FOOD AND NUTRITION SECURITY VULNERABILITY TO MAINSTREAM HYDROPOWER DAM DEVELOPMENT IN CAMBODIA

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Report prepared by IFReDI, with inputs from R. Johnstone, E. Baran (WorldFish), Chheng P., Touch B.T., So N. and H.E. Nao Thuok

FOREWORD

His Excellency Professor Nao Thuok

Director General of the Fisheries Administration

Ministry of Agriculture, Forestry and Fisheries

For centuries the mighty Mekong has provided a secure source of food and nutrition to the peoples of South East Asia. In more recent times, the huge potential energy of the Mekong has also been seen as a source of power, and many hydro-electric schemes have been considered to tap the energy of this mighty river. However, the potential to produce power and the resource to provide food are not entirely compatible. When considering the requirements of today's population, wise decisions will need to be made in order to secure the most benefits for the people of Cambodia. These decisions need to be based on sound, accurate facts.

This study has considered the likely impacts of building dams on the Mekong, using various scenarios based upon current proposals and plans. These impacts include the likely effect of such dams on fish migrations to and from spawning grounds; the subsequent effect on breeding and therefore fish stocks; the potential changes to food security arising from changes to yields on capture fisheries, and lastly, the potential impacts on the diet and nutrition, focusing particularly on those who depend on fish for essential elements of their food intake.

Armed with this knowledge and a full understanding of the impacts of any decision to dam the Mekong, Cambodia's leaders will be better prepared to properly weigh the consequences of their decisions.

The Fisheries Administration is grateful for the support received from development partners in carrying out this study. DANIDA, Oxfam and WWF have generously provided funds to enable the work to be carried out. I am also grateful for the close working partnership which developed between the FiA staff and these organisations during the course of the study. This close working partnership enabled many problems to be faced and inevitable obstacle to be overcome in a timely manner.

H. E. Professor Nao Thuok
Delegate of the Royal Government of Cambodia,
Director General, Fisheries Administration,
Ministry of Agriculture, Forestry and Fisheries,
Kingdom of Cambodia

EXECUTIVE SUMMARY

The 'Food and Nutrition Security Vulnerability to Mainstream Hydropower Dam Development in Cambodia' project examined national food and nutrition vulnerability arising from the potential construction of the Stung Treng (ST) and Sambor (SB) dams.

This project consisted of three components: i) an assessment of the food consumption in rural households nationwide, ii) an assessment of the impacts of Cambodian mainstream dams on fish yield, and iii) an assessment of the impacts of Cambodian mainstream dams on fish consumption and food security in Cambodia. The project was implemented, under IFReDi's responsibility, from June 2011 to September 2012 by a multidisciplinary team (hydrological modeller, dam specialist, fishery scientists, nutritionists, surveyors) supervised by an external Technical Advisory Committee.

The Household Food Consumption Survey was carried out in 1,200 households nationwide, in five of the ecological zones in the country (Phnom Penh, Coastal, Plains, Plateau/Mountain and Tonle Sap) and was done taking into consideration the stratification framework of the National Institute of Statistics for the National Census.

2011 BASELINE ASSESSMENT OF NUTRITION IN CAMBODIA

The purpose of this baseline was twofold: i) to assess the current food consumption and energy and nutrient intake of Cambodians; ii) to assess the relative contribution to food and nutrition security made by three major ecological groups of fish species of various sensitivity to dam development:

- floodplain residents or "black fish" such as snakeheads (រ៉ស់), which are resilient to dam impacts;
- short-distance migrants or "grey fish" such as Kryptopterus (ត្រីកំភ្លៀវស្នឹង), which are restricted to local tributaries and are sensitive to dam development on tributaries and
- long-distance transboundary migrants or "white fish" such as Henicorhynchus (ត្រីរៀលតុបប), which are very sensitive to dam development.

The contribution of other aquatic animals (OAAs) was also considered in this assessment.

Conclusions

The Cambodian diet is a combination of rice, fish and vegetables, reaching 955 grams per person per day.

Aquatic resources are the second largest dietary component at 173 grams per person and per day, accounting for 18% of the total food intake. Aquatic resources are also the major contributor of animal intake[1] (76%, of which half is freshwater capture fish).

Inland fish consumption amounts to 110 g/person/day or 40.3 kg/person/year, while that of marine fish reaches 16.2 kg/person/year. The consumption of other aquatic animals (marine + freshwater) is 5.1 kg/person/year. The smallest contribution to the diet comes from the aquaculture sector, with 1.3 kg/person/year only (2%). These results are consistent with the results of the previous fish consumption studies in Cambodia.

[1] All foods of animal origin (for example: meat, eggs, dairy)

Of the inland fish, floodplain resident fish (i.e. black fish) comprise 30% of total fish intake, followed by long-distance transboundary migrants (white fish) very sensitive to dam development (25% of total fish intake). The overall per capita consumption of floodplain resident fish is relatively higher than other fish categories due to their availability throughout the year.

In the Cambodian diet, rice is the major energy contributor (60% of the total energy intake), followed by aquatic resources (12% to the total energy intake). Fish and other aquatic animals contribute 37% of total protein intake per person, 28% of total fats intake per person and 37% of total iron intake per person. As the overall intake of fat in the Cambodian diet is very low, the fat and protein contributed by fish is very important. The survey results also show that only 25% of the population have the necessary levels of energy and only 19% have the required levels of iron.

Across all ecological zones, fish and fish products are generally eaten more than any other of the body building foods such as meat or poultry. Higher consumption of fish is observed in the *Coastal* and *Tonle Sap* ecological zones, while the lowest consumption is observed in the *Mountains and Plateaus*.

In terms of gender, the consumption of fish and fish products by men and women is similar.

Disaggregation by age group shows that the consumption pattern is the same for all age classes; only the quantity consumed varies. Proportionately, pre-school children have their fish intake dominated largely by inland fish and fish products. Adolescents and pregnant women are also relatively more dependent on the availability of inland fish for their overall food security.

ASSESSMENT OF FISH CATCHES BASED ON THE CONSUMPTION STUDY

The individual fish consumption figures above multiplied by the current Cambodian total population (i.e. 14,100,000 persons) indicates that the yield of inland fish amounts to 570,000 tonnes per year. When complemented by other aquatic animals, this amounts to 625,000 tonnes of inland capture resources harvested each year. These results are consistent with previous estimates.

Marine resources amount to 254,000 tonnes per year (more specifically 229,000 tonnes of fish and 16,000 tonnes of other marine aquatic animals).

This brings the figure for capture fisheries to 870,000 tonnes per year, and the grand total for aquatic resources in Cambodia to 889,000 tonnes per year (including 19,000 tonnes of aquaculture products).

Impact of mainstream dams on the fish yield

The study built into a model:

- the predicted future yields of inland fish and other aquatic animals
- the predicted future quantities from the aquaculture sector and from imports,
- the losses from non-consumptive disposal (exports, utilization for aquaculture feed and fertilizer, and post-harvest waste)
- the expected changes in river hydrology and accessible wetland habitats, and
- the population growth

for each development scenario and for each hypothesis about reservoir production yield.

Conclusions

In 2030 the human population of Cambodia is expected to reach 20 million (+43%), which will be the most significant obstacle to improved or sustained food security.

In the absence of mainstream dams and regardless of population growth, the increased output from the aquaculture sector and forecasted declines in exports will be balanced by losses experienced by capture fisheries in response to dam development on tributaries and irrigation development in the lower part of the basin (i.e. loss of wetlands producing capture fish). The supply of aquatic resources appears relatively insensitive to the level of aquaculture production from dam reservoirs. Thus the aquaculture sector would not compensate for losses to supply arising from Cambodian mainstream dam impacts.

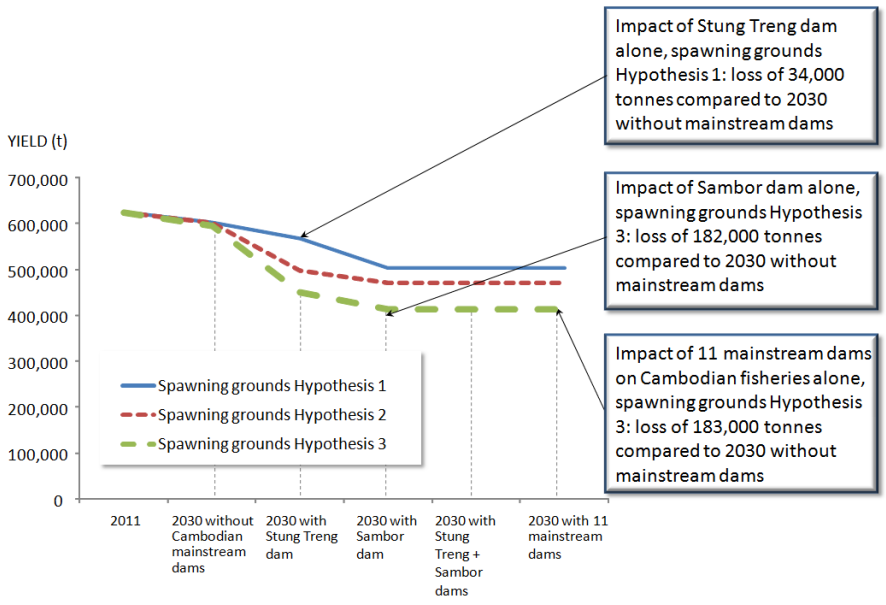
Given the population growth, the relative stability of the farmed fish supply and the decline of the capture fish yield for reasons other than mainstream dams (i.e. 4-5% decline), the study predicts fish consumption will be reduced by 30.6% by 2030 even in the absence of mainstream dams.

The development of the *Stung Treng dam alone* is predicted to reduce yields of fish and other aquatic animals by 6% to 24% or 34,000 – 145,000 tonnes.

The *Sambor dam alone* is predicted to reduce yields of fish and other aquatic animals by 16% - 30 % or 98,000 – 182,000 tonnes compared to 2011 baseline values.

The *combination of the Stung Treng and Sambor dams* is predicted to reduce yields of fish and other aquatic animals by a similar amount (98,000 – 182,000 tonnes) because the Sambor dam alone would then block all fish migrations upstream (maximum impact regardless of other upstream dams).

Mainstream Cambodian dams are therefore predicted to reduce the supply of inland fish and other aquatic animals by between 34,000 to 182,000 tonnes from the baseline values. The uncertainty range depends mainly upon the hypothesized distribution of long-distance migrants' spawning habitat, which highlights the importance of new research on spawning areas.



Predicted annual yield of inland fish and other aquatic animals under each development scenario and hypothesized distribution of long-distance migrants' spawning habitat.

IMPACT OF MAINSTREAM DAMS ON THE FISH CONSUMPTION

The model developed for the study integrates all the factors driving the production of overall aquatic resources (i.e. capture yields, aquaculture production, imports, exports and losses) and their trends up to 2030.

When all the fish production factors and the population growth are integrated, the future consumption of aquatic resources per capita is expected to decline even in the absence of dams.

In the absence of mainstream dams, the per capita supply of inland fish and OAAs is expected to decline from approximately 63 kg per capita in 2011 to approximately 44 kg per capita by 2030.

However the construction of Cambodian mainstream dams would reduce this supply by a further 6 to 34% depending on the scenario considered. This would result in fish consumption dropping to 29-41 kg/person/year (as opposed to 63 kg/person/year in 2011).

IMPACT OF MAINSTREAM DAMS ON FOOD SECURITY AND HEALTH

The above results imply that after the construction of the mainstream dams there will be a further reduction of the already low number of individuals who have adequate levels (RDA) of energy, protein and iron.

A reduction of 34% of the available fish and fish products for consumption would have a dramatic impact on the proportion of the population living in the plains who are able to obtain their daily dietary allowances (RDAs), and who are already considered as the least nutrient-secure ecological zone.

A reduction in the availability of fish and specifically of long-distance migrants, which is important for the provision of iron, would have a strong detrimental impact on the rural population driving iron security even lower and posing a risk to public health.

Children, especially in rural areas, will also be directly affected by the reduction of inland fish availability. School children could be considered as the most food-insecure age group. The data on pregnant women's nutrition shows that they are the most vulnerable group to protein reduction, with the lowest rate of protein RDA satisfaction.

Therefore, the predicted reduction of per capita supply of inland fish and OAAs is expected to result in:

- negative effects on public health that affect strongly some of the most vulnerable population groups, such as those living in remote rural areas and school children;
- aggravation of existing malnutrition and creation of more people who cannot obtain the recommended daily allowance of key nutrients, thus exposing more people to health risks.

1. INTRODUCTION

The 'Food and Nutrition Security Vulnerability to Mainstream Hydropower Dam Development in Cambodia' project examined national food and nutrition vulnerability arising from the potential construction of the Stung Treng (ST) and Sambor (SB) dams.

The project was co-funded by the Fisheries Administration, World Wildlife Fund for Nature (WWF), Oxfam Australia and DANIDA. The research activities were coordinated by the Inland Fisheries Research and Development Institute (IFReDI) of the Fisheries Administration.

This project consisted of three components: i) an assessment of the food consumption in rural households nationwide, ii) an assessment of the impacts of Cambodian mainstream dams on fish yield, and iii) an assessment of the impacts of Cambodian mainstream dams on fish consumption and food security in Cambodia. The project was implemented from June 2011 to September 2012 by a multidisciplinary team (hydrological modeller, dam specialist, fishery scientists, nutritionists, surveyors) supervised by an external Technical Advisory Committee.

The project took into consideration the five ecological zones in the country; namely, *Phnom Penh*; *Plains* (Kandal, Kampong Cham, Prey Veng, Svay Rieng and Takeo provinces); T*onle Sap* (Banteay Meanchey, Kampong Thom, Battambang, Pursat, Kampong Chhnang and Siem Reap provinces); *Plateau/mountains* (Kampong Speu, Kratie, Pailin, Mondul Kiri, Otdor Meanchey, Preah Vihear, Ratanak Kiri, and Stung Treng provinces); and the *Coastal* zone (Kep, Preah Sihanouk, Koh Kong, and Kampot provinces).

The household food consumption survey focused on indicators of food security, taking a representative sample of households nationwide consisting of 1,200 households.

The project built upon previous studies by improving and updating estimates of fish consumption and yield for Cambodia and by disaggregating these estimates according to ecological zone and province, and by the three groups (guilds) of fish species (floodplain residents, short-distance migrants and long-distance migrants). The project also employed the latest hydrological and fisheries impact models available for the region.

This allowed for a more refined assessment of dam impacts on food and nutrition security in Cambodia, accounting for the differences in the impact vulnerability of the three major fish group types. The study represents the first attempt to undertake a food consumption survey at the national level. The results provide valuable food and nutrition security data relevant to other development projects and programs both nationally and regionally.

The current report is a summary of the findings of the two main scientific reports of the project:

- Touch Bunthang, Chheng Phen, So Nam, Wilma Hurdata, Nao Thuok. 2012. Baseline Assessment of Diet and Nutrition in Cambodia 2011. Report for the project "Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia", Inland Fisheries Research and Development Institute (IFReDI), Fisheries Administration, Phnom Penh, Cambodia. 124 pp.
- Halls A.S., Chheng Phen, So Nam, Nao Thuok. 2012. Impacts of mainstream dams on fish yield and consumption in Cambodia. Report for the project "Food and nutrition security vulnerability to mainstream hydropower dam development in Cambodia", Inland Fisheries Research and Development Institute (IFReDI), Fisheries Administration, Phnom Penh, Cambodia. 90 pp.

FISH GROUPS IN THE MEKONG AND SENSITIVITY TO DAM DEVELOPMENT

Three main fish groups (or "guilds") having very different migration patterns are to be distinguished.

The group of floodplain residents or "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. It is not very sensitive to dam development.

The group of long-distance migrants or "white fish" is made of species that undertake 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. This group is very sensitive to dam development, in particular on the mainstream.*

The group of short-distance migrants or "grey fish" is made of species that are not grey in colour but ecologically intermediate between the two previous groups; this group 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. This group is sensitive to dam construction on tributaries, but not on the mainstream.

Examples of black fishes:

Channa striata

Clarias batrachus

Anabas testudineus

Examples of white fishes:

Henicorhynchus siamensis

Paralaubuca typus

Pangasius krempfi

Examples of "grey" fishes:

Belodontichthys dinema

Mystus albolineatus

Kryptopterus cheveyi

2 MAIN FINDINGS

2.1 IMPORTANCE OF FISH TO FOOD AND NUTRITION IN CAMBODIA

2.1.1 THE CAMBODIAN DIET - FOOD CONSUMPTION

The Cambodian diet is a combination of rice, fish and vegetables in this order of consumption at both individual and household levels. The total average daily per capita[2] food consumption is 955 grams per person per day (Figure 1).

Fish and fish products intake (from both inland and marine sources, plus aquaculture and other aquatic animals) is the second largest dietary component at 172.5 grams per person per day, accounting for 18% of the total food intake.

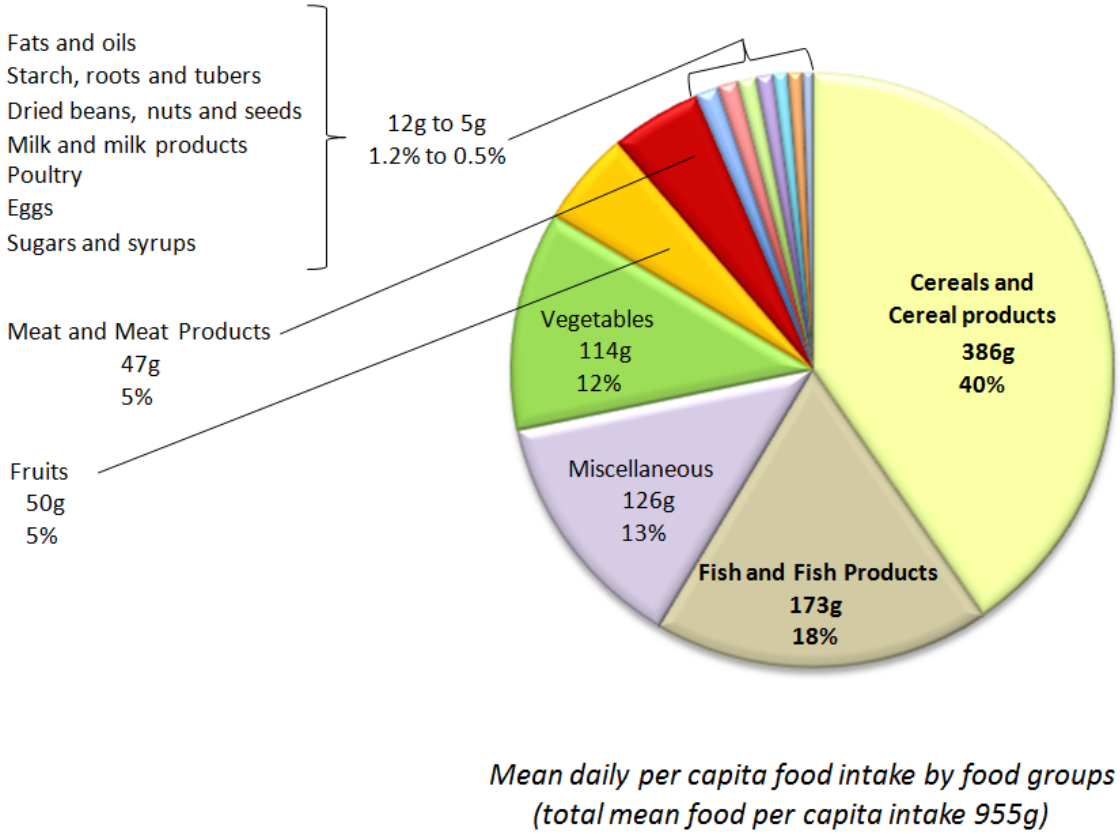


Figure 1: Average one-day individual food intake (in grams) and percent of total food intake by groups: Cambodia, 2011

[2] Per capita = per person

Inland fish, which includes floodplain residents, long-distance migrants and short-distance migrants, is consumed at 110.5 grams or 11.6% of the total food intake and two-thirds (64%) of the total consumption of fish and aquatic animals. Other freshwater aquatic animals represent 10.8 g/person/day or 6.3% of the total fish intake. In comparison, *marine fish* (including Other marine Aquatic Animals - OAAs) is consumed at 47.6 grams per person and per day or 5% of the total food intake and just over one-fourth (27.6%) of the total fish intake (**Error! Reference source not found.**). Therefore, inland fish is consumed in much larger quantities than marine fish.

Table 1: Average daily fish consumption (grams) per individual and percent of total food intake: Cambodia, 2011

			Average (g/person/day)	% Total Food Intake	% Total Fish Intake
Inland capture resources	Inland fish	Floodplain residents	*51.5*	5.4	29.8
		Long-distance migrants	*42.5*	4.5	24.6
		Short-distance migrants	*16.5*	1.7	9.5
	Other inland aquatic animals		*10.8*	1.1	6.3
Marine capture resources	Marine fish		44.5	4.7	25.8
	Other marine aquatic animals		*3.1*	0.3	1.8
Aquaculture			*3.7*	0.4	2.1
Grand total			*172.5*	*18.1*	*100*
Daily food consumption (g/person/day)			***955***		

Of the inland fish, *floodplain residents are* consumed more than any other type of fish at 51.5 grams per person and per day, which is 5% of the food intake and 30% of the total fish intake. This dominant category is followed by *long-distance migrants* (42.5 g/person/day), *short-distance migrants* (16.5 g/person/day) and *aquaculture fish* (3.7 g/person/day). One of the reasons for the higher consumption of *floodplain residents* is that they are available all year round, while *long-distance migrants* are seasonal. While *floodplain residents* are consumed mainly fresh, long-distance migrants are also largely processed into products such as fish sauce, fish paste, or fermented and/or smoked.

Fish and fish products is the second largest dietary component at 173 grams per person per day;

Floodplain resident fishes are consumed more than any other type of fish, followed by white fish;

Aquaculture intake represents 2.1% of the total fish intake, which is lower than the contribution of any other fish or other aquatic animals group to food intake

Aquaculture fish is the least consumed at 3.7 grams, which represents 0.4% of the total food intake and 2% of the total fish intake only. Intake of inland OAAs is higher than intake of aquaculture fish at 10.8 grams (Figure 2).

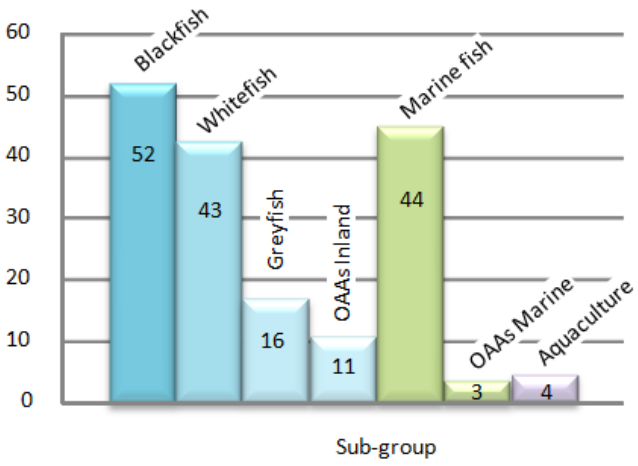


Figure 2: Average daily per capita consumption of fish (in grams) per sub group

Figure 3 shows the percentage of each fish sub-group in terms of total fish consumption, clearly demonstrating the importance of inland fish and the proportion of both *floodplain residents* and *long-distance migrants* as part of fish and fish products consumption.

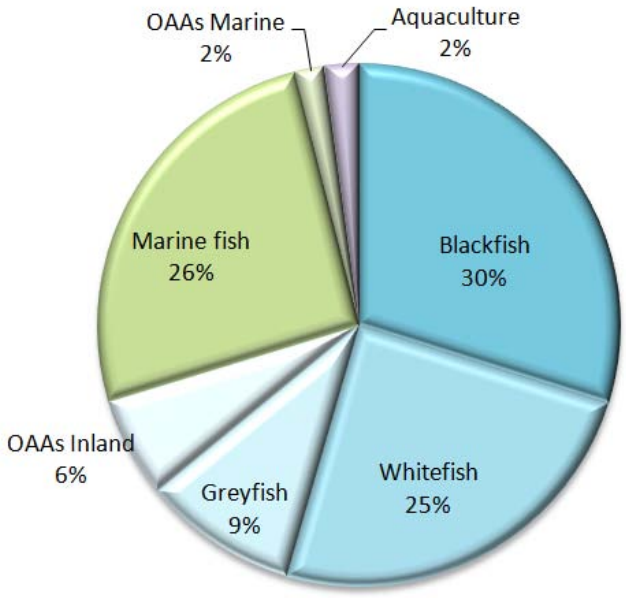


Figure 3: Fish sub-groups as percentage of total fish intake

When these daily figures are converted to annual figures, Cambodian people consume on average 63 kg of fish and aquatic products (fresh water fish, marine fish and other fish products) per person and per year. The consumption of *inland fish* amounts to 40.3 kg/person/year, while that of *marine fish* reaches 16.2 kg/person/year. The consumption of all inland capture resources (i.e. harvested freshwater fish and other freshwater aquatic animals) reaches 44.3 kg/person/year. The overall consumption of other aquatic animals (marine + freshwater) is substantial, at 5.1 kg/person/year, i.e. 8% of the consumption of all aquatic products, and is four times more important than the consumption of aquaculture products (1.3 kg/person/year only).

Table 2: Average annual fish consumption of fish per person and per year. Cambodia, 2011

			Annual intake in Fish and Fish Products (kg/person/year)	
Inland capture resources	Inland fish	Floodplain residents	18.8	40.3
		Long-distance migrants	15.5	
		Short-distance migrants	6.0	
	Other inland aquatic animals		3.9	3.9
Marine capture resources	Marine fish		16.2	17.4
	Other marine aquatic animals		1.1	
Aquaculture			1.3	1.3
Grand total			***63***	

These results are very much in line with the results of the previous fish consumption studies in Cambodia:

- Ahmed *et al*. (1998[3]) found an average per capita consumption of *fresh inland fish* of 43.5 kg per year.
- Hortle (2007[4]) found 36.8 kg/person/year of inland fish and other inland aquatic animals consumed, while the current study finds 44.3 kg/person/year (i.e. 20.3% more). The difference can be explained by the fact that Hortle's figure includes a number of extrapolations for provinces not surveyed, whereas the present study has national coverage.

[3] Ahmed M., Hap Navy, Ly Vuthy, Tiongco M. 1998 Socioeconomic assessment of freshwater capture fisheries in Cambodia: report on a household survey. Mekong River Commission, Phnom Penh, Cambodia. 186 pp.

[4] Hortle K.G. 2007 Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No.16, Mekong River Commission, Vientiane, Lao P.D.R. 87 pp.

2.1.1.1 CONSUMPTION OF FISH ACROSS ECOLOGICAL ZONES

Across all ecological zones fish and fish products are generally eaten more than any other of the body building foods such as meat or poultry. Higher consumption of all kinds of fish (i.e. marine + freshwater) is observed in the *Coastal* area at 247.5 grams and *Tonle Sap* area due to their proximity to large fishing areas. The lowest consumption is observed in the *Mountains and Plateaus* zone at 143.2 grams per day (Figure 4).

Across all ecological zones fish and fish products are generally eaten more than any other of the body building foods such as meat or poultry;

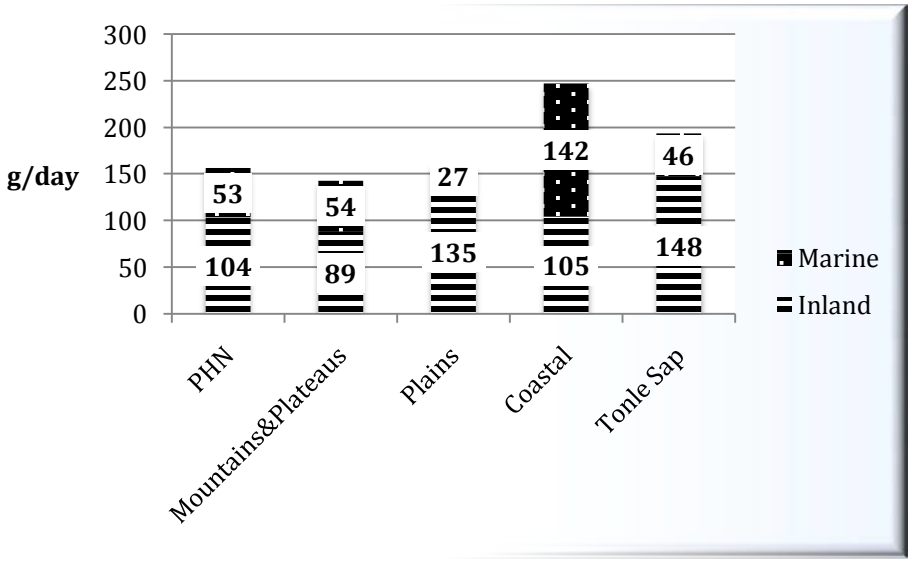


Figure 4: Average daily per capita fish consumption disaggregated by inland and marine fish

Consumption of inland fish including OAAs is higher than consumption of marine fish across all ecological zones except for the *Coastal* area. The highest consumption of inland fish and OAAs is in the *Tonle Sap* zone at 147.9 grams/person/day while the lowest is in *Mountain and Plateaus* at 89.4 grams per capita per day. Consumption is similar in *Phnom Penh* and *Coastal* areas at 104 and 105.1 grams per capita per day, respectively. High consumption of inland fish is also observed in the *Plains* zone at 134.6 grams per capita per day.

The breakdown of the composition of the inland fish consumed shows that *floodplain residents* are consumed the most in the *Tonle Sap* (77.2 grams per capita per day), *Coastal* (60.1 grams per capita per day) and *Phnom Penh* (45.2 grams per capita per day) zones. Long-distance migrants are consumed more in the *Plains* (58.5 grams per capita per day) and the *Mountains and Plateau* areas (32.7 grams per capita per day). These differences reflect the fish consumption patterns, with floodplain residents eaten fresh or whole whereas long-distance migrants are often processed. People in mountainous areas away from water bodies naturally consume more processed fish such as dried fish and fish paste (prahoc).

Aquaculture fish is consumed least across all the different ecological zones and consumption of OAAs is higher than the consumption of aquaculture fish everywhere except in Phnom Penh (Figure 5).

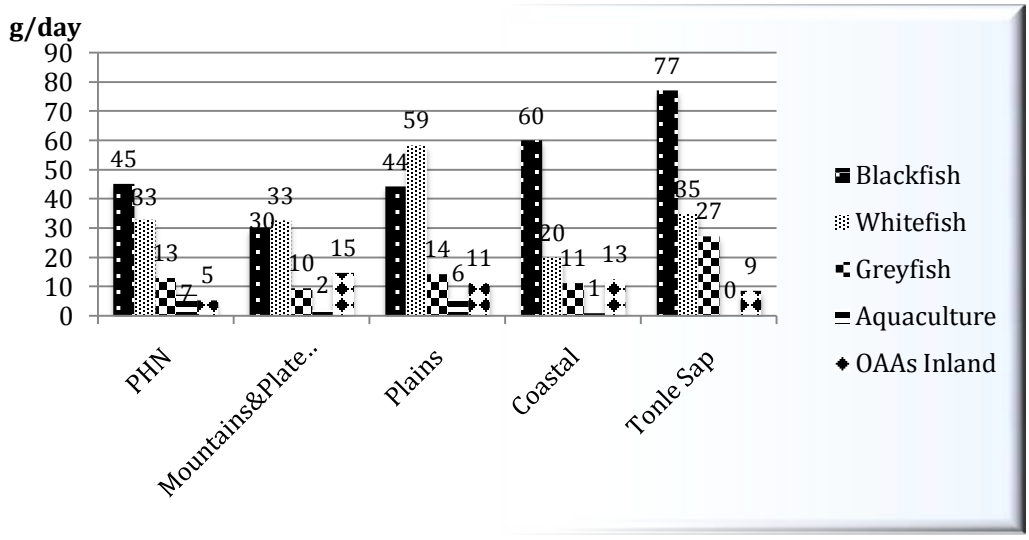


Figure 5: Average daily consumption of fish per sub-group and ecological zone

Marine fish is naturally consumed more in the *Coastal* area at 134.8 grams per capita per day, followed by *Mountain and Plateau* areas at 51.8 grams per capita per day. The *Phnom Penh* and *Tonle Sap* areas feature similar consumption rates at 48.4 grams and 41.8 grams per capita per day, respectively. The lowest intake of *marine fish* is recorded in the *Plains* zone at 25.4 grams per capita per day.

Distance from the coast and purchasing power are among the main factors that influence accesses to marine fish; hence, consumption of marine fish is higher in the larger urban areas such as Phnom Penh, Battambang and Seam Reap.

2.1.1.2 CONSUMPTION OF FISH IN URBAN VERSUS RURAL AREAS

In *urban* areas the total average food intake is 962.3 grams per person per day of which 180.7 grams is fish. In *rural* areas the total average food intake per person per day is 909 grams, of which 164 grams is fish. In both cases, fish comprises about 18% of the total food intake.

Fish comprises 18% of total food intake in both rural and urban areas

Consumption of inland fish including aquaculture fish and OAAs is slightly higher in *rural* areas at 127.2 grams than in *urban* areas at 122.7 grams per capita per day.

Consumption of marine fish in *urban* areas is higher at 52.96 grams, while in *rural* areas it is much lower at 35.7 grams per capita per day (Figure 6).

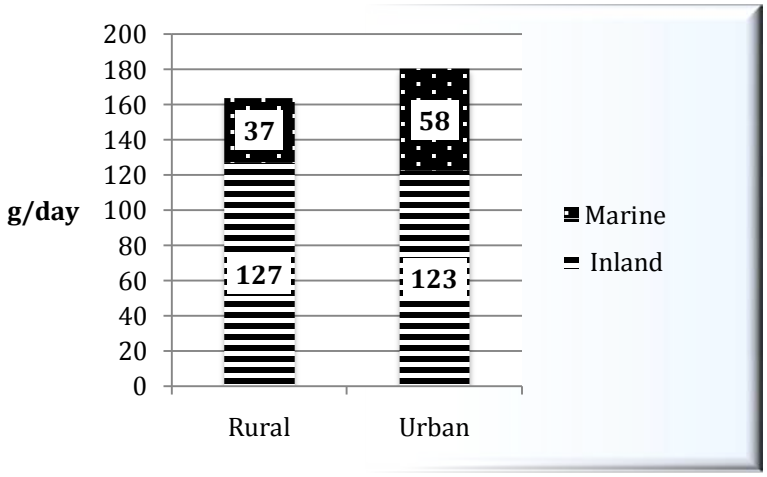


Figure 6: Average daily consumption of fish in rural and urban areas

The breakdown of inland fish consumption shows that people eat floodplain residents more than any other fish both inside and outside urban areas, and is closely followed by the consumption of long-distance migrants, especially in rural areas. The higher consumption of long-distance migrants in rural areas could be at least partly attributed to the ability to store the processed long-distance migrants for longer periods of time even in the absence of cold storage.

Inland fish and whitefish in particular is consumed more in rural areas

Aquaculture fish is the least consumed among inland fish in both rural and urban areas at 2.9 grams and 4.5 grams per capita per day, respectively (Figure 7).

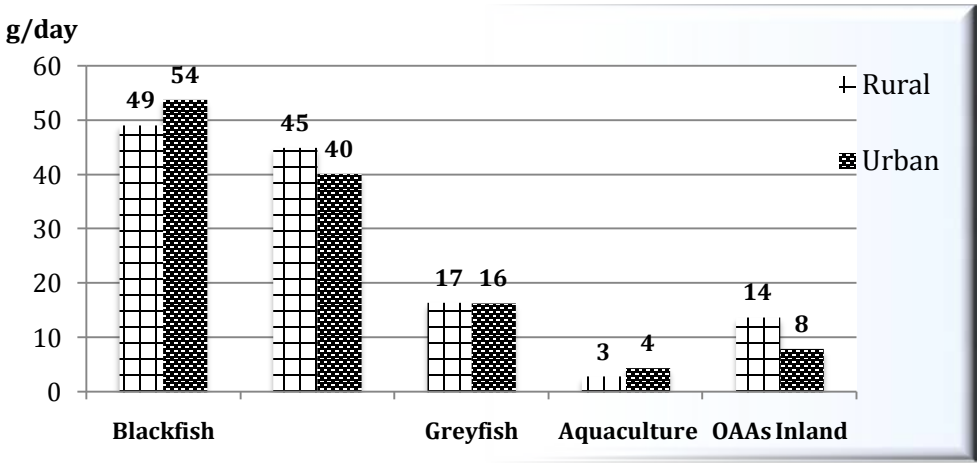


Figure 7: Average daily consumption of inland fish disaggregated by sub-groups and urban and rural areas

2.1.1.3 CONSUMPTION OF FISH ACCORDING TO GENDER

In terms of weight, *males* consume marginally more fish at 180.4 grams per capita per day than females at 166 grams per capita per day (probably in proportion to body weight). However, fish and fish products account for a similar proportion in the diet of both genders (19% of total food intake for *females* and 18% for *males* respectively). Consumption of OAAs is higher than the consumption of aquaculture fish for both genders (Figure 8).

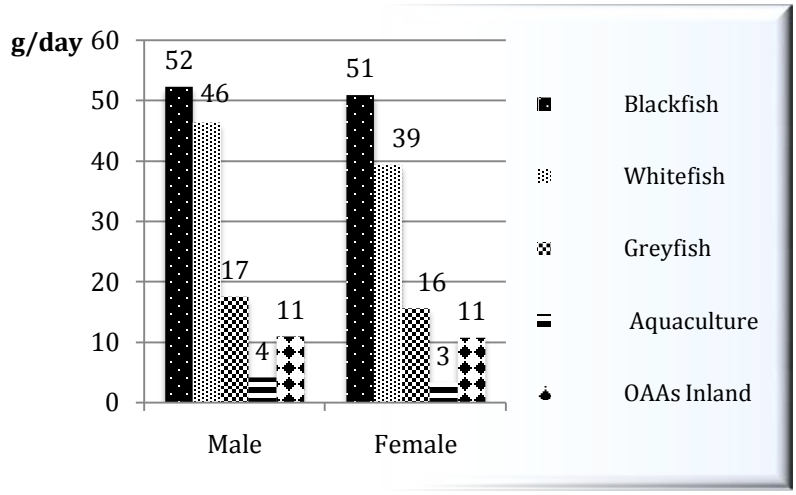


Figure 8: Average daily consumption of inland fish disaggregated by sub-group and gender

2.1.1.4 CONSUMPTION OF FISH ACCORDING TO AGE

Disaggregation by age group shows that across all ages, the majority of fish and fish products consumed by each of the age groups are from inland origin (Figure 9).

The 20-59 year olds are the biggest consumers of fish and fish products at 196.2 grams per day. Proportionally, pre-school children also have their fish intake dominated largely by inland fish and fish products. Pregnant women consume 190.7 grams of fish and fish products per day, 160.9 grams of which is from inland origin.

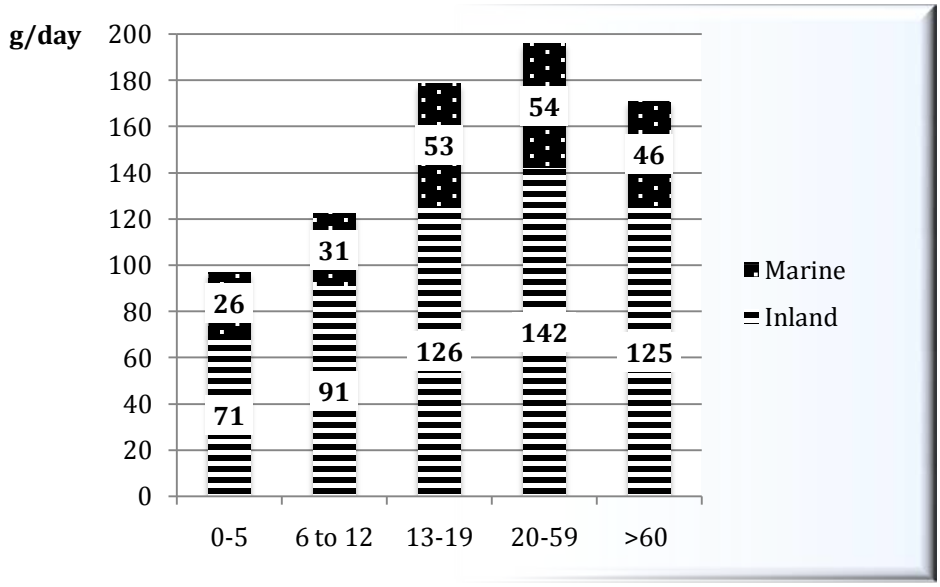


Figure 9: Average daily per capita fish consumption by age

In terms of consumption of the different inland fish-subgroups according to age, the data shows that *floodplain residents* dominate in the composition of inland fish and fish products consumption. However, it is closely followed by the amount of *long-distance migrants* consumed across all ages (Figure 10). Generally speaking, the consumption pattern is the same for all age classes; only the quantity consumed varies.

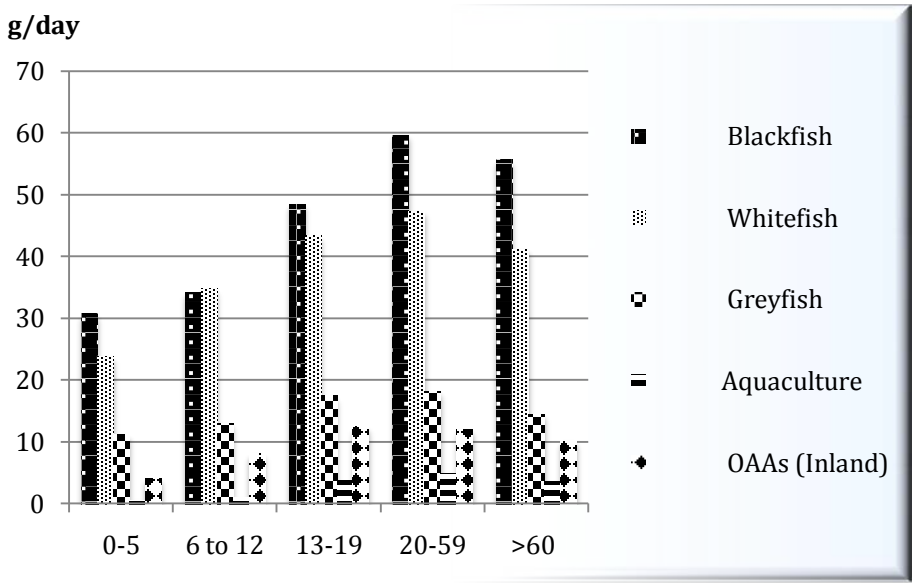


Figure 10: Average daily per capita fish consumption by fish sub-group

Adolescents and pregnant women eat more inland fish than any of the other age groups in terms of a percentage of their total food intake, which makes them more dependent on the availability of inland fish for their overall food security (Figure 11).

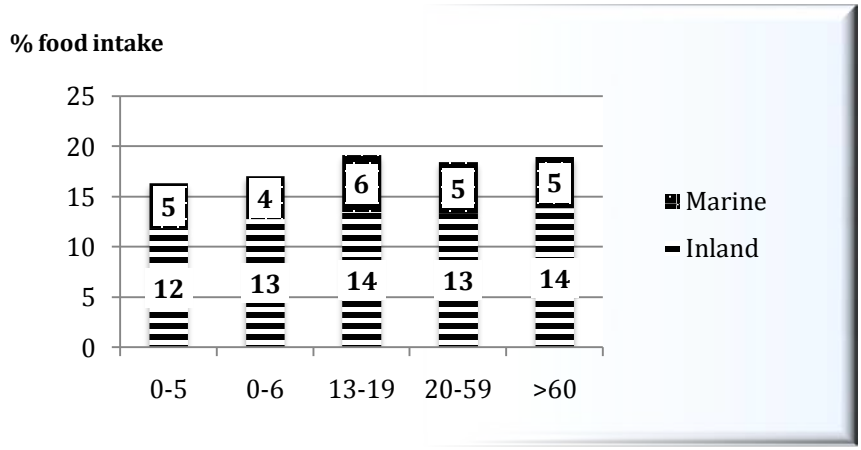


Figure 11: Fish as a percentage of total food intake

2.1.2 THE CAMBODIAN DIET – ENERGY AND NUTRITION

In the Cambodian diet, rice and fish are the most frequently eaten food groups. Rice is consumed almost three times a day and fish about two to three times a day.

As the dominant food group in the Cambodian diet, rice is the major energy contributor with about 1,095 kcals or 60% of the total energy intake, followed by aquatic resources contributing about 12% to the total household energy intake in a day.

However, fish and fish products are the main contributors of *protein*[5] at 36.59% of total intake per capita, *fats* at 27.8% of total intake per capita, and *iron* at 37.3% of total intake per capita (Figure 12, Figure 13, Figure 14).

Rice is the second biggest contributor of protein at 35% of the total intake per capita, 17% of the fats, and 32% of the iron per capita.

FISH AND FISH PRODUCTS CONTRIBUTE:

37% of total intake of PROTEIN[1] per person

28% of total FAT intake per person

37% of total IRON intake per person

[5]Protein–from both animal and plant origins

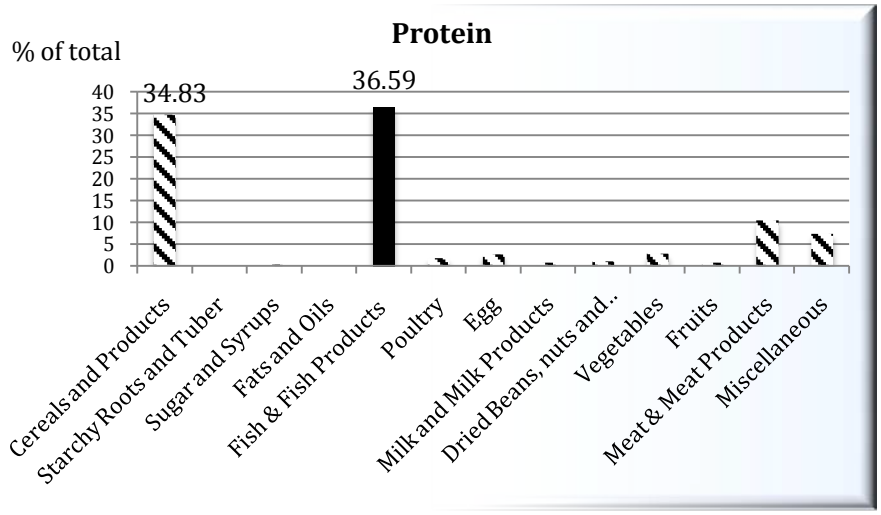


Figure 12: Percentage contribution of food groups to total intake of protein by individuals

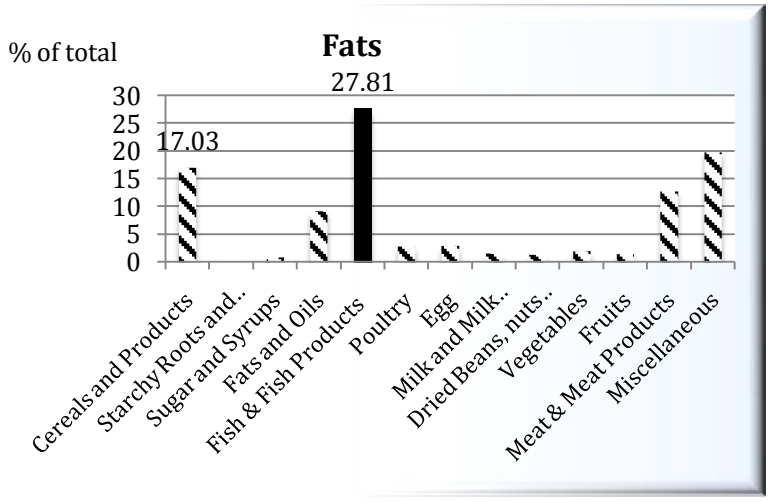


Figure 13: Percentage contribution of food groups to total intake of fats by individuals

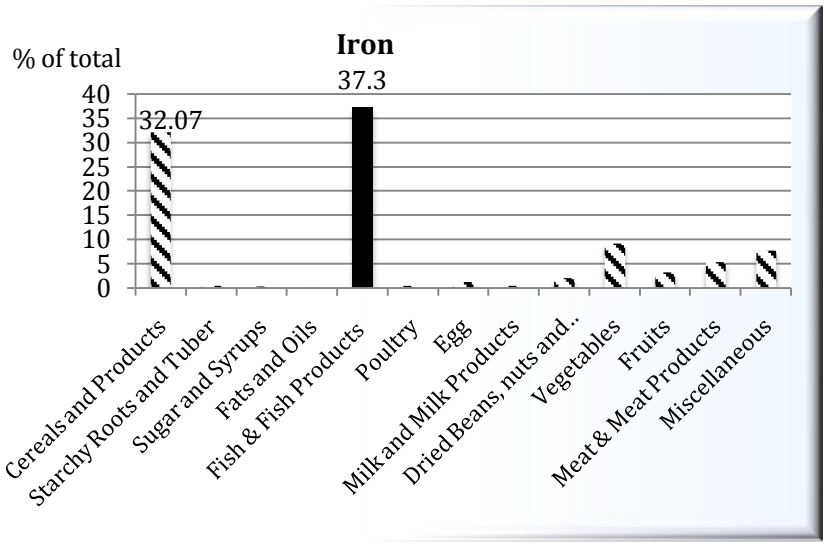


Figure 14: Percentage contribution of food groups to total intake of iron by individuals

In terms of the contribution of different fish sub-groups to nutrition, the data shows that floodplain residents contribute 11.7% of the total daily household protein intake, followed by long-distance migrants with 9.5% (Figure 15).

In addition, about one-fourth (27%) of the total household fat intake comes from fish consumption, with *long distance-migrants* accounting for the largest share (11.8%).

Whitefish accounts for 12% of total household fat intake

Whitefish accounts for 21% of total household iron intake

Further to this, long-distance migrants account for 20.9% of the total household iron intake almost one-third (34%) of which is contributed by fish.

This data demonstrates the importance of fish, and long-distance migrants in particular, to the protein and especially fat and iron intake in the Cambodia diet.

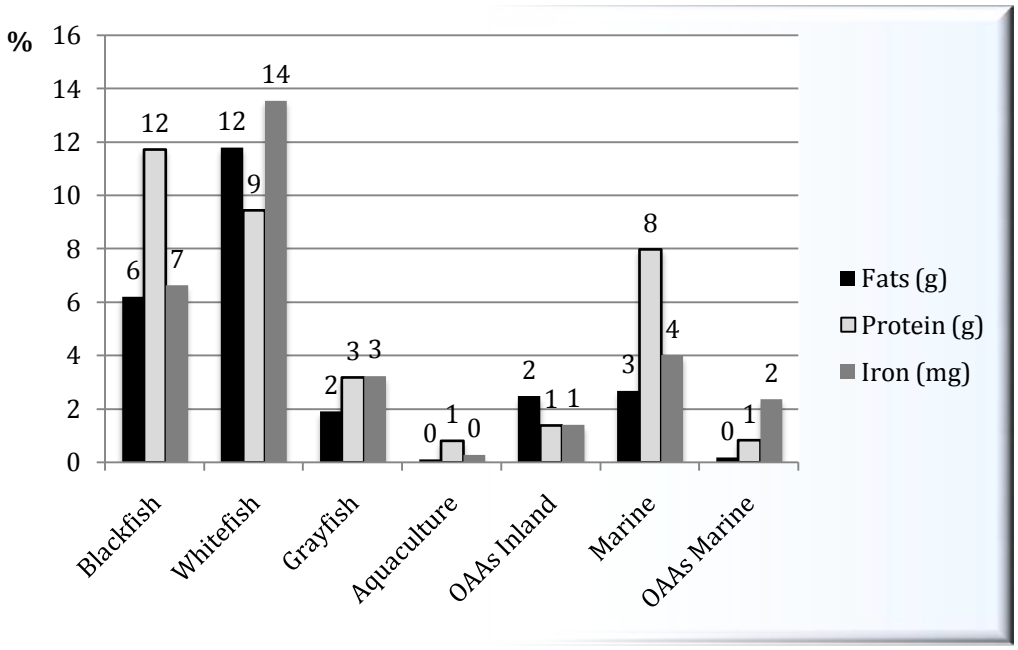


Figure 15: Percentage contribution of fish sub-groups to total nutrition of households

Aquatic resources are the major contributor of animal intake[6] with more than three-fourths (76%) of the total animal intake. Meat and meat products together with poultry contribute less than one-fourth of the total animal intake with about 20% and 4%, respectively. Thus, as already established in the section above, fish is the main contributor of the macronutrients, protein, fats and the micronutrients especially iron.

Among the fish sources, inland fish contributes the most to animal intake, at 55%. Floodplain residents provide the highest percentage (about 23%) followed by long-distance migrants (19%) while aquaculture fish contributes the least with only about 2%.

Marine fish together with other aquatic animals from marine sources contribute almost 21% (Figure 16 below).

[6] All food of animal origin (for example: meat, eggs, dairy)

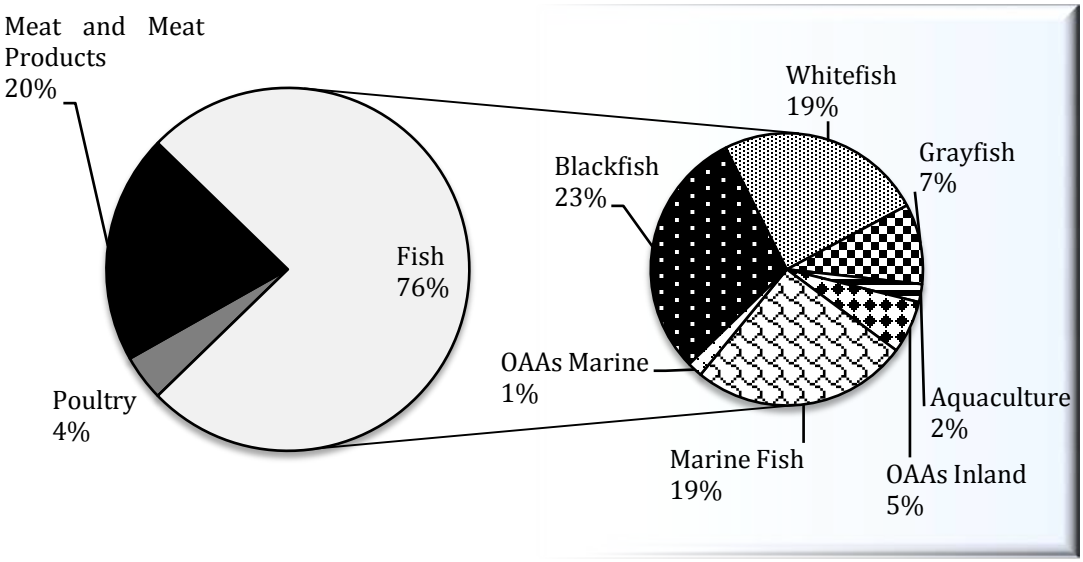


Figure 16: Animal intake and breakdown of fish sub-group contribution

In terms of the different ecological zones, the contribution of fish to total animal intake varies. In the *Tonle Sap* zone, fish accounts for 76% of the total animal intake with inland fish accounting for 58% of the total fish intake. Those living in *Mountains & Plateaus* also consume more fish than other animal protein sources, with fish accounting for 70% of total animal intake, while meat and meat products contribute only 24%, and poultry 6%. In the *Coastal* zone, marine fish accounts for 25% of the total fish intake.

In *Phnom Penh*, fish contributes relatively less to animal intake, accounting for 66% of the total. This is due to the relatively higher intake of meat and meat products (26%) and poultry (8%) compared to those living in the other ecological zones.

The data on the role of fish in nutrition shows that fish is the major contributor to protein, fat and iron intake in the Cambodian diet. In addition, it also provides 12% of the total energy intake by individuals (Table 3).

Table 3 Proportion contribution of fish to energy and nutrient intake: Cambodia, 2011

Energy and Nutrients	% Of Total Individual Intake
Energy (Kcal)	12%
Fats (g)	28%
Protein (g)	37%
Iron (g)	37%

The most important role of fish in terms of energy is the fact that when energy needed by the body cannot be supplied by rice and other carbohydrate-rich foods, the body metabolizes the protein from fish to sustain its caloric needs for the proper functioning of various physiological and biochemical processes such as digestion and metabolism.

As the overall intake of fat in the Cambodian diet is very low, the fat and protein contributed by fish is very important. The low fat intake of Cambodians is the reason for the low calorie levels, which result in protein-calorie deficiency (*marasmus*) and is the major reason for stunted growth and development in Cambodia.

89% of people obtain recommended levels of PROTEIN, and aquatic resources contribute 35% of this protein intake

Only 25% of people obtain recommended levels of ENERGY, and aquatic resources contribute about 12% of this intake

Only 19% of people obtain recommended levels of IRON, and aquatic resources represents 37% of this intake

Disaggregating by ecological zone, adequate energy intake is highest when consumption of energy-giving foods, body-building foods and fish is also high as in the case of *Coastal* areas where adequate levels are obtained by about one-half (52%) of the households. This zone can therefore be considered to be the most food secure.

Households in other ecological areas have lower levels of adequate energy intake—along with lower consumption of energy-giving foods and fish—ranging from one-fifth (21%) to about more than one-fourth (28%). The least food secure are the *Tonle Sap* and the *Plains* areas, where only one-fifth (21%) of individuals obtain adequate levels of energy.

The nutrition survey data also shows that adequate protein intake is high with 89% of individuals obtaining the required levels. This high result reflects the impact of fish on nutrition, which outweighs by far any other protein-rich food, as fish contributes more than half (55%) to the total individual animal protein intake.

However, the data also shows that only 25% of the population obtains the necessary levels for energy and only 19% obtains the required levels for iron. There are no established levels for intake of fats in Cambodia; however, intake levels are recognized as low.

An analysis of the number of children and women who obtain the Recommended Daily Allowance (RDA) shows that in terms of energy, school children have the lowest rate of RDA satisfaction. For iron levels, the under 5 year olds and pregnant women are amongst the most deficient; and finally in terms of proteins, pregnant women are the most vulnerable group (Figure 17).

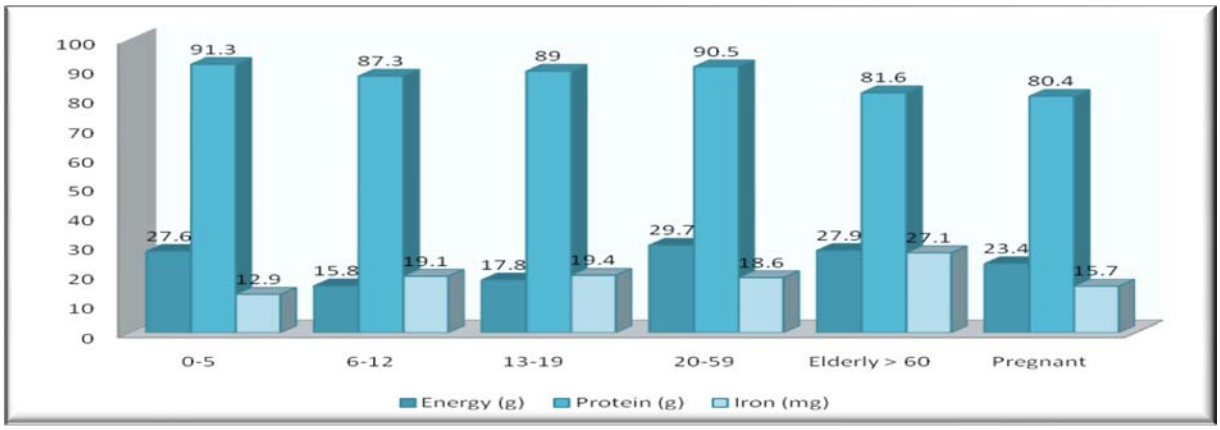


Figure 17 Proportion meeting recommended daily allowances (RDAs) by age group and pregnant women: Cambodia, 2011

Therefore, while the low adequacy levels for energy and iron are a concern, the intake of fats must also be highlighted. 'Fats' are an important dietary component, which in the context of the Cambodian diet, are directly linked to the supply of fish. The fat of fish contains essential Omega-3 and 6 fatty acids such as linoleic and linolenic acids, precursors of the essential eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These nutrients are not synthesized by the body and must be obtained from food. DHA in particular –'Smart fat'–is a key component of the phospholipids membranes of the eyes and brain and is essential for brain and eye development in infants and children; it also reduces heart disease, lowers blood pressure, and strengthens the immune system. DHA is essential for normal growth and development, healthy skin and reproduction.

2.2 FISH CATCHES DERIVED FROM THE CONSUMPTION STUDY

According to the Cambodian National Institute for Statistics, the estimated population of Cambodia was 12,014,343 in 2000 and is expected to grow to 15,104,768 by 2015. This gives a figure of 14,095,147 people in 2011 (rounded up to 14,100,000). The total fish yield can be derived by multiplying the individual fish consumption figures above by the total population (Table 4).

Thus, the latest catch estimate, based on the current study, amounts to *570,000 tonnes of inland fish per year*. When complemented by other aquatic animals, this amounts to 625,000 tonnes of inland capture resources available for consumption each year.

These results are very much in line with previous estimates:

- In 2011 according to national statistics, the catch reached 490,000 tonnes (i.e. 16% difference only)
- According to Hortle (2007[7]), the average inland fish catch in Cambodia, estimated from other consumption studies, amounts to about 482,000 tonnes (and 587,000 tonnes when other aquatic animals are included). However, we must highlight that this figure includes conservative extrapolations for provinces that are not covered in Hortle's review but that are covered in the current study
- In their 2008 study encompassing the previously overlooked production of black fish (i.e. local resident fish species) in rainfed rice fields, Hortle *et al*.[8] came to the conclusion that the total fish production in Cambodia would range between 524,000 and 616,000 tonnes per year of fish + other aquatic animals.

[7] Hortle K.G. 2007 Consumption and the yield of fish and other aquatic animals from the Lower Mekong Basin. MRC Technical Paper No.16, Mekong River Commission, Vientiane, Lao P.D.R. 87 pp.

[8] Hortle K.G., Troeung R., S. Lieng 2008 Yield and value of the wild fishery of rice fields in Battambang Province, near the Tonle Sap Lake, Cambodia. MRC Technical Paper No. 18, Mekong River Commission, Vientiane, Lao P.D.R. 62 pp.

Table 4: Annual fish catch estimated from the present fish consumption survey

			Annual intake of fish and fish products (kg/person/year)	Population	Annual yield (tonnes, rounded up)	Total inland fish (rounded up)	Total inland or marine capture catch	Total capture (inland + marine)	Grand total aquatic resources
Inland capture resources	Inland fish	Floodplain residents	18.8	14,100,000	265,000	570,000	625,000	870,000	889,000
		Long-distance migrants	15.5		219,000				
		Short-distance migrants	6.0		85,000				
	Other inland aquatic animals		3.9		56,000				
Marine capture resources	Marine fish		16.2		229,000		245,000		
	Other marine aquatic animals		1.1		16,000				
Aquaculture			1.3		19,000				

2.3 ESTIMATED CHANGES OF THE SUPPLY/AVAILABILITY OF FISH AND OTHER AQUATIC ANIMALS UNDER CAMBODIAN DAM DEVELOPMENT SCENARIOS

2.3.1 MODELLING APPROACH AND HYPOTHESES

The total quantity of fish and OAAs available for consumption in Cambodia was estimated from the yield of fish and OAAs from inland (*i*), marine (*m*) and aquaculture (*a*) adjusted for imports (*I*), exports (*E*), waste (*W*), other utilisation (*U*), using the following formula:

$$C=(Y_i+I_i-E_i-W_i-U_i)+(Y_m+I_m-E_m-W_m-U_m)+(Y_a+I_a-E_a-W_a-U_a) \quad \text{Eq. 1}$$

The available figures were reviewed in detail to obtain the current baseline and the 2030 possible forecasts for:

- Yield of inland fish and Other Aquatic Animals (Yi)
- Other sources and disposal of fish and OAAs
- Yield of marine fish and OAAs (Ym);
- Yield from aquaculture (Ya);
- Exports (E);
- Imports (I);
- Other utilisation (U);
- Waste (W)

in order to assess the amount of fish actually accessible to people for consumption. Thus, the model does not only focus on river fish, but on all sources of fish (including marine fish and aquaculture fish) and other freshwater and marine aquatic animals.

The project also reviewed:

- dam development scenarios until 2030
- the baseline area of fish habitats (rivers, floodplains and rain-fed wetlands);
- the proportions of white, grey and black fish in the total fish yield (inland fish yield, imports and sources of disposal were disaggregated by the three main guilds of fish (i.e. white / grey / black fish) to account for differences in their response to dam development in the river system)
- estimates of dam reservoir fish production
- estimates of Cambodian human population size and growth

then modelled, for 2030 and the three hypotheses regarding the distribution of spawning sites basinwide (see below):

- the impacts of each development scenario on fish habitat area and accessibility;
- the hydrological consequences of each dam development scenario and its impacts on the flood index (FI), flood timing and duration (these parameters were shown to be important to fish production)
- the yield created by dam reservoirs

All these parameters were then integrated into the model in order to predict for each dam development scenario:

- the change in total fish yield in 2030 compared to the baseline;
- the total quantity of fish and OAAs available for consumption, integrating predicted future quantities of fish and OAAs from the aquaculture sector, imports and disposal (exports, utilisation for aquaculture feed and fertilizer, and post-harvest waste).

Three hypotheses concerning the distribution of *long-distance migrants'* spawning habitat in the main channel and its tributaries (excluding the Tonle Sap River and Lake) were considered in the assessment:

Hypothesis 1: *All spawning habitat is uniformly distributed in main channels and tributaries of Cambodia (*low impact scenario*).*

Assuming that *long-distance migrants* spawn only in river channels in Cambodia, the total area of river channels available for spawning under the baseline (1,310 km^2) would decline by a maximum of almost 50%. Tributary dams would remove approximately 11% of the spawning area by 2030. An additional 10% of the channel area would be removed by the Stung Treng HPP, while Sambor would remove approximately 40% of the available area.

Hypothesis 2: *Spawning habitat is uniformly distributed in main channels and tributaries throughout the Lower Mekong Basin (*medium impact scenario*).*

Dams are expected to deny *long-distance migrants* access to upstream spawning and refuge habitats. Therefore, the aggregated yield of *long-distance migrant* species is assumed to vary linearly with the available spawning habitat area (SHA).

Dams will deny long-distance migratory fish access to spawning grounds

The yield of long-distance migratory fish is in direct relation to the availability of spawning grounds

Under the hypothesis that *long-distance migrants'* spawning habitat exists throughout the Lower Mekong Basin, approximately two-thirds of the spawning area would be lost if Sambor HPP is developed, compared to a 56% loss for Stung Treng HPP. Relatively minor losses (less than 10%) of spawning area would be expected from the development of tributary dams by 2030.

Hypothesis 3: *All spawning habitat is uniformly distributed in main channels and tributaries of the LMB above Kratie (*high impact scenario*).*

Under the hypothesis that all spawning habitat for *long-distance migrant* species exists upstream of Kratie, modest (approximately 12%) reductions to the baseline spawning habitat area would be expected from tributary dam development by 2030. However, the development of Stung Treng HPP would deny access to the majority (more than 80%) of the spawning area, while the development of Sambor HPP would effectively remove all *long-distance migrants'* spawning area from the system.

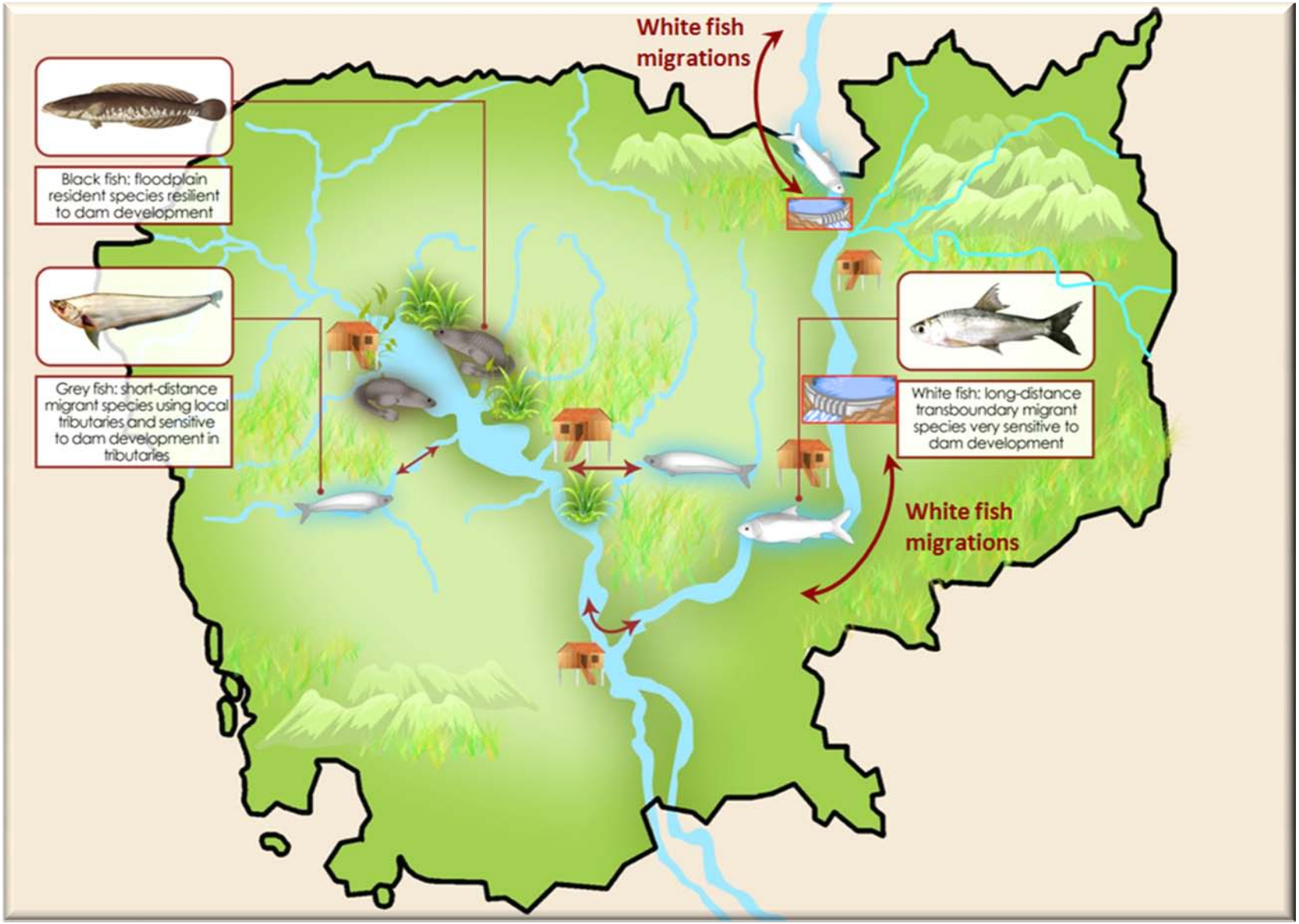


Figure 18: Fish groups, migrations and sensitivity to dam development

The losses in habitat expected under each scenario are illustrated below.

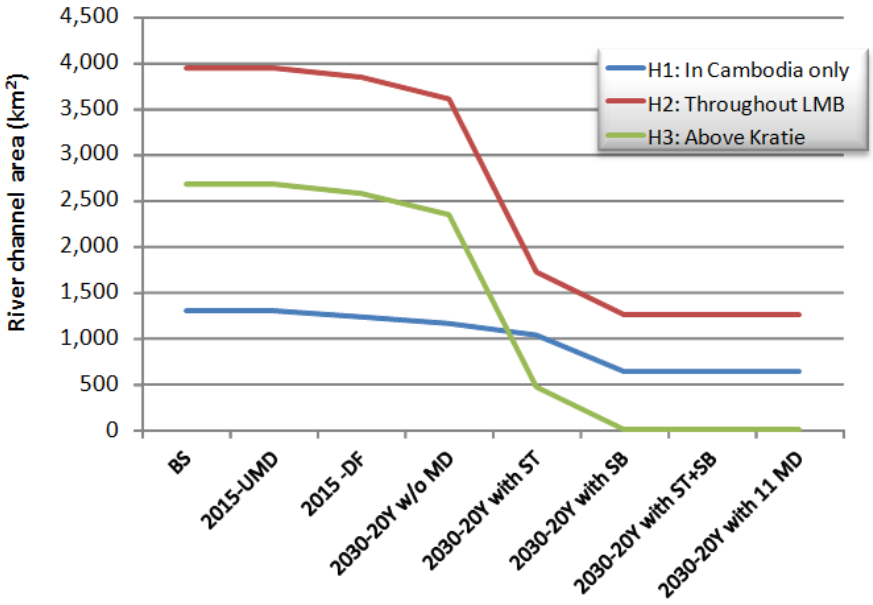


Figure 19: Estimated spawning channel area (km^2) accessible to *white fish* species under each development scenario and for each spawning habitat distribution hypothesis.

It is assumed that any fish ways, ladders or passes designed to mitigate the barrier impacts of dams on upstream migrations of *long-distance migrants* would not be effective (i.e. zero passage of fish). Downstream passage impacts on *long-distance migrants* were therefore not considered. Extinctions of *long-distance migrants* including threatened species such as the highly migratory Mekong Giant Catfish (*Pangasianodon gigas*) are therefore likely under high development scenarios, particularly under Hypothesis 3. Passage impacts on *floodplain residents* and *short-distance migrants* were assumed to be negligible due to their limited migrations and flexible behaviour.

2.3.2 PREDICTED CHANGES TO CAPTURE FISHERIES YIELD

NOTE

In the Fisheries and impacts study, the baseline fish yield is derived from initial unpublished fish consumption figures per person from the Nutrition study. However, these figures were updated later on. Furthermore, in the Fisheries and impacts study, individual consumption figures are derived from household consumption divided by an assumed household size of 5 persons per household; however, later analysis of the consumption survey data showed that average household size was 4.2 individuals, not 5.

Subsequently, as stated on page 51 of the report "Impacts of mainstream dams on fish yield and consumption in Cambodia", the yield of inland fish and OAAs was estimated to be approximately 850,000 tonnes "*in order to balance consumption"*, but the consumption figures used were actually inadequate (the yield of inland fish and OAAs derived from the Consumption survey actually amounts to 624,000 tonnes of inland fish per year).

For these reasons IFReDI and scientists of the Technical Advisory Group decided not to include in the current synthesis *absolute fish yield modelled figures* from the Fisheries and impacts study, but to keep instead total fish yield figures derived from the field-based Consumption survey. What was kept from the Fisheries and impacts analysis was the *relative fish yield impact results* based on a thorough and transparent modelling approach.

In response to the likely development during the next 20 years in the form of new tributary dam irrigation projects and water abstraction in the Lower Mekong Basin, the yield of fish and other aquatic animals from inland capture fisheries is predicted to decline from approximately 4% to 5% or 24,000 – 29,000 from the 2011 baseline (i.e. 626,000 tonnes). This decline is irrespective of any mainstream dam development.

Table 5: Predicted loss of total yield in fish and other aquatic animals in the absence of any dam development

Hypotheses about spawning of long-distance migratory fishes	*H1*	*H2*	*H3*
2030 without mainstream dams (%)	-3.7	-3.8	-4.7
2030 without mainstream dams (tonnes)	-23,000	-24,000	-29,000

The model outputs give the current figures for the yield of fish and other aquatic animals (marine + freshwater + aquaculture) accessible to human consumption for each scenario in 2030 (Table 7):

Table 6: Losses in yield of inland fish and other aquatic animals for each scenario compared to a scenario without mainstream dams. Percentages.

Hypotheses about spawning of long-distance migratory fishes	Loss of total yield in fish and other aquatic animals (%) compared to 2030 without mainstream dams		
	H1	*H2*	*H3*
2030 with Stung Treng dam	-6%	-17%	-23%
2030 with Sambor dam	-16%	-21%	-29%
2030 with Stung Treng + Sambor	-16%	-21%	-29%
2030 with 11 mainstream dams	-16%	-21%	-29%

This corresponds to the following losses related to the 2011 baseline:

Table 7: Losses in yield of inland fish and other aquatic animals for each scenario compared to a scenario without mainstream dams. Tonnes.

Hypotheses about spawning of long-distance migratory fishes	Loss of total yield in fish and other aquatic animals (%) compared to 2030 without mainstream dams		
	H1	*H2*	*H3*
2030 with Stung Treng dam	-34,000	-103,000	-145,000
2030 with Sambor dam	-98,000	-130,000	-182,000
2030 with Stung Treng + Sambor	-98,000	-130,000	-182,000
2030 with 11 mainstream dams	-99,000	-131,000	-183,000

Thus, the development of the *Stung Treng dam* alone is predicted to reduce yields of fish and OAAs by 6% to 24% or 34,000 – 145,000 tonnes.

The Sambor dam alone is predicted to reduce yields of fish and OAAs by approximately 16% to 30% or 99,000 – 183,000 tonnes compared to 2011 baseline values.

Stung Treng HPP will reduce yields by 6-24% or 34,000 – 145,000 tonnes

Sambor HPP will reduce yields by 16-31% or 98,000 – 182,000 tonnes

This reduction is almost as much as if all 11 mainstream dams were constructed, because the Sambor dam alone, being the closest to Cambodian productive floodplains, would block access to spawning grounds for all the long-distance migratory fish found in these floodplains. Once access is blocked by Sambor, the other dams would have no additional impact on long-distance migratory fish harvested in Cambodia. However, the other dams would naturally have an impact on the migratory species harvested in other countries and local impacts.

WHAT WOULD BE THE IMPACT OF MAINSTREAM DAMS BEYOND CAMBODIA'S BORDERS?

The MRC Strategic Assessment of Hydropower on the Mainstream considered three scenarios for mainstream dam development: i) 11 dams between the Chinese border and Kratie (thus including Stung Treng and Sambor in Cambodia and Don Sahong in Laos); ii) 9 dams in Laos and Thailand between the Chinese border and the Cambodian border; iii) 6 dams between the Chinese border and Vientiane. The table below summarizes the conclusions of that study about the impact of these dams on the overall Mekong fish production (not only on Cambodia's fish production as in the current study):

	No mainstream dams	**6 mainstream dams**	**9 mainstream dams**	**11 mainstream dams**
Losses in 2030 compared to 2000 (t) *Fish production in 2000: 2.1 million tonnes/year*	10 to 26% loss	13 to 28% loss	17 to 32% loss	26 to 42% loss

A recent study on dams on tributaries also showed that although most attention has been given to mainstream dams, some tributary dams could have a strong impact on fish production and biodiversity basinwide; this study calls for regional coordination of dam development on Mekong tributaries.

Given the strong migratory behaviour of about a third of fish biomass landed (38%, see Table 4), the vast majority of the predicted losses would be among species that belong to the *long-distance migrants* guild.

Predicted losses of Other Aquatic Animals by 2030 and in the absence of dams would be minimal and mainly due to reductions in wetland areas. Mainstream dams would reduce the yields of OAAs by a further 4%.

Mainstream Cambodian dams are therefore predicted to reduce the supply of inland fish and OAAs for consumption by between 34,000 to 183,000 tonnes from the baseline values depending mainly upon the hypothesised distribution of *long-distance migrants'* spawning habitats. This highlights the importance of new research on spawning areas in order to narrow this large uncertainty range.

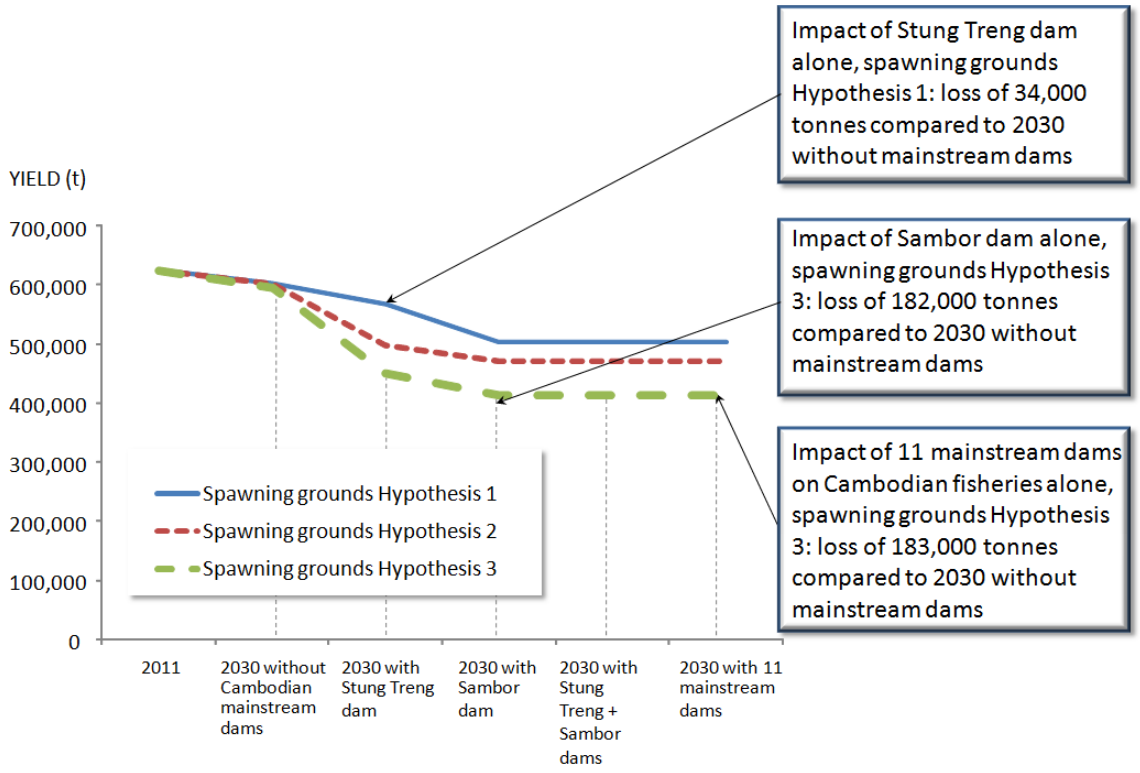


Figure 20: Predicted annual yield of inland fish and other aquatic animals under each development scenario and hypothesised distribution of *long-distance migrants'* spawning habitats.

2.3.3 PREDICTED CHANGES TO THE SUPPLY OF AQUATIC RESOURCES FOR CONSUMPTION

Although the above sections focus on the future of inland aquatic resources, the section below details the actual supply of aquatic resources to the population. To do so, the model:

- combines the predicted future yields of inland fish and OAAs above with the predicted future quantities from the aquaculture sector and from imports,
- deduces non-consumptive disposal (exports, utilisation for aquaculture feed and fertilizer, and post-harvest waste),
- integrates predicted changes in river hydrology and accessible wetland habitats, and
- integrates the population growth

for each development scenario and for each hypothesis about reservoir production yield.

Conclusions:

Population growth: by 2030 the human population of Cambodia is expected to grow from approximately 14 million in 2011 to 20 million by 2030 (+43 %), which has the heaviest impact on individual access to aquatic resources.

Aquaculture: Per capita consumption in Cambodia appears to have remained unchanged since year 2000 in spite of a 20% increase in population size from approximately 11.8 million to 14 million. This suggests that yields of fish and OAAs from inland aquatic habitats and aquaculture production have grown in the recent past to meet increasing consumption demand. However, in the absence of mainstream dams and regardless of population growth, the supply of inland fish and other aquatic animals available for consumption is predicted to remain relatively stable from 2011 until 2030. The increased output from the aquaculture sector and forecasted declines in exports will be balanced by losses experienced by capture fisheries in response to dam development *on tributaries* (not on the mainstream) and irrigation development in the lower part of the basin (i.e. loss of wetlands producing capture fish). The supply of fish and OAAs for consumption appears relatively insensitive to the assumed level of aquaculture area production from dam reservoirs. This implies that aquaculture would not compensate for losses to supply arising from Cambodian mainstream dam impacts.

Aquaculture will not compensate for the fishery losses resulting from the mainstream dams

Fishery losses due to dam construction: from -34,000 to -183,000 tonnes (see above sections).

CAN AQUACULTURE COMPENSATE FOR THE LOSS OF FISH CAUSED BY MAINSTREAM DAM DEVELOPMENT?

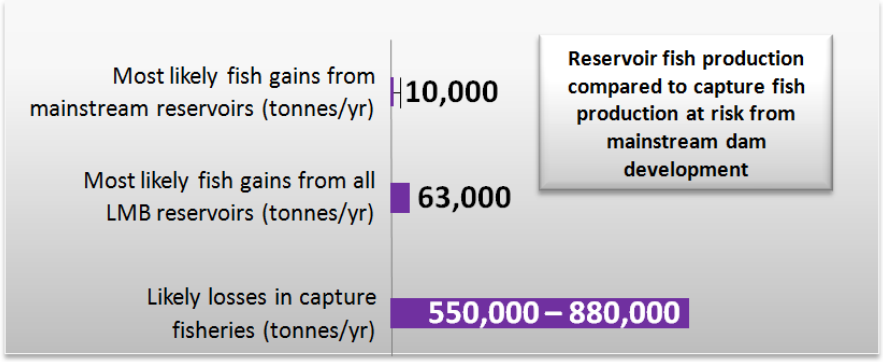
In the context of dam development, two sources of new fish production may compensate for the loss of wild capture fish: reservoir fisheries and aquaculture. We briefly review below the potential of these two sources.

Reservoir fisheries.

These fisheries result from the creation of a new water body and are generally characterized by high productivity for about a decade. This productivity results from the progressive decay of wood and other organic material following the reservoir impoundment. However, after 10-15 years the original input of organic matter is consumed and the productivity declines sharply (case of multiple dam reservoirs in Africa). In Asia, the Nam Ngum reservoir, still productive after four decades, is an exception due to the fact that wild fish still could, until recently, migrate between the reservoir and productive and pristine upstream tributaries (the Nam Ngum and Nam Leuk Rivers) where they could breed and complete their lifecycle.

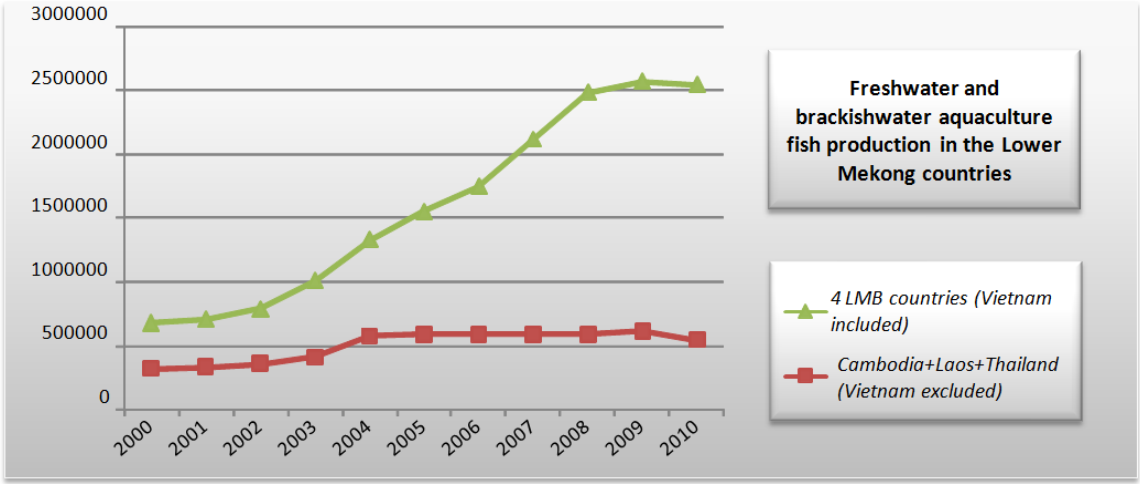
In general, reservoir creation results in a radical change in fish catch composition, with the disappearance of most commercial river species and the sudden dominance of low-value plankton feeders such as Clupeids.

The productivity of reservoirs ranges from 20 to 200 kg/ha/year (low end of the range for deep and large reservoirs, high end for shallow and small reservoirs). In the Mekong, there is consensus among experts that the fish production of planned dam reservoirs will reach 60,000 tonnes per year maximum. When this figure is compared to the losses expected in river fisheries (i.e. 550,000 – 880,000 tonnes/year in the case of 11 mainstream dams), the conclusion is that, unfortunately, reservoir fisheries will not compensate for more than 10% of the loss of fish caused by mainstream hydropower development.



Aquaculture production

Aquaculture production in the Lower Mekong Basin is large, growing fast (374% growth during the last decade) and similar in volume to the capture fishery yield (2.5 million tonnes from aquaculture vs. about 2.1 million tonnes from capture fisheries in 2010). However, there is a common misperception that this applies to all Mekong countries; in fact 79% of the Mekong fresh- and brackish-water aquaculture production comes from Vietnam alone. When Vietnam is excluded, FAO figures show that aquaculture production in the 3 other countries has not progressed significantly in real terms.



Thus, Cambodia's aquaculture production has grown by 311% over the past decade, but in 2010 the country contributed only 2.3% of the overall freshwater fish aquaculture production in the Lower Mekong Basin, and its capture fishery production remains seven times higher than its aquaculture production.

Two other factors limit the replacement of lost capture fish by aquaculture fish in Cambodia:
- aquaculture depends on capture fisheries for the supply of fingerlings (26% of fingerlings are caught from the wild);
- aquaculture depends on capture fisheries for feed supply (22% of the inland fish catch is used as feed in the aquaculture sector).

Last, in socioeconomic terms, the aquaculture sector is not equivalent to the capture fisheries sector because i) capture fisheries are accessible to the rural poor, unlike aquaculture, which requires substantial investment; ii) capture fisheries generate many more jobs than aquaculture, and iii) the fish produced by aquaculture is usually high-value fish marketed to wealthy consumers, so the loss of capture fish would be detrimental to the food security of the rural poor even if a similar amount of fish were produced by the aquaculture sector.

Table 8: Baseline situation and consequences of Cambodian mainstream dam construction on the availability and consumption of aquatic resources by 2030

2011	Absence of mainstream dams	*Total aquatic resources (baseline; tonnes)*	*889,000*	
		2011 population	14,100,000	
		Total aquatic resources per person and per year (kg)	*63.0*	
2030	Absence of mainstream dams	2030 population	*20,086,000*	
		Total aquatic resources per person and per year	Loss of 30.6%	
		Total aquatic resources per person and per year (kg)	43.8	
	Construction of Cambodian mainstream dams		*Low impact hypothesis (Spawning hypothesis H1, Stung Treng dam only)*	*High impact hypothesis (Spawning hypothesis H3, Sambor + Stung Treng dams)*
		Loss in % compared to baseline	*6*	*34*
		Total aquatic resources per person and per year (kg)	*41.1*	*28.9*
		Loss in kg/person/year compared to 2011	*22*	*34*

The model indicates, due to the above reasons and in the absence of mainstream dams, a loss of 30.6% in fish supply (in terms of kg of aquatic resources per person and per year) by 2030 compared to 2011.

In the event that mainstream dams are constructed, the model also indicates that the outcome of dam construction in the low impact scenario *(Spawning hypothesis H1, Stung Treng dam only)* would be a further 6% loss, whereas the High impact scenario *(Spawning hypothesis H3, Sambor + Stung Treng dam*s) would result in a further 34% loss.

When all factors driving the production of overall aquatic resources now and in the future are integrated, the model shows that the per capita supply of inland fish and OAAs for consumption will decline significantly by 2030. In the absence of mainstream dams, the per capita supply of inland fish and OAAs is expected to decline from approximately 63 kg in 2011 to approximately 44 kg per person and per year by 2030. The construction of Cambodian mainstream dams would reduce this supply by an additional 6 to 34% depending on the scenario. This would result in fish consumption dropping to 29-41 kg/person/year.

Therefore, it is concluded that the construction of mainstream dams in Cambodia would aggravate the ongoing decline of consumption by 6 to 34%. Aquaculture would not compensate for losses to supply arising from Cambodian mainstream dam impacts, and the total amount of inland fish available for consumption as well as the consumption per person would dramatically decline.

Without dam construction, inland fish consumption will be reduced in 2030 to 44 kg per person and per year

In the Best Case Scenario, construction of mainstream dams will reduce inland fish by a further 6% to 41 kg per person

In the Worst Case Scenario, construction of mainstream dams will reduce inland fish by a further 34% to 29 kg per person

HOW FEASIBLE AND EFFECTIVE ARE FISH PASSES FOR MAINSTREAM DAMS?

The Mekong system is characterized by the importance of migratory fishes in the catch (at least 35% of the catch i.e. 700,000 tonnes each year basinwide) and the exceptional intensity of migrations (e.g. 34 tonnes of fish; i.e. 3 million individuals, caught every hour during the migration peak in the Tonle Sap River). Dams and their reservoirs constitute a double obstacle to fishes: the dam is a physical obstacle to adults trying to migrate upstream, and the reservoir is an environmental obstacle to larvae and juveniles trying to migrate downstream. We detail below these two obstacles:

<u>Physical obstacle</u>

Fish passes are a way to overcome the physical obstacle. There are seven main types of fish passes, and their applicability to Mekong mainstream dams is detailed in the table below.

In South America, where 388 rivers have already been dammed, two large reviews of fish passes in 2007 and 2012 concluded that more than 100 passes have been constructed, 20 have been evaluated and only 2 have been considered satisfactory.

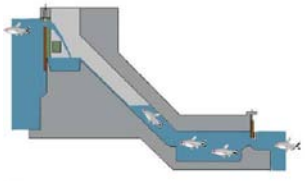
In the Mekong, a meeting of 17 fish specialists convened by the MRC in 2008 concluded that "existing mitigation technology cannot handle the scale of fish migration on the Mekong mainstream". This conclusion applies to mainstream dams only; the group also concluded that "if dams are built upstream and on tributaries, specific mitigation measures should be designed from the start and integrated into dam engineering and operation".

<u>Environmental obstacle</u>

Experience from South America shows that reservoirs created by dams constitute a major environmental obstacle to downstream migrations, in particular when their length is greater than about 20 km:
- in the reservoir, sediment deposition (due to slower water flows) results in clearer water and thus lower water density, which results in turn in the sinking and disappearance of floating fish eggs and larvae;
- clearer waters in reservoirs also result in a much higher mortality rate (due to visual predators) among juvenile fish trying to migrate downstream; the often low oxygen content in reservoirs can also be unsuitable for these fishes;
- juvenile and adult fish genetically fit for running rivers do not pursue the downstream migration when they face over a long distance the calm and chemically different reservoir waters, as if they had entered an inappropriate river.

<u>Conclusion</u>

In a nutshell, fish passes can help mitigate the impact of dams but they are not a magic bullet. Fish passes must be considered for all dams on tributaries, but a proper design requires studies of swimming capabilities of target species to make sure that these passes will be efficient. On the mainstream and in the lower part of the Mekong, the intensity of migrations is such that no fish pass can provide a realistic mitigation measure.

		Conditions of use	# of species able to pass	Applicability on the Mekong mainstream
Pool passes		*Work well for low dams (height <10m)*	*Many*	*Possible only on low dams in tributaries*
Vertical slot passes		*Work for low and medium dams (height <30m) but low capacity and design must be tailored for target species*	*Many*	*Possible only for low to medium dams on tributaries after swimming capabilities of target species have been studied. Low capacity*
Weir type passes		*Work for low and medium dams (height <30m)*	*Several*	*Possible only for low to medium dams on tributaries after swimming capabilities of target species have been studied*
Denil type passes		*Work for low and medium dams (<30m height) and only for large fish species*	*Several*	*Very small capacity. Cannot accommodate the intensity of peak migrations at downstream dams*
Natural bypass channels		*Work for low dams (height <10m)*	*Many*	*Possible in Don Sahong*
Fish locks		*Work for high dams but very low capacity.*	*Very few*	*Cannot accommodate the intensity of peak migrations at downstream dams. One constraint is the difficulty of attracting fish into the lock*
Fish lifts		*Work for high dams but very low capacity.*	*Few*	*Cannot accommodate the intensity of peak migrations at downstream dams. One constraint is the difficulty of attracting fish into the container*

2.4 THE POTENTIAL IMPACT OF HYDROPOWER DAM DEVELOPMENT ON FOOD AND NUTRITION SECURITY IN CAMBODIA

The data on the Cambodian diet clearly demonstrates the dependency of Cambodian people on fish. Fish is not only the second most consumed food in terms of the composition of daily meals, but also the main source of key nutrients such as protein, fat and iron, establishing a direct link between fish intake and health.

On the basis of these findings, the reduction of the supply of fish will have direct implications for both nutrition and public health in the country.

Depending on the three hypotheses discussed in this document, the amount of fish and OAAs available for consumption will be reduced to varying degrees.

The reduction of the supply of fish will have direct implications for both nutrition and public health in the country

In terms of nutrition, the above results would mean that in the *best-case scenario*, after the construction of the mainstream dams, there will be further reduction of the already low number of individuals who obtain adequate levels (RDA) of energy, protein and iron. In addition, there will also be a significant and important reduction in the intake of animal fats which is not reflected here as there are no RDA values for fat intake in Cambodia.

While this potentially dramatic reduction will affect the entire population and its dietary habits, there are particular segments of the population which will be more affected than others and whose ability to obtain adequate nutrients will be greatly jeopardized.

2.4.1 Ecological zone impacts

The reduction of inland fish available for consumption will affect mostly the *Tonle Sap* and *Plains* zones, which are the areas with the heaviest reliance on inland fish. The reduction of long-distance migrants will particularly affect the population in the *Plains* who eat more long-distance migrants than those living in any other ecological zone. **A reduction of 34% (the worst case scenario) of the available fish and fish products for consumption will have a dramatic impact on the proportion of the population living in the *Plains* who meet their daily allowances (RDAs), and who are already considered the people living in the least nutrient-secure ecological zone.**

2.4.2 Impacts on rural versus urban areas

Urban areas have greater food security than rural areas. Consumption of fish in urban areas is higher than in rural areas, with rural areas having a higher level of consumption of inland fish and a higher intake of long-distance migrants. However, despite the current availability of long-distance migrants, the poor overall nutrition in rural areas results in households and individuals in these areas being more nutrient-insecure, with less than 20% of the individuals obtaining adequate levels of iron. Therefore, a reduction in fish availability, and specifically in long-distance migrants, will have a strong detrimental impact on the rural population. In particular, it will pose a risk to public health by threatening to remove a vital source of iron from people's diets.

2.4.3 Impacts by gender

A reduction of the availability of inland fish for consumption will affect both sexes almost equally.

2.4.4 Impacts on age groups and pregnant women

The group with the highest levels of adequate energy intake was adults (20-50 years old) at one-third (29.7 %) of people. School children (6 to 12 years old) had the lowest levels of adequate energy intake at only about 15.8%. Thus, *school children* could be considered the most food-insecure age group and *adults* the most food secure. The data on pregnant women's nutrition shows that they are the most vulnerable group to protein reduction, with the lowest rate of protein RDA satisfaction.

The survey data shows that pregnant women are the most dependent on inland fish and in particular on the availability of long-distance migrants. Therefore, any dramatic reduction of these sources of protein will aggravate the already low levels of protein RDA satisfaction and put at risk the health of mothers and their babies.

Further to this, a United Nation Children's Emergency Fund (UNICEF)/World Food Program (WFP) survey shows that fish is part of the daily diet of 74-80% of all children of over 11 months old, for whom the main source of protein in rural areas is *prahoc*, which is the fermented fish paste made from long-distance migrants. Thus, children, especially in rural areas, will also be directly affected by the reduction of inland fish availability.

3 CONCLUSIONS

Based on the detailed technical studies summarized in this report, the following conclusions can be drawn:

The current per capita supply of inland fish is 63 kg per person in 2011. The future supply of inland fish is predicted to change as follows:

- In the absence of mainstream dams, the per capita supply of inland fish and OAAs available for consumption is expected to decline to approximately 44 kg per person by 2030 due to an increase in demand that cannot be met by additional supply;
- The construction of the Cambodian mainstream dams will decrease the supply of fish further by 6-34% down to between 29-41 kg per person depending on the spawning habitat hypothesis and dam development scenario;
- The Sambor dam would have a greater impact on supply compared to the Stung Treng dam and, in Cambodia, an impact equivalent to that of all mainstream dams together.

As the rates of people who are able to obtain adequate energy, protein and iron intake are all highly dependent on fish, the reduction of fish and fish products available for consumption will reduce the number of individuals and households who obtain recommended levels of energy and important nutrients.

This will aggravate existing malnutrition, thus exposing an increasing number of the population to health risks. Reduced fish consumption will have negative effects on public health and seriously impact some of the most vulnerable groups of people, such as those living in remote rural areas, school children and pregnant women.