WATER AND FOOD CHALLENGE PROGRAM IN THE MEKONG
Optimizing the management of a cascade of reservoirs at the catchment level
MK3

FISH AND FISHERIES IN THE SESAN RIVER BASIN
MK3 catchment baseline- fisheries section

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"Information on fish stocks, biodiversity, capture fisheries and aquaculture is inadequate and needs further research in order to make qualified assessments."
WorldBank 2006
Options for integrated development and management of the Se San–Sre Pok–Se Kong sub-basins

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EXECUTIVE SUMMARY

The present report was prepared for the Water and Food Challenge Program project "Optimizing the management of a cascade of reservoirs at the catchment level" (MK3). It constitutes the baseline assessment of fish and fisheries in the Sesan River Basin.

Hydrology

The Sesan River is 420 km long and flows from Dak Glei commune in Vietnam to Stung Treng in Cambodia (from Dak Glei to Plei Krong in Vietnam the river is called Krong Poko). With 19,000 km^2 the Sesan River contributes around 10% to the annual discharge of the Mekong. The maximum discharge (4,500 $m^3.s^{-1}$ on average) occurs in September and the lowest (250 $m^3.s^{-1}$) in March. Following the construction of the Yali dam in Vietnam, natural water levels and flows in the Sesan River started to change significantly after 1996, with unpredictable variations and lower water quality.

River environment

A new methodology combining GIS information, available maps and Google Earth information was developed for the current project. As a result, eight ecological zones were identified along the Sesan River. Starting from Stung Treng, these zones are characterized mainly by wetlands (up to km 58) and then by a long string of sand banks (km 58 to 156). The Sesan River connects with the Srepok River through a narrow rocky corridor at km 38. From km 233 to the Yali site (km 286) it is no longer possible to identify the natural features of the Sesan River due to the presence of several dams and construction sites. Before dam construction the Yali Falls was a natural obstacle to fish migrations. The Yali reservoir stretches from km 286 to km 309 (Plei Krong). Upstream of Plei Krong the river becomes a mountain stream featuring a succession of wetlands, sand banks and rocky channels. With at least 235 irrigation dams, weirs or other recorded structures blocking waterways, connectivity in the Vietnamese part of the Sesan Basin has been altered considerably.

Fish biodiversity

The 3S system (Srepok, Sesan and Sekong Rivers) is characterized by a high level of fish biodiversity with 329 species. This corresponds to 42% of all Mekong fish species, for an area representing only 10% of the Mekong Basin. The Sesan River features 133 fish species, i.e. approximately 40 to 50% fewer species than the Sekong and Srepok Rivers.

The 3S rivers are also home to 14 endangered fish species, including the critically endangered species *Aaptosyax grypus* (giant salmon carp)*, Catlocarpio siamensis* (giant carp) *and Pangasianodon gigas* (giant catfish). Fifteen species are found exclusively in the Sekong River and two in the Srepok River; they are found in no other Mekong tributary and nowhere else in the world. No species is exclusively found in the Sesan River.

Fish migration

The 3S system is characterized by at least 89 migratory fish species belonging to 15 families. More specifically, the Sekong, Sesan and Srepok Rivers are characterized by 64, 54 and 81 migratory fish species respectively. At least 41 migratory fish species are commonly caught by fishermen in the Sesan River, and these migratory species represent 60% of the fishermen's total catch.

Fish catch

The total catch in the Sesan River Basin is not precisely known and estimates range between 370 and 6,700 tonnes of fish per year.

Population and total fish catch estimates for the Sesan River

Fish catch (kg) per family per year	Source	Population estimates	Number of families (6 persons/family)	Total catch (tonnes)	
				Lower range	*Upper range*
73.2	Province statistics	30,000	5,000	*366*	610
131	KCC 2009			655	1,092
129.3	Baird and Meach Mean according to KCC 2009			646.5	1,078
365	Baird 2009	50,000	8,333	1,825	3,042
500				2,500	4,167
800				4,000	*6,667*

This wide range of estimates underlines the urgent need for a proper assessment of fish catches along the Sesan River. The contribution of the Sesan River to the fish production of floodplains in Cambodia in Vietnam should also be assessed.

The total value of the fish production along the Sesan River ranges from USD 1 to 25 million, the central estimate being between 2-16 million USD, depending on estimates of total yield and of price per kilo.

Capture fisheries dependent livelihoods

The population living along the Sesan River Basin in Cambodia and Vietnam reaches 840,000 people. The number of people dependent on riverine resources along the Sesan River is subject to multiple contradictory estimates; in Cambodia, this number ranges from 30,000 to 50,000 people. Dependency might be less in Vietnam. Overall, it is difficult to assess the degree of dependency of local populations since it depends on distance to a river, household wealth, and level of local development.

Fish is still regarded as the main source of protein in the diet of the Sesan people. Estimates of fish consumption along this river vary between 15 and more than 100 kg/person/year (17-53 kg/person/year along the Sekong and around 25 kg/person/year along the Srepok River).

There is unanimous agreement that there has been a drastic decline in the abundance of most fish species, or more specifically in the catch per fisherman, along the 3S rivers. This decline applies to species in all families and to all three of the rivers. In the Sesan River for instance *Henicorhynchus siamensis* and *H. lobatus* had not been seen upstream for about ten years (though they reappeared in 2010 for an unknown reason). The Srepok seems to be the river where the decline is smallest.

Aquaculture

With only 20 to 40 tonnes of fish produced in 2010 there is no substantial aquaculture sector in the Cambodian part of the 3S. In Vietnam no detailed and recent aquaculture statistics could be found; in 2003 about 5,000 tonnes (i.e. less than 1 percent of the national production) were produced in the 3S. Actually, 2010 reviews indicate that 70-80 per cent of the catch originates from reservoir fisheries.

1 INTRODUCTION

The objective of the MK3 project is to contribute knowledge and recommendations so that cascades of reservoirs corresponding to hydropower dams in the Mekong Basin are managed in ways that are more fair and equitable for all water users. This project seeks to understand at the catchment scale the cumulative upstream and downstream consequences of management decisions taken for multiple reservoirs. Revised rules for water storage infrastructure management will in particular take into account fisheries and agricultural potential as well as hydropower generation.

The MK3 project has two study sites: the Sesan Basin in Cambodia / Vietnam and the Nam Theun Basin in Laos (Table 1).

Table 1: Dams in the Sesan and Nam Theun Basins.

	In operation	Under construction	Probable future	Potential
Sesan	Plei Krong Yali Sesan 3 Sesan 3A Sesan 4A O Chum 2	Upper Kontum Sesan 4	Lower Sesan 2	Sesan 1 Prek Liang 1 Prek Liang 2 Lower Sesan 3
Nam Theun	Theun Hinboun Nam Theun 2	Nam Gnouang		Nam Theun 1 Nam Theun 4 Nam Mouan

The present component of the project focussing on i) the Sesan Basin and ii) fisheries will:
- establish a fisheries baseline for the Sesan catchment, focussing on fish biodiversity, fish production, fisheries zoning, resource use and the fisheries sector;
- Identify ecological flows suitable for fish in the Sesan catchment (how much flow should be left for downstream fish production);
- contribute to the identification of a set of ecological sustainability principles which will guide multiple uses of water resources and riverine systems;
- assess the impacts of dam development on the fisheries sector (how much capture fish will be lost due to dam construction, how this loss can be mitigated, and how much fish can be produced from reservoirs).

The present report constitutes the Sesan catchment baseline for the fisheries component of the MK3 project; a second reports will focus on ecological sustainability principles and on dam impacts in the Sesan.

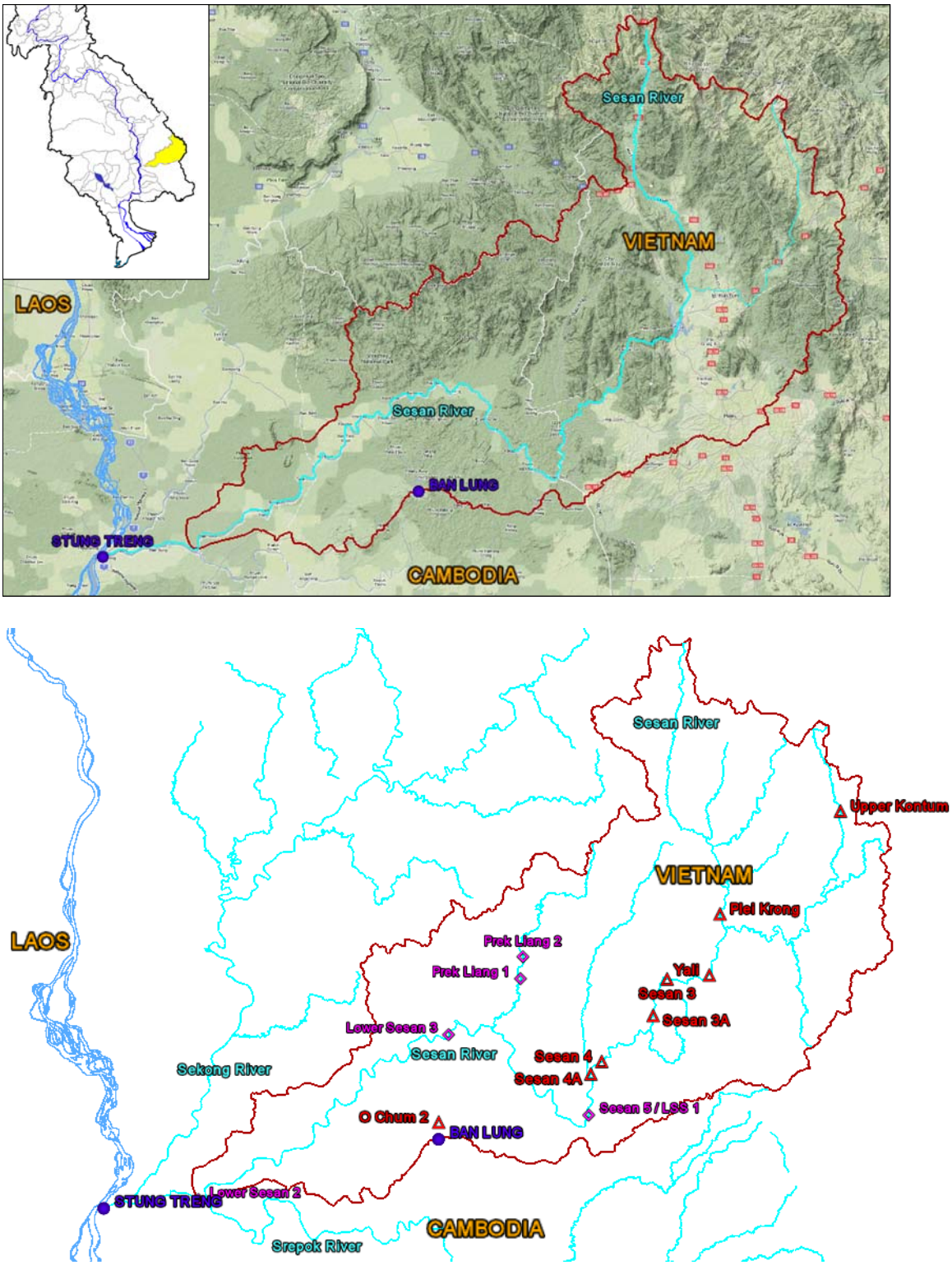


Figure 1: Location maps. Orange: country borders; purple: Sesan watershed; red: existing projects; pink: planned projects.

2 SESAN RIVER ENVIRONMENT

The surface area of each river of the 3S is detailed below:

Table 2: Sub-areas per country and per basin. Source: 3S ADB RETA project (http://reta.3sbasin.org).

Sub-basin	**Cambodia** (km^2)	**Laos** (km^2)	**Viet Nam** (km^2)	**Total** (km^2)
Sekong	5,565	22,565	690	28,820
Sesan	7,630	-	11,260	18,890
Srepok	12,780	-	18,160	30,940
Total	25,975	22,565	30,110	78,650
Total %	33 %	28.7 %	38.3 %	100%

The above figure for the Sesan River Basin area is widely accepted (e.g. SWECO 2006, KCC 2008, MRC interactive GIS atlas) but varies depending on authors and goes up to 76,700 km^2 (CEPA 2007), which actually corresponds to the cumulated surface area of all 3S catchments (78,644 according to the MRC GIS atlas).

2.1 HYDROLOGY OF THE SESAN RIVER

The hydrology of the Sesan River, under pristine conditions and under current conditions, is detailed in the Hydrology section of this project and summarized in other reviews (in particular CNMC 2009). We propose here a brief overview.

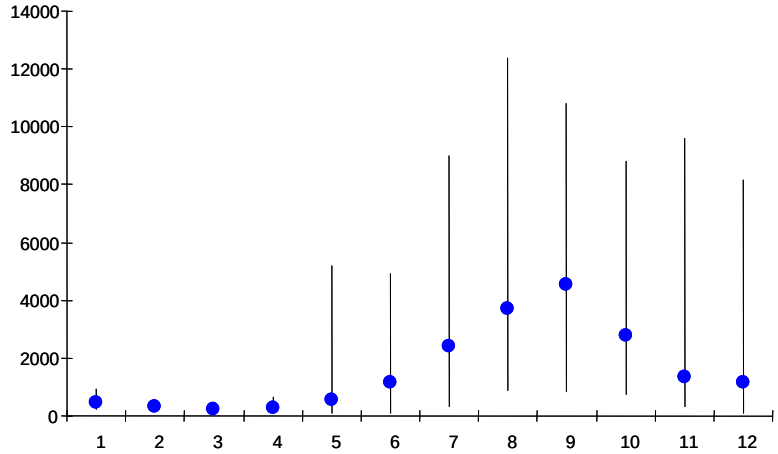


Figure 2: Monthly distribution of discharge ($m^3.s^{-1}$) in the Sesan River. Source: Ban Komphun station, 1961-1970 records.

Table 3: Monthly distribution of discharges ($m^3.s^{-1}$) in the Sesan River. Source: Ban Komphun station, averaging of 1961-1970 annual records[1]

Month	Maximum	Minimum	Average
1	911	240	478
2	570	184	321
3	360	160	245
4	650	110	274
5	5,200	112	564
6	4,930	85	1,168
7	9,000	330	2,402
8	12,400	898	3,709
9	10,800	855	4,529
10	8,800	730	2,761
11	9,600	310	1,342
12	8,171	88	1,178

The Sesan River contributes around 10% to the annual discharge of the Mekong flow, although figures vary according to authors; e.g.:
- 16.7% according to MRC 1992;
- 10% according to KCC 2009.

2.2 ECOLOGICAL ZONES IN THE SESAN RIVER

We analyze in this section the environmental features of the rivers, in order to identify i) sections of the rivers constituting favourable habitats and ii) ecological boundaries, in particular obstacles to migratory fishes. As noted in Baird and Meach Mean (2005): "there are considerable differences in the species composition of the catches for fisheries in rocky areas as opposed to sandy areas. Microhabitats in the Sesan River are clearly important for maintaining different communities of fishes".

On most maps, the Sesan River is identified up to Trung Nghai (Krong Poko hydrological station, next to Plei Krong dam, 14°22'53.21"N 107°52'28.20"E); then it splits into two main tributaries: Krong Poko to the north and Dak Bla to the east. In fact according to the Vietnamese Department of Water Resource Management, Krong Po Ko is the old name of the upper stream of the Sesan River (Cong Tran Thanh, pers. comm., 21 09 2011; see Figure 3).

Figure 3: Location of the upper branch of the Sesan River (i.e. Krong Poko) in Vietnam.

[1] The above average flows, reflected in CNMC 2009, are totally different from those quoted in the Lower Sesan 2 EIA (i.e. minimum flow 377 $m^3.s^{-1}$ and maximum flow 902 $m^3.s^{-1}$, in Voeun Sai)

2.2.1 Methodology

A methodology combining GIS information, available maps and Google Earth information was developed for the MK3 project. A GIS-based terrain model was used to i) generate a grid of 1 minute cells covering the target rivers; ii) identify the slope of each kilometre of the target rivers, and iii) identify tributaries and their network. Then using Google Earth high resolution information, target rivers were examined in detail, and for each cell of one minute (i.e. of 1,852 m), the dominant habitat characterizing the cell was identified. This resulted in a large scale *and* detailed ecological examination in which river slope, access to tributaries, deep pools, vegetated islands, sand bars and rapids or waterfalls could be identified. Combining the slope assessment from GIS and the flight mode function in Google Earth for quasi-horizontal perspectives reveals waterfalls that are not clearly visible on maps and that constitute obstacles to fish migrations.

This methodology provides a basis for assessing the impact on fish resources of a dam located in a particular section of any river.

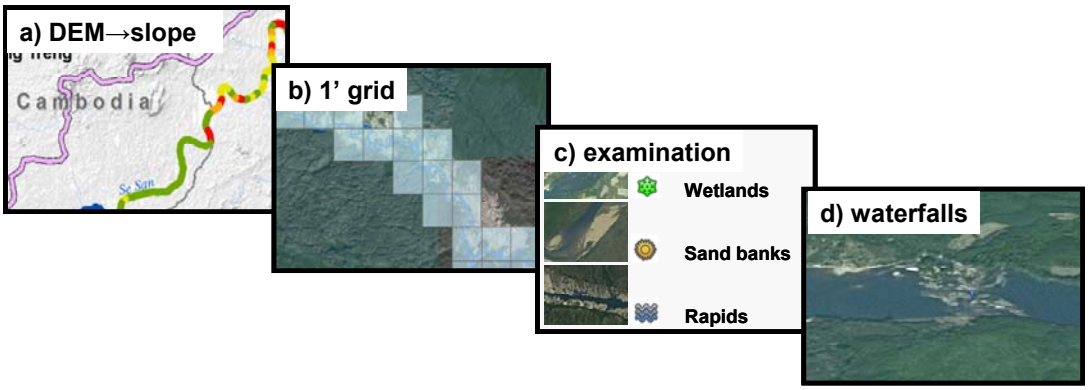
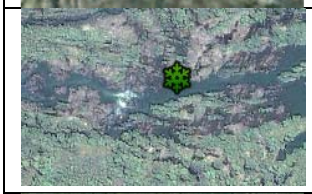
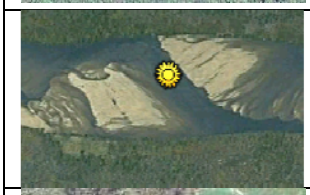


Figure 4: Steps of the methodology developed to identify the ecological features of the Sesan River

For the purpose of that study, the Sesan River was examined in detail from its connection to the Mekong (Stung Treng province, Cambodia) up to its spring in Kontum province (Vietnam). This was done using Google Earth, at an average altitude of 4,000 m. Three major features of the river were noted:

River feature	Symbol	Characteristics
	Stream	This identifies a simple river stretch without any noticeable feature
	Channel	Zones where the river is bordered by rocky banks offering limited lateral habitats but possibly deep pools, i.e. fish shelters in the dry season
	Wetland	Riverine wetlands are characterized by vegetated islands. These are zones with multiple shallow channels, slower currents and some plants; they are favourable to fish and can constitute breeding sites
	Sand bank	Zones where the currents are slower, with shallow or emerged non-vegetated zones; theses habitats may be temporary and are not very favourable to fish
	Rapids	Zones characterized by a shallow rocky substrate, “white water” and strong currents; they constitute obstacles to fish migrations
	Reservoir	River area already converted into a dam reservoir (change from running river to lacustrine environment for fish)

2.2.2 Results

Slope analysis

The river was split into 1 km long segments and the slope analysis was based on the altitude difference between two ends of a segment. The resulting map is provided in Figure 5. The analysis highlighted three steep areas (S1, S1, S3, slope >1%) to be examined more closely with Google Earth as they might include waterfalls not passable by fish.

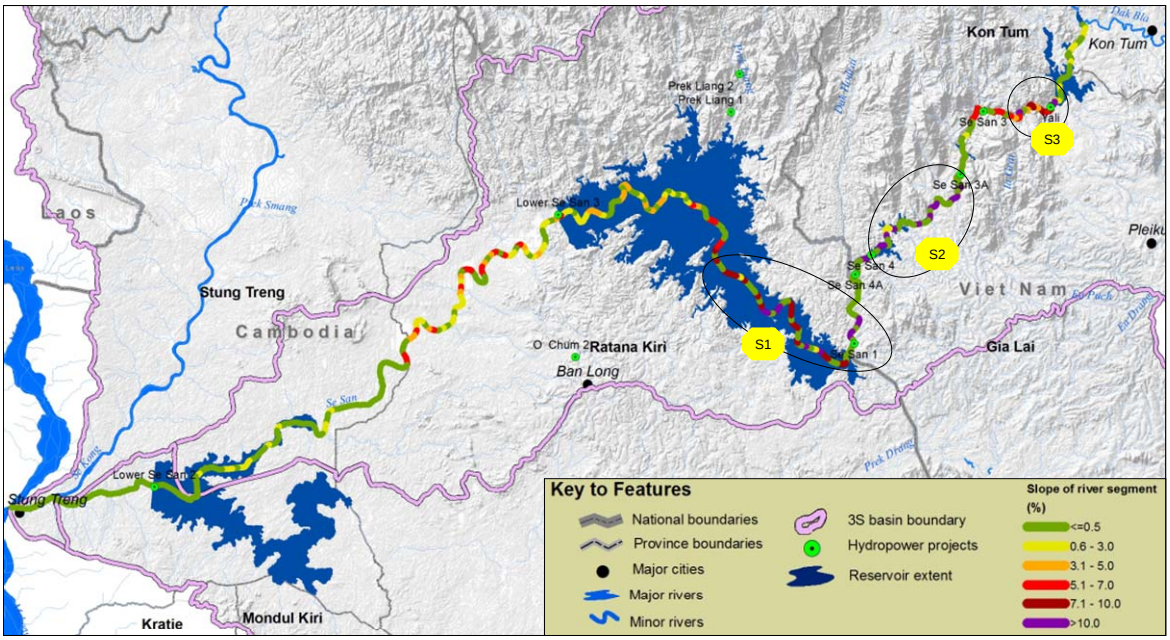


Figure 5: Slope analysis of the Sesan River. The analysis highlights three steep areas (S1, S2, S3) to be examined more closely with Google Earth.

Google Earth examination

Eight ecological zones can be distinguished in the Cambodian part of the Sesan River:

• **From Stung Treng (Km 0) to Km 19 (Kamphun commune)**: large river (600 to 900 m wide); large sand banks and mouth of the Sekong River. The tributaries of the Sesan River in this section are very short (maximum 15 km) and not branched.

• **From Km 19 (Kamphun commune) to Km 58 (Sre Ko commune)**: vegetated islands and wetlands (downstream and upstream of the Lower Sesan 2 dam site, from Kamphun to Sre Ko communes); these places might be fish spawning and breeding sites. The connection of the Sesan River with the Srepok River is characterized by a narrow rocky corridor (km 38) where currents must be strong and difficult to pass for several species. Like in the previous zone the tributaries of the Sesan River in this section are very short (maximum 15 km) and not branched.

Figure 6: Connection between the Sesan and Srepok Rivers. The Sesan River is characterized by a deep and narrow rocky channel at this place.

• **From Km 58 (Sre Ko commune) to Km 156 (Kaoh Peak commune**, upstream of Veun Sai): river characterized by large sand banks; no wetlands; river about 400 m wide. The tributaries of the Sesan River in this section become long (up to 40 km) and very branched, creating a substantial network and favourable habitat for fish species (*under pristine conditions*, which might not be the case if these streams are extensively barred by fishing gears or irrigation dams; the latter point cannot be determined with Google Earth).

• **From Km 156 (Kaoh Peak commune) to Km 233 (in Malik commune)**: section characterized by a succession of sand banks and islands, with access to long (50 km or more) and branched tributaries. The river is 250 to 350 m wide. A few minor rapids, in particular in the upstream section (e.g. km 216, zone S1 of the Slope analysis), characterize this zone.

• **From Km 233 (Malik commune in Cambodia) to the Yali dam site (Km 286)**: due to the presence of Plei Krong, Yali, Sesan 3, Sesan 3A, Sesan 4 and Sesan 4A dams already constructed and active or under construction, it is no longer possible to identify on available Google Earth maps the natural features of the Sesan River between Plei Krong and the Cambodian border. Flow retention by the dams result in a shallow river characterized by a succession of wetlands and rapids, with some rocky channels. Tributaries are of medium length (around 20 km long) and quite branched.

• **From Km 286 (Yali dam) to Km 309 (Plei Krong dam)**: this section mainly represents the Yali reservoir and a few kilometres of the Krong Poko stream (i.e. Sesan River upstream of the Dak Nghe confluence). For fish this is a transformed and lacustrine environment, subject to large scale variability, in which migrations are restricted to the Dak Nghe River and upstream, as much as the numerous local irrigation dams allow.

From Km 309 (Plei Krong dam) to Km 361 (Ngok Tu commune): this section, relatively narrower (50 to 100 m wide), is characterized by a succession of wetlands, sand banks and rocky channels. The size of the river and the abundance of wetlands makes this zone favourable to fish.

From Km 361 (Ngok Tu commune) to Km 420 (TT. Dak Glei commune): in this section, the river becomes a very narrow (around 20 m wide) and meandering mountain stream; it is difficult to characterize it precisely; yet it features a diversity of habitats (wetlands, streams, rocky channels, and sand banks) although the image resolution does not allow one to distinguish them precisely. There might be rapids between Km 361 and Km 372.

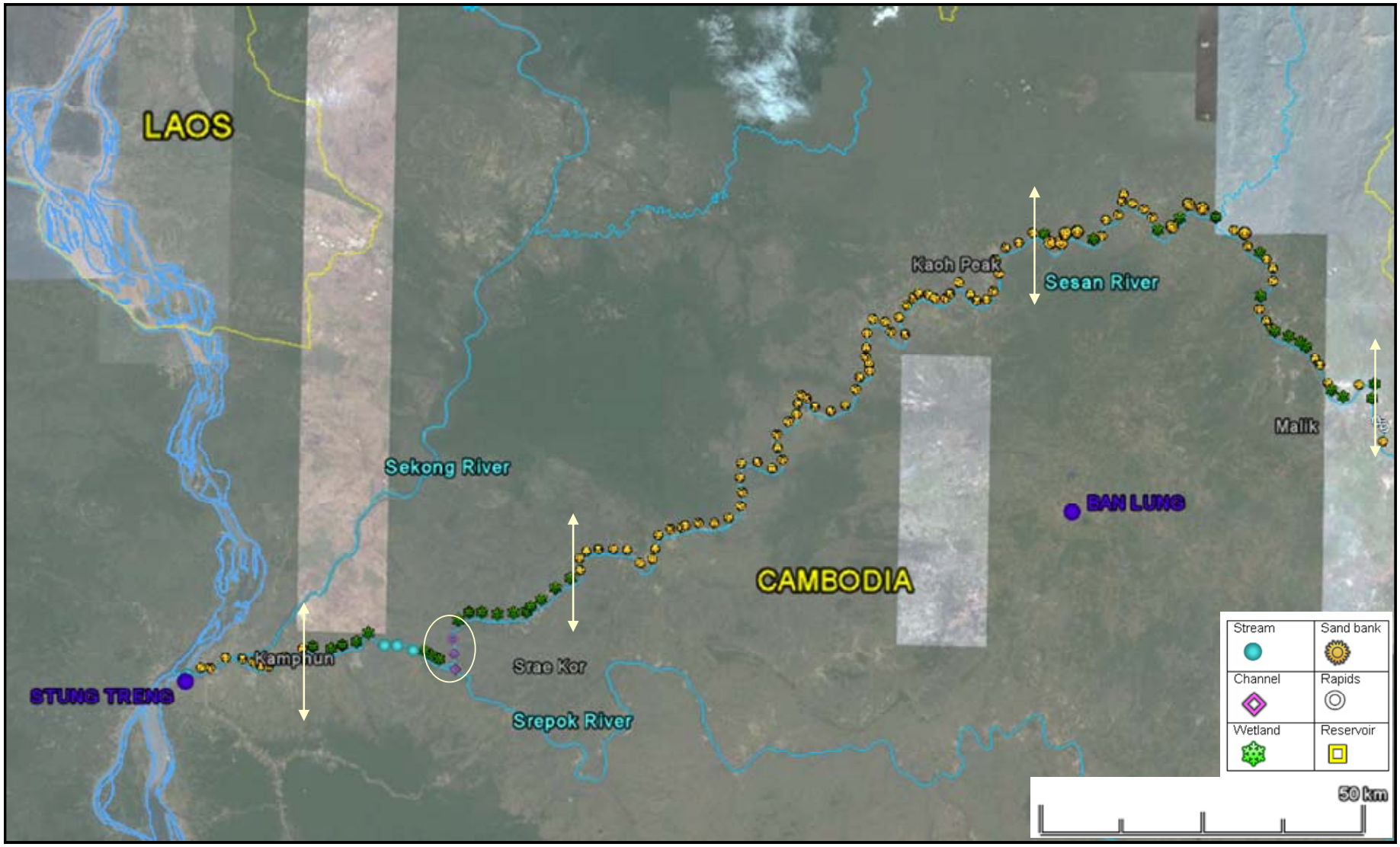


Figure 7: Four downstream ecological zones of the Sesan River (in Cambodia; continued next page).

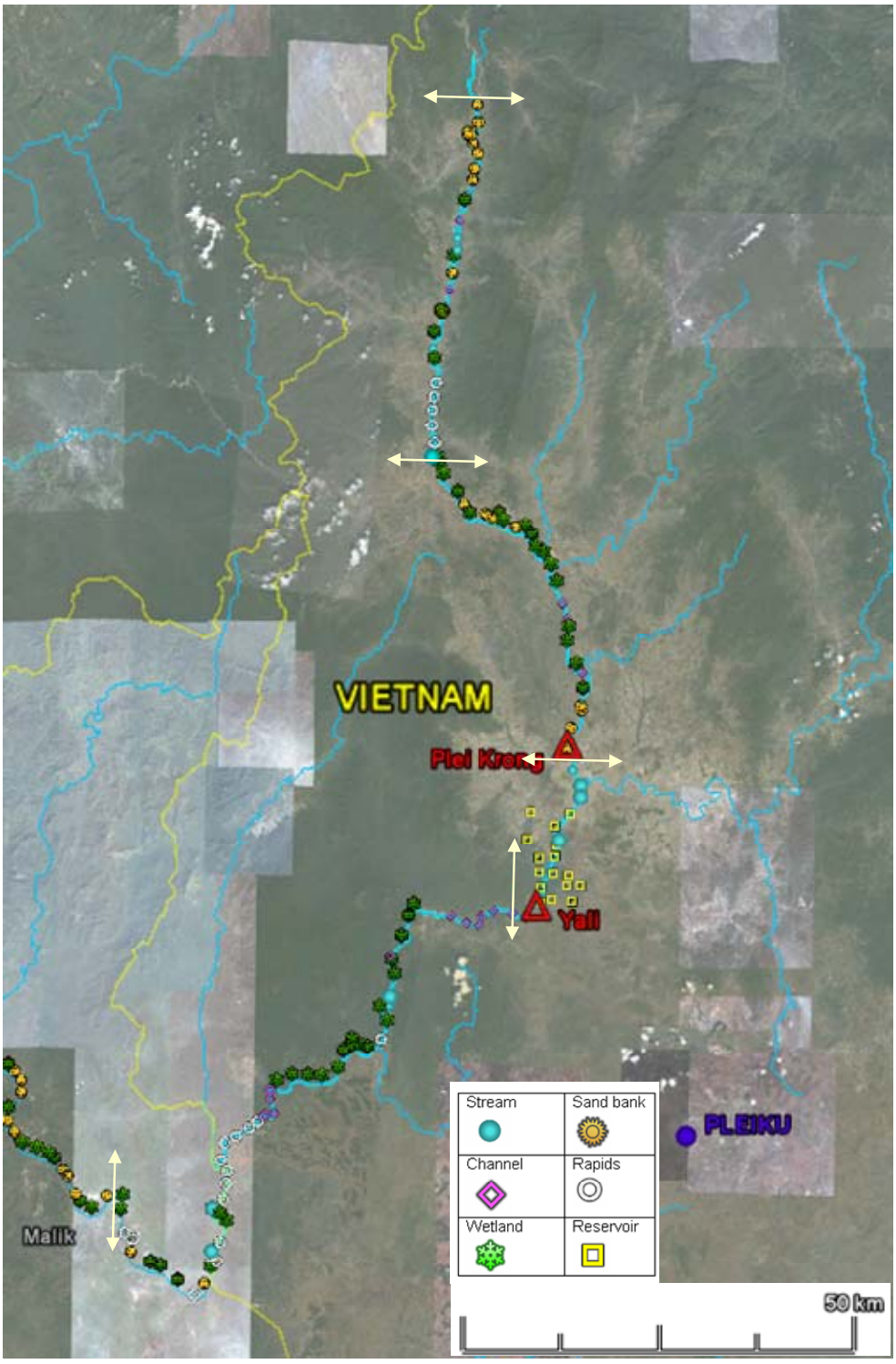


Figure 8: Four upstream ecological zones of the Sesan River (in Vietnam).

Waterfalls and thresholds

The connection between the Sesan and Srepok Rivers is characterized by a narrow rocky corridor already mentioned (Figure 6).

Zone S1 actually corresponds to a series of sand banks and wetlands, and is not an obstacle to fish migrations, as shown in Figure 9:

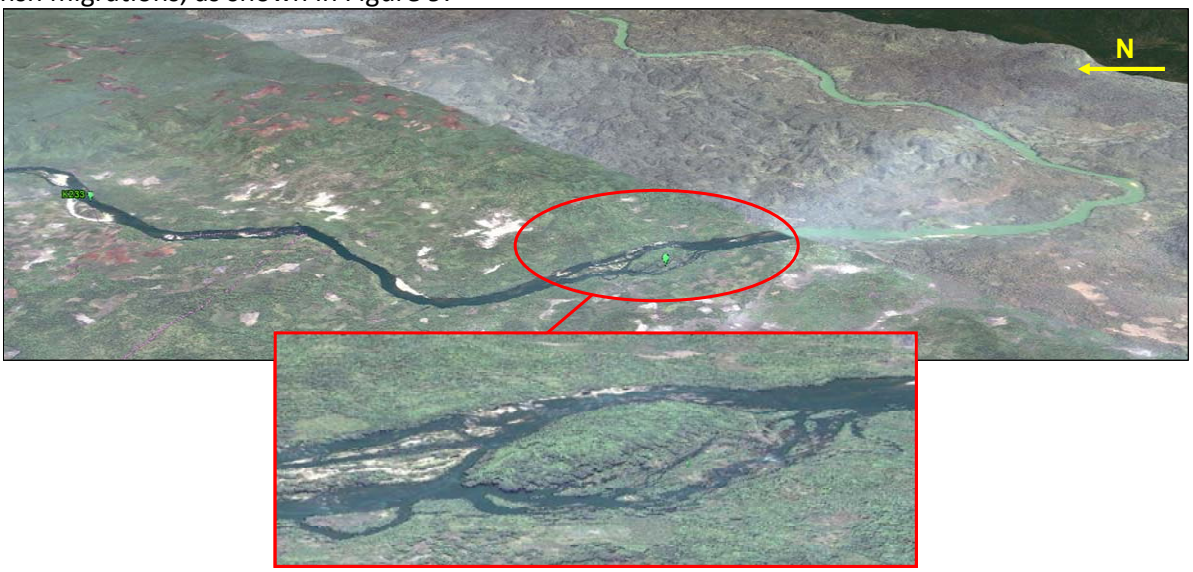


Figure 9: Detail of the S1 zone

Zone S2 is characterized by a narrow rocky channel more than by rapids or waterfalls, but in this anthropized zone of the river it is not possible to tell from the image whether this is a natural feature or the river bed made visible due to water retention by the Sesan 3/3A dams upstream (Figure 10).

Zone S3: as the name indicates, the Yali Falls dam is located at a place characterized by major waterfalls that probably constituted a natural barrier to fish migrations before the construction of the Yali dam (Figure 11).

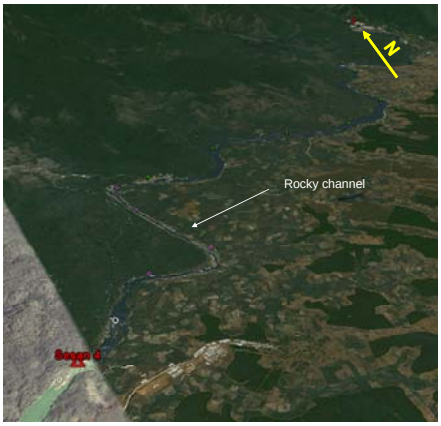


Figure 10: Detail of the S2 zone

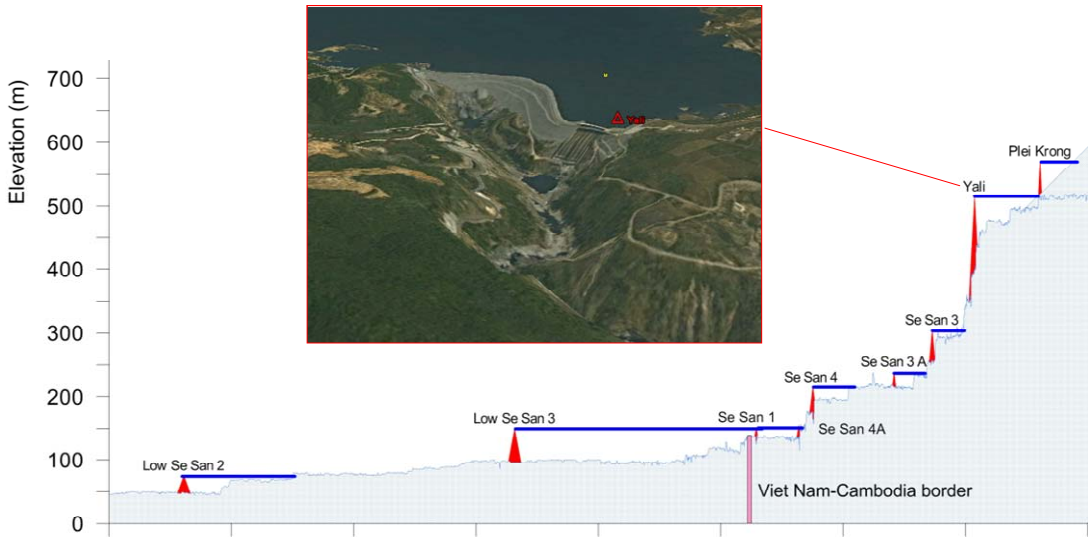


Figure 11: Detail of the S3 zone

Breeding and spawning sites

In the 3S watersheds, Srun Lim Song (2002) lists 5 creeks as being good places for fish breeding and spawning during the wet season. Theses main creeks are:

- Khampha in Thokeo commune of Siempang district.
- Smong in Sekong commune of Siempang district.
- Kleang in Siempang district.
- So in Kbal Romeas commune of Sesan district.
- Anchanh in Talat commune of Sesan district.

2.3 CONNECTIVITY IN THE SESAN BASIN

River connectivity is important to fish, in particular for migratory fishes that move between different habitats to complete their life cycle. Actually, recent records show that connectivity in the Vietnamese part of the Sesan Basin has been altered substantially, as noted in:

• IWARP & VNMC (2003): There are 580 structures of different types and scales in the sub-area 7V, including, in the Sesan River Basin, 238 structures, comprising 61 small and medium reservoirs and 177 small weirs.

• WASI (2010): In Gia Lai province alone, 235 large and small irrigation structures have been recorded, including 138 dams.

2.4 POPULATION ALONG THE SESAN RIVER

The table below shows the population in the Sesan River Basin.

Table 4: Population in the Sesan River Basin. Source: 2007 Commune Database in Cambodia, 2010 statistical yearbook of Gia Lai and Kon Tum in Vietnam.

	Sesan
Kon Tum	432,865
Gia Lai	314,100
Ratanakiri	85,029
Stung Treng	9,890
Total	841,884

In Vietnam, due to relatively higher living standards and the development of the agricultural sector, the population is not as dependent upon capture fisheries as it is Cambodia and Laos. Actually the number of people living along the Sesan River and depending upon river resources is subject to multiple contradictory estimates. Thus:

- Ryder (2007) estimates that in Northern Cambodia, 29,000 people depend mainly on the Sesan River for their daily lives;
- an early study for the Lower Sesan 2 EIA, cited in Baird (2009), estimated that there are 28,951 people residing upstream along the Sesan River in Cambodia and another 11,025 people living upstream of the Sekong River;
- KCC (2008) estimates that the Lower Sesan 2 project will impact the fish supply of around 30,000 people living along the two rivers upstream of the project site.
- Wyatt and Baird (2007) estimate that the number of people impacted by changes to the Sesan River environment and resources by the Yali dam amounts to approximately 55,000 people from 90 villages.
- The number of villages along the Sesan River alone amounts to about sixty, plus about thirty villages located on tributaries of the Sesan River (Figure 12)

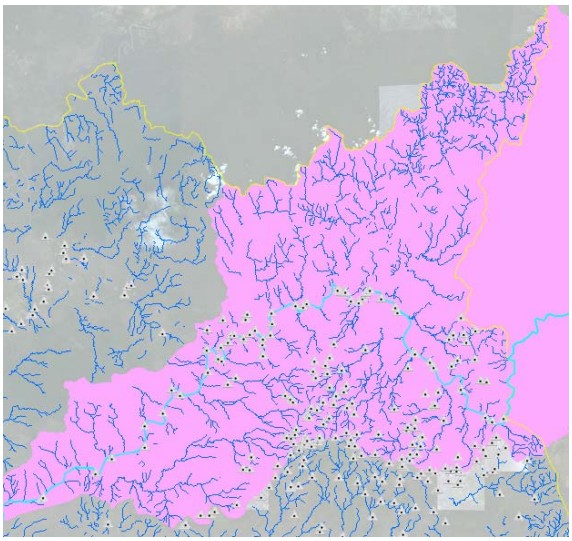


Figure 12: Distribution of villages in the Sesan Basin in Cambodia.

These estimates lead to the rough conclusion that **the number of people dependent on riverine resources along the Sesan River ranges from 30,000 to 50,000.**

3 FISH SPECIES IN THE 3S RIVERS

3.1 SPECIES RICHNESS IN THE 3S RIVERS

The Sesan River is closely connected to the Sekong and the Srepok Rivers (their respective mouths are less than 30 km apart), and the 3S Rivers constitute one ecological unit, so we also review here fish faunas and migrations in the Sekong and Srepok.

The current review of fish species in the Sekong, Sesan and Srepok Rivers is derived from six main lists of fishes detailed in Baird 1995, MFD 2003, Baird and Meach Mean 2005, Nguyen Huu Duc *et al.* 2006, Chan Sokheng *et al.* 2008 and Kottelat 2009. We compiled these species lists, updated their taxonomy using FishBase (www.fishbase.org) as a reference, and the result is detailed in Annex 1. Overall, **the 3S system is characterized by 329 fish species, i.e. 42% of the 781 fish species found in the Mekong (although the surface area of the 3S, i.e. 78,600 km^2, represents only 10% of the 800,000 km^2 of the Mekong watershed area). This qualifies this area as being very rich from a fish biodiversity viewpoint.**

More specifically, the Sekong River is characterized by 213 fish species, the Srepok River by 240 species, and the Sesan River by 133 species only. Thus the Sesan River is home of approximately 40 to 50% less species than the Sekong and Srepok Rivers.

Table 5: Fish species richness in the 3S.

	Sekong	Sesan	Srepok
Families	33	26	33
Species	213	133	240

This analysis is in line with the findings of the ADB-RETA 40082 study (2010a), which estimates the number of each fish species in each river as 214, 133 and 204 species for the Sekong, Sesan and Srepok Rivers respectively.

A closer analysis of the species distribution indicates that among the 329 fish species of the 3S, 91 are common to the three basins, whereas 95, 61 and 7 species are found only in the Srepok, Sekong and Sesan Rivers respectively (Figure 13).

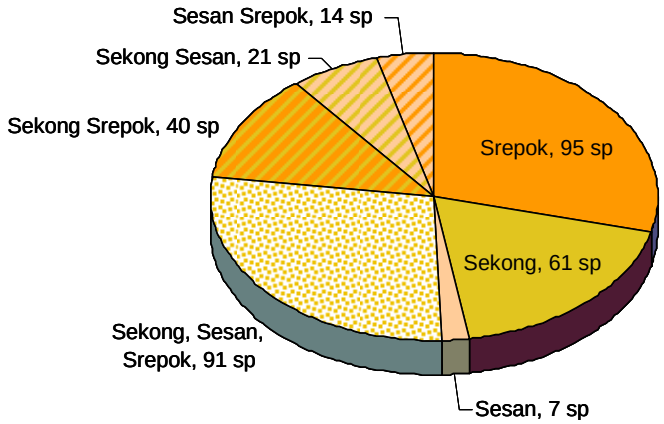


Figure 13: 3S fish species and their distribution in each of the 3S Rivers.

In the Lower Sesan 2 project area, the EIA, using local knowledge through posters (PRA) and catches by selected fishermen, identified 106 fish species. However, the EIA also recognizes that this figure is an underestimate and acknowledges that CEPA (2006) identified 130 species in the same zone.

3.2 ENDANGERED SPECIES IN THE 3S RIVERS

The IUCN Red List of endangered species, updated in July 2011, was used to assess the endangered species present in the 3S Rivers. **The 3S Rivers are home to 14 endangered or critically endangered fish species**, as detailed in Table 6:

Table 6: Endangered and critically endangered species found in the 3S Rivers.

3S species	Red List status
Aaptosyax grypus	Critically endangered
Catlocarpio siamensis	Critically endangered
Pangasianodon gigas	Critically endangered
Dasyatis laosensis	Endangered
Luciocyprinus striolatus	Endangered
Pangasianodon hypophthalmus	Endangered
Poropuntius bolovenensis	Endangered
Poropuntius deauratus	Endangered
Probarbus jullieni	Endangered
Probarbus labeamajor	Endangered
Schistura bairdi	Endangered
Schistura bolavenensis	Endangered
Sewellia patella	Endangered
Yasuhikotakia sidthimunki	Endangered

3.3 FISH ENDEMICITY IN THE 3S RIVERS

The above data set combined with the identification of endemic species in FishBase (www.fishbase.org. / Information by ecosystem / Mekong / All fishes) indicates that among the Mekong endemics (i.e. the fish species found nowhere else in the world other than the Mekong):

- 62 Mekong endemics are found in the Sekong River
- 24 Mekong endemics are found in the Sesan River
- 45 Mekong endemics are found in the Srepok River

The above species can be found in the specific rivers mentioned but also in one of the other 3S rivers, or in another Mekong river; we therefore refined the analysis to identify the Mekong endemics that are found only in one of the 3S Rivers (Table 5). This analysis shows that:

- fifteen “super-endemic” species are found in the Sekong River and nowhere else in the world:
  Devario salmonata, Poropuntius lobocheiloides, Schistura bairdi, Schistura bolavenensis, Schistura clatrata, Schistura fusinotata, Schistura imitator, Schistura khamtanhi, Schistura nomi, Schistura rikiki, Schistura tizardi, Serpenticobitis octozona, Sewellia diardi, Sewellia elongata, Sewellia speciosa.

- two “super-endemic” species are found only in the Srepok River:
  Sinibrama affinis and Toxabramis hotayensis
- the Sesan River does not feature any species that are not found in other Mekong rivers.

There results highlight the exceptional value of the Sekong River in terms of biodiversity conservation.

Table 7: Endemism among fish species of the 3S Rivers.

	Sekong River	Sesan River	Srepok River
Mekong endemics found in the 3S Rivers among other Mekong rivers	62	24	45
Mekong endemics found only in one of the 3S Rivers	15	0	2

4 FISH MIGRATIONS IN THE 3S RIVERS

Identifying the species migrating in the 3S requires an analysis of the successive publications or information sources about migratory species, which is detailed below in 4 steps.

Step 1

The MRC surveys based on local knowledge systematically gathered throughout the basin resulted in a preliminary description of migration patterns for 23 species basinwide (MRC 2001, MRC 2003, Poulsen *et al*. 2002, 2004). Out of these, sixteen were known at that time to migrate in the 3S system, but one can be removed as migrations are not absolutely necessary to this species:

Labeo chrysophekadion: this species, although migratory, can spawn in a variety of habitats, in particular in reservoirs in July – October (Kamonrat *et al.* 1972, Boonmon and Kantejit 1977, Watanadirokul *et al.* 1983, Chabjinda *et al.* 1992)

This leaves us with 15 3S migratory species formally identified in MRC 2001 (Table 8):

Table 8: Species migrating to the 3S according to the 2001 MRC study.

Family	Species
Bagridae	Hemibagrus filamentus
Clupeidae	Tenualosa thibeaudeaui
Cobitidae	Botia modesta (now Yasuhikotakia modesta)
Cyprinidae	Bangana behri
	Catlocarpio siamensis
	Cirrhinus microlepis
	Mekongina erythrospila
	Paralaubuca typus
Pangasiidae	Pangasianodon hypophthalmus
	Pangasius bocourti
	Pangasius conchophilus
	Pangasius krempfi
	Pangasius larnaudii
	Pangasius macronema
Sisoridae	Bagarius yarrelli

Note: The MRC surveys also mention *Henicorhynchus spp.* and P*robarbus spp.* but not at the species level.

Step 2

A compilation of the 3S migratory species cited in Baird *et al.* (1999), Mekong Fish Database (MFD 2003) and Baird and Shoemaker (2008) allows us to identify an additional 16 species. Out of these, two species can be removed as their migratory nature is disputable.

Labeo erythropterus: this migratory species is also able to proliferate in impoundments (Rainboth 1996).

Wallago attu: Poulsen and Valbo-Jørgensen (2000) believe that this species undertakes only short longitudinal migrations to the nearest stream, as well as some localized movements to pursue schools of smaller fish on which it preys. During the flood season it stays in swamps, canals and streams on the floodplain.

The 14 additional species identified are detailed in Table 9.

Table 9: 3S migratory species identified in 3 studies in addition to those identified in MRC 2001.

Anguillidae	Anguilla marmorata	Baird *et al*. 1999
Cyprinidae	Cirrhinus molitorella	Baird *et al*. 1999
	Crossocheilus reticulatus	Baird and Shoemaker 2008
	Henicorhynchus lobatus	Baird and Shoemaker 2008
	Henicorhynchus siamensis	MFD 2003
	Hypsibarbus lagleri	MFD 2003
	Hypsibarbus malcolmi	Baird and Shoemaker 2008
	Hypsibarbus wetmorei	MFD 2003
	Luciosoma bleekeri	MFD 2003
	Probarbus jullieni	Baird and Shoemaker 2008
	Probarbus labeamajor	Baird and Shoemaker 2008
	Scaphognathops bandanensis	Baird and Shoemaker 2008
	Thynnichthys thynnoides	Baird and Shoemaker 2008
Siluridae	Wallago leeri	Baird and Shoemaker 2008

Step 3

Baird *et al.* (2003) list 28 species[2] believed to migrate from the Tonle Sap to Khone Falls (and therefore possibly to the 3S on their way upstream). Eight of these species are already present in the above list of 3S migratory species, and 20 additional species, all present in the 3S system (Baran 2010), are considered as probable migrants. Among these 20 species, 6 are doubtful[3], but the literature (in particular from MFD 2003 and Halls and Kshatriya 2009) confirms that 14 species are migratory, and therefore to be added to the list of migratory species found in the 3S system.

> *Amblyrhynchichthys truncatus, Cosmochilus harmandi, Cyclocheilichthys enoplus, Epalzeorhynchos frenatus, Garra fasciacauda, Gyrinocheilus pennocki, Labiobarbus leptocheilus, Leptobarbus hoevenii, Lobocheilos melanotaenia, Osteochilus microcephalus, Puntioplites falcifer, Sikukia gudgeri, Syncrossus helodes, Thynnichthys thynnoides.*

[2] Amblyrhynchichthys truncatus, Barbonymus altus, Cosmochilus harmandi, Crossocheilus oblongus, Cyclocheilichthys enoplus, Epalzeorhynchos frenatus, Garra fasciacauda, Gyrinocheilus pennocki, Henicorhynchus lineatus, Labiobarbus leptocheilus, Leptobarbus hoevenii, Lobocheilos melanotaenia, Osteochilus melanopleurus, Osteochilus microcephalus, Parambassis wolffii, Puntioplites falcifer, Sikukia gudgeri, Syncrossus helodes, Thynnichthys thynnoides, Yasuhikotakia caudipunctata.

[3] There is to date no study confirming that Crossocheilus oblongus, Henicorhynchus lineatus, Parambassis wolffii or Yasuhikotakia caudipunctata are migratory. Furthermore, Barbonymus altus and Osteochilus melanopleurus do not fully depend on migrations, since they can breed in impoundments or floodplains.

Step 4

We propose here a novel review of migratory species sensitive to dam development in the 3S, based on i) the compilation of 3S species detailed in the above section and ii) an extensive review of migratory species in the Mekong Basin. These migratory species were identified and classified using life-history ecological information in the following databases and published resources: Mekong Fish Database (MFD 2003), FishBase (www.fishbase.org), Baran *et al.* 2006 amended by So Nam (pers. comm.), Halls and Kshatriya (2009) and Halls (2010). For each species of the 3S, the migratory nature of the species was reviewed by a compilation of the above sources, and for disputable cases finalization of the list was done by E. Baran based on additional literature. We present in Table 10 an overview of this list and in Annex 2 the details, in particular the sources of information. This comprehensive review leads to the conclusion that **the 3S system is characterized by at least eighty-nine migratory fish species belonging to 15 families.**

More specifically, the Sekong, Sesan and Srepok Rivers are characterized by 64, 54 and 81 migratory species respectively (Figure 14)

In the Sesan River, 54 migratory species out of 133 fish species represent 40% of migratory fish; this is a third more than acknowledged in the Lower Sesan 2 EIA (32% of fish species identified as migratory species; KCC 2009). In the Srepok River, Vietnamese experts already estimated in 2006 that "*more than 50 species migrate all the way from the Mekong and far up into Vietnam. A large part of the migrations is for reaching spawning and nursery grounds*" (SWECO-Groner *et al*. 2006).

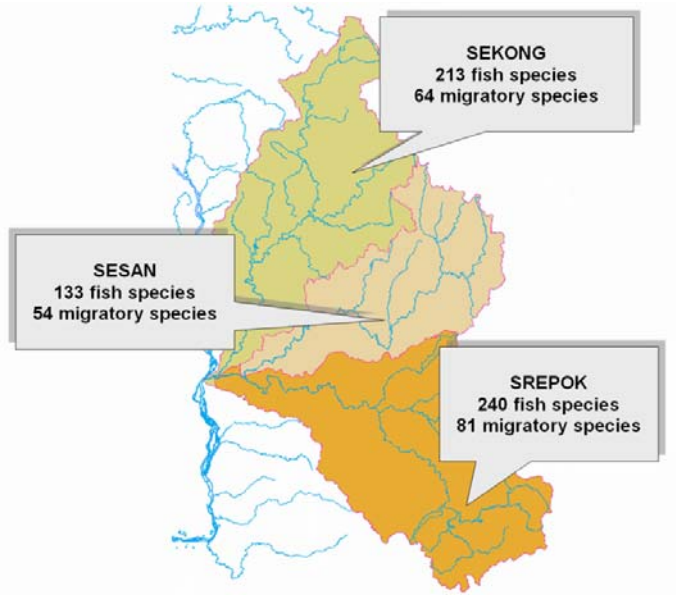


Figure 14: Total number of species and number of migratory fish species in the 3S

Baird and Shoemaker (2008) give a couple of reasons that might explain the significantly lower fish diversity and less intensive migrations in the Sesan River:

"Local people have long recognized that more fish generally migrate up the Srepok and Xekong rivers in Cambodia than the Sesan River. There are a few reasons for this. First, the Xekong and Srepok are both generally deeper rivers than the Sesan, and so their habitats are more

preferable for migrating fish. Secondly, most cyprinids migrate upriver along the edges of rivers. Therefore, if the fish leave the Mekong, enter the Xekong River and travel up along its southern bank, which the majority do, they will enter the Sesan River and will soon continue right into the Srepok, which flows into the Sesan from the southeast. On the other hand, if the fish leave the Mekong and move up the northern bank of the Xekong, they will mainly continue migrating right up the Xekong to Laos."

The second pattern is illustrated below (Figure 15):

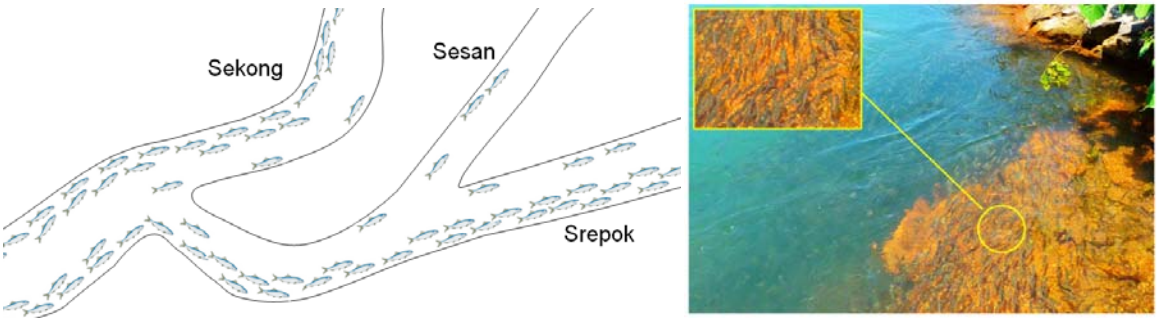


Figure 15: Schematic fish migrations along the banks of the 3S Rivers and photo from the Nam Ngum River.

More generally, the number of migratory species is proportional to the number of fish species, and both numbers are proportional to the surface area of the watershed (Figure 16):

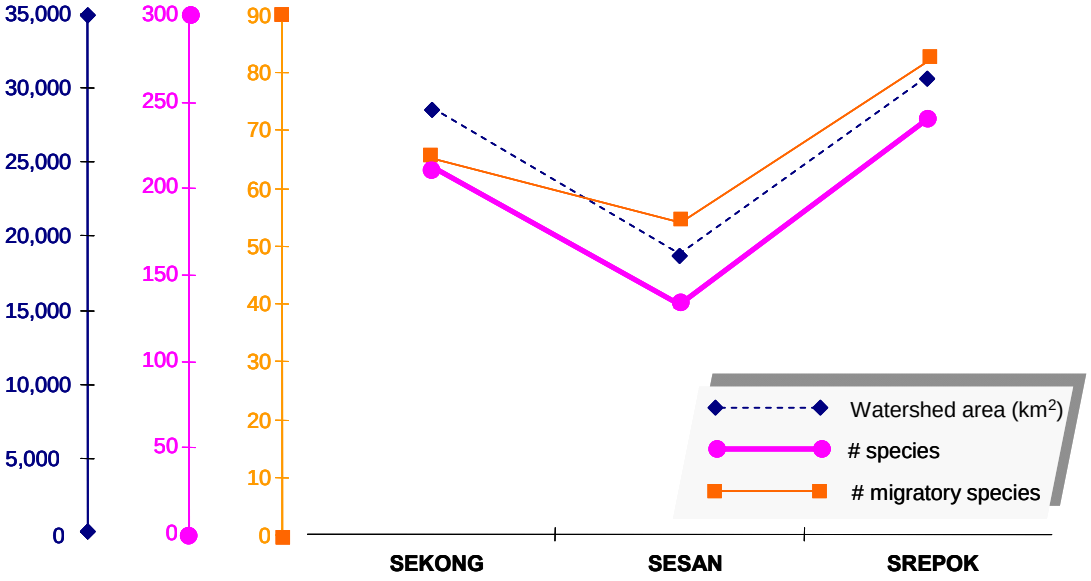


Figure 16: Number of fish species, of migratory species and watershed area of the 3S rivers.

Table 10: 89 migratory species in the 3S rivers. For each species the river in which the species is found is detailed. Non-exclusive migratory species able to breed in reservoirs have been excluded.

Family	Species	Found in the 3S
Anguillidae	Anguilla marmorata	Sekong, Srepok
Bagridae	Hemibagrus filamentus	Sekong, Sesan, Srepok
	Hemibagrus wyckii	Sekong, Sesan, Srepok
	Hemibagrus wyckioides	Sekong, Sesan, Srepok
Clupeidae	Tenualosa thibaudeaui	Sekong, Sesan
	Tenualosa toli	Srepok
Cobitidae	Acanthopsoides delphax	Sesan, Srepok
	Syncrossus beauforti	Sekong, Sesan, Srepok
	Syncrossus helodes	Sesan, Srepok
	Yasuhikotakia modesta	Sekong, Sesan, Srepok
Cynoglossidae	Cynoglossus microlepis	Srepok
Cyprinidae	Aaptosyax grypus	Sesan
	Amblyrhynchichthys truncatus	Sekong, Srepok
	Bangana behri	Sekong, Sesan, Srepok
	Bangana pierrei	Sekong
	Barbichthys laevis	Srepok
	Catlocarpio siamensis	Sekong
	Cirrhinus jullieni	Sekong, Sesan, Srepok
	Cirrhinus microlepis	Sekong, Sesan, Srepok
	Cirrhinus molitorella	Sekong, Sesan, Srepok
	Cosmochilus harmandi	Sekong, Sesan, Srepok
	Crossocheilus atrilimes	Sekong, Sesan, Srepok
	Crossocheilus reticulatus	Sekong, Sesan, Srepok
	Cyclocheilichthys apogon	Sekong, Srepok
	Cyclocheilichthys armatus	Sekong, Sesan, Srepok
	Cyclocheilichthys enoplus	Sekong, Sesan, Srepok
	Cyclocheilichthys furcatus	Srepok
	Cyclocheilichthys heteronema	Srepok
	Epalzeorhynchos frenatus	Sekong
	Garra fasciacauda	Sekong, Srepok
	Henicorhynchus lobatus	Sekong, Sesan, Srepok
	Henicorhynchus siamensis	Sekong, Sesan, Srepok
	Hypsibarbus lagleri	Sekong, Sesan, Srepok
	Hypsibarbus malcolmi	Sekong, Sesan, Srepok
	Hypsibarbus pierrei	Srepok
	Hypsibarbus wetmorei	Sekong, Sesan, Srepok
	Labiobarbus leptocheilus	Sekong, Sesan
	Labiobarbus lineatus	Sesan
	Labiobarbus siamensis	Srepok
	Leptobarbus hoevenii	Sekong, Sesan, Srepok
	Lobocheilos melanotaenia	Sekong, Sesan, Srepok
	Luciocyprinus striolatus	Sekong
	Luciosoma bleekeri	Sekong, Sesan, Srepok
	Mekongina erythrospila	Sekong, Sesan, Srepok
	Osteochilus microcephalus	Sekong, Sesan, Srepok
	Osteochilus schlegelii	Srepok
	Osteochilus waandersii	Sekong, Sesan, Srepok
	Paralaubuca harmandi	Srepok
	Paralaubuca riveroi	Sekong, Srepok
	Paralaubuca typus	Sekong, Sesan, Srepok
	Probarbus jullieni	Sekong, Sesan, Srepok
	Probarbus labeamajor	Sekong, Sesan, Srepok
	Probarbus labeaminor	Srepok
	Puntioplites bulu	Srepok
	Puntioplites falcifer	Sekong, Sesan, Srepok
	Puntioplites proctozystron	Sekong, Srepok
	Raiamas guttatus	Sekong, Sesan, Srepok
	Rasbora aurotaenia	Srepok
	Scaphognathops bandanensis	Sekong, Sesan, Srepok
	Sikukia gudgeri	Sekong, Srepok
	Thynnichthys thynnoides	Sekong, Sesan, Srepok
	Tor sinensis	Sekong, Srepok
	Tor tambroides	Sekong, Srepok

Family	Species	Found in the 3S
Dasyatidae	Dasyatis laosensis	Sekong, Sesan, Srepok
	Himantura krempfi	Srepok
Datnioididae	Datnioides undecimradiatus	Sekong, Sesan, Srepok
Gyrinocheilidae	Gyrinocheilus pennocki	Sekong, Sesan, Srepok
Notopteridae	Chitala blanci	Sekong, Sesan, Srepok
Pangasiidae	Helicophagus waandersii	Sekong, Sesan, Srepok
	Pangasianodon gigas	Srepok
	Pangasianodon hypophthalmus	Sekong, Sesan, Srepok
	Pangasius bocourti	Sekong, Sesan, Srepok
	Pangasius conchophilus	Sekong, Sesan, Srepok
	Pangasius djambal	Srepok
	Pangasius krempfi	Sekong, Sesan, Srepok
	Pangasius kunyit	Srepok
	Pangasius larnaudii	Sekong, Sesan, Srepok
	Pangasius macronema	Sekong, Sesan, Srepok
	Pangasius mekongensis	Srepok
	Pangasius polyuranodon	Srepok
	Pseudolais micronemus	Srepok
	Pseudolais pleurotaenia	Sekong, Sesan, Srepok
Schilbeidae	Clupisoma sinense	Sesan, Srepok
Siluridae	Hemisilurus mekongensis	Srepok
	Phalacronotus apogon	Sekong, Srepok
	Phalacronotus bleekeri	Sekong, Sesan, Srepok
	Wallago leerii	Sekong, Sesan, Srepok
Sisoridae	Bagarius yarrelli	Sekong, Sesan, Srepok
Soleidae	Brachirus harmandi	Sekong, Srepok

5 FISH CATCHES IN THE 3S RIVERS

To our knowledge, when dealing with fish catch assessment and monitoring in the 3S system, three sources of data exist:

- the AMCF catch monitoring programme carried out by the MRC Assessment of Mekong Capture Fisheries Project between 2002 and 2005 and detailed briefly in Starr (2008). This monitoring includes one village in the Sekong, one in the Sesan and two in the Srepok River. Unfortunately, data from this monitoring are not public and have been processed and partly published only twice, by Halls and Kshatriya (2009) and Halls (2010), without detailing 3S results.
- WWF fish monitoring in the Srepok River, as put in place and detailed in Chan Sokheng *et al*. 2008. However, these authors do not give in their report any details about the results of their fish abundance survey; in particular, abundance by species is not detailed.
- fish abundance in the Sesan River by Baird and Meach Mean (2005) for the 3S Rivers Protection Network. This study summarizes the monitoring of fish catches over one year by 22 fishermen in 7 villages located in Ratanakiri province. The authors publish in Appendix 2 of their report 50 [gear x fisherman] data sets representing sixteen fishing gears monitored (gillnets of 10 different mesh sizes, castnets, longlines and single lines with large and small hooks, and fish poisoning using native fruits), 1,609 fishing sessions and 24,062 hours of fishing. The full data set is summarized in Annex 3 and represents a total catch of 2,233 kg. This report is remarkable in that raw data are provided in an annex. Unfortunately, the report does not provide any analysis of the data set gathered (the only analysis done consists in dividing catch by time spent fishing in order to provide CPUE -Catch per hour spent fishing). As opposed to the claim of the report sub-title ("Before and after the construction of the Yali Falls Dam") there is no analysis of catches before and after dam construction[4], no analysis of the time fishermen spend fishing each year nor of the catch per fisherman per year, no inference about the total catch per family or village per year, and no assessment of the representativeness of this large sample nor of the likely total catch along the Sesan River. In short, this data set is the most comprehensive available about Sesan fisheries but remains to be analyzed.

5.1 TOTAL FISH CATCH ESTIMATES

In Vietnam, as far as we know there is no specific assessment of fish catches along a particular river: "*Fishing in Sesan and Srepok rivers in the territory of Vietnam is characterized by self-sufficiency for individual households so available data on production and economic values of catch fishes is almost none*"[5]

The general view is that fisheries are underdeveloped in the SA-7V sub-area, and although province statistics do exist, capture fishery yields are not distinguished from aquaculture production. Yet it can be deduced from the total fish production and aquaculture production

[4] *There were no quantitative fisheries data from the Sesan River collected before the dam was built to compare with the quantitative fisheries data collected via this research in 2003-2004.*" Baird and Meach Mean 2005, p. 25.

[5] Source: 2010 update of the IWARP & VNMC report "Analysis of sub-area 7V" for the MRC Basin Development Plan.

figures that the cumulated capture fish production in Gia Lai, Kon Tum and Dak Lak provinces amounts to about 500 tonnes (see Table 15), which is clearly a gross underestimate.

In 2001 the total fish production amounted to 5,600 tonnes in this area (IWARP & VNMC 2003). The 2010 update of this review does not provide any fisheries production figure, and capture fisheries, whose importance to local livelihoods is recognized and emphasized, are mentioned in the Ecosystem section of the report, together with plankton, benthos and aquatic insects, although a full section is dedicated to Aquaculture production. This reflects the remaining absence of capture fisheries from official agendas in the Vietnamese part of the 3S Rivers.

In Cambodia, estimates of fish catches in the 3S and in particular along the Sesan River are subject to a very large variability:

- according to the Lower Sesan 2 EIA (KCC 2009), the amount of fish caught in the Sesan and Srepok Rivers (in Cambodia) amounts to 647 tonnes per year;
- as opposed to this estimate, official records of the capture fishery in the Sekong alone in 2006 show about 9,500 tonnes (ADB-RETA 40082. 2010a) and actual catches are probably much more than this, since official records do not measure subsistence catches;
- the Profile of the sub-area Sekong-Sesan-Srepok in Cambodia by the CNMC (2009) surprisingly does not provide any figure for total fish production in the 3S, although the importance of fisheries is recognized.

Such discrepancies call for a more detailed review of catches based on catch per household and population.

Baird (2009) reviewed the possible impacts of the Lower Sesan 2 dam on adjacent villages, and details catches is two of them:

- Hang Khou Suon village, at the confluence of the Sekong and Mekong Rivers; there villagers claimed during interviews to catch over 365 kg of fish a year per family, out of which they make about 100 kg of fish paste per year for their own household consumption.
- Srae Kor village located along the Sesan River, about 50 km upstream of the Mekong confluence; here the catch is estimated by villagers to be around 500-800 kg per year per family (mostly migratory fishes).

These figures represent 3 to 6 times more that those of the Lower Sesan 2 EIA, in which the catch of families living along the Sesan River in Ratanakiri province, monitored by logbooks during two months of the dry season, amounts to 0.36 kg/family/day, i.e. 131 kg/family/year (KCC 2008, p.46). The updated study (KCC 2009), by dividing catches in Baird and Meach Mean (650 tonnes) by the local population along the Sesan and Srepok Rivers in Ratanakiri province, finds a similar yield of 129.3 kg/family/year, but it is unclear where the 650 tonne figure comes from since it is not mentioned in Baird and Meach Mean.

Last, the CNMC (2009) cites province data about fish catch (in kg) per capita and per year along each river of the 3S system (Table 11 11):

Table 11: Fish catches in the Cambodian part of the 3S. Source: CNMC 2009.

Fish catch (kg/capita/year)	Sekong	Sesan	Srepok
2002	141.7	18.2	29.1
2003	113.3	15.1	25.1
2004	87.2	10.8	18.6
2007	32.7	4.4	4.4
2008	104.6	12.5	12.2
2009	119.9	12.3	12
Average	99.9	12.2	16.9

Assuming an average number of 6 persons per family, the figure for the Sesan River would be 73.2 kg/family/year.

As a comparison, official provincial statistics estimate fish catches at 1,500 tonnes in Stung Treng province (this also includes catches along the Mekong), and 450 tonnes in Ratanakiri province (RGC 2010).

An overview of the catch per family according to these different sources highlights the inconsistency between studies and figures (Table 12):

Table 12: Catch per family (kg/family/year) along the Sesan River according to different sources

Province statistics	73.2	Along the river
KCC 2009	131	Around the LSS2 site
Baird and Meach Mean according to KCC 2009	129.3	Along the river
Baird 2009	365	A few km upstream of LSS2 site
	500-800	At the confluence with the Mekong

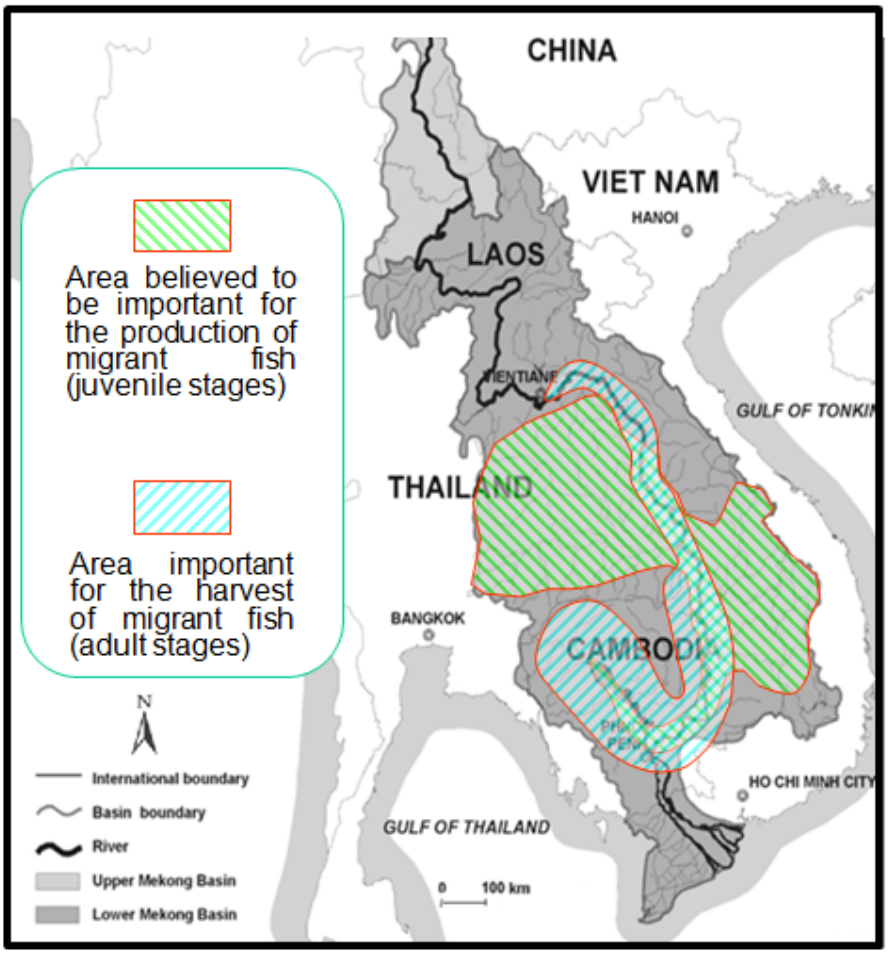
There is unfortunately no way to assess which of these figures is the most accurate. The most detailed data set allowing a calculation of catch per family per year is that of the Baird and Meach Mean (2005), but these authors do not indicate the timing of the catch and do not provide information allowing the catch to be related to Sesan families.

Relating the above figures of catch per capita in Cambodia to the population estimates for the Sesan River Basin (section 2.4) leads to the conclusion that **the total catch in the Sesan River Basin ranges between 370 and 6700 tonnes of fish per year. This wide range reflects the diversity of opinions between sources and underlines the urgent need for a proper assessment of fisheries and fish catches along the Sesan River.**

Table 13: Population and total fish catch estimates for the Sesan River

Fish catch (kg) per family per year	Source	Population estimates	Number of families (6 persons/family)	Total catch (tonnes)	
				Lower range	*Upper range*
73.2	Province statistics	30,000	5,000	366	610
131	KCC 2009			655	1,092
129.3	Baird and Meach according to KCC 2009			646.5	1,078
365	Baird 2009	50,000	8,333	1,825	3,042
500				2,500	4,167
800				4,000	6,667

Beyond the assessment of local yield, **what is also needed is an assessment of the contribution of the Sesan River's fish to the production of floodplains in Cambodian in Vietnam**. In a system characterized by massive and long-distance fish migrations, the catch (of adult fishes) in a given area is not a good indicator of the relative importance of this area for the system, because that area can be an important breeding site in which larvae and juvenile fish do not contribute immediately to local catches but can contribute, after a few months, to catches in another part of the system. Thus, small streams along the west coast of the United States and Canadian are not significant fishing areas but are very significant for the production of juvenile salmons that will contribute after a year or more to the intensive coastal salmon fishery. The importance of upstream tributaries in the sustainability of the Lower Mekong fisheries was highlighted in the Strategic Assessment of Mekong mainstream dams.



17: Potential role of upstream tributaries in the Mekong fish production. Source: Baran 2010

5.2 CATCHES OF MIGRATORY FISH SPECIES IN THE 3S RIVERS

For the present analysis we have compiled Baird and Meach Mean's data and fixed taxonomic problems by i) updating species names using www.fishbase.org and ii) leaving aside or lumping some mixed taxonomic groups such as *Barbodes altus/Systomus binotatus* or *Henicorhynchus lobatus/Henicorhynchus siamensis/Henicorhynchus spp.*

Then we matched the resulting catch data with the list of migratory species detailed in Table 10, and kept only the migratory species. The remaining migratory species and their contribution to the total catch are detailed in Table 14.

This shows that **at least 41 migratory fish species are commonly caught by fishermen in the Sesan River, and these migratory species represent 60% of the fishermen's total catch.**

Baird and Flaherty (2004) provide a table, based on interviews, of dominant catches in large stream bag nets in Stung Treng province (Siempang district). A comparison of this table and of the above table indicates that:
- *Hypsibarbus spp.* and *Cyclocheilichthys spp.* are taxa dominant in both lists (in the top 10 fish catches);
- Pangasius species are among the dominant in both cases (top 10-20 species);
- *Hypsibarbus filamentus*, a common species and the #1 catch in Siempang district and a common one basinwide, is surprisingly absent from the Sesan monitoring records.

Table 14: Migratory species caught during one year of monitoring in the Sesan River (data from Baird and Meach Mean 2005).

Taxonomic group	Total catch (kg)	% of total catch
Hypsibarbus spp. (lagleri,malcolmi, pierrei)	268.9	12.04
Hemibagrus wyckioides	104.2	4.67
Labiobarbus leptocheilus	100.25	4.49
Bagarius yarrelli	90.55	4.05
Cyclocheilichthys spp. (enoplus and others)	89.8	4.02
Puntioplites falcifer	76.97	3.45
Henicorhynchus spp. (lobatus, siamensis and others)	71.55	3.20
Pangasius spp. (krempfi, hypophthalmus and others)	65.9	2.95
Pangasius larnaudii	50.2	2.25
Cirrhinus microlepis	39.5	1.77
Scaphognathops bandanensis	31.8	1.42
Helicophagus waandersii	29.5	1.32
Wallago leerii	28.75	1.29
Tor spp.	28.35	1.27
Probarbus spp.	26	1.16
Osteochilus waandersii	23.65	1.06
Hypsibarbus wetmorei	22.1	0.99
Chitala blanci	21.95	0.98
Luciosoma bleekeri	20.65	0.92
Cosmochilus harmandi	16.15	0.72
Pseudolais pleurotaenia	15.9	0.71
Hemibagrus wyckii	15.75	0.71
Lobocheilos melanotaenia	14.5	0.65
Raiamas guttatus	11.8	0.53
Paralaubuca typus	11.6	0.52
Gyrinocheilus pennocki	9.15	0.41
Pangasius polyuranodon	8.8	0.39

Taxonomic group	Total catch (kg)	% of total catch
Osteochilus microcephalus	7.95	0.36
Pangasius bocourti	6.95	0.31
Pangasius macronema	6.2	0.28
Catlocarpio siamensis	5.4	0.24
Mekongina erythrospila	4.95	0.22
Yasuhikotakia modesta	4.85	0.22
Cirrhinus molitorella	3.85	0.17
Leptobarbus hoevenii	3	0.13
Syncrossus helodes	2.6	0.12
Hemisilurus mekongensis	2.55	0.11
Pangasius conchophilus	2.3	0.10
Tenualosa thibaudeaui	1.2	0.05
Amblyrhynchichthys truncatus	1	0.04
Aaptosyax grypus	0.25	0.01
Catch (migratory species, kg)	1347.27	
Total catch (migratory + non migratory species, kg	2233.28	
Percentage of migratory species in the total catch	60.33	

The Lower Sesan 2 EIA confirms this ranking of dominant species in catches by also listing *Hypsibarbus malcolmi, Hemibagrus wyckioides, Gyrinocheilus pennocki, Pangasius larnaudii, Cyclocheilichthys enoplos, Helicophagus waandersi, Henicorhynchus lobatus, Cirrhinus molitorella., Hypsibarbus malcolmi,* and *Osteochilus hasseltii* among the dominant species in fishermen's catches (KCC 2009).

5.3 AQUACULTURE PRODUCTION IN THE SESAN BASIN

Aquaculture is not developed in the 3S River Basins in Cambodia. In 2010, aquaculture production amounted to 40 tonnes in Stung Treng province, 30 tonnes in Ratanakiri province and 20 tonnes in Mondulkiri province (RGC 2010). The Cambodian National Mekong Committee confirms this assessment:

> Until now, in the Cambodian part of the SA-7C zone, *"there is no large scale aquaculture (even up to 0.5 ha) in this sub-area, only a few small scale aquaculture schemes have been implemented by communities with the support of NGOs and by individual farmers/gardeners*" (CNMC 2009).

The 2009 CNMC review cites only two aquaculture projects:

- "Development of fish stocks for improving natural fish resources in the Se Kong-Se San-Sre Pok River Basin in Cambodia", a government project to be implemented by the Fisheries Administration in Stung Treng, Ratanakiri and Mondulkiri provinces between 2011 and 2015. This project is actually a fish stocking project rather than an aquaculture project, and
- "Integrated aquaculture development in the Se Kong-Se San-Sre Pok River Basin in Cambodia", another five-year government project to be implemented by the Fisheries Administration in Stung Treng, Ratanakiri and Mondulkiri provinces.

In Vietnam, IWARP and VNMC (2003) indicates that at the beginning of the current decade aquaculture production was not much developed in the SA-7V area and that the 5,000 tonnes of fish produced annually represented only 0.8% of the national production (Table 15).

However, this figure is a mixture of capture fish production (loosely estimated at about 500 tonnes) and of aquaculture fish production.

Table 15: Aquaculture production in the Vietnamese part of the 3S in 2001.

	Unit	Gia Lai, Kon Tum, Dak Lak	% of national production
Aquaculture area	ha	4,234	0.56
Production	tonnes	5,638	0.79
Fish production	tonnes	*5,089*	
Shrimp production	tonnes	*52*	

The 2010 update of the 2003 IWARP & VNMC report "Analysis of sub-area 7V" for the MRC Basin Development Plan indicates that most of the fishing comes from reservoirs ("*in most localities, fish catching in reservoirs accounts for 70- 80% of total fish production on average"*), although the productive nature of rivers and streams is recognized (but not quantified). The report gives some indications about reservoir productivity ("A*ccording to preliminary assessments, fish production at some key water bodies in the Central is estimated as hundred kilograms a year in Sa Thay river, 30 tons a year in the Great Lake and about 100 tons in Lak Lake*"). The update also emphasizes that the trend in reservoir fisheries is increasing (more fishing, more production), and that production of fingerlings for stocking is one of the management measures being developed at the province level.

As for the aquaculture sector, the 2010 report also underlines that the SA-7V area features 11 hatcheries units producing 800 million to 1 billion larvae annually, mostly *Ctenopharyngodon idella* (80%), *Hypophthalmichthys harmandi*, *Aristichthys nobilis, Labeo rohita,* and *Cyprinus carpio.* However, the report does not provide any aquaculture production figures at the basin or sub-basin level, by explicit lack of data; what is provided is the surface area used by the aquaculture sector (Table 16):

Table 16: Land used for aquaculture purposes in the Sesan and Srepok Basins.

	Land use for aquaculture (ha, 2005 data)		Total (ha)	Source
Sesan Basin	*Krong Po Ko*	*121*	402	National land inventory in 2005 of Kon Tum and Gia Lai provinces
	Dak Bla	*125*		
	Lower Sesan	*156*		
Srepok Basin	*Ea Lop - Ea Hleo*	*6*	1537	National land inventory in 2005 of Gia Lai, Dak Lak and Dak Nong provinces
	Krong Ana	*1,064*		
	Krong Kno	*58*		
	Lower Srepok	*409*		

6 ECONOMIC VALUE OF FISHERIES ALONG THE 3S RIVERS

In the Vietnamese part of the 3S, the fisheries production was valued at 81.8 billion VND in 2000, 115.9 VND in 2005 and 146.3 billion VND in 2008 (1994 value). Source: 2010 update of the IWARP & VNMC report "Analysis of sub-area 7V" for the MRC Basin Development Plan.

In Cambodia, the value of fish catches in the Sesan River, like the estimate of fish catches, is subject to multiple contradictory estimates.

- "*The market value of fish production in the project area ranged from 545,950 to 781,477 USD. Market value of fish production upstream of the project area was 1,948,680 USD. Thus, total market value of fish production in project area and upstream of project area ranged from 2,404,630 to 2,730,157 USD.*" (KCC 2009, p.15)
- The present value of production from fisheries and wetlands in the Sekong, Sesan and Srepok River Basins amount to respectively USD 4,059,000 in the Sekong Basin, 2,317,000 in the Sesan Basin and 2,629,000 in the Srepok Basin (total: USD 9 million; catch figures not specified). Source: CNMC 2009.
- *"The official records of capture fishery in the Sekong in 2006 were about 9,500 tons per year, with a value of about 17 million USD. Actual catches and values are probably much more than this, since official records do not measure subsistence catches, and valuation only considers the initial sale value of catch."* (ADB RETA 2010a).

An alternative estimate can be based of the catch figures and the price per kilogram:
"On average, villagers of Ratanakiri province […] are able to sell it from 10,000 to 15,000 riel per kilogram in the market town" (Baird 2009, p.34), i.e. USD 2.5 to 3.75/kg. From this estimate and the total catch estimates in Table 13 it is possible to derive a range for the fish production value (Table 17).

Table 17: Fish catches in the Sesan according to different sources and corresponding total value.

Catch per family per year	Source	Total catch (tonnes)		Price per kg (USD)	Value (USD million)	
		Lower range	Upper range		Lower range	Upper range
73.2	Province statistics	366	610	2.5	0.9	2.3
131	KCC 2009	655	1,092		1.6	4.1
129.3	Baird and Meach Mean according to KCC 2009	646.5	1,078		1.6	4.0
365	Baird 2009	1,825	3,042	3.75	4.6	11.4
500		2,500	4,167		6.3	15.6
800		4,000	6,667		10.0	25.0

These estimates show that **the total value of the fish production along the Sesan River ranges from 1 to 25 million US dollars, the central estimate being between 2 and 16 million USD, depending on estimates of total yield and of price per kilo.**

7 FISHERIES-BASED LIVELIHOODS ALONG THE SESAN RIVER

7.1 FISH CONSUMPTION ALONG THE 3S RIVERS

To our knowledge, three sources of information are available about fish consumption along the Sesan River and more generally in the 3S Rivers:

- according to the Lower Sesan EIA (KCC 2008), villagers at the project site consumed from 0.5 kg to 5.5 kg per family per day depending on their catches by season; this translates into a range of 30.4 to 334.6 kg/capita/year;
- according to CNMC (2009) fish consumption per capita per year in the Cambodian part of the 3S (zone SA-7C) varied during the period 2000-2004, the Sekong Basin presenting the highest value of fish consumption (53 kg/capita/year), followed by the Srepok Basin (25 kg/capita/year) and the Sesan Basin with the lowest value (15 kg/capita/year), the the average consumption in the SA-7C being estimated at 29 kg per capita per year;
- Hortle (2007) compiled multiple studies in the Lower Mekong Basin, and provides consumption figures (in kg/capita/year) for the Sekong River (17.1 kg/capita/year, from Funge-Smith 1999). For Stung Treng and Ratanakiri provinces, Hortle justifies the use as a conservative proxy of the Svay Rieng figures, i.e. 22.8 kg/capita/year.

These figures are summarized in the table below; in summary **estimates of fish consumption along the Sesan River vary between 15 and more than 100 kg/person/year, while they vary between 17 and 53 kg along the Sekong and around 25 kg/person/year along the Srepok River.**

Table 18: Fish consumption in the 3S according to different sources.

	Fish consumption (kg/capita/year)	Source
Sekong	53	CNMC 2009
	17.1	Hortle 2007
Sesan	30.4-334	KCC 2008
	15	CNMC 2009
	22.8	Hortle 2007
Srepok	25	CNMC 2009

7.2 DEGREE OF DEPENDENCY OF RIVERINE POPULATIONS

The dependency of the Sesan population on river resources has been highlighted by multiple studies and authors, in particular in the Cambodian part of the river (e.g. Halcrow 1999, McKenney 2001, Bush 2005, Baird and Meach Mean 2005, Rutkow et al. 2005, Swift 2006, SWECO-Groner 2006, CEPA 2007, Halcrow 2010). All major institutions and even dam developers recognize this dependency:

• "*Fish are an important source of protein in the local diet throughout the 3S area, and both river and pond fisheries are important contributions to household sustenance and economy for rural communities, especially in Cambodia.*" (WorldBank 2006)

• "*In Cambodia and Laos the majority of people are still close to the river system and remain highly dependent on natural resources*. […] *Reduced access to fisheries is reported in all three countries but appears to have more significant implications in Cambodia and Laos where aquatic resources continue to constitute the main sources of animal protein in rural diets, and where there are few alternative sources of animal protein*." (ADB-RETA 40082 2010b)
• *"Fish and rice is the main source of protein and calories for the population of SA-7C, particularly rural people living along the rivers, lakes, and aquatic habitats*." (CNMC 2009)
•*"Fish are important protein sources of villagers along the Sesan and Srepok Rivers (approximately 40,000 people). It is considered that the socio-economic impact from the consequent loss of fish will be one of the single largest impacts of the dam."* (KCC 2008)

In fact the degree of dependency of people on fisheries is not a binary factor (dependent/non-dependent) but depends on three main factors:

- *distance to a river* (people of villages located several kilometers away from a river are less dependent on fish resources than those located along river banks);
- *household wealth* (within the same village, fish resources from the river are more important to poor households than to wealthy households who have more alternative livelihood options and income sources);
- *level of local development* (one kilogram of fish is more valuable to people's livelihood in a poor and undeveloped village than in a more developed village with diversified production and commercial activities).

For these reasons and the resulting gradient of situations, it is often difficult to formally quantify the number of people dependent on fisheries resources.

What is clear in the case of the Sesan River is the large majority of villages are i) close to a river; ii) poor by national standards, and iii) undeveloped, which makes the vilagers' dependency upon fish resources very high.

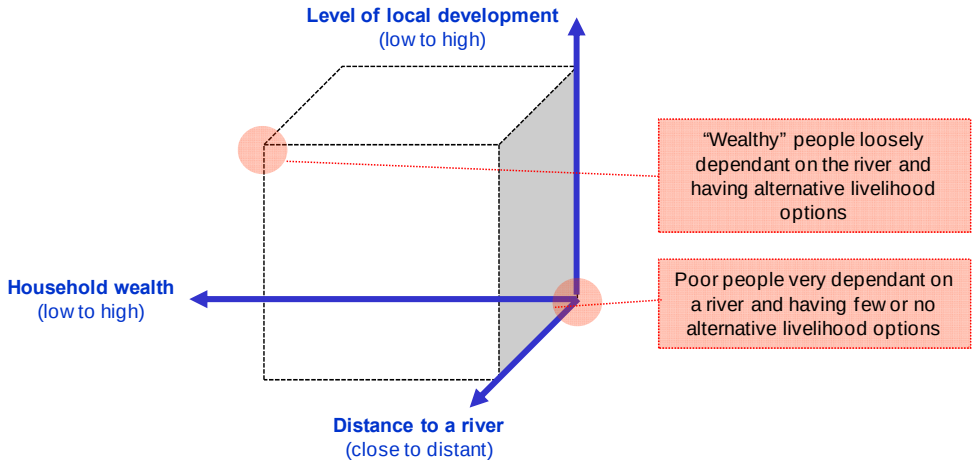


Figure 18: The three main factors of dependency of people on river fish resources.

8 PAST TRENDS IN FISH RESOURCES AND FISHERIES

8.1 TRENDS IN MIGRATORY FISH CATCHES

Baran and Seng Sopheak (2010) systematically tested, based on fishermen's interviews, the hypotheses about fish migrations in the 3S formulated by Baird and Shoemaker (2008), with a focus on about fifteen species dominant in catches.

Their study shows that *Henicorhynchus siamensis* and *H. lobatus* had not been seen for about ten years in the Sekong River, but had come back in 2010. In the Sesan and Srepok, no interruption in annual migrations was mentioned by fishermen. These species have 3 annual upstream migration waves in the Sekong (like in the Tonle Sap and Khone Falls) but 2 only in the Sesan and Srepok (no December wave). Fish move back downstream during the wet season. Abundance had declined a lot in the Sekong and the Sesan. Overall, the pattern shows a rarefaction of *Henicorhynchus* in the Sesan River and in the two other rivers during the last decade. In 2010, the reason why this fish was abundant enough to migrate far upstream along the Sekong again is unknown.

Hypsibarbus malcolmi and *H. lagleri* were present and considered relatively abundant in the Sekong and Srepok Rivers, although their migration pattern was unclear. Rarefaction issues were highlighted in the Sesan, but causes are unclear. *Hypsibarbus pierrei* migrates all along the Sesan but its abundance in this river had declined sharply. In the Srepok Rivers it was still abundant up to km 200 and beyond. *Hypsibarbus wetmorei* was present in both rivers, but its abundance had declined considerably in the Sesan and it had not been seen for three years in the Upper Srepok.

Labeo chrysophekadion was present in the Sesan and Srepok Rivers, but considered abundant in the Srepok and rare in the Sesan River. *Labeo erythropterus* used to migrate upstream at the beginning of the rainy season and downstream at the end. In 2010, the species was still present but rare (a few fishes per fisherman per year). It had not been caught for 3 years at km 53 in the Sesan.

Scaphognathops bandanensis is characterized by a dry season (April-May) upstream migration and a migration downstream later, although timing varies. For this species like for *Henicorhynchus spp* in the Sekong or *Hypsibarbus* in the Sesan, people mentioned that after years of decline since about 2000, the year 2010 was characterized by much higher abundance. *Bangana behri* still migrated into the 3S, but was considered absent in the upper part of the Sekong River beyond km 350, and downstream; only a few fish were caught per fisherman and per year in each river.

Among Pangasiidae, *Pangasius conchophilus* was still considered abundant in the Srepok River while abundance in Sesan River had declined sharply. The abundance of *Pangasius larnaudii* had declined a lot in the Sesan but seemed to be sustained in the Srepok River. *Wallago attu* was present in the 3 rivers but was becoming quite rare. Although it was still present in the 3S, *Wallago leeri* was also caught in very low quantities.

Overall, this study undertaken in 2010 highlights a drastic decline in abundance, or more specifically in catch per fisherman, for most of these species. This pattern was already reported by S. Bush a few years earlier (Bush 2005). This decline applies to species in all families and to fish in each of the three rivers, though the Srepok seems to be the river where the decline is smallest.

8.2 TRENDS IN FISH YIELDS

The construction of the Yali dam, the first of the Sesan River dam, started modifying the hydrology of the river as early as 1996 (Wyatt and Baird 2007) and the MRC recognized that in 2001-2003 the water level in Sesan River was fluctuating by up to one meter a day downstream of the Yali dam in Cambodia. This daily water level combined with flash floods caused multiple problems to communities living along the Sesan River banks in Cambodia, as detailed, among others, in RPFO & NTFPP (2000), McKenney (2001), Baird *et al*. (2002), Wyatt and Baird (2007) and RCC (2008):

- unusual flooding events, leading to drowning in several instances (32 villagers drowned in 2000 according to 3SPN 2007)
- increased dry-season flows (less access to river banks and sand bars, increased bank erosion, loss of edible river plants)
- unpredictable fluctuations in river flow and water level (river bank gardens and boats washed away)
- lower water quality and impact on health (loss of some edible algae such as *Telectadium edule*, water not drinkable any more, itchiness, bumps, irritation of eyes, etc.)
- decline in fisheries resources (dramatic reduction of catches, in particular large species)

Table 19: Species reported by villagers to have largely declined since the Yali Falls dam was built, and causes given for this decline. Sources: Baird *et al*. 2002 and Baird & Meach Mean 2005.

Latin Name	Cause attributed by villagers to
Bagarius yarelli	
Bangana behri	Algae decline
Belodontichthys truncatus	Deep water habitat loss
Boesemania microlepis	Deep water habitat loss
Channa cf. marulius	
Henicorhynchus lobatus/spp.	Algae decline
Hypsibarbus spp.	Algae decline
Labeo erythropterus	Algae decline
Leptobarbus hoeveni	
Luciosoma bleekeri	
Macrochirichthys macrochirus	Poor water quality
Mekongina erythrospila	Algae decline
Micronema micronema/spp.	Deep water habitat loss
Morulius spp.	Algae decline
Oxyeleotris marmorata	Deep water habitat loss
Pangasius conchophilus	Deep water habitat loss
Pangasius hypophthalmus	Deep water habitat loss
Pangasius krempfi	Deep water habitat loss, poor water quality
Pangasius larnaudiei	Deep water habitat loss
Pangasius polyuranodon	Deep water habitat loss
Paralaubuca typus	Algae decline
Scaphognathops bandanensis/spp.	Poor water quality, algae decline
Thynnichthys thynnoides	
Wallago attu	Deep water habitat loss
Wallago leeri	Deep water habitat loss

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10 ANNEX 1: FISH SPECIES IN THE 3S RIVERS

Species	Sekong	Sesan	Srepok
Aaptosyax grypus		1	
Acanthopsoides delphax		1	1
Acanthopsoides gracilentus	1		1
Acanthopsoides gracilis	1		
Acanthopsoides hapalias	1	1	
Achiroides leucorhynchos			1
Achiroides melanorhynchus			1
Akysis ephippifer	1		1
Akysis varius	1		
Albulichthys albuloides			1
Amblyceps serratum	1	1	
Amblyrhynchichthys truncatus	1		1
Anabas testudineus	1	1	1
Anguilla marmorata	1		1
Annamia normani	1		1
Auriglobus nefastus	1		
Bagarius bagarius			1
Bagarius suchus			1
Bagarius yarrelli	1	1	1
Bagrichthys macracanthus	1	1	1
Bagrichthys macropterus	1	1	
Bagrichthys obscurus	1		1
Balitora annamitica	1	1	1
Bangana behri	1	1	1
Bangana pierrei	1		
Barbichthys laevis			1
Barbonymus altus	1	1	1
Barbonymus gonionotus			1
Barbonymus schwanenfeldii	1	1	1
Belodontichthys truncatus	1	1	1
Betta splendens			1
Boesemania microlepis	1		
Brachirus harmandi	1		1
Brachirus orientalis			1
Carinotetraodon lorteti			1
Catlocarpio siamensis	1		
Channa gachua	1	1	1
Channa lucius			1
Channa marulia	1		
Channa marulioides			1
Channa micropeltes	1	1	1
Channa orientalis	1	1	1
Channa striata	1	1	1
Chitala blanci	1	1	1
Chitala lopis			1
Chitala ornata	1	1	1
Cirrhinus cirrhosus			1
Cirrhinus jullieni	1	1	1
Cirrhinus microlepis	1	1	1
Cirrhinus molitorella	1	1	1
Clarias batrachus		1	1
Clarias fuscus	1		

Species	Sekong	Sesan	Srepok
Clarias gariepinus			1
Clarias macrocephalus			1
Clarias meladerma			1
Clupeichthys aesarnensis	1		
Clupisoma sinense		1	1
Coilia lindmani			1
Coilia macrognathos			1
Corica laciniata			1
Corica soborna			1
Cosmochilus harmandi	1	1	1
Crossocheilus atrilimes	1	1	1
Crossocheilus oblongus	1	1	
Crossocheilus reticulatus	1	1	1
Ctenopharyngodon idella			1
Cyclocheilichthys apogon	1		1
Cyclocheilichthys armatus	1	1	1
Cyclocheilichthys enoplus	1	1	1
Cyclocheilichthys furcatus			1
Cyclocheilichthys heteronema			1
Cyclocheilichthys lagleri			1
Cyclocheilichthys repasson	1	1	1
Cynoglossus feldmanni			1
Cynoglossus microlepis			1
Cyprinus carpio carpio			1
Dasyatis laosensis	1	1	1
Datnioides polota			1
Datnioides undecimradiatus	1	1	1
Dermogenys pusilla			1
Devario acrostomus			1
Devario gibber	1		1
Devario leptos			1
Devario salmonata	1		
Discherodontus ashmeadi	1	1	1
Doryichthys contiguus	1		
Epalzeorhynchos frenatus	1		
Esomus danricus			1
Esomus metallicus	1	1	
Garra cambodgiensis	1	1	1
Garra fasciacauda	1		1
Garra fuliginosa			1
Glossogobius aureus	1		
Glyptothorax filicatus	1		
Glyptothorax fuscus		1	1
Glyptothorax lampris	1		1
Glyptothorax laosensis	1	1	1
Gyrinocheilus aymonieri	1		1
Gyrinocheilus pennocki	1	1	1
Hampala dispar	1	1	1
Hampala macrolepidota	1	1	1
Helicophagus waandersii	1	1	1
Hemibagrus filamentus	1	1	1
Hemibagrus guttatus			1
Hemibagrus microphthalmus	1		
Hemibagrus nemurus	1	1	
Hemibagrus spilopterus	1	1	1
Hemibagrus wyckii	1	1	1

Species	Sekong	Sesan	Srepok
Hemibagrus wyckioides	1	1	1
Hemimyzon khonensis	1		
Hemimyzon papilio			1
Hemisilurus mekongensis			1
Henicorhynchus lineatus	1	1	
Henicorhynchus lobatus	1	1	1
Henicorhynchus ornatipinnis			1
Henicorhynchus siamensis	1	1	1
Himantura chaophraya	1		1
Himantura imbricata			1
Himantura krempfi			1
Homaloptera confuzona	1	1	
Homaloptera leonardi		1	
Homaloptera orthogoniata	1		
Homaloptera smithi	1	1	
Homaloptera tweediei	1		
Homaloptera yunnanensis	1		
Homaloptera zollingeri	1		
Hypophthalmichthys molitrix			1
Hypophthalmichthys nobilis			1
Hyporhamphus limbatus			1
Hypsibarbus lagleri	1	1	1
Hypsibarbus malcolmi	1	1	1
Hypsibarbus pierrei			1
Hypsibarbus suvattii			1
Hypsibarbus wetmorei	1	1	1
Kryptopterus bicirrhis	1	1	
Kryptopterus cheveyi			1
Kryptopterus cryptopterus	1	1	1
Kryptopterus limpok	1		
Labeo chrysophekadion	1		1
Labeo dyocheilus	1		1
Labeo erythropterus		1	
Labeo rohita			1
Labiobarbus leptocheilus	1	1	
Labiobarbus lineatus		1	
Labiobarbus siamensis			1
Laides longibarbis	1		1
Lepidocephalichthys berdmorei		1	1
Lepidocephalichthys hasselti	1	1	1
Leptobarbus hoevenii	1	1	1
Lobocheilos melanotaenia	1	1	1
Lobocheilos rhabdoura	1		1
Luciocyprinus striolatus	1		
Luciosoma bleekeri	1	1	1
Luciosoma setigerum	1		
Lycothrissa crocodilus			1
Macrochirichthys macrochirus	1	1	1
Macrognathus circumcinctus			1
Macrognathus maculatus			1
Macrognathus semiocellatus	1		1
Macrognathus siamensis	1	1	1
Macrognathus taeniagaster		1	1
Mastacembelus armatus	1	1	1
Mastacembelus erythrotaenia			1
Mastacembelus favus	1		

Species	Sekong	Sesan	Srepok
Mekongina erythrospila	1	1	1
Misgurnus anguillicaudatus		1	1
Monopterus albus	1	1	1
Mystacoleucus atridorsalis	1		
Mystacoleucus chilopterus			1
Mystacoleucus marginatus	1		
Mystus albolineatus			1
Mystus atrifasciatus	1		1
Mystus bocourti			1
Mystus gulio			1
Mystus multiradiatus			1
Mystus mysticetus			1
Mystus singaringan	1	1	1
Mystus wolffii			1
Nemacheilus longistriatus	1	1	
Nemacheilus pallidus		1	1
Nemacheilus platiceps	1	1	1
Neolissochilus stracheyi	1		1
Notopterus notopterus	1	1	1
Ompok bimaculatus	1	1	1
Onychostoma meridionale	1		
Ophisternon bengalense			1
Opsarius koratensis	1	1	
Opsarius pulchellus	1	1	1
Oreochromis mossambicus			1
Oreochromis niloticus niloticus			1
Osphronemus exodon	1	1	1
Osphronemus goramy			1
Osteochilus lini	1		1
Osteochilus melanopleurus	1	1	1
Osteochilus microcephalus	1	1	1
Osteochilus schlegelii			1
Osteochilus vittatus	1	1	1
Osteochilus waandersii	1	1	1
Oxyeleotris marmorata	1		1
Pangasianodon gigas			1
Pangasianodon hypophthalmus	1	1	1
Pangasius bocourti	1	1	1
Pangasius conchophilus	1	1	1
Pangasius djambal			1
Pangasius krempfi	1	1	1
Pangasius kunyit			1
Pangasius larnaudii	1	1	1
Pangasius macronema	1	1	1
Pangasius mekongensis			1
Pangasius polyuranodon			1
Pangio anguillaris	1	1	1
Pangio fusca		1	
Pangio oblonga		1	1
Papuligobius ocellatus	1	1	1
Parachela maculicauda	1		
Parachela siamensis	1		
Paralaubuca barroni	1		1
Paralaubuca harmandi			1
Paralaubuca riveroi	1		1
Paralaubuca typus	1	1	1

Species	Sekong	Sesan	Srepok
Parambassis apogonoides			1
Parambassis siamensis	1	1	1
Parambassis wolffii	1		1
Phalacronotus apogon	1		1
Phalacronotus bleekeri	1	1	1
Phalacronotus micronemus	1	1	
Polynemus dubius			1
Poropuntius bolovenensis	1		1
Poropuntius consternans	1		
Poropuntius deauratus	1	1	
Poropuntius laoensis			1
Poropuntius lobocheiloides	1		
Poropuntius normani	1		1
Pristolepis fasciata	1	1	1
Probarbus jullieni	1	1	1
Probarbus labeamajor	1	1	1
Probarbus labeaminor			1
Pseudobagarius inermis	1		
Pseudolais micronemus			1
Pseudolais pleurotaenia	1	1	1
Pseudomystus siamensis	1	1	1
Pseudomystus stenomus	1		
Puntioplites bulu			1
Puntioplites falcifer	1	1	1
Puntioplites proctozystron	1		1
Puntius aurotaeniatus	1	1	
Puntius binotatus		1	1
Puntius brevis	1		1
Puntius orphoides	1		1
Puntius partipentazona	1	1	
Puntius rhombeus	1		1
Raiamas guttatus	1	1	1
Rasbora amplistriga	1	1	1
Rasbora atridorsalis			1
Rasbora aurotaenia			1
Rasbora borapetensis	1	1	
Rasbora dusonensis	1	1	1
Rasbora hobelmani			1
Rasbora paviana	1	1	1
Rasbora rubrodorsalis	1		
Rasbora tornieri			1
Rasbora trilineata	1	1	
Rhinogobius giurinus			1
Rhinogobius taenigena	1		
Scaphiodonichthys acanthopterus	1		
Scaphognathops bandanensis	1	1	1
Scaphognathops stejnegeri	1		1
Schistura bairdi	1		
Schistura bolavenensis	1		
Schistura clatrata	1		
Schistura coruscans			1
Schistura daubentoni		1	1
Schistura defectiva			1
Schistura dorsizona	1		
Schistura fusinotata	1		
Schistura imitator	1		

Species	Sekong	Sesan	Srepok
Schistura kengtungensis			1
Schistura khamtanhi	1		
Schistura kongphengi	1		
Schistura nomi	1		
Schistura rikiki	1		
Schistura tizardi	1		
Serpenticobitis octozona	1		
Sewellia diardi	1		
Sewellia elongata	1		
Sewellia patella		1	
Sewellia speciosa	1		
Sikukia gudgeri	1		1
Sinibrama affinis			1
Sinohomaloptera kwangsiensis			1
Sundasalanx mekongensis	1		
Syncrossus beauforti	1	1	1
Syncrossus helodes		1	1
Tenualosa thibaudeaui	1	1	
Tenualosa toli			1
Tetraodon baileyi	1		1
Tetraodon barbatus			1
Tetraodon cambodgiensis	1		
Tetraodon cochinchinensis	1		
Tetraodon leiurus	1	1	
Tetraodon suvattii	1		
Tetraodon turgidus	1		
Thynnichthys thynnoides	1	1	1
Tor laterivittatus	1		1
Tor sinensis	1		1
Tor tambra	1		
Tor tambroides	1		1
Toxabramis hotayensis			1
Toxotes chatareus	1		
Toxotes microlepis		1	
Trichogaster microlepis			1
Trichogaster pectoralis			1
Trichogaster trichopterus	1	1	1
Trichopsis schalleri	1		
Trichopsis vittata	1		1
Tuberoschistura cambodgiensis			1
Wallago attu		1	1
Wallago leerii	1	1	1
Xenentodon cancila	1	1	1
Xenentodon canciloides	1		1
Yasuhikotakia caudipunctata			1
Yasuhikotakia eos	1	1	1
Yasuhikotakia lecontei		1	1
Yasuhikotakia longidorsalis			1
Yasuhikotakia modesta	1	1	1
Yasuhikotakia morleti			1
Yasuhikotakia nigrolineata	1	1	1
Yasuhikotakia sidthimunki	1		
Yasuhikotakia splendida	1		
Grand Total	*213*	*133*	*240*

11 ANNEX 2: MIGRATORY FISH SPECIES IN THE 3S RIVERS

Details of the 90 migratory species in the 3S system. For each species the river in which this species is found is detailed. Non-exclusive migratory species able to breed in reservoirs have been excluded. The degree of certainty about the migratory nature of each species is expressed by the number of sources citing this species as being migratory (among the 5 main sources used).

Latin name (verified in fishbase.org)	Family	Found in the 3S	Migratory ' in MFD 2003? (Yes =1)	Belongs to guilds 2,3,8,9 in Halls and Kshatriya 2009? (Yes =1)	Classified as "White fish" by Tonle Sap fisherme n in Baran *et al*. 2006? (Yes =1)	White fish accordin g to So Nam (pers. com.)? (Yes =1)	Belong s to guild 4 in Halls 2010? (Yes =1)	Additional comments by EB	Conclusio n modified by EB based on a final review? (Yes=1)	Degree of certainty about migratio n
Aaptosyax grypus	Cyprinidae	Sesan	1	1				MFD: It is restricted to the Middle Mekong Basin and a few large tributaries. It is becoming increasingly rare due to the damming of major tributaries. Impacted status confirmed		2/5
Acanthopsoides delphax	Cobitidae	Sesan, Srepok	1			1				2/5
Amblyrhynchichthys truncatus	Cyprinidae	Sekong, Srepok	1	1				A white fish species (Bardach 1959). It migrates up from Cambodia to Laos in January and February, and it returns to Cambodia in June-July (Baird *et al*. 1999)		2/5

Anguilla marmorata	Anguillidae	Sekong, Srepok	1	1		1		All Anguilla are catadromous migrants		3/5
Bagarius yarrelli	Sisoridae	Sekong, Sesan, Srepok	1			1				2/5
Bangana behri	Cyprinidae	Sekong, Sesan, Srepok	1	1						2/5
Bangana pierrei	Cyprinidae	Sekong	1					Labeo pierrei (former record) = invalid synonym of Bangana pierrei. Amendment made. Migrates through Khone Falls		1/5
Barbichthys laevis	Cyprinidae	Srepok				1	1			2/5
Brachirus harmandi	Soleidae	Sekong, Srepok		1		1		Not typically estuarine like other Brachirus. Reported from the Xe Bangfai Basin (Kottelat 1998); Larvae/juveniles recorded from the drift in both the Mekong and Bassac Rivers in An Giang (Nguyen Thanh Tung *et al*. 2005)		2/5
Catlocarpio siamensis	Cyprinidae	Sekong	1				1			2/5
Chitala blanci	Notopteridae	Sekong, Sesan, Srepok	1				1	An endemic mainly carnivorous species living in rapids and deep pools in large rivers of the Middle Mekong. It does not migrate extensively but is exposed due to its habitat requirements		2/5
Cirrhinus jullieni	Cyprinidae	Sekong, Sesan, Srepok						A white fish species (Bardach 1959). Migrates up the Mekong River from Cambodia to southern Lao PDR in January-February (Baird *et al*. 1999).	1	1/5

Cirrhinus microlepis	Cyprinidae	Sekong, Sesan, Srepok	1	1						2/5
Cirrhinus molitorella	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Clupisoma sinense	Schilbeidae	Sesan, Srepok	1	1				Migrations in the mainstream, but long-distance actually unclear		2/5
Cosmochilus harmandi	Cyprinidae	Sekong, Sesan, Srepok	1	1	1					3/5
Crossocheilus atrilimes	Cyprinidae	Sekong, Sesan, Srepok	1				1			2/5
Crossocheilus reticulatus	Cyprinidae	Sekong, Sesan, Srepok	1			1				2/5
Cyclocheilichthys apogon	Cyprinidae	Sekong, Srepok	1							1/5
Cyclocheilichthys armatus	Cyprinidae	Sekong, Sesan, Srepok	1				1			2/5
Cyclocheilichthys enoplus	Cyprinidae	Sekong, Sesan, Srepok	1					The most abundant white fish in the basin		1/5
Cyclocheilichthys furcatus	Cyprinidae	Srepok	1	1		1				3/5
Cyclocheilichthys heteronema	Cyprinidae	Srepok	1			1				2/5
Cynoglossus microlepis	Cynoglossidae	Srepok	1	1						2/5
Dasyatis laosensis	Dasyatidae	Sekong, Sesan, Srepok	1	1						2/5
Datnioides undecimradiatus	Datnioididae	Sekong, Sesan, Srepok	1			1				2/5
Epalzeorhynchos frenatus	Cyprinidae	Sekong	1					Unclear case, but Cambodia-Laos long distance migrations also mentioned in Baird *et al*. 1999		1/5
Garra fasciacauda	Cyprinidae	Sekong, Srepok		1				OK		1/5
Gyrinocheilus pennocki	Gyrinocheilidae	Sekong, Sesan, Srepok	1	1				Migrations mentioned		2/5

Helicophagus waandersii	Pangasiidae	Sekong, Sesan, Srepok	1	1				Migrations in the mainstream, but long-distance actually unclear		2/5
Hemibagrus filamentus	Bagridae	Sekong, Sesan, Srepok	1				1	It undertakes short local migrations within the Mekong mainstream at the onset of the flood season and as the water level rises (Poulsen and Valbo-Jørgensen, 2000, Singanouvong *et al*. 1996)		2/5
Hemibagrus wyckii	Bagridae	Sekong, Sesan, Srepok	1				1	Migrates for reproduction in the wet season (Singanouvong *et al*. 1996)		2/5
Hemibagrus wyckioides	Bagridae	Sekong, Sesan, Srepok	1					Although Bardach (1959) indicated that it is a black fish species, it has been found to migrate upstream from July-September (Singanouvong *et al*. 1996); it also enters inundated areas (Baird and Phylavanh 1999)		1/5
Hemisilurus mekongensis	Siluridae	Srepok	1			1		Migrates upstream in April-July. The migratory activity seems to be strongly associated with river discharge (Singanouvong et al. 1996)		2/5
Henicorhynchus lobatus	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Henicorhynchus siamensis	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Himantura krempfi	Dasyatidae	Srepok						A white fish species (Bardach 1959)	1	1/5

Hypsibarbus lagleri	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Hypsibarbus malcolmi	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Hypsibarbus pierrei	Cyprinidae	Srepok				1		This fish species migrates up the Mekong River in southern Lao PDR in March-April (Baird *et al*. 1999)		1/5
Hypsibarbus wetmorei	Cyprinidae	Sekong, Sesan, Srepok	1	1						2/5
Labiobarbus leptocheilus	Cyprinidae	Sekong, Sesan				1		A white fish species (Bardach, 1959). The species migrates from Cambodia to Lao PDR in January-February, in June-July it moves into the floodplains for spawning. After spawning, the fish migrates down the Mekong River again (Baird *et al*. 1999)		1/5
Labiobarbus lineatus	Cyprinidae	Sesan	1			1		A white fish species (Bardach, 1959). The species migrates from Cambodia to Lao PDR in January-February		2/5
Labiobarbus siamensis	Cyprinidae	Srepok		1				A white fish species (Bardach, 1959). The species migrates from Cambodia to Lao PDR in January-February, and in June -July it moves into the floodplains for spawning		1/5
Leptobarbus hoevenii	Cyprinidae	Sekong, Sesan, Srepok	1				1			2/5

Lobocheilos melanotaenia	Cyprinidae	Sekong, Sesan, Srepok	1				1	The fish migrates up from Cambodia to southern Lao PDR in January-February and downstream in November-December (Baird *et al*. 1999)		2/5
Luciocyprinus striolatus	Cyprinidae	Sekong					1	Migrates into small and medium sized streams in May-June to spawn (Baird *et al*. 1999) → should have been listed as a migratory fish in MFD 2003.		1/5
Luciosoma bleekeri	Cyprinidae	Sekong, Sesan, Srepok	1	1						2/5
Mekongina erythrospila	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Osteochilus microcephalus	Cyprinidae	Sekong, Sesan, Srepok	1					Clearly a WF species (Singanouvong *et al*. 1996, Baird *et al*. 1999); disputably classified in guild 5 in Halls and Khsatriya 2009		1/5
Osteochilus schlegelii	Cyprinidae	Srepok	1					"White fish" based on Bardach 1959 only; probably grey but no clear info		1/5
Osteochilus waandersii	Cyprinidae	Sekong, Sesan, Srepok	1	1		1		The fish species migrate up from Cambodia to southern Lao PDR in January-February (Baird *et al*. 1999)		3/5
Pangasianodon gigas	Pangasiidae	Srepok	1	1						2/5
Pangasianodon hypophthalmus	Pangasiidae	Sekong, Sesan, Srepok	1	1						2/5
Pangasius bocourti	Pangasiidae	Sekong, Sesan, Srepok	1	1		1				3/5

Pangasius conchophilus	Pangasiidae	Sekong, Sesan, Srepok	1	1						2/5
Pangasius djambal	Pangasiidae	Srepok						All Pangasiids are white fish	1	1/5
Pangasius krempfi	Pangasiidae	Sekong, Sesan, Srepok	1	1		1				3/5
Pangasius kunyit	Pangasiidae	Srepok	1	1						2/5
Pangasius larnaudii	Pangasiidae	Sekong, Sesan, Srepok	1	1						2/5
Pangasius macronema	Pangasiidae	Sekong, Sesan, Srepok	1	1						2/5
Pangasius mekongensis	Pangasiidae	Srepok						All Pangasiids are white fish	1	1/5
Pangasius polyuranodon	Pangasiidae	Srepok	1	1		1				3/5
Paralaubuca harmandi	Cyprinidae	Srepok				1		Bardach 1959 and So Nam pers. comm. say it is a WF, and associated with the typical white fish Paralaubuca typus →WF		1/5
Paralaubuca riveroi	Cyprinidae	Sekong, Srepok				1		Bardach 1959 and So Nam pers. comm. say it is a WF, and associated with the typical white fish Paralaubuca typus →WF		1/5
Paralaubuca typus	Cyprinidae	Sekong, Sesan, Srepok	1	1						2/5
Phalacronotus apogon	Siluridae	Sekong, Srepok	1					Migrations from mainstream (common habitat) to floodplains		1/5
Phalacronotus bleekeri	Siluridae	Sekong, Sesan, Srepok	1			1		This species spends the dry season in deep pools in the mainstream and migrates longitudinally to spawn in the early flood and also laterally into floodplains		2/5

Probarbus jullieni	Cyprinidae	Sekong, Sesan, Srepok	1	1						2/5
Probarbus labeamajor	Cyprinidae	Sekong, Sesan, Srepok	1	1		1				3/5
Probarbus labeaminor	Cyprinidae	Srepok						A third species (Probarbus labeaminor?) was reported at Sungkom district, Nong Khai province (Thailand) with similar migratory habits to Probarbus jullieni and Probarbus labeamajor. Source: Poulsen and Valbo-Jørgensen 2000 Fish migrations and spawning in the Mekong	1	1/5
Pseudolais micronemus	Pangasiidae	Srepok	1			1		Formely Pangasius micronemus		2/5
Pseudolais pleurotaenia	Pangasiidae	Sekong, Sesan, Srepok	1			1		Formely Pangasius pleurotaenia		2/5
Puntioplites bulu	Cyprinidae	Srepok	1	1						2/5
Puntioplites falcifer	Cyprinidae	Sekong, Sesan, Srepok	1			1	1			3/5
Puntioplites proctozystron	Cyprinidae	Sekong, Srepok	1	1				White classification based only on Bardach 1959; possibly a grey fish though		2/5
Raiamas guttatus	Cyprinidae	Sekong, Sesan, Srepok				1		MFD says "Adults prefer clear waters with moderate to swift currents (Kottelat 1998, Rainboth 1996), while juveniles occur in quiet pools further downstream" (Kottelat 1998) so can be considered migratory		1/5

Rasbora aurotaenia	Cyprinidae	Srepok				1		Migrates up from the Tonle Sap to Laos PDR in January-February (Baird *et al*. 1999).		1/5
Scaphognathops bandanensis	Cyprinidae	Sekong, Sesan, Srepok	1				1			2/5
Sikukia gudgeri	Cyprinidae	Sekong, Srepok	1					This fish migrate in large quantities up from Cambodia to Lao PDR in January-February		1/5
Syncrossus beauforti	Cobitidae	Sekong, Sesan, Srepok	1	1		1		Formerly Botia beauforti. Found in deep running streams and waterfalls (Krachangdara 1994). Enters the flooded forest during the high-water periods and returns to the rivers during November and December in the lower Mekong (Rainboth 1996)		3/5
Syncrossus helodes	Cobitidae	Sesan, Srepok	1	1				Formerly Botia helodes. A white fish species (Bardach 1959), which moves into flooded areas during the rainy season and returns to rivers during November and December (Rainboth 1996)		2/5
Tenualosa thibaudeaui	Clupeidae	Sekong, Sesan	1	1		1				3/5
Tenualosa toli	Clupeidae	Srepok	1	1		1				3/5
Thynnichthys thynnoides	Cyprinidae	Sekong, Sesan, Srepok	1				1			2/5
Tor sinensis	Cyprinidae	Sekong, Srepok	1			1		Native villagers report that it undergoes upstream reproductive migrations in the mainstream and larger tributaries of the [...]		2/5

								[...] Nam Theun in such large numbers that "the rivers turn red" (Roberts 1999). Not clearly a long distance migrant though		
Tor tambroides	Cyprinidae	Sekong, Srepok	1			1		In central Thailand the species moves downstream at the onset of the flood and returns upstream after one or two months to spawn near the mouths of small streams in July; the young subsequently ascend these streams (Smith 1945)		2/5
Wallago leerii	Siluridae	Sekong, Sesan, Srepok	1			1	1	In Thailand it was reported to migrate downstream in groups in October-November (Poulsen and J. Valbo-Jørgensen 2000). Probably a grey species though		3/5
Yasuhikotakia modesta	Cobitidae	Sekong, Sesan, Srepok	1	1				Formerly Botia modesta. A white fish species (Bardach 1959), known for large migrations during January in upland areas of the Mekong (Rainboth 1996); There is an upstream migration from around the saline intrusion zone in the Delta to just below the Khone Falls from November to March. From May to July, the species migrates the opposite way apparently to flooded areas in Southern Cambodia		2/5

12 ANNEX 3: SESAN FISH CATCH DATA IN BAIRD AND MEACH MEAN 2005

Effort: One year by 22 fishermen in 7 villages of Ratanakiri province. Number of fishing sessions: 1,609. Number of hours fished: 24,062
Gears monitored: 2.5 cm gillnet, 3 cm gillnet, 4 cm gillnet, 5 cm gillnet, 6 cm gillnet, 8 cm gillnet, 10 cm gillnet, 12 cm gillnet, 13 cm gillnet, Longline + single hooks, Longline + baited hooks, 3 cm castnet

Species	**Total weight in Kg**
Aaptosyax grypus	0.25
Acantopsis sp.	8.3
Acantopsoides sp.	0.25
Achiroides sp.	12.9
Amblyrhychichthys truncates	1
Amphostistus laoensis	1.7
Bagarius yarrelli	90.55
Bagrichthys macracanthus	7.75
Bagrichthys macropterus	4.95
Bangara behri	149.2
Barbodes altus	19.8
Barbodes altus/Systomus binotatus -	2.25
Barbodes schwanefeldi	43.25
Belondichthys truncatus	7.2
Botia helodes	2.6
Botia helodes/ B. lecontei -	0.7
Botia lecontei	0.6
Botia modesta	4.85
Botia nigrolineata	0.5
Catlocarpio siamensis	5.4
Channa cf. marulius	0.85
Channa gachua	3.35
Channa micropeltes	11.5
Channa sp.	14.75
Channa striata	23.95
Chitala blanci	21.95
Chitala ornata	6.75
Cirrhinus jullieni /spp.	0.65
Cirrhinus microlepis	39.5
Cirrhinus molitorella	3.85
Clarias batrachus	4.25
Coius undecimradiatus	3.8
Cosmocheilus harmandi	16.15
Crossocheilus siamensis	1.55
Cyclocheilichthys enoplos	19.05
Cyclocheilichthys sp.	70.75
Cyclocheilichthys sp./ Sikukia gudgeri -	9.8
Garra cambodgiensis	0.75

Species	Total weight in Kg
Gyrinocheilus pennocki	9.15
Hampala dispar	2.55
Hampala macrolepidota	3.8
Hampala macrolepidota/ H. dispar	48.4
Helicophagus waandersii	29.5
Hemibagrus nemurus	76.45
Hemibagrus wyckioides	104.05
Hemililurus mekongensis	2.55
Henicorhynchus lobatus	22.45
Henicorhynchus siamensis	32.6
Henicorhynchus spp.	16.5
Hypsibarbus spp.	268.9
Hypsibarbus wetmorei	22.1
Kryptopterus cryptopterus	3.7
Kryptopterus sp.	5.95
Labeo erythropterus	43.9
Labiobarbus cf. leptocheilus	100.25
Laides siamensis	0.95
Leptobarbus hoeveni	3
Lobocheilus melanotaenia	14.5
Luciosoma bleekeri	20.65
Macrochirichthys macrochirus	1.75
Macrognathus sp.	1.6
Mastacemblus spp.	7.7
Mekongina erythrospila	4.95
Micronema bleekeri	5.45
Micronema cf. micronema	4.9
Micronema sp.	4.7
Miscellaneous	8.25
Monopterus albus	0.5
Morulius spp.	102
Mystus spp.	12.8
Mystus wyckii	15.75
Mystus wyckioides	0.15
Notopterus notopterus	5.01
Ompok bimaculatus	7.25
Osphronemus exodon	44.1
Osteocheilus hasselti	39.6
Osteocheilus melanopleurus	22.8
Osteocheilus microcephalus	7.95
Osteocheilus sp.	26.1
Osteochilus waandersii	23.65
Oxyeleotris marmorata	1.5
Oxyeleotris marmorata/ Gobiidae spp.	0.6
P. siamensis/ B. macropterus	7.8
Pangasius bocourti	6.95
Pangasius bocourti/ Pangasius concophilus	9.1
Pangasius cf. polyuranodon	8.8
Pangasius concophilus	2.3
Pangasius krempfi/ P. hypophthalmus -	11
Pangasius larnaudii	50.2

Species	Total weight in Kg
Pangasius macronema	6.2
Pangasius macronema/ P. pleurotaenia -	0.95
Pangasius macronema/ spp.	0.1
Pangasius pleurotaenia	15.9
Pangasius sp.	54.9
Pangasius/Laides sp. --	0.1
Paralaubuca typus	11.6
Poropuntius deauratus	9.95
Poropuntius sp.	0.7
Pristolepis fasciata	5.8
Probarbus spp.	26
Pseudomystus siamensis	4.55
Pseudomystus/ Bagrichthys macropterus	0.5
Puntioplites falcifer	76.97
Raiamas guttatus	11.8
Rasbora sp.	0.65
Scaphognathops bandanensis / spp.	31.8
Systomas binotatus	10.05
Tenualosa thibaudeaui	1.2
Tetraodon sp.	2.8
Tor tambroides /spp.	28.35
Toxotes microlepis	4.95
Trichogaster trichopterus	3.45
Wallago leeri	28.75
Xenentodon cancila	0.95