is rated as the world's 12th longest river, and is placed in 8th position in terms of flow volume. Its fish bio-diversity is outstanding, and may eventually surpass any of the other river basins that have been studied worldwide, where data have been collected on fish bio-diversity.

There are an estimated total of about 1,200 fish species found in the Mekong Basin. The number of recognized and described species is increasing every year, as taxonomic and classification experts are able to gain access to remote areas and collect samples from hitherto unexplored habitats in mountain streams and

other upland regions. Even large species, of up to 20 kg in weight, have only recently been scientifically described from the Mekong basin within the last decade [REF]. There are undoubtedly more fish species to be discovered and reported on in the scientific literature. Most or all of these species are almost certainly known to local people, and have local names, but some are as yet not known to science.

As with most, or perhaps all other freshwater fish communities, the resident fish fauna of the Mekong Basin is dominated by the Cyprinidae [carps] family. Other important families include Osteoglossidae [featherbacks], Clupeidae [herrings and anchovies], Siluridae [catfishes], Sisoridae [catfishes] and Pangasiidae [catfishes] and a large number of other families with their associated genera and species

There are a large number of catfish species families and groups in the Mekong Basin region. Typically, “catfish” are assumed to be bottom-dwelling species, and it’s true to say that many are (but not all species). Some Pangasid species are predatory (eating other fish), and some graze on algae and its associated biota. Some species eat fruits and flowers on a seasonal basis when they are available. Some species of the Pangasiidae are carnivorous only, and only eat live, dead, or decaying prey items. Other “catfish” species are active predators and consume a wide range of prey-items, including prawns, crabs and other fish species (Silurids, Bagrids, and members of the Sisoridae genus).

The indigenous and scientific knowledge surrounding what actually governs the fish production in all of the Mekong’s diverse range of habitats (Mekong main-stream, tributaries, the Great Lake in Cambodia, small rivers and seasonal back-swamps) is limited to say the least. Our knowledge of migratory patterns, fisheries ecology and biology of many species is fragmented and poorly understood in many cases. However, some models do exist that try to incorporate all aspects of Mekong fisheries, and the likely effect(s) that water-related development may have on the future of this resource.

The Mekong owes its rich fish bio-diversity mostly to the annual variation in extreme flow patterns and climatic changes throughout the different seasons. This involves periods of the flood-pulse, and also when waters begin to recede at the end of the rainy period, allowing other processes to take place, including the re-oxygenation of nutrients in floodplain areas. The annual flood-pulse physically moves aquatic organisms and their juveniles into appropriate areas where they can complete their life-cycles [flooded forests, floodplains, mangrove swamps and, in some cases, into lower areas such as the Mekong delta in Vietnam]. An annual re-generation of phyto- and zooplankton populations as a result of the release of oxidized nutrients, supplies the basic food-fuel required for almost all of the aquatic biota associated with the food chain, and upon which many people ultimately rely on for their livelihoods in terms of Mekong fisheries.

Most migrations of animal populations, including fish, are cyclical in nature. This requires that the adults of most species return to other habitats and environments where they can carry other essential and critical life-cycle events. Some species of Pacific Salmonids for example, simply die after completing their migratory route to remote areas in Northern American streams from the marine environment. Many have spent a number of years feeding and developing into adult fish thus enabling them to return to riverine environments where they can eventually spawn. Their death contributes to the nutrient chain and, following their bodily decomposition, this provides food for juveniles. To our present knowledge, no

such processes occur with Mekong fish species, but the Mekong basin fish species are always full of unexpected surprises and uncertainties.

Fish migration is difficult to define. Some freshwater species only need to move a few meters to spawn and / or feed from their current environment. Other species make a journey of hundreds, or even thousands of kilometers, to enter the habitats necessary for them to carry out critical life-cycle events that enable their populations to continue. It is probably safe to assume that ALL species of Mekong fishes are migratory to one extent or another. It just depends on who is describing a migration, or what is being precisely defined.

The Lao PDR, within the Mekong catchment zone [including the upland areas], **may** represent the most important country in S.E. Asia in terms of fish biodiversity, but this is difficult to substantiate at present. Hydropower, irrigation and other forms of water-related development will almost certainly have an influence on this, but accurate predictions are difficult to make.

3 POTENTIAL IMPACTS OF HYDROPOWER

3.1 Species Composition

Hydropower development expected to have some effect on fish production, both locally and regionally (lower LMB countries). Giant species (mentioned above) are already under threat for various reasons other than by further hydropower development in the Mekong Basin. Several species (about 10) are already at the “economically” extinction phase of their existence, but only a very few are at their “biologically” extinction phase (perhaps up to around 4 species).

Concerning hydropower project, there are some main groups of fishes that may be affected, both locally, and regionally.

Generally smaller fishes dominated by the Cyprinidae family (carps) that use eyesite to locate their food items in the relatively clear waters of the dry-season months. They typically have large eyes, and occupy the middle to upper parts of the water column (but not always). These may decline in number if re-suspension of base sediments is caused as a result of water-discharge during the dry-season months.

Some reservoirs in Thailand (Ubolratana for example) and the Nam Ngum reservoir in the Lao PDR have developed large populations of small pelagic species (*Clupeichthys* spp.). These species (two) occupy the “pelagic zone” of the two above-mentioned reservoirs at least and probably many other reservoirs throughout the region of S.E. Asia. They are not only important as a staple diet for riparian / reservoir predatory fish populations, but they are a source of protein for more lucrative aquaculture operations, such as the net-cage culture of expensive, marketable species.

Most species of fish do not occupy the pelagic zone of reservoirs, but thrive in marginal zones around the edges of reservoirs to a depth where oxygen becomes a limiting factor (typically around 10 m in tropical Asian reservoirs), but this varies depending on locality.

3.2 Impacts form Hydrological Changes

There are concerns that river regulation and the changes in the hydrological regime may have negatively impacted on fish populations, by preventing migration, or preventing access to, and escape from flooded plain areas and thereby causing damage to fisheries. Furthermore, fisheries may have been impacted already by pollution, such as from pesticides usage in irrigated tail-waters and from other sources.

The fish populations of the Mekong Basin have evolved and have diversified in a range of environments and habitats over hundreds of thousands of years. The specific habitats include the Mekong mainstream (and its “deep holes or pools”), tributaries, rapids, floodplains, and flooded forest areas with a range of variable base substrates. Natural variation in the annual hydrological conditions due to rainfall patterns causes a change to the size of species-specific fish population level. During years when rainfall is higher than normal, this causes a greater inundation of otherwise dry land in the floodplain areas. This in turn increases the available habitat for feeding and spawning. For some short-lived early-spawning species, the effects of a “flood year” can sometimes be observed relatively quickly. For other, slow growing, large species, the effects of a “flood year” may be delayed for some while, but not always so and not necessarily so.

Permanent changes to Mekong hydrological patterns will undoubtedly have an effect on fisheries production throughout the basin. It is a biological and ecological certainty. The main current threats to alterations in the Mekong hydrological pattern appear to be mainstream and tributary large storage dams for hydropower generation and for irrigation. The excessive abstraction of water for dry-season agriculture may be beneficial under some circumstances. Channelization, in whatever form it takes, can be highly damaging to fisheries. Channelization, including the destruction of rapids for the purposes of large vessel navigation may prove disastrous. Deforestation is a worldwide problem and has severe consequences for many river habitats, and the aquatic species that live there.

Since the absurd plans of the 1960's and 1970's intending to build the Mekong mainstream “cascade” (involving a large number of storage dams for hydropower development) have now been abandoned, the situation now looks much better for future mainstream and Great Lake fisheries. The construction of the mainstream Manowan dam in Yunnan Province in Southern China, and the near completion (or completion) of one more mainstream dam may have some consequences for downstream fisheries production in the LMB countries. However, they are at least “run-of-river” projects (although no such real thing exists in reality), and therefore the impacts that accrue from them are likely to be less than if large storage dams are built in the future.

Due mainly to the lack of English written literature from China, we are not certain about the migratory movements of fish in Yunnan Province, and how these relate to the LMB countries. However, through personal conversations with a number of experts, they are probably small in comparison to the annual migrations taking place in the Mekong in the Southern part of the Lao PDR, Cambodia, and between the Cambodian Great Lake and the Mekong mainstream via the Tonle Sap River.

Where migration routes cross international borders, stock-management becomes a trans-boundary issue and requires international cooperation. With the adoption of policies on decentralization, the four MRC member countries have taken steps

towards integrating management-intervention, which is crucial for the effective management of migratory fish stocks.

As I have attempted to explain in this brief document, it is near to impossible to realize any “near-accurate” figures concerning “catch” and “catch opportunities” in the rivers that will be impacted by some of the various hydro-development schemes in existence. Or the ones being planned for the Mekong region (NT2-XBF and the Theun-Hinboun projects, to mention just a few).

4 FISHERIES

4.1 Mekong Resources

Fish probably represent the most important component of the family protein requirements of the rural populations of S.E. Asian countries. As much as 2 million tonnes are estimated to be harvested on an annual basis in the Lower Mekong Basin (LMB) countries. However, other aquatic animals also need to be taken into consideration. These include reptiles, amphibians, crustaceans, and others that exist, and rely on the Mekong’s various seasonal habitats during the wet and dry periods for their continued existence and survival. In some cases, the life-cycles of the various species involved are not clearly understood, and some are poorly documented in scientific literature.

In terms of livelihoods, the Mekong River supports the life-requirements of some 70 million people. This figure also includes the various industries associated with the direct capture of fish, whose income relies on the fishing industry in general. The “fisheries” industry can be divided up into various categories and components. These include the fishing communities themselves, fish processing operations, marketing, law enforcement organizations, transport and various other sectors.

As noted above the present fisheries yield of the Lower Mekong Basin are thought to be around 2 million tons per year. The estimate is: 500,000 tons for Cambodia; 133,000 tons for Lao PDR; 795,000 tons for Northeastern Thailand; and 597,000 tons for Vietnam. The first hand value is calculated to be about US\$1,478 billion per year. FAO statistics indicate a steady increase in the fish yield in all lower Mekong countries during the period from 1988 to 1993. It seems however, that the stock is currently being utilized close to, or above the production capacity. The data on fish populations and catch is by nature uncertain, but there are indications that an over-exploitation of fisheries resources is in process. These include a decrease in the average size of some of the larger fish species being caught that form part of the international-trade and local commercial fisheries.

The fisheries sector, and its development and sustainability has always been, and will remain, problematical for the countries of the (LMB) in S.E. Asia. Unlike the forestry, agricultural and other sectors, fisheries and the trends they move towards, are difficult to monitor, manage and control. This is particularly so when river systems are co-managed by a number of different countries through which any particular river passes. The central governmental and the political policies regarding the management of the fisheries sector of one particular country, are not necessarily agreed to, and supported by the all the countries of the region.

Historically, this had led to a level of dispute and conflict between the countries that connect with each other via the Mekong River in S.E. Asia.

Assessing the aquatic resources of large deep rivers, and the monitoring of their quality and sustainability, is difficult because of the nature of all the factors that control them (physical, political, anthropological, ecological, environmental and climatical). The problem is compounded by the fact that the Mekong River is a host to a large number of trans-boundary migratory fish stocks. Anthropological exogenous and endogenous factors over the past few decades have altered the hydrological patterns in the Mekong and its tributaries. This has caused changes to resident biota, historical fish migration routes, river-side dry-season horticulture / agriculture, and the riparian natural plant population communities that interact with the various aquatic communities.

4.2 Staple diet

Fish is an important part of the staple diet, and the most important source of protein in the Mekong Basin. The average basin consumption of fish is 36 kg / person / year. This varies from 20 kg / person / year in the mountainous zones to around 60 kg / person / year in the flood plain areas of Cambodia and Vietnam. The Great Lake of Cambodia is amongst the world's most productive freshwater fisheries region, representing about 60 percent of Cambodia's total freshwater fisheries annual catch.

Aquatic production far outweighs all other sources of the basic protein and other nutrient requirements in the lives of S.E. Asia's rural poor populations. This is not only limited to fish-catch alone, but also includes crabs, frogs, prawns, snails, snakes and certain aquatic weeds. Disruption to this production may have profound implications for food security issues, and the eventual political and social stability [or instability] of the LMB countries.

Based on my own personal observations and information, it should be stated that the above estimates for fish consumption of 20 kg / person / year (mountainous regions) and 60 kg / person / year (floodplain zones) are probably underestimates from Mekong Basin wilderness fisheries.

The Government of the Lao PDR is well aware of the importance of wilderness fisheries to local economies and food security issues. These have to be balanced, and weighed against, the benefits that come from water-related development projects. Evidence to date suggests that all aspects are being considered.

5 NT2 NAKAI HIGHLAND RESERVOIR

The Nam Theun is host to a cold-water fish fauna. Many of these species also occur in lowland habitats, but some species are new to science, and have yet to be fully described and reported on in scientific literature.

The construction of a reservoir involves a conversion of a lotic (flowing) system into a lacustrine one (static). This may particularly have an affect on some rheophilic species (those fish species that require flowing water to complete their life-cycles). Certain species will have no problem in adapting to the new "reservoir" conditions and will likely proliferate and dominate the species composition. These will include a number of Cyprinid species, and also the labyrinthine group of species including Snakeheads (*Channa* spp.), Climbing Perches (*Anabas testudi-*

neus) and several species of Gouramy (*Trichogaster trichopterus*, *Trichogaster trichopterus*, *Trichogaster microlepis*, *Trichopsis pumila*, *Trichopsis vittata* and *Osphronemus exodon*). A number of other species will also thrive and survive in the reservoir. These include a whole range of small species from the *Rasbora* genus and several other genera. The effect that NT2 will have on prawns, frogs, crabs, snakes and other aquatic animals, that also form part of the diet of the Lao rural population, is uncertain on the Nakai Highland. It may increase, or decrease in availability. Irrigated land during the dry-season months may favor the production of strictly non-fishery (fish) protein production for human exploitation.

6 XE BANG FAI

The additional discharge of about 280 m³/sec of water into the XBF has the potential to be damaging to fisheries, particularly during the dry-season months. During this period, this may cause the erosion of riverbanks and the re-suspension of base substrate material (sand, silt and base muds). This has the potential to smother important primary production elements that form an essential part of the diet of many fish species during the dry-season months. Erosion effects, and elevated water levels, may also cause damage to certain plant species that have become established on the rocky outcrops both within, and along the riverbanks of the XBF. Some of these plant species undoubtedly form an important part of the ecological association between the river and various aquatic animal populations. This may ultimately negatively affect fish production. This has probably already taken place at the Theun-Hinboun Project, but cannot be adequately assessed and reported on.

There is a possibility that NT2 will discharge polluted [thermal and chemical] water into the Xe Bang Fai (XBF). This is particularly a potential threat to the XBF if the NT2 reservoir is not cleared of vegetation prior to the dam being closed. However, given that the total clearance of vegetation is not likely to take place (apart from the extraction of expensive hardwoods), the problem may be mitigated to some degree by fitting a variable water intake at the dam and provision is being made for a re-oxygenation weir below the powerhouse. This is being planned at NT2.

Impacts to fisheries must be expected as a result. Many species of fish rely on the annual production of a filamentous algae species (or perhaps several different species) that develop on hard and soft substrates during the dry-season months. It [or they] only appear during the dry-season months, because light can penetrate the relatively clear, shallow waters. This provides the “food fuel” for many species of fish to build up the necessary fish reproductive products (eggs and sperm), and also provides the necessary energy to enable fish to undertake migrations. Not all fish species utilize it, but many do. Those that do not use it are in many cases predatory species, which of course rely on the availability of the prey species to complete their life cycles.

Having “gorged” on this for 3, 4 or 5 months, they are then ready to migrate to their many different critical environments for spawning. When the seasonal rains arrive in May and June, that continue until about October each year, the filamentous algae dies [because of water turbidity and reduced light penetration], and the material joins the detrital food chain. This provides food for other species that are “bottom” dwellers [some Cyprinids and various species of catfish, including Pangasids, Bagrids, Silurids and other fish families].

Fish rely on certain physical and chemical factors concerning the annual rise and fall of the mainstream and tributary waters to gauge their movements (migrations). The additional discharge of water into the Xe Bang Fai may cause migratory disorientation, and cause fish to move prematurely on an annual basis. Initially, this may appear to be a positive impact, because more fish may be caught out of season. But when the system reaches a new equilibrium phase, the overall production of fish may be less due to disruption of natural habitats and normal conditions. These include perturbations to spawning and feeding habitats brought about by non-seasonal flow patterns and natural hydrology. Any seasonal deviation in flow regime will almost certainly have an effect on fish production.

Fish populations have evolved in alliance with natural conditions (forests, floodplains, water flows and flood-pulses etc.). Disruption to any of these elements will have some effect.

Also the issue of “thermal pollution” needs some consideration. The Nam Theun is a “cool water” river, because of its high elevation. The sections of the XBF that may be affected by the NT2 are warm in comparison to many upland streams and rivers. Fish, being poikilotherms (cold-blooded animals), rely on ambient water temperature to grow and carry out their normal bodily functions. There may only be a minimal effect in the XBF, because the water discharged to the XBF will have been stored in a shallow reservoir (Nakai Highlands), and will traverse a 27km channel before being discharged into the XBF. Both the above factors could mean that water temperatures in the XBF might remain more-or-less the same given the seasonal variation that exists anyway.

The current, ongoing, pre-impoundment fisheries study concerning the XBF (financed by NTEC) aims to look at a RELATIVE index of abundance of fishery resources. This is to say that it will try to compare pre- and post impoundment levels of relative fish catch using a technique known as Catch Per Unit of Effort or [CPUE] used as an abbreviation. The pre-impoundment study is due to be completed in the year of 2006, and will result in a final report in addition to annual reports summarizing the data collected during each year.

The CPUE data are being collected from 21 fishers in seven different villages throughout the anticipated “Impact Zone of the lower XBF”. A reliable “fish production figure” is unobtainable for a river such as the XBF, because of the seasonal movements of fish during their annual migrations. Apart from a few species that do not appear to migrate over large distances at least, a “standing crop” (kg / ha / year) is impossible to calculate, and does not exist in reality. The so-called “standing crop” moves all the time. Sometimes it is in the XBF, sometimes it is in the Mekong, and sometimes it is in the Mekong floodplains and flooded-forest areas of Cambodia and elsewhere. The factors that actually affect the available “fishery production” in the XBF are dependent on a huge number of variables, and are way beyond the confines of the XBF itself, and its surrounding landscape. This is why the relative index of CPUE is being used.

7 NAM KADING AND NAM HINBOUN

The Nam Kading refers to the section of the Nam Theun that extends from the Theun-Hinboun dam to the river’s confluence with the Mekong at Pak Kading in central Lao PDR. The river meanders from the Mekong confluence for approximately 30km, as if it were a “normal” lowland tributary, before it starts its ascent to the Nakai Highlands. It is within this section of the river that conditions begin to

change. Huge sections of rock have toppled down from their ancient sedimentary bases higher up the valley, and now partially block the river's flow in some cases. This has created a special habitat for a range of fish species and other aquatic animals and plants. In addition to water entering this environment, it is cool in comparison with rivers flowing along the Mekong floodplains, such as the Nam Hinboun, Sekong and many other Mekong tributaries from the LMB countries. There are sections of rapids and riffle, and deep pools throughout the section of the Nam Kading that extend up to the Theun-Hinboun dam.

At the onset of seasonal rains in late April or May, many fish embark on their upstream spawning migrations in the Nam Theun and other Mekong tributaries. The fish come from the Mekong itself, and also from dry-season refuge habitats within the Nam Theun (deep pools). They move upstream to unknown spawning locations, but possibly as far up as the Nakai Highlands. They certainly reach the Theun-Hinboun dam, as I personally witnessed in April / May 1998. Huge numbers of fish (some of them large, and estimated to weigh up to several kilograms) are gathering below the dam crest, and clearly trying to get by it. Only under exceptional circumstances (flash-floods) can a very limited number of fish pass over the dam.

Because there is no provision at Theun-Hinboun for a return route for juvenile fish to return to the Nam Kading for population recruitment, fish populations have probably been badly impacted below the dam, all the way to the Mekong confluence. There is a major Nam Theun tributary approximately 40km downstream of the Theun-Hinboun dam, the Nam Mouan. It is just possible that if some species are not able to pass the Theun-Hinboun dam, these adult fish may return downstream and enter this tributary for spawning. The problem is that not enough knowledge is known about the "homing" behaviour of S.E. Asian fish in large tropical rivers such as the Nam Theun.

8 GREAT LAKE

It is assumed that NT2 will have an insignificant impact on fisheries bio-diversity in the Great Lake of Cambodia. Given that less than, or approximately 1% of the average inundation area may be affected, fish species bio-diversity should remain intact. As previously mentioned, the reasons why certain species are in decline, are way beyond, and not confined to hydropower development in the Mekong Basin at its present level. There is a potential threat to fisheries, and fish-bio-diversity if there is non-regulated, and poorly thought-out hydropower sector development. Upstream countries must consider the effects that their immediate development requirements might have on LMB countries, and the Mekong Basin and its fishery, which is clearly important in the lives of millions of people.

Several "giant" fish species are occasionally caught in the Bagnet [or Dai] fishery as they exit the Great Lake of Cambodia on their annual migrations, along the Tonle Sap River that connects the Great Lake to the Mekong at Phnom Penh. Some examples of these species include: *Catlacarpio siamensis*, *Pangasianodon gigas*, *Probarbus jullieni*, *Bosemania microlepis* and others. These fish are late maturing species, and have been in decline for many years now for various reasons other than hydropower development. This is probably mostly due to over-fishing with gillnets together with a general degradation of habitats, including the areas where they spawn. What appears to sustain the productive fishery of the Cambodian Great Lake is the reproductive capabilities of small, early maturing species. These fish often become sexually mature within one year and hence can

be harvested on a regular (annual) basis, but typically these stocks appear to remain intact. This is a common feature in many “fisheries” (marine and fresh-water) worldwide.

There is no evidence to-date that production in the Great Lake of Cambodia is in decline. Species compositions appear to be changing, but overall production (around 235,000 tonnes / year) seems to be the same as it has been for the past 20 or so years at least.

Fish “standing crop” estimates for the Great Lake vary considerably and range from around 139 kg / ha / year (Van Zalinge *et al.*) and further estimates by the Mekong River Commission (MRC) of 205 kg / ha / year to later figures of up to 330 kg / ha / year. In addition there is the question about how strong correlation exists between the lake area and the fish production and finally fish catch. It is therefore impossible to accurately estimate what the impact on fisheries caused by changed hydrological conditions.

The impacts of potential 20-year development are even more difficult to predict from a fisheries point of view. The status of fisheries in the LMB countries will be dependent on what further developments in terms of water-related projects take place both within the LMB countries and further upstream in Yunnan Province in China (the Mekong mainstream Hydro-cascade) and the Langcang Navigation Project to aid shipping through rapids. The latter project may send much larger volumes of water more quickly into the LMB countries during the wet-season months, and has the potential to cause increased flooding in the Mekong delta region of Vietnam. Also, it has to be said that this may partially compensate for water retention (Hydro-Irrigation) schemes that represent a potential threat to fisheries in the Great Lake of Cambodia.

9 MRC STRATEGY FOR FISHERIES MANAGEMENT

Within its Fisheries Programme, the M.R.C.S. has produced a strategy and an outline of a programme for an integrated fisheries management and development program. This is intended to cover both capture fisheries and aquaculture. The strategy emphasises the basin wide needs and benefits of structural, institutional, and human resource development efforts.

9.1 Institutional Strengthening

This will have to take place at different levels; local; district, provincial], and central / ministerial. The way forward is to begin at the local level, and then get it accepted at the provincial level and then seek approval at the central / ministerial level. There are many examples where this appears to have worked. Also, there must be a close association between resource “users” (fisher people in this case) and at the / District / Provincial level. Under a co-management situation, whereby local people [villagers] feel they can have a “voice” and can communicate with authorities [District and Provincial], this represents an essential component in any development process. Villagers are always the ones who ultimately represent the managers of natural resources.

What is initially required is a statement of the problems that need to be addressed and accurately identified, usually at the local level. There is an urgent need to clearly define the objectives of field and other forms of research, which has not always been the case in the Lao PDR. But the situation is now changing,

particularly as talented graduates in fisheries, and other areas, are returning from educational institutions within the Lao PDR and from overseas.

Training can be provided from external sources [resource management experts], and these can be brought in as and when appropriate. Also, a technical back-up system should be made available from a wide range of people who / that have specialised in certain areas (biology, ecology, engineering etc.).

One area that is particularly lacking in the Lao PDR's educational system, and is preventing talented young Lao people from conducting scientific research appears to be a lack of understanding of statistics and statistical methods. This prevents them from reporting on their findings and their significance in the scientific literature. Analysis of field data and interpretation of results from field data, is also a problem. Methods of data storage, and how to deal with it, are problematical for everyone. But it's important to decide on how the data should be analysed, before data collection begins.

9.2 Capacity Building

One way forward is for a system to be generated that allows the training of trainers [local nationals, in their own respective languages], with perhaps expatriate inputs where appropriate.

Several things that seem to be holding back scientific contributions to Asian fisheries knowledge is a lack of clearly defined objectives regarding various studies being undertaken, lack of knowledge on how to record, store, analyse and interpret data.

The lack of knowledge in basic statistics cannot be solved by "quick-fix" methods involving 2 or 3 day courses. Although this may be a starting point, an understanding of what statistics mean must be viewed in a broader context of the issues involved. That is to say, [why has this result been obtained]. There are often second, or third or more factors that can confuse the statistical result, leading researchers to think they are "on the right track". Parametric statistics are not mathematics, and are based on probabilities and associated factors. They still remain the strongest tools we have concerning examining data sets. This is a difficult issue to explain to people with little or no statistical training and background knowledge.

There is also a necessity to make sure that monitoring systems are in place in parallel with field research. Some field projects concerning fisheries have passed from a research phase [when basic things are trying to be understood] into a monitoring phase. The monitoring phase has to be something that can be achieved, and adequately reported on, given the limitations that are necessary to achieve it [budgets, human resources, geographical position etc.].

In particular, there appears to be a problem with the continuity of project fisheries staffing within the Lao PDR. This is to say that once people have gained experience in certain areas, they are then sometimes diverted to other departments or projects, where they have to "begin again". It is not my duty or responsibility to comment on this further and it is clearly a Lao issue and a subject for them to decide upon, considering what is appropriate for their needs and requirements.

9.3 Compensation and Mitigation

Hydropower and various other forms of water-related development generally have a negative impact on riverine wilderness fisheries. These also impact on the livelihoods of local rural populations, and cause a disruption to food consumption and local economies as a result. This is a sad, but an inevitable result of various “development” processes.

The means and ways of providing compensation for those villagers that are affected remains a controversial issue. Direct monetary compensation does not appear to work very well, and is anyway probably inappropriate in many cases. Perhaps the best way forward is to maybe study ways of agricultural / horticultural diversification, backed up by improved marketing methods for the products obtained from it. Dry-season irrigation schemes should also be considered and “driven” by extracting water from the Mekong mainstream and its larger tributaries. However, electrical pumps appear to be far cheaper to operate [about 50% cheaper] than diesel fuel operated units.

Mitigation procedures are difficult to define, and have anyway to be project-specific. In some cases, mitigation procedures simply do not exist. Rivers with large populations of migratory fish species rely on the linearity and continuity of riverine environments and habitats that are interconnected. If these are intact, this enables fish to move as, and when appropriate. Physical structures that interrupt these movements may create problems. Some species can negotiate some well-designed fish pass structures, but many cannot. Fish populations deprived of access to historical feeding or spawning grounds will suffer. Also included are those species that are denied access to re-distribution routes and “escape” channels when population numbers reach critical levels. One example of this is when large numbers of fish exit from the Great Lake of Cambodia, when the rains cease in late October.

10 FISH PASSES AND FISH MIGRATIONS IN THE MEKONG BASIN

Technology exists to move fish over or around concrete structures built on rivers [fish lifts etc.], but they are expensive and require a high level of commitment by experienced and skilled staff to operate effectively. This issue not only concerns an upstream migration to allow fish access to historical spawning areas, but provision also has to be made for juveniles to return to downstream areas where they can recruit to existing fish populations.

Different life-history stages of fish normally require separate habitats to optimize survival, growth and reproduction. Migration enables the necessary shifts to be made, but the distance travelled is dependent on habitat distribution and life-history stage. Migrations are usually undertaken for at least three reasons: trophic, dispersal / refuge and reproduction. Migrations may be lateral, taking place between flooded areas and the main stream, or longitudinal. Some migrations may involve a movement of only a few meters, whilst others may involve vast distances covering hundreds or thousands of kilometres. Traditionally, fish species have been categorized into migratory and non-migratory types, often based on some arbitrary minimum distance the species migrates for reproduction. However, any migration (short or long), for whatever reason, and at any life stage, may be important. Therefore, it seems more logical to regard most if not *all Mekong fish species as migratory*, albeit to different degrees of physical movement.

Water-related development projects tend to block fish migration corridors, thus preventing the necessary shift between habitats. To alleviate this, fish passage structures have been constructed at some sites in order to restore, or maintain the linearity of the riverine system. In SE Asia, only a few fish passage facilities currently exist. In Thailand, structures are in place at the Kwan Phayao, Nong Han and Pak Mun Reservoirs and at some other sites. As far as the authors are aware, no fish passage facilities have so far been incorporated into any water-related projects in Cambodia or the Lao PDR. However, a design is under consideration for the Stung Chinit Water Resources Development Project in central Cambodia, and a fish passage option is still under review at the Theun-Hinboun Hydropower Project in the Lao PDR.

Fish pass design has had a long history, dating back some 300 years (Clay, 1995). With an acknowledgement of the devastating effects that water-related development can have on migratory fish populations, the search for an appropriate design began in earnest some 50 years or so ago. Much of the early pioneering work was carried out in North America, Canada and Europe and was directed at maintaining migratory populations of salmonids. Millions of dollars have been spent on fish pass research and design for what amounts to only a limited number of species. Such research has yet to be directed at the hundreds of important migratory species found in other countries of the world, and in the tropical regions in particular.

Due to a scarcity of biological data on tropical riverine species in general, design criteria for fish pass structures in the tropics have mostly been based on educated guesswork, and the applied experiences from work on salmonids. Early designs were the so called “pool and weir” and “submerged orifice” types. Both consist of a concrete flume divided into chambers by cross-baffles. With the former type, fish are required to move over the cross-baffles with the current. The latter design requires the fish to move through an opening near the base of each chamber. The main disadvantage of both designs is that they require relatively constant flows to operate effectively, and are rather inefficient at dissipating the kinetic energy of the water flow.

A third type of fish pass is named after its original designer, Denil. The design incorporates a series of vanes on the sides and base of the flume. This has the effect of turning part of the flow back on itself, and is much more efficient at dissipating kinetic energy. However, although it has a proven track record in temperate countries, it likewise cannot accommodate widely fluctuating current flows.

A fourth design, known as the “vertical slot”, is a variation on the “submerged orifice” type. Instead of having a single hole near the chamber base, it incorporates a continuous slot from top to base of each chamber. Unlike the other designs, energy dissipation is reported to be excellent and it can operate efficiently over a much wider range of flows, and up to at least a 5 or 6 m difference in head. It has the added advantage of facilitating the movement of almost all sizes and life-cycle stages of fish at any preferred water depth. In Australia, the original fish pass structures at the Ben Anderson Barrage on the Burnett River, and the Kolan Barrage on the Kolan River in Queensland have recently been re-designed and upgraded to the “vertical slot” design. Both fish pass structures have proven far more effective than the original design, and the Ben Anderson has been declared the most successful fish pass in Australia.

Unfortunately, for projects built on tropical rivers where fish faunas are rich, and where differences in head may exceed 10 m, the options for fish pass designs

appear to be limited at present. Fish locks (or lifts) have been incorporated into various project designs in many countries, and have a good track record of success. They have the main advantage of facilitating the bi-directional movement of a wide range of species and life-cycle stages of those species. They are disadvantageous in that they require regular attendance and maintenance, and are comparatively expensive.

In Europe, the building of nature-like bypass channels is one approach, which has received attention in recent years. In essence, the idea is to create a channel that resembles a natural river or stream, which allows the fish to pass an obstruction in the river channel. However, this approach is probably not suitable or practical for large-scale high-head dams.

10.1 Cases

The Pak Mun Dam in Northeast Thailand is located close to Ubonratchathani, is built on the Mun River and was completed in 1994. The dam is of the run-of-river type, and is the first hydropower dam in SE Asia where a fish ladder has been incorporated. A recent draft report by the World Commission on Dams concludes that the fish ladder, which is of the combined pool and weir type, is not well designed and is performing poorly. The report also notes that important spawning habitats have been lost due to inundation by the head pond and that fish yields above the dam have been considerably reduced. One hundred or more fish species have disappeared from the upstream areas since the construction of the dam.

The Theun-Hinboun Hydropower Project in central Lao PDR has a 105 MW generating capacity and came "on-line" in early 1998. It is currently the Lao PDR's most important single project in terms of generating foreign exchange through electrical power sales to Thailand. The barrage is built on the Theun River, which supports a rich and diverse range of fish species, many of which are migratory. Earlier EIA reports recommended a fish pass option be investigated. However, a decision was taken not to proceed with an in-depth study of the various possibilities. As predicted, the main wet-season spawning migration in the Theun River was blocked in 1998 (Warren, pers. obs.) and compensation is now under review for those villagers that have suffered damage to their fisheries both upstream and downstream from the dam. Perhaps the greatest "loss" of all surrounds the wasted opportunity to have built an experimental fish pass at Theun-Hinboun. Even several different designs could have been test-run under "real" conditions, and built at a fraction of the total cost of the 260 million-dollar project during its construction phase. Perhaps there are valuable lessons to be learned here for the decision-makers involved with any future water-related development in any of SE Asia's river basins.

