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FISH PRODUCTIVITY BY AQUATIC HABITAT AND ESTIMATED FISH PRODUCTION IN CAMBODIA

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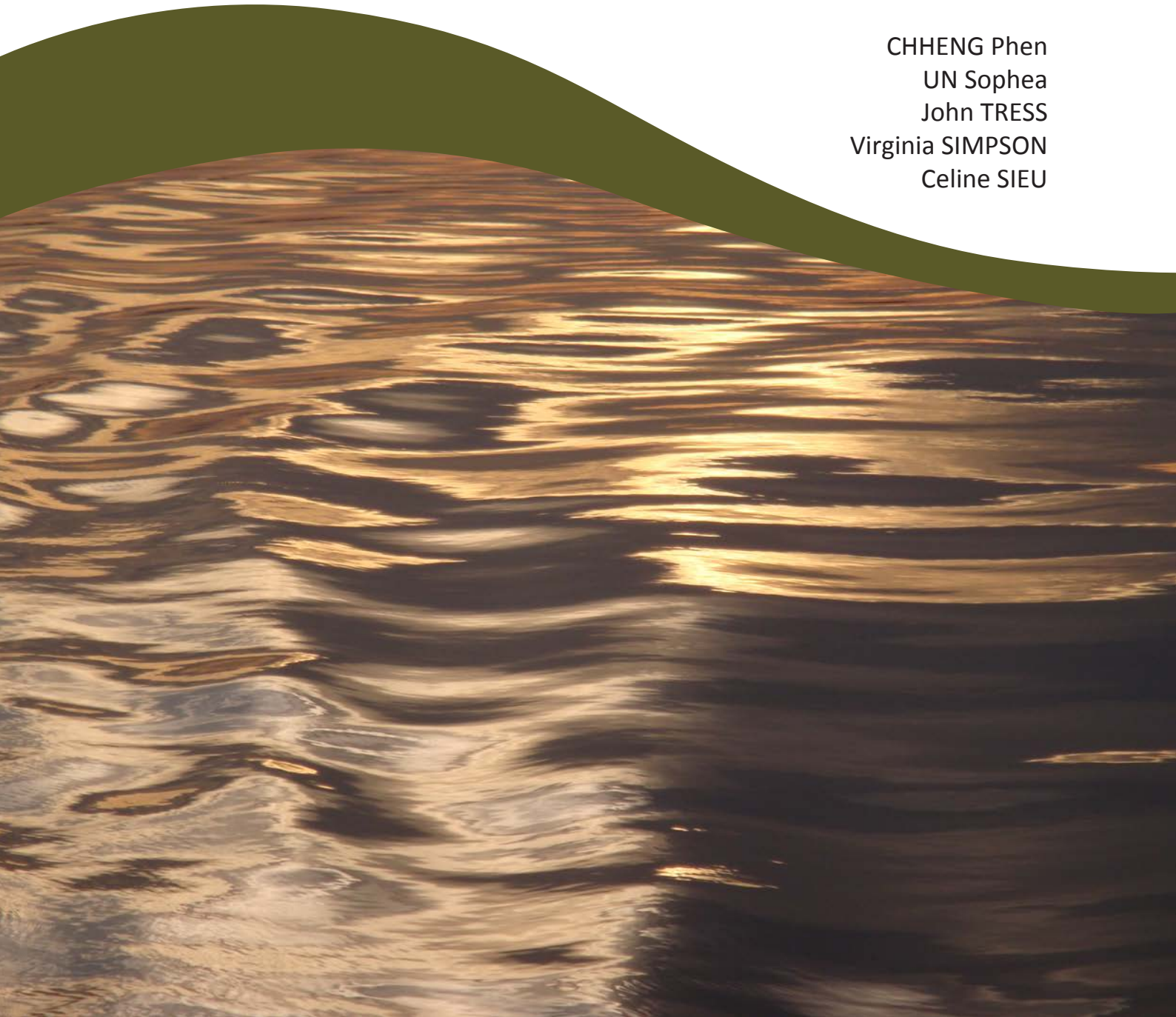

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Chheng Phen supervised the study, led the field surveys and contributed to the report
Un Sophea reviewed literature and prepared the report
John Tress contributed GIS assessments and maps
Virginia Simpson and Celine Sieu revised and upgraded the report

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EXECUTIVE SUMMARY

We present a review of existing information about the fish productivity of main aquatic habitats in Cambodia, i.e. rice fields, flooded swamps, shrub land, flooded forest, open water and reservoirs. We find an average fish production of 112 kg/ha/year in rain-fed rice fields, 113 kg/ha/year in flooded rice fields, 121 kg/ha/year in reservoirs, 66 kg/ha/year in the flooded forest, 167 kg/ha/year for shrub land, 94 kg/ha/year in open water and 92 kg/ha/year in flooded grassland and swamps. When these values are related to the surface area of each habitat in Cambodia, we find that rice fields contribute – or can potentially contribute- more than 60% of the total fish production. The second habitat contributing most to the fish production is flooded shrub land. The smallest production originates from reservoirs and flooded forests, whose surface area is very limited. The sum of these production figures per habitat corresponds to a total fish production of 560,000 tonnes per year.

1. INTRODUCTION

Between 2012 and 2015, the project "Assessing economic and welfare values of fish in the Lower Mekong Basin", was implemented by WorldFish, IFReDI and partners to quantify the multiple values of fish resources in Cambodia. One of the components of this project focused on fish production, through an assessment of the fish productivity of different aquatic habitats, leading to an estimate of the fish production nationwide. The present report details the results of this component.

The project built upon existing literature and addressed knowledge gaps with field studies. We first reviewed all existing publications related to stock, production or productivity of fish in different habitats of the Lower Mekong and in similar tropical habitats outside the Mekong Basin in Vietnam, Thailand or Bangladesh. Where secondary data was not available – as it was the case with shrub lands and open waters - primary research was undertaken to fill the knowledge gaps. Results of that research are detailed in a series of technical reports (Chheng and So 2012**,** Chheng *et al.* 2014, Un *et al.* 2014), and we present below a synthesis combining both approaches. First, fish production by habitat type is detailed, then the extent of each habitat in Cambodia is assessed, which leads to an assessment of the total fish production in the country.

STOCK, PRODUCTION, PRODUCTIVITY

In a number of papers reviewed, it is unclear whether results refer to fish stock, fish production, or fish productivity. These notions are clarified below.

Stock: fish biomass present in water at time t.

The stock unit is kilograms or tonnes, and this notion is independent from fishing. For instance, in 1986 a Russian survey estimated the fish stock in the coastal zone of Cambodia at 50,000 tonnes (out of which fishing should not extract more than 20,000). It is only in the case of exhaustive fishing (e.g. pumping a pond dry) that the catch is equal to the stock; otherwise the catch is only a fraction of the stock.

Production: fish biomass harvested.

The production unit is kilograms or tonnes. Production is synonymous with "catch" and "yield". This variable depends on fishing effort (more fishing, more production) and the time unit is often not mentioned. For instance, the production of a pond can amount to 1 tonne of fish each time it is harvested, but the pond can be harvested three times in a year.

Productivity: production per year

The productivity unit is kilograms per surface area and per year (usually kg/m^2/year or tonnes/ha/year). Thus, productivity is synonymous with "annual catch" and "annual yield". The productivity of the above pond is 3 tonnes per year.

2. FISH PRODUCTION BY HABITAT

2.1. FRESHWATER FISH PRODUCTIVITY

Habitats are classified into seven types for this review:

- rice field habitats
    - (1) rain-fed rice fields;
    - 2) flooded rice fields;
- 3) flooded swamps/marshes/grasslands;
- 4) shrub lands;
- 5) flooded forest;
- 6) open water; and
- 7) reservoirs.

2.1.1. Rain-fed rice field habitat

Hortle *et al.* (2008) monitored fishers' catch during one season (July 2003-February 2004) in Battambang province, and found a fish productivity ranging from 67 to 162 kg/ha/year[1], with an average of 119 kg/ha/year, of which 76.6% were fish. By multiplying the average value (119 kg/ha/year) by the percentage of fish composition (76.6%), the fish catch was found to be 91.6 kg/ha/year. On less detailed bases, Degan (pers. comm.) estimated the productivity of fish in rain-fed rice fields around the Great Lake to be as high as 150 kg/ha/year.

In the lowlands, Gregory *et al.* (1996) found that the average fishery production in rice fields reached 125 kg/ha/year, of which 82% (=102.5 kg/ha/year) were fish. Guttman (1999) in his study on *Rice field fisheries – a resource for Cambodia* also estimated that the fish productivity in the five districts of Svay Rieng province was over 80 kg/ha/year. Elsewhere in the Mekong Basin, rainfed rice fields were found to feature a large range of fish productivities; thus, according to Little *et al.* (1996) fish rain-fed rice fields fish production in Khu Khat (Northeast Thailand) ranged between 25 and 125 kg/ha/year. In contrast, the rice field fish production in rain-fed rice fields also in northeast Thailand reached 209 kg/ha/year according to Middendorp (1992).

These various sources indicates that the average fish catch in rain-fed rice fields is about 112 kg/ha/year (see table 1.), ranging between 25 and 209 kg/ha/year (Table 1).

[1]This study assumes that productivity of a season of 8 months can represent one year, but this is probably an underestimate. During the dry season, people continue to catch fish and other aquatic animals from drying mud or ponds, but these catches from March to July were not included in Hortle's study.

Table 1. Fish productivity in rain-fed rice field habitat

Habitat	Fish catch (kg/ha/year)	Sources
Rain-fed rice field	91.6	Hortle et al. 2008
	150	Degen (pers. comm.) cited in Guttman 1999
	102.5	Gregory et al., 1996
	80	Guttman, 1999
	25– 125	Little et al., 1996
	209	Middendorp, 1992
Average:	112	
Minimum:	25	
Maximum:	209	

Can annual fish productivity be twice higher than the fish stock?

Hortle et al. 2008 are the only authors providing both, for a given aquatic habitat, an estimate of fish stock (in kg per hectare at time t) and an estimate of fish productivity (in kg/ha/year).

Actually, in the rain fed rice fields studied, the total stock of fish and other aquatic animals amounts to 64.7 kg/ha. Fish represents 70% of this stock, i.e. 45.3 kg/ha (at the end of the wet season, which means probably the highest standing stock measurable before predation within an enclosed environment reduces that stock.

The fish productivity of the same habitat amounts to 91.6 kg/ha/year.

It is worth noting that the amount of fish extracted each year from one hectare of rain fed rice field is twice as high as the highest standing stock measureable (whereas production over a year is usually a fraction of the stock). This might be explained by the very high productivity of such a type of tropical habitat, in which two generations or more of fish are generated within one year, allowing the yearly catch to be superior to the stock at time t.

2.1.2. Flooded rice field habitat

In Cambodia, only one study, to our knowledge, has assessed the production of flooded rice field systems (i.e. including canals, as well as connected trap ponds and lakes). The survey shows a catch of 97 kg/ha/year in large open systems before management interventions.

In Bangladesh (1998 – 2000 study, reported in Dey and Prein 2005), fish catch in seasonally flooded rice fields ecologically similar to those in Cambodia ranged from 30 to 491 kg/ha/season (mean = 92.7 kg/ha/season, the flooded season being by extension assimilated to the whole year). In another study, Dey and Prein (2006) note that wild fish harvest from Bangladeshi flooded rice fields has declined from 200 to less than 100 kg/ha/year, from which we keep an average productivity figure of 150 kg/ha/year under "natural" conditions. From these sources we derive an average productivity of 113 kg/ha/year in flooded rice fields, ranging from 30 to 491 kg/ha/year (Table 2).

Table 2.Fish productivity in flooded rice field habitat

Habitat	Fish catch (kg/ha/year)	Sources
Flooded rice field	97	WorldFish 2016
	30 - 491 = 92.7	Dey et al. 2005
	100 - 200 = 150.0	Dey and Prein 2006
Average:	113	
Minimum:	30.0	
Maximum:	491.0	

2.1.3. Flooded grassland/marsh/swamp habitat

Fish production in flooded grassland as well as in marsh/swamp habitat is indirectly provided in Lieng et al. (2001). Fishery production in natural grassland was estimated at about 113 kg/ha, of which fish comprised 95% (107.4 kg/ha) and aquatic animals only 2% (2.3 kg/ha). Fish production in natural swampland was estimated at around 84 kg/ha, of which fish contributed 90% (75.6 kg/ha) and aquatic animals only 3% (2.5 kg/ha). It can be derived from these figures that fish productivity in flooded grassland/marsh/swamp amounts to 91.5 kg/ha/year, ranging from 75.6 to 107.4 kg/ha/year (Table 3).

Table 3.Fish productivity in flooded grassland/marsh/swamp habitat

Habitat	Fish catch (kg/ha/year)	Sources
Flooded Grassland / Marsh / Swamp	107.4	Lieng et al., 2006
	75.6	Lieng et al., 2006
Average:	91.5	
Minimum:	75.6	
Maximum:	107.4	

2.1.4. Shrub land habitat

In absence of secondary data available for fish production in flooded shrub habitat in Cambodia, a field study was undertaken in 2014 in the shrub land areas around the Tonle Sap Lake (Chheng et al 2014 and Appendix 2). Four sites were assessed for fish biomass and diversity in the dry season. Mosquito netting and electro fishing gear were used to herd fish from 50x50m quadrats into a mosquito net trap, after which they were sorted and weighed. The standing stock of the shrub lands sites averaged 82.7kg per hectare (the range was 49.05 to 126.66kg/ha)

Noting that in rain-fed rice fields the annual fish productivity amounts to 2.02 the fish stock, it can be assumed by inference that the maximum fish productivity in shrublands amounts to twice the standing stock, i.e. 82.7 x 2.02 = 167 kg/ha/year. High uncertainty level is acknowledged in this figure, but the absence of real fish productivity data for shrub land habitats and the fact that these habitats does not allow calculating a better productivity figure for that habitat.

2.1.5. Flooded forest habitat

Troeung (2001) estimated the average fish catch (only black fish was included) in fishing lot n°2 in the Tonle Sap zone of Battambang province. The estimated fish catch was 36.8 kg/ha/year. However, had the migratory white and grey fish species been included, the average fish catch would have been be much higher. In another study, Troeung et al. (2003) estimated the fish production at 95kg/ha/year; however, this figure includes only large and middle-scale fisheries catches in fishing lots and not the (minor) artisanal catch. Using these two sources, fish productivity in flooded forests can, by estimated at about 66 kg/ha/year (Table 4)

Table4. Fish productivity in flooded forest habitat

Habitat	Fish catch (kg/ha/year)	Sources
Flooded forest	36.8	Troeung, 2001
	95.0	Troeung et al., 2003
Average:	66	
Minimum:	36.8	
Maximum:	95.0	

2.1.6. Open water habitat

Data on fish production in open water habitat in the Tonle Sap zone originate from the field survey conducted on the Tonle Sap Lake in Pursat province, using trammel nets and seine nets in dry season (Chheng and So 2011, and Appendix 3). The result was an average fish catch of 31.3 kg/ha/season. This value is possibly higher when related to a full year, in particular since the catch in wet season is higher than in dry season.

Another study of Tonle Sap fish sanctuaries (Chheng 2011) compared the productivity of sanctuaries and that of open water test sites. For the present review, data from open water non-protected areas were re-analysed, and show a fish productivity of 85.1 kg/ha/year in the Tonle Sap open waters.

In Bangladesh, de Graaf et al. (2001) amounted the fish productivity of open waters in permanent floodplain wetlands ("perennial beels") at 165 kg/ha/year.

Averaging the above figures gives a fish productivity in open water habitat of 93.8 kg/ha/year, ranging from 31.3 to 165 kg/ha/year (Table 6).

Table 6.Fish productivity in open water habitat

Habitat	Fish catch(kg/ha/year)	Sources
Open water	31.3	Present review, 2011
	85.1	Chheng, 2010
	165.0	De Graaf et al., 2001
Average:	93.8	
Minimum:	31.3	
Maximum:	165	

2.1.7. Reservoir habitat

Fish yields in reservoirs exhibit a large variability. Tran et al. (2001) report in the natural Lak Lake of Vietnam a fish productivity of 126 kg/ha/year (baseline situation with a self-recruiting natural population). Although this is a natural lake, it can be considered as a reservoir since the area is limited to 658 ha, i.e. too small to be open water. Tran et al. (2001) also report that the highest fish yield in a reservoir in Vietnam reached 214 kg/ha/year. On the other end of the range, the fish yield in Sirindhorn reservoir in Northeast Thailand was only 21 kg/ha/year (Sricharoendham et al., 2000). In the same region, Pholprasith and Sirmongkonthaworn (1999) found a fish yield of 61 kg/ha/year in the Ubolratana reservoir. In the Nam Ngum reservoir of Lao PDR, the fish yield was estimated to 185 kg/ha/year (Mattson et al. 2001). Based on the above sources, we propose as average fish productivity in reservoir habitat 121.4 kg/ha/year (Table 7).

Table 7.Fish productivity in reservoir habitat

Habitat	Fish catch (kg/ha/year)	Sources
Reservoir	126.0	Tran et al., 2001
	214.0	Tran et al., 2001
	21.0	Sricharoendham et al., 2000
	61.0	Pholprasith & Sirmongkonthaworn, 1999
	185.0	Mattson et al., 2001
Average:	121.4	
Minimum:	21	
Maximum:	214	

3. COMPARISON BETWEEN HABITATS

Figure 1 shows differences in fish productivity by habitat. This information is important for identifying habitats to be conserved or developed. Findings from this review show that fish productivity is, on average, the highest in shrublands with 167 kg/ha/year, followed by reservoirs (121 kg/ha/year), rice fields (112-113 kg/ha/year), open water and flooded grassland/marsh/swamp (92-94 kg/ha/year) and flooded forest (66 kg/ha/year), respectively.

We acknowledge that simple averaging of productivity figures from the literature is a crude approach to assessing the productivity of each habitat, and yet the results show some coherence, in line with ecological principles: the most productive habitat is shrub land, which is confirmed by field experience and reflects the high productivity of the vegetation. The second most productive habitat is reservoirs, although they exhibit an extremely high variability, which is explained by that of their environmental conditions, as detailed by Bernacsek (1997 a & b). Rice fields are the third most productive fish habitat, reflecting the findings of Gregory and Guttman (1996), and their high primary productivity. Grasslands, marshes and swamps come fourth; they are usually considered to be extremely productive and biodiverse habitats (Ricklefs 1990), but in the case of Cambodian floodplains, their primary productivity is probably less than that of shrub land and rice fields. It is surprising to see the productivity of open water as high as that of marshes and swamps, but open waters are a corridor between extremely productive vegetated habitats nearby and they may reflect a fraction of this productivity, in particular through the presence of a large number of migratory species. Flooded forest is the least productive habitat, which should not come as a surprise since we are referring here to a not-so-dense habitat of large flooded trees such as *Barringtonia acutangula* and *Diospyros cambodiana*, whereas the term “flooded forest” is commonly used to refer to shrub land, a habitat with a much higher density, vegetation turnover and primary productivity.

Fish productivity for the whole country can be estimated by multiplying the fish productivity of each habitat by the surface area of that habitat, as detailed below.

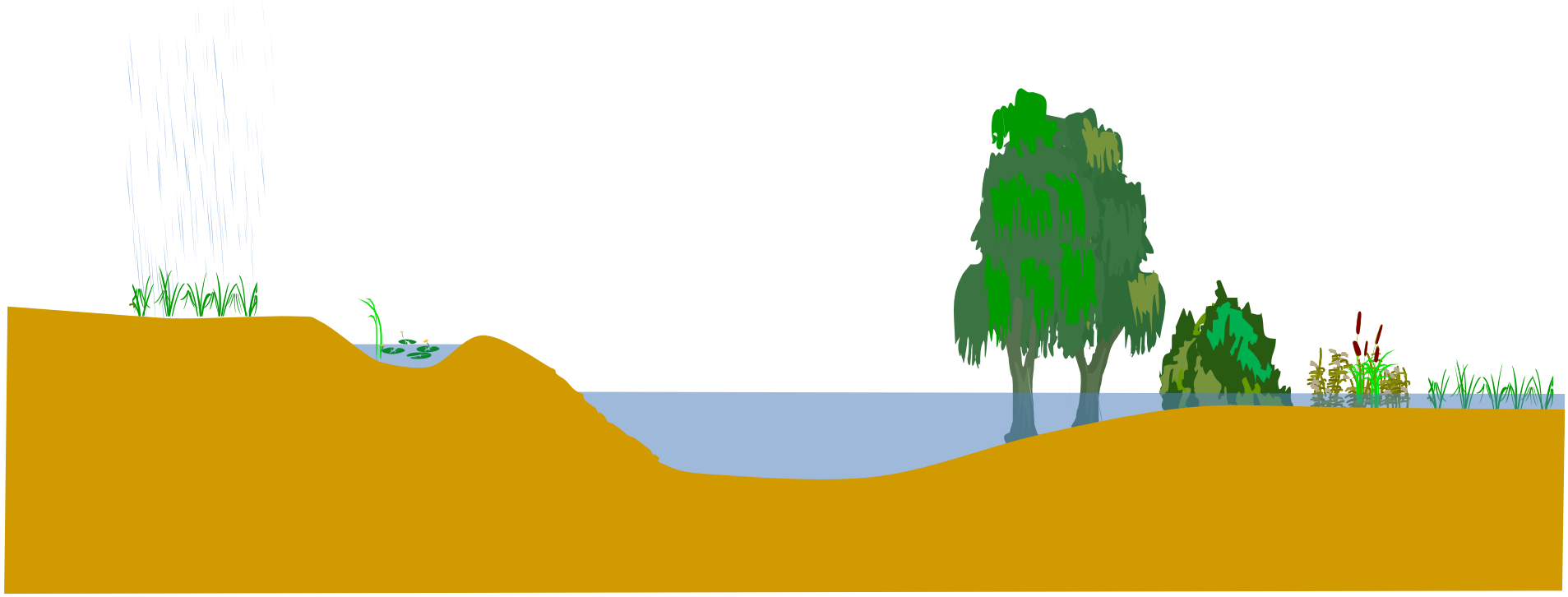

Figure 1.Biological difference and fish productivity (kg/ha/year) by habitat.

4. TOTAL AREA BY HABITAT

There are few data sources allowing a quantification of habitat areas in Cambodia; they include the MRC land-use database post-2000 (as cited in Hortle et al. 2008) and the MRC GIS data post-2000 (as cited in Hortle 2009). The latter is the land use file from the Cambodia Reconnaissance Survey, created by Japan International Cooperation Agency (JICA) and the Cambodia Ministry of Public Works and Transportation (MoPWT) in March 2003.

However, using the MRC post-2000 land-use database poses difficulties because its habitat classification does not match that of the present study (e.g. rain-fed rice fields are not distinguished from flooded rice fields, nor flooded forest from shrub land). Furthermore, estimates of the total area of wetlands in Cambodia from this database varied over time (41,000 km^2 in Hortle et al. 2008, 46700 km^2 in Hortle 2009). For these reasons, we used the Cambodia Reconnaissance Survey done by JICA and MoPWT (2003) instead to calculate the surface area of each aquatic habitat in Cambodia (Table 12)

Table 12. Total area by habitat. Source: JICA and MoPWT, 2003

Land use category	**Area** (1,000 ha)	**Percentage (%)**
Rain-fed rice field	3,215.6	65.9
Flooded rice field (receding and floating rice fields)	371.8	7.6
Flooded grassland/marsh/swamp	302.8	6.2
Flooded forest	20.6	0.5
Flooded shrub land	533.6	10.9
Open water (Mekong, Tonle Sap and main rivers)	416.9	8.6
Reservoir	11.8	0.3
Total:	**4,873.1**	**100.0**

This assessment shows that the total area of aquatic habitats contributing to fish production in Cambodia amounts to 48,700 km^2 (more than the surface area of Switzerland), including 66% of rain-fed rice fields.

5. TOTAL FISH PRODUCTION

We propose below a combination of surface area of each habitat with the average fish productivity of each habitat determined above.

Land use category	Area ('000 ha)	Fish productivity (kg/ha/year)	Total fish production (tonnes/year)	Percentage (%)
Rain-fed rice fields	3,215.60	112	360,147	64.2
Flooded rice fields	371.8	113	42,013	7.5
Flooded shrub land	533.6	167	89,111	15.9
Open water	416.9	93.8	39,105	7.0
Flooded grass land / marsh / swamps	302.8	91.5	27,706	4.9
Flooded forest	20.6	65.9	1,358	0.2
Reservoirs	11.8	121.4	1,433	0.3
Total:	4,873.1		560,873	100

From this assessment, the average fish production of Cambodian aquatic habitats is estimated at about 560,000 tonnes per year.

The weighted average fish productivity figure by hectare of aquatic habitat reaches 115kg/ha/year, which is close to the 100 kg/ha/year used by Hortle (2007) as a medium-level to estimate the total production of all Cambodian wetlands.

A large uncertainty range around this figure should be underlined, since the maximum and minimum values of the estimate span between 128,000 tonnes (a very minimal figure contradicted by much higher actual fishery yields) and 960,000 tonnes (an unrealistic figure given the current high level of fish exploitation estimated at 505,000 tonnes for the 2014 fishing season).

It is important to note that rice fields contribute – or can potentially contribute- more than 60% of this fish production. Our estimate of rice field fish production is higher than the extrapolation done by Balzer et al. (2002), who multiplied the fish yield per hectare per year given by Ahmed et al. (1998) by the 1.8 million hectares of potential Cambodian rice fields and predicted an annual production of 45,000 to 110,000 tonnes of fish. These figures are also higher than the estimate of 390,000 tonnes of inland yield, of which 108,500 tonnes were reported from rice field fisheries (FiA, 2010). In all cases, these results highlight the importance of rice fields in the fish supply to markets, and therefore as a habitat to be carefully managed. The shrub lands of the Tonle Sap floodplains appear as the second aquatic habitat contributing most to fish production in Cambodia. At the other end of the spectrum, reservoirs and flooded forest (i.e. flooded tall trees) contribute the smallest share to total fish production, given their very small total surface area in the country (0.3 and 0.2% of total wetlands respectively).

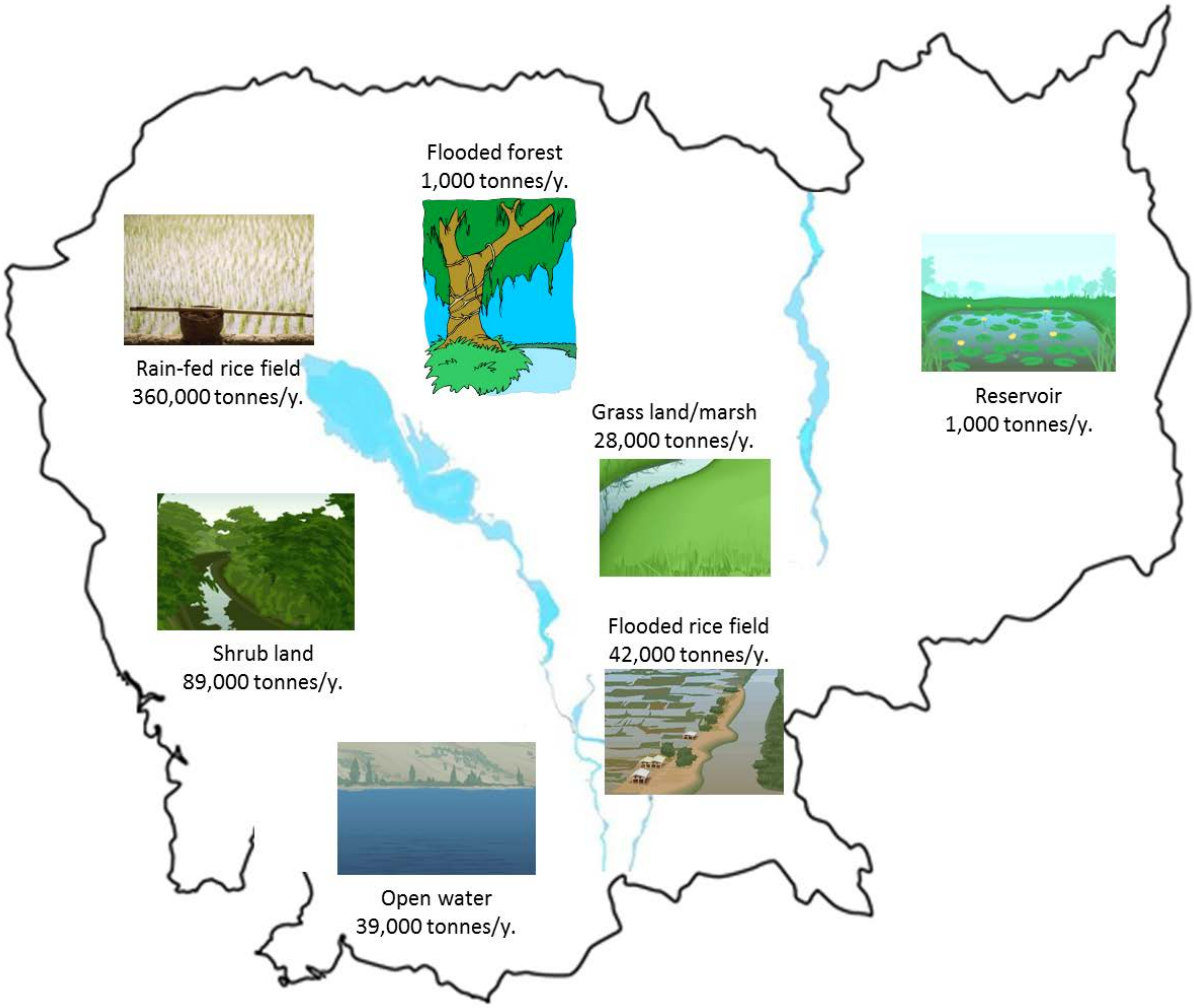

Figure 3: Aquatic fish habitats and their annual fish production in Cambodia.

PRODUCTIVITY OF OTHER AQUATIC ANIMALS (OAAs)

Other Aquatic Animals (OAAs) consist of frogs, snails, crabs, shrimps and other taxa found in aquatic habitats and usually consumed by Cambodians.

Rain-fed rice field habitat

In the rain-fed rice fields of southeast Cambodia, Gregory et al. (1996) found an average fishery catch of 125 kg/ha/year, of which 18% were OAAs – i.e. 22.5kg/ha/year. Hortle et al. (2008) in Battambang rice fields estimated an average productivity of 119 kg of fish per hectare and per year, of which 23.4% were OAAs, i.e. an average OAAs productivity of 27.8 kg/ha/year. Averaging these two figures gives a mean OAAs productivity of 25.1 kg/ha/year.

In the same MRC study, Hortle et al. also evaluated the standing stock by exhaustively harvesting rice fields in pumping one-hectare plots, and found a OAAs standing stock of 19.5°kg/ha.

Flooded grassland/swamp habitat

Lieng et al. (2006) found that fishery productivity in natural grassland was about 113 kg/ha/year, of which OAAs represented 2% - i.e. 2.3 kg/ha/year. In swamps, OAAs productivity was estimated at 2.5 kg/ha/year. A combination of these two figures fives a mean OAAs productivity of 2.4 kg/ha/year.

The productivity and contribution of the other categories of aquatic habitats to the production of other aquatic animals is unknown.

When the two above figures are combined with surface areas of aquatic habitats, we get a rough estimate of total OAAs production per year in Cambodia:

Rain-fed rice fields:

- 3,216,000 ha;
- 25.1 kg of OAAs per hectare and per year;
- 80,000 tonnes of OAAs per year

Flooded grassland/swamp:

- 303,000 ha;
- 2.4 kg of OAAs per hectare and per year;
- 700 tonnes of OAAs per year

Thus, rain-fed rice fields would produce about 80,000 tonnes of other aquatic animals per year, which supplements the fish production of these habitats.

6. CONCLUSION

From this review, we found that according to the literature and field studies, the average value of fish productivity by habitat in the region ranges between:

- 25 and 209 kg/ha/year (average 112 kg/ha/year) for rain-fed rice fields
- 30 and 491 kg/ha/year (average 113 kg/ha/year) for flooded rice fields
- 21 and 214 kg/ha/year (average 121 kg/ha/year) for reservoirs
- 37 and 95 kg/ha/year (average 66 kg/ha/year) for flooded forest
- 167 kg/ha/year for shrub lands
- 31 and 165 kg/ha/year (average 94 kg/ha/year) for open water
- 76 and 107 kg/ha/year (average 92 kg/ha/year) for flooded grassland and swamps.

When these values are related to the surface area of each habitat in Cambodia, we find that:

- rain fed rice fields produce around 360,000 tonnes of fish/year
- flooded rive fields produce around 42,000 tonnes of fish/year
- reservoirs produce around 1000 tonnes of fish/year
- open water produces around 39,000 tonnes of fish/year
- shrub lands produce around 89, 000 tonnes of fish/year
- flooded forest produces around 1000 tonnes of fish/year only
- flooded grassland and swamps produce around 28,000 tonnes of fish/year

The sum of these production values corresponds to a total fish production of 560,000 tonnes per year.

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8. APPENDIX I: SHRUB LANDS ASSESSMENT REPORT: EXECUTIVE SUMMARY

The 'Fish Production' component of the "Assessing economic and welfare values of fish in the Lower Mekong Basin" project is designed to assess the economic value of capture fisheries in Cambodia. The standing stock of the Tonle Sap Lake has been assessed across seven different habitats, and this report presents the methodology used to survey the shrub lands habitat, and provides the findings.

Four sites were assessed for fish biomass and diversity in the dry season of 2004. Two of the sites were in Kampong Tralach district of Kampong Chhnang province, and two in Kampong Thom province inside the Chhnuk Tru area. The sites were named Beong Phuk1, Beong Phuk2, Koh Krawbey1 and Koh Krawbey2. The type of habitat chosen for the study was characterised by a water depth of 0.8-1.1 metres at the time of the study, and the presence of shrubs typical of the area. Other selection criteria included acceptability of the site to local communities and authorities; accessibility by road; and the suitability of the area for the methodology employed. All sites were areas managed by fisheries communities.

Mosquito netting and electro fishing gear were used to herd fish from 50x50m quadrats into a mosquito net trap. The quadrat was divided into three subsections by more mosquito nets, to make it easier to exhaust the fish in each section. The sections were exhausted one by one, and collecting the sample from a whole quadrat took approximately four days. The fish were then sorted by species and weighed.

The result across all sites was that 61 fish species were caught and the mean standing stock of the assessment sites was 20.7kg per site (2,500 m2) or 82.7kg/ha with a range of 49.05 to 126.66kg/ha. This is a greater average biomass than the flooded forests and less than the flooded rice fields, which border the shrub lands. This may be due to the higher vegetal productivity of the shrub lands area (i.e. the production of greater volumes of organic matter), which makes the water nutrient rich and also provides a high density habitat similar to brush parks. Testing this possibility would be a useful topic for further research. On the other hand, the biomass levels in shrub lands more closely resemble those of the flooded grassland (30-491 kg/ha/year, averaging 121), probably because there is a less defined line between the two types of habitat. There was also some diversity between the four sites in catch composition. *Channa striata, Pristolepis fasciata, Trichopodus microlepis, Parambassis siamensis* and *Cyclocheilichthys apogon*, in descending order, contributed the greatest biomass to the total across all sites.

Overall, the exhaustion fishing technique used for this assessment was regarded successful. However, it must be noted that this assessment provides a snapshot of standing stock only, in the particular phase of the dry season during which the research was carried out. It is difficult to infer the actual productivity of the sites from the standing stock, which would require year-long monitoring of the fish imports and exports to and from the area. Nevertheless, the study presents a first step toward filling a knowledge gap regarding the productivity of shrub land habitats in Cambodia, which appears not to have ever been formally studied before.

9. APPENDIX II: OPEN WATER ASSESSMENT REPORT: EXECUTIVE SUMMARY

The 'Fish Production' component of the "Assessing economic and welfare values of fish in the Lower Mekong Basin" project is designed to assess the economic value of capture fisheries in Cambodia. The standing stock of the Tonle Sap Lake has been assessed across seven different habitats, and this report presents the methodology used to survey the open water habitat, and provides the findings.

A one hectare quadrat was identified in the Tonle Sap Lake, and fenced off with two metre high, 10mm mesh-size mosquito net.

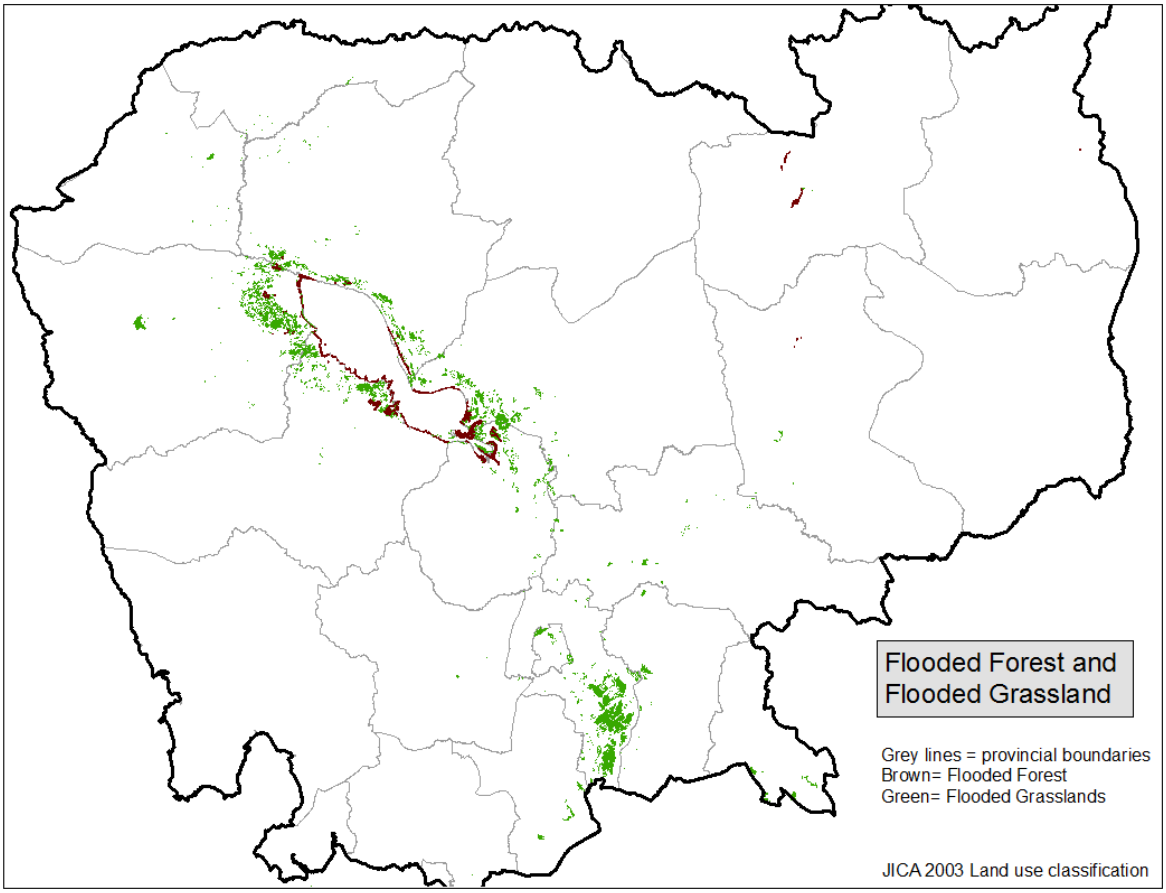
There was careful consideration of the relative biases in fish catch that might result from positioning of the net, given that fish tend to swim close to fences. The decision was made that one set of trammel net would be mounted in the middle of the fenced area. It consisted of three connected panels which varied from each other by size of the mesh. Each panel was 20m long and 2m high. Thus, the total length was 60m. Each panel consists of three layers, the two outside layers having the same mesh size and the inside layer having a mesh size four times smaller. The first panel consists of two outside layers of 30mm mesh size, and one inside layer of 7.5mm mesh size. The second panel consists of two outside layers of 60mm mesh size, and one inside layer of 15mm mesh size. The third panel consisted of two outside layers of 120mm mesh size, and one inside layer of 30mm mesh size.

The net was set at 5am. The net was checked every one hour starting at 6 a.m. and checking stopped at 9 a.m. after checking 4 times. Fishes caught were identified, weighed and measured the total length individually, and released if fish still alive.

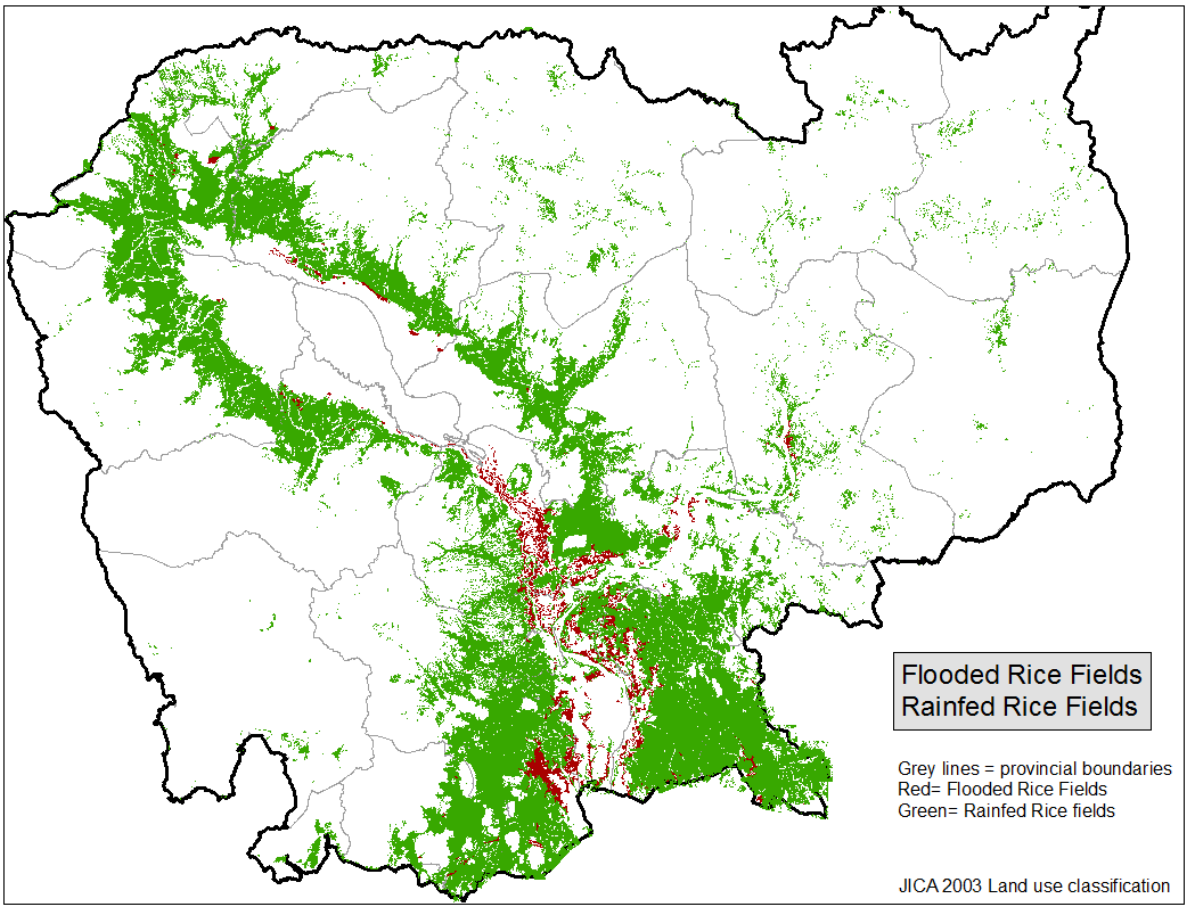
The 420 meter seine net was placed on a small boat. The boat was moved inside the fenced area, at a fenced side about 20m from corner. The seine was released closely along the fence and moved along the fence gradually until the net was completely in the water. At least 2 people were needed to pull each end of the seine, and the remaining people were distributed along the net. Then, all pulled the net together gradually. One seining was about 1.30 hours. In total 4-5 seining operations were conducted to make sure all fish in the fenced area were caught.

Results of the survey show that the trammel net caught 1.7% of fish in the one Ha area in four hours of fishing. The catch amounted to 29.74 kg. Overall, 64 fish species were identified. The low diversity found here might be a result of the limited sample area because the assessment was done in only one area in Pursat province, and the assessment was undertaken in May, i.e. at the end of the fishing season in Cambodia when the lake is almost empty.

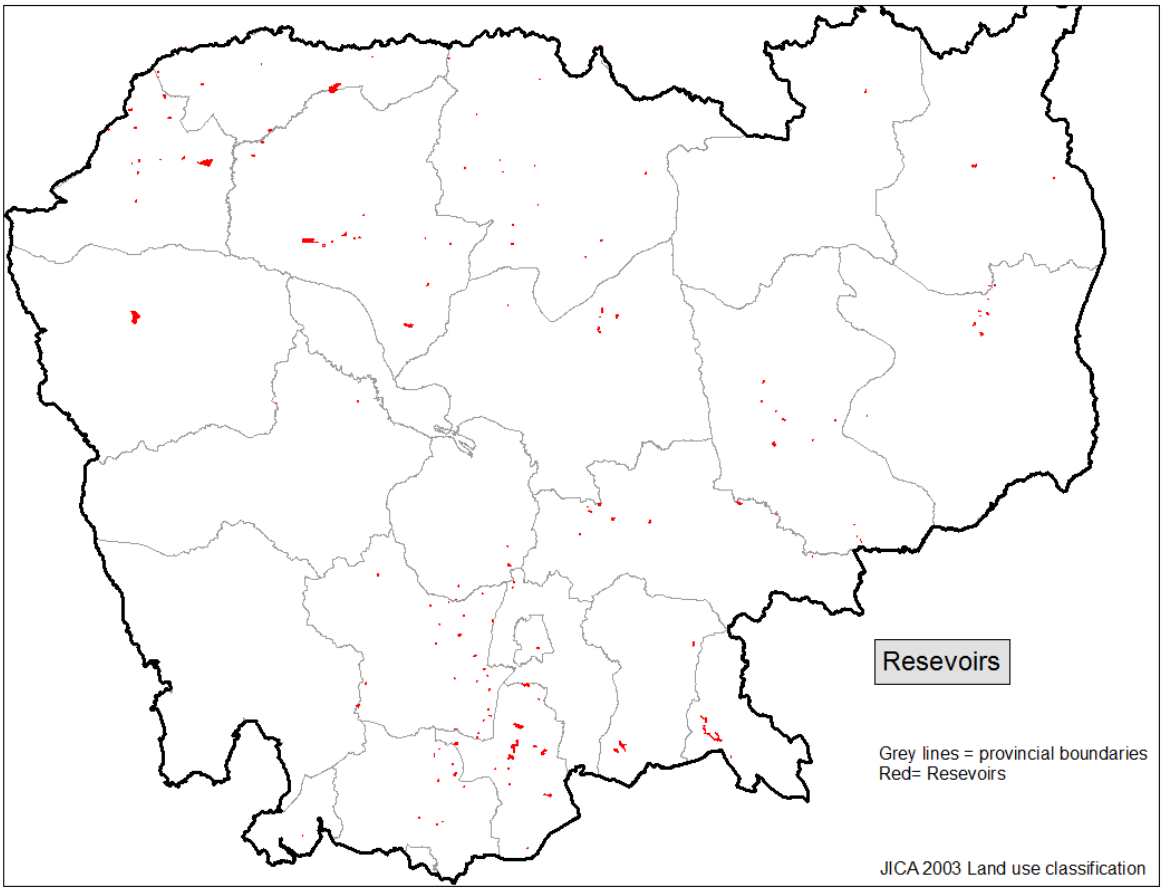
10. APPENDIX III. MAPS OF AQUATIC HABITATS IN CAMBODIA.



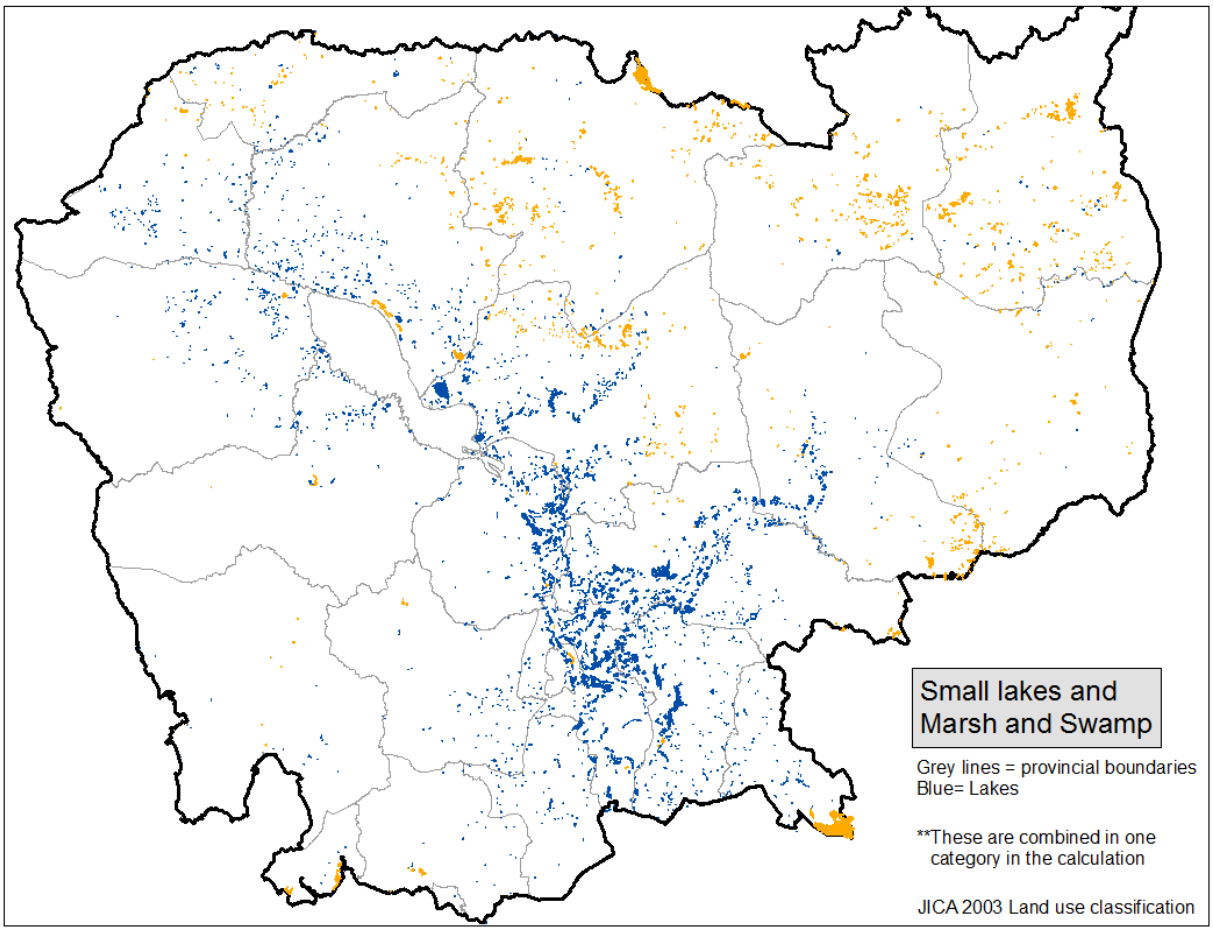
Map of flooded forests and flooded grasslands.



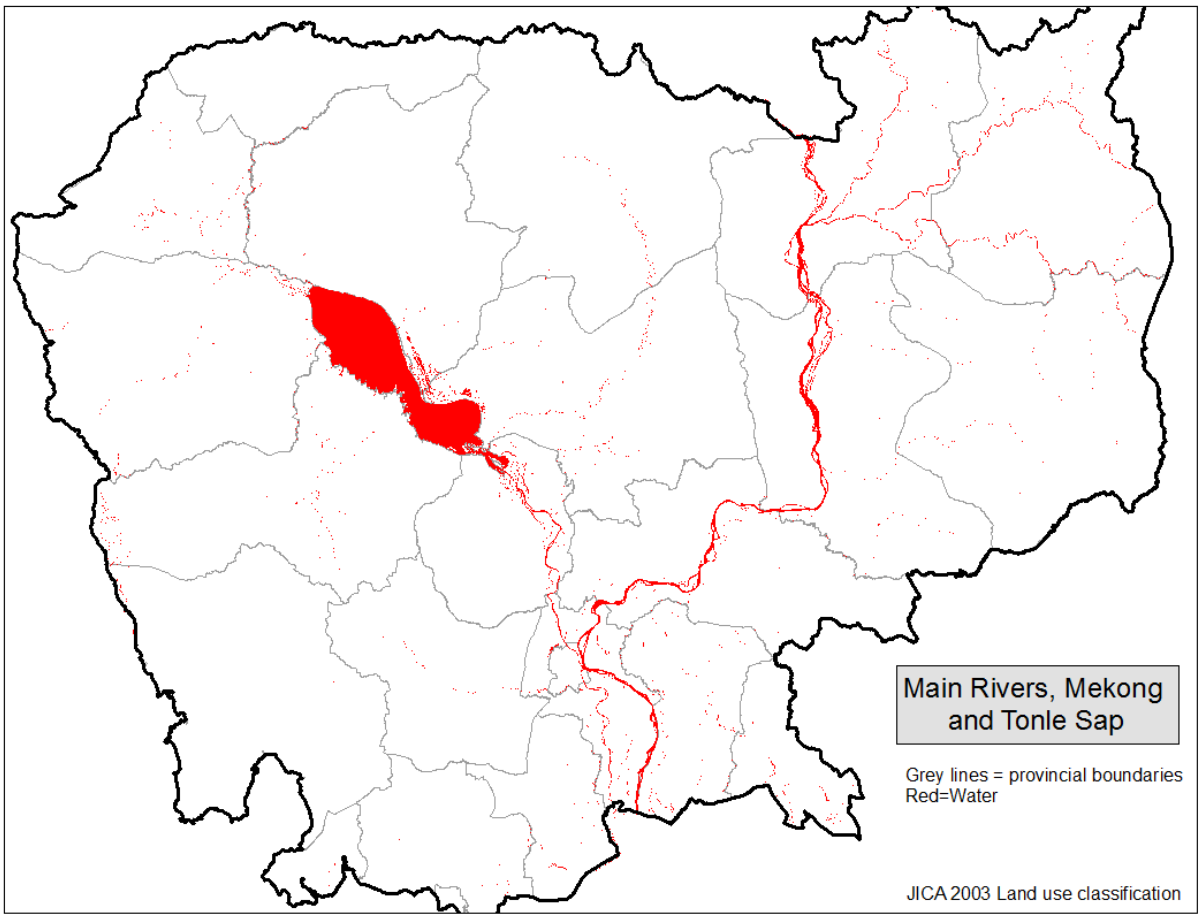
Map of rice fields in Cambodia.



Map of reservoir habitat in Cambodia.



Map of marsh and swamp habitat in Cambodia.



Map of open water habitats in Cambodia.

Australian Government

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WorldFish

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