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MRC SEA for Hydropower on the Mekong mainstream

FISHERIES BASELINE ASSESSMENT WORKING PAPER

10 April 2010

The MRC SEA of Hydropower on the Mekong mainstream comprises 4 main phases: (i) scoping, (ii) baseline assessment, (iii) opportunities & risks assessment, and (iv) avoidance, enhancement and mitigation assessment.

The Baseline Assessment Report has two volumes:

VOLUME I: Summary Baseline Assessment Report

VOLUME II: Baseline Assessment Working Papers

This working paper is one of eight in Volume II of the baseline assessment report. The two volumes formally conclude the baseline assessment phase of the SEA and documents the outcomes of the baseline consultations and SEA team analysis.

Disclaimer

This document was prepared for the Mekong River Commission Secretariat (MRCS) by a consultant team engaged to facilitate preparation of a Strategic Environment Assessment (SEA) of proposals for mainstream dams in the Lower Mekong Basin.

While the SEA is undertaken in a collaborative process involving the MRC Secretariat, National Mekong Committees of the four countries as well as civil society, private sector and other stakeholders, this document was prepared by the SEA Consultant team to assist the Secretariat as part of the information gathering activity. The views, conclusions, and recommendations contained in the document are not to be taken to represent the views of the MRC. Any and all of the MRC views, conclusions, and recommendations will be set forth solely in the MRC reports.

This document incorporates a record of stakeholder consultations and subsequent analysis. Whether they attended meetings or not all stakeholders have been invited to submit written contributions to the SEA exercise via the MRC website.

For further information on the MRC initiative on Sustainable Hydropower (ISH) and the implementation of the SEA of proposed mainstream developments can be found on the MRC website: *http://www.mrcmekong.org/ish/ish.htm* and *http://www.mrcmekong.org/ish/SEA.htm*

The following position on mainstream dams is provided on the MRC website in 2009.

MRC position on the proposed mainstream hydropower dams in the Lower Mekong Basin

More than eleven hydropower dams are currently being studied by private sector developers for the mainstream of the Mekong. The 1995 Mekong Agreement requires that such projects are discussed extensively among all four countries prior to any decision being taken. That discussion, facilitated by MRC, will consider the full range of social, environmental and cross-sector development impacts within the Lower Mekong Basin. So far, none of the prospective developers have reached the stage of notification and prior consultation required under the Mekong Agreement. MRC has already carried out extensive studies on the consequences for fisheries and peoples livelihoods and this information is widely available, see for example report of an expert group meeting on dams and fisheries. MRC is undertaking a Strategic Environmental Assessment (SEA) of the proposed mainstream dams to provide a broader understanding of the opportunities and risks of such development. Dialogue on these planned projects with governments, civil society and the private sector is being facilitated by MRC and all comments received will be considered.

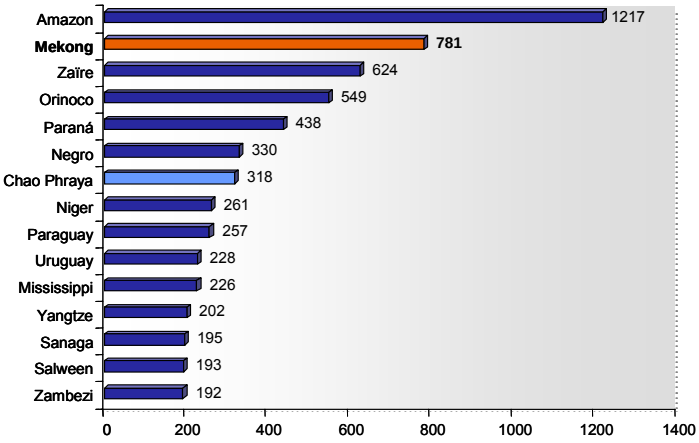
CONTENTS

1 STATUS OF MEKONG FISH BIODIVERSITY[1]

1.1 FRESHWATER FISH DIVERSITY IN THE MEKONG AND WORLDWIDE

The following analyses focus on species richness, and rely on FishBase (*www.fishbase.org*), the reference global fish database (32,000 species). Fish species richness was queried from FishBase for 455 ecosystems, out of which 204 rivers and 32 lakes were identified. The top 15 rivers and top 10 lakes are displayed below.

Figure 1: Fish species richness for different rivers of the world



Source: FishBase, December 2009

Conclusions:

The Mekong River is the second river in the world for its fish diversity, after the Amazon. It was ranked third in 2000 (Dudgeon 2000) but its species list has been substantially updated since then. The Mekong region is thus a biodiversity hotspot, whose magnitude is only being discovered: in the last decade more than 279 new species of fish have been discovered in this basin (WWF 2009). When all animals and plants are considered, it is more than a thousand new species that have been discovered in the basin within a decade.

[1] This section reflects the on going-work of the project "Scenario-based assessment of the potential effects of alternative dam construction schemes on freshwater fish diversity in the Lower Mekong Basin" implemented by NIES (Japan), WorldFish Center, Ubon Ratchatani University (Thailand) and IFReDI (Cambodia), and Funded by Mitsui Bussan.

Notes:

• These numbers originating from the global database do not reflect yet the larger species richness identified during this study and described in section 1.5.

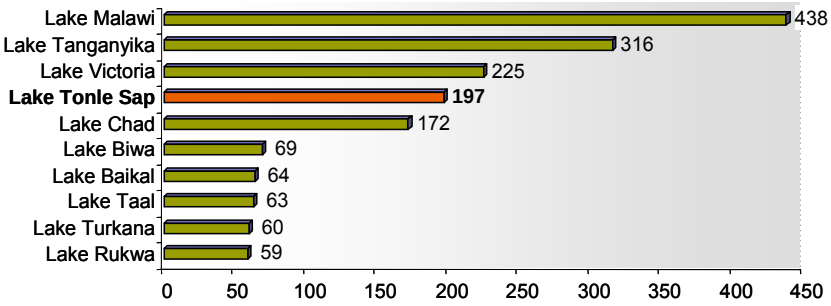
• Many publications mention a fish species richness in the Mekong equal or close to 1200 species (e.g. Coates *et al.* 2003, MRC 2003, Poulsen *et al.* 2004). However, this number originates from the introduction section of W. Rainboth's book "Fishes of the Cambodian Mekong" (Rainboth 1996). According to this taxonomist, "the total number of species recorded or expected from the Mekong, as inferred from the known zoogeography of Southeast Asia, includes about 1 200 species" (p. 5). The author actually details his "method" in an interview to "Catch and Culture" in August 1996[2]. These sources show that the widespread figure of 1200 fish species in the Mekong is not a factual figure.

Alternatively, in the Mekong Fish Database produced by the MRC (MFD 2003), 924 species only are listed, 815 species being "confirmed" and 45 species "expected" (the remainder consisting of synonymous or questionable species). In a recent article, Hortle (2009) reviews the issue and concludes that "the available data indicate that there are about 850 freshwater fish species recorded from the Mekong, with a total of about 1100 if the possible coastal or marine visitors are included".

Unlike all the above figures, the number of Mekong fish species presented here (781 so far) originates from FishBase, the reference global database of fishes worldwide (*www.fishbase.org*), in which each record is backed by a scientific study or publication. This is certainly an underestimate but is also the most rigorous assessment available so far.

FishBase was also used to compare the Tonle Sap Lake in Cambodia with lake ecosystems worldwide:

Figure 2: Fish species richness for different lakes of the world.



Source: FishBase, December 2009

[2] "I included species from parts of adjacent river basins, such as the Chao Phya. Also, I included estuarine and shoreline species. I included about 150 species of goby! Right now, the total number is any body's guess, and the more effort we put into looking, the higher the number will be." W. Rainboth in Catch and Culture, August 1996.

Conclusions:

In terms of fish biodiversity, the Tonle Sap Lake appears, with 197 species recorded so far, as the lake ecosystem having the fourth highest fish diversity in the world, or the richest lake in the world after east-African lakes.

Note: these numbers originating from the global database do not reflect yet the larger species richness of the Tonle Sap identified during this study and described in section 1.4.

Last, FishBase was used to identify the number of freshwater, brackish, marine and threatened species for 302 countries or territories worldwide. The table below indicates the rank of Mekong countries for each of these categories.

Table 1: Rank of Lower Mekong countries for 4 different categories of fish species out of 302 countries or territories. Source: FishBase, December 2009.

	Number of / Rank in freshwater species	Number of / Rank in threatened species
Cambodia	488 / 18	NA
Lao PDR	587 / 14	21 / 16
Thailand	837 / 8	61 / 6
Viet Nam	629 / 12	55 / 7

So among countries and territories of the world, Lao PDR, Thailand and Viet Nam are among the top 5% for their number of freshwater fish species and number of threatened fish species.

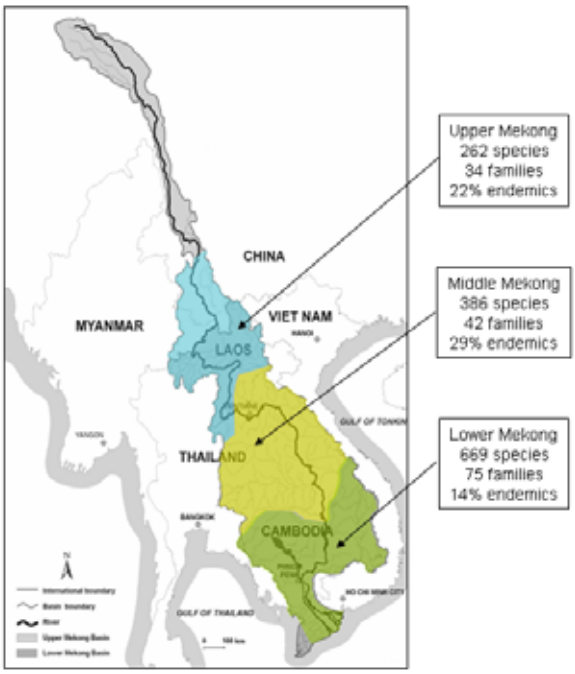
1.2 FRESHWATER FISH DIVERSITY IN THE 3 MAIN MIGRATION ZONES

An analysis of the above database allows characterizing the biodiversity in each of the 3 migration zones identified initially by Poulsen *et al.* in 2002.

Table 2: Biodiversity in the 3 main Mekong migration zones

Migration zones	Location	Species	Families	Endemics	% endemics
Upper Mekong	Mekong China -lower reach	262	34	57	21.8
	Mekong northern Laos				
	Nam Ou				
Middle Mekong	Mun / Chi	386	42	112	29.0
	Nam Kadinh				
	Nam Mang				
	Nam Ngum				
	Songkhram				
	Xe Bang Fai				
	Xe Bang Hiang				
Lower Mekong	Mekong down Khone Falls	669	75	96	14.3
	Mekong Stung Treng - Kratie				
	Sekong				
	Sesan				
	Srepok				
	Tonle Sap				
	Mekong delta				

Figure 3: Biodiversity in the 3 main Mekong migration zones



Conclusions:

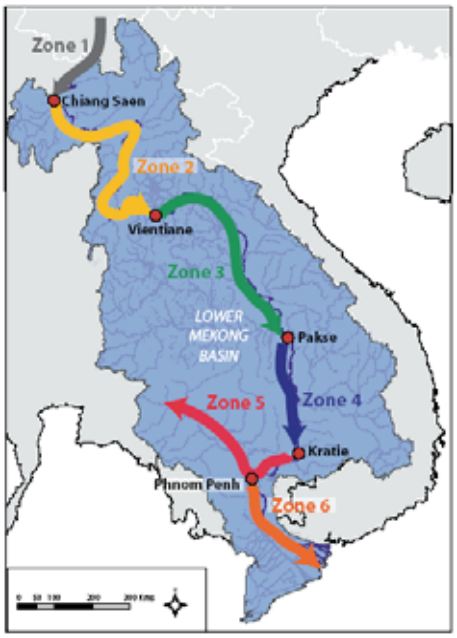
With 669 species, the lower Mekong migration zone is by far the area exhibiting the highest species diversity. This high diversity is largely due to the conjunction of freshwater, estuarine and marine fish faunas, with in particular the incursion of coastal species into the freshwater, up to the Tonle Sap or even higher upstream. Since the coastal species are not Mekong-specific, they are not considered as endemics in the classification, which partly explains why the Lower Mekong migration zone also has the lowest endemicity.

1.3 FRESHWATER FISH DIVERSITY IN THE SIX MAIN ECOLOGICAL REACHES

In the analysis below we follow the ecological zones or "reaches" of the Mekong mainstream defined in MRC 2005 and originating from the Integrated Basin Flow Management project (report nº 7, unpublished). In this classification based on geomorphological descriptors, six main zones are identified:

Zone 1: Upper Mekong River in China to Chiang Saen: headwaters and mountain river
Zone 2: Chiang Saen to Vientiane: upland river in a steep narrow valley
Zone 3: Vientiane to Pakse: midstream section; large river
Zone 4: Pakse to Kratie: zone including large wetlands (in Siphandone, and Stung Treng)
Zone 5: Kratie to Phnom Penh: downstream section; floodplains and the Great Lake
Zone 6: Phnom Penh to the South China Sea: Mekong delta, tidal zone

Figure 4: Ecological zones in the Mekong Basin



The biodiversity analysis detailed in section 1.4 allowed quantifying species diversity for each ecological reach.

Table 3: Number of fish species and families in each ecological zone of the Mekong (mainstream).

	Z1 China	Z2 Chiang Saen - Vientiane	Z3 Vientiane - Pakse	Z4 Pakse-Kratie	Z5 Kratie -PP and TS	Z6 PP-Delta
Number of species	151	140	NA	252	284	486
Endemic species	19	26	NA	40	31	28
Introduced species	7	4	NA	5	4	3
Native species	125	110	NA	207	249	455
Number of families	13	12	NA	36	40	56

Conclusions:

This analysis confirms the previous one and shows that species richness is lower in China and northern Laos (although quite high already, with more than a hundred species), increases downstream and culminates in the delta. Conversely the proportion of endemics is relatively higher upstream and decreases below Khone Falls.

1.4 FRESHWATER FISH DIVERSITY IN MEKONG HYDROLOGICAL SUB-BASINS

For this analysis 45 sources of information were reviewed, including substantial lists of fish species in the Mekong mainstream (China included) and in sub-basins. Sources are listed in the Bibliography section. Overall 860 Mekong fish species belonging to 81 families have been identified. This is much more than previously recorded and documented in FishBase (781 so far), and can be explained by the integration of recent species lists from China and from the delta (these recent publications are not reflected in FishBase yet).

This study resulted in a mapping of species compositions in 20 locations (river basins and mainstream locations), detailed in Table 4 and in Figure 5. .

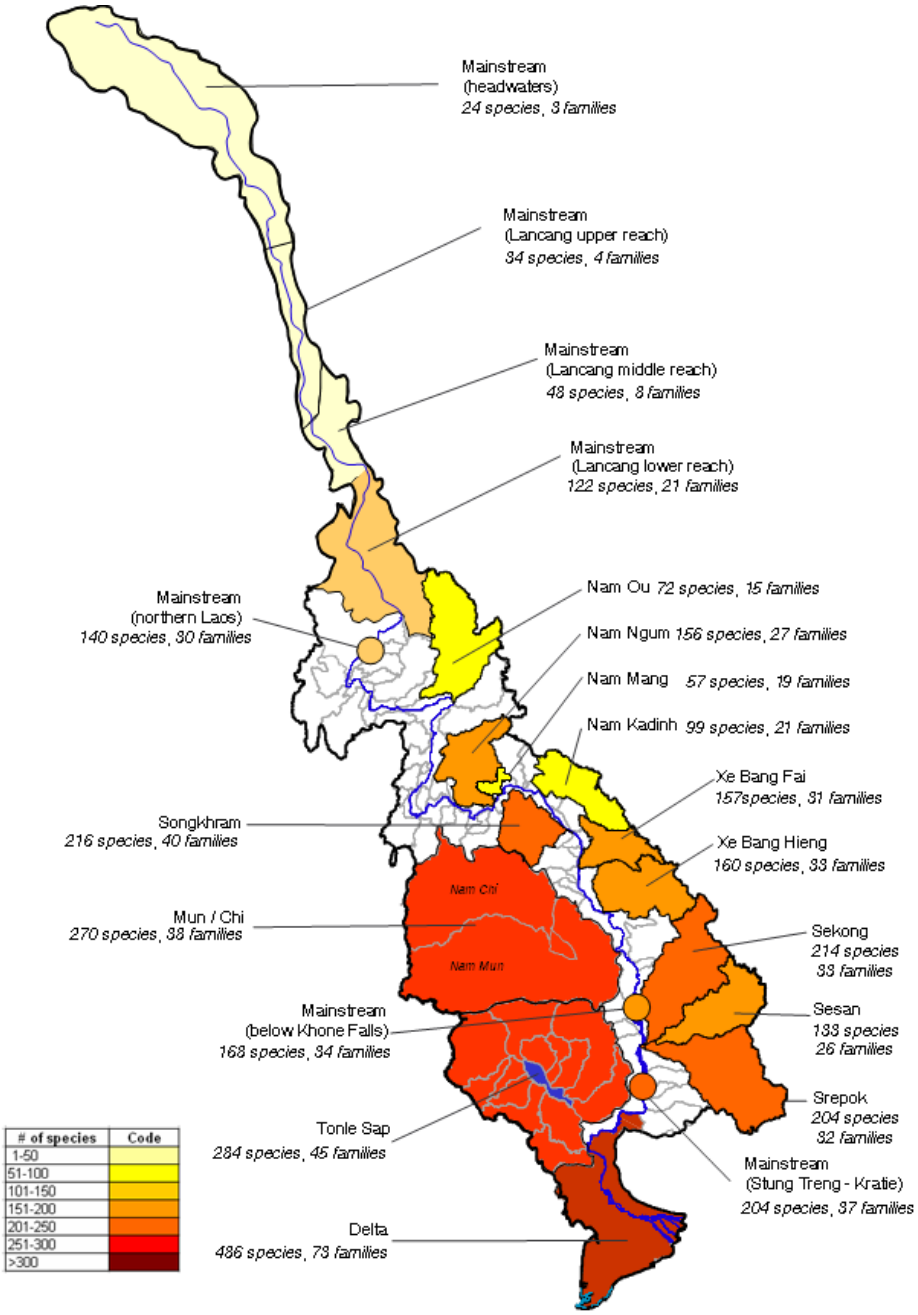
Table 4: species richness in 20 locations of the Mekong Basin

Location	Species	Families	Endemic
Mekong China -headwater	24	3	4
Mekong China -upper reach	34	4	4
Mekong China -middle reach	48	8	7
Mekong China -lower reach	122	21	15
Mekong northern Laos	140	30	26
Nam Ou	72	15	29
Nam Ngum	156	27	43
Nam Mang	57	19	17
Nam Kadinh	99	21	38
Songkhram	216	40	39
Xe Bang Fai	157	31	51
Xe Bang Hiang	160	33	47
Mun / Chi	270	38	49
Mekong down Khone Falls	168	34	25
Mekong Stung Treng - Kratie	204	37	33
Sekong	214	33	63
Sesan	133	26	24
Srepok	204	32	38
Tonle Sap	284	45	31
Mekong Delta	486	73	28

Conclusions:

This analysis shows a strong gradient of species richness from the headwaters down to the sea, with 24 species in Tibet and 486 in the delta. This phenomenon is standard in big rivers and reflects the fact that hydrological predictability and habitat diversity increase downstream, allowing more species to develop. Another unsurprising finding is that in sub-basins the species richness is roughly proportional to the size of the watershed; thus, the Mun/Chi and Tonle Sap basins feature the highest number of species. The delta is the area characterized by the highest species diversity, because of the combination of estuarine, freshwater and marine faunas, the two latter groups making temporary incursions in the estuarine area.

Figure 5: Species richness in 20 locations in the Mekong Basin.



2 STATUS OF MEKONG CAPTURE FISH PRODUCTION

2.1 FISH CATCH IN THE MEKONG COUNTRIES

2.1.1 FRESHWATER FISH CATCH ACCORDING TO NATIONAL DATA

We present in Table 5 FAO fisheries catch statistics since 2000. These statistics represent a compilation of official statistics provided by the riparian countries. 2008 and 2009 data are not available yet.

Table 5: Freshwater capture fisheries statistics for the four LMB countries according to the FAO (tonnes).

	2000	2001	2002	2003	2004	2005	2006	2007
Cambodia	245300	384500	359800	308250	249600	323500	421400	419400
Lao PDR	29250	31000	33440	29800	29800	26560	26925	26925
Thailand	201205	202200	198200	197493	202600	194159	208400	218010
Viet Nam	180000	188542	163615	148959	134075	130400	136200	133600

Source: *http://www.fao.org/fishery/statistics/global-capture-production/en*

In the rest of this review we focus on the 2005-2007 period since these years reflect the latest trends in a sector and an environment evolving rapidly (aquaculture, infrastructure development, market forces, demography, etc).

Table 6: LMB freshwater capture fisheries production according to national statistics (FAO; average of the 2005-2007 statistics; tonnes).

	2005	2006	2007	Average
Cambodia	323500	421400	419400	388100
Lao PDR	26560	26925	26925	26803
Thailand	194159	208400	218010	206856
Viet Nam	130400	136200	133600	133400
Total				755160.

Source: *http://www.fao.org/fishery/statistics/global-capture-production/en*

Note: As of December 2009, FAO/national statistics are not yet available for 2008. According to the Cambodian Minister of Agriculture, Forestry and Fisheries (1st July 2009), Cambodian freshwater fisheries production amounted to 365,000 tones in 2008.

Conclusions:

According to respective national statistics, the inland fisheries sector in the four countries of the Lower produces around 755,000 tonnes each year. By comparison, the total production of inland capture fisheries worldwide amounted to 10.1 million tonnes in 2006 (FAO 2009); thus according to national statistics, the Mekong fisheries produce 7% of the world's freshwater fisheries

2.1.2 FRESHWATER FISH CATCH ACCORDING TO FIELD SURVEYS

FAO statistics are disputed and considered much underestimated since they originate from individual countries and are *not based on field studies* (Coates 2002, Barlow *et al.* 2008)[3]. Coates (2002) in particular, in his review of inland fishery statistics in Southeast Asia, argues that the total reported production from inland waters appears to be under-estimated by a factor of between 2.5 and 3.6. One can also note a discordance within FAO statistics between the inland fish catch figures and inland fish consumption, the latter being more than double the catch (see section 3.2.1). At the moment there are three main alternative sources of science-based statistics: studies based on catch monitoring and assessment projects, on wetland productivity and on fish consumption at the household level. We detail below the figures originating from these sources:

Table 7: Estimates of LMB freshwater capture fisheries production, based on fishery surveys

	Cambodia[1]	Lao PDR[1]	Thailand[1]	Viet Nam[1]	*Total*
Estimated fish yield (tonnes)	682,150	182,700	932,300	844,850	*2,642,000*

Source: Van Zalinge *et al*. 2004;

Table 8: Estimates of LMB freshwater capture fisheries production based on wetland productivity studies.

	Cambodia	Lao PDR	Thailand	Viet Nam	Total
Km^2 of wetland	49,393	10,196	86,734	47,573	193,896
Low fish productivity scenario (50 kg/ha/y)	197,572	20,392	173,468	190,292	581,688
Medium fish productivity scenario (100 kg/ha/y)	395,144	40,784	346,936	380,584	1,163,376
High fish productivity scenario (200 kg/ha/y)	790,288	81,568	693,872	761,168	2,326,752

Source: Hortle 2007. Surface of wetlands calculated by GIS, yield per surface area hypothesized, based on a range of 20 field studies.

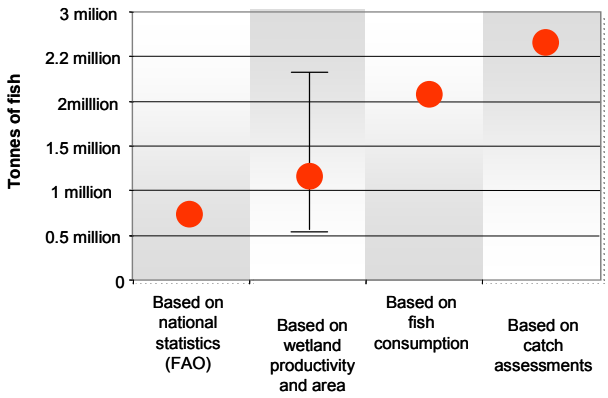
Table 9: Estimates of LMB fish production, based on fish consumption in households

	Cambodia	Lao PDR	Thailand	Viet Nam	Total
Estimated yield (tonnes/year) of inland fish in the LMB, based on consumption studies	481,537	167,922	720,501	692,118	2,062,077

Source: Hortle 2007, based on 20 fish consumption surveys

[3] Furthermore FAO statistics are produced by country, whereas alternative catch assessments focus on the Mekong Basin only. This implies that Mekong catches *sensu stricto* would be even lower according to FAO statistics.

Figure 6: Estimates of Mekong fish production according to national statistics and to scientific assessments



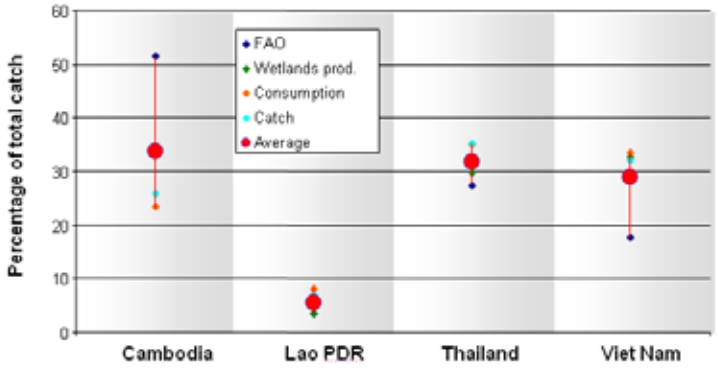
Conclusions:

According to scientific estimates alternative to FAO statistics, the fish production of the Lower Mekong amounts to more than one million tonnes, and up to 2.6 million tonnes. The most reliable assessment, based on a synthesis of 20 household consumption studies, estimates fish production at 2.1 million tonnes of freshwater fish. The coastal fish production dependent on Mekong nutrient outflow is not included in these figures.

Table 10: Share of each country in the total catch, depending on sources of data considered (cf. Tables 6 to 9 above)

	Cambodia	Lao PDR	Thailand	Viet Nam
Range in %	23-51	4-8	27-35	18-34

Figure 7: Share of each country in the total catch, depending on sources of data considered



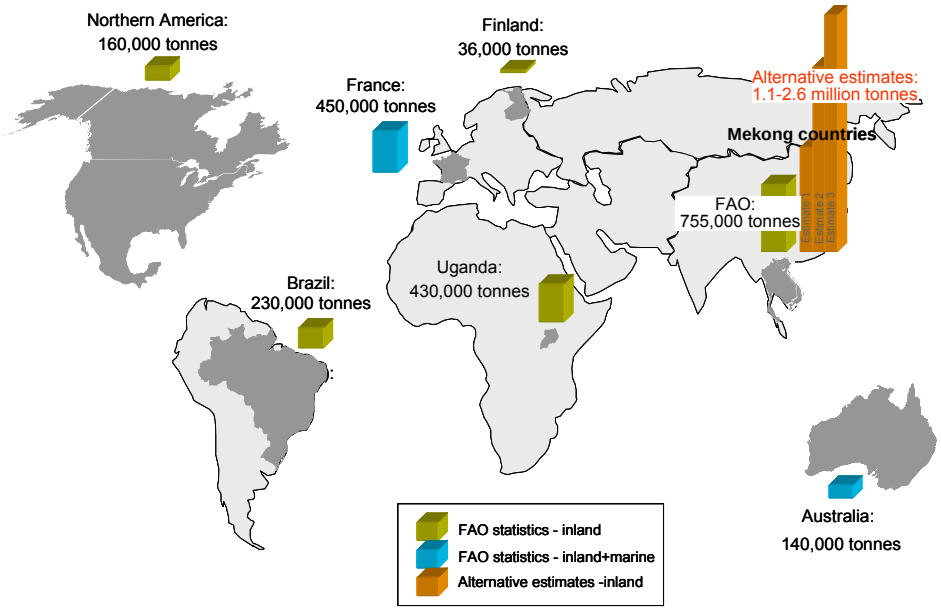
Conclusions:

According to all studies and sources of data, Cambodia, Thailand and Viet Nam produce respectively about one third of the overall Mekong fish catch, and Lao PDR produces around 5%.

2.1.3 FRESHWATER FISH CATCH IN THE MEKONG AND WORLDWIDE

As mentioned above, according to FAO statistics, the inland fisheries sector in the four countries of the Lower produces around 755,000 tonnes each year, but according to alternative field-based estimates, this sector produces up to 2.64 million tonnes of fish a year (the most robust assessment being 2.1 million tonnes). Thus, depending on the source of information considered, Mekong fisheries produce between 6 and 22% of the world's freshwater capture fish[4], the most likely estimate being 18% [5].

Figure 8: Comparison of fish production in the Mekong and in other countries worldwide.



Source: FAO statistics: 2005-2007 average. Brazil, Uganda and Finland are the countries with the biggest inland fisheries in South America, Africa and Western Europe respectively. Alternative estimates for the Mekong correspond to the 3 main assessment approaches (wetland productivity, fish consumption and catch estimates).

[4] Minimum: estimate based on low wetland productivity: 0.58/(10.1-0.755+0.58) in million tonnes = 5.8%
Maximum: estimate based on fish catches: 2.64 / [10.1 + (2.64 – 0.755)] in million tonnes = 22%

[5] Most likely estimate based on fish consumption: 2.1 / [10.1 + (2.1 – 0.755)] in million tonnes = 18%

2.2 MEKONG FISH CATCH AND POPULATION

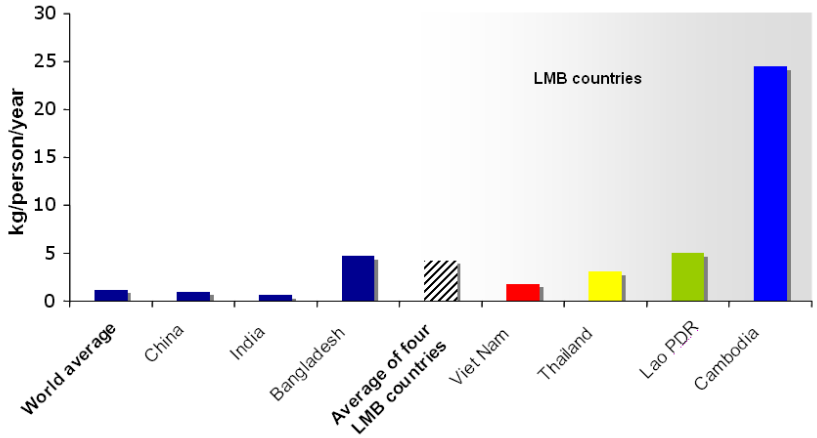
Fish catch figures are compared with population statistics in Table 11.

Table 11: Freshwater capture fisheries and population

	Average freshwater fish catch 2000-2007 in tonnes	2005 population	catch (kg) per person/y
World	7556635	6512276000	1.1604
China	1309551	1312253000	0.998
India	703099	1130618000	0.622
Bangladesh	714662	153122000	4.667
4 LMB Countries	722889	169766000	4.258
Viet Nam	151924	84074000	1.807
Thailand	202783	65946000	3.075
Lao PDR	29213	5880000	4.968
Cambodia	338969	13866000	24.446

Source: Fish catches from FAO, population data from UN World Population Prospects, 2005. (*http://esa.un.org/unpp/index.asp*)

Figure 9: Freshwater fish catch per person and per year (average 2000-2007). LMB countries are compared to the 3 countries having the biggest inland fish production worldwide. Source: FAO data.



Conclusions:

According to FAO data, freshwater fish catch per inhabitant of Cambodia, Lao PDR, Thailand and Vietnam is nearly four times the world average. Cambodia's freshwater fish catch amounts to nearly 25 kg/person/year; this is by far the highest in the world in terms of catch per inhabitant.

Actually above population statistics correspond to the whole population of each country, and a pro-rata calculation needs to be made to assess the proportion of each country's inhabitants found within the

boundaries of the Mekong Basin. The latter is calculated following MRC (2003). There is also a wide range in estimates of fish catches, the lower one originating from the production estimate of low productivity wetlands, and the upper one from catch assessment studies (see section 2.1.2). We integrate below these figures and compare the fish catch per inhabitant of the Lower Mekong Basin with the world average.

Table 12: Fish catch per LMB inhabitant, compared to the world average. Sources:

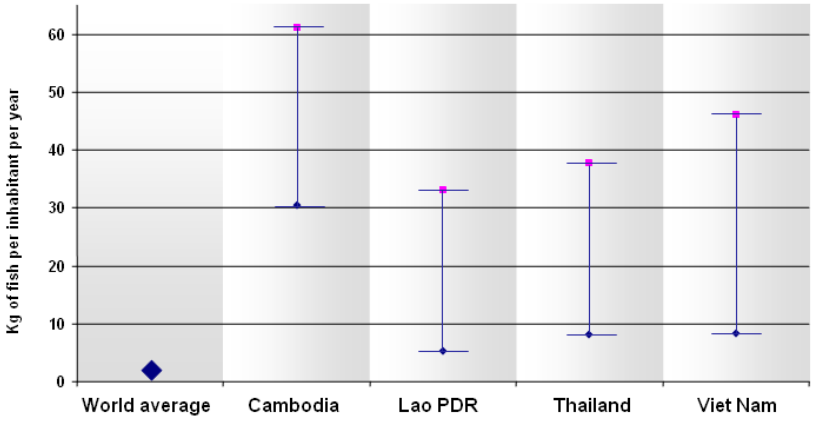
	Freshwater fish catch (FAO, tonnes)	Freshwater fish catch (MRC; catch)	Country population in 2005	% of LMB population in the country	LMB population in 2005	Catch per LMB inhabitant (FAO, kg)	Catch per LMB inhabitant (MRC, kg)
World	7556635		6512276000			1.2	
Cambodia	338969	682,150	13866000	80.4	11148264	30.4	61.2
Lao PDR	29213	182,700	5880000	93.9	5521320	5.3	33.1
Thailand	202783	932,300	65946000	37.5	24729750	8.2	37.7
Viet Nam	151924	844,850	84074000	21.8	18328132	8.3	46.1

[1] http://www.fao.org/fishery/statistics/global-capture-production/en

[2] http://esa.un.org/unpp/index.asp

[3] MRC 2003a

Figure 10: Range of estimates of catch per inhabitant of the LMB, compared to the world average



Conclusions:

Within the Lower Mekong Basin, in Lao PDR, Thailand and Viet Nam each person produces between 5 and 29 times more freshwater fish than the world average. Cambodia stands out as being the country in the world with the highest fishing intensity: each Cambodian in the LMB harvests 26 to 53 times more freshwater fish than the world average.

2.3 MEKONG FISH CATCH AND FOOD SECURITY

2.3.1 FISH CONSUMPTION IN THE MEKONG ACCORDING TO FAO DATA

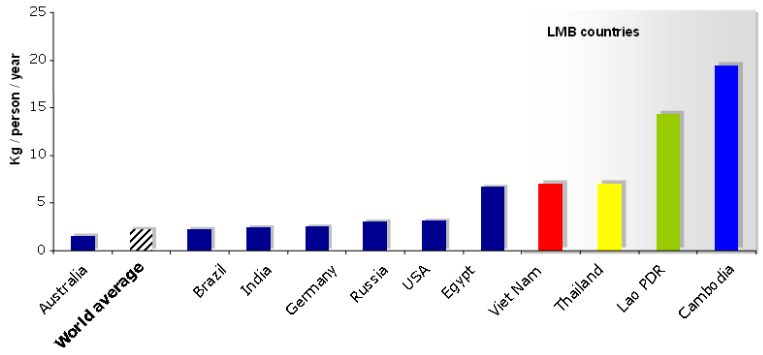
This first analysis is a comparison of freshwater fish consumption in the Lower Mekong Basin based exclusively on FAO data. Data for the countries of the LMB are compared to those of countries having the greatest freshwater fish consumption in their continent or geographic zone.

Table 13: Fish consumption per person in the LMB countries and worldwide.

	2000	2001	2002	2003	2004	2005	Average
Australia	1.51	1.6	1.55	1.66	1.83	1.86	1.57
Brazil	2.26	2.44	2.57	2.42	2.66	2.64	2.28
World average	*2.17*	*2.24*	*2.23*	*2.25*	*2.35*	*2.44*	*2.28*
Germany	2.16	2.65	2.49	2.79	2.85	3.47	2.49
Egypt	6.91	7.39	7.44	8.21	8.03	7.89	6.70
India	2.61	2.79	2.55	2.59	2.8	2.86	2.46
Russian Federation	3.28	3.1	3.19	3.65	3.11	3.72	3.01
United States of America	2.77	3.19	3.33	3.65	3.8	4.05	3.11
Cambodia	17.75	28.78	25.3	21.69	18.09	23.39	19.43
4 LMB countries	*11.51*	*14.73*	*14.45*	*14.00*	*13.11*	*14.98*	*13.80*
Lao PDR	13.65	15.24	17.25	17.26	16.99	19.03	14.35
Thailand	7.76	7.77	7.84	8.4	8.49	8.15	7.06
Viet Nam	6.89	7.11	7.42	8.64	8.86	9.33	7.04

Sources:[1] FAO; http://faostat.fao.org/site/610/default.aspx, Updated on 18 December 2009
[2] UN; http://esa.un.org/unpp/index.asp.

Figure 11: Freshwater fish consumption per person and per year worldwide and in the LMB countries



Source: FAO data

Note: in the above figure, the origin of freshwater fish consumed (either from capture fisheries or from aquaculture) is not specified. This figure reflects an update in FAO data on 18 December 2009.

Conclusions:

According to the FAO, in the four countries of the LMB:

• the average consumption of freshwater fish per person amounts to 13.8 kg/person/year; by comparison, the global average is only 2.3 kg/person/year, so freshwater fish consumption in the LMB is six times higher than the world average. In Cambodia, the consumption of freshwater fish amounts to 19.4 kg/person/year, i.e. more than 8 times the world average and higher than anywhere else in the world[6]. It should be noted that above statistics integrate aquaculture fish, but in the Mekong Basin fish locally consumed originates largely from capture fisheries.

• According to FAO consumption figures, people in the LMB countries eat 1.55 million tonnes of freshwater fish per year. Given the absence of massive import of freshwater fish towards the LMB countries, this figure is incompatible with FAO freshwater fish catch statistics in the LMB (0.72 million tonnes per year, see section 2.1.)

• However, like for capture statistics, these FAO statistics reflect official estimates and are considered largely underestimated. Thus Hortle (2009) found that official estimates of fish consumption in Mekong provinces of the four countries of the region represented between 86% and 8% only of survey-based estimates.

2.3.2 FISH CONSUMPTION IN THE MEKONG ACCORDING TO FIELD SURVEYS

FAO statistics are available by country only; however, a number of studies have been undertaken more specifically within the Lower Mekong Basin. The most recent and comprehensive overview of fish consumption in the Lower Mekong basin is that of Hortle (2007); it is based on a thorough review and synthesis of 20 fish consumption studies basinwide in 19,139 households.

Conclusions:

Despite differences with FAO figures (by a factor 1.4 to 5.3), twenty food consumption studies undertaken in the LMB lead to the same conclusion as FAO data: the four countries of the Lower Mekong Basin feature the highest consumption of freshwater fish in the world. According to the above studies, this consumption corresponds to around 80 grams of fresh fish per person, each day of the year.

We present in Figure 13 a comparison of freshwater fish catch and freshwater fish consumption per person and per year in the LMB. Catch estimates obtained by different methods (sections 1.1.1. and 1.1.2) have been related to population within the Mekong Basin in each country (see Table 12) and to consumption figures according to the FAO and to Hortle 2007 (section 1.2.1).

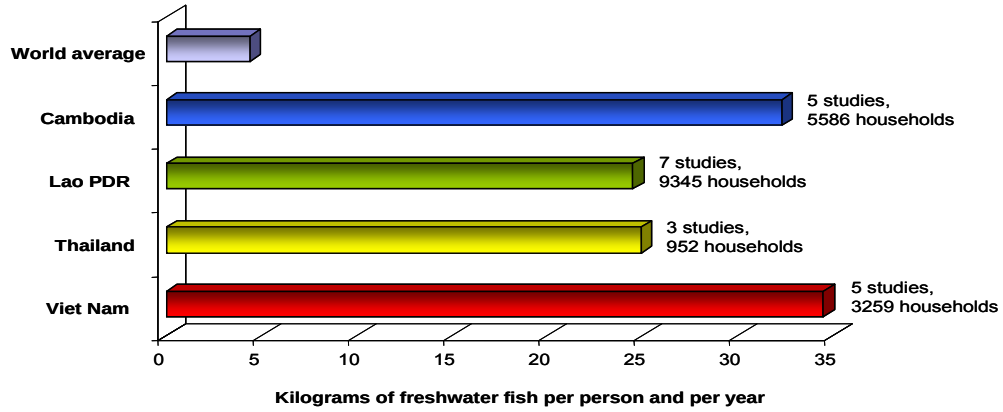
[6] These statistics are focussed on freshwater fish; when marine fishes are also included, then the top-three countries in the world are Japan, Iceland and Portugal (Hortle 2007)

Table 14: Estimated per capita consumption of inland fish (in kg/year) in the LMB, based on consumption studies

	Cambodia	Lao PDR	Thailand	Viet Nam
Inland fish (kg/person/year)	32.3	24.5	24.9	34.5

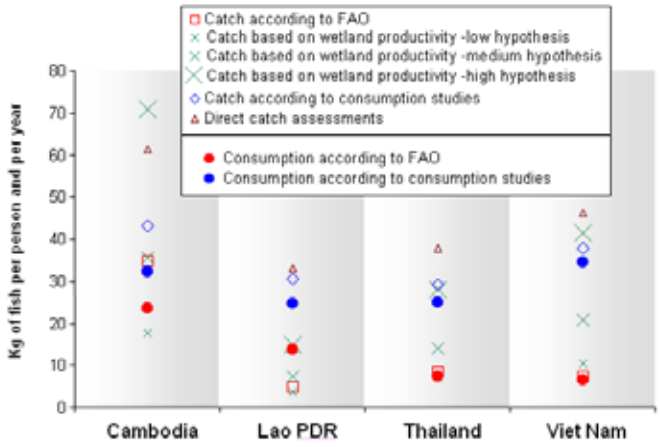
Source: Hortle 2007

Figure 12: Consumption of freshwater fish per inhabitant and per year.



Source: Hortle 2007.

Figure 13: Comparison of fish catch and fish consumption in the LMB according to different sources



This graph shows that:

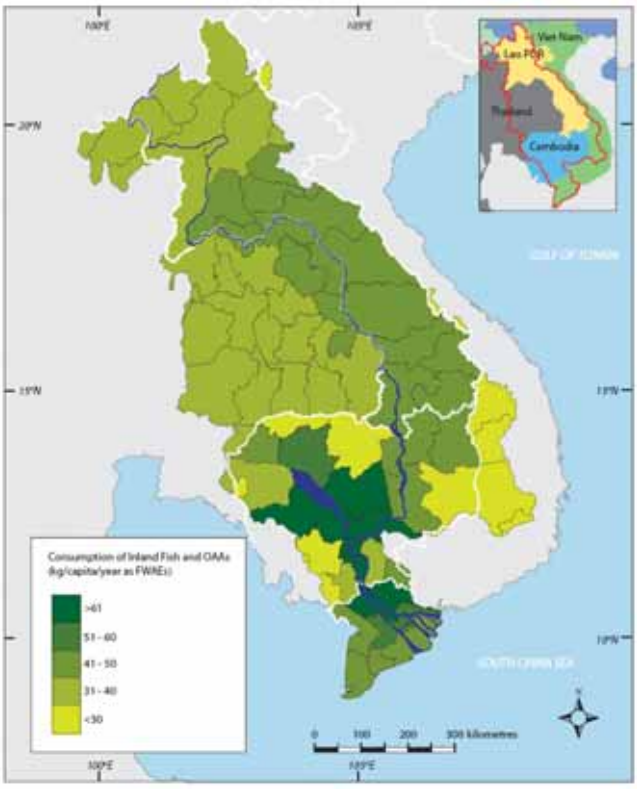
- in Cambodia, the fish catch estimate based on low wetland productivity (i.e. the most conservative estimate) is not compatible with any of the fish consumption figures;

- similarly, in Lao PDR the two fish catch estimates based on low and medium wetland productivity assumptions are not compatible with any of the fish consumption estimates;
- more generally, the fish catch estimates based on low and medium wetland productivity assumptions are not compatible, for most countries, with the results of extensive consumption studies detailed in Hortle 2007;
- in Lao PDR, the FAO estimate of fish catch per person is inferior to FAO estimates of fish consumption per person.

The estimate of fish consumption based on 20 studies in more than 19,000 households is robust, leading to the conclusion that fish catch estimates based on low and medium wetland productivity assumptions are too conservative. FAO freshwater fish catch statistics for LMB countries, being in the same range as the above estimates, are also too low; this is confirmed by the fact that they are largely inferior to the FAO's own consumption statistics for the same countries (see section 1.2.1.1).

Hortle (2007) provides a map of fish consumption by province, based on the above results. This map is a reflection of the importance of fish to the population's food security in the different areas of the Mekong Basin.

Figure 14: Consumption of inland fish and other aquatic animals per person and per year in Mekong provinces.



Source: Hortle 2007.

2.3.2.1 CONTRIBUTION OF FISH TO PROTEIN SUPPLY IN THE LOWER MEKONG BASIN

In the Mekong the bulk of the protein (76%) is derived from rice, but rice is nutritionally incomplete and particularly poor in lysine, an essential amino-acid. With 97.6 mg of lysine per gram of protein, fish provides a nutrient essential to growth, which is lacking in a rice-based diet (Guttman and Funge-Smith 2000).

Several studies have highlighted the high contribution of fish to protein supply in some Mekong countries or in particular locations: between 30% and 50% of total protein consumption in Lao PDR (STEA 2003), 65% to 75% of the animal protein requirements of households in Cambodia (Ahmed *et al*. 1998), etc. However most estimates are patchy and relate to specific locations. For this reason we focused below on the contribution of freshwater fish to the food balance of people in LMB countries, as detailed in FAO data that allow comparing Mekong countries together and with the rest of the world.

The food balance is based on "all animal proteins", i.e. the sum of freshwater fish + bovine meat + pig meat + poultry meat + other animal products (including dairy, eggs, goat and mutton meat, etc.) + marine fish and seafood.

Table 15: Average consumption of animal protein by source of protein, in grams/person/day (average 2000-2003).

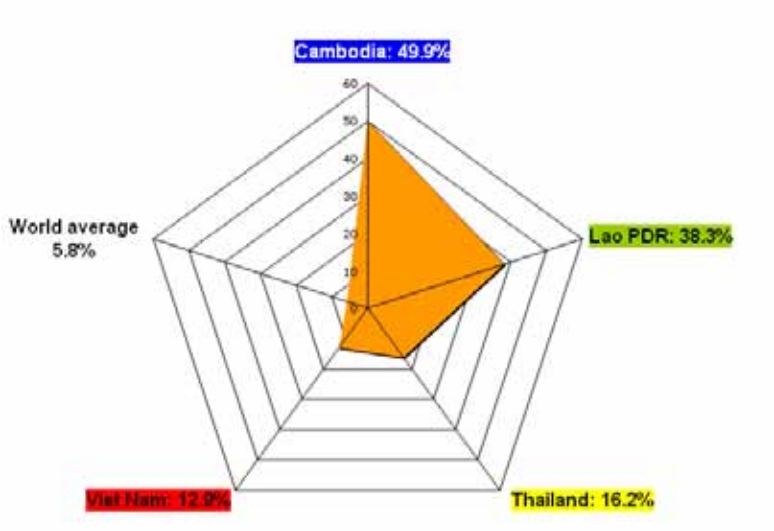
	Cambodia	Lao PDR	Thailand	Viet Nam	World
Freshwater fish	7.21	4.25	2.35	2.09	1.39
Marine fish, seafood	0.70	0.22	7.58	2.73	3.03
Bovine meat	1.93	2.28	1.43	0.85	3.63
Pig meat	2.47	1.76	2.80	5.90	4.40
Poultry meat	0.60	0.82	4.57	1.62	4.01
Other animal products	1.56	1.77	5.69	3.01	12.07
Total	*14.45*	*11.09*	*14.49*	*16.20*	*24.11*
% of freshwater fish protein in total	*49.87*	*38.31*	*16.19*	*12.87*	*5.78*

Source: FAO food balance sheets (*http://faostat.fao.org/site/368/default.aspx).* No data newer than 2003.

Conclusions:

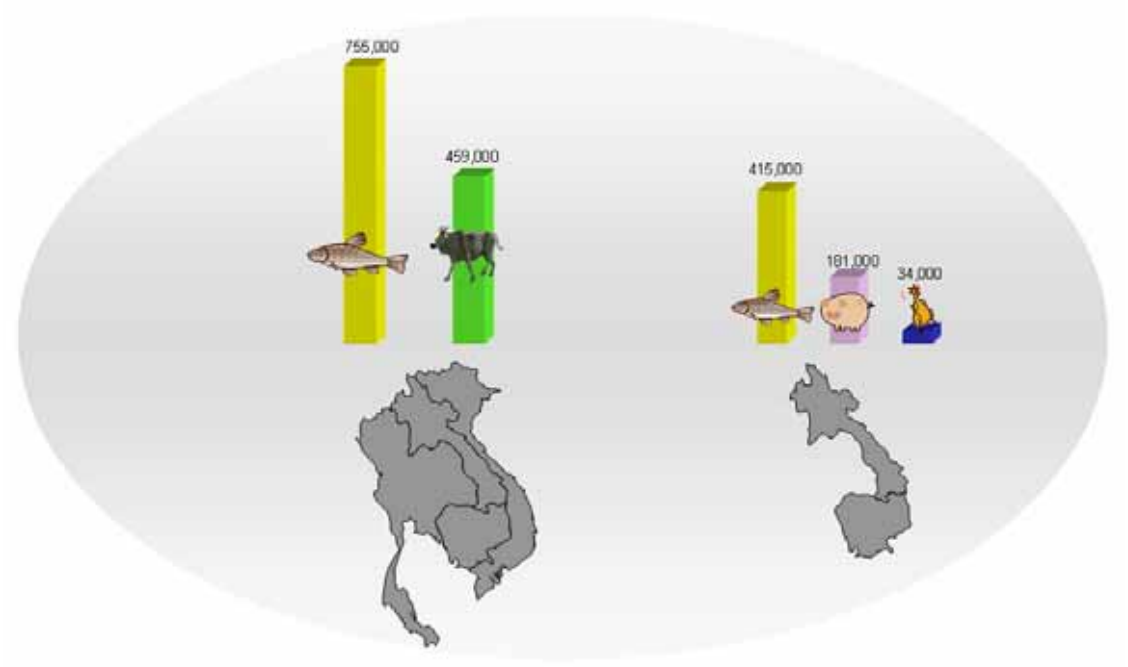
In the Lower Mekong Basin, fish is a very important part of the protein supply; the share of protein coming from freshwater fish in the diet represents between 2.2 and 8.6 times the world average.

Figure 15: Importance of freshwater fish as source of protein in the diet of people in the LMB and worldwide



When statistics are focused on some sources of protein or countries, some interesting patterns appear:

Figure 16: Importance of fish compared to other sources of protein in some selected cases.



Source: FAO statistics

Conclusions:

Food production varies depending on countries and is proportional to the population size; there are alternatives to fish in three of the Lower Mekong countries (either chicken or pork), but not in Cambodia where fish is by far the dominant source of protein. Freshwater fish is a commodity whose scale of production is often overlooked: in the whole LMB there is much more freshwater fish harvested than cattle produced, and in Cambodia and Lao PDR, fish production amounts to twice the combined production of pig and chicken.

2.4 CAPTURE FISHERIES IN THE SIX MAIN ECOLOGICAL REACHES

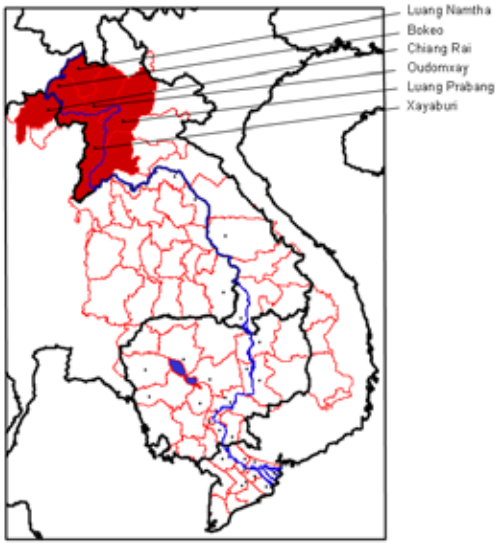
Since the ecological reaches describe the Mekong mainstream, we detail below fish catch, fish consumption and to some extent socioeconomic activities in the provinces bordering the Mekong River, from China down to the sea.

2.4.1 ZONE 1: UPPER MEKONG RIVER IN CHINA TO CHIANG SAEN

The upper Mekong Basin in China produces around 25,000 tonnes a year (Xie and Li 2003). This low production, confirmed by Heinonen and Vainio-Mattila (1999), is explained by the fact that the river flows in deep gorges, with a subsequent low productivity (no floodplains) and that population density along banks is very low. Given the relief of the area, most of the fish catch is expected in the area downstream of Xishuangbanna or in the Simaogangzhen area. No detailed statistics about fish consumption and socioeconomics could be found for this zone; however, Xie and Li (2003) indicate that the capture fisheries in this zone employ about 15,000 persons.

2.4.2 ZONE 2: CHIANG SAEN TO VIENTIANE

This zone corresponds to Luang Namtha, Bokeo, Oudomxay, Luangprabang and Sayabouri provinces in Lao PRD and Chiang Rai in Thailand.



According to discussions with district leaders in these provinces, fishing is not considered as a significant livelihood option for local people because it is not done on a large scale. People on the Mekong river banks do fish for household consumption, but this goes unrecorded in district or provincial level statistics and not reflected in social development plans. The table below gives some very low yet official statistics about the yield in some districts of that zone, and about the ratio between the mainstream and some tributaries.

Table 16: Capture fish production in some districts along the Mekong in zone 2.

District Name	Mekong (tonnes/year)	Tributary (tonnes/yea)	Total (tonnes/yea)	Tributary Name
Paktha (Bokeo)	3.6	1.2	4.8	Nam Tha River
Pakbeng (Oudomxay)	1.8	1.5	3.3	Nam Beng River
Nan (Luang Prabang)	9	1.2	10.2	Nan River
Sayaboury	1.8	1.8	3.6	Houng River,
Paklay (Sayabouri)	3.6	1.2	4.8	Lay River, Phoun, Nham, and Nhang

Sources: Bokeo provincial economic and social development plans of 2008-2009; Oudomxay provincial economic and social development plans of 2009-2010; Luangprabang provincial economic and social development plans of 2008-2010; Sayaboury provincial economic and social development plans 2008-2009.

In contrast with the above estimates, the study of fish consumption and catch in Luang Prabang province done by the MRC in 1999 (Sjorslev 2000) and based on actual field work, systematic sampling and seasonal records concludes that the total catch of fish and aquatic animals for Luangprabang Province is within a range of 10,000 to 14,000 tons per year. The authors note that this range is considerably higher than existing government estimates, the latter referring only to the "commercial" catch and not being collected in any systematic way.

A more detailed estimate using fish consumption estimates in the table below, and multiplying these by the population of each province[7], lead to an estimate of 29,000 tonnes consumed, plus the catch sold or exchanged. Lorenzen (2003) and Garaway (2005) amount to 70% the share consumed, to 20% the share sold, and to 10% the share given as gift or payment in kind. This leads to a final estimate of 41,000 tonnes of fish harvested in this zone.

This estimate is roughly in line with the alternative estimate (60,000 tonnes) resulting from a different calculation detailed in Barlow *et al.* (2008). It can be concluded that the capture fish production in zone 2 ranges between 40,000 and 60,000 tonnes,

Fish consumption is detailed in a few studies summarised in Hortle (2007):

[7] Population figures for each province are from the Population & Housing Census 2005. Luang Namtha: pop. = 134900, 18.6 kg of fish consumed/person/year (average of Oudomxay, Sayaboury and Luangprabang), total annual fish consumption = 2509 tonnes; Oudomxay: pop. = 276960, 16 kg of fish consumed/person/year, total annual fish consumption = 4431 tonnes; Bokeo: pop. = 156173, 18.6 kg of fish consumed/person/year (average of Oudomxay, Sayaboury and Luangprabang), total annual fish consumption = 2905 tonnes; Chiang Rai: pop. = 62,000, 18.6 kg of fish consumed/person/year (like Bokeo on the other side of the river), total annual fish consumption = 2905 tonnes; Luangprabang, pop. = 425246, 27.5 kg of fish consumed/person/year, total annual fish consumption =11694 tonnes; Xayaboury: pop. = 360195, 12.8 kg of fish consumed/person/year, total annual fish consumption =4610 tonnes. Total for the 6 provinces: 29,000 tonnes of fish consumed.

Table 17: Fish consumption in some provinces along the Mekong in zone 2.

Province	Total inland fish consumption (kg/person/year)	Source
Oudomxay	16.0 (60% fresh, 40% preserved)	Hortle 2007 based on FAO-PADP 1998
Sayaboury	12.8 (50% fresh, 50% preserved)	Hortle 2007 based on FAO-PADP 1998
Luang Prabang	27.5 (40% fresh, 60% preserved)	Hortle 2007 based on Sjorslev 2000

Fishing in the Mekong occurs year round as well as in tributaries, but in the latter fishing becomes more intensive during the flood season and during transition periods. Main fishing gears include gillnet, cast-net and traps in tributaries.

Available official data indicate that fishing plays a minor role in the employment of the provinces of zone 2 (see table below). This reflects the fact that very few people are full-time professional fishers, which is common in the region where fishing is a part time activity and a part of a diversified livelihood portfolio.

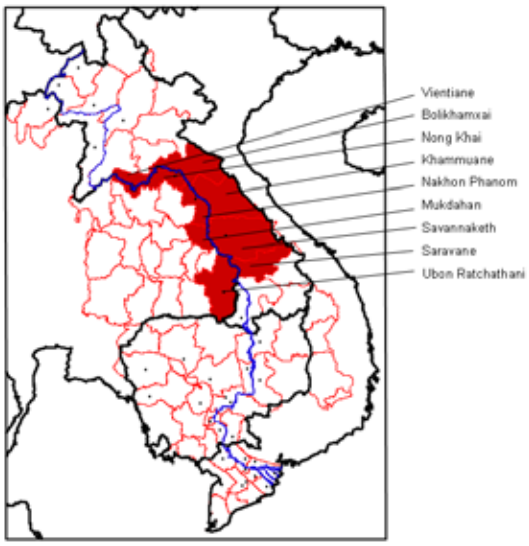
Table 18: Percentage of people involved in river fishing as a main sources of employment.

Province	River fishing
Bokeo	3%
Oudomxay	4.47%
Luangprabang	0.50%
Sayaboury	0.20%

Source: Questionnaires to district officials, December 2009 field survey.

2.4.3 ZONE 3: VIENTIANE TO PAKSE

This zone corresponds to Vientiane, Bolikhamxai, Khammuane, Savannaketh and Saravane provinces in Lao PRD and Nong Khai, Nakhon Phanom, Mukdahan and Ubon Ratchathani provinces in Thailand (Amnat Charoen province was not included because of its limited connection with the Mekong River).



On the Lao side of this bank, capture fish production and consumption in this zone is poorly known, and we could not find statistics for this specific mainstream zone. The most detailed source of information on fisheries in this zone actually originates from the Lower Songkhram Basin (e.g. Khumsri et al. 2006, Tai Baan Research Network Songkhram River Basin 2006, Hortle and Suntornratana 2008) and from the lower Mun River area (e.g. Roberts 1993, Amornsakchai et al. 2000), but these sub-basins are not retailed in this review focussing on the mainstream.

In zone 3 along the mainstream, information is available about fish consumption, thanks to studies by Garaway in Laos (1999, 2005). According to these studies, fish consumption in Savannaketh province

amounts to 17.5 kg of fish per person per year (Garaway 1999) or 19.5 kg of fish per person per year (48% fresh fish, 52% preserved fish; details in Hortle 2007). Bush (2003) complements this information by showing that fish and other aquatic animals are present in 85% of all meals.

On the Thai side of this reach (corresponding mostly to Nong Khai and Nakhon Phanom provinces) consumption of inland fish was amounted two decades ago to 25.3 kg/person/year (Prapertchob et al. 1989). More recently, Suntornratana (2002) amounted fish consumption in the Lower Songkhram Basin (a tributary reaching the mainstream in Nakhon Phanom Province) to 42 kg/person/year (47% fresh and 53% preserved).

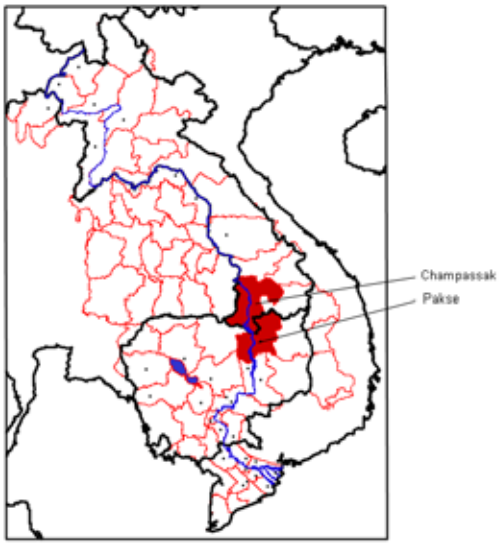
When these figures are related to the population in these provinces[8], this corresponds to a catch of around 116,000 tonnes in zone 3.

In economic terms, inland fisheries in Thailand's Northeast are officially valued at 3,643 million bath (National Economic and Social Development Board, 2007), i.e. 0.4 percent of the wealth of the region. This very low value is contradicted by the very high fish consumption rate in this region and by the important role of fishing in livelihoods and household income, as demonstrated by Hortle and Suntornratana 2008 for the Lower Songkhram Basin[9]. In that sense, fish catch in that zone should be seen as a contribution to livelihoods and to food supply rather than as a formal economic driver. An alternative value of capture fish in Northern Thailand is 23,850 million bath, i.e. about USD 700 million (Na Mahasarakarm 2007).

[8] Vientiane: no detailed figures could be found for this province, where the relationship between fish consumption and catch is blurred by fish imports in the capital city and fish production in the Nam Ngum reservoir; Vientiane is not included in our calculation for that zone. Population figures for each province were obtained from Wikipedia (*http://en.wikipedia.org*). Bolikhamxai: pop. = 215000, 19.5 kg of fish consumed/person/year (Hortle 2007 in Savannaketh), total annual fish consumption = 4200 tonnes; Khammuane: pop. = 359000, 19.5 kg of fish consumed/person/year (Hortle 2007 in Savannaketh), total annual fish consumption = 7000 tonnes; Savannaketh: pop. = 721000, 19.5 kg of fish consumed/person/year (Hortle 2007), total annual fish consumption = 14000 tonnes; Saravane: pop. = 337000, 19.5 kg of fish consumed/person/year (Hortle 2007 n Savannaketh), total annual fish consumption = 6500 tonnes; Nong Khai: pop. = 884000, 19.5 kg of fish consumed/person/year like in Bolikhamxai on the other site of the river), total annual fish consumption = 17000 tonnes; Nakhon Phanom: pop. = 684000, 42 kg of fish consumed/person/year (Suntornratana 2002), total annual fish consumption = 29000 tonnes; Mukdahan: pop. = 311000, 19.5 kg of fish consumed/person/year (like Savannaketh on the other side of the river), total annual fish consumption = 6000 tonnes; Ubon Ratchathani: pop. = 1691000, 19.5 kg of fish consumed/person/year (like Savannaketh), total annual fish consumption = 33000 tonnes. Total for the 8 provinces: 116,000 tonnes of fish consumed.

[9] It can also be argued that if the value of inland fish was extremely low, the loss of fishery resources in the Mun River Basin following dam construction would not have triggered social protests during more than a decade and ultimately the seasonal opening of that dam.

2.4.4 ZONE 4: PAKSE TO KRATIE



This zone corresponds to Champassak Province in Lao PDR and Stung Treng province in Cambodia. Statistics from Kratie Province has been classified under Zone 5 (Kratie to Phnom Penh) since there is an ecological similarity between Champassak and Stung Treng (islands, wetlands) that is not much reflected in Kratie Province.

There is much more information available for this zone than for the previous one; this zone 4 includes extensive wetland areas in Siphandone, Khone Falls and around Stung Treng; fishing is intensive in these wetlands and in the mainstream, and migrations are a striking feature in this area, as detailed in more than 30 scientific papers (details in Baran *et al.* 2005). Four publications in particular detail the remarkable importance of aquatic biodiversity and fisheries in that zone:

- Traditional fisheries and fish ecology on the Mekong River at Khone waterfalls in Southern Laos (Roberts and Baird 1995)
- Aquatic biodiversity in the Siphandone wetlands (Baird 2001)
- Fisheries bioecology at the Khone Falls (Baran *et al.* 2005).
- Biological surveys of the Mekong River between Kratie and Stung Treng (Bezuijenet al. 2008).

An example of frequent and complex fish migrations fluxes in this zone is given in Figure 27.

In Champassak province, official statistics mention a river fish production of 8,000 tonnes and a sale of fish amounting to 8,900 tonnes (Champassack provincial economic and social development plans, 2009-2010). However, when consumption figures per capita detailed below are multiplied by the population in Champassak Province[10], they give a catch of at least 22,600 tonnes per year, plus the catch sold or exchanged. Assuming that 70% is consumed locally (Baird 1998, confirming Lorenzen 2003 and Garaway 2005) this gives an alternative estimate of 32,000 tonnes of fish harvested in the Lao part of this zone (left bank and Siphandon islands). It should be noted that in Khong district alone, Baird (1998) estimated the catch at 4,000 tonnes a year, and in 2001 in this district fish trade towards Thailand and Pakse was estimated at 435 tonnes/year (Aloun Phonvisay and Bush 2001), for a value of USD 440,000.

Province and district officials reckon that fishing is one of the main occupations for farmers in all Mekong districts, and they estimate that fisherfolks represent 1.3% of the population in Pakse, and 30% in Khong district (December 2009 field survey).

[10] Population of 607370 (Population & Housing Census 2005", National Statistics Centre) x 37.2 kg/person/year (Singhanouvong and Phouthavongs 2003) = 22,594 tonnes of fish consumed

Fish consumption in Champassak province was estimated at 37.2 kg/person/year, made of 69% of fresh fish and 31% of preserved fish (Singhanouvong and Phouthavongs 2003, details in Hortle 2007). Actually fish consumption varied from 28.9 kg/person/year in the highlands of the province to 57 kg/person/year in Khong Island. A district-level study done in Khong Island (Baird *et al.* 1998) gave an alternative figure of 43 kg of fish consumed per person and per year. All these figures are exceptionally high since the average freshwater fish consumption worldwide is 4.4 kg/person/year.

In Cambodia, there is limited knowledge on fisheries in Stung Treng Province, the most recent and detailed information coming from Allen *et al.* (2008) and Bezuijen *et al.* (2008), complemented by Israel et al. (2005), Try Thuon (2003), Srun Lim Song (2002) and Chea Vannaren (1999). Ecologically, the area around Stung Treng is characterized by the presence of deep pools which are critical dry-season habitats for many migratory fish species. Deep pools can be 10-60 m deep and 100-300 m long (Hill 1995); 19 deep pools have been identified in Stung Treng Province and 39 in Kratie Province (Poulsen *et al.* 2002a).

According to national statistics, Stung Treng produces around 8,000 tonnes of fish (table below). In absence of alternatives, these statistics are considered reliable enough since Cambodia is the only country of the region integrating family and rice field fisheries that remain unrecorded in Lao statistics. When this production is added to that of Zone 4 above the Cambodian border (i.e. 32,000 tonnes), this leads to a total estimate of 40,000 tonnes of fish harvested in Zone 4[11].

Table 19: Catch statistics in Stung Treng Province.

	2006				2007				2008			
	Lots	Family	Rice field	*Total*	Lots	Family	Rice field	*Total*	Lots	Family	Rice field	*Total*
Stung Treng	2000	5000	2000	*9000*	2000	3500	2100	*7600*	1500	3100	2300	*6900*

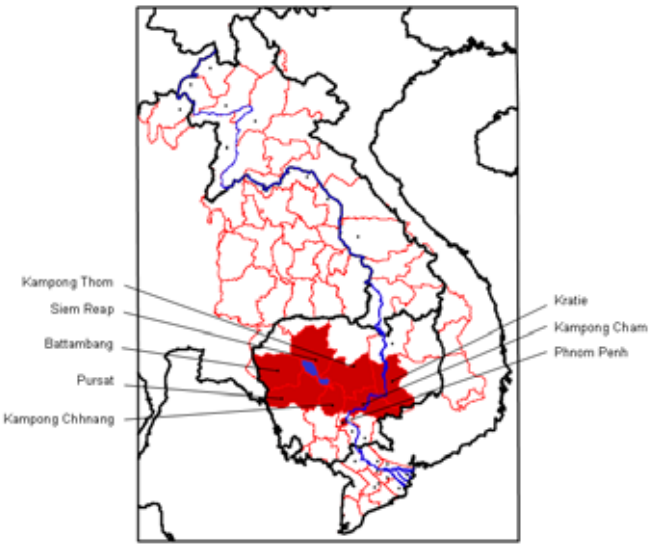
Source: FiA 2008, 2009

This table shows that professional fisheries actually produce less than a quarter of the catch, three quarters being due to activities (family- and rice-field fishing) that does not qualify as “professional”. In Stung Treng, this is confirmed by the fact that in province statistics, only 1% of families are recorded as having fishing as a primary occupation. Allen *et al.* (2008) showed that individual households by the river would catch in average between 0.6 and 1.5 tonnes of fish a year, depending on the location, with peaks in December-January and April-May.

[11] An estimate based exclusively on fish consumption like in the upstream provinces is not possible since there are no consumption studies in Stung Treng; in the consumption map basinwide (Figure 14) Hortle (2007) uses for Stung Treng the figure of Svay Rieng, underlining that this is a conservative estimate. This disputable similarity would lead, given the population of the province, to an estimated catch of 3800 tonnes.

2.4.5 ZONE 5: KRATIE TO PHNOM PENH

This zone corresponds to Kratie, Kampong Cham, Phnom Penh Provinces (Kandal stretching mostly south of Phnom Penh in the delta was classified under Zone 6), and the provinces around the Tonle Sap (Kampong Chhnang, Pursat, Battambang, Siem Reap and Kampong Thom).



Downstream of Kratie start the large and hugely productive Cambodian floodplains. This zone, including the Tonle Sap system, is characterized by exceptionally intensive fishing, described in numerous publications, in particular:

- La pêche dans les eaux douces du Cambodge (Chevey and Le Poulain 1940)
- Diversity and spatial distribution of freshwater fish in Great Lake and Tonle Sap river (Lim 1999)
- Proceedings of the Annual meeting of the Department of Fisheries (1999, 2000, 2001).
- Socio-economic survey of the Tonle Sap Lake (Keskinen 2003)
- Cambodian inland fisheries (Baran 2005)
- Socioeconomics and livelihood values of Tonle Sap lake fisheries (Hap Navy *et al.* 2006).

Catches in zone 5 are detailed below. According to Cambodian official statistics, Zone 5 produces around 230,000 tonnes of fish annually. The large difference between the production of Zone 5 and that of Zones 4 or 3 (respectively 40,000 and 116,000 tonnes) is mainly due to the fact that the surface area of zone 5, including the Tonle Sap provinces, is much larger than that of the two other zones (in which large tributary basins are such as Mun/Chi or 3S rivers are not included). However the huge production of Zone 5 also results from the huge productivity of floodplains (100 to 200 $kg.ha^{-1}.year^{-1}$; Hortle 2009) that are the dominant environmental feature of that zone.

Table 20: Catch statistics in the provinces of Zone 5. Source: FiA 2008, 2009

	2006			2007			2008		
	Lots	Family	Rice field	Lots	Family	Rice field	Lots	Family	Rice field
Kratie	2500	6500	3000	2000	4500	2500	1500	3100	2500
Kampong Cham	7000	13000	9500	6000	11000	9000	5500	9000	9500
Phnom Penh	12000	9500	2000	9500	7500	1500	8400	6000	1000
Kampong Chhnang	18000	16500	10000	17000	16000	9000	16000	13000	9000
Pursat	15000	15000	8000	14000	12000	8500	12000	11000	9000
Battambang	10000	13000	7200	10000	11000	8500	9500	10500	9500
Siem Reap	13000	14000	8000	12000	13000	9000	11000	13000	9500
Kampong Thom	11000	14500	8000	10500	13000	8000	11500	12000	9500
		246200			***225000***			***212500***	

When fish consumption statistics per person (see below) are multiplied by the population in each province[12], they give a catch of at least 485,000 tonnes per year in Zone 5, plus the catch sold or exchanged.

Fish consumption in zone 5 has been reviewed by Hortle (2007), based on detailed surveys by Ahmed *et al.* (1998). Results show that fish consumption in the provinces of Zone 5 varies between 43.4 and 105.2 kg/person/year; the average is 65kg of inland fish consumed per person and per year in zone 5, which is a world record (see section 2.3). Out of this, 65% is consumed fresh and 35% preserved.

Table 21: Fish consumption in provinces of Zone 5 (kg/person/year).

	Kratie	Kampong Cham	Phnom Penh	Kampong Chhnang	Pursat	Battambang	Siem Reap	Kampong Thom
Fresh fish	22.8	40	51.6	67.9	60.1	22.1	34.5	38.7
Preserved fish	11.7	25.2	19.3	37.3	22.5	21.3	26.8	27
Total	34.5	65.2	70.9	105.2	82.6	43.4	61.3	65.7

Sources: Ahmed *et al.* 1998

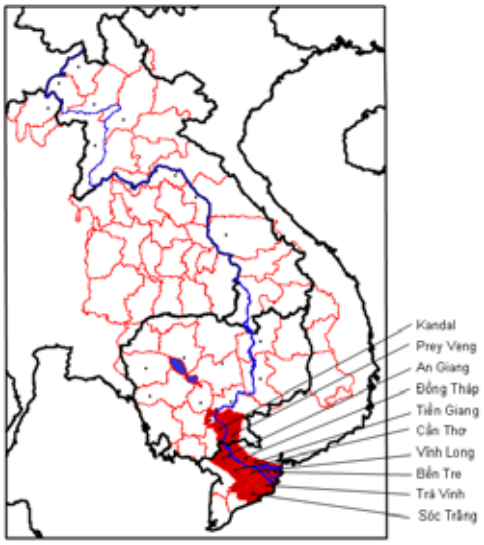
Note: in absence of local consumption studies in Kratie, Hortle (2007) applies Svay Rieng's figures to that province

The economic and livelihoods values of fisheries in Zone 5 are detailed in Ahmed *et al.* (1998), Hap Navy *et al.* (2006) and Baran *et al.* (2007). All authors underline that the vast majority of people living in this zone are involved in small-scale, non-commercial fishing, although this is also part of an occupational pluralism. According to Hap Navy *et al.* (2006) for instance, the 1.25 million people living around the Tonle Sap Lake earn US$ 233 million annually from the lake; of this, home consumption of fisheries products is worth USD 13 million. Yet, most households are very poor, with 72% of these making less than USD1000 a year. All households are very dependent on aquatic resources for their livelihoods.

[12] Population figures for each province were obtained from the 2008 Population Census and consumption figures from Hortle 2007. Kratie: pop. = 318500; 34.5 kg of fish consumed/person/year (Hortle 2007 p. 51), total annual fish consumption = 11000 tonnes; Kampong Cham: pop. = 1680000, 65.2 kg of fish consumed/person/year, total annual fish consumption = 109000 tonnes; Phnom Penh: pop. = 2000000, 70.9 kg of fish consumed/person/year, total annual fish consumption = 142000 tonnes; Kampong Chhnang: pop. = 472000, 105.2 kg of fish consumed/person/year (Hortle 2007), total annual fish consumption = 50000 tonnes; Pursat: pop. = 397000, 82.6 kg of fish consumed/person/year, total annual fish consumption = 33000 tonnes; Battambang: pop. = 1024000, 43.4 kg of fish consumed/person/year, total annual fish consumption = 44000 tonnes; Siem Reap: pop. = 896000, 61.3 kg of fish consumed/person/year, total annual fish consumption = 55000 tonnes; Kampong Thom: pop. = 631000, 65.7 kg of fish consumed/person/year, total annual fish consumption = 41000 tonnes. Total for the 8 provinces: 485,000 tonnes of fish consumed.

2.4.6 ZONE 6: PHNOM PENH TO THE SOUTH CHINA SEA

This zone between Phnom Penh and the seashore corresponds to Kandal and Prey Veng Provinces in Cambodia, and An Giang, Đồng Tháp, Cần Thơ / Hậu Giang, Tiền Giang, Vĩnh Long, Bến Tre, Sóc Trăng and Trà Vinh provinces in Vietnam. Although they formally belong to the Mekong Basin, Bạc Liêu, Cà Mau and Kiên Giang provinces were not integrated to this review since they are not related to the Mekong mainstream.



Zone 6 is characterized by a deltaic environment and a tidal influence. Catch statistics for this zone are detailed in the table below.

Table 22: Catch statistics in the provinces of Zone 6.

	2006	2007	2008
Kandal	72500	71000	61500
Prey Veng	20500	19500	18700
An Giang	53403	51851	40650
Đồng Tháp	21756	16030	16428
Sub-total	*168159*	*158381*	*137278*
Cần Thơ / Hậu Giang	10276	9893	9325
Tiền Giang	75155	75637	75789
Vĩnh Long	8048	7937	7853
Bến Tre	75699	76226	81389
Sóc Trăng	31870	31370	31316
Trà Vinh	58008	58385	60821
Sub-total	*259056*	*259448*	*266492*

Source: FiA 2008, 2009; General Statistics Office of Vietnam (*http://www.gso.gov.vn/default_en.aspx?tabid=491*)

However, these statistics do not distinguish between freshwater and marine fish catches; the sub-total restricted to Kandal, Prey Veng, An Giang and Đong Tháp corresponds to provinces located between 130 and 350 km away from the sea and that do not have a marine fishing fleet, and in which the proportion of freshwater fish is considered insignificant.

Once again, detailed fish consumption studies are the best alternative to official statistics. When fish consumption statistics per person (see below) are multiplied by the population in each province (see table below), the conclusion is that at least 520,000 tonnes of freshwater fish are harvested each year in Zone 6.

Table 23: Population, freshwater fish consumption and corresponding catch in Zone 6 provinces

Province	Total population	Proportion in the LMB	Population in the LMB	Freshwater fish consumption (kg/person/year)	Source	Total consumption (tonnes)
Kandal	1,075,000	100	1,075,000	67.7	Hortle 2007	72778
Prey Veng	946,000	65	567,600	26.9	Hortle 2007	15268
An Giang	2,250,573	100%	2,250,573	49.5	Hortle 2007	111403
Dong Thap	1,682,725	100%	1,682,725	49.5	Like An Giang	83295
Can Tho	1,171,069	100%	1,171,069	29.6	Like Tien Giang	34664
Tien Giang	1,742,140	70%	1,219,498	29.6	Hortle 2007	36097
Vinh Long	1,069,081	100%	1,069,081	29.6	Like Tien Giang	31645
Ben Tre	1,360,272	100%	1,360,272	36.2	Like Tra Vinh	49242
Soc Trang	1,301,710	100%	1,301,710	36.2	Like Tra Vinh	47122
Tra Vinh	1,062,010	100%	1,062,010	36.2	Hortle 2007	38445
Total						***519,958***

Note: population figures are from the Social Atlas of the Lower Mekong Basin (MRC 2003)

In Zone 6, freshwater fish consumption is high but variable; the table below, from Hortle (2007) who summarised 5 fish consumption studies in this zone, shows that it varies between 26.9 and 67.7 kg/person/year.

Table 24: Fish consumption in provinces of Zone 5 (kg/person/year).

	Kandal	Prey Veng	An Giang	Tien Giang	Tra Vinh
Fresh Inland Fish	45.5	21	36.8	29.6	22.7
Preserved Inland Fish	22.2	5.9	12.7	-	13.5
Total consumption of inland fish	67.7	26.9	49.5	29.6	36.2

Sources: Ahmed *et al.* 1998 (Kandal), Setboonsarng, *et al.* 1999 (Kandal and Prey Veng), Sjorslev 2002 (An Giang), Setboonsarng *et al.* 1999 (Tien Giang), and Phan *et al.* 2003 (Tra Vinh).

On the socioeconomic ground, capture fisheries remain an important part of local livelihoods in provinces of Zone 6 in Vietnam, even though there are few full-time fishers (Table 25).

Table 25: Role of fishing in people's activities

	An Giang	An Giang	Dong Thap	Whole delta
	Phan and Pham 1999	Sjorslev 2000	Nguyen Van Trong, Pham Mai Phuong 2004	Pham Trong Thinh 2009
Full time fishers	3%	7%	4.7%	8.1%
Part-time fishers	37%	66%	22.1%	43.8%

According to the recent study of Pham Trong Thinh (2009) in this zone, of the total catch 17 % is used for consumption and 83% is sold. Ninety-two percent of households estimated that the catch had been decreasing, but people's impression was that their overall well-being had increased, thanks to factors outside the fishery sector. This being said, the level of dependence upon aquatic resources remains very high among the 32% of the population qualifying as poor or very poor.

Table 26: Weath status and dependence on fish in the Vietnamese provinces of Zone 6. Source: Pham Trong Thinh 2009.

	Weath Status			
Percentage in the population	**Very poor**	**Poor**	**Middle**	**Well-off**
% of the population	6.8	25.3	59.7	8.2
Level of dependence on fish and other aquatic animals	59.4	31.2	5.5	3.8

According to the province stastistics and to interviews gathered during December 2009 field surveys, this fish production is in decline compared to 10 or 30 years ago (cf. table below). The reasons given are that up to 1975, aquatic resources were abundant, but after 1978, canal systems were dug, agriculture was developed, and with it the use of chemicals toxic for fish. In the 1990's the spreading of electric fishing gears had a negative impact on fish abundance, and after 2006 dykes and sluice gates aimed at protecting against saline intrusion contributed to reducing fish abundance further. This trend subsequently led to a decline in employment and income from fisheries, especially amongst poor households

Table 27: Catch statistics in An Giang and Dong Tap provinces, 1996-1998 and 2006-2008 periods.

An Giang				trend (%)
1996	72004	*2006*	53403	-26
1997	74300	*2007*	51851	-30
1998	76577	*2008*	40650	-47

Dong Thap				trend (%)
1996	28292	*2006*	21756	-23
1997	26705	*2007*	16030	-40
1998	27118	*2008*	16428	-39

Sources: Tong Cuc Thong Ke et al. 1999 and General Statistics Office of Vietnam (*http://www.gso.gov.vn/default_en.aspx?tabid=491*)

Overview

Table 28: Main characteristics of fisheries in the 6 ecological reaches of the Mekong

	Number of fish species	**Freshwater fish catch** (tonnes)	**Percentage of the catch**	**Freshwater fish consumption** (kg/person/year)
Zone 1 (China)	151	25,000	2.0	-
Zone 2 (Chiang Saen -Vientiane)	140	50,000	4.0	16 - 27.5
Zone 3 Vientiane - Pakse	NA	116,000	9.4	17.5 - 42
Zone 4 Pakse-Kratie	252	40,000	3.2	28.9 - 57
Zone 5 Kratie -PP and TS	284	485,000	39.2	43.4 - 105.2
Zone 6 PP-Delta	486	520,000	42.1	29.6 - 67.7
		1,236,000		

Thus according to the above review, around 1.2 million tonnes of fish are harvested and consumed each year along the Mekong River in the 6 main ecological reaches. This is lower than the 2.1 million tonnes of

fish harvested estimated from consumption studies basinwide, but is explained by the fact that 35 other provinces not included here[13] also contribute the overall catch.

Most of this catch is realized in the three lower zones (Zones 4 to 6 totalling 85% of the overall catch), and these zones are also those where fish species richness and fish consumption are the highest. Zone 4 (Pakse-Kratie) does not exhibit such high fish production and consumption, but is characterized for its high fish biodiversity that can be related to the extent and diversity of specific habitats (water falls, islands and wetlands).

Keeping in mind that in a system characterized by intensive migrations, fish harvest in Zones 4 and 5 is largely conditioned by the connexion of these zones with other zones and tributaries (see Figure 23), Zone 5 would be the zone in which mainstream dam construction would have the most dramatic impact on fish production.

3 STATUS OF MEKONG AQUACULTURE PRODUCTION

The aquaculture sector is full of promise. As detailed by Dugan *et al.* (2006), cultivating fish has the potential to improve water productivity, through aquaculture in ponds, but also integration of fish into irrigation systems, rice-fish culture and integrated aquaculture-agriculture. After several years of expansion, aquaculture is still considered as having a tremendous potential for expansion in Asia (Dey *et al.* 2005, 2008); aquaculture is very beneficial to the income and food security of rural households, particularly in the case of integrated agriculture-aquaculture and rice-field fisheries (Prein and Ahmed 2000, Dey and Prein 2005).

3.1 STATUS OF AQUACULTURE PRODUCTION IN THE MEKONG BASIN COUNTRIES

In terms of biomass produced, we analyzed FAO data for national freshwater and brackish water aquaculture production in 2007, and compared them to Mekong fish production figures detailed in section 1.1.2[14].

[13] The provinces having a majority of their territory lying within the Mekong Basin are: Attapeu, Phongsaly, Sekong, Vientiane, Xaysomboun and Xiengkhuang Provinces in Lao PDR; Amnat Charoen, Burirum, Chaiyaphum, Kalasin, Loei, Maha Sarakham, Nakhon Ratchasima, Nong Bua Lamphu, Phayao, Roi Et, Sakon Nakhon, Si Saket, Surin, Udon Thani and Yasothon Provinces in Thailand; Banteay Meanchey, Kampong Speu, Kong Pailin, Mondul Kiri, Otdar Meanchey, Preah Vihear, Ratana Kiri and Takeo Provinces in Cambodia; Bac Lieu, Ca Mau, Dak Lak, Kien Giang and Kon Tum Provinces in Vietnam

[14] Thus aquaculture figures here cover the whole country, whereas capture fisheries statistics are restricted to the Mekong Basin, which represents a substantial bias in favour of aquaculture. In 2000 for instance, aquaculture in the Mekong Delta represented only 65% of aquaculture in the whole of Viet Nam.

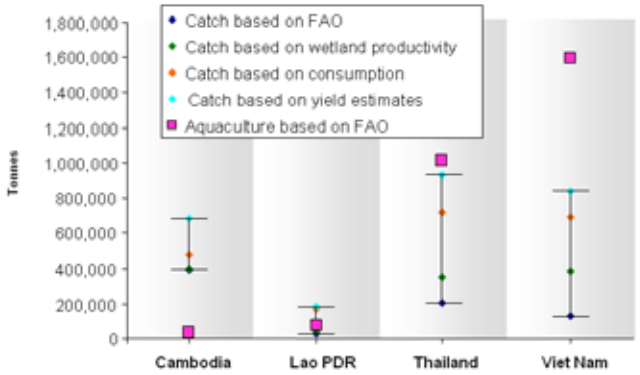
Table 29: Production of inland and brackish aquaculture fish in tonnes.

	2005	2006	2007	Average 2005-2007
Cambodia	25900	34070	34070	31346.67
Lao PDR	78000	78000	78000	78000
Thailand	957576	1046406	1027231	1010404
Viet Nam	1293500	1511527	1986000	1597009
				2716760

Source: FAO Figis (*http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en*)

Note: According to the Minister of Agriculture, Forestry and Fisheries (1st July 2009), aquaculture production in Cambodia amounted to 40,000 tonnes in 2008.

Figure 17: Comparison of capture fisheries estimates (bars indicate the range, depending on different approaches) and aquaculture figures. Period 2005-2007.



Sources: data from Tables 6 to 9, and from FAO Figures

Conclusions:

The freshwater aquaculture sector produces more than Mekong capture fisheries in Thailand and Viet Nam (with a high dominance of the aquaculture sector in the latter country). In Lao PDR, production of both sectors is similar, and in Cambodia the production of the aquaculture sector is 12 to 22 times *inferior* to the production of the capture fishery sector.

3.2 DOMINANT SPECIES IN THE AQUACULTURE SECTOR

National statistics compiled by the FAO indicate the species dominant in the inland aquaculture sector of each Lower Mekong country.

Table 30: Fish species dominant in the inland aquaculture sector of LMB countries

Scientific name	2005	2006	2007
CAMBODIA			
Siluroidei	13,200,000	17,600,000	17,600,000
Pangasius spp	10,000,000	16,000,000	16,000,000
Barbonymus gonionotus	10,620,000	12,600,000	12,600,000
Cyprinus carpio	8,400,000	10,000,000	10,000,000
Hypophthalmichthys molitrix	2,100,000	2,618,000	2,618,000
Ctenopharyngodon idellus	1,500,000	1,800,000	1,800,000
Clarias batrachus	1,050,000	1,400,000	1,400,000
Leptobarbus hoeveni	880,000	1,100,000	1,100,000
Hypophthalmichthys nobilis	750,000	900,000	900,000
Oreochromis mossambicus	440,000	660,000	660,000
Oreochromis niloticus	440,000	660,000	660,000
Total	49,380,000	65,338,000	65,338,000
LAO PDR			
Oreochromis niloticus	22,920,000	25,467,000	25,467,000
Probarbus jullieni	9,000,000	10,000,000	10,000,000
Cirrhinus microlepis	8,640,000	9,600,000	9,600,000
Hypophthalmichthys molitrix	7,155,000	7,950,000	7,950,000
Barbonymus gonionotus	6,739,000	7,488,000	7,488,000
Cyprinus carpio	6,264,000	6,960,000	6,960,000
Cirrhinus molitorella	6,138,000	6,820,000	6,820,000
Hypophthalmichthys nobilis	5,281,000	5,868,000	6,520,000
Catla catla	5,400,000	6,000,000	6,000,000
Ctenopharyngodon idellus	5,400,000	6,000,000	6,000,000
Labeo rohita	4,770,000	5,300,000	5,300,000
Cirrhinus mrigala	4,230,000	4,700,000	4,700,000
Total	91,937,000	102,153,000	102,805,000
THAILAND			
Oreochromis niloticus	146,392,000	172,018,000	164,824,000
C.gariepinus x C.macrocephalus	114,846,000	124,539,000	117,075,000
Barbonymus gonionotus	44,208,000	44,343,000	46,787,000
Trichogaster pectoralis	35,624,000	41,043,000	41,056,000
Channa striata	18,910,000	16,054,000	15,444,000
Pangasius hypophthalmus	14,041,000	14,144,000	17,285,000
Osteichthyes	6,720,000	6,850,000	12,372,000
Osphronemus goramy	7,561,000	8,379,000	8,068,000
Cyprinus carpio	4,195,000	3,852,000	4,350,000
Anabas testudineus	3,741,000	1,574,000	3,549,000
Labeo rohita	1,960,000	1,450,000	2,790,000
Cirrhinus mrigala	981,000	868,000	859,000
Oxyeleotris marmorata	699,000	576,000	696,000
Channa micropeltes	252,000	390,000	290,000
Hypophthalmichthys molitrix	219,000	261,000	275,000
Oreochromis mossambicus	122,000	194,000	181,000
Nonopterus albus	106,000	94,000	102,000
Trichogaster spp	23,000	25,000	115,000
Notopterus spp	25,000	1,000	4,000
Total	400,625,000	436,655,000	436,122,000
VIET NAM			
Osteichthyes	877650000	955568000	1020450000
Pangasius spp	564000000	780000000	1275000000
Total	1,441,650,000	1,735,568,000	2,295,450,000

Source: FAO data in FishBase (*www.fishbase.org*)

The above statistics are synthesized in terms of percentages in the table below.

Table 31: Percentage of each species in the inland aquaculture production of LMB countries

	Percentage of national production				Annual total production
	Cambodia	Lao PDR	Thailand	Viet Nam	(average 2005-2007, tonnes)
Osteichthyes (= various fish species)			1.3	52.1	640496
Pangasius spp	22.0			47.9	588500
Oreochromis niloticus	0.8	25.1	40.5		219553
C.gariepinus x C.macrocephalus			29.0		143113
Barbonymus gonionotus	21.8	8.0	11.5		69489
Trichogaster pectoralis			7.2		35687
Pangasius hypophthalmus			5.0		24648
Cyprinus carpio	15.6	7.4	1.0		15245
Channa striata			2.0		9956
Hypophthalmichthys molitrix	5.7	10.2	0.1		9948
Labeo rohita		6.8	0.6		8097
Hypophthalmichthys nobilis	1.9	8.4			7070
Siluroidei (= various catfishes)	23.7				7000
Ctenopharyngodon idellus	3.7	6.4			6100
Cirrhinus mrigala		6.0	0.2		5869
Osphronemus goramy			1.1		5195
Catla catla		6.4			5000
Cirrhinus microlepis		6.2			4800
Probarbus jullieni		5.1			4000
Cirrhinus molitorella		4.0			3100
Anabas testudineus			0.4		2208
Clarias batrachus	2.4				700
Oreochromis mossambicus	0.8		0.04		454
Leptobarbus hoeveni	1.5				450
Channa micropeltes			0.1		249
Trichogaster spp			0.02		96
Oxyeleotris marmorata			0.02		85
Monopterus albus			0.01		56
Notopterus spp			0.002		11

Source: FAO data in FishBase (www.fishbase.org). Red, orange and yellow colors highlight respectively the first, second and third most abundant species in each country.

Conclusions:

Pangasiid catfishes are the dominant fish group produced in aquaculture. This group actually includes a majority of *Pangasianodon hypophthalmus* and P*angasius bocourti* whose cycles are well mastered.

The second dominant species is the introduced tilapia *Oreochromis niloticus*, coming first in Thailand and Lao PDR. This species is followed by a number of other catfishes (Silurids), in particular the hybrid "*Clarias gariepinus x C. macrocephalus*" famous for its high growth rate. The first native Cyprinid farmed in the region is the Java/silver barb *Barbonymus gonionotus*, present in particular in Cambodia where *O. niloticus* farming is not developed. The carp *Cyprinus carpio* is also present in several countries, but its rank is quite variable. All together, 24 freshwater fish species are grown in the Mekong aquaculture sector. Cambodia and Lao PDR have not contributed statistics to the FAO for 2 and 3 years respectively, and Viet Nam does not provide details about the species raised. It can also be noted that some species

farmed at a substantial scale in some countries are not reflected in these statistics (e.g. hybrid "*Clarias gariepinus* x *C. macrocephalus*" or *Channa spp* in Cambodia).

4 SOCIOECONOMIC STATUS OF MEKONG FISH RESOURCES

The values of Mekong fish resources (economic valuation analyses with direct use and indirect use values, economic impact analyses, socio-economic analyses and livelihood analyses) were comprehensively reviewed in 2007 by Baran *et al.* This review is freely available on the internet[15] and we will not paraphrase it here. The statistics proposed below are updates and additional notes.

4.1 ECONOMIC VALUE OF CAPTURE FISHERIES

The economic value of capture fish harvested in the Lower Mekong Basin has been estimated at between $1.4 and $2 billion US dollars per year (first sale value; Sverdrup Jensen 2002, Van Zalinge *et al*. 2004, MRC 2008a). Actually the economic value of Mekong fisheries is derived from catch estimates multiplied by an average price per kilogram; the latter is supposed to integrate the variability between species, countries and seasons. The problem is that despite numerous economic valuation projects over the years (e.g. Sultana *et al.* 2003[16], Israel *et al.* 2005, MRC 2008b), no transparent price per kilo or tonne has ever been produced, and economic valuation of fish resources remains a much neglected issue in the Mekong Basin.

The most "detailed" pricing system is that used in Sverdrup-Jensen (2002; Table 32)

Table 32: Value of fish production in the LMB according to Sverdrup-Jensen (2002)

	Quantity (tonnes)	Price (US$ per kg)	Value (US$ millions)
Riverine capture fisheries	1,533,000	0.68	1,042
Aquaculture	260,000	1.05	273
Reservoirs	240,000	0.68	163
Total	*2,033,000*		*1,478*

The most recent estimate is that of Hortle (2009) who, integrating inflation, has valued Mekong fish resources at USD 2.1-3.8 billion on first sale and between USD 4.2-7.6 billion on retail markets[17].

The contribution of fisheries resources to GDP is detailed in Table 33:

[15] http://www.worldfishcenter.org/v2/pubs.html, keyword "values"

[16] This very comprehensive and poorly known analysis is available at http://www.fmsp.org.uk/FTRs.htm

[17] In the original publication the author actually values a production of "3.6 million tonnes" at USD3.6-6.5 billion, for a price per kilogram varying between USD 1 and 1.8 at first sale and USD 2-3.6 on retail markets. Assuming a catch of freshwater fish of 2.1 million tonnes (see section 2.1.2) this corresponds to a total value of USD 2.1-3.8 billion at first sale and USD 4.2-7.56 on retail markets.

Table 33: Contribution of the fisheries sector (capture + aquaculture) to GDP in Mekong countries

Country	Share of GDP	Sources
Cambodia	11.7%-16% 8% - 12%	Starr 2003 - Van Zalinge *et al*. 2004 Kurien *et al*. 2006
Lao PDR	6.8%	FAO statistics (http://www.fao.org/fishery/countrysector/FI-CP_LA/en#fn7)
Thailand	NA	
Viet Nam	7%	Thai Thanh Duong 2003

Kirby and Mainuddin (2009) recently showed, in a conservative assessment, that the economic value of capture fish in the Lower Mekong is at least as important as that of livestock.

In Thailand, the contribution of aquaculture to the GDP was estimated at 2.07% GDP (Sugiyama *et al*. 2004).

4.2 ECONOMIC VALUE OF AQUACULTURE FISH

FAO statistics indicate the value of the inland and brackens water aquaculture production:

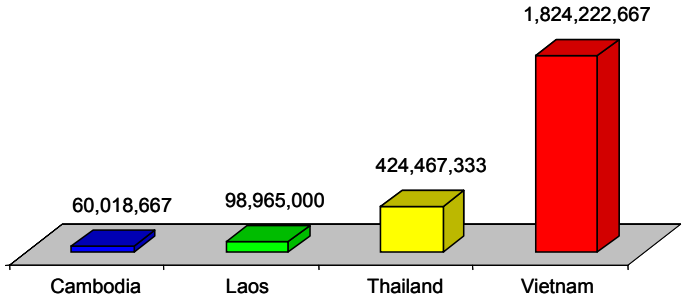
Table 34: Value of species produced in the LMB aquaculture sector.

Species	2005	2006	2007
CAMBODIA			
Barbonymus gonionotus	10,620,000	12,600,000	12,600,000
Clarias batrachus	1,050,000	1,400,000	1,400,000
Ctenopharyngodon idellus	1,500,000	1,800,000	1,800,000
Cyprinus carpio	8,400,000	10,000,000	10,000,000
Hypophthalmichthys molitrix	2,100,000	2,618,000	2,618,000
Hypophthalmichthys nobilis	750,000	900,000	900,000
Leptobarbus hoeveni	880,000	1,100,000	1,100,000
Oreochromis mossambicus	440,000	660,000	660,000
Oreochromis niloticus	440,000	660,000	660,000
Pangasius spp	10,000,000	16,000,000	16,000,000
Siluroidei	13,200,000	17,600,000	17,600,000
Total	*49,380,000*	*65,338,000*	*65,338,000*
LAO PDR			
Barbonymus gonionotus	6,739,000	7,488,000	7,488,000
Catla catla	5,400,000	6,000,000	6,000,000
Cirrhinus microlepis	8,640,000	9,600,000	9,600,000
Cirrhinus molitorella	6,138,000	6,820,000	6,820,000
Cirrhinus mrigala	4,230,000	4,700,000	4,700,000
Ctenopharyngodon idellus	5,400,000	6,000,000	6,000,000
Cyprinus carpio	6,264,000	6,960,000	6,960,000
Hypophthalmichthys molitrix	7,155,000	7,950,000	7,950,000
Hypophthalmichthys nobilis	5,281,000	5,868,000	6,520,000
Labeo rohita	4,770,000	5,300,000	5,300,000
Oreochromis niloticus	22,920,000	25,467,000	25,467,000
Probarbus jullieni	9,000,000	10,000,000	10,000,000
Total	*91,937,000*	*102,153,000*	*102,805,000*

THAILAND			
Anabas testudineus	3,741,000	1,574,000	3,549,000
Barbonymus gonionotus	44,208,000	44,343,000	46,787,000
C.gariepinus x C.macrocephalus	114,846,000	124,539,000	117,075,000
Channa micropeltes	252,000	390,000	290,000
Channa striata	18,910,000	16,054,000	15,444,000
Cirrhinus mrigala	981,000	868,000	859,000
Cyprinus carpio	4,195,000	3,852,000	4,350,000
Hypophthalmichthys molitrix	219,000	261,000	275,000
Labeo rohita	1,960,000	1,450,000	2,790,000
Nonopterus albus	106,000	94,000	102,000
Notopterus spp	25,000	1,000	4,000
Oreochromis mossambicus	122,000	194,000	181,000
Oreochromis niloticus	146,392,000	172,018,000	164,824,000
Osphronemus goramy	7,561,000	8,379,000	8,068,000
Osteichthyes	6,720,000	6,850,000	12,372,000
Oxyeleotris marmorata	699,000	576,000	696,000
Pangasius hypophthalmus	14,041,000	14,144,000	17,285,000
Trichogaster pectoralis	35,624,000	41,043,000	41,056,000
Trichogaster spp	23,000	25,000	115,000
Total	*400,625,000*	*436,655,000*	*436,122,000*
VIET NAM			
Osteichthyes	877650000	955568000	1020450000
Pangasius spp	564000000	780000000	1275000000
Total	*1,441,650,000*	*1,735,568,000*	*2,295,450,000*

Source: FAO in FishBase (*www.fishbase.org*)

Figure 18: Value of the inland aquaculture sector in LMB countries. US dollars. Yearly average, 2005-2007 period.



Source: FAO data in FishBase (www.fishbase.org)

Conclusions

During the 2005-2007 period, aquaculture generated each year around USD 60, 100, 400 and 1800 million in Cambodia, Lao PDR, Thailand and Viet Nam respectively, i.e. around USD 2.4 billion all together.

4.3 EMPLOYMENT VALUE OF CAPTURE FISHERIES AND AQUACULTURE

Figures about the number of people involved in the fishery sector are scarce. This is partly due to the lack of assessment, but also to the elusive nature of involvement in fishing, since a minority of people are full-time fishers, while a majority of farmers spend time and gain from fishing. Thus, in Cambodia, Keskinen (2003) stated that around the Tonle Sap Lake, fishing was a primary occupation for 17.1% of people only, but a secondary occupation for 28.5%. Fish related activities make up to two thirds of income in the villages of the Tonle Sap system, (Rab *et al*. 2004, 2006). In Lao PDR, full time fishers account for only a few percent of the Lao population, but fishing is central to livelihoods in the southern provinces of the country (Roberts and Baird 1995, Baird 1996, MRAG 2002).

Table 35: Number of people involved in the fishery sector (Inland capture fisheries + aquaculture)

	Number of Households/People	Sources
Cambodia	1,640,000 people 4 million people or 29% of Cambodia's population derive employment from fisheries	FAO and WorldFish Center 2008 Kurien *et al*. 2006
Lao PDR	NA	
Thailand	50,198 households 3.13 million fishers	FAO statistics (www.fao.org/fishery/countrysector/naso_thailand/en Lymer *et al*. 2008
Viet Nam	2,834,238 people In the Mekong delta, fisheries and aquaculture contributed to 10% of the national labor force.	FAO and WorldFish Center 2008 FAO statistics www.fao.org/fishery/countrysector/FI-CP_VN/en

Table 36: Number of people involved in the aquaculture sector (inland + marine)

	People involved	Farms	Sources
Cambodia		53800 farms in 2008	Minister of Agriculture's speech 01/012009
Lao PDR	5,5200 families or 8.3% of rural households	503,460 ha	FAO statistics (www.fao.org/fishery/countrysector/FI-CP_LA/en#fn7 Souvannaphanh *et al*. 2003
Thailand	80,704 households	**Freshwater** aquaculture: 390,853 farms and 131,500 ha in 2002; more than 440 000 in 2004	FAO statistics (www.fao.org/fishery/countrysector/naso_thailand/en)
Viet Nam	670,000 people	327 092 ha of freshwater farms (36.3%) 575,137 ha of marine and brackish water farms (63.7%)	FAO statistics (www.fao.org/fishery/countrysector/FI-CP_VN/en)

5

6 FISH ECOLOGYAND RISKS IN RELATION TO DAM DEVELOPMENT

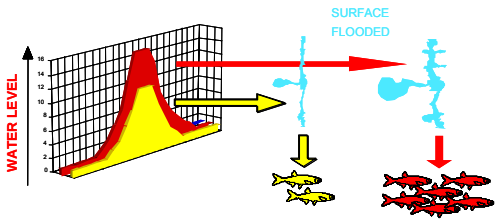
In general dams constitute a threat to fish because of i) modification of flows and subsequent impacts on water and habitat quality/quantity, and ii) a barrier effect making fish migrations difficult or impossible for adult or juvenile fish (WCD 2000). Flow modifications result in particular in changes in downstream discharge (volume, timing and amplitude), changes in downstream habitats, nutrient trapping in reservoirs, and deterioration of water quality. The sections below show that flows and migrations are the main drivers of the Mekong fish production.

6.1 FACTORS DRIVING FISH PRODUCTION

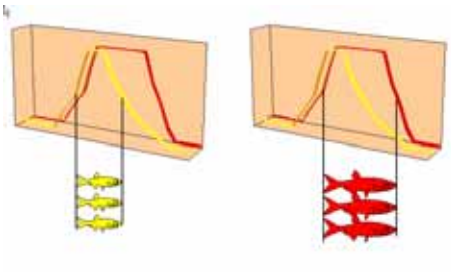
The analysis of factors driving fish production in the Mekong Basin has been done mostly in relation to an attempt to model that production, in view of better assessing the consequences of environmental modifications. The initial identification of factors driving fish production is given in Baran *et al.* (2001; unpublished report whose excerpts are presented here), developed further in Baran and Cain (2001) and in Baran *et al.* (2003), and summarized in Kurien *et al.* (2006). All these factors have been analyzed further for the Tonle Sap (e.g. Baran and Jantunen 2005).

A summary of these studies is presented graphically below:

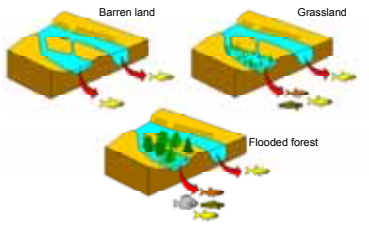
1) a bigger flood is correlated with higher fish production



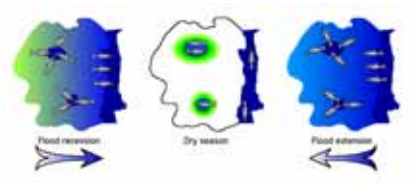
2) a longer flood is correlated with higher fish production



3) the nature and diversity of the vegetation in the flooded areas is most probably correlated with the diversity and abundance of fish production



4) the sustainability of the fish resource is dependent upon the presence and accessibility of refuges for fish in the dry season. These refuges consist of ponds in floodplains and deep pools in the Mekong mainstream. Almost no literature is available about ponds, but the role and functioning of deep pools has been much more studied (e.g. Poulsen *et al.* 2002a, Baran *et al.* 2005, Baird 2006).

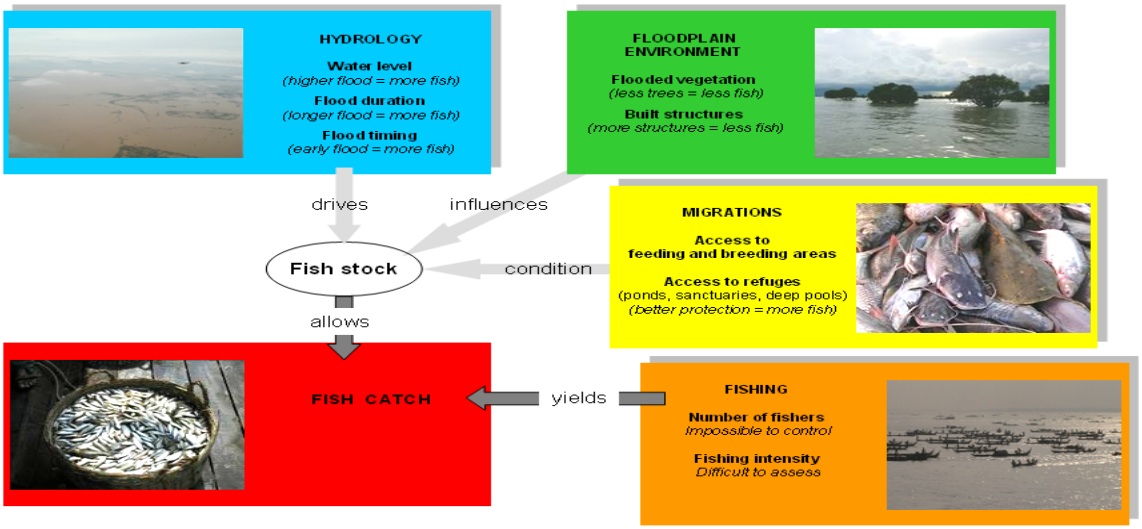


5) in a system driven by migrations, connectivity is an essential feature; the possibility for fish to move between their breeding and feeding zones is central to fish production sustainability. This issue has led to several analyses, in particular the study of the influence of built structures on the Tonle Sap fisheries (Baran *et al.* 2007), and the role of dams on migrations (Halls and Kshatriya *in press*).

6) last, the presence of an active fishery sector is a condition for converting the natural productivity of the system into tangible production; when it does not reach overfishing, this fishery sector contributes to enhancing the natural productivity of the system (Baran and Myschowoda 2008).

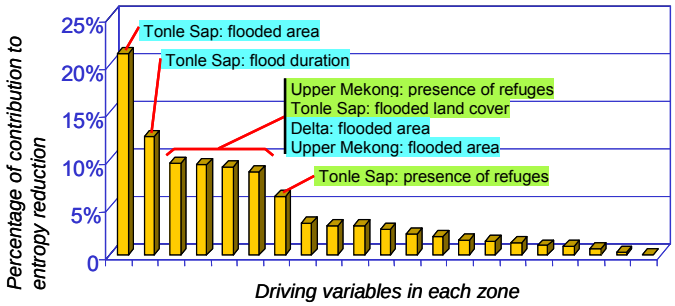
The interactions between these different factors are summarized below:

Figure 19: Overview of main factors driving fish production in the Mekong Basin



In their model of environmental factors driving fish production in the Lower Mekong Basin, Baran *et al.* (2003) considered three groups of fishes (black fishes, white fishes and opportunists) and three geographic sectors (Upper Mekong, Tonle Sap system and Mekong Delta). The conclusion of their modelling work – based on expert consultations only – is summarized in Figure 21.

Figure 20: Factors driving fish production basinwide



Source: Baran *et al*. 2003

According the model developed, the area of flooding around the Tonle Sap is the most influential parameter driving fish production; among 7 influential factors, the area flooded is present 3 times, highlighting the importance of natural flooding for natural fish production. It should be noted however that this model, developed in 2001, is based on the evidence available at that time; it did not encompass built structures or access to breeding sites. The importance of the latter issues was highlighted subsequently.

6.2 FISH GROUPS IN THE MEKONG

Three main fish groups (or "guilds") having very different migration patterns are to be distinguished. The group of "*black fish*" is made of species with limited lateral migrations and no longitudinal migrations; these tough fish do not leave floodplains and wetlands, and spend the dry season in local ponds; this group includes *Channidae* (Snakeheads), *Clariidae*, *Bagridae* or *Anabantidae.* The group of "*white fish*" undertakes long distance migrations, in particular between lower floodplains and the Mekong mainstream. This group includes many cyprinids (e.g. *Henicorhynchus spp.* and *Cirrhinus sp*.) but also most *Pangasidae* catfishes. A third group, that of "*grey fish*", was defined later on (Lévêque and Paugy 1999, Poulsen *et al.* 2002;

Table 37):

Table 37: Characteristics of main fish groups migrating

	White fish	Black fish	"Grey" fish
Migrations	Long distance longitudinal migrations	Local movements	Short range longitudinal migrations, lateral migrations
Body form	Round or fusiform	Body vertically compressed; no scales or long scales or armored body	Body laterally compressed, spiny, usually with strong scales
Color	Silvery or light	Very dark, often black	Rather dark, usually ornamented and coloured
Reproduction guild	Non-guarders; open substrate spawners	Guarders; build complex nests	Guarders; nest builders or open substrate spawners
Dry season habitat	Main channel, lake or sea	Floodplain ponds	Tributaries or edges of main streams
Wet season habitat	Main channel or floodplain	Floodplain or swamps	Floodplain

This "grey fish" group, made of fish that are not grey in colour but ecologically intermediate between the two previous groups, corresponds to fishes that do not spend the dry season in floodplain ponds, but do not undertake long distance migrations either. When the flood recedes they leave the floodplain and tend to spend the dry season in local tributaries; their ecological and physiological characteristics are intermediate between those of black and white fish.

Figure 21: Examples of fish species belonging to the main fish migration groups.

White fish is the group of fish most sensitive to dam development, because of the need to migrate over long distance. Black fish is the group most resilient to the impact of dams and tend to replace, to a certain extent, vanishing white fish. Grey fish are intermediate between these the two previous ones.

6.3 SPECIES GUILDS

Going beyond these three simple fish groups, Halls and Kshatriya (*in press*), drawing on Welcomme *et al.* (2006), proposed a series of 10 fish groups of similar migratory ecology (i.e. guilds) relevant to the Mekong. These guilds are detailed below.

Table 38: Migratory guilds for the Mekong and mainstream dam impact forecasting.

Migratory guild	Potential range of habitat utilized	Typical characteristics*	Likely impact of mainstream dams on migrations.
1. Rithron resident guild	Running river upstream	• Resident in rapids, torrent s, rocky areas and pools upstream • Limited migrations.	Little or no impact
2. Migratory main channel (& tributaries) resident guild	Sea to running river upstream	• Long distance migrants; spawning in the main channel upstream. • May migrate to deep pools in the main channel during the dry season. • Adults do not enter floodplains. • Vulnerable to overexploitation and sensitive to damming • May respond favorably to fish passage facilities.	Medium
3. Migratory main channel spawner guild	Floodplains to running river upstream	• Spawn in the mainstream, in tributaries and around floodplains • Adults and drifting larvae return to floodplains to feed. • May migrate to deep pools in the mainstream during the dry season. • Sensitive to damming	Very high
4. Migratory main channel refuge seeker guild	Floodplains to slow river downstream	• Spawn in floodplains • Migrations between floodplains and mainstream deep pools in the dry season. • Sensitive to damming	Very high
5. Generalist guild	Floodplains and slow river downstream	• Limited non-critical migrations in mainstream. • Highly adaptable, often tolerant of low oxygen concentrations. • May be semi-migratory often with sedentary local populations; may seek refuge in deep pools during dry season. • May undertake lateral migrations to floodplains. • This guild is well represented in most rivers.	Little or no impact
6. Floodplain resident guild (blackfish)	Floodplains	• Limited migrations between floodplains pools, river margins, swamps, and inundated floodplains. • Tolerant to low oxygen concentrations or complete anoxia.	Little or no impact
7. Estuarine resident guild	Estuary	• Limited migrations within the estuary in response to daily and seasonal variations in salinity. • Usually confined to the brackish part of system.	Little or no impact.
8. Semi-anadromous guild	Estuary and lower slow river downstream	• Enters fresh/brackish waters to breed. • Enters freshwaters as larvae and juveniles (bligate or opportunistic) • Impacted by river mouth dams that stop migration into the river.	High (for dams located in river mouths or lower potomon)
9. Catadromous guild	Marine to running river upstream	• Reproduction, early feeding and growth at sea. • Juvenile or sub-adult migration to freshwater habitats • Vulnerable to overexploitation and tend to disappear when river is dammed preventing longitudinal upstream migration. • May respond favorably to fish passage facilities.	Very high
10. Marine guild	Estuary	• Enter estuaries opportunistically.	Little or no impact

Source: adapted from Halls and Kshatriya *in press*.

6.4 FISH MIGRATIONS

Fish migrations in the Mekong basin have been identified as a major feature several decades ago (e.g. Chevey and Le Poulain 1940) and subject since then to numerous publications: in 2006, Baran reviewed 26 studies dealing with Mekong fish migrations. The major features of these migrations are presented below, as well as new developments.

Northcote (1984) defines migration as "movements that result in an alternation between two or more separate habitats, occur with a regular periodicity, and involve a large proportion of the population". From a spatial perspective fish migration can be lateral, longitudinal or vertical, and the movements can be either active or passive (in particular in the case of eggs and larvae).

Fish migrate when they cannot complete their life cycle in a single habitat: when requirements for reproduction and for feeding at different life stages cannot be met in the same place, then fish have to move between places to survive. This process also optimizes survival, growth and reproduction. Fish also sometimes migrate to avoid unsuitable water quality; e.g. out of the Great Lake in the dry season when the water is warm and has low oxygen content. Generally speaking, breeding and feeding are the two main factors that drive fish migrations in the Mekong system.

- *Feeding migrations*: extensive wetlands and floodplains in the Basin (respectively 185,000 and 50,000 km^2 according to Hortle *et al.* 2008 and TKK and SEA START-RC 2008), and their multiple resources (vegetation debris, invertebrates, algae, etc.) constitute a rich feeding place for both adults and juveniles. Thus, in the lower stretches of rivers almost all fish species at all life stages temporarily migrate to floodplains at the beginning of the rainy season. This process, which involves long or short distance migrations, contributes to increased growth and survival of individuals, and thus to the very high productivity of the system.

- *Breeding migrations*: the Mekong is the river with the highest discharge variability in the world: rainy season flows can be 30 fold higher than dry season flows. If fish did not migrate this huge pulse would wash larvae and juveniles away; actually it forces adult fish to move upstream for spawning, so that their larvae and juveniles can drift down to floodplains with the flood and grow there, in good conditions, during the wet season.

Most species combine feeding and breeding migrations, so it is almost impossible to dissociate these two patterns. Thus, in the case of the Mekong upstream migrations are mainly breeding migrations undertaken by larger, often adult fish; downstream migrations are mainly feeding migrations undertaken at both life stages. Fish movements also include lateral migrations between the mainstream or tributaries and floodplains. Migration however has a high mortality cost (predation, fishing) and if the conditions remain locally suitable, there are instance where some species or sub-populations stop migrating over long distances (e.g. in man-made brush parks where species like *Henicorhynchus sp.* can be found year round; Hortle, pers. comm.). Brush parks that contribute to deforestation are an illegal fishing method.

6.4.1 MIGRATIONS IN SPACE

Three major migration systems can be distinguished in the Mekong Basin (Poulsen *et al.* 2002), as detailed in Figure 22.

• The Lower Mekong migration system, characterized by its extensive floodplains, is limited downstream by the sea (although in reality the extent and volume of migrations between the river and the sea is not known), and upstream by the Khone Falls bottleneck on the mainstream. Khone Falls is only a partial bottleneck for fish, as demonstrated for instance by the intensive local fishery almost exclusively based on migrations, or by the migration of species such as the giant catfish that feeds in the Tonle Sap and breeds in upper Lao PDR/Thailand; however the role of the Khone Falls as a bottleneck has not been quantified so far. The proportion of Lower Mekong species that can breed in northern Cambodian tributaries without crossing the falls is also unknown.

• The Middle Mekong migration system is characterized by big tributaries and local wetlands; fish tend to migrate between these two habitats and the Mekong mainstream. Few publications detail the ecology of this area (Ubolratana Suntornratana *et al.* 2002, Jutagate *et al.* 2007) and the location of the upper boundary of this zone (approximately around Vientiane) is unclear.

• In the Upper Mekong migration system (which includes to some extent the Chinese Mekong or Lancang) fish migrate upstream to spawning habitats during the wet season. The upper limit of this ecological zone and the role of the local short tributaries in migrations are unknown.

We detail below these areas, and an estimate of their fish biomass (excerpt from Barlow *et al.* 2008)

1. Fish resources in the Lower Mekong migration system correspond to 100% of the Mekong yield in Cambodia and in Viet Nam. One estimate (Van Zalinge *et al.* 2004) based on fisheries catch studies amounts to 682,000 tonnes in Cambodia and 845,000 tonnes in Viet Nam. A second estimate, based on household consumption studies (Hortle 2007), amounts to 481,000 tonnes in Cambodia and 692,000 tonnes in Viet Nam. These estimates thus give a range for the fish production in the Lower Mekong Migration System:

• Estimate 1: (Cambodia: 682,000 tonnes x 100%) + (Viet Nam: 845,000 tonnes x 100%) = 1.53 million tonnes

• Estimate 2: (Cambodia: 481,000 tonnes x 100%) + (Viet Nam: 692,000 tonnes x 100%) = 1.17 million tonnes

Thus, the Lower Mekong migration system produces between 1.2 and 1.5 million tonnes of fish annually.

2. Fish resources in the Middle Mekong Migration System correspond to 100% of the yield in the Thai Mekong basin, and by our estimates 80% of the yield in the Lao Mekong. According to Van Zalinge *et al.* (2004) (Estimate 1), the Mekong Basin produces annually 932,000 tonnes in Thailand and 183,000 tonnes in Lao PDR; according to Hortle (2007) (Estimate 2), Thailand produces 720,000 tonnes a year and Lao PDR 168,000 tonnes. This leads to the following estimates of fish production for the middle system:

• Estimate 1: (Thailand: 932,000 tonnes x 100%) + (Lao PDR: 183,000 x 80%) = 1.08 million tonnes

• Estimate 2: (Thailand: 720,000 tonnes x 100%) + (Lao PDR: 168,000 x 80%) = 850,000 tonnes

Thus, the Middle Mekong migration system produces between 850,000 to 1 million tonnes annually. In this system, the environmental impact of dams will be spread between many more tributaries than in the lower system.

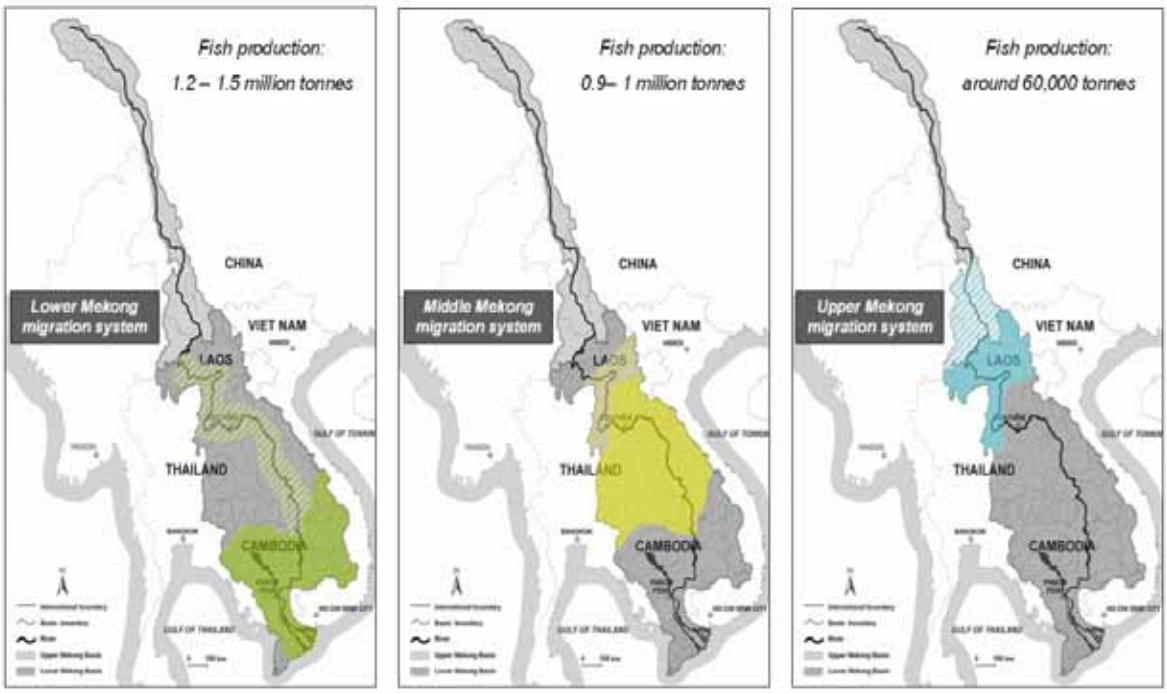
3. Fish resources in the Upper Mekong migration system correspond to 100% of the yield in the Chinese-Langcang Mekong (25,000 tonnes according to Xie and Li 2003) and 20% of the yield in the Lao section of the Mekong Basin. Hence, the estimates of fish production for the Upper Mekong Migration System are:

• Estimate 1: (China: 25,000 tonnes x 100%) + (Lao PDR: 183,000 x 20%) = 62,000 tonnes

• Estimate 2: (China: 25,000 tonnes x 100%) + (Lao PDR: 168,000 x 20%) = 58,000 tonnes

Thus, the Upper Mekong system produces around 60,000 tonnes of fish a year; this makes it the zone where there is the least to lose from hydropower development; however, this is a region of specific biodiversity, with a number of local species characteristic of headwaters, rapids and high streams. It should also be noted that this calculation of local yields at risk does not reflect far-fetched impacts, such as sediment retention in upstream dams and its impact on overall fish and river productivity.

Figure 22: Main migration systems within the Lower Mekong Basin

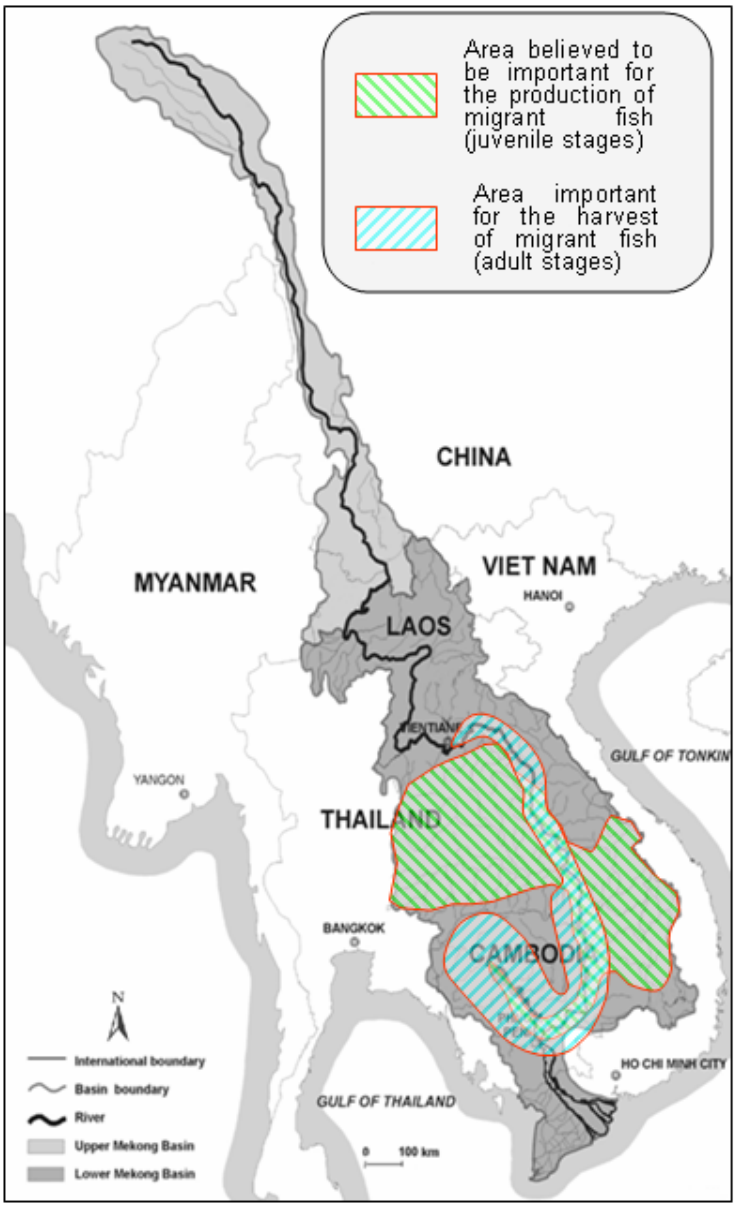


Note: a recent paper by Bin Kang et al. (2009) clarified the northern extent of the Upper Mekong migration system, that should be limited to the lower reach of the Lancang (from the Lao border to the Hiaohei sub-basin).

Last, given the large scale migration phenomenon, it must be highlighted that the southern area of the Mekong Basin (Lower Mekong migration system, Ecological zone 5) is productive because of its

connection with the adjacent zones upstream. In particular large tributaries in the Middle Mekong migration system are, for many migrant species, breeding areas or migration corridors allowing the downstream area to harvest the adult fish originating from upstream as juveniles (Figure 23).

Figure 23: Components of the fish production based on migrant fishes: production area for larvae and juveniles (originating from upstream breeding sites) and production area for adults (harvested downstream in floodplains).



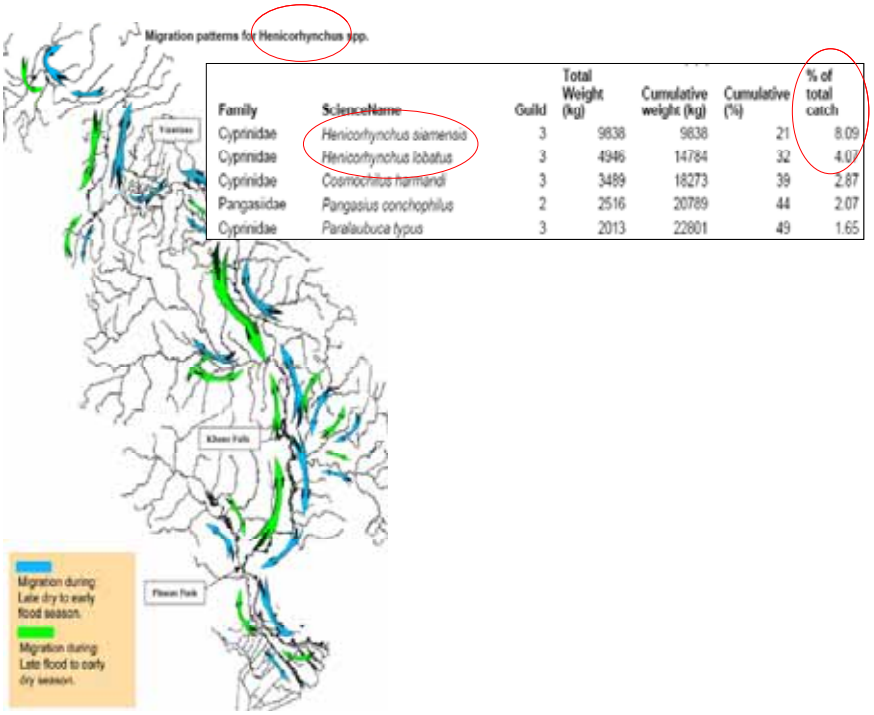
This map reflects dominant hypotheses about the functioning of the system but is not backed by data, and the limits of each area, although based on those of major watersheds, are arbitrary.

Migrations in tributaries

In the analysis below we combined the results of fish migration surveys done by Poulsen and his team (Poulsen *et al.* 2002, 2004) and documented in two CD-ROMs (MRC 2001 and MFD 2003), and the only assessment of fish abundance basinwide based on a standardized field sampling (protocol based on gill nets described in Starr 2008, preliminary results in Halls and Kshatriya *in press*).

Migration studies based on local knowledge systematically gathered throughout the basin resulted in a description of migration patterns for 23 species. Figure 24 shows an example of such a description for one particular species.

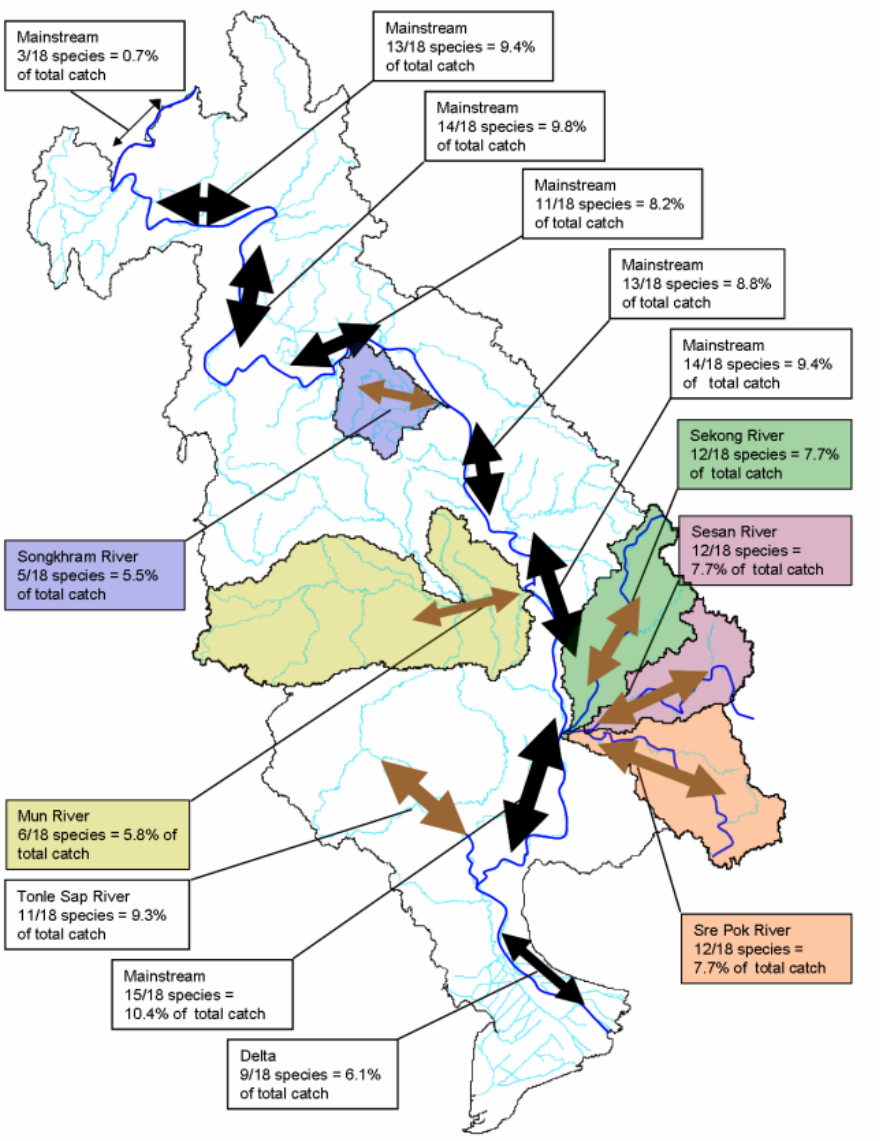
Figure 24: Combination, for one given species, of migration map produced by the MRC and of biomass estimates resulting from gillnet monitoring basinwide



Family	ScienceName	Guild	Total Weight (kg)	Cumulative weight (kg)	Cumulative (%)	% of total catch
Cyprinidae	Henicorhynchus siamensis	3	9838	9838	21	8.09
Cyprinidae	Henicorhynchus lobatus	3	4946	14784	32	4.07
Cyprinidae	Cosmochilus harmandi	3	3489	18273	39	2.87
Pangasiidae	Pangasius conchophilus	2	2516	20789	44	2.07
Cyprinidae	Paralaubuca typus	3	2013	22801	49	1.65

This information was then compiled for all the sub-basins of the Mekong, and weighted by the relative importance of each species in catches basinwide. The resulting map shows the main migration corridors in the Mekong Basin and, for the first time, the relative biomass involved (as indicated by the width of arrows). It should be noted that this map is based only on 18 species for which migration maps are available *and* relative importance in catches of gillnets is known; thus it should be taken as an indication of main migration corridors based on information available, but not as a precise summary of overall migrations basinwide.

Figure 25: Main migration corridors and their relative importance



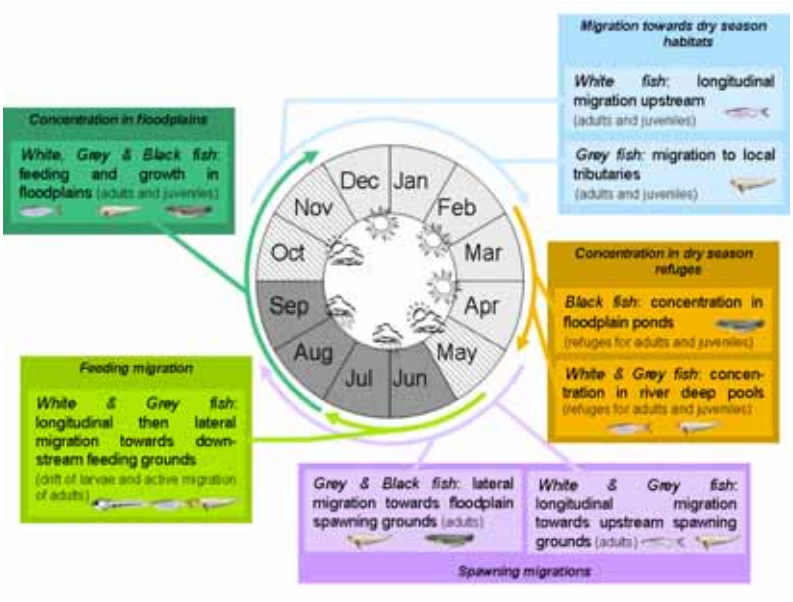
Conclusions:

The main migration corridor is the Mekong mainstream, and the area between Phnom Penh and Stung Treng features the highest number of migratory species for which migration maps exist. There are relatively far fewer species migrating in the delta, but a surprisingly steady number of species migrating all along the mainstream up to Northern Laos. This latter location is the place of least migration in the LMB. With 12 out of 18 species for which migration maps exist, the 3S system (Sesan, Srepok, Sekong Rivers) seems to play an important role (as important as the Tonle Sap River) among migratory species.

6.4.2 MIGRATIONS IN TIME

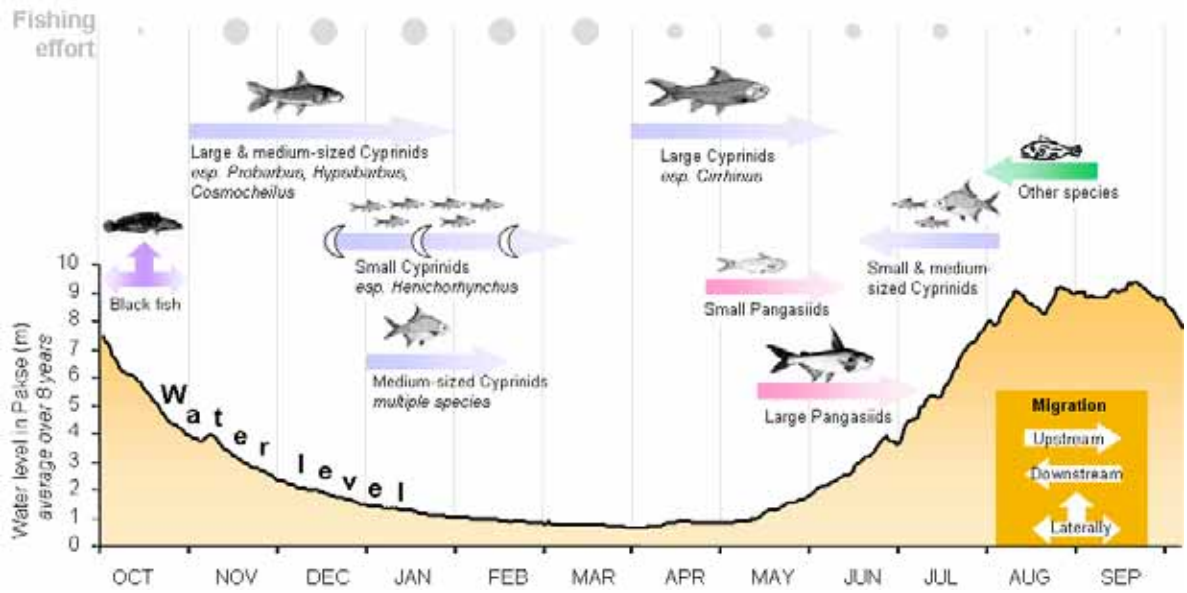
• In the Lower Mekong migration system most migrations take place during rising flood and during the drawdown period (Figure 26). For many fish species the spawning season occurs during rising water levels. White fish species generally migrate upstream for spawning, and subsequently the river transports the eggs and larvae downstream and onto floodplains. Black fish species, of which several are piscivores, often breed relatively early, so that by the time the larvae of the white fish arrive on the floodplain, the black fish are ready to exploit these for food.

Figure 26: Life cycle and migrations of fishes in the Lower Mekong migration zone



• In the Middle Mekong migration system, Khone Falls (southern Lao PDR) is a special and well studied area characterized by a series of waterfalls between the Lao plateaux and the southern lowlands of the Lower Mekong migration zone. In this is ecological corridor, multiple studies (Warren *et al.* 1998, Baird 2001, Baran *et al.* 2005) allowed the identification over time of eight distinct waves of fish migrations per year (Figure 27)

Figure 27: Migration patterns at Khone Falls



Source: Baird 2001

6.5 DAMS AND DISRUPTION OF MIGRATIONS

In the analysis below, we illustrate the area of the basin in which movements of long-distance migrants are already obstructed by existing dams. The map produced results from a superimposition of the map of migrations (Figure 25) and of a map of dams in hydrological basins.

A recent paper by Barlow *et al.* (2008) reviewed the possible consequences of mainstream dam development on fish production. The paper compares the conclusions based on three different approaches: the first one is based on interviews of a panel of experts (Dugan 2008); the second is based on analyses of published literature (Baran and Jutagate 2008); and the third one (Halls and Kshatriya *in press*) categorizes different species of fish into guilds based on their biology and then uses a fisher catch survey to determine the proportion of the catch that is highly threatened by dam construction.

The results from the three studies indicate that the migratory fish resources at risk from mainstream dam development in the Mekong is in the range 0.7 – 1.6 million tonnes per year (Table 39).

Figure 28: Areas where long-distance fish migrations between the mainstream and upper reaches are already obstructed by dams.

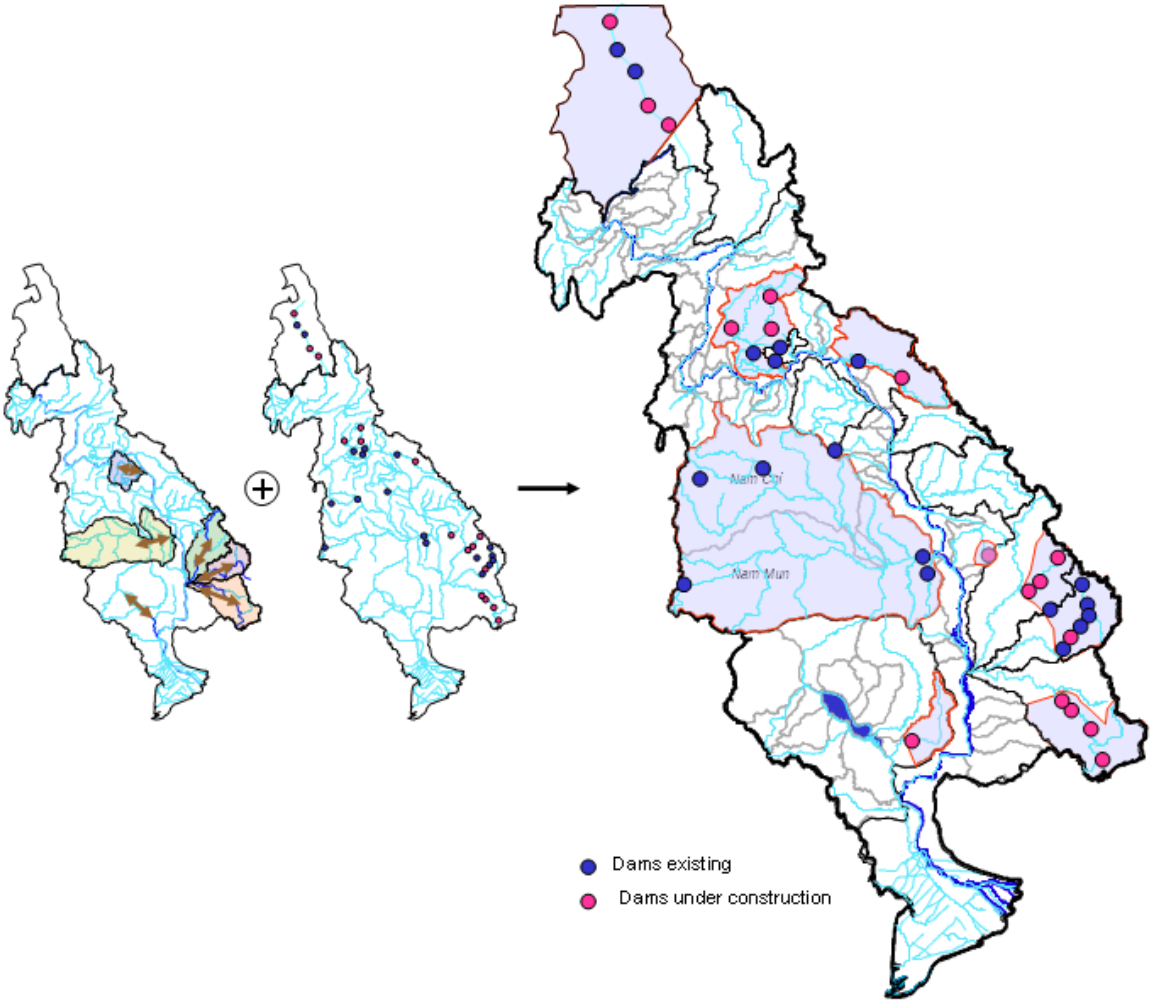


Table 39: Migratory fish resources at risk from mainstream dam development in the Mekong

Method	Estimate Derived	Annual yield (tonnes)	Annual Value (USD million)
1	Highly migratory fish resources in the LMB	1,320,000	2,500*
2	Highly migratory fish resources in the LMB	1,270,000 – 1,570,000	2,400 – 3,000*
	- Lower Mekong Migration System (Viet Nam to Khone Falls)	*750,000 – 950,000*	*1,400 – 1,800**
	- Middle Mekong Migration System (Khone Falls to Vientiane)	*500,000 – 600,000*	*950 – 1,100**
	- Upper Mekong Migration System (Vientiane to China border)	*20,000*	*37**
3	Highly vulnerable migratory fish groups in the LMB	744,000	1,400*

The size of the migratory fish resources in the Lower and Middle Migrations Systems (between the delta and Vientiane) is far larger than the resource in the Upper Migration System (northern Lao PDR).

Therefore, dams built in the Lower and Middle Migration Systems are likely to have a greater impact on fisheries production in the LMB than dams built in the Upper Migration System.

Barriers to migration do not have the same effect on all fish species. An analysis of studies worldwide (Welcomme *et al.* 1989) shows that:

- obligate migratory fish species tend to disappear when the main channels are blocked, despite mitigation measures such as fish passes or fish stocking;
- floodplain spawners are selected against when the annual flood is reduced or eliminated;
- fish assemblages tend to shift from floodplain spawners toward main channel spawners.

In Africa, a review of case studies (Lévêque 1997) concludes that the closure of a dam is generally followed by two phases: i) an increase in fish populations fit to lacustrine conditions such as small clupeids, then ii) a subsequent increase of predators that sharply reduces the previous populations. Overall the change in species composition is marked and hard to predict, but native riverine species often disappear.

In South America, three main generic fishery states have been identified: i) in undisturbed, unregulated rivers, catches are dominated by high value large silurids and characins; ii) in developed, regulated rivers, fisheries are still supported by migratory fish of decreasing size, but there is an increasing contribution of less valuable species and appearance of exotics; iii) in dammed rivers with reservoir fisheries, the proportion of migratory fish in catches descends well below 50%, catches become dominated by "black fish" species, and the number of exotic species rises further.

In the Mekong River system, white fish that undertake long-distance longitudinal migrations of several hundred kilometres will be much more impacted by barriers to migrations than black fishes whose home range is much smaller. The "white fish" guild includes in particular Cyprinidae (many species), Balitoridae, Cobitidae and Pangasiidae. That latter family will be among those severely impacted since a majority of its species migrate over long distances with complex migration patterns such as the Mekong giant catfish (*Pangasianodon gigas*) and the anadromous *Pangasius krempfi*.

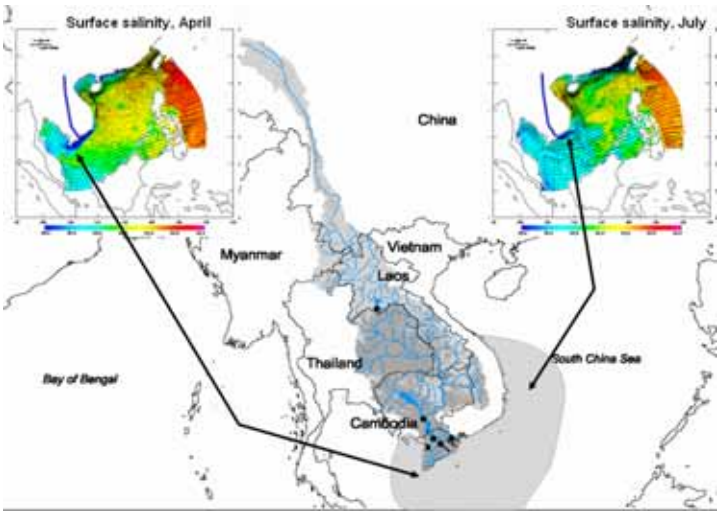
The "grey fish" guild is a rather heterogeneous group composed of species having in common the need to migrate between floodplains and local tributaries. Thus, they will not be sensitive the physical barrier constituted by mainstream dams, but might be as sensitive as "white fish" to dams built on local tributaries. Overall the characteristics of "grey fish" species vary a lot from species to species, and it is difficult to predict an overall response for that guild.

The "black fish' guild is characterized by adaptations that allow individuals to endure adverse conditions on the floodplain, such as low dissolved oxygen. These fishes are able to better survive in lacustrine conditions and are believed to be able to somehow adapt to altered hydrographs. This guild includes families such as Channidae, Clariidae, Bagridae and Anabantidae. It is believed that robust black fishes might do well in reservoirs; this actually reflects confusion between the robustness of adult individuals and an assumed similar robustness throughout their life history that would enable them to breed in and adapt to reservoirs. Such robustness at all life history stages remains to be demonstrated.

6.6 INTERACTIONS BETWEEN THE RIVER AND THE COASTAL ZONE

The importance and richness of the estuarine and coastal areas, which constitute an intrinsic part of the Mekong system, should be highlighted. In tropical systems the connexions between rivers outflows and coastal productivity are well known (review in Loneragan and Bunn 1999) and in the Mekong the importance of river inputs to the fisheries productivity of the coastal zone has been known for a long time (Chevey 1933, Lagler 1976, Poulsen *et al.* 2002). The extent of the Mekong influence in the coastal zone and of the subsequent coastal estuary whose productivity depends upon Mekong discharge and sediments is illustrated below.

Figure 29: Extent of brackish areas around the Ca Mau peninsula, depending on seasons.



Source: Xue *et al.* 2000.

A remarkable concentration of fish can be noticed at the mouths of the Bassac and Mekong Rivers at the beginning of the dry season. The fish are attracted by the enormous concentration of nitrogenous material coming from the Mekong and their scales register the sharp acceleration of growth that results.

Chevey 1933

The loss of nutrients, either dissolved or in organic silt, from the plume of the Mekong/Bassac will certainly diminish productivity in the near-shore areas and to a lesser extent in the off-shore areas. The fishery of the Mekong plume in the South China Sea also will be subject to impacts of the controlled and augmented low-flow regime.

Lagler 1976

Unfortunately the rivers outflow - coastal productivity connection has been poorly recognized in research and development agendas (Blaber 2002) and as far as we know there is no information to be reviewed on that topic. This highlights an important gap in research regarding the impact of Mekong mainstream dams on fish resources.

7 FUTURE TRENDS WITHOUT MAINSTREAM HYDROPOWER DEVELOPMENT

7.1 TRENDS IN AQUACULTURE AND CAPTURE FISHERIES

The only statistics available on a yearly basis and allowing an assessment of trends over years are those of the FAO, originating from riparian line agencies. We present below the trends in fisheries and aquaculture for the countries of the Lower Mekong Basin.

Table 40: Production in the capture fisheries and aquaculture sectors in the four LMB countries since 2000. Inland capture fisheries, inland and brackish aquaculture production, in tonnes.

	2000	2001	2002	2003	2004	2005	2006	2007
Aquaculture Cambodia	14002	13463	14133	17886	20200	25500	33570	33570
Aquaculture Lao PDR	42066	50000	59716	64900	64900	78000	78000	78000
Aquaculture Thailand	259885	262815	275262	329006	486397	506331	498392	475751
Aquaculture Viet Nam	365015	383186	441827	599824	761566	961100	1157045	1530300
Capture Cambodia	245300	384500	359800	308250	249600	323500	421400	419400
Capture Lao PDR	29250	31000	33440	29800	29800	26560	26925	26925
Capture Thailand	201205	202200	198200	197493	202600	194159	208400	218010
Capture Viet Nam	180000	188542	163615	148959	134075	130400	136200	133600

Source: FAO Figis (*http://www.fao.org/fishery/statistics/global-aquaculture-production/query/en*)

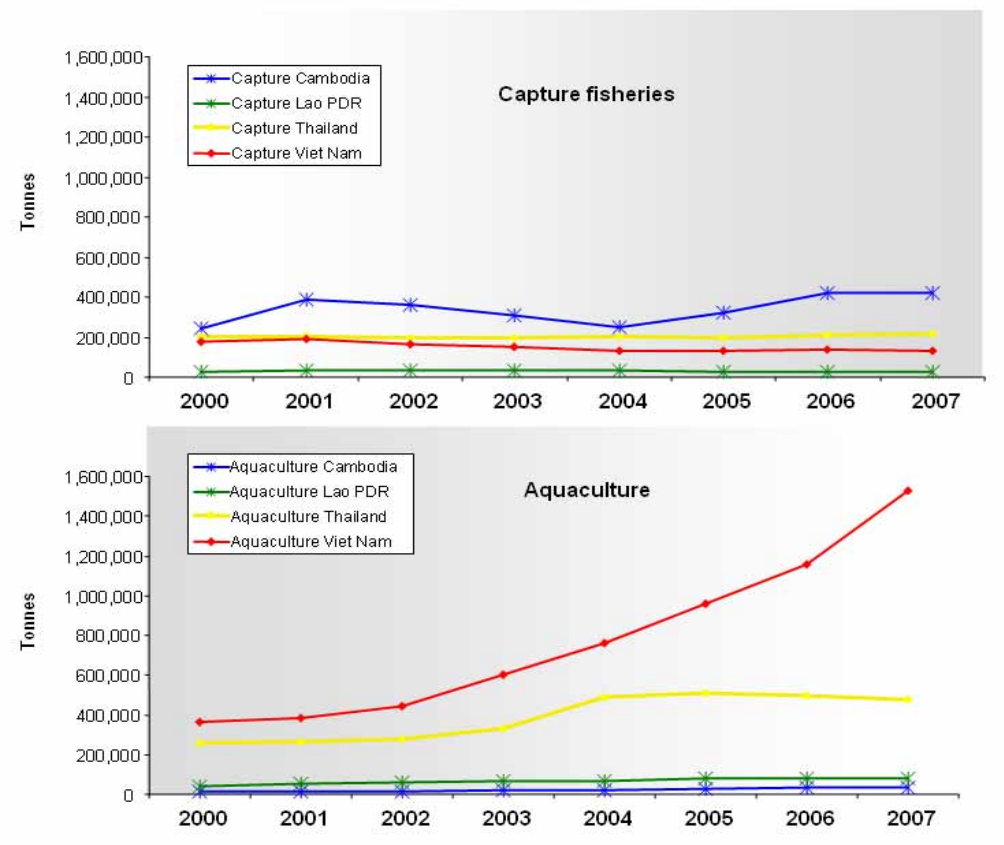
Table 41: Growth in the inland/brackish aquaculture sector (percentage of growth compared to the previous year). Source: FAO Figis.

	2001	2002	2003	2004	2005	2006	2007
Cambodia	-3.8	5.0	26.6	12.9	26.2	31.6	0.0
Lao PDR	18.9	19.4	8.7	0.0	20.2	0.0	0.0
Thailand	1.1	4.7	19.5	47.8	4.1	-1.6	-4.5
Viet Nam	5.0	15.3	35.8	27.0	26.2	20.4	32.3

Conclusions:

Capture fisheries: While many press articles refer to declining catches among fishermen, there is no evidence from national statistics that the yield from capture fisheries is declining in the four LMB countries. However, recent reviews emphasize the fact that capture fisheries yields are becoming static and that little or no growth is to be expected from that sector in the years to come (Lymer *et al. 2008*; Kirby *et al.* 2008). In Cambodia the only long-term database of field-based catch records, from the *dai* fishery in Cambodia, indicates no upward or downward trend in yields between 1995-96 and 2007-08 (Halls *et al.* 2008). Baran and Myschowoda (2008) examined long-term trends in catches in the Tonle Sap area and concluded that over the last 60 years there has been a decline in the catch per fisherman because the fish biomass, although it increased substantially over time, did not increase as fast as the human population.

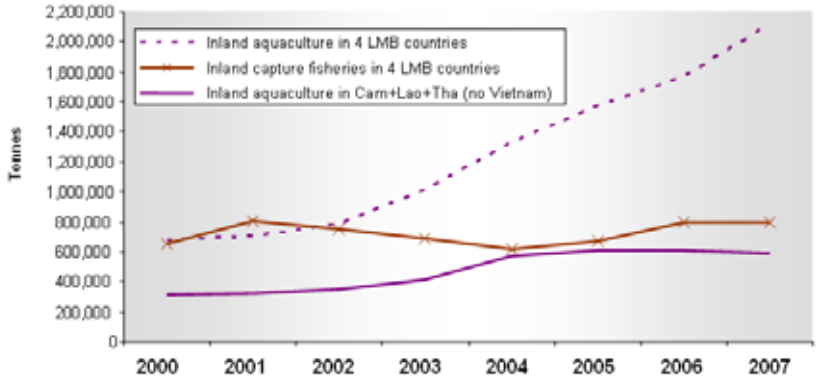
Figure 30: Production in inland capture fisheries and in inland/brackish aquaculture sectors in the four LMB countries since 2000.



Source: FAO Figis.

Aquaculture sector: in inland/brackish water aquaculture, only one country, Viet Nam, features a high annual growth (+28% a year over the last 5 years) and high production levels (1.5 million tonnes in 2007). In Cambodia, annual growth is substantial but the production level is very low; in Lao PDR figures are erratic but low; and in Thailand the inland/brackish aquaculture production, having reached a high level - around 500,000 tonnes/year - is showing signs of stabilization if not decline.

Figure 31: Comparative trends in inland/brackish water aquaculture and capture fisheries.



Source: see Table 40.

Conclusions:

According to national statistics, when all countries are lumped together, the production of the inland/brackish aquaculture sector in the LMB is more than double that of the inland fisheries sector (respectively 1.82 and 0.75 million tonnes on average over the last 3 years). However, when the exceptional case of Viet Nam is put aside, the production of the inland aquaculture sector in Cambodia, Lao PDR and Thailand remains inferior to the production of the inland fisheries sector in these countries.

7.2 PERSPECTIVES IN AQUACULTURE AND CAPTURE FISHERIES

Tentative forecasts are proposed below; they are based on a projection of growth observed in the past 7 years in both capture and aquaculture sectors (inland and brackish aquaculture, freshwater fisheries; Table 40).

Table 42: Average growth rate in aquaculture and capture fisheries for the LMB countries

	Average growth between 2000 and 2007 (%)
Aquaculture Cambodia	14.1
Aquaculture Lao PDR	9.6
Aquaculture Thailand	10.2
Aquaculture Viet Nam	23.1
Capture fisheries Cambodia	10.9
Capture fisheries Lao PDR	-0.9
Capture fisheries Thailand	1.2
Capture fisheries Viet Nam	-3.9

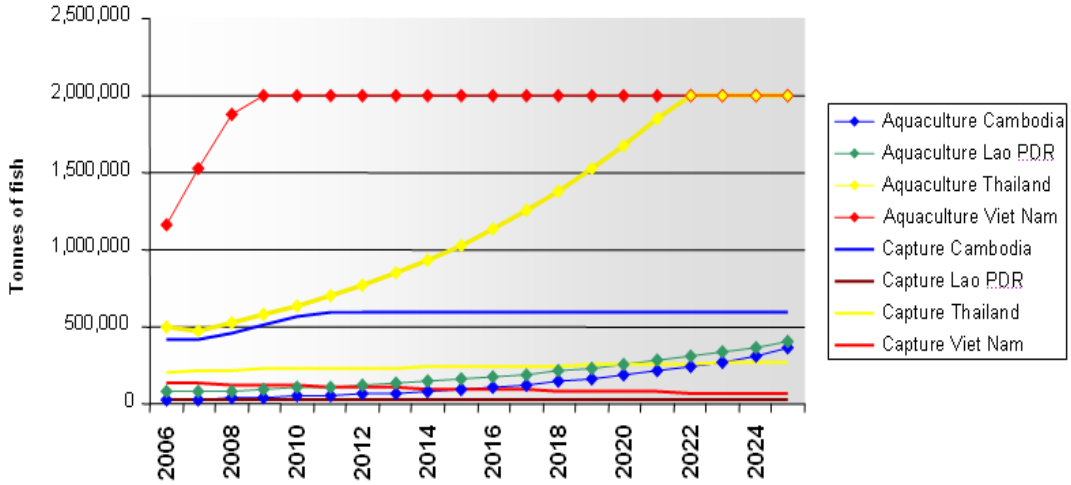
Some assumptions are made:

- aquaculture production in Viet Nam and Thailand cannot grow beyond 2 million tonnes a year, because of i) market pricing making fish production less valuable when production doubles, ii) space available, and iii) risk of diseases at very high production levels;
- capture fish yield in Cambodia cannot go beyond 600,000 tonnes (record annual yield so far has been 421,000 tonnes) because 2 million tonnes of fish caught basinwide corresponds to the

maximum estimate accepted (and to a baseline situation, in good environmental conditions) and Cambodia harvests approximately a third of this total biomass (section 1.1.3)

Under these assumptions, the fish production expected by 2025 is illustrated in Figure 32.

Figure 32: Status of fisheries and aquaculture production predicted on the basis of the growth rate experienced since 2000.

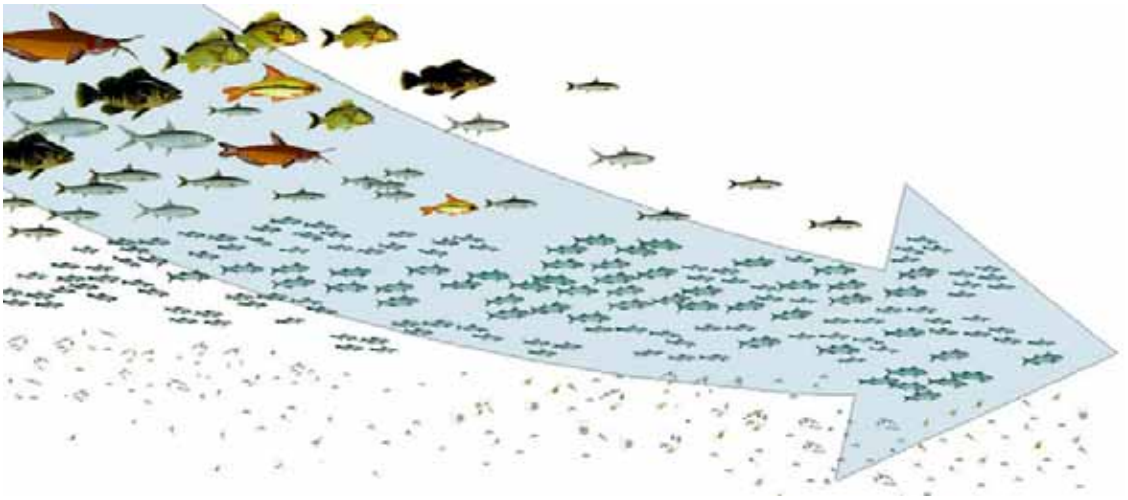


Conclusions:

If the average growth rate of the past 7 years is sustained, Viet Nam is expected to reach a plateau in aquaculture production (an arbitrary 2 million tonnes a year) a few years from now, while Thailand would reach the same plateau around 2020. At the same period aquaculture production in Cambodia and Lao PDR would reach around 200,000 and 300,000 tonnes respectively. As for capture fisheries, Cambodia would reach a plateau (an arbitrary 600,000 tonnes) a few years from now, while catch in the three other countries would remain steady and close to their current level. These predictions are of course very hypothetical since they depend completely on economic and governance factors currently not accounted for.

Two qualitative predictions can also be made about capture fisheries: i) a progressive reduction over years of the size and quality of fish harvested, and ii) an increased variability and unpredictability of catches from year to year. The first trend, due to the progressive disappearance of big species particularly targeted by fishers, corresponds to the process of "fishing down food webs" (Pauly *et al.* 1998) and has already been described in the case of Mekong fisheries by Van Zalinge *et al.* in 2001; it is largely confirmed by fishermen. The second trend is the consequence of the first one: big species that live several years and are not very sensitive to annual hydrological variability are replaced by small opportunistic species whose abundance is largely driven by the annual flood pattern, as they grow quickly and die young. This will create a boom-and-bust cycle, with years of high abundance followed by years of shortage.

Figure 33: Fishing down food webs, or the progressive replacement, by intensive fishing, of large long-life species by small short-life species.



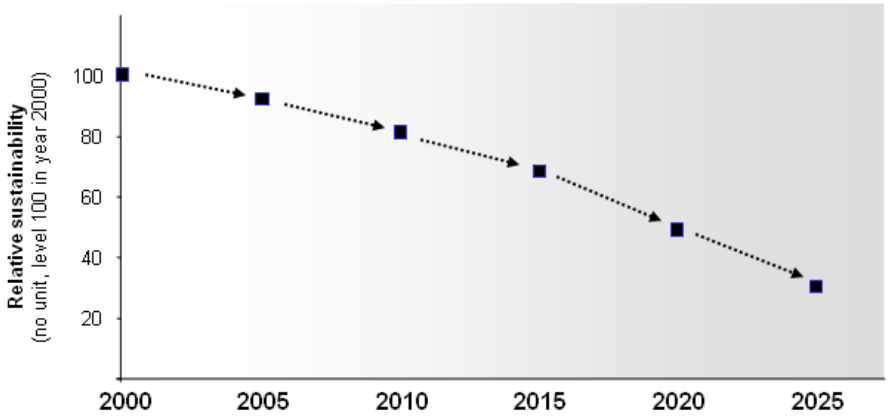
Since accurate predictions cannot be made on growth rates only, we detail below a more detailed semi-quantitative approach for capture fisheries. This approach integrates the BDP2 "Definite future" scenario whose dams, assumptions and model forecasts are detailed in Annex 1.

This prediction of trends is based on the factors driving fish catch detailed in section 3.1; these factors are the flood level, the flood duration, the flood timing, the presence and nature of flooded vegetation, the number of built structures reducing hydrological connectivity, the availability of refuges, the number of fishers and the fishing intensity (i.e. fish mortality rate due to the evolution of gears).

Trends are expressed by a number (-2 for strong decrease, -1 for moderate decrease, 0 if unchanged, +1 if moderate increase, +2 if strong increase) and a brief justification; then each factor is given a weight depending on its impact on the sustainability of the catch (1 if small, 2 if moderate, 3 if important). Ultimately for each factor the trend and the weight are multiplied, and the resulting number is a number of units expressing the impact on fish catch. For each period of five years between 2000 and 2025 all units are summed; the sum is a number expressing, in relative terms, the overall trend related to the fish catch. The result of this process is presented in Table 43.

Thus, the overview, assuming a level 100 in 2000, results in the conclusion that there has been a loss – quantified in relative units – of sustainability between 2000 and 2005, and more loss between 2005 and 2010. This leads to the prediction, in the case of the definite future scenario, of a progressive erosion of sustainability over the next 15 years, for the reasons detailed in the table. In 2025 and in absence of mainstream dams, the prospects of sustainability of Mekong fisheries would be approximately a third of what they are now, for a combination of reasons pertaining to fishing pressure, dams existing and in construction on tributaries, and changes in the floodplain environment.

Figure 34: Trend in sustainability of Mekong fisheries. Figure based on Table 43, with a baseline in 2000 (level 100).



7.3 AQUACULTURE AS A REPLACEMENT OF CAPTURE FISHERIES?

The above results show that the production of capture fisheries is exceptionally high and is not declining (the apparent decline in catch per unit of effort being attributed to an increase in population and fishing effort rather than to a decrease in biomass harvested). However, in some discourses the decline of capture fisheries is already framed in relation to dam construction basinwide (Bush and Hirsch 2005, Friend *et al.* 2009), and aquaculture is presented as a means of replacing the losses of capture fisheries. Although this strategy is not part of official policies in the Mekong countries, it is recurrently mentioned in multiple reports, EIAs, discussions and fora.

Replacing capture fisheries production by aquaculture production is not realistic, for several reasons detailed below.

• As currently practiced, an unclear but large proportion of the aquaculture sector depends on capture fisheries for feed. According to Nuov and Nandeesha (1993), 4 kg of fresh low value fish are needed as feed during the fishing season to produce one kilogram of cage culture fish. The use of inland wild fish as aquafeed is not significant in Northern Thailand and Lao PDR, but very substantial in Cambodia and Viet Nam (FAO 2005). In Viet Nam, farm-made feed uses on average 13.6% of freshwater fish and 86% of marine species (FAO 2005). The demand for capture fish creates a competition between the aquaculture sector and rural communities: in Cambodia, 16% of low value fish is used for aquaculture and 84% for human consumption (So *et al.* 2007); this competition led to the ban of snakehead culture in Cambodia in 2004. However, at the scale of the Lower Mekong Basin a precise assessment of the role of low value capture fish versus imported pellet feed in the aquaculture sector remains to be done.

Table 43: Trends in fish catch defined and predicted for the 2000-2005 period

	2000-2005				2005-2010				2010-2015				2015-2020				2020-2025			
	Trend	Reason	Weight	Impact	Trend	Reason	Weight	Impact	Trend	Reason	Weight	Impact	Trend	Reason	Weight	Impact	Trend	Reason	Weight	Impact
Flood level	0	Flow close to baseline	3	0	0	Flow close to baseline	3	0	0	Beginning of a reduction of flood level	3	0	-1	Progressive reduction of flood level	3	-3	-1	Flood level reduced by 15% in northenn Laos, down to -3% in Vietnam	3	-3
Flood duration	0	Flow close to baseline	2	0	0	Flow close to baseline	2	0	0	Beginning of a small change in duration	2	0	-1	Modelling predicts a small shortening (5-10%) of duration	2	-2	-1	Modelling predicts a small shortening (5-10%) of duration	2	-2
Flood timing	0	Flow close to baseline	1	0	0	Flow close to baseline	1	0	0	Flow close to baseline	1	0	0	Modelling predicts a marginal change (a few days) in timing	1	0	0	Modelling predicts a marginal change (a few days) in timing	1	0
Flooded vegetatio	-1	Increased deforestation for rice cultivation	1	-1	-1	Increased deforestation for rice cultivation	1	-1	-1	Deforestation, first irrigation schemes (pollutants)	1	-1	-2	Deforestation, more irrigation schemes (pollutants)	1	-2	-2	Deforestation, more irrigation schemes (pollutants)	1	-2
Built structures	0	No major infrastructure development	3	0	-1	More floodplain roads and dykes	3	-3	-1	More floodplain roads and dykes	3	-3	-2	More floodplain roads and dykes, more dams; reservoirs won't compensate	3	-6	-2	More floodplain roads and dykes, more dams	3	-6
Refuges	-1	More pumping in floodplains, deep pools unchanged	2	-2	-1	Systematic pumping in floodplains, deep pools unchanged	2	-2	-2	Systematic pumping in floodplains, deep pools unchanged	2	-4	-2	Systematic pumping in floodplains, sediments in deep pools because of reduced flushes	2	-4	-2	Systematic pumping in floodplains, deep pools unchanged	2	-4
Number of fishers	1	Population growth, more demand	3	-3	1	More demand, economic crisis, women involved	3	-3	1	More population but more urban alternatives; slight augmentation	3	-3	0	More urban alternatives; CPUE decreasing	3	0	0	More urban alternatives; more agriculture; CPUE bad	3	0
Fishing intensity (technology)	1	Gear size increases and mesh size decreases progressively	2	-2	1	Gear size increases and mesh size decreases progressively	2	-2	1	Gear size increases and mesh size decreases progressively	2	-2	1	Gear size increases and mesh size decreases progressively	2	-2	1	Gear size increases and mesh size decreases progressively	2	-2
Overall trend (arbitrary units):	-8				-11				-13				-16				-16			

• Producing aquaculture fish is much more costly than capturing wild fish (although the market price of capture fish can be higher because wild fish is favored by consumers). From an all-inclusive economic viewpoint, the cost of one tonne of fish is much lower in the fisheries sector than in the aquaculture sector, since capture fishes are grown at almost no cost (no hatcheries, no installations, no feed, no maintenance, only the cost of gears and the fishers' time).

• Intensive aquaculture does not contribute much to food security in rural areas (although this sector provides employment and income to workers) and extensive aquaculture is not very productive. Intensive aquaculture (e.g. catfish production in the delta) is very technical, usually based on high value carnivorous species, and accessible only to better-off individuals having land, access to information and sufficient capital; this production mode targets the export market and generates income. More generally intensive aquaculture has a history of environmental impacts and social conflicts (Bush 2008). Extensive aquaculture on the contrary is based on herbivorous or omnivorous species; it is neither capital nor technology intensive and, like capture fisheries, it does provide substantial income at the household or village level and a contribution to food security. However, this system, which could locally replace the loss of capture fish, is not very productive for several reasons: no or little inputs are used, the supply of fingerlings is always a bottleneck, and without genetic maintenance, it tends to lose 20-40% productivity over a few years (Brummett and Ponzoni 2009). In fact studies have shown that technically a higher productivity is possible, through the use of manures or farm wastes for instance (Prein and Ahmed 2000, IIRR et al. 2001) but it is mainly socio-economic and institutional reasons (e.g. land availability, access to quality fry, tenure issues) that have impeded aquaculture development in some of the LMB countries (Phillips 2002, Lebel et al. *in press*).

• Under current practices, a significant proportion of the aquaculture sector depends on capture fisheries for fingerlings. Viet Nam being an exception in terms of aquaculture infrastructure and technology, in the rest of the basin cage fish aquaculture remains largely dependent on fish seed caught in the wild. In Cambodia for instance, in 2001 the culture of 19 species out of 33 (57%) was based on supply of fingerlings from the wild (DoF 2001). More generally the level of dependency of the artisanal aquaculture sector on wild fry in unknown, and this is an area where research is needed.

In Viet Nam the catfish production has recently soared, but this is largely an export commodity (although increasing living standards progressively make this commodity more affordable for the local market). Given the considerable investment in promoting aquaculture development in Cambodia, Lao PDR and Thailand over the last decades, it is difficult to conceive, in the years to come, development of the extensive aquaculture sector leading to production able to replace losses from the fisheries sector. In Cambodia for instance, at a growth rate of 20% per year, it would take 27 years for aquaculture to produce as much as local fisheries. Thus aquaculture can *ameliorate* fish supply from capture fisheries but cannot replace it.

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