



Project
“A Climate Resilient Mekong: Maintaining the Flows that Nourish Life”
led by the Natural Heritage Institute

FEATURES OF HIGH FISH PRODUCTIVITY IN THE MEKONG BASIN

Case of 32 biodiversity hotspots

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EXECUTIVE SUMMARY

In 2010 the BDP2 program of the Mekong River Commission identified 32 environmental hotspots in the basin, mostly wetlands along the Mekong River. These hotspots were identified based on species richness, area sensitivity, number of species at risk and existing protection schemes. In the current analysis we used these 32 hotspots as an entry point and focused on fish productivity, which was not covered in the BDP 2 assessment.

Our analysis shows that the size of hotspots varies considerably (from 400 to 540,000 ha), which calls for a standardization by hectare -at risk of introducing a devaluation of the large hotspots. The highest diversity of aquatic habitats is found in the largest hotspots: the Songkhram River, the Tonle Sap Lake, the Chiang Saen – Chiang Khong corridor, and the Mekong mainstream north of Stung Treng. However the highest number of habitats per hectare is found in two of the smallest hotspots: Nong Bong Kai in Thailand and Tra Su in Vietnam.

Biodiversity

In the BDP2 review only 20 of the 32 hotspots feature fish-related information. Fish species diversity is realistically documented for 12 hotspots only. Among those, four hotspots stand out: Kut Ting marshland and Bung Khong Long area; the Chiang Saen - Chiang Khong river corridor and Siphandon wetlands. Despite their high absolute fish diversity, large hotspots such as the Tonle Sap system and the Songkhram River are characterized by a relatively lower diversity per hectare. Three Mekong hotspots stand out for their number of endemic fish species (Bun Kong Long area, Kut Ting marshland and the Songkhram River) and four for their high number of endangered species (Kut Ting marshland; the Chiang Saen - Chiang Khong river corridor, the Mekong upstream of Luang Prabang and the Siphandon wetlands). In the BDP2 review only four hotspots are documented for important spawning grounds and two for the presence of migratory fish species.

Overall, five hotspots feature higher fish habitat and biodiversity scores: the Chiang Saen – Chiang Khong section of the Mekong mainstream, the Siphandon wetland, the Kut Ting marshland, the Nong Bong Kai and Bun Khong Long areas in Thailand. The Mekong channel upstream of Luang Prabang also stands out for its high number of endangered fish species.

Productivity

In a system featuring more than 37% of long distance migratory fishes, a focus on productivity is biased by an undervaluation of upstream breeding zones where juveniles are generated but not caught and an overvaluation of downstream feeding zones where adults are caught but not generated. There is unfortunately no estimate at the moment of the virtual production/productivity of upstream zones where the juveniles of most long-distance migratory species are generated.

An analysis focusing on fish consumption as a proxy of fish productivity shows that 9 hotspots are located in areas of very high fish consumption (i.e. mainly in the Tonle Sap watershed), 20 in areas of medium to high fish consumption and 3 in areas of lower fish consumption. The analysis focusing on fish catch along the 6 main stretches of the Mekong shows that hotspots 2 to 5 (between the Chinese border and Vientiane) and 13 to 15 (between Pakse and Kratie) are located in the sections of the Mekong Basin where fish yield is the lowest. Hotspots 8, 9 and 12, located on the mainstream between Vientiane and Siphandon, correspond to a moderately productive zone. Downstream of Sung Treng, hotspots 18, 19, and 21 to 32 are located in the most productive section of the Mekong Basin.

In conclusion the choice of the 32 environmental hotspots as a reference in view of assessing the impact of sediment load modification on fish biodiversity and productivity can be disputed for several reasons; in particular the large range of hotspot sizes results in a juxtaposition of systems of different nature; the fact that several hotspots were also selected from an ornithological perspective, and the fact that no data is available on fish productivity for these hotspots.

An assessment of the fish productivity and impact of sediment reduction in different zones in the Mekong would require a typology of the different ecozones or watersheds, an estimate of the ratio of migratory and non-migratory fish in each zone and a fish stock estimate for each zone. The approach and model developed by Ziv *et al.* (2012) offers perspectives for such assessment.

1 INTRODUCTION

The Mekong Basin is remarkable for its productivity but also for its biodiversity. According to *fishbase.org*, the basin is the second richest river in the world in terms of fish biodiversity after the Amazon.

The Mekong is regarded as the largest inland fishery in the world. Catch estimates differ depending on sources, ranging between 0.75 million tons (FAO FIGIS figures) and 2.6 million tons. According to the most reliable source (Hortle 2007), the fish harvest amounts to around 2.1 million tons a year, which corresponds to 18% of the world freshwater fish catch.

In the Mekong Basin, Cambodia produces between 23 and 51% of the overall Mekong fish catch, while Thailand contributes 27 to 35% and Vietnam fish production represents 18 to 34% of the LMB fish yield (Baran 2010). Laos harvests only around 5% of that total production.

Capture fisheries in the Mekong Basin contribute between USD 1.4 billion per year (Sverdrup-Jensen 2002) and USD 2.2-3.9 billion (Hortle 2009) to the economy of the riparian countries. In the Mekong Delta in Vietnam, inland fisheries provide full-time and part-time jobs to 60% of the people and 88% of the poor people there depend heavily on fisheries (UNEP 2010). In Cambodia, inland fisheries provide employment to 11% of the Cambodian people (UNEP 2010). Fish is also extremely important to food security since the four riparian countries are the top four in the world for freshwater fish consumption.

The Mekong is also remarkable for its fish migrations. Baran (2010) showed that that migratory fish makes up to 37% of the total biomass harvested. This assessment is very close to the 38.5% of the total catch attributed to migratory species by Halls and Kshatriya (2009) following a different approach.

In Figure 1 below we summarize the interactions between biodiversity, fish migrations, fisheries and food security in the Lower Mekong Basin.

In 2010 the Basin Development Plan –Phase 2 (BDP 2) of the Mekong River Commission identified 32 environmental hotspots in the basin (5 in Laos, 4 in Thailand, 13 in Cambodia, 6 in Viet Nam, and 4 hotspots shared by more than one country; MRC 2010). The BDP report describes valuable wetland ecosystems of the Lower Mekong Basin and their species composition, with an emphasis on rare and endangered species, and expected impacts of different basin development scenarios on these hotspots. The 32 environmental hotspots are classified based on species richness, area sensitivity, number of species at risk and existing protection schemes (Ramsar sites, Biosphere Reserves, Protected Areas, Important Bird Areas and Greater Mekong Subregion).

In the current report we use the 32 BDP2 hotspots as an entry point and focus on fish productivity, which was not covered in the BDP 2 assessment more focused on biodiversity and conservation.

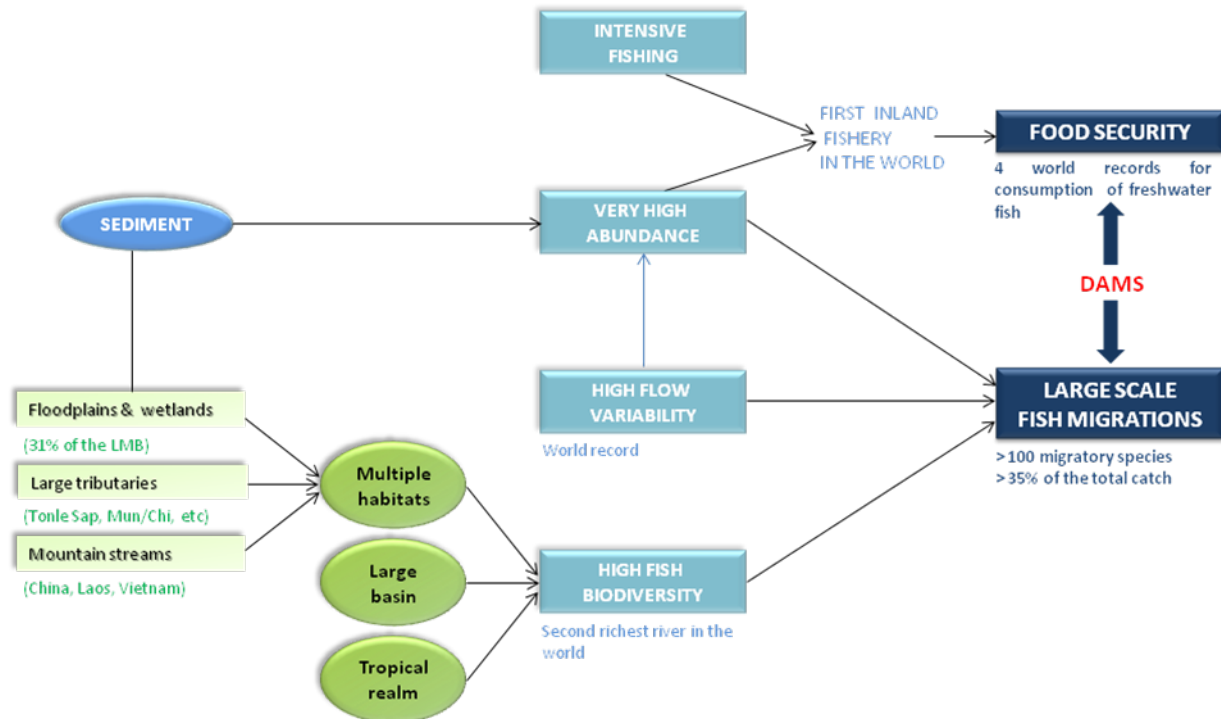


Figure 1: Interactions between biodiversity, fish migrations, fisheries and food security in the Lower Mekong Basin. Source : modified from Baran and Un (in press).

2 GENERIC FEATURES OF THE 32 MEKONG HOTSPOTS

In this section we describe a few features that have not been detailed in the BDP2 analysis, starting with a brief overview of the hotspots, from North to South.

2.1 Brief overview

- **# 1 Nong Bong Kai Non-Hunting Area (Thailand):** a very small spot very rich in fish
- **# 3 Mekong channel from Chiang Saen to Chiang Khong:** this stretch is remarkable in terms of habitat diversity, endemic species and endangered species. If this area is combined with hotspot number 5 (Mekong Channel from Luang Prabang to Vientiane, Laos), the combination corresponds to the Ecological zone 2 (from Chiang Saen to Vientiane) of the 6 mainstream ecological zones defined by the BDP (MRC 2005).
- **# 6 Mekong channel from Vientiane to the Mun River confluence and # 12 Mekong channel from Savannakhet to Khone Falls/Siphandon:** the combination of these two hotspots corresponds to BDP zone 3 (Vientiane to Pakse; MRC 2005). The fish yield in this zone does not contribute much to the economy but is extremely important to the local people's livelihood and food security (Garaway, 1999; Na Mahasarakarm, 2007).
- **# 7 Bung Khong Long non-hunting area (Thailand) and # 8 Kut Ting Marshland (Thailand):** Two wetlands very small but very rich in term of number of fish species, of endemics and of endangered species
- **# 13 Khone Falls –Siphandon (Laos):** a very well documented area of extremely high importance in the Mekong. The Khone Falls constitute a natural barrier to many migratory species but the extensive wetland made of “four thousand islands” represents “*an ecologically unique area that is essentially a microcosm of the entire lower Mekong River*” (Hill and Hill 1994). Regardless of the Khone Falls and country border this zone can be combined to hotspot **# 14 (Mekong channel from Lao border to Kratie)**, which then constitutes the hydrological Zone 3 (Pakse to Kratie) defined by the BDP (MRC 2005).
- **# 19 Tonle Sap Lake, Tonle Sap River, Prek Toal, and adjacent floodplain (including Chhnuk Tru, Stung / Chi Kreng / Kampong Svay, Veal Srongae; Cambodia):** This group corresponds to vast areas of high fish biodiversity, but the latter is always proportional to watershed area. Thus these hotspots are characterized by a high biodiversity but a low biodiversity per hectare. Endemism is also relatively low in this zone (the lowest after the delta).
- The remaining hotspots (one in Laos, six in Cambodia, six in Vietnam) are characterized by the absence of fish-related information in the BDP 2 report; the reason for selection as hotspots is often their importance vis-à-vis bird life.

2.2 Map of the hotspots

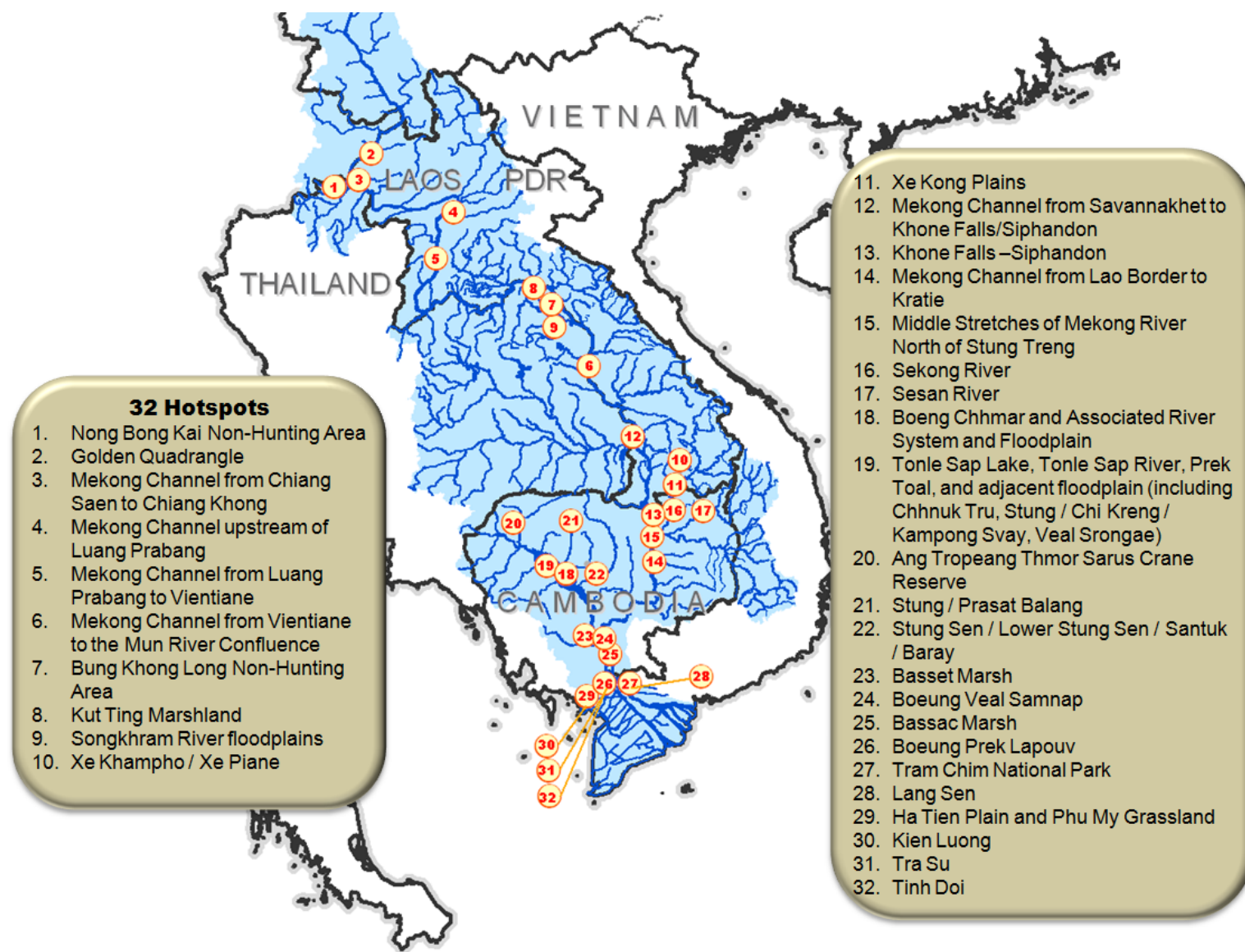


Figure 2: Location of the 32 environmental hotspots identified by the BDP2. Source: MRC 2010 for the list of sites, complemented with Internet and Google Earth for the identification of sites

2.3 Size of the hotspots

The BDP2 technical note n° 9 presents fragmentary information on fish for some of the hotspots. In fact twenty out of 32 hotspots are documented for at least one descriptor of the fish resource (species richness, endangered species, endemic species, habitats, important spawning ground or presence of migratory species). The surface area of these different hotspots is also partly documented, and we have complemented data using Google Earth¹ (Table 1)

#	Name of Hotspot	Area (ha)
1	Nong Bong Kai Area	434
2	Golden Quadrangle	185200
3	Chiang Saen - Khong Mekong	3000
4	Mekong Channel upstream of Luang Prabang	19400
5	Luang Prabang - Vientiane Mekong	28900
6	Vientiane - Mun River Mekong	65900
7	Bung Khong Long Area	2 214
8	Kut Ting Marshland	2 600
9	Songkhram River	300 000
10	Xe Khampho / Xe Piane	2 000
11	Xe Kong Plains	37 150
12	Savannakhet - Siphandon Mekong	90100
13	Siphandon	6 000
14	Lao Border - Kratie Mekong	62500
15	Stung Treng Mekong	14 600
16	Sekong River	14 116
17	Sesan River	20 504
18	Boeng Chhmar	39 405
19	Tonle Sap system	541 800
20	Ang Tropeang Thmor Reserve	12 659
21	Stung / Prasat Balang	100 675
22	Stung Sen	12 390
23	Basset Marsh	2 770
24	Boeung Veal Samnap	11 286
25	Bassac Marsh	52 316
26	Boeung Prek Lapouv	9 276
27	Tram Chim National Park	7 740
28	Lang Sen	3 280
29	Ha Tien Plain and Phu My	6 981
30	Kien Luong	7 624
31	Tra Su	860
32	Tinh Doi	1 643

Table 1: Surface area of the 32 BDP2 hotspots.

¹ For river stretches, the Google Earth area measurement tool of was used to quantify the surface area of riverine zones in a given stretch

The size of the hotspots varies considerably, from 400 to 540,000 ha. Figure 3 below illustrates the heterogeneity of the hotspots in terms of surface area, since they range from small swamps (e.g. Nong Bong Kai, 434 ha) to large ecosystems (Tonle Sap, 541,000 ha). This has an important implication in terms of comparison of the hotspot features, and calls for a standardization by hectare (at risk of introducing a devaluation of the large hotspots).

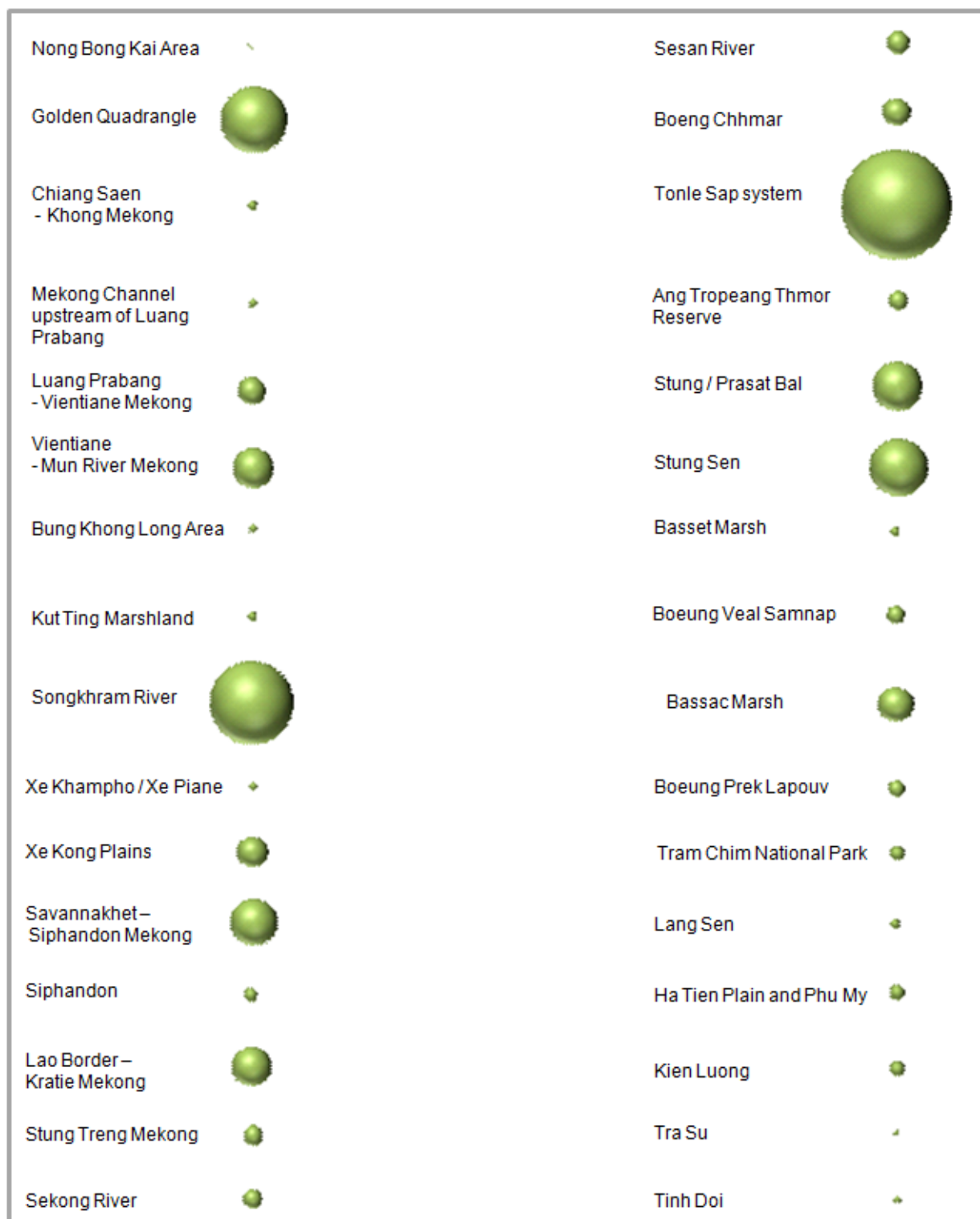


Figure 3: Comparison of the surface area of the 32 BDP2 hotspots

2.4 Aquatic habitats

The BDP 2 report identifies the number of different aquatic habitats present in each hotspot: *River channels; Deep pools; Rapids & waterfalls, Riverine sandbars & beaches or islands; Riverbanks & river bank gardens; Seasonally inundated forests; Lakes, ponds, marshes & swamps; Seasonally inundated grasslands; Riverine floodplains, and Ricefields.*

We summarized in Table 2 and Figure 4 the number of habitats in each hotspot.

#	Name of Hotspot	# of habitat	Area (ha)	# of habitats per ha	# of habitats/ha (rank)
1	Nong Bong Kai Area	4	434	0,922	1
31	Tra Su	4	860	0,465	2
3	Chiang Saen - Khong Mekong	7	3000	0,233	3
8	Kut Ting Marshland	4	2600	0,154	4
28	Lang Sen	5	3280	0,152	5
10	Xe Khampho / Xe Piane	3	2000	0,150	6
23	Basset Marsh	4	2770	0,144	7
32	Tinh Doi	2	1643	0,122	8
7	Bung Khong Long Area	2	2214	0,090	9
13	Siphandon	5	6000	0,083	10
30	Kien Luong	5	7624	0,066	11
29	Ha Tien Plain and Phu My	4	6981	0,057	12
15	Stung Treng Mekong	7	14600	0,048	13
27	Tram Chim National Park	3	7740	0,039	14
24	Boeung Veal Samnap	4	11286	0,035	15
4	Mekong upstream of Luang Prabang	5	19400	0,026	16
22	Stung Sen	3	12390	0,024	17
26	Boeung Prek Lapouv	2	9276	0,022	18
5	Luang Prabang - Vientiane Mekong	6	28900	0,021	19
20	Ang Tropeang Thmor Reserve	2	12659	0,016	20
17	Sesan River	3	20504	0,015	21
16	Sekong River	2	14116	0,014	22
11	Xe Kong Plains	5	37150	0,013	23
18	Boeng Chhmar	5	39405	0,013	24
14	Lao border - Kratie Mekong	6	62500	0,010	25
25	Bassac Marsh	4	52316	0,008	26
6	Vientiane - Mun River Mekong	5	65900	0,008	27
21	Stung / Prasat Balang	4	100675	0,004	28
12	Savannakhet - Siphandon Mekong	3	90100	0,003	29
9	Songkhram River	8	300000	0,003	30
19	Tonle Sap system	7	541800	0,001	31
2	Golden Quadrangle	2	185200	0,001	32

Table 2: Number of aquatic habitats and number of habitat per hectare in the 32 Mekong hotspots

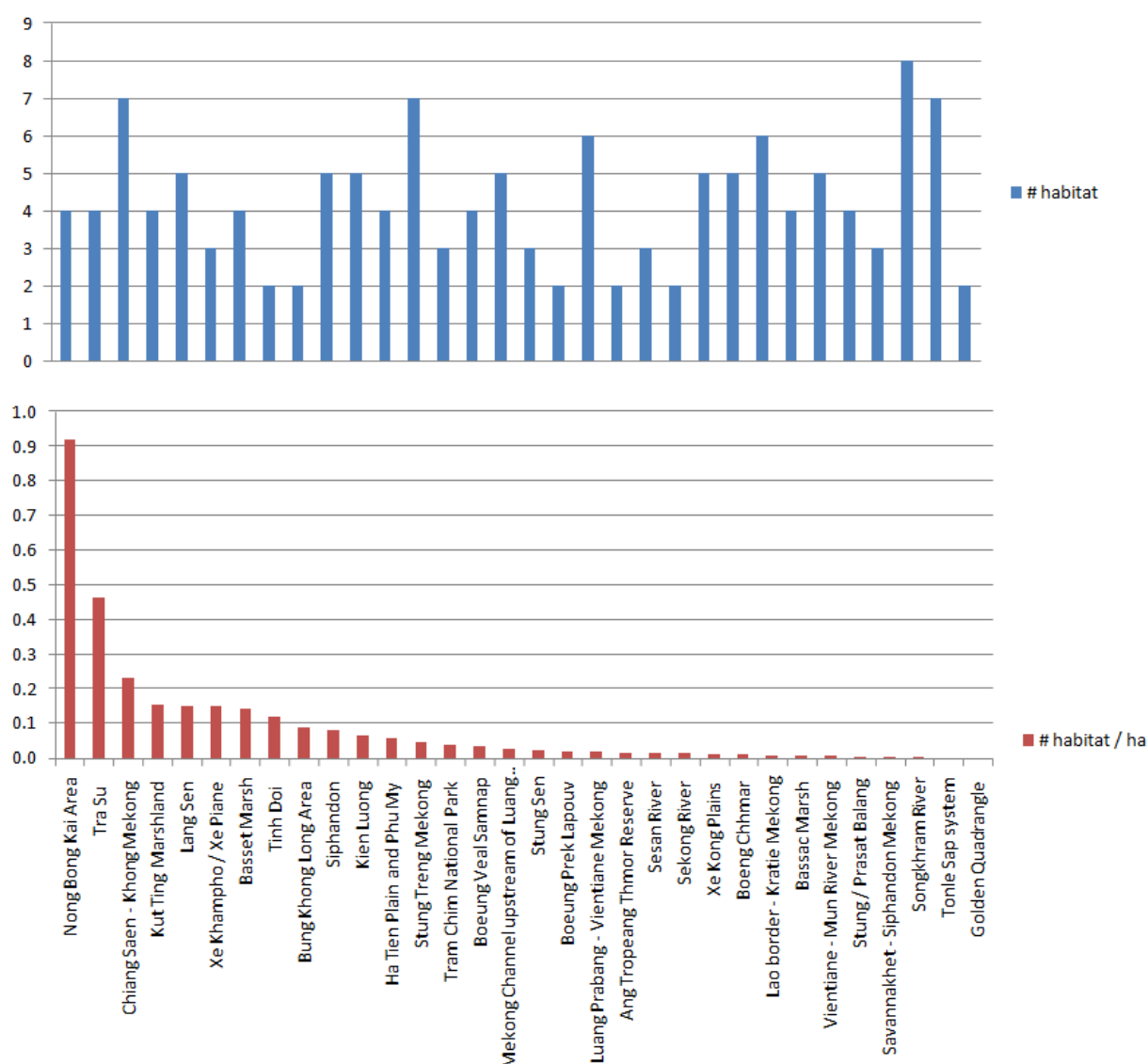


Figure 4: Absolute number of aquatic habitats and number of aquatic habitats per hectare in the Mekong hotspots

The highest diversity of aquatic habitats is found in the largest hotspots: (Songkhram River, Tonle Sap Lake, Chiang Saen – Chiang Khong corridor, Mekong mainstream north of Stung Treng) and the highest number of habitats per hectare is found in two of the smallest hotspots : Nong Bong Kai in Thailand and Tra Su in Vietnam. The highest diversity of aquatic habitats is found in four hotspots (Songkhram River in Thailand, Chiang Saen – Chiang Khong section of the Mekong mainstream in Laos/Thailand , and the middle stretches fo the Mekong north of Stung Treng and the Tonle Sap Lake in Cambodia. Two of these hotspots (Songkhram River and Tonle Sap Lake) are characterized by a very large surface area (>300,000 ha) which explains the diversity, but two of them (Chiang Saen – Chiang Khong corridor and the Mekong mainstream north of Stung Treng.) are substantially smaller (3000 to 14,600 ha) and therefore more remarkable for their intrinsic diversity. In terms of habitats per hectare, the highest density of habitats is found in two of the smallest hotspots : Nong Bong Kai in Thailand and Tra Su in Vietnam. These two hotspots feature a diversity of aquatic habitats much higher than all the other Mekong hotspots of the Mekong.

Here again in the analysis focused on habitat diversity *per hectare* the large hotspots have a low rank despite a high number of habitat for some of them.

3 FISH BIODIVERSITY IN THE 32 MEKONG HOTSPOTS

3.1 Fish-related information

Only 20 of the 32 hotspots feature fish-related information. This is explained by the fact that some wetlands have been identified as hotspots since they are of importance for bird conservation (e.g. Ang Tropeang Thmor Sarus Crane Reserve, Stung Prasat Balang site of the critically endangered Bengal florican, Basset marsh, Lang Sen wetland reserve, Phu My grassland, Kien Long, Tinh Doi, etc).

#	Name of Hotspot	Data on fish
1	Nong Bong Kai Area	yes
2	Golden Quadrangle	yes
3	Chiang Saen - Khong Mekong	yes
4	Mekong Channel upstream of Luang Prabang	yes
5	Luang Prabang - Vientiane Mekong	yes
6	Vientiane - Mun River Mekong	yes
7	Bung Khong Long Area	yes
8	Kut Ting Marshland	yes
9	Songkhram River	yes
10	Xe Khampho / Xe Piane	yes
11	Xe Kong Plains	yes
12	Savannakhet - Siphandon Mekong	yes
13	Siphandon	yes
14	Lao Border - Kratie Mekong	yes
15	Stung Treng Mekong	yes
16	Sekong River	yes
17	Sesan River	yes
18	Boeng Chhmar	yes
19	Tonle Sap system	yes
20	Ang Tropeang Thmor Reserve	-
21	Stung / Prasat Balang	-
22	Stung Sen	-
23	Basset Marsh	-
24	Boeung Veal Samnap	-
25	Bassac Marsh	yes
26	Boeung Prek Lapouv	-
27	Tram Chim National Park	-
28	Lang Sen	-
29	Ha Tien Plain and Phu My	-
30	Kien Luong	-
31	Tra Su	-
32	Tinh Doi	-

Table 3: Fish information in the 32 BDP2 hotspots.

3.2 Fish species richness

Fish species diversity is realistically documented for 12 hotspots only. Fish species diversity is documented for 13 of the 32 hotspots, but the figure for Boeung Tonle Chhmar (500 species) is unrealistic. Boeung Tonle Chhmar is a subset of the Tonle Sap system whose species diversity is amounted to 215 species². More specifically, the UNDP Boeung Tonle Chhmar core area management plan 2008-2012 mentions 107 fish species (TSCP, MoE, MAFF 2008). Thus 12 hotspots only are considered in the fish species richness analyses.

#	Name of Hotspot	Nb of species	Fish diversity (rank)	Area (ha)	Fish diversity / ha	Rank fish diversity / ha (rank)
8	Kut Ting Marshland	123	9	2 600	4,73	1
13	Siphandon	205	2	6 000	3,42	2
3	Chiang Saen - Khong	100	10	3000	3,33	3
7	Bung Khong Long Area	66	11	2 214	2,98	4
15	Mekong upstream of Stung Treng	167	4	14 600	1,14	5
16	Sekong River	149	6	14 116	1,06	6
17	Sesan River	149	7	20 504	0,73	7
11	Xe Kong Plains	127	8	37 150	0,34	8
25	Bassac Marsh	155	5	52 316	0,30	9
1	Nong Bong Kai Area	46	12	434	0,11	10
9	Songkhram River	183	3	300 000	0,06	11
19	Tonle Sap system	215	1	541 800	0,04	12

Table 4: Fish diversity and fish diversity per hectare in the 12 hotspots where fish richness has been documented.

Fish diversity and fish diversity per hectare in the hotspots are illustrated in Figure 5 below.

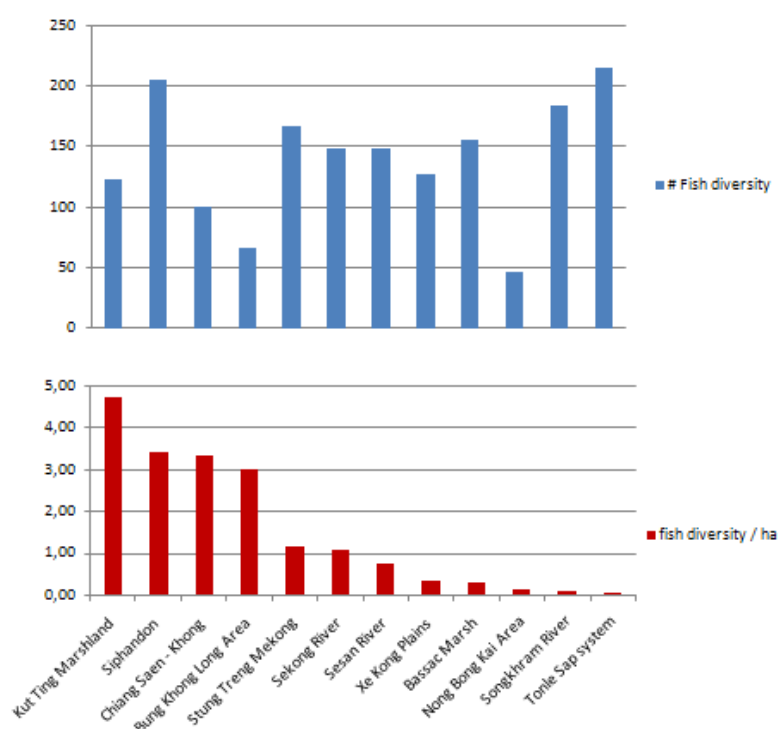


Figure 5: Absolute fish diversity and fish diversity per hectare in the Mekong hotspots

² The number of species for the Tonle Sap is itself underestimated; Baran *et al.* (2007) identified 296 species for this zone.

In terms of fish biodiversity, four hotspots stand out: Kut Ting marshland; Bung Khong Long; Chiang Saen - Chiang Khong river corridor and Siphandon wetlands. With 3 species or more per hectare, a group of four hotspots features a significantly higher relative fish diversity than all others hotspots: the Kut Ting marshland and the Bung Khong Long area in Thailand, and the Chiang Saen - Chiang Khong mainstream corridor and the Khone Falls / Siphandon area in Laos. These 4 hotspots are of limited surface area (6000 ha or less). The Siphandon site is remarkable due to its high absolute diversity (over 200 species) as well as its high diversity per hectare.

Despite their high absolute fish diversity, the large hotspots such as the Tonle Sap system and the Songkhram River are characterized by a relatively lower diversity per hectare. Hotspots defined as large areas or long river segments suffer from a devaluation of their biodiversity value when the latter is a ratio of number of species per hectare. If the species richness per hectare is useful for the prioritization of management and protection interventions, the analysis based on absolute biodiversity remains essential to highlight the richness of some Mekong biota, whatever their size.

3.3 Endemics fish species

In the BDP2 assessment of 32 hotspots, endangered fish species are documented for 12 hotspots only (Table 5 and Figure 6).

#	Name of Hotspot	# Endemics	Rank endemics	#Area	Endemics/ha	Rank Endemics/ha
7	Bung Khong Long Area	9	3	2 214	0,00406504	1
8	Kut Ting Marshland	9	2	2 600	0,00346154	2
13	Siphandon	3	6	6 000	0,0005	3
3	Chiang Saen - Khong Mekong	1	8	3000	0,00033333	4
4	Mekong upstream Luang Pbg	1	9	3000	0,00033333	5
5	Luang Pbg - Vientiane Mekong	2	7	28900	6,9204E-05	6
9	Songkhram River	20	1	300 000	6,6667E-05	7
6	Vientiane - Mun River Mekong	3	5	65900	4,5524E-05	8
14	Lao Border - Kratie Mekong	1	10	62500	0,000016	9
12	Savannakhet - Siphandon	1	11	90100	1,1099E-05	10
19	Tonle Sap system	5	4	541 800	9,2285E-06	11
2	Golden Quadrangle	1	12	185200	5,3996E-06	12

Table 5: Endemic fish species and endemic fish species per hectare in 12 hotspots

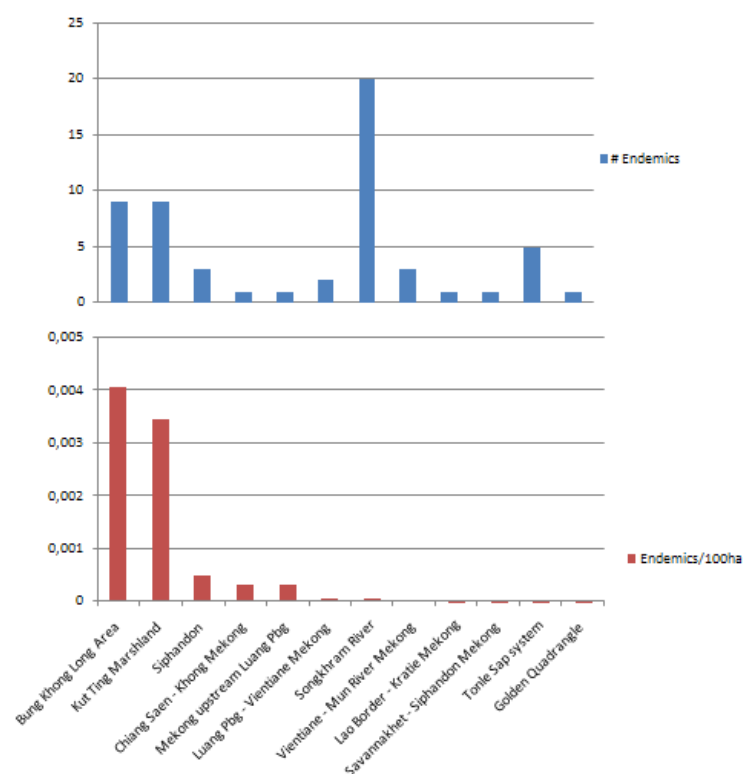


Figure 6: Number of endemic fish species and number of endemic fish species per hectare in the 12 hotspots.

In terms of endemic fish species, three Mekong hotspots stand out: **Bun Kong Long area, Kut Ting marshland and the Songkhram River**. One hotspot stands out in terms of absolute number of endemic fish species: the Songkhram River in Thailand, with 20 endemic fish species. Two other hotspots are characterized by an exceptionally high number of endemic fish species per hectare: Bung Khong Long and Kut Ting marshland in Thailand.

3.4 Endangered fish species

In the BDP2 assessment of 32 hotspots, endangered fish species are documented for 12 hotspots (Table 6 and Figure 7).

#	Name of Hotspot	# of endangered species	Endangered species (rank)	Area (ha)	# of endangered species /ha	Endangered species /ha (rank)
3	Chiang Saen - Khong Mekong	2	7	3000	0,00066667	1
8	Kut Ting Marshland	1	8	2 600	0,00038462	2
4	Upstream Luang Prabang	1	9	3000	0,00033333	3
13	Siphandon	2	6	6 000	0,00033333	4
5	LPB - Vientiane Mekong	5	4	28900	0,00017301	5
6	Vientiane - Mun Mekong	6	3	65900	9,1047E-05	6
11	Xe Kong Plains	3	5	37 150	8,0754E-05	7
9	Songkhram River	7	1	300 000	2,3333E-05	8
14	Lao border - Kratie Mekong	1	10	62500	0,000016	9
12	Savannakhet - Siphandon	1	11	90100	1,1099E-05	10
19	Tonle Sap system	6	2	541 800	1,1074E-05	11
2	Golden Quadrangle	1	12	185200	5,3996E-06	12

Table 6: Endangered fish species and endangered fish species per ha for 12 hotspots where the presence of endangered fish species has been documented

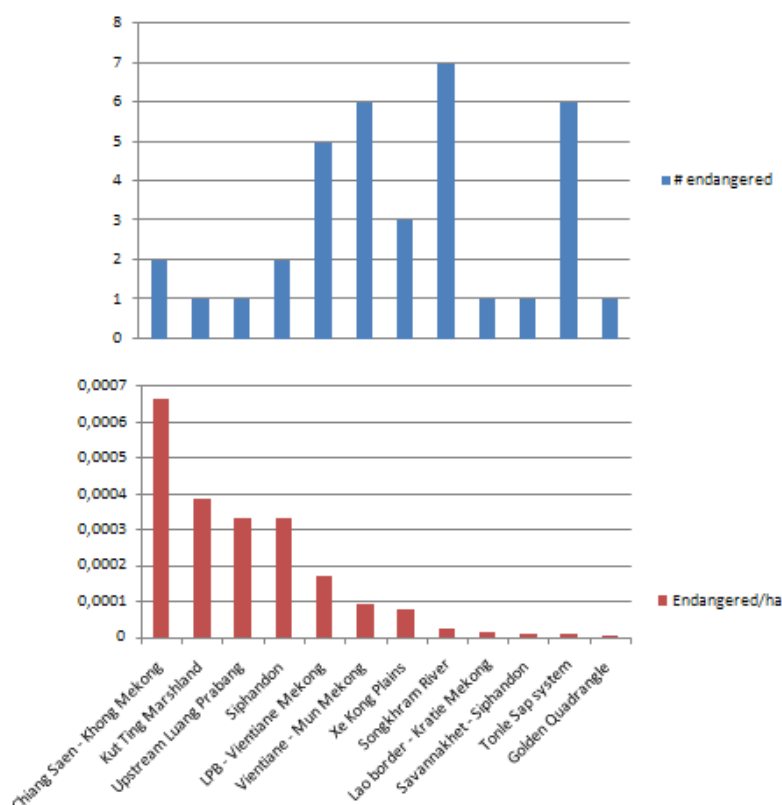


Figure 7: Number of endangered fish species and number of endangered fish species/ha for 12 Mekong biodiversity hotspots

In terms of endangered fish species, four Mekong hotspots stand out: Kut Ting marshland; the Chiang Saen - Chiang Khong river corridor, the Mekong upstream of Luang Prabang and the Siphandon wetlands. Four hotspots stand out in the analysis of the number of endangered fish species per hectare: the Kut Ting marshland in Thailand, the and the Chiang Saen - Chiang Khong mainstream corridor, the Mekong upstream of Luang Prabang (actually the Chiang Khong - Luang Prabang river corridor) and the Khone Falls / Siphandon area in Laos. The absolute number of endangered fish species is the highest in the Songkhram River (7 species) and the number of endangered species per hectare in the Chiang Saen - Chiang Khong river corridor is by far the highest in the Mekong.

3.5 Spawning grounds and migratory fishes

In the BDP2 review only four hotspots are documented as important spawning grounds and two for the presence of migratory fish species. Hotspots known for their fish spawning grounds are the Chiang Saen - Chiang Khong Mekong corridor, the Khone Falls / Siphandone area (in particular Don Tholati wetland), the Xe Khampho / Xe Plane wetlands and the Mekong mainstream upstream of Stung Treng (between Stung Treng and Khone Falls).

#	Name of Hotspot	Important spawning ground	# of migratory species
1	Nong Bong Kai Non-Hunting Area		15
3	Mekong Channel from Chiang Saen to Chiang Khong	Yes	
9	Songkhram River floodplains		116
10	Xe Khampho / Xe Pian	Yes	
13	Khone Falls –Siphandon	Yes	
15	Middle Stretches of Mekong River North of Stung Treng	Yes	

Table 7: Mekong hotspots where migratory species and spawning ground have been documented

3.6 Conclusions about fish biodiversity in the 32 hotspots

In the table below we propose a summary presentation of the hotspots biodiversity value. For each criterion, hotspots have been ranked in 3 categories of decreasing biodiversity value: first tier of the 32 hotspots in red, second tier in orange and third tier in yellow. This method allows visualizing the overall value of each hotspot vis-à-vis fish biodiversity, without entering a definite ordering and prioritization of hotspots, since the latter exercise should include many other criteria than those four.

According to this table, five hotspots stand out for being in the first tier of all hotspots for at least two fish biodiversity criteria:

- The **Chiang Saen – Chiang Khong section of the Mekong mainstream** (high diversity of habitats, high species diversity, high endemism, presence of a high number of endangered species)
- The **Siphandon wetlands** in the Mekong mainstream at the Lao/Thai/Cambodia border (same reasons)
- The **Kut Ting marshland** in Thailand (same reasons, very small area)
- The **Nong Bong Kai area** in Thailand (small area but high diversity of habitats and high species diversity)
- The **Bun Khong Long area** in Thailand (small area but high diversity of habitats and high number of endemic species)

The **Mekong channel upstream of Luang Prabang** also stands out for its high number of endangered fish species.

#	Name of Hotspot	Area (ha)	Species /ha (rank)	Endemic sp/ha (rank)	Endangered sp/ha (rank)	Habitats/ha (rank)
1	Nong Bong Kai Area	434	1			1
2	Golden Quadrangle	185200		12	12	32
3	Chiang Saen - Khong Mekong	3000	4	4	1	3
4	Mekong Channel upstream of Luang Prabang	3000		5	4	16
5	Luang Prabang - Vientiane Mekong	28900		6	5	19
6	Vientiane - Mun River Mekong	65900		8	6	27
7	Bung Khong Long Area	2214	5	1		9
8	Kut Ting Marshland	2600	2	2	2	4
9	Songkhram River	300000	11	7	8	30
10	Xe Khampho / Xe Piane	2000				6
11	Xe Kong Plains	37150	9		7	23
12	Savannakhet - Siphandon Mekong	90100		10	10	29
13	Siphandon	6000	3	3	3	10
14	Lao Border - Kratie Mekong	62500		9	9	25
15	Stung Treng Mekong	14600	6			13
16	Sekong River	14116	7			22
17	Sesan River	20504	8			21
18	Boeng Chhmar	28000				24
19	Tonle Sap system	541800	12	11	11	31
20	Ang Tropeang Thmor Reserve	12659				20
21	Stung / Prasat Balang	100675				28
22	Stung Sen	145783				17
23	Basset Marsh	2770				7
24	Boeung Veal Samnap	11286				15
25	Bassac Marsh	52316	10			26
26	Boeung Prek Lapouv	9276				18
27	Tram Chim National Park	7740				14
28	Lang Sen	3280				5
29	Ha Tien Plain and Phu My	6981				12
30	Kien Luong	7624				11
31	Tra Su	860				2
32	Tinh Doi	1643				8

4 FISH PRODUCTIVITY OF THE 32 HOTSPOTS

“Fish productivity” is defined as a *biomass per surface area and per year*. The term *“fish production”*, which refers to a *biomass per year* regardless of the area considered, is often inappropriately used instead of fish productivity.

Fish productivity of the 32 hotspots is not documented in the BDP 2 analysis. Actually only one study (Hortle 2010) has examined fish productivity at a large scale, other studies being focussed on the fish productivity of floodplains or rice fields.

In his study of fish productivity basinwide and impact of dams, Hortle identified productivity by habitat for three broad classes of habitat³ then assessed, using GIS, the extent of each habitat class in each country, and ultimately calculated the resulting production per country. Unfortunately the resolution of this large scale approach is not compatible with the size and habitat diversity of most BDP2 hotspots.

Given the need of a finer resolution and in absence of comprehensive high resolution fish productivity studies, we focussed on fish production and fish consumption studies as proxies.

4.1 The ecological bias in linking importance to productivity

In a system featuring more than 37% of long distance migratory fishes, a focus on productivity is biased by an undervaluation of upstream breeding zones where juveniles are generated but not caught and an overvaluation of downstream feeding zones where adults are caught but not generated. Attributing a high importance or conservation score to zones of high fish productivity is justified from a social perspective (developed fishing sector, intensive consumption and marketing, etc) but is ecologically biased in a system characterized by a production relying on at least 37% of long-distance migrants (Baran 2010). For these long distance migrants there is a disconnect between upstream breeding zones where juveniles are generated but not caught and downstream feeding zones where adults are caught but not generated.

In absence of fish stock data, fish production or fish productivity figures always refer to fish *harvested* by fishermen, i.e. mostly adult fishes. Not only the production/productivity figure depends on the fishing effort –a factor never accounted for in the Mekong, resulting in an undervaluation of the fish stock in areas of low fishing pressure such as Laos, as opposed to Cambodia- but it also reflects a focus of fishermen on valuable fish, i.e. big adult individuals, and a neglect of larvae and small juvenile fish more difficult to catch and of low economic value.

There is unfortunately no estimate at the moment of the virtual production/productivity of upstream zones where the juveniles of most long-distance migratory species are generated. Furthermore studies of fish larvae by Chea Tharith, Thach Phanara and Nguyen Thanh Tung have focused on Cambodia and Vietnam, with little information on Laos and Thailand. However preliminary evidence from Sinthavong Viravong (Sinthavong Viravong 2006, Sinthavong Viravong et al. 2010) and records about spawning migrations and breeding zones (MFD 2003)

³ River - floodplain. Includes Tonle Sap-Great Lake, Mun-Chi, Sekong, Songkhram, Ngum R. Includes the rivers within the major flood zone.

² Rain-fed outside the river-floodplain zone. Mainly rice-fields on formerly forested land. Mostly inundated to about 50 cm. Most is covered by rice during the wet season.

³ Large water-bodies outside the flood zone. Includes reservoirs and canals

indicate clearly the importance of tributaries upstream of Khone Falls, in particular in Laos, for species that constitute close to 40% of the Mekong fish yield and more than 60% of the catch in downstream floodplains.

The nexus between so called low productivity zones producing larvae and juveniles and the high productivity zones where adults are harvested is illustrated in Figure 8.

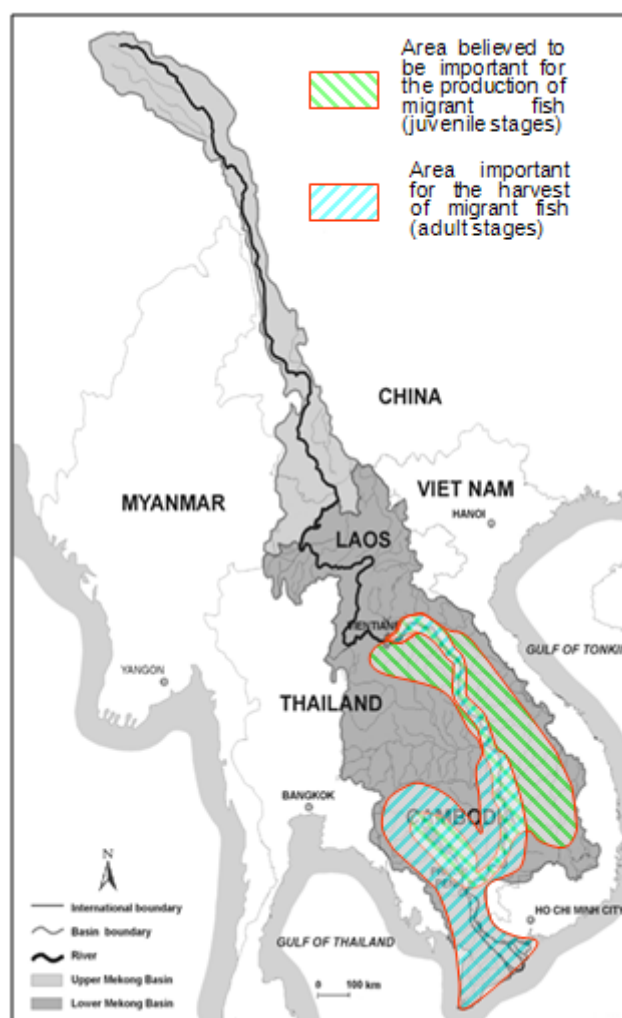


Figure 8: Important areas for the productivity of migratory fishes. Source: Baran 2010

4.2 Fish productivity of the 32 hotspots and the fish consumption proxy

The figures of this section originate from an analysis of human fish consumption in the Lower Mekong Basin based on a review 20 field surveys in the four riparian countries (Hortle 2007). Fish consumption is not fish productivity but can be and has been used as a proxy of fish production. Actually since fish consumption is calculated per inhabitant and per year, this is the closest proxy of a standardized productivity figure.

Table 8 below gives for each hotspot, the fish consumption per capita and per year in the province(s) where this hotspot is located. The consumption figure used below corresponds to:

1. the fish consumption/capita/year of the province where is located the hotspot, for hotspots located on one single province;
2. the weighted average of fish consumption/capita/year per the number of inhabitant of each province, for hotspots located on more than one province.

Hotspots have been ranked in 3 categories based on the fish consumption of the province(s) where they are located:

1. >50 kg/capita/year (red),
2. 50 – 31 kg/capita/year (orange),
3. < 31 kg/capita/year (yellow)

#	Name of Hotspot	Fish consumption (kg/capita/year)	Rank
28	Lang Sen	60	1
27	Tram Chim National Park	55	2
23	Basset Marsh	54	3
24	Boeung Veal Samnap	54	4
25	Bassac Marsh	54	5
19	Tonle Sap system	53	6
21	Stung / Prasat Balang	53	7
22	Stung Sen	53	8
18	Boeng Chhmar	53	9
31	Tra Su	49	10
32	Tinh Doi	49	11
20	Ang Tropeang Thmor Reserve	42	12
13	Siphandon	38	13
10	Xe Khampho / Xe Piane	38	14
11	Xe Kong Plains	38	15
16	Sekong River	38	16
14	Lao Border - Kratie Mekong	36	17
29	Ha Tien Plain and Phu My	36	18
30	Kien Luong	36	19
12	Savannakhet - Siphandon Mekong	35	20
6	Vientiane - Mun River Mekong	35	21
15	Stung Treng Mekong	34	22
9	Songkhram River	33	23
7	Bung Khong Long Area	33	24
1	Nong Bong Kai Area	32	25
5	Luang Prabang - Vientiane Mekong	31	26
3	Chiang Saen - Khong Mekong	31	27
2	Golden Quadrangle	31	28
26	Boeung Prek Lapouv	30	29
4	Mekong Channel upstream of Luang Prabang	26	30
17	Sesan River	23	31
8	Kut Ting Marshland		

Table 8: Fish consumption in the provinces the hotspots belong to

Notes:

1. The value for Hotspot 2 (Golden Quadrangle) does not include Yunnan (in China) and Shan (in Myanmar) provinces which are not documented by Hurtle.
2. No value is given for hotspot 8 (Kut Ting Marshland), located on Bueng Kan province (Thailand) which is not documented.

This analysis shows that 9 hotspots are located in areas of very high fish consumption, i.e. mostly in the Tonle Sap watershed; 20 hotspots are located in areas of medium to high fish consumption and 3 in areas of lower fish consumption. All hotspots characterized by very high and high fish consumption are located in the floodplains and delta area.

4.3 Fish productivity of the 32 hotspots and the fish production proxy

Twenty-five of the 32 Mekong hotspots are located along the mainstream and the Tonle Sap, which corresponds to the 6 ecological reaches of the Mekong mainstream defined by the MRC (2005). The fish production of these 6 reaches has been detailed in Baran (2010). The fish production figure for each reach represents a proxy of the fish production of the area where the hotspots is located.

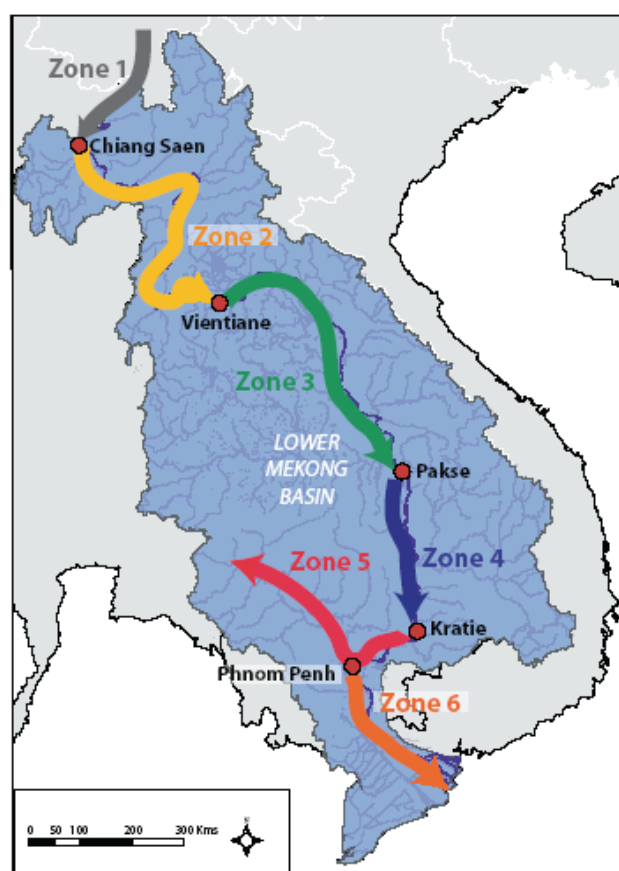


Figure 9: The 6 ecological reaches of the Mekong. Source: MRC 2005.

Table 9 below presents the grouping of 25 mainstream hotspots in the 6 ecological reaches, and the corresponding fish catch for each group.

#	Name of Hotspot	Ecological Reach	Fish catch (tonnes/year)
2	Golden Quadrangle	Zone 2 Upland river in a steep narrow valley	50,000
3	Chiang Saen - Khong Mekong		
4	Mekong Channel upstream of Luang Prabang		
5	Luang Prabang - Vientiane Mekong		
6	Vientiane - Mun River Mekong	Zone 3 Midstream section, large river	116,000
8	Kut Ting Marshland		
9	Songkhram River		
12	Savannakhet - Siphandon Mekong		
13	Siphandon	Zone 4 Zone including large wetlands	40,000
14	Lao Border - Kratie Mekong		
15	Stung Treng Mekong		
18	Boeng Chhmar	Zone 5 Downstream section ; floodplains and the Great Lake	485,000
19	Tonle Sap system		
21	Stung / Prasat Balang		
22	Stung Sen		
23	Basset Marsh	Zone 6 Mekong Delta	520,000
24	Boeung Veal Samnap		
25	Bassac Marsh		
26	Boeung Prek Lapouv		
27	Tram Chim National Park		
28	Lang Sen		
29	Ha Tien Plain and Phu My		
30	Kien Luong		
31	Tra Su		
32	Tinh Doi		

Table 9: Fish production in the Mekong reaches the hotspots belong to

Hotspots 2 to 5 (between the Chinese border and Vientiane) and 13 to 15 (between Pakse and Kratie) are located in the sections of the Mekong Basin where fish yield is the lowest. If the low productivity of the upstream section can be confirmed (no floodplains, irregular hydrologic regime, limited migrations between this zone and the downstream productive floodplains), the low productivity of the Pakse-Kratie area is most probably an artifact reflecting the low population density and subsequent fishing effort in this zone. This zone is ecologically very important and is a nursery area for many species (see sections 2.1 and 3.5).

Hotspots 8, 9 and 12, located on the mainstream between Vientiane and Siphandone, correspond to a moderately productive zone. Despite the absence of floodplain, the production of this section benefits from an extensive system of tributaries.

Downstream of Sung Treng, hotspots 18, 19, and 21 to 32 are located in the most productive section of the Mekong Basin: 485,000 tonnes for the floodplain systems (hotspots 18, 19, 21 and 22) and 520,000 tones for the Mekong Delta (hotspots 23 to 32). The high production of this section results from the combination of high biodiversity, high organic content, extended floodplains and the associated flood pulse process.

5 CONCLUSION

In Table 10 we juxtaposed the rank of each hotspot for fish biodiversity (number of species, of endemics and of endangered species per hectare), habitat diversity (number of aquatic habitats per hectare) and productivity proxies (fish consumption by province and fish production by river stretch for the 6 main Mekong stretches).

#	Name of hotspot	Species /ha	Endemics /ha	Endangered sp /ha	Habitats/ha	Fish consumption	Fish productivity by stretch
1	Nong Bong Kai Area	Red			Red	Orange	
2	Golden Quadrangle		Yellow	Yellow	Yellow	Orange	Yellow
3	Chiang Saen - Khong Mekong	Red	Red	Red	Red	Orange	Yellow
4	Mekong upstream of L. Prabang		Orange	Red	Orange	Yellow	Yellow
5	Luang Prabang - Vientiane		Orange	Orange	Orange	Orange	Yellow
6	Vientiane - Mun River Mekong		Orange	Orange	Yellow	Orange	Orange
7	Bung Khong Long Area	Orange	Red		Red	Orange	
8	Kut Ting Marshland	Red	Red	Red	Red		Orange
9	Songkhram River	Yellow	Orange	Orange	Yellow	Orange	Orange
10	Xe Khampho / Xe Piane				Red	Orange	
11	Xe Kong Plains	Yellow		Orange	Yellow	Orange	
12	Savannakhet - Siphandon		Yellow	Yellow	Yellow	Orange	Orange
13	Siphandon	Red	Red	Red	Red	Orange	Yellow
14	Lao Border - Kratie Mekong		Yellow	Yellow	Yellow	Orange	Yellow
15	Stung Treng Mekong	Orange			Orange	Orange	Yellow
16	Sekong River	Orange			Yellow	Orange	
17	Sesan River	Orange			Yellow	Yellow	
18	Boeng Chhmar				Yellow	Red	Red
19	Tonle Sap system	Yellow	Yellow	Yellow	Yellow	Red	Red
20	Ang Tropeang Thmor Reserve				Yellow	Orange	
21	Stung / Prasat Balang				Yellow	Red	Red
22	Stung Sen				Orange	Red	Red
23	Basset Marsh				Red	Red	Red
24	Boeung Veal Samnap				Orange	Red	Red
25	Bassac Marsh	Yellow			Yellow	Red	Red
26	Boeung Prek Lapouv				Orange	Yellow	Red
27	Tram Chim National Park				Orange	Red	Red
28	Lang Sen				Red	Red	Red
29	Ha Tien Plain and Phu My				Orange	Orange	Red
30	Kien Luong				Orange	Orange	Red
31	Tra Su				Red	Orange	Red
32	Tinh Doi				Red	Orange	Red

Table 10: 32 Mekong hotspots, biodiversity descriptors and fish productivity proxies. Color chart: Red (high rank), Orange (medium rank), Yellow (lower rank)

This table shows the discrepancy between what can be called hotspots of high biodiversity value (mainly upstream of the Lao border, upper left part of the matrix) and hotspots of high productivity value (mainly downstream of the Lao border, lower right part of the matrix). This view of the system is actually biased for several reasons:

- upstream hotspots of apparent low productivity may contribute significantly to the system productivity, but their production is not harvested locally;

- 37 to 70% of the high productivity of downstream hotspots might be driven by a fish supply (larvae and juveniles) from upstream areas, which is not reflected in this table;
- the higher productivity of downstream areas also reflects a higher fishing effort reflecting itself a higher population density (e.g. 22 inhabitants per km² in Luang Prabang province, 83 in Kampong Chhnang province and 595 in An Giang province);

More generally the choice of the 32 environmental hotspots as a baseline in view of assessing the impact of sediment load modification on fish biodiversity and productivity can be disputed for several other reasons; in particular:

- the large range of hotspot sizes results in a juxtaposition of systems of different nature (e.g. a 434 ha swamp vs. a 5000 km² floodplain)
- The selection of the hotspots results from a multi-criteria approach (fish, plants, birds, etc) and only 60% of the hotspots include fish data;
- no data is available on fish productivity for the hotspots.

As of now there is no estimate of the fish productivity of different zones in the Mekong; such a detailed assessment would require:

- a typology of the different ecozones or watersheds
- an estimate of the ratio of migratory and non migratory fish in each zone
- a fish stock estimate for each zone

This approach is similar to the one developed and modelled by Ziv *et al.* (2012) for river segments blocked by dams. In this study, the modeling approach at the basin level computes the dry-season population (i.e. resident species) and the contribution of each locality to the wet-season productivity in the floodplains via the transfer of migratory species. The model assumes i) that each upstream habitat has a local carrying capacity reaching its limit at the end of each season, and that ii) migration is described as the number of returning offspring as function of distance. Migratory species fraction at each site is a function of distance-dependent migration cost, habitat suitability for different fish guilds, and inter-guild competition.

In this model the carrying capacity in each catchment is proportional to the total discharge, namely runoff (precipitation minus evapo-transpiration) multiplied by surface area. This quantity is taken an indicator for the amount of resources available for fish.

At this stage the model developed does not encompass sediment or nutrient loads. However it is possible to upgrade this model by integrating sediment load as a more refined descriptor of the amount of resource available to fish, if a sediment-focused project can provide baseline and future sediment loads in each catchment. This is an option to be considered for the second phase of the project “Maintaining the Flows that Nourish Life”.

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