The Don Sahong Dam:

Potential Impacts on Regional Fish Migrations, Livelihoods and Human Health

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August, 2009

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Acronyms

AMRC – Australian Mekong Resource Centre

DSD – Don Sahong Dam (Don Sahong Hydropower Project)

EIA – Environmental Impact Assessment

MFCB - Mega First Corporation Berhad (Malaysia)

MRC – Mekong River Commission

NGO – Non-Government Organisation

UN – United Nations

WFP – World Food Programme

WWF – Formerly World Wide Fund for Nature or World Wildlife Fund (USA)

EXECUTIVE SUMMARY

Plans are presently in the making to build a 30-32 meter-high hydroelectric dam with between 240 MW and 360 MW installed generating capacity on the Hou Sahong Channel of the mainstream Mekong River. The project would be less than one kilometre north of the Laos-Cambodia border, in the Khone Falls area of Khong District, Champasak Province, southern Laos. There are various concerns regarding the Don Sahong Dam (DSD), but the main ones relate to its potential impacts on aquatic resources, and especially aquatic biodiversity and wild-capture fisheries. The impacts on migratory fish are amongst the most important. This paper focuses on the DSD's potential impacts on fish and fisheries, and particularly the project's regional implications in relation to fisheries, including its possible impacts on food security, nutrition and poverty alleviation in Laos and neighbouring countries in the Mekong Region.

The findings of the study—including fieldwork conducted over a number of years and specifically in preparation for writing this report—suggest that various fish species that support important fisheries throughout the region undertake long distance migrations up and down the Mekong River past the Khone Falls at various times of years. It is clear that for large numbers of people directly above the Khone Falls, the vast majority of fish caught are highly migratory and originate from below the Khone Falls. Farther up the Mekong River, most of the major fish species that pass through the Khone Falls still make up a significant part of fish catches, especially at certain times of the year. In Champasak, interviews indicate that all the main species found in the Khone Falls migrations are still abundant in local catches. Farther upriver, in Savannakhet, Khammouane, Bolikhamxay and Vientiane Municipality these migratory fish apparently continue to constitute significant portions of peoples' overall catches. Many of the fish that migrate up the Khone Falls probably also enter larger Mekong tributaries, such as the Mun River in Thailand, and the Xedon and Xebanghieng Rivers in Laos.

The Hou Sahong Channel has been shown to be the only channel that fish can easily pass year-round as there are no waterfalls along its course. It is especially important for important long-distance upriver dry season migrations. As most of these fish pass through the Hou Sahong Channel—which would be blocked by the DSD—there is a high risk that the dam could cause serious impacts to fisheries far upstream in both northern Laos and northern Thailand. In addition, fish would not be able to complete their lifecycles upstream from the Khone Falls, and thus their populations downstream from the dam would also be seriously threatened, including important fisheries in the Tonle Sap in Cambodia and the Mekong Delta in Viet Nam. The Tonle Sap River and Great Lake support by far the most important fisheries in Cambodia, while the Mekong Delta in Viet Nam also supports large fisheries.

Thus, fisheries and associated livelihoods both far above and far below the dam would be seriously jeopardised by the DSD. Furthermore, the fish stocks that could be lost upstream of the Khone Falls include a wide variety of species that are not only crucial for local livelihoods, but are also important for the overall ecology of the Mekong Basin. These include the keystone minnow species, *Henicorhynchus lobatus* (*pa soi* in Lao; *trey riel* in Khmer), which is an important source of food for many predatory fish species, as well as Irrawaddy dolphins in the Mekong River.

Mitigation measures have been proposed in the DSD's draft environmental impact assessment, but based on current knowledge and past experiences, they are unlikely to be fully effective and the risk of severe impacts is high. The record for fish passes in the Mekong region and globally is quite poor, and it would very difficult, if possible at all, to develop a fish pass that could accommodate all species during all seasons. In addition, it would be impossible to replicate the conditions of the Hou Sahong Channel in an adjacent channel, as possible alternative channels for fish passage are all much narrower, with greatly reduced water volumes.

Ultimately, fisheries losses in the Mekong region from the DSD could negatively impact the nutritional status of hundreds of thousands or even millions of people dependent on these fisheries, thus decreasing the health of a large human population, especially in parts of Laos, Cambodia and Thailand where nutritional standards are already low. Threatened Mekong fisheries are extremely important for meeting the nutritional needs of people in the region. Those living closer to the dam, both upriver and downriver from the project, would generally be impacted more than those located farther away. However, impacts would continue for well over a thousand kilometres, from the Mekong Delta in Viet Nam, past Cambodia, Laos and Thailand, continuing on to northern Laos.

Considering the DSD's wide and deep footprint, the project could ultimately make it much more difficult for governments in the region, especially those of Laos and Cambodia, to reach their health-related United Nations Millennium Development Goals, or their objectives for reducing poverty. For national governments and the international aid agencies that support them, the DSD should be a major concern.

1. INTRODUCTION

There are presently plans to build a 30-32 meter high concrete hydroelectric dam with between 240 MW and 360 MW installed generating capacity on the Hou Sahong Channel of the mainstream Mekong River, less than one kilometre north of the Laos-Cambodia border, in the Khone Falls area of Khong District, Champasak Province, southern Laos.[1] The Malaysian company Mega First Corporation Berhad (MFCB), a publicly traded firm, is hoping to develop the Don Sahong Hydropower Project (hereafter referred to as the Don Sahong Dam (DSD)) over the next few years. The MFCB has already funded feasibility studies and an environmental impact assessment (EIA) for the project.

This dam has been very controversial for a number of reasons (see Khamin and Middleton 2008). There are various concerns regarding the DSD, but the main ones relate to its potential impacts on aquatic resources, and especially aquatic biodiversity and wild-capture fisheries. The impacts on migratory fish is the most important issue (Khamin and Middleton 2008; Barlow *et al.* 2008; Dugan 2008a; WWF 2007; Baran and Ratner 2007; Bangkok Post 2007).[2] For example, in a

[1] Officially, the Lao People's Democratic Republic, or Lao PDR.

[2] Letter from Scientists concerned for the sustainable development of the Mekong River to Government and international agencies responsible for managing and developing the Mekong River Re: Concerns about the Don Sahong Dam, planned for the mainstream Mekong River in the Khone Falls area, Khong District, Champasak Province, Southern Lao PDR, dated 25 May 2007.

paper presented at an international fisheries symposium held in Ubon Ratchathani University in September 2008, Chris Barlow, MRC Fisheries Programme Manager, stated that dams on the Mekong mainstream "will be very deleterious for the fisheries based on migratory species (the 'white fishes') in the Mekong" (Barlow 2008: 19).[3] In specific reference to the Khone Falls and the DSD, Baran and Ratner (2007: 2) wrote, "Obstructing fish migration at Khone Falls … would have social, ecological and economic implications basin-wide."

The Mekong River Basin is known for having the highest diversity of fish species of any river basin in Asia.[4] Mekong inland fisheries are also now widely recognised to be amongst the most productive in the world, and their contribution to food security and nutrition is extremely important (Hortle 2007; Baran *et al.* 2007). In many parts of the region—including areas above and below the Khone Falls—it has been estimated that over 80% of the animal protein consumed by rural people comes from wild-caught fish and other aquatic animals (Hortle 2007; Thuan and Chambers 2006; Baird *et al.* 1998). In recent years it has become increasingly evident how extremely important wild-capture fisheries are for maintaining rural livelihoods in the Mekong region (see, for example, Hortle 2007).

Many Lao people like to say "We don't raise fish, fish raise us," indicating the limited importance of aquaculture in rural Laos as compared to wild-capture fisheries, which are often the real mainstay for rural diets. Yet despite the importance of wild-capture fisheries to rural populations in Laos and the Mekong region, their significance has long been under-appreciated in development circles in Laos (Bush 2004; Baird and Shoemaker 2008), especially those concerned with health, food security and rural livelihood issues more generally. The term 'fisheries' translates into 'aquaculture ponds' for many international development workers, which indicates where most of the emphasis by development agencies has been. Rarely are wild-capture fisheries given the attention that they deserve, although there have been some notable exceptions, especially in recent years.

A high proportion of wild fish caught from large rivers in the Lower and Middle Mekong Basin are highly migratory. Indicative of this, it has been estimated that at least 78% of the fish caught in the Sesan River in Ratanakiri Province migrate from the Mekong River (see Baird 2009; Baird and Meach 2005). A high proportion of the fish caught in the Khone Falls area are also known to be highly migratory (Baird 2001), and most of the fish caught above the Khone Falls in the Siphandone area are migratory (Baird *et al.* 1998; Baird 2001). Baran (2006) reported that 87% of Mekong mainstream fish species for which information is available are migratory. The Mekong River upstream from the Siphandone area is similarly dominated by migratory fish species. Thus, the DSD could potentially cause very significant negative impacts to fish catches and fish consumption below and above the Khone Falls.

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[3] Halls and Kshatriya (2009: 8) describe 'white fishes' as being "Migratory species intolerant to low dissolved oxygen concentrations and which typically inhabit lotic (flowing water) environments." This includes all the main migratory species in the mainstream Mekong River.

[4] Various estimated that there are between 785 and 1,700 species of fish in the Mekong River Basin (Coates *et al.* 2003; Bao *et al.* 2001; AMRC 2008). Baird (2001) has confirmed that at least 205 species of fish are found in the Khone Falls area.

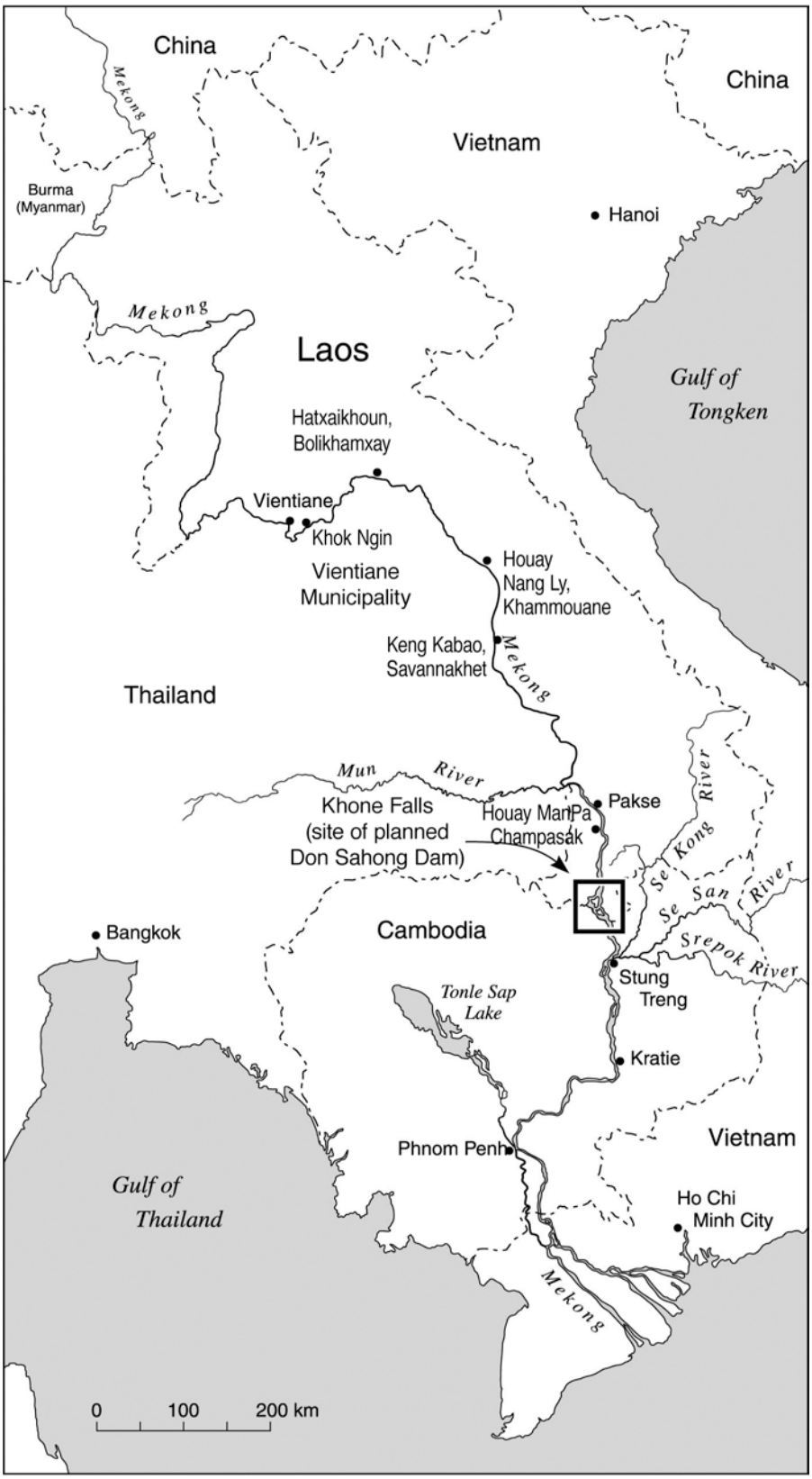

Figure 1. Proposed location of the Don Sahong Dam and study sites between the Khone Falls and Vientiane Municipality.

The regional fisheries implications of the DSD are important to address, particularly as the draft EIA, which was completed in July 2007 (MFCB 2007), did not adequately investigate this important issue. Instead, the authors of the EIA simply assume that the dam's impacts on long-distance migratory fish can be fully mitigated, thus largely removing the issue of regional impacts from being carefully assessed.

This paper focuses on the DSD's potential impacts on fish and fisheries, and particularly the project's regional fisheries implications. The potential impacts of the DSD on migratory fish stocks are assessed—along with the implications of these impacts for food security, nutrition and poverty alleviation within Laos and the region.

2. THE NATURE OF MEKONG RIVER BASIN AND FISH MIGRATIONS

The Mekong River Basin is unique globally in that the annual variations between low water and high water volumes in the mainstream river are greater than for any other large river in the world—with peak rainy season water levels, which are achieved in August and September—being approximately 30 times as much as dry season water levels in March and April (Cunningham 1998). This is largely because most of the basin is located in a region that is heavily influenced by a monsoon climate, including extreme dry and rainy seasons. The low water levels that exist at the height of the dry season are one of the reasons why deep-water pools are important dry season habitats in the Mekong Basin, especially for large brood stock (Baird 2006a; Baran *et al*. 2005; Baird and Flaherty 2005). The hydrological conditions that exist in the Mekong Basin have contributed to the creation of a variety of aquatic habitats and ecological conditions (Baird 2007). They have helped create the conditions for a high diversity of aquatic life.

Considering the broad differences in ecological conditions in different parts of the Mekong Basin at different times of the year, it should come as little surprise that it is rarely if ever the case that a single species of fish or other aquatic animal is well adapted to all the ecological conditions that exist in one particular place over the course of a year, or life-cycle. Thus, one fish might be content to inhabit the mainstream Mekong River when water volumes and currents are low, but once water levels rise and currents become strong, the same fish may well need to move to a different location in order to survive. The diverse hydrological conditions of the Mekong are one of the fundamental reasons why many of the fish in the Mekong River Basin are particularly mobile, with some species, such as *Pangasius krempfi*, migrating well over 1,000 kilometers up the Mekong River each year (Hogan *et al.* 2007; Roberts and Baird 1995). Certainly, a large number of fish species migrate hundreds of kilometres annually (Poulsen *et al.* 2004; Baird and Flaherty 2004; Baird *et al.* 2003).[5]

Because fish migrations are such an important aspect of the ecology of the Mekong Basin (Baran *et al.* 2005), it is crucial to ensure that migration routes for different fish species are not blocked

[5] The MRC has also recorded large *P. krempfi* in villager fish catch data from Khammouane, Bolikhamxay and Vientiane in recent years, with the species being especially abundant between June and October (MRC pers. comm. June 2009).

and that cyclical fish movements are not otherwise disrupted. While this is, of course, generally the case for fish populations worldwide, the principle is especially important for the Mekong Basin, because the particular hydrological conditions there contribute to more migratory behaviour amongst fishes as compared to fish stocks in other tropical and sub-tropical river basins globally.

3. THE KHONE FALLS AND THE HOU SAHONG CHANNEL

The Khone Falls constitutes the only large complex of waterfalls and rapids area located along the lower mainstream Mekong River. Following a geological fault-line for approximately 9 km (Bramati and Carulli 2001), the Khone Falls are located approximately 760 km from the South China Sea. The Falls consist of a large number of small to large channels separated by many large and small islands and natural rock structures and seasonally inundated vegetation, creating a complex ecological system, one rich in aquatic resources (Daconto 2001). Some of the channels that are part of the Khone Falls area have high waterfalls on them that make upriver fish movements impossible (i.e. Khone Phrapheng Falls, Tham I Deng Falls, Somphamit Falls). These waterfalls can be considered biogeographical barriers to fish migrations, at least upward movements. In other cases, fish are able to migrate past small waterfalls and rapids under particular conditions and during certain times of year. In some cases, only a small proportion of fish that attempt to travel upstream are able to achieve their goal. Finally, there are a few channels that fish can migrate past, although sometimes in only small numbers, year-round. However, there is only one channel in the Khone Falls area through which fish can easily pass upriver year round: the Hou Sahong Channel (Roberts and Baird 1995) (see Figure 1).

Figure 2. Just below the Don Sahong Dam site.

The Hou Sahong Channel is located between Sahong Island, which makes up the west bank of the channel, and Sadam Island, which makes up the east bank of the channel. The channel is approximately seven kilometers long, and unlike most others in the Khone Falls area, there are no waterfalls located along its length (see Figure 1). There are some smaller rapids located along its course, such as Tat Louang, Tat Tieu and Tat Pho, but none that act as significant barriers to fish movements (see Baird *et al.* 2001; Roberts and Baird 1995). Also, unlike the Hou Sadam Channel, which is located east of Sadam Island—and is also without any waterfalls along its course—the Hou Sahong Channel is large enough to support the migrations of large groups of large and small fish year-round. The Hou Sadam Channel, in contrast, is not very wide. Therefore, local people report that a relatively small number of fish pass through that passage each dry season. The channel is frequently intentionally blocked by local people who make fish traps along it in the dry season and at the beginning of the rainy season (Roberts and Baird 1995).

Essentially, the Hou Sahong Channel is unique within the Khong Falls area, and local people and scientists who have studied fish in the Khone Falls area widely believe that a large proportion of the fish that migrate up the Mekong River from Cambodia to Laos pass through the Hou Sahong Channel (Baird 1996; Roberts and Baird 1995; Singhanouvong *et al.* 1996b). In fact, this is common knowledge amongst local people in the Khone Falls area. Locals commonly report that the Hou Sahong Channel is by far the most important migratory fish passage year round.

4. FISH MIGRATIONS IN THE KHONE FALLS AREA

The mainstream Mekong River in southern Laos at the Khone Falls supports at least 205 fish species (Baird 2001), many of which are highly migratory and can only be found in the Khone Falls area during certain seasons (Baran *et al.* 2005; Baird *et al.* 1999a; Baird 1996).[6] The following is a summary of some of the main fish migrations that occur in the Khone Falls area:

December to February: A number of important species of medium-sized cyprinid carps migrate from the Sekong, Sesan and Srepok Rivers in Cambodia and Laos to the Mekong River in Stung Treng Province, Cambodia and then upriver to Laos and finally to Thailand. The main highly migratory species involved are *Scaphognathops bandanensis* (*pa pian* in Lao), *Mekongina erythrospila* (*pa sa-i* in Lao),[7] *Hypsibarbus malcolmi*/spp. (*pa pak* in Lao), *Labeo erythropterus* (*pa va souang* in Lao), *Bangana behri* (*pa va na no* in Lao), *Gyrinocheilus pennocki* (*pa ko* in Lao), and *Cirrhinus molitorella* (*pa keng* in Lao) (Swift 2006; Baird and Meach 2005; Baird and Flaherty 2004; Poulsen *et al.* 2004; Baird 1995; Roberts and Warren 1994). All of these fish migrate past the Khone Falls (Baird and Flaherty 2004), most via the Hou Sahong Channel. Most, if not all of the species, appear to travel up the Mekong River at least as far as the section of the river that acts as the border between Laos and Thailand (Warren *et al.* 1998; Singhanouvong *et al.* 1996a).

[6] Only five are non-native.
[7] *Mekongina erythrospila* is especially valued in Cambodia, where it is one of the most expensive fish species (Thuan and Chambers 2006; Baird 2009).

January to March: Important schools of small cyprinid fishes, triggered by changes in lunar phases and hydrological conditions, migrate from the Tonle Sap Lake in Cambodia to Laos during this season. At least 32 fish species are known to participate in these long distance migrations (see Table 1). The most important species are *Henicorhynchus lobatus*[8]*, Henicorhynchus siamensis* (both *pa soi* in Lao; *trey riel* in Khmer) and *Paralaubuca typus* (*pa tep* in Lao), along with loaches such as *Botia modesta* and others (Baird and Shoemaker 2008; Baran *et al.* 2005; Poulsen *et al.* 2004; Baird *et al.* 2003; Poulsen and Valbo-Jørgensen 2000; Roberts and Baird 1995) (see Table 1). One of the species is the IUCN-listed 'endangered' species *Tenualosa thibaudeaui* (Poulsen *et al.* 2004), a species previously abundant in the Khone Falls area but now considerably rarer (Roberts 1993). Genetic studies of *Henicorhynchus lobatus* and *H. siamensis* in the Mekong River have not found any genetic differences between fish sampled near Nong Khai, Thailand and those from Chau Doc in Viet Nam's Mekong Delta, except for a separate population of *H. lobatus* near Ubon Ratchathani, Thailand (Hurwood *et al.* 2006). Overall, their findings support the hypothesis that these fish migrate long distances up and down the mainstream Mekong River (see Baird *et al.* 2003). Crucially for this study, most of the fish in this group pass the Khone Falls by travelling up the Hou Sahong Channel.

April: During the time of the year when water levels are at their lowest, schools of the large cyprinid fish, *Cirrhinus microlepis* (*pa phone* in Lao), migrate up the Mekong River from Cambodia to Laos. These fish rely almost exclusively on the Hou Sahong Channel to pass the Khone Falls, and there is a specialised fishery located there for targeting these highly migratory fish (Roberts and Baird 1995). The *Cirrhinus microlepis* caught at the Khone Falls probably originate from the Tonle Sap Lake (Baird *et al.* 1999; Poulsen *et al.* 2004).

April to May: Shortly after the above migrations, large schools of small migratory *Pangasius macronema* (*pa nyone thamada* or *pa nyone lang khieo* in Lao)[9] migrate up the Mekong River from Cambodia to Laos. Like *Cirrhinus microlepis*, these fish rely on the Hou Sahong Channel to migrate upstream past the Khone Falls, and there are some important fisheries for the species centered in the Hou Sahong Channel, including an important communal fishery managed by people from Hang Sadam Village (Baird *et al.* 2001).

May to June: Various species of catfish from the Pangasiidae family migrate up the Mekong River in Cambodia to Laos via the Khone Falls at the beginning of the rainy season. These include *Pangasius conchophilus* (*pa pho* or *pa ke* in Lao), *Pangasius larnaudii* (*pa peung* in Lao), *Pangasius bocourti* (*pa nyang* or *houa mouam* in Lao), *Pangasius hypophthalmus* (*pa souay kheo* in Lao) and *Pangasius krempfi* (*pa souay hang leuang* in Lao) (Baird *et al.* 2004; Singhanouvong *et al.* 1996b; Roberts and Baird 1995; Roberts 1993). *Pangasius krempfi* migrate from as far away as the estuary of the Mekong Delta in southern Viet Nam (Hogan *et al.* 2007). Most of these fish are believed by local people to rely on the Hou Sahong Channel to pass the Khone Falls.

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[8] It should be noted that while *Henicorhynchus* is the genus that most ichthyologists use for this species, Roberts (1997) included the species in the genus *Cirrhinus*.

[9] For the purposes of this study, and due to taxonomic uncertainty, *Pangasius macronema* and *Pangasius siamensis* are considered to be the same species, *Pangasius macronema*.

Table 1. Fish species that migrate up the Mekong River from the Tonle Sap River each dry season (adapted from Baird et al. 2003)

#	**Latin Name**	**Lao Name**
1	*Henicorhynchus lobatus*	*Pa soi houa lem*
2	*Henicorhynchus siamesis*	*Pa soi houa po*
3	*Henicorhynchus lineatus*	*Pa soi lai*
4	*Cirrhinus microlepis*	*Pa phone mak koke (sm) or pa phone (lg)*
5	*Paralaubuca typus*	*Pa tep*
6	*Labiobarbus leptocheilus*	*Pa lang khon*
7	*Thynnichthys thynnoides*	*Pa koum*
8	*Lobocheilus melanotaenia*	*Pa khiang*
9	*Garra fasciacauda*	*Pa kom*
10	*Barbodes altus*	*Pa vian fai*
11	*Gyrinocheilus pennocki*	*Pa ko*
12	*Sikukia gudgeri*	*Pa khao*
13	*Puntioplites falcifer*	*Pa sakang*
14	*Cyclocheilichthys enoplos*[10]	*Pa chok*
15	*Cyclocheilichthys sp. or spp.*	*Pa doke ngieu*
16	*Cosmocheilus harmandi*	*Pa mak ban*
17	*Epalzeorhychus frenatum*	
18	*Crossocheilus reticulatus*	*Pa khang lai*
19	*Crossocheilus siamensis*	*Pa khang lai*
20	*Osteocheilus melanopleurus*	*Pa nok khao*
21	*Osteocheilus microcephalus*	*Pa khang lao*
22	*Amblyrhychichthys truncates*	*Pa ta po*
23	*Luciosoma bleekeri*	*Pa mak vai*
24	*Leptobarbus hoeveni*	*Pa phong*
25	*Rasbora* sp.	*Pa sieu ao*
26	*Tenualosa thibaudeaui*	*Pa mak phang*
27	*Schistura* sp.	*Pa it*
28	*Acantopsis* sp.	*Pa hak kouay*
29	*Botia modesta*	*Pa mou man*
30	*Botia helodes*	*Pa kheo kai*
31	*Botia caudipunctata*	*Pa mou man*
32	*Parambassis wolfii*	*Pa khap khong*

[10] It should be noted that both small juveniles and large adults migrate upriver from the Tonle Sap River to the Khone Falls and beyond.

July to September: There is some evidence that during the height of the rainy season the famous Mekong Giant Catfish (*Pangasius gigas*[11]), *'pa beuk'* in Lao, a species that reaches over 300 kg in weight, migrate past the Khone Falls from Cambodia each year, and that these large fish travel up the Hou Sahong Channel on what may be a very long migration (Hogan *et al.* 2004; Poulsen *et al.* 2004). Genetic studies suggest that all the *P. gigas* are part of a single population (Lorenzen *et al.* 2006). Although this species is considered to be endangered, some have been accidentally caught in traps set in the Hou Sahong Channel in recent years. In 2007, for example, at least three large fish were caught in the Hou Sahong Channel (Mollot *et al.* 2007; *pers. comm.* Chaloun Souriyavong, Khong District Livestock and Fisheries Office). One fish weighing over 100 kg was photographed by a Thai photographer, Suthep Krisnavarin. The suspected long migration of the species is one of the reasons that Roger Mollot (2008) believes that mainstream Mekong dams are a serious threat to the species.

October to January: The 'endangered' and 'data deficient' IUCN-categorized carps, *Probarbus jullieni* (*pa eun deng* in Lao) and *Probarbus labeamajor* (*pa eun khao* in Lao), both of which reach up to 70 kg in weight, spawn in the Khone Falls area near the proposed site of the DSD during the cold season. *Probarbus jullieni* is a CITES Appendix 1 species (Baird 2006a; Poulsen *et al.* 2004). The spawning patterns of these threatened species near the Khone Falls could be drastically impacted by the hydrological changes directly downstream from the dam that would be caused by the construction and operation of the DSD.

5. METHODOLOGY

One of the biggest deficiencies of the EIA for the DSD is that it fails to consider the regional implications for fish and fisheries of developing the dam. In order to fill some of the gaps in the research, original fieldwork was conducted along the Mekong River in the Khone Falls area as well as in five different locations along the Mekong River upstream of the Khone Falls:

1) Houay Man Pa Village, Champasak District, Champasak Province
2) Keng Kabao Village, Xayboury District, Savannakhet Province
3) Houay Nang Ly Village, Tha Khek District, Khammouane Province
4) Hatxaikhoun Village, Paksan District, Bolikhamxay Province
5) Khok Ngin Village, Sisatanak District, Vientiane Municipality

See Figure 1 (page 7) for the approximate locations of the five villages.

All five study sites are situated upstream from the Khone Falls and adjacent to the mainstream Mekong River in Lao. For each village visited, the author interviewed an experienced fisher or group of fishers in Lao language about fish and fisheries in the Mekong River. In all cases at least one of the people interviewed was an active male fisher with a long experience living in the village, and was between 50 and 60 years old. Interviews were all done in early February 2009.

The method used for interviewing fishers about the occurrence of particular species of fish followed the methodology outlined in Baird (2006c). That is, the fish species were identified

[11] This species is often referred to as being in the genus *Pangasianodon*.

using multiple means, including 1) a set of colour photographs to help identify fish, 2) Lao language names for fish in the Mekong River, and 3) information about the behaviours of particular species, including migratory behaviour. Through considering various factors it was possible to make a fairly accurate assessment of species' presence and absence near each village. Using single methods are, in contrast, rarely effective.

The survey findings were then roughly compared with raw fish catch data collected through the Fisheries Programme of the Mekong River Commission, in order to provide some additional evidence regarding presence and absence of particular fish species in fish catches upstream of the Khone Falls. This helped inform the analysis regarding fish migrations.

6. RESULTS

The following are the results of the study of the potential impacts of the DSD on fish and fisheries.

6.1 The Extent of Upstream Fish Migrations

Table 2 includes a summary of the results of interviews in relation to the fish species believed to migrate upriver from below the Khone Falls to the parts of the Mekong River where experienced fishers were questioned. These fish have been selected because all but one (the Anguilla eel) support important fisheries in the Khone Falls area as well as other parts of the Mekong region. All are also known to be highly migratory. They all pass through various channels in the Khone Falls area. However, the Hou Sahong Channel is undoubtedly the most important channel for all these species, with those species migrating upstream in the dry season especially being reliant on the Hou Sahong Channel (Baird 1996).

While more detailed research would be required to definitively confirm and clarify the initial responses from the fishers, the findings certainly indicate that there is a high likelihood that many fish populations that pass the Khone Falls via the Hou Sahong Channel migrate hundreds of kilometers further upstream from the Khone Falls. Some species support important fisheries upstream, and some almost certainly migrate up the Mekong River past Vientiane (see, also, Poulsen and Valbo-Jørgensen 2000).

Let us consider the groups of fish species that are most likely to be migrating from below the Khone Falls. The first group, and possibly the most important from a villager livelihoods' perspective, includes many cyprinids and loaches (especially *Henicorhynchus* spp., *Paralaubuca* and *Botia* spp.) that migrate from the Tonle Sap Lake in Cambodia (or areas nearby) and which are caught in large numbers in the Khone Falls area (Baird *et al.* 2003). While not all the small carps caught upstream of the Khone Falls migrate from below the Falls, it seems likely, based on interviews with experienced fishers, that many migrate at least as far upriver as Vientiane, and quite likely farther upriver.

It seems highly likely, based on interviews with fishers, that at least some of the different species of medium-sized cyprinids (especially *Mekongina erythrospila* and *Scaphognathops bandanensis*) that migrate from the Sekong, Srepok and Sesan River systems in northeastern

Cambodia and southern Laos and past the Khone Falls (Baird and Flaherty 2004; Baird 2009) move as far upriver as south of Vientiane, although some fish found in upstream areas probably originate from local streams.

Cirrhinus microlepis are now much rarer than they once were above the Khone Falls, but they are still caught, at least up to Bolikhamxay Province, and probably farther. These fish may come from the Tonle Sap River in Cambodia (Baird *et al.* 2003; Roberts and Baird 1995). In addition, even though populations are depleted at present, this species has demonstrated its ability to rebound from over-fishing if the conditions are right. For example, in 1976, when fishing was extremely restricted in Cambodia due to the draconian policies of the Khmer Rouge, fishers in southern Laos report an upsurge in the numbers of fish seen and caught (Roberts 1993).

The large catfish, *Pangasius krempfi,* is a species that almost certainly migrates far up the Mekong River to spawn each rainy season. Villagers have reported the species as far up the Mekong River as Nan District, Luang Phrabang Province (*pers. comm.*, villagers living along the Mekong River in Nan District, Luang Phrabang Province, 2001). The MRC has also recorded the species in fish catches in Khammouane, Bolikhamxay, Vientiane and Bokeo fish catches (MRC *pers. comm.* June 2009). This anadromous fish species spawns in the Mekong River but spends much of its early life in the Mekong estuary and South China Sea (Hogan *et al.* 2007; Roberts and Baird 1995).

The small catfish *Pangasius macronema* migrates from Cambodia to above the Khone Falls (Baird *et al.* 2001), and from interviews with fishers along the Mekong River it seems likely that it migrates at least as far upstream as Vientiane.

It is less clear how far the catfish *Pangasius conchophilus* migrates, and while the ones caught near Vientiane may not be migrating from south of the Khone Falls, additional research is required. It is known, however, that this species migrates from below the Khone Falls to above it in large quantities (Baird *et al.* 2004).

Poulsen *et al.* (2004) reported that *Pangasius larnaudii* below the Khone Falls constituted a single population, and since we know that fish of this species migrate upstream past the Khone Falls (Baird *et al.* 2004), upriver populations may also be a part of the same population.

The Anguilla eel, *Anguilla marmorata*, is not a common species, but it has been reported as far up the Mekong River as Luang Phrabang (*Per comm.* Interviews with villages in Nan District, Luang Phrabang Province, 2001), and during this study it was reported in Bolikhamxay Province. MRC fish catch data have also recorded this species from the Vientiane area (MRC, *pers. comm.* June 2009). This species is catadromous, which means that it spends most of its life in freshwater but spawns in salt water areas in the South China Sea. It is clearly highly migratory.

It is worth mentioning some other fish species that are not included in Table 2 may also migrate long distances past the Khone Falls, such as the giant catfish, *Pangasius gigas*, already discussed earlier.

Table 2. Fish species' presence and absence along Mekong River between the Khone Falls and Vientiane Municipality

	Fish Species	**Khone Falls**	**Champa-sak**	**Savanna-Khet**	**Kham-mouane**	**Bolikhamx ay**	**Vientiane Municipality**
1	Various small cyprinids and loaches, especially *Henicorhynchus lobatus/*spp. and *Paralaubuca typus, Botia* spp., etc. (from the Tonle Sap River)	Yes, migrate up in Jan-Feb (Baird *et al.* 2003)	Yes, migrate up in Feb-March, May-June migrate down-stream	Yes, migrate up in March and migrate down in May	Yes, migrate up Feb-March; also some appear earlier from nearby streams	Yes, migrate up in Feb-March; also some appear earlier from nearby streams	Yes, migrate up in dry season; also some appear earlier from nearby streams
2	*Mekongina erythrospila* (from the Sekong, Sesan and Srepok Rivers)	Yes, migrate up between Dec and Feb (Baird and Flaherty 2004)	Yes, migrate up in Jan-Feb (Warren *et al*. 1998) and migrate down in May	Yes, migrate up in Jan-Feb; migrate down in May	Yes, migrate up in Feb-March; some in area earlier, from other streams	Yes, migrate up in Feb; some in area earlier, from other streams	Yes, migrate up in Feb; some in area earlier, from other streams
3	*Scaphognathops bandanensis* (from the Sekong, Sesan and Srepok Rivers)	Yes, migrate up between Dec and Feb (Baird and Flaherty 2004)	Yes, migrate up in Jan-Feb (Warren *et al.* 1998) and migrate down in May	Yes, migrate upriver in March-April	Yes, migrate up with *Mekongina* in Feb-March; some found in area earlier	Yes, migrate up in March-April; some found in area earlier	Not reported; MRC *(pers. comm.)* recorded in fish catch data in Vientiane
4	*Labeo erythropterus* and *Bangana behri* (from the Sekong, Sesan and Srepok Rivers)	Yes, migrate up between Dec and Feb (Baird and Flaherty 2004)	Yes, migrate up in Jan-Feb	Yes, some migrate up in dry season	Yes, some migrate up in dry season	Yes, *Bangana behri* migrate up in Jan-Feb	Yes, some *Bangana behri* migrate up in dry season; larger fish not from south
5	*Hypsibarbus malcolmi* (from the Sekong, Sesan and Srepok Rivers)	Yes, migrate up between Dec and Feb (Baird and Flaherty 2004)	Yes, migrate up in Jan-Feb and migrate down in May	Yes, migrate up in April and again in May	Yes, migrate up in May; some in area earlier	Yes, migrate up in Feb-March; some in area earlier	Generally have but no clear migrations reported

6	*Cirrhinus microlepis* (from the Tonle Sap River, and the lower Mekong in Cambodia?)	Yes, migrate up in March--April (Roberts and Baird 1995); and Jan-Feb (Baird *et al.* 2003)	Yes, migrate upriver in the dry season	Yes, few migrate upriver; in the past many	Yes, few migrate up in Feb-March; and others in April-May; in the past many	Yes, few migrate up in April-May	Not reported
7	*Pangasius krempfi* (from the South China Sea and Mekong Delta Estuary)	Yes, migrate up in May-July (1.5 kg to 10 kg.) (Hogan *et al.* 2007; Baird *et al.* 2004)	Yes, migrate upriver in May	Yes, some large (2-3 kg each) migrate up in June-July	Yes, some migrate up in July (no eating; full of eggs); recorded in MRC fish catch data during June-October	Yes, some migrate up in July-August (3 kg + and no eating; yellow tails); recorded in MRC fish catch data during June-October	Yes, some migrate up in September (never saw small ones); recorded in MRC fish catch data during June-October
8	*Pangasius macronema* (from the Tonle Sap River and the Mekong River in southern Cambodia?)	Yes, migrate up from March to May (Baird *et al.* 2001)	Yes, migrate upriver in April-May	Yes, historically migrated to area but now few	Yes, migrate up in March-April; migrate down in May	Yes, migrate up in April-May	Yes, migrate up in March-April
9	*Pangasius conchophilus* (probably not a long distance migratory, but possibly)	Yes, migrate up in May-June (Baird *et al.* 2004)	Yes, migrate upriver in May	Yes, some migrate up	Yes, migrate up between May and July; also found generally	Yes, migrate up in May; also found generally	Yes, migrate up in May; also found generally
10	*Pangasius larnaudii* (from Mekong River in Cambodia)	Yes, migrate up in May-June (Baird *et al.* 2004)	Yes, migrate upriver in May	Yes, some migrate up in rainy season	Yes, some migrate up in rainy season; also caught in November –January	Yes, migrate up in May; also caught in November - January	Yes, catch at end of rainy season; also caught in November - January
11	*Anguilla marmorata* (from the South China Sea)	Yes (Roberts and Baird 1995)	Yes, rare	Not reported	Not reported; MRC reported in catches in Kham-mounane Province	Yes, rare; MRC reported in catches in Kham-mounane Province	Not reported

It is likely that at least some large *Macrobrachium rosenbergi* giant freshwater shrimp migrate upriver from the Mekong Delta to well above the Khone Falls. They have been found in the Khone Falls area (Baird 2001), and are considered a transboundary species between Cambodia and Viet Nam downstream (Coates 2001).

There are other fish species that migrate past the Khone Falls using the Hou Sahong Channel, such as the predatory large species *Belodontichthys* sp., *Aaptosyax grypus, Hemibagrus nemurus* and others, such as the carp *Cosmocheilus harmandi*. But it is unclear how far upstream they migrate. More research is required to confirm the extent of these species' migrations.

6.2 The Importance of Upstream Fish Migrations for Fisheries above the Khone Falls

The schools of fish that migrate past the Khone Falls each year make up the largest proportion of fish caught by people living in the Siphandone Wetlands area, which is almost all located upstream from the Khone Falls. Illustrative of this, a 1998 survey of fisheries activities throughout Khong District, Champasak Province determined that *Henicorhynchus lobatus* and other small cyprinids that migrate upstream past the Khone Falls from the Tonle Sap Lake in Cambodia make up the vast majority of fish caught by people in the district, and are thus crucial for the livelihoods of the vast majority of the over 70,000 people living in the district (Baird *et al.* 1998).

It is known that many other migratory species that move from below to above the Khone Falls also support important fisheries in Laos and Thailand (Coates 2001; Poulsen and Valbo-Jørgensen 2000; Warren *et al.* 1998; Singhanouvong *et al.* 1996a; b; Hill and Hill 1994). This has been confirmed through the interviews conducted with fishers along the Mekong River upriver from the Khone Falls.

All the fish species mentioned above, with the exception of the Anguilla eel and giant inland shrimp, support important fisheries, both upstream and downstream of the Khone Falls. For communities directly above the Khone Falls, it is obvious that the vast majority of fish caught are highly migratory and originating from below the Khone Falls. Farther up the Mekong River, it appears that most of the major fish species that pass through the Khone Falls still make up a significant part of fish catches, especially at certain times of the year. In Champasak, for example, interviews indicate that all the main species found in the Khone Falls migrations are still abundant in local catches. Farther upriver, in Savannakhet, Khammouane, Bolikhamxay and Vientiane Municipality these migratory fish apparently continue to constitute significant portions of peoples' overall catches. Many of the fish that migrate up the Khone Falls probably also enter larger Mekong tributaries, such as the Mun River in Thailand, and the Xedon and Xebanghieng Rivers in Laos. However, the farther away from the Khone Falls, the relative importance of these migratory fish apparently decreases relative to other species that do not migrate past the Khone Falls. This is to be expected.

Figure 3. A fish trap on the Hou Xang Pheuak.

6.3 Numbers of People Expected to be Impacted Upstream

It is difficult to assess, based on a rapid study such as this, exactly how many villages, households or people might be affected by the loss of migratory fish upstream from the DSD and the Khone Falls, but based on fisheries literature, and the above reports from fishers, the number could be very high. Included amongst those who would be impacted are all of those villages located adjacent to or nearby the mainstream Mekong River upstream of the Khone Falls to at least Vientiane. While the villages located in Champasak Province, closer to the Khone Falls, would be impacted more than villages farther upstream, the data presented above makes it clear that impacts would extend at least as far as Vientiane, and possibly farther. For example, species such as *Pangasius krempfi* migrate at least as far upriver as Luang Phrabang Province (Hogan *et al.* 2007).

There are also hundreds of villages located along the Mekong River in Thailand between Ubon Ratchathani and Nong Khai Provinces, and they too would be negatively impacted by the DSD through losing access to migratory fish.

Furthermore, many of the small cyprinids and other fish species that migrate up the mainstream Mekong past the Khone Falls migrate into large rivers and streams that flow into the Mekong River, including the Mun River in Thailand and the Xedon River in Laos.

Ultimately, because such a large number of villages and people would be affected, the number of people could possibly reach the millions, once all the people in Laos and Thailand who would lose access to migratory fish are considered.

6.4 The Importance of Upstream Fish Migrations for Fisheries below the Khone Falls

Many of the fish stocks that pass through the Khone Falls during long distance migrations are the basis for the most important wild-capture fisheries downriver from the Khone Falls. The most obvious example is *Henicorhynchus lobatus,* a small fish species that is believed to be by far the most important fish species in Cambodia by catch weight, making up approximately 21 percent of the whole inland fish catch in Cambodia (Baran 2005; Van Zalinge *et al.* 2000). In the bag-net fishery in the Tonle Sap River, it was even more abundant, making up 67.5% of the catch (along with *Henicorhynchus siamensis*) (Lieng *et al.* 1995). Baird *et al.* (2003) found that *H. lobatus* made up 45.4% of the total catch for the fence-filter trap fishery, one of the most important fisheries in the Khone Falls area. *Paralaubuca typus* was the next most abundant at 33.2%, and *H. siamensis* being third at 5.4%. With these sorts of statistics, it is not surprising that Roberts (1997) and Roberts and Baird (1995) wrote that *H. lobatus* and *H. siamesis* were the most abundant species in the lower and middle Mekong Basin. Poulsen *et al.* (2004: 45), of the MRC Fisheries Programme, came to the same conclusion, writing,

> These two species [*Henicorhynchus lobatus* and *H. siamensis*] are probably the most abundant in fisheries of the lower Mekong basin. For example, in the *dai* fisheries of the Tonle Sap River, they currently comprise about 50% of the catch from November to February (MRC monitoring data). Throughout their migration routes they are caught in huge numbers during their peak migration period between October and February. They thus play a crucial role for the livelihood of local communities and are the foundation for a number of processing activities such as drying and smoking and the production of fish sauce (*Prahoc* in Khmer or *Padaek* in Lao), fish paste and animal feed.

Other species, such as *Scaphognathops bandanensis, Hypsibarbus malcolmi, Mekongina erythrospila, Gyrinocheilus pennocki, Bangana behri,* and *Labeo erythropterus*, are also well known for being amongst the most abundant fish species caught in northeastern Cambodia and southern Laos (Baird and Flaherty 2004; Baird and Meach 2005; Warren *et al.* 1998; Roberts and Warren 1994). For example, just below the Khone Falls, *Scaphognathops bandanensis* is the most abundant species in a 4-9 cm meshed set gillnet fishery, making up 28.7% of the total catch. The second most abundant is *Mekongina erythrospila* (26.9%).

Pangasius krempfi catfish also support an important fishery in the Khone Falls area, and others upstream and downstream (Hogan *et al.* 2007), including in the Mekong Delta area (Roberts and Baird 1995). They make up 73% of the catch by weight for a 12-16 cm meshed multi-filament set gillnet fishery just below the Khone Falls (Hogan *et al.* 2007). The species also makes up a significant (4.7%) portion of the wing trap fishery in the Khone Falls area (Baird *et al.* 2004).

Other pangasid catfishes are important for many different fisheries as well, with *Pangasius conchophilus* making up over 40% of the catch of the large wing-trap fishery in the Khone Falls,

and other migratory species constituting large percentages of the catch by weight, including *Henicorhynchus lobatus* (12.5%), *Scaphognathops bandanensis* (7%), *Pangasius bocourti* (3.8%), and *Pangasius larnaudii* (2.7%) (Baird *et al.* 2004) (Roberts and Baird 1995; Baird *et al.* 2001; 2004; Baran *et al.* 2005).

6.5 The Impacts of the Don Sahong Dam to Downstream Fisheries

When it comes to fish migrations in the Mekong River Basin, it seems apt to consider the well-known adage, "What comes up must come down". If fish were unable to migrate above the Khone Falls, they would not be able to feed, reproduce or complete other parts of their lifecycles above the Khone Falls. It is not expected that the DSD would significantly impact downstream migrations of mature fish past the Khone Falls, because the Hou Sahong Channel is but one of many possible channels that can facilitate these downstream movements year-round. In addition, areas downstream from the dam would not face the types of major hydrological impacts that have been subjected to other rivers, such as the Sesan River in northeastern Cambodia (see Baird 2009; Wyatt and Baird 2007; Baird and Meach 2005). However, it is possible that some fish migrating downstream could be killed or seriously injured through trying to pass through the turbines of the dam. Large fish species would be expected to be impacted more than smaller species (Halls and Kshatriya 2009).

The DSD could also negatively affect fish larvae drift during the height of the rainy season. That is because some species, such as *Pangasius krempfi*, are believed to migrate far up the Mekong River to spawn. The young larvae of the species are then believed to be washed down the Mekong River through the Khone Falls and eventually to the Mekong Delta in Viet Nam (Hogan *et al.* 2007; Bao *et al.* 2001). If these larvae were washed into a slow-flowing reservoir, or through the DSD's turbines, the impacts could be serious, although without understanding how the flow pattern would be affected by the dam it is difficult to know how significant impacts might be. More research is required.

However, even without considering the impacts on downstream moving fish larvae, the DSD would negatively impact fish migrating upstream and thus lead to smaller fish populations above the Khone Falls. In turn, this would affect fish downstream as well, since there would be less fish to migrate downstream from above the Khone Falls than in the past. Ultimately, this would impact fisheries downstream in Cambodia and Viet Nam as well. It is crucial to recognise that due to the highly migratory nature of many fish species, the impacts on fish above the Khone Falls in Laos or Thailand can be expected to negatively impact fish and fisheries located in neighbouring downstream countries, such as Cambodia and Viet Nam.

There have already been a number of studies conducted that give us an idea of the types of impacts that could affect migratory fish if the DSD were to be built. In considering these, it is useful to divide up the impacts based on geography. The closest fishery in Cambodia impacted would be the one associated with Talat Stream, a large and long perennial stream that flows into the Mekong River just a few kilometres downstream from the Khone Falls, in Thalaboriwath District, Stung Treng Province, northeastern Cambodia. Every year at the end of the rainy season large quantities of fish migrate out of the stream into the mainstream Mekong River. Although many are caught using various types of traps and bag-nets as they try to migrate to the Mekong

(see Baird and Flaherty 2004), at least some of the fish that do make it into the Mekong River end up migrating upriver past the Khone Falls via the Hou Sahong Channel. If these fish were no longer able to migrate past the Khone Falls, the effective catchment of the Talat Stream fishery would be reduced, thus decreasing the biological potential of fish populations associated with the Talat Stream. This could affect species such as *Scaphognathops bandanensis* and *Hypsibarbus malcolmi.* This same sort of problem could affect fisheries associated with other streams as well.

If we look at the next scale of impacts, further downstream, it can be expected that important fisheries in the Sekong, Sesan and Srepok Rivers in northeastern Cambodia and southern Laos would be negatively impacted if the medium-sized cyprinid carps that migrate between the Mekong River above the Khone Falls and these rivers could no longer move past the Khone Falls via the Hou Sahong Channel. The details of the migration of this group of species below the Khone Falls have been well documented by Baird and Flaherty (2004), while the migrations above the Khone Falls have been studied by Warren *et al.* (1998). Baird (1995), Baird and Flaherty 2004, and Baird and Meach (2005) have discussed the migratory patterns of these species, including *Mekongina erythrospila* and *Scaphognathops bandanensis*, below the Khone Falls.

Then there are the fish species that migrate in the dry season from between the Tonle Sap Lake in Cambodia and the Mekong River above the Khone Falls, including *Henicorhynchus lobatus, Paralaubuca typus* and *Botia modesta* (Baird *et al.* 2003; Poulsen *et al.* 2004). It is hard to know how significant the loss of habitat would be for the at least 32 fish species that migrate from the Tonle Sap River to the Khone Falls each dry season (Baird *et al.* 2003). It is possible that the loss of a small number of fish upriver of the Khone Falls could significantly affect the size of the brood stock and thus populations downstream; it is also possible that the loss of these fish might not have a significant impact on downstream reproduction in the Tonle Sap Lake. The problem is that the impacts would not become clear until after the DSD is built, and by then it would be too late to change course. What we do know is that the Tonle Sap small cyprinid fishery in Cambodia is extremely important to the livelihoods and food security of a large portion of the human population of Central Cambodia (Hortle 2007), and any significant impacts to the biological potential of the fishery would be socially and economically devastating to rural Cambodia.

There are also other long distance migratory fish species that would be impacted, such as the large eel, *Anguilla marmorata* (Baird *et al*. 1999a). Crucially, the large catfish *Pangasius krempfi* migrates up the Mekong River from the Mekong Delta in southern Viet Nam, and spawns far upriver from the Khone Falls (Hogan *et al.* 2007). Therefore, if migratory stocks of this species were prevented from migrating upstream of the Khone Falls, it could have a drastic impact on the species, potentially even leading to its extinction. It is unclear whether the species would be able to adjust its behaviour so as to spawn further below the Khone Falls, far downstream from where it used to spawn. However, it seems unlikely that any adjustment, if possible at all, would come without a significant cost to the population. Therefore, the DSD could end up decimating estuary fisheries for *Pangasius krempfi* in Viet Nam. At this point it is unclear how important these fisheries are, but in the early 1990s *Pangasius krempfi* was observed mixed with catches of tongol tuna caught by commercial fishers in salt oceanic waters in the South China Sea (Roberts and Baird 1995). MRC fish catch data have reported the species

to be present in catches in Khammouane, Bolikhamxay, Vientiane and Bokeo Provinces (MRC, *pers. comm.* June 2009).

It should be added that hydrological changes downstream from the DSD could have a negative impact on fish migrations, as it is now understood that many fish rely on particular 'hydrological triggers' to start them off on their migrations. That is, certain hydrological events cause certain migratory or other behaviour to occur. Therefore, fish could become confused or otherwise impacted due to hydrological changes downstream, potentially causing various problems by interrupting crucial parts of their lifecycles (Baran 2006; Baran *et al.* 2005; Hogan *et al.* 2007).

6.6 Numbers of People Expected to be Impacted Downstream

It should be clear from the previous section that if all the migrations of fishes were impacted by the DSD (and it should be recognised that some may have been missed), a very large area and number of villages would be impacted downstream from the Khone Falls, including the mainstream Mekong River from the Khone Falls downstream to the estuary of the Mekong Delta in the South China Sea, the Tonle Sap River and the Great Lake, the Sekong, Sesan and Srepok River systems, and various perennial streams that flow into the above-mentioned large rivers downstream from the Khone Falls.

Although it is difficult to accurately assess the exact number of people, households, and villages that might be negatively impacted by the loss of migratory fish due to the DSD, it could exceed millions of people. Certainly the fish stocks that would be impacted above the Khone Falls are also an important part of many fisheries below the Khone Falls, including in the Sesan, Srepok, Sekong Basins (Baird and Meach 2005), and of course, the Tonle Sap River (Lieng *et al.* 1995 Downstream from the Khone Falls, the areas that would be the heaviest impacted are adjacent to the mainstream Mekong River in Stung Treng Province. In addition, villages situated away from main rivers but located near large streams such as the Talat Stream in Stung Treng Province would also be negatively impacted. Furthermore, villages situated adjacent to the Mekong River downstream from Stung Treng would be impacted, as well as villages near the Tonle Sap River and Great Lake. Parts of the Mekong River south of Phnom Penh and into the Mekong Delta would be impacted by the loss of some migratory fish species, such as *Henicorhynchus* spp. In addition, fishers in the South China Sea in Viet Nam could lose access to highly migratory *Pangasius krempfi* catfish. Millions of people live in these areas.

Apart from the above, hundreds of thousands of people living along or near the Sekong, Sesan and Srepok Rivers in northeastern Cambodia, southern Laos and possibly the Central Highlands of Viet Nam would be negatively impacted through losing migratory fish.

Because the number that could be impacted is so high, and the area that would be impacted is so wide, it is not possible to provide exact statistics. More research is required.

6.7 Gas Supersaturation below the Don Sahong Dam

Gas supersaturation is a little-known phenomenon that occurs in rivers, usually below large dams but also in natural conditions below large waterfalls. It occurs when the force of water is so strong that it becomes supersaturated with oxygen, resulting in what has come to be known as 'gas bubble disease', which is when supersaturated water causes damage to the internal organs of living organisms, such as fish. Gas bubble disease has been documented downstream of the Khone Falls area (Baird *et al.* 1999b). There is a danger that gas bubble disease could affect areas downstream from the DSD, especially after part of the water flow to the Khone Phapheng Falls is diverted into the Hou Sahong Channel to generate additional electricity, which is presently envisioned (MFCB 2007). However, it is unclear how far downstream gas bubble disease might occur, if at all. Gas supersaturation, although not discussed in the draft EIA for the DSD (MFCB 2007), should, therefore, be considered a possible threat to aquatic life downstream from the DSD, although the extent of possible impacts remains unclear.

6.8 Habitat Destruction below the Don Sahong Dam

If the DSD is built, the project would cause the destruction of a considerable amount of aquatic habitat, through changing local hydrological patterns within the Khone Falls area and below the Khone Falls. This, in turn, would negatively affect tracts of seasonally inundated vegetation. These seasonally flooded forests are important aquatic habitats for fishes in the Khone Falls area. They are a source of food for some species, and a refuge from predators, strong currents and the hot sun for others (Baird 2007; Roberts 1993). Therefore, losses of flooded forest habitat would negatively affect some important fish species, as well as adversely impacting the overall aquatic ecosystem.

6.9 Cumulative Impacts on Fish and Fisheries

It is highly likely that the DSD, if built, would disrupt upstream fish migrations from Cambodia to Laos that pass the Khone Falls. However, there are so many different species that interact with each other and the environment in ways that we know little or nothing about. Thus different species could be impacted in various ways (c.f. Baran and Jutagate 2008).

The fish stocks that could be lost upstream of the Khone Falls include a wide variety of species that are not only crucial for local livelihoods, but for the overall ecology of the Mekong Basin as well. *Henicorhynchus lobatus* is a good example of a Mekong keystone species. It is not only an important source of food for people throughout the Lower Mekong River Basin; it is also a crucial source of food for various predatory fish species, including migratory ones, (Lieng *et al.* 1995; Baird *et al.* 1998; 2003; Poulsen *et al.* 2004). These include the catfishes *Hemibagrus wyckioides, Hemibagrus nemurus, Micronema* spp., *Wallago* spp., *Pangasius sanitwongsei,* and *Bagarius yarelli,* which feed heavily on grazing algae eaters during the low-water dry season, and would be negatively impacted if migratory *H. lobatus* were lost from below the Khone Falls. Below the Khone Falls, *H. lobatus* is also an important part of the diet of Irrawaddy dolphins, at least in the dry season (*Orcaella brevirostris*) (Baird and Mounsouphom 1997; Baird and Beasley 2005).

In fact, the loss of these migratory species would lead to dramatic negative changes in whole aquatic communities, both upstream and downstream of the Khone Falls. The loss of other species of fish, such as *Scaphognathops bandanensis* and *Paralaubuca typus*, could result in similar problems, but so far there has not been enough research done to definitively predict cumulative or synergistic impacts. Still, these impacts are an important issue, and the risk that they present should not be underestimated. Unfortunately, it is not possible to fully predict the cumulative and synergistic impacts from the dam until it has been built, at which point not building the project would no longer be a real option.

7. DISCUSSION

7.1 Mitigating the Impacts of the Don Sahong Dam

The draft EIA for the DSD recognises that the Hou Sahong Channel is indeed the most important channel in the Khone Falls area for fish passage, and that it is especially important for the many dry-season upstream migrations that occur each year (MFCB 2007). However, it is assumed that the impacts of blocking the only channel in the Khone Falls that fish can easily migrate up year-round can be mitigated through expanding the Hou Sadam and Hou Xang Pheuak Channels found on either side of the Hou Sahong Channel. It has also been proposed that additional water would be diverted into the Hou Sadam Channel so as to attract more fish into the channel. The EIA contends that the use of fish passes is also a possibility for the Hou Xang Pheuak and Khone Lan Rapid. Because the EIA's authors consider that all the impacts on migratory fish species can be fully mitigates, the EIA does not consider the regional impacts of the project (MFCB 2007).

The DSD evidently represents a serious threat to migratory fish in the Mekong River Basin. Illustrative of this, it is clear from field observations made in January 2009 that the conditions of the Hou Sahong Channel, with its continuous flow of water and great width, could never be duplicated through implementing the mitigation measures so far proposed within the project's EIA (MFCB 2007). The record of fish passes in the Mekong River and globally is very poor (Bernacsek 2000; Thorncraft *et al.* 2006). As Baran *et al.* (2007: 24) wrote,

> "[F]ish passes are often proposed to help fish migrate. However, there are no examples of fish passes that work in the Mekong Basin. This is mainly due to ecological factors and the intensity of migrations which fish passes cannot accommodate."

Indeed, it would be very difficult to create one or more fish passes (or fish ladders) that would be able to effectively accommodate the unique biological requirements of all the fish species that migrate past the Khone Falls each year. Therefore, it must be considered that the likelihood of being able to mitigate all or even most of the impacts caused by the DSD is small. The reality is that regardless of what anyone claims, nobody really knows enough about the migratory requirements of the various fish species involved to be able to say with any certainty what the result of various mitigation measures might be. We can only guess, and based on what is known, the prospects for avoiding serious impacts appear to be small. For example, Hou Sadam is many kilometres long, and is narrow throughout its length. Widening it significantly all the way along its length seems unlikely to be feasible or economical.

7.2 Fisheries Impacts, Nutrition, Food Security and Poverty in the Mekong River Basin and the Don Sahong Dam

Some fisheries experts in the Mekong River Commission (MRC) and WorldFish have attempted to quantify the potential negative impacts of the DSD and other mainstream Mekong dams on migratory fish—predicting that impacts could reach as high as over US$200 million per year.[12] However, I do not have sufficient data to provide more than a very rough estimate of the amount of fish that would be lost if a dam is built on the Hou Sahong Channel. One serious challenge is that it would be very difficult, if not impossible, to determine the amount of fish that pass through the Hou Sahong Channel during all seasons with a useful level of accuracy, and while it would be possible to estimate the amount of fish caught in the Khone Falls area, including the Hou Sahong Channel, these data would only be of limited use. They could tell us what has been caught, but what we really need to know is the amount of fish that have not been caught—the amount of fish that successfully move upriver through the Hou Sahong Channel each year. We also need to know how far they are migrating, and their significance in fish catches. This paper has provided some preliminary information of this nature.

Although I am not able to provide definitive quantitative statistics regarding fish migrations above the Khone Falls, it is still useful to consider some important issues related to the potential losses of migratory fish, and the resultant implications in terms of food security, human nutrition, and ultimately poverty alleviation efforts in the Mekong region. These issues are, in fact, crucial when it comes to a project such as the DSD, one with such a potentially large ecological footprint when it comes to fisheries impacts.

Kent Hortle (2007) from the MRC Fisheries Programme has estimated that Cambodians consume 32.3 kg of inland fish per capita/year, as well as another 4.5 kg of other aquatic animals. This compares to 24.5 kg of inland fish consumption per capita/year in Laos. The estimated consumption of fish and other aquatic animals in the Mekong River Basin is believed to be 2.6 million tonnes annually, making the region one of the most productive for inland fish globally. In line with this, Dugan (2008b) has reported that it is now estimated that the fish production in the Mekong Basin is 3 million tonnes per year, of which 2.4 million tonnes, or 80%, are wild-caught.

The DSD could cause serious human nutritional problems throughout the Mekong region, as wild-caught fish are by far the most important source of animal protein for people living along large rivers and streams in the lower Mekong River Basin (Hortle 2007). In addition, a reduction in available fish in the marketplace as a result of impacts caused by the DSD could also lead to fish shortages and increases in prices. This would result in less fish consumption, especially by poorer consumers who would no longer be able to afford to purchase as much fish to eat.

Let's consider the region directly downstream from the dam, northeastern Cambodia, where fish make up the most important source of animal protein for local people (Roberts and Warren 1994; Baird 2009). Already, in Stung Treng Province, the provincial government's Department of

[12] Neither of the reports with these estimates have been publically released, and so it is not possible to provide statistics here.

Planning (2003) has reported that 44.8% of children under five years old are underweight. As people are already not consuming enough animal protein, a further reduction of fish without replacement protein could lead to serious increases in nutritional problems.

The issue is particularly troublesome considering recent reports that the percentage of children classified as acutely malnourished in Cambodia has increased. While the number fell by half between 2000 and 2005, it increased from 8.4% in 2005 to 8.9% in 2008. This represents a considerable setback for the government of Cambodia (Corey-Boulet 2008). Part of this decline may be due to the decreased availability of easy-to-access and cheap fish in Cambodia. Losing a large quantity of wild-caught fish due to the DSD would be especially devastating considering that fish and other aquatic animals are by far the most important sources of animal protein in Stung Treng and Cambodia more generally. Apart from people losing fish that they catch, impacts to fisheries could also negatively affect consumers by making fish scarcer in the market and driving up fish prices. This could be particularly problematic for poor people who purchase fish on the market.

In Laos, the situation is even more worrying. Recent research by the World Food Programme (WFP) has found that Laos' rural population is experiencing serious nutritional problems, with 50% of all children being chronically malnourished. Crucially, advances in general development in Laos have not translated into improved nutrition for the people, with nutrition levels being about the same as they were a decade ago (Krahn 2007). People living near large rivers in the southern Lao province of Attapeu, for example, have been found to be consuming insufficient amounts of fats and animal protein (Meusch *et al.* 2003), and this is likely to be an even greater problem in parts of the country less endowed with aquatic resources than the lowlands of Attapeu.

Of particular relevance in relation to the DSD, the Lao people are particularly lacking in meat, fish and edible oils (Krahn 2007), the exact food types that are threatened by the dam. Krahn (2007: 10) writes, "Managed access to wild meat and aquatic resources (animal protein) is critical for ensuring food security for vulnerable groups. Wild meat and aquatic resources, especially wild fish, is the biggest source of animal protein in rural Lao PDR."

Clearly, losing large quantities of fish protein could have a devastating effect on the nutritional standards of rural populations in Laos as well as in Cambodia, but also in parts of Thailand and maybe even Viet Nam as well. While it is hard to estimate what percentage of the fish that rural people normally consume would be lost, even if just 10% were taken from the millions of people living above and below the proposed site of the DSD and dependent on migratory fish for protein, the results would be devastating. They could well be nationally and regionally significant in relation to human nutritional indices. In particular, many rural people are presently existing in borderline conditions, not being technically malnourished but being close to it, or they are already undernourished, but only marginally. The loss of a few kilograms of protein per capita a year might not seem like much, but such losses could substantially increase the number of malnourished people in the region. People who are undernourished achieve less when they go to school, and are ultimately less able to support social and economic improvements amongst the people.

The loss of migratory fish could badly affect efforts to meet the United Nations Millennium Development Goals (MDGs), which are very much linked to human wellness and good health. In relation to the Second Millennium Development Goals Progress Report for 2008 for Laos, the *Vientiane Times* (2009) reported that while there have been various advances made in health care in Laos in recent years, there has been little reduction in the extent of child malnutrition since 1990. The report noted that despite considerable efforts, 38% of children less than five years of age are underweight and 41 percent of the children in this age group suffer from chronic malnutrition.

Following from the above discussion about food security, nutrition, health and human wellbeing, it is important to consider the implications of the DSD in relation to efforts to alleviate poverty, not only in Laos but more generally in the region. One goal that has been made a priority by all the governments in the Mekong region is to reduce poverty. In addition, in recent years poverty alleviation has become the explicit goal of most international aid agencies. It is the main stated overall objective of multilateral banks and international aid agencies working in Laos, including non-governmental organisations (NGOs).

The DSD would reduce the nutritional status for large numbers of families in various parts of the Mekong River Basin, especially parts of Laos, Cambodia and Thailand. Those living closer to the dam, both upriver and downriver from the project, would generally be impacted more than those located farther away. However, impacts would continue for well over a thousand kilometres, from the Mekong Delta in Viet Nam, past Cambodia, Laos and Thailand, continuing on to northern Laos. Considering its wide and deep foot print, it can be expected that the DSD could ultimately make it much more difficult for governments in the region, especially those of Laos and Cambodia, to reach their objectives in terms of reducing poverty. For national governments and the international aid agencies that support them, the DSD should be a major concern.

8. CONCLUSIONS

This study has shown that the potentially most serious impact of the DSD would be on fish stocks that normally migrate long distances past the Khone Falls via the Hou Sahong Channel, which would be blocked by the DSD. It might be possible to mitigate some of the impacts of the project, but it seems highly unlikely that it would be possible to mitigate all of the impacts of the dam on all the different fish migrations that rely on the Hou Sahong Channel each year. Moreover, it is quite possible that mitigation measures might not be at all successful in mitigating severe negative impacts of the dam. Right now, the extent that it would be possible to mitigate the impacts is impossible to accurately predict, and thus any mitigation plans should be considered extremely risky and uncertain.

Based on the fieldwork conducted for this study, and a review of the relevant scientific literature from the Mekong region, there is considerable evidence that at least some of the fish stocks that migrate upriver past the Khone Falls reach as far as Vientiane and adjacent parts of Thailand, and even northern Laos, and that these populations also migrate downstream past the Khone Falls, reaching as far as the Tonle Sap Lake in Cambodia and Mekong Delta in Viet Nam. Therefore, the fisheries impact area potentially covers large parts of Laos and Cambodia, as well

as significant areas in Thailand and Viet Nam. The aquatic communities could change dramatically, leading to synergistic and cumulative impacts, and still wider reductions in fish stocks. Some species could become extinct.

Since these fisheries are important for livelihoods throughout the Mekong Basin, even a partial impact to these fish populations could have a devastating impact on the human population of the Mekong River Basin, especially people living along the Mekong River and its large tributaries, but also potentially small tributaries as well. In that fish are important sources of protein for much of the population of the Mekong River Basin, including the poor, and are crucial for maintaining good nutrition and health, the loss of large quantities of fish to the human population in the Basin due to the DSD could have devastating development results for Laos, Cambodia, Thailand and Viet Nam. Increased levels of malnutrition could result, seriously jeopardising efforts to alleviate poverty and improve the quality of life of the human population in the Mekong region generally.

The stakes are indeed high, and it is therefore important that any decision to move forward with the dam considers the serious risks involved for Laos and the region. While it is certainly true that more research is required to confirm some of the preliminary findings presented in this paper, it would be disingenuous to say that we do not already know enough to reasonably predict that the impacts would be serious. We have indeed learnt a lot about Mekong fisheries over the last two decades, and we do not need to know everything about Mekong fish and fisheries to suggest that the DSD represents a serious threat to fisheries in the Mekong River Basin.

ACKNOWLEDGEMENTS

Thanks to Chaloun Souriyavong from Khong District for his assistance, and Jutta Krahn from the World Food Programme. Michael Thorne from the British Antarctic Survey assisted with some data management. Thanks also to the MRC's Fisheries Programme for providing me with unpublished fish catch data from the Mekong River upriver from the Khone Falls in Laos. Although this research was done as an independent study, the author is thankful for the useful comments provided by reviewers on an earlier version of the paper. I take responsibility for any deficiencies that may remain.

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