Mekong River Commission

Yield and value of the wild fishery of rice fields in Battambang Province, near the Tonle Sap Lake, Cambodia

MRC Technical Paper
No. 18

July 2008

Meeting the Needs, Keeping the Balance

Mekong River Commission

Yield and value of the wild fishery of rice fields in Battambang Province, near the Tonle Sap Lake, Cambodia

MRC Technical Paper

No. 18

July 2008

Published in Vientiane, Lao PDR in July 2008 by the Mekong River Commission

Cite this document as:

Hortle K.G., Troeung R., and 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. 62 pp.

Editor: T.J. Burnhill
Graphic design: T.J. Burnhill
Photographs: K.G. Hortle, S. Chan, R. Troueng, and J.G. Garrison

184 Fa Ngoum Road, Unit 18, Ban Sithane Neua, Sikhottabong District,
Vientiane 01000, Lao PDR
Telephone: (856-21) 263 263 Facsimile: (856-21) 263 264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org

Table of Contents

Summary xi

1. Introduction 1

2. Methods 3
   - 2.1 Study area 3
   - 2.2 General features of the fishery 4
   - 2.3 Study sites 5
   - 2.4 Rainfall 8
   - 2.5 Inundation of rice fields and rice growing 8
   - 2.6 Catch assessment 9
   - 2.7 Standing crop 10
   - 2.8 Socio-economic information on fishers 11
   - 2.9 Statistics 11

3. Results 13
   - 3.1 General socioeconomic observations 13
   - 3.2 Fishing gears, effort and total catch 14
   - 3.3 Yield and composition of the catch 19
   - 3.4 Composition and catch by gear 22
   - 3.5 Value of the catch 22
   - 3.6 Disposal of the catch 24
   - 3.7 Comparison between sites 24
   - 3.8 Relationship to habitat variables 26
   - 3.9 Standing Crop 27
   - 3.10 Catches as a proportion of standing crop 30
   - 3.11 Length-frequency data 31

4. Discussion 37
   - 4.1 Comparison with rice-field fisheries elsewhere 37
   - 4.2 Significance to livelihoods and food security 40
   - 4.3 Implications for fishery yield estimates 40
   - 4.4 Integration of fisheries and agriculture 43

5. References 45

Appendix 1. Effort, total catches and CPUE for all gears and sites combined 49

Appendix 2. Total effort, catch and CUPE for all gear types 51

Appendix 3. List of species of fish and taxa of OAAs recorded, with proportions of total weight in catches and standing crop estimation, and categorisation by diet and as black or white/grey fishes 53

Appendix 4. Total catch of each species by each type of gear 55

Appendix 5. Taxa recorded in this study with total catch quantities and value 59

Appendix 6. Length frequency distributions for the five most abundant species of fishes 61

Table of Figures

Figure 1. Location of study area. 3

Figure 2. Map of the study sites. 6

Figure 3. Rainfall in Battambang in 2003 and 2004, compared with the long-term mean from1920 – 2004. 8

Figure 4. Total catches by each of 26 kinds of gear versus total effort for that gear. 18

Figure 5. Total catches of fish and OAAs at each site each month. 18

Figure 6. Composition of the total catch of 26,730 kg. 20

Figure 7. Proportions of the total weight and total value of fish of different trophic guilds in the catches. 21

Figure 8. Composition of the total catch of fish each month, showing the six species comprising most of the weight in catches, nine sites combined. 21

Figure 9. Total catch and weighted average price of all fish and OAAs each month. 23

Figure 10. Monthly prices of the six fish species which contributed the most to total catches by weight. 23

Figure 11. Dendrograms of site similarity based on total catches. 26

Figure 12. Proportional composition by weight of the dominant fauna in catches compared with the fauna recorded by pumping rice fields to estimate standing crop. 29

Figure 13. Ordination of sites based on multi-dimensional scaling of faunal composition. 29

Figure 14. Length-frequency for catches of *Channa striata* at Site 1. 32

Figure 15. Apparent changes in length, as exemplified by *Anabas testudineus* at Site 5. 33

Table of Tables

Table 1.	The area of agricultural land in Cambodia in 1992 and 2004.	1
Table 2.	Selected features of the study sites as determined from dry-season aerial photographs and ground-truthing.	7
Table 3.	General pattern of rice growing for wet season rain-fed rice in Battambang.	9
Table 4.	The dates of the two occasions when sites were pumped for standing crop estimation.	10
Table 5.	Summary of age and gender data from fisher interviews.	13
Table 6.	The main income-earning activities of fishers interviewed during the study period.	14
Table 7.	Types of gear used by fishers in this study.	15
Table 8.	Fishing effort as total fisher-days, summed for all nine sites, total area 225 ha.	16
Table 9.	Total catch of fish & OAAs (kg) by each gear, summed for all nine sites.	16
Table 10.	CPUE as mean catch by each category of gear (kg/fisher-day), summed for all sites.	17
Table 11.	Summary statistics for catches, value, no. of taxa and effort at each site.	25
Table 12.	Summary statistics for standing crop on the first and second occasions of pumping 1-ha plots in rice fields.	28
Table 13.	Comparison of the proportions of the main taxa in catches and pump samples at each site.	30
Table 14.	Correlation matrix for comparison of total catches with total standing crop from pumping.	31
Table 15.	Summary of fish measured from sub-samples of fisher catches and from pumping on two occasions for standing crop estimation.	33
Table 16.	Increase in total length of identifiable cohorts of three common species between pumping occasions.	34
Table 17.	Estimates of yields from rain-fed rice fields and floodplain habitat.	39
Table 18.	Estimated wetland areas in the LMB and Cambodia.	40
Table 19.	Estimated annual inland catches for Cambodia, based on information from 1994–1997.	41

Acknowledgements

The following provincial fisheries officials are thanked for assisting with field data collection: Mr Heng Piseth, Mr Chhea Hav, Mr Kheng Makkhen, Mr Sam Mardy, Mr Yim Hour, Mr Uy Sarun, Mr Chan Tey, Mr Chhem Sophea, and Mr Ouch Chham. Drs Matthias Halwart and Andrew Noble are thanked for their helpful comments on a draft manuscript. The senior author acknowledges the support of the Water Studies Centre, Monash University, Australia, for providing office space and computer support during the preparation of this report.

Summary

For most rural people in Cambodia, rice fields and associated habitats are important sources of fish and other aquatic animals (OAAs), which provide both nutrition and income. A lack of quantitative information contributes to a general neglect of rice field fisheries in development planning, which usually favours intensification of rice production that may negatively impact the fishery. The main objective of this study was to quantify the yield and value of the rice field fishery in an area typical of the rain-fed, lowland, wet-season rice fields that surround the floodplain of the Tonle Sap-Great Lake system.

At nine sites, each 25 ha in area, the fishing effort and catches of fish and OAAs by local fishers were monitored for one season (July 2003 – February 2004), and standing crop was measured twice by pumping and sieving water from one-hectare plots adjacent to each site in the late wet season.

Fishing activity was greatest during October and November, when paddy water levels were highest, rice was in the vegetative stage and other work opportunities were limited. Fisher numbers peaked at about 2 persons/ha; most fishers (82%) were male and most (79%) were aged 16 – 50 years. Ten main types of gear were used. Traditional traps and hook and line were the most used and most productive (accounting for 72% of the total catch), because they can be used around rice fields without disturbing the crop.

Catches included 35 species of fish, which made up 77% of the total catch weight, with air-breathing ‘black fish’ accounting for about 88% of the fish catch by weight. Most of the fish catch consisted of carnivores, which were more valuable than omnivores (based on market values); no herbivores were recorded. About 80% of the total fish catch by weight comprised six species: *Channa striata* (chevron snakehead), *Macrognathus siamensis* (peacock eel), *Anabas testudineus* (climbing perch), *Clarias batrachus* (walking catfish), *Trichogaster trichopterus* (three-spot gourami), and *Monopterus albus* (swamp eel). Six taxa of OAAs comprised 23% of the total catch, and crabs, frogs and shrimps were the most abundant OAAs.

Catches at each site appeared to reflect hydrology; in general sites that were deeper and inundated for longer periods attracted greater total fishing effort and produced larger total catches. Catches were also influenced by proximity to permanent waters, as the two sites with the most fish species were close to a permanent river. The mean yield (fish plus OAAs) was 119 kg/ha/season (±25 as 95% confidence limits) with a mean value of US$102/ha (±$23/ha), based on market prices. This study underestimates the yield and value of the fishery, because additional catches are made by fishers using unmonitored illegal gears, and unmonitored catches are also made during the dry season.

Mean standing crop in the one-hectare rice field plots was 64.7 kg/ha (±4.9), of which about 70% was fish. Carnivorous black fishes, and crabs and snails were proportionately more

abundant than in catches, and fewer species were recorded than in catches, which reflect a diversity of habitats targeted by fishers. The biomass of fish in standing-crop samples increased significantly between sampling occasions, but the biomass of OAAs declined, a finding consistent with growth of fish and predation on OAAs. The composition of the fauna was similar in all of the standing crop samples, reflecting general homogeneity of rice fields as a habitat. The composition of catches was more variable between sites, reflecting the response of the fauna to small and heterogeneous areas of non-rice field habitats.

Most of the fish in catches were small; among five common species all individuals were less than 32 cm and half were less than 10 cm in length. Analyses of length-frequency data suggested growth rates of 1–4 cm/month, which indicates that virtually all fish were caught in their first or second year of life.

The gross income from rice production at the time of the study was about $150 /hectare/ year with a single crop, so with some level of management (for example development of trap-ponds), the capture fishery could become more valuable than rice farming. The indigenous carnivorous fish species may be significant agents for controlling the pests of rice, and fish feed upon organisms, including insects, crabs and snails, which would otherwise be inaccessible as food for people. Research and development of rice-fish culture should include these indigenous fish species that are hardy, adaptable, preferred as food and generally more valuable than the introduced herbivorous/omnivorous species that are usually promoted in rice-fish culture.

The rice-field fishery is accessed by most rural people for some part of the year; it is a common-property resource, which limits the incentive for farmers to invest in its conservation. Land holdings are generally small, often fragmented, and distant from their owners' houses. Farmers are usually not present to prevent others fishing on their land or to prevent theft of aquacultured fish. Increasing the yield from the fishery is a technically feasible way to improve output from rice fields, but the management problems which arise from current ownership patterns and small fragmented landholdings need to be addressed if the full potential of rice-field fisheries is to be realised.

The yield figure found in this study is consistent with the values that have been found in other studies in the Lower Mekong Basin and elsewhere in Asia. Previously published estimates for the total fishery yield from Cambodian rice fields are based on unrealistically low values for yield per unit area and under-estimates of the area of rice field habitat, leading to a significant under-estimate for the total national yield from rice fields. Moreover, rice fields probably produce a much larger share of the total yield of inland fisheries in Cambodia than is generally recognised. Elsewhere in the Lower Mekong Basin, rice field habitats' contribution to fisheries is also under-recognised; in each country rice fields are the most extensive aquatic habitat and there are general similarities in fishing methods, target species and high participation rates. Rice-field habitats should be given appropriate emphasis in research to quantify inland fisheries yield in each country and to improve management for fisheries, especially given their particular importance in supporting livelihoods and nutrition for the rural poor.

1. Introduction

Wild capture fisheries are important sources of food and income for rural people throughout Asia. Assessment of fisheries should take into account the contribution from the large areas of agricultural land that are typically used for rice farming, an industry that is based on vast areas of anthropogenic wetlands, which can be referred to as ‘rice-based ecosystems’ because they support a wide biodiversity. In the four countries of the Lower Mekong Basin (LMB) up to 100 species of wild fish, other aquatic animals and plants are harvested by rural people in any particular location, supporting their livelihoods and providing essential protein and micronutrients (Balzer *et al*. 2005; Halwart 2006). A recognition that rice-farming landscapes produce much more than rice led the International Rice Commission to recommend that member countries should promote the sustainable development of aquatic biodiversity in rice-based ecosystems, that management measures should enhance the living aquatic resource base, and that attention should be given to the nutritional contribution of aquatic organisms to the diet of rural people (IRC, 2002). To support this recommendation, quantitative data are required which show the actual yield and economic value of the fishery and how best to optimise the value of all forms of production from rice-based ecosystems.

Table 1. *The area of agricultural land in Cambodia in 1992 and 2004.*
Based on official national data summarised by ACI and CamConsult (2006, Table 284).

Year	Area (ha) of land used for:			Percentage of Area		
	Rice	Other Crops	Total	Rice	Other Crops	Total
1992	1,844,100	187,000	2,031,100	90.8%	9.2%	100.0%
2004	2,374,175	440,348	2,814,523	84.4%	15.6%	100.0%

In Cambodia, rice is the most important crop by area farmed, production tonnage and value (ACI and CamConsult, 2006), and the estimated area of planted to rice increased by about 29% between 1992 and 2004 to about 2.4 million ha (Table 1). This increase can be attributed to intensification of land use (i.e. on fallow or un-worked land) and to clearing of forest or scrub, both in the flood recession zone and on the surrounding terraces where rain-fed rice is grown. According to ACI and CamConsult (2006, Table 294) 81.3% of Cambodia’s rice farming land is terraces, i.e. land surrounding floodplains where ‘rain-fed’ rice is grown during the wet season. Only 11.1% of the rice-field area is within floodplains and comprises recession rice (8.1%) and floating rice (3.0%); the remaining area is riverbank rice (5.4%) and others (2.1%). Irrigation is relatively undeveloped, as only 22% of the rice-field area in Cambodia receives supplemental irrigation. However, only one percent is fully irrigated and able to produce more than one crop per year.

Most of Cambodia’s rice-farming land is within the Lower Mekong Basin, which includes the Tonle Sap system, other lowland tributaries, and distributaries in south-east Cambodia. It should be noted that ‘rice fields’ as a land-use class in GIS data covers a much larger area than the planted areas as indicated in Table 1, e.g. about 26,097 km^2 in 1992–3 (MRCS, 1994). Associated habitats include small water bodies (ponds and canals), other wetland crops, such as lotus, and small patches of brush.

Cambodian's main sources of animal protein are inland fish and OAAs; which are estimated to provide about 80% of the average intake of animal-derived protein (Hortle, 2007). About 84% of Cambodians are rural (Anonymous, 1999), and virtually all rural households would directly access rice fields for food and seasonal income from the fishery The large and seasonally spectacular river-floodplain fisheries along the Tonle Sap and Mekong River have been relatively well-studied, but rice-field fisheries are relatively innocuous, being often referred to as 'the invisible fishery' (Halwart, 2006), so they are poorly researched.

This study was carried out to provide a quantitative estimate of fisheries yield (kg/ha/season) and value (first-sale prices in Battambang) from accurately defined areas in typical lowland rain-fed rice-field habitat in Cambodia. In addition, we estimated standing crop (kg/ha of fish and OAAs) in rice-fields to complement the estimate of yield. The study also aimed to provide information on the usage of gears and the composition of the catch.

The data obtained in this study represent a baseline for the yield that is currently being obtained in the absence of any management from a wild fishery in typical lowland rain-fed Cambodian rice-fields. The results provide the basis for a valuation of the fishery and illustrate a methodology to use for assessing yield prior to enhancements or changes to management.

In a wider context, because of the vast extent of rice-field habitat, the yield and composition of this part of the fishery needs to be quantified throughout the lower Mekong Basin generally, if the yield of the system as a whole is to be understood and if fisheries are to be managed effectively.

2. Methods

2.1 Study area

Battambang is a large province in Cambodia which borders the north-western edge of the Tonle Sap (or Great) Lake, which is the largest lake in South-East Asia and is the centre of inland fish production in the Mekong River system (Figure 1). Population density in the province is about 68 persons per km^2, and 83% of the population is rural (Anonymous, 1999), with most households still employed directly or indirectly in agriculture or related activities. The mean household size is 5.3 persons, and most people live in small villages or communes which are spread fairly evenly through the province along unclassified roads in proximity to the farms. Single-crop rain-fed rice farming is the dominant land use, as is usual in Cambodia. Formerly, floating rice was cultivated in the zone around the Great Lake that floods each year as a result of backing-up of the Mekong and Tonle Sap floodwaters, but recession rice farming is now more common in this zone. In many respects the pattern of rice-farming and fisheries resembles that described in detail by Balzer *et al*. (2005) in Kampong Thom Province, which lies along the north-east edge of the Tonle Sap.

Figure 1. Location of study area

This study was carried out in Sangke District, which extends from the provincial capital, Battambang, to the dry-season shoreline of the Tonle Sap Lake. The landscape is generally flat alluvial plains; although the study area is about 500 km inland (i.e. from the mouth of the Mekong) the elevation is less than 20 mASL, with a general slope towards the Tonle Sap or its tributaries (Figure 1). The main rivers that drain to the lake are incised several metres into the plain. The Tonle Sap – Great Lake system floods regularly each year, peaking around late September, mainly because of the inflow and backing up of water from the Mekong. In the wettest years, Tonle Sap floodwaters extend to the main highway, which runs from Phnom Penh in the south-east to Battambang town. In most years, including during the years of this study, the sites on the eastern side of the highway are not reached by Tonle Sap floodwaters, but are inundated by local rainfall.

Rice farming is the main land use in the Sangke district. About two-thirds of the rice cultivation area is rain-fed rice and about one third is floating/recession rice, according to data from the provincial Department of Agriculture. Most houses, with their associated fruit and vegetable gardens, are sited along roads (usually unsurfaced), which are built on natural levees or spoil beside rivers and canals. Families typically own one to two parcels of land that are usually at some distance from their houses; in Cambodia land ownership averages one hectare per family (ACI and CamConsult, 2006), as is probably also the case in Battambang.

Agriculture has long been practised in this part of Cambodia, so most natural vegetation has been cleared and the land surface extensively modified to trap rainwater in paddies and to control drainage. Some remnant ‘flooded forest’ to the east of the study area is important wet-season habitat for fish which migrate seasonally from the Great Lake. Paddy walls are typically about 0.5 m high, and larger levees have been formed from spoil from the main drainage canals; such levees support the roads used by tractors, buffaloes and motorcycles. Drainage is controlled via canals and along the remnants of modified stream courses.

Rice cultivation in this area, as is usual in Cambodia, is not highly intensive. One crop is grown each year, relying mainly on natural rainfall, with limited use of canal water for irrigation of seedlings or some low-lying fields. Yield of wet-season rice averages about 2.2 t/ha in Battambang, higher than the national average of 1.7 t/ha, but less than half of what can be achieved under intensive cultivation (ACI and CamConsult, 2006).

2.2 General features of the fishery

In the study area, the fishery is entirely based upon naturally occurring fish and other aquatic animals (OAAs), with little evidence of stocking or any kind of management for the rice-field fishery. Most people live at some distance from their rice fields so they cannot control fishing activity on their land. Fishing is apparently open-access, but in this province most fishers are local people, so farmers generally know who fishes in their fields and are often given some of the catch, as well as fishing themselves.

The fishery is highly seasonal, because most of the landscape is dry for about half of the year (Dec. – Jan. to May – June). Fish and other aquatic animals (OAAs) that have survived the dry season locally in remnant water bodies or by aestivating in mud, breed at the onset of and during the wet season and their fry or larvae rapidly colonise newly-flooded rice fields. The common 'black fish' are hardy and fecund species that are widespread in the lowlands because they can tolerate anoxia — all gulp air at the water surface and have accessory respiratory structures.[1]

Fish and OAAs disperse by moving along the small channels connecting paddies and many species at times may also move overland. The fry of fish from the Tonle Sap – Great Lake and its tributary rivers — 'white' or 'grey' fish — are intolerant of anoxia but also colonise rice-field habitats by swimming up drainage canals and streams. The paddies and associated canals and ponds are fished throughout the wet season, using a wide range of gears, but fishing activity peaks during the vegetative phase of the rice crop, when other seasonal employment opportunities are limited.

2.3 Study sites

Nine sites were selected east and southeast of Battambang Town, the capital of the province as shown in Figure 2. The sites were selected to be representative of the dominant rice-field habitats in the surrounding areas and the district generally. Sites were chosen to be accessible from motorbike paths and to be in reasonably well-frequented areas, because in this part of Cambodia lawlessness is still a problem. The fishing gears were a mixture of small-scale artisanal gears; i.e. there were no medium or large-scale commercial gears, because the sites were not close to any very large canals or rivers where such licensed gears operate. The sites were also selected only where the owners allowed access for surveyors and for pumping of a part of the site in their rice fields for standing crop assessment.

The study sites were all 500 metres square, i.e. 25 ha in area. The position of the corners of each site was recorded by GPS to provide data that was used to locate the sites accurately on a district map and on dry-season aerial photographs which were linked to GIS data. The photographs had a resolution of about 0.5 m. From the aerial photographs the area of brush (scrub and trees) was estimated by planimetry, the number of paddy fields was counted, and the areas of the smallest and largest paddy fields were also measured by planimetry. Ground-truthing was carried out during the wet season, and in the following dry season to identify remnant water bodies. The aerial photographs and GIS images were examined to confirm the location of larger temporary and permanent watercourses and ponds. Table 2 shows that the sites varied in elevation from 12 to 17 mASL, and on most sites brush occupied less than 2% of the area, with only three sites having significant remnant vegetation. The number of paddy fields varied from 40 to 123 in each 25 ha site, with sites having mean paddy field areas of 0.2 to 0.6 ha. Overall, paddy fields varied from 0.04 to 1.97 ha in size. In general, paddy fields

1 Black fish are air-breathing fish that can spend their entire lives on floodplain habitats and are well-defined morphologically and behaviourally. Grey and white fish migrate short and long distances respectively from rivers and streams onto flood plains to feed; they are intolerant of anoxia and generally require dry-season refuges in well-oxygenated water, typically deep pools. There are insufficient data to classify many Mekong system fishes as grey or white, so they are combined in one group here.

are smaller (and hence more numerous in a given area) where slopes are steeper. The sites had varying degrees of exposure to seasonal and permanent watercourses and farm ponds.

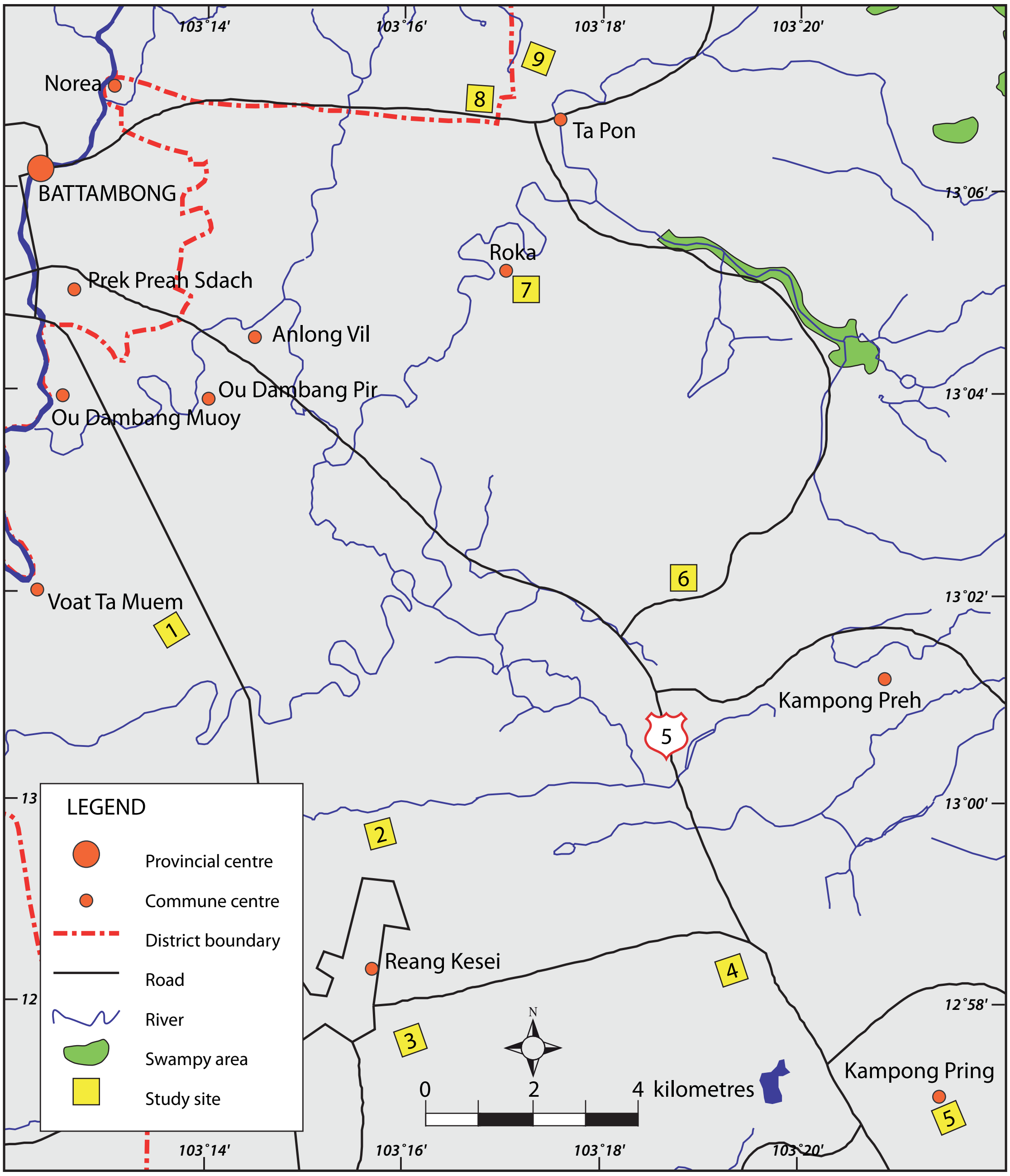


Figure 2. Map of the study sites

Table 2. *Selected features of the study sites as determined from dry-season aerial photographs and ground-truthing.*

Site	Elev. (mASL)	Trees/scrub		Paddy Fields				No. of farm ponds in the 25-ha plot		Distance to permanent watercourse	Watercourses and state in dry season (April)
					Area/field (ha)						
		Area (ha)	% cover	Number	Mean	Min.	Max.	Perm.	Seas.		
1	13	0.23	0.90%	57	0.44	0.09	0.87	2		200	Large canal along east edge, some residual water
2	15	0.34	1.40%	85	0.29	0.05	1.31			50	Large stream parallel to north edge, some residual water
3	17	4.89	19.60%	71	0.35	0.08	1.33		2	>200	No major watercourses near site
4	12	0.07	0.30%	40	0.63	0.17	1.97	2		>200	No major watercourses near site
5	14	0.04	0.20%	67	0.37	0.06	1.41	3		>200	Large canal along south edge, some residual pools
6	13	0.23	0.90%	66	0.38	0.06	1.14	2		>200	Small canals connecting to ponds hold some water
7	12	0.05	0.20%	111	0.23	0.05	0.84			100	Large river (S. Chas) to the west
8	12	0.00	0.00%	50	0.5	0.05	1.38	2		0	Canals along south and east edges, residual pools
9	12	0.19	0.80%	123	0.2	0.04	0.72			>200	No major watercourses near site

2.4 Rainfall

Battambang receives most of its rainfall during the Southwest Monsoon from about May to November, as is usual for most of Cambodia. Long-term rainfall between 1920 and 2004, with 60 years of complete data, averaged 1318 mm/year. Typically, there is very little rainfall from December to March (on average 5.6% of the annual total), and because of high temperatures and evaporation rates through May there is usually little standing water in most paddy fields until June. Over the period April 2003 – March 2004, encompassing the study period, rainfall was 1,221 mm, or 93% of the annual average. (Figure 3).

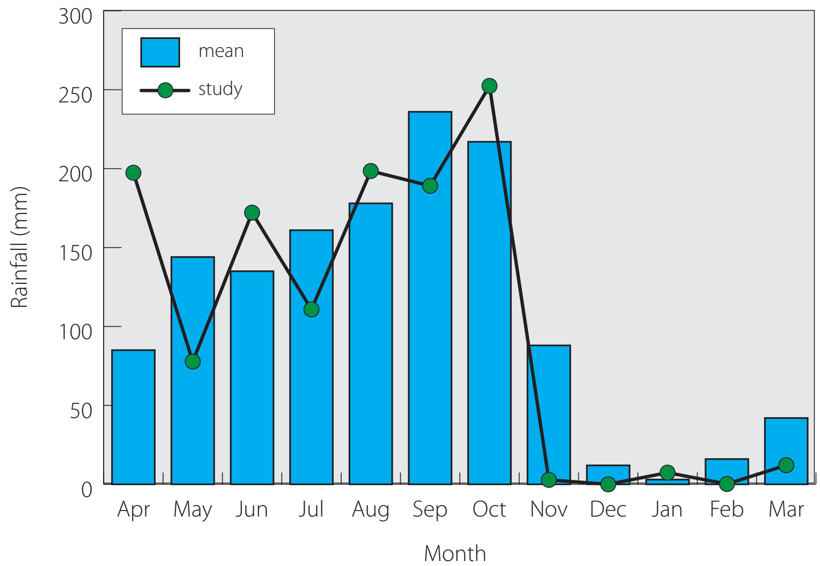


Figure 3. Rainfall in Battambang in 2003 and 2004, compared with the long-term mean from1920-2004. Based on daily rainfall records from the Cambodian Department of Water Resources and Meteorology.

2.5 Inundation of rice fields and rice growing

The general pattern of inundation and of rice-growing is as follows. Seeds are planted (to grow seedlings) from May through to July in nursery areas where the seedlings can be watered from canals. Transplanting of seedlings starts in June and continues through to September, when most of the paddy fields are fully inundated. In this area, most strains of rice are traditional slow-growing varieties that are harvested after about five to seven months, so the earliest-planted paddies are harvested during November while the latest are harvested during February.

Table 3. *General pattern of rice growing for wet season rain-fed rice in Battambang.*

Activity	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Land preparation												
Seedbed												
Transplanting												
Harvesting												

Through October and most of November 2003, 100% of the area of the study sites was under water. On the western side of the highway the paddies were typically 0.4 – 0.6 m deep, and held significant water through to December, as drainage was constrained by having to pass through a limited number of culverts under the highway. On the eastern side of the highway, the paddies were generally shallower, 0.3 – 0.5 m deep, and drained earlier (through canals to the east) so that at least half the area was dry by November. In terms of apparent depth and duration of flooding, Sites 5, 6 and 7 were the driest and shallowest, Sites 8 and 9 were intermediate, and sites 1 to 4 were the wettest.

2.6 Catch assessment

The plots were visited four times each month for seven months (August 2003 – February 2004); a total of 28 times. During the other five months there was relatively limited fishing in the study sites, although some catches were made in residual water bodies and in fields where fishers dig and rake through mud to catch aestivating fish, crabs, molluscs and frogs.

On each survey occasion, two surveyors visited each plot to interview fishers and to measure their catches. The local surveyors generally knew the villagers who fished in each area, so they could organise the interviews in advance. The total numbers of fishers and the gears used by each fisher in each plot were recorded based on direct observation and by interviewing fishers. About 30 – 50% of people fishing on a surveyed day were interviewed regarding their use of gear and their catches and the results. They were also asked to estimate their effort (number of days fishing) over the period since the previous interview (about one week). The exact time each gear was being used during each day was not recorded, so effort was expressed as ‘fishing days’ only. The catch per gear and the effort data were used to estimate the catches of those who were not interviewed in detail, based on their reported gear and effort.

Interviews were based on a standard format that included basic information on the people fishing, effort and gears. Identifications were based on a chart of photos of about 150 species found in the area, as well as by reference to drawings and keys in Rainboth (1996), and names were updated from FishBase (Froese and Pauly, 2007). Fishers kept their catches for the surveyors to identify and weigh. Animals were weighed using calibrated pan balances accurate to five grams. Representative sub-samples of the five most common fish species were selected from all gears at each site on all occasions, and the total lengths of fish were measured to the nearest centimetre using fish measuring boards. The price of each taxon was determined from interviews as the sale price in the nearby Battambang market in Riel/kg for each species.

2.7 Standing crop

Standing crop was estimated for plots one hectare in area that were adjacent to, and considered representative of, each 25 ha plot. Standing crop estimation followed a pumping procedure. Each one-hectare plot was already enclosed by the walls of paddy fields; inlet and outlet channels were blocked and the walls were repaired where necessary to fully isolate each field. Water was pumped from each plot using an agricultural diesel-powered pump with the intake in the deepest corner of the plot. A fence of 2 mm nylon mesh around the intake prevented animals from passing through the pump. While the water level was falling, collectors walked through the plot and collected fish and OAAs by hand and by using dip-nets of 5 mm mesh. Complete removal of water took up to two days in each plot as the depth varied from 0.1 – 0.6 m. After most of the water had been pumped from a plot, animals were collected using dipnets from the remaining small pool of water. The total weight of each taxon was recorded and then the lengths of representative sub-samples of animals were measured to the nearest millimetre. Representative sub-samples of the five most common fish species were selected and the total lengths of fish were measured to the nearest centimetre using fish measuring boards.

The plots were pumped twice, in September and November 2003, as shown in Table 4. After pumping, the plots rapidly re-filled with water from adjacent paddies. During the period between sampling it was assumed that fish and OAAs could readily colonise the plots, directly via connecting channels and through locally overtopped paddy walls, or by moving overland, a common behaviour of many species of fish and OAAs in this area.

Table 4. *The dates of the two occasions when sites were pumped for standing crop estimation.*

Site	Occasion		Elapsed Days
	1	2	
1	13 Sep 03	02 Nov 03	50
2	14 Sep 03	07 Nov 03	54
3	27 Sep 03	12 Nov 03	46
4	28 Sep 03	13 Nov 03	46
5	25 Oct 03	22 Nov 03	28
6	24 Oct 03	23 Nov 03	30
7	23 Oct 03	21 Nov 03	29
8	16 Oct 03	25 Nov 03	40
9	17 Oct 03	26 Nov 03	40

2.8 Socio-economic information on fishers

During interviews, data were also recorded on the age and gender of fishers and their usual income-earning occupations at the time of the survey. Fishers were asked to estimate the proportion of their catch that was eaten by themselves or their families and the proportion sold.

2.9 Statistics

To estimate the similarity of the fauna at each site two indexes were used (Hellawell, 1978), calculated for pair-wise comparisons of the fauna at each site with every other site. Sorensen's index (S) takes account only of the presence of each taxon at each site; these included all taxa of OAAs and all species of fish. The index is defined as:

$$S = 2c/(a+b)$$

where: a = no. of species at Site a,

b = no. of species at site b and

c = no. of species present at both sites.

Spearman's non-parametric correlation coefficient ρ (Rho) takes account of the relative abundance of each species at each site, in terms of rank. This coefficient was calculated using the six taxa of OAAs and the ten fish species at each station which contributed most of the weight of catches. Rho is defined as:

$$\rho = 1 - 6\sum d^2/(n^3-n)$$

where d is the difference in the magnitude of the rank of each species for the pair of stations and n is the total number of species in the comparison.

For each index, dendrograms were constructed by single linkage clustering, i.e. by joining site pairs with the highest values first, then joining site pairs with the next highest values, and so on, until all sites were connected.

Plate 1. Ploughing fields prior to planting in July creating a temporary but fertile aquatic environment in which plankton grows rapidly. There is little fishing at this time.

Plate 2. Planting rice seedlings in late July. Vast expanses of dry land become wetlands.

Plate 3. Fishing activity is most intense in October – November, when the rice is growing and ripening and there is less labour needed in farming or other occupations.

Plate 4. Small holes (*anlung*) are made to trap fish that exit rice fields, a simple but effective method that requires little or no equipment.

Plate 5. Access for most fishers is by foot, cycle, or motorcycle along levee roads.

Plate 6. Bullocks are still commonly used as draught animals by farmers, and manure is the most-used fertiliser in a farming system that continues to support production of other common-property resources, including the wild capture fishery.

Plate 7. Harvesting rice by hand in December. Most water has gone.

Plate 8. Most of the landscape is very dry from February to May, but some fish and OAAs are still present in deep cracks and in a few residual water bodies.

Plate 9. During the dry season, people continue to catch fish and OAAs from drying mud or ponds, but catches from March to July were not included in this study, so the study underestimates total catches and value of the wild fishery.

Plate 10. Many people make large catches of aquatic insects by light-trapping at night. Insects are attracted to the light, hit the plastic sheet and fall into the pool of water. The yield and value of this 'aerial fishery' is not known, but would add to the unaccounted economic value of the wild fishery.

Plate 11. Weighing and measuring snakeheads (*Channa striata*) and large snails.

Plate 12. Pumping to estimate standing crop.

Plate 13. Single-hook set pole and line (*santuch bangkai*) was the most commonly used and productive gear, accounting for about 23% of the weight of all fish caught, and 19% of all fisher-days. It is particularly effective for snakeheads and other carnivorous fish.

Plate 14. Typical catches from single-hook set pole and line. Left: snakeheads (*Channa striata*), climbing perch (*Anabas testudineus*) and walking catfish (*Clarias macrocephalus*). Right: peacock eel (*Macrognathus siamensis*), climbing perch (*Anabas testudineus*) and silver catfish (*Mystus atrifasciatus).*

Plate 15. Single hand-held hook and line (*santuch ple muoy)*—simple, commonly used and productive, accounting for about 7% of all fish caught and 9% of all fisher-days.

Plate 16. Among traditional traps, horizontal cylinder traps (*tru*) are the most commonly used (about 14% of all fisher-days) and most productive (about 14% of all catches).

Plate 17. One kind of horizontal cylinder trap, specially designed for catching crabs.

Plate 18. Horizontal cylinder traps with bamboo fences (*lop phsom pruol*) are the second most productive trap, accounting for about 12% of the total catch and 8% of fisher-days.

Plate 19. Traps are widely used in a range of habitats, here deploying vertical rice field cylinder traps (*lop nheuk*).

Plate 20. Active collecting with a wedge-shaped scoop basket (*Chhnieng chunhchot*) — commonly used by the end of the fishing season in February, with a catch of climbing perch, *Anabas testudineus*.

Plate 21. A specialised gear, bamboo tube trap (*loan*) for eels, with the catch of swamp eels, *Monopoterus albus*, one of the most commonly caught species. These traps accounted for 4% of all fish and 3% of fisher-days.

Plate 22. Vertical bamboo vase traps (*tom*) are specialised gears that accounted for only 1% of fisher-days and catches.

Plate 23. Despite policing efforts by fisheries inspectors, fine-mesh fyke nets are commonly seen — here in the early wet season. These illegal gears block migration routes and catch all kinds of fish and their fry before they access inundated areas where they would feed and grow through the wet season.

Plate 24. Cast nets (*samnanh*) are commonly used in all open-water areas, accounting for about 10% of all catches by weight and about 9% of the total fisher-days. Sometimes they are used in pairs to increase efficiency.

Plate 25. Gillnets (*mong reay sre*) are less popular in the rice field environment than in larger rivers or lakes where they may be the dominant gear. In this study they accounted for only 6% of fisher days and 5% of catches.

Plate 26. Small-handle seine net (*anchorng*), a relatively uncommon gear accounting for 2% of catches and fisher-days. In this example it is technically illegal because of the fine mesh.

Plate 27. Larger fish, especially snakeheads and walking catfish are sold on roadsides or in local markets.

Plate 28. Peacock eels (*Macrognathus siamensis*) and swamp eels (*Monopterus albus*) on sale in Battambang market.

Plate 29. The forgotten animals of the 'invisible fishery' on sale in Battambang — common other aquatic animals include frogs, crabs, snails and shrimps. OAAs accounted for about 23% of the weight and 11% of the value of all catches.

Plate 30. Trey riel and other fish from the commercial catches in the Tonle Sap – Great Lake tributaries begin to arrive in Battambang in December, so fish prices tend to remain stable despite the declining supply of rice-field fish.

3. Results

3.1 General socioeconomic observations

Over the period of the study a total of 1217 fisher interviews were made, with the number of interviews being approximately proportional to the number of people fishing at a site each month, so that interviews varied from a high of 428 people in November 2003, when fishing activity was most intense, to only 27 people in February 2004, when most fishing had ceased. Some people were interviewed more than once, so the total does not reflect the actual number of interviewees, but because interviewees were randomly selected the results should accurately reflect the characteristics of the fishers. Table 5 shows that most fishers (about 82%) were male, and most fishers (79%) were aged 16 – 50 years, with fairly similar proportions at each site. There were more children at Sites 5, 6 and 7, probably reflecting proximity to settlements and better access from the highway.

At the study sites there were at least 463 fishers, the number estimated to be fishing in the peak month, which was October 2003 at Sites 5, 6 and 7, and November 2003 at the other sites. Therefore, at the peak of the season there were about 2 fishers per hectare.

Table 5. *Summary of age and gender data from fisher interviews.*
Based on interviewees in each category over the seven-month period of the study.

Location	Total interviewees					Age Group (years)			
	All	Male	Female	% male	% female	<15	16 – 30	31 – 50	>50
Site1	151	119	32	78.8%	21.2%	7.3%	38.4%	43.7%	10.6%
Site2	168	138	30	82.1%	17.9%	5.4%	38.1%	45.2%	11.3%
Site3	167	134	33	80.2%	19.8%	4.8%	38.3%	44.9%	12.0%
Site4	170	135	35	79.4%	20.6%	4.1%	38.2%	47.1%	10.6%
Site5	124	100	24	80.6%	19.4%	18.5%	36.3%	39.5%	5.6%
Site6	98	70	28	71.4%	28.6%	24.5%	36.7%	26.5%	12.2%
Site7	125	107	18	85.6%	14.4%	20.0%	34.4%	35.2%	10.4%
Site8	113	100	13	88.5%	11.5%	8.0%	34.5%	46.9%	10.6%
Site9	101	92	9	91.1%	8.9%	8.9%	38.6%	41.6%	10.9%
Total	1217	995	222	81.8%	18.2%	10.3%	37.2%	42.0%	10.5%

Rice growing is the main economic activity in the study area, but people with small holdings or who own no rice-growing land usually gain seasonal income as wage labourers, either in cultivation (e.g. harrowing using buffalos or small tractors), rice planting, or rice harvesting (Table 6). Rice fields also support other important industries: large-scale harvesting of insects, based on light-trapping (Hortle *et al.*, 2005), capture and sale of rats, which are sold as food for people or farmed crocodiles, and capture and sale of waterbirds. These wild products are typically sold in Battambang town and some are exported to Thailand. Their harvest is seasonal, based on rainfall and abundance of food, including rice. Fishers also earn other income from labouring and from selling vegetables and fruits.

Table 6. *The main income-earning activities of fishers interviewed during the study period. The table is a summary of the activities reported by fishers.*

Activity	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04
Wage labour – cultivation of rice-fields	■						
Wage labour – rice planting		■	■				
Wage labour – rice harvesting					■	■	■
Vegetable selling	■	■			■	■	■
Vegetable selling – corn and beans		■					
Fruit selling	■						
Insect (especially crickets) selling		■	■	■			
Rat selling					■	■	■
Water bird selling				■	■	■	■
Wage labour – house building			■	■			
Wage labour – brick factory				■			
Transport – motor taxi fee			■				

3.2 Fishing gears, effort and total catch

Fishers used 26 types of gear in ten main categories, classed by mode of action, as shown in Table 7. Four kinds of gears were observed to be usually lined with nylon mosquito-netting mesh of 2 mm aperture, illegal under Cambodian fisheries law[1], which specifies the minimum mesh for all gears as 15 mm aperture. Other 'illegal' methods, including electro-fishing and poisoning, were also being practised, but no data could be collected on catches from these gears.

The usual number of gears per fisher was estimated and is shown in Table 7, but could not be recorded on each occasion, so effort is expressed as fisher-days for each gear; i.e. the number of days per month each fisher was estimated to be using a gear at a site. The exact time spent fishing during a fisher-day could not be determined, but would usually be several hours each day. Most fishers specialised in one type of gear on any occasion; about 90% of all fisher records were for only one kind of gear on one day, but fishers change their gears during the season to adjust to changing environmental conditions and target species. Seasonal changes in effort and catch are tabulated in the summary tables in Appendix 1, which were simplified by combining effort and catches by gear category to produce Tables 8 – 10.

1 The Fisheries Law 2004 is open to interpretation on private land.

Table 7. *Types of gear used by fishers in this study. Page numbers and codes follow Deap* et al. *(2003)*

Page No.	Code	Cat. No.	Category	Name	Khmer Name	Fishing Period			Approximate number used by a typical fisher	Often used with mosquito net mesh
						day	night	day + night		
14	1.1	1	Capture by hand	Capture by hand in dried ditch or canal	*Bach Bat Pralay*	x			usually several fishers	
14	1.1	1	Capture by hand	Capture by hand in water	*Chap Dai*	x			1	
16	2.1.1	2	Scoop nets	Wedge-shaped scoop basket	*Chhnieng Chunhchoat*	x			1	
22	2.2.1	2	Scoop nets	Long-handled circular scoop bag	*Thnorng Moul*	x			1	yes
32	3.1.1	3	Wounding gear	Frog gaff	*Kangva Kongkaep*	x			1	
34	3.2.1	3	Wounding gear	Two-pronged eel fork	*Chamrob*	x			1	
38-40	3.3.1&2	3	Wounding gear	Eel clamp	*Kangva Trey Chhlonh*	x			1	
70	4.1.3	4	Hook & line	Pole and line for catching frogs	*Santuch Bobok Kongkaep*	x			1	
72	4.1.4	4	Hook & line	Hand-held single hook and line	*Santuch Phlay Muoy*	x			1–5	
76	4.2.1	4	Hook & line	Single-hook set pole and line	*Santuch Bongkai*			x	20–100	
93	5.1.1.2	5	Traps	Vertical bamboo vase trap	*Tom*			x	3–5	
95	5.1.1.2	5	Traps	Bamboo funnel basket trap	*Chongnoum*			x	3–5	
102	5.1.1.6	5	Traps	Vertical ricefield cylinder trap	*Lop Nhek Sre*			x	3–7	
104	5.1.2.1	5	Traps	Horizontal ricefield cylinder trap	*Tru*			x	3–6	
108	5.1.2.2	5	Traps	Bamboo tube trap for eel	*Lawn Antong*		x		10–50	
110	5.2.3	5	Traps	Horizontal cylinder trap for frogs	*Lop Kongkaep*		x		20–30	
119	5.1.2.6	5	Traps	Big horizontal cylinder trap	*Lop Rungvel*			x	3–5	
131	5.1.2.8	5	Traps	Horizontal cylinder trap with bamboo fences	*Lop Phsom Pruol*			x	5–6	
147	5.4.1	5	Traps	Hole trap	*Anlung Ungkoup*		x		10–40	
165	6.1.1	6	Gill nets	Gill net	*Mong Reay Sre*			x	1–3	
175	7.1.1	7	Seine nets	Small hand-dragged seine net	*Uon Hum*	x			1 gear, 2 fishers	
182	7.3.1	7	Seine nets	Small-handle seine net	*Anchorng*	x			1 gear, 2 fishers	yes
202	9.1.2	9	Pushed Gear	Hand-held scissors push net	*Chheub*	x			1	yes
214	11.1.2	11	Covering nets	Frog trap net	*Kantrup Kongkaep*	x			1	
216	11.2.1	11	Covering nets	Cast net	*Samnanh*	x			1	
224	12.1.1	12	Bag nets	Fyke net (fine mesh)	*Lu Sbai Mong*			x	1–5	yes

During the period when rice is growing in inundated paddies, fishers may not move through rice fields, so are restricted to using hook and line and small traps around the edges of paddies, and using other gears such as gillnets, cast nets, small seines, traps and fyke nets in adjacent canals and ponds. Some specialised gears for frogs and eels are used only after rice fields have been wet for several months and the population of these target species has increased. After water levels fall and where rice has been harvested, fishers can move through the fields using active methods, including capture by hand and, using wounding gears such as clamps and gaffs. Pumping water out of fenced-off parts of canals is a common (but illegal practice) when water levels are low, and capture by hand, sometimes aided with wedge-shaped scoop baskets is practised in shallow residual water through rice fields. Tabulations of the number of fishers using each category of gear each month, and for the number of sites at which the gear was being used, showed similar patterns to Table 10 so are not presented here.

Table 8. *Fishing effort as total fisher-days, summed for all nine sites, total area 225 ha*

Category	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Total	%
Traps (9 types)	696	1148	1963	3964	2104	72		9947	43.3%
Hook & line (includes hand-held & set single hooks)	912	904	2413	2189	208	80		6706	29.2%
Covering nets (cast nets & frog trap nets)			751	1228	80			2059	9.0%
Gill nets (one type)			712	732				1444	6.3%
Bag nets (one type – fyke nets)			50	560				610	2.7%
Wounding gear (eel clamps, eel forks & frog gaffs)				48	148	396	307	899	3.9%
Pushed gear (hand-held scissors net)					112	132		244	1.1%
Seine nets (2 types of small hand-pulled seines)			160	144	216	32		552	2.4%
Capture by hand (in water or in canals pumped dry)					164	168	80	412	1.8%
Scoop nets (2 types of small hand-held nets)			12				80	92	0.4%
Total	1608	2052	6061	8865	3032	880	467	22,965	100.0%

Table 9. *Total catch of fish & OAAs (kg) by each gear, summed for all nine sites.*

Category	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Total	%
Traps (9 types)	1070	976	3130	4582	2819	63		12,641	47.3%
Hook & line (includes hand-held & set single hooks)	382	791	1752	3431	87	93		6537	24.5%
Covering nets (cast nets & frog trap nets)			1021	1595	56			2672	10.0%
Gill nets (one type)			808	643				1451	5.4%
Bag nets (one type - fyke nets)			173	847				1020	3.8%
Wounding gear (eel clamps, eel forks & frog gaffs)				6	160	315	382	863	3.2%
Pushed Gear (hand-held scissors net)					96	432		529	2.0%
Seine nets (2 types of small hand-pulled seines)			158	203	150	14		525	2.0%
Capture by hand (in water or in canals pumped dry)					131	97	57	285	1.1%
Scoop nets (2 types of small hand-held nets)			30				178	208	0.8%
Total	1452	1767	7073	11,307	3500	1015	617	26,730	100.0%

Note: Totals may not sum due to rounding.

Table 10. *CPUE as mean catch by each category of gear (kg/fisher-day), summed for all sites.*

Category	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Mean
Traps (9 types)	1.54	0.85	1.59	1.16	1.34	0.88		1.27
Hook & line (includes hand-held & set single hooks)	0.42	0.88	0.73	1.57	0.42	1.16		0.97
Covering nets (cast nets & frog trap nets)			1.36	1.30	0.70			1.30
Gill nets (one type)			1.13	0.88				1.00
Bag nets (one type - fyke nets)			3.46	1.51				1.67
Wounding gear (eel clamps, eel forks & frog gaffs)				0.13	1.08	0.80	1.24	0.96
Pushed gear (hand-held scissors net)					0.86	3.27		2.17
Seine nets (2 types of small hand-pulled seines)			0.99	1.41	0.70	0.43		0.95
Capture by hand (in water or in canals pumped dry)					0.80	0.58	0.71	0.69
Scoop nets (2 types of small hand-held nets)			2.50				2.23	2.26
Total	0.90	0.86	1.17	1.28	1.15	1.15	1.32	1.16

Note: Totals may not sum due to rounding.

Tables 8 and 9 show that the largest total catches were made with the most-used gears, with catch rates varying between 0.1 and 3.5 kg/fisher-day for any type of gear (Appendix 1). The highest catch rate was recorded for fine-mesh fyke nets, which could explain why they are widespread and popular, despite efforts by fisheries inspectors to destroy these illegal gears. Overall, mean CPUE (catch per unit effort) was 1.16 kg/fisher-day, averaged across all gears. Allowing for the use by some fishers of two kinds of gear (approximately 10% of fisher-days) the mean catch per fisher was about 1 kg/day, averaged across all gears, sites and months.

Traps accounted for about 43% of the effort and 47% of the weight of catches, and three categories of gear (traps, hook and line, and covering nets) accounted for about 82% of the total effort and the total weight of catches (Tables 8 and 9). Some types of gear that are commonly used in other environments, such as gill nets, bag nets and seines were relatively unimportant in the fishery, as dense vegetation in and near rice fields tends to limit the effectiveness of such gears.

As shown in Figure 4, total catches depend largely upon total effort. The data for this graph are shown in Appendix 2. The gears which are apparently more effective, in terms of catch per fisher-day, correspond with points above the line in Figure 4; including for example horizontal cylinder traps with fences (HTF) and vertical rice-field cylinder traps (VRT), whereas less apparently efficient gears correspond with points below the line in the centre of the graph, such as hole traps (HT) and hand-held single hook and line (HSH). If the graph were to take into account the total investment in terms of actual effort per gear or method, and the time and cost of preparation and materials, the relationship might be improved, because points above the line (such as HTF and VRT) would be moved to the right, whereas points below the line (such as HT and HSH) would be moved to the left. Combining gears within the ten main categories results in an even better correlation (r^2=0.98), because within each group lower CPUE by less efficient gears tends to be balanced by higher CPUE by more efficient gears.

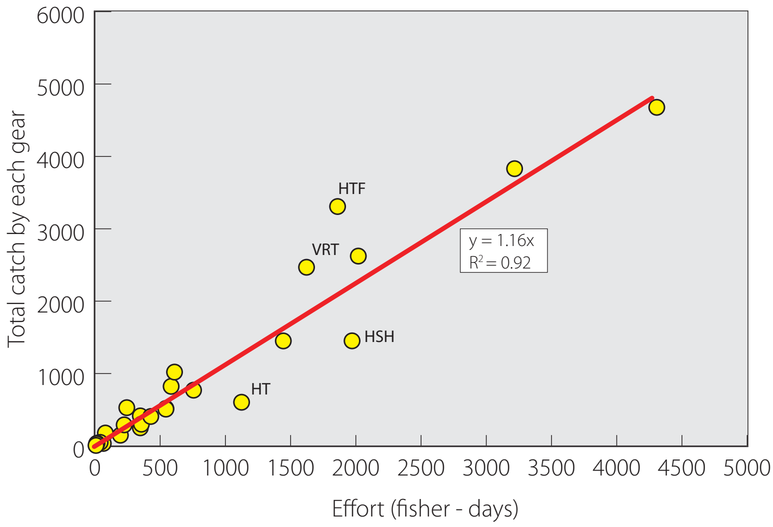


Figure 4. Total catches by each of 26 kinds of gear versus total effort for that gear.

Labelled points are HTF – horizontal cylinder trap with bamboo fences; VRT – vertical rice-field cylinder trap; HT – hole trap and HSH hand-held single hook and line; refer to text for discussion.

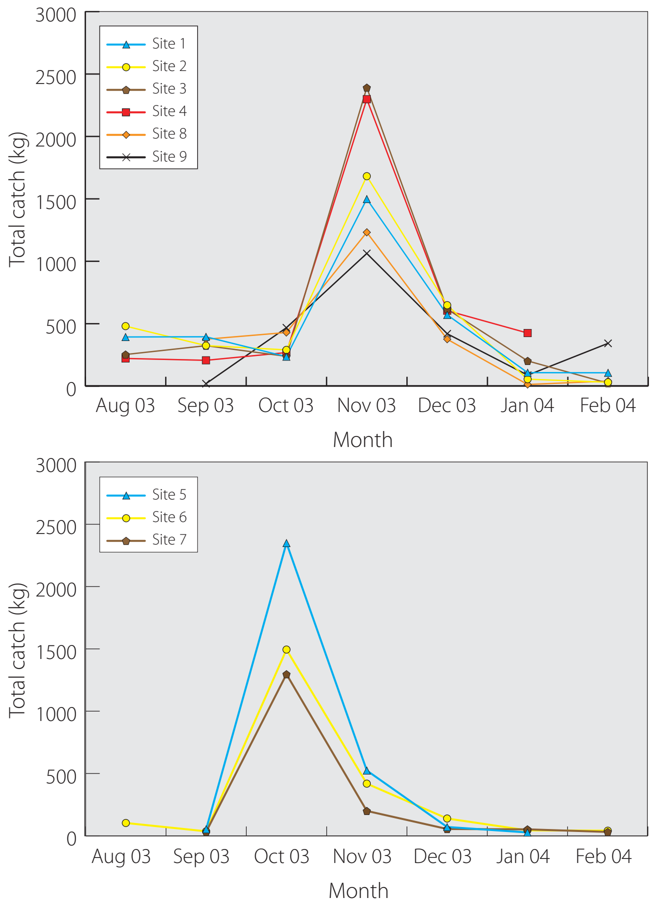


Figure 5. Total catches of fish and OAAs at each site each month

Total effort, total catches and mean CPUE were all highest in October and November. Figure 5 shows that the seasonal pattern of catches varied between two groups of sites: at Sites 5, 6 and 7 catches were highest in October, whereas at the other sites catches were highest in November; similarly the second-highest catches were in November at Sites 5, 6 and 7, and during December at the other sites. Peak catches were approximately one month early at Sites 5, 6 and 7 because these sites were shallower and drained faster than the other sites. The months of peak catches coincided for fish and for OAAs at all sites, except at Site 1, where highest catch of OAAs was in August 2003.

Of the total weight of all fish and OAAs, 57% was caught during the peak month, with between 44% and 78% of the total at any site being caught in the peak month. During the two peak months (i.e. the months of the largest and second largest catch at a site) about 74% of the total catch was made, with 62–95% being caught at any site. Therefore, a very large proportion of the catch is made in the period of about two months between the last transplanting of rice seedlings and the first harvest, when labour is not needed for other work and when inundation of most of the landscape prevents many other activities. For a family in which three people fished most days, catches of about 100 kg/month could readily be achieved over the two-month peak period, providing a significant boost for household consumption and supplementary income.

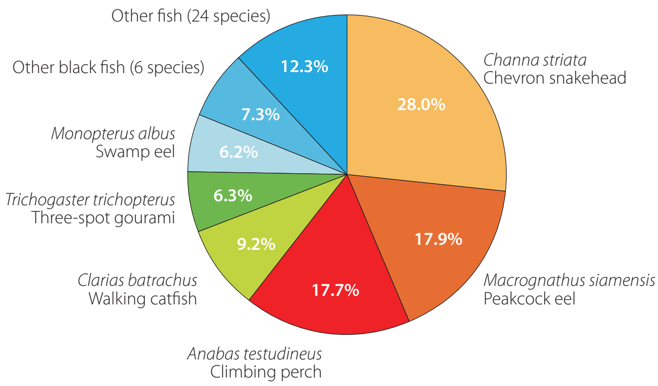
3.3 Yield and composition of the catch

Fishers caught 35 species of fish, as well as six taxa of OAAs which were not identified to species (Appendix 3). Of the total catch of 26.7 tonnes (from the nine sites), about 77% comprised fish and 23% comprised OAAs. As shown in Figure 6, most of the total catch of fish (about 88% by weight) was made up of 12 species of ‘black fishes’, species that gulp air and have modified respiratory structures, features that allow them to tolerate anoxic conditions in wetland habitats; black fishes typically do not migrate far when water levels fall. The other fishes (i.e. the 24 species making up 7% of the weight of fish) are relatively intolerant of anoxia and migrate to dry-season refuge habitats in permanent water bodies, such as canals, streams and the Great Lake–Tonle Sap system; those that migrate to local refuges are termed ‘grey’ fishes whereas species that migrate long-distances are termed ‘white’ fishes, as noted in Appendix 3.

Most of the catch of OAAs consisted of crabs, frogs and shrimps in approximately equal proportions (Figure 6), and it is interesting to note that the total catch of each of these taxa was greater than the catch of most of the individual species of fish. All OAAs are eaten, but some are fed to animals; for example crabs are commonly fed to pigs and shrimps are fed to ducks.

As shown in Figure 7, the fish catch was dominated by carnivores, including snakeheads, peacock eels, gouramies and walking catfish; a full list is presented in Appendix 3. The omnivores mainly comprised species which eat only small proportions of plant material, and there were no purely herbivorous fish. Carnivores were generally more valuable than omnivores, which increased their proportional contribution to total value, as discussed below.

Figure 8 (top) shows that the same species of fish tended to dominate catches each month, whereas Figure 8 (bottom) shows that among OAAs, crabs were more abundant early in the season while frogs became relatively more abundant later in the season, as might be expected based on their life cycles. Large numbers of crabs survive the dry season deep in rice-field mud and are caught early in the season soon after they emerge, whereas tadpoles require time to grow and metamorphose into frogs, which are mostly caught later in the wet season and in the early dry.



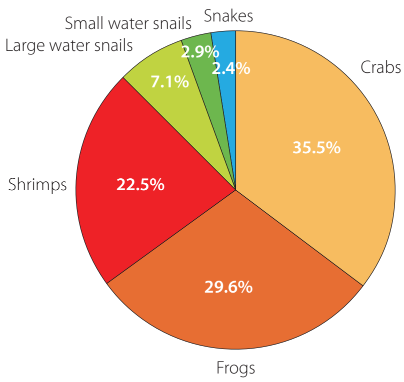


Figure 6. Composition of the total catch of 26,730 kg. Fish – 20,469 kg (top), OAAs – 6,261 kg, (bottom). For fish, only species comprising more than 5% of the total weight are shown.

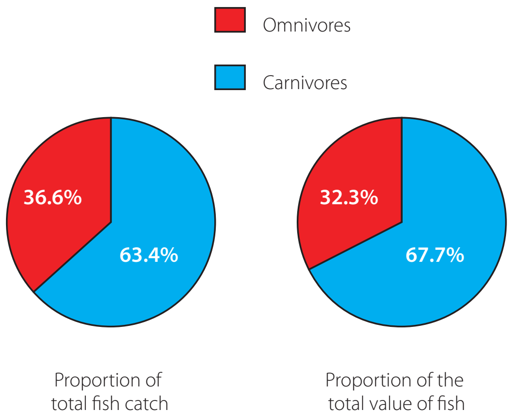


Figure 7. Proportions of the total weight and total value of fish of different trophic guilds in the catches. Appendix 3 shows the composition by species. Value was derived from Appendix 5.

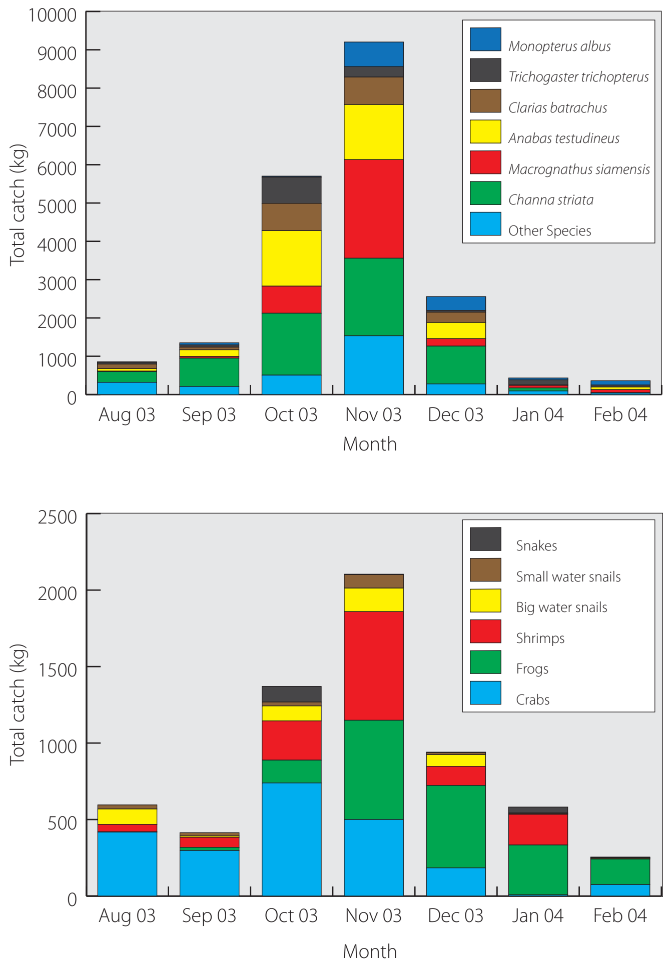


Figure 8. Composition of the total catch of fish each month, showing the six species comprising most of the weight in catches, nine sites combined (Top). Composition of the total catch of OAAs each month, nine sites combined (Bottom).

3.4 Composition and catch by gear

The catch of each species by each type of gear is shown in Appendix 4. Gears tended to be selective for certain species. For example, the larger carnivores including *Channa striata*, *Clarias* spp. and *Ompok bimaculatus* were caught disproportionately by hook and line, whereas several smaller fish species were caught disproportionately by traps. For OAAs, shrimps were caught disproportionately by bag nets, but the other five taxa were all caught mainly by traps. Three main groups of gears caught about 82% of the total catch weight; traps accounted for about 47% of the catch, about 25% was taken with hook and line, and about 10% was caught using cast nets. Gill nets caught about 5% of the catch and the other seven main types of gears each caught less than 5% of the total catch.

3.5 Value of the catch

Over the period of the study fishers caught about 26,730 kg of fish and OAAs with a total value of about US$22,912, calculated as a weighted average based on 647 individual site-date price records (Appendix 5). Mean prices varied between US$0.05/kg and $1.36/kg; snails and crabs were the lowest-value animals (US$0.05 – 0.07/kg) and were predominantly used to feed animals; the most valuable fish (all worth more than US$1.20/kg on average) were the larger good-eating fish, which were carnivorous or primarily carnivorous, these included *Channa striata*, *Monopterus albus*, *Macrognathus siamensis*, *Clarias macrocephalus*, *Clarias batrachus* and *Ophisternon bengalense*. The value of carnivorous fish averaged US$1.06/kg and the value of omnivorous fish averaged US$0.88/kg, as weighted means across all catches. Similarly, carnivorous OAAs (frogs and snakes) were far more valuable than omnivorous or herbivorous OAAs (Appendix 5). Over the entire area of 225 ha that was surveyed, the mean value of the catch was approximately US$101 per hectare.

The price of fish and OAAs overall appears to be insensitive to the quantity caught from rice fields and associated habitats, as shown in Figure 9, because prices in markets also depend upon the supply from other sources. For example, markets also receive fish and OAAs from large catches which are made in the Tonle Sap – Great Lake system during the flood recession from December to February. This supply would tend to offset the effect of lower rice field catches in those months. The prices of individual species or taxa varied to some extent between months, which might reflect short-term changes in supply (Figure 10). However, there was no evident relationship between quantity and price for all taxa combined ($r^2 = 0.36$, $p > 0.05$, $n = 7$ months), nor for 11 of 12 individual taxa tested for such a relationship. For one fish, *Trichogaster trichopterus*, quantity and price were positively correlated ($r^2 = 0.77$, $p = 0.01$), perhaps a spurious correlation related to catches for this species peaking in October, prior to catches of most other species peaking (i.e. the price might reflect lower availability of fish overall).

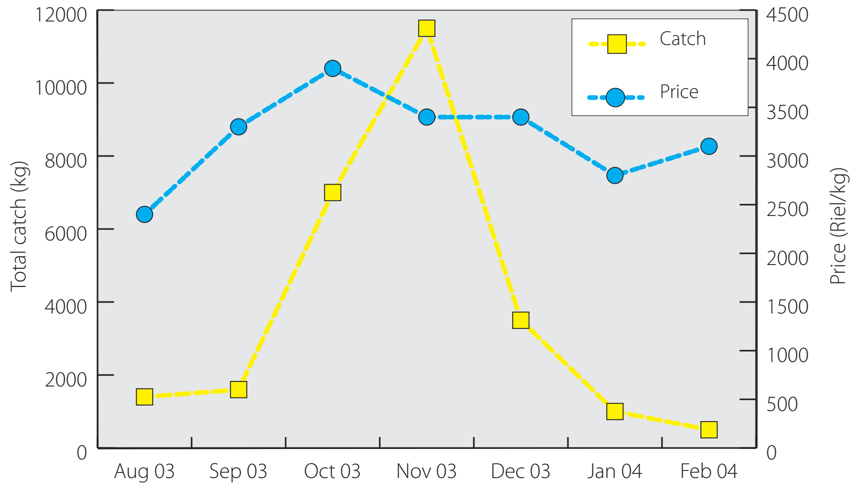


Figure 9. Total catch and weighted average price of all fish and OAAs each month. US$ = Riel 4000.

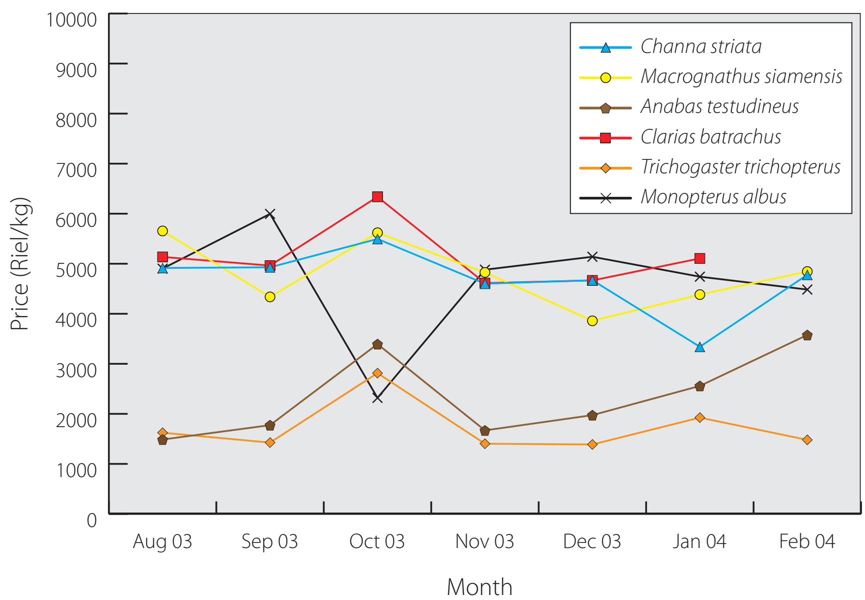


Figure 10. Monthly prices of the six fish species which contributed the most to total catches by weight. Prices are weighted averages from all sites and gears combined. *Clarias batrachus* was uncommon in Feb-04 and no price was recorded.

3.6 Disposal of the catch

Most fishers catch what is needed for household consumption and sell the excess, but also tend to sell larger higher-value fish and eat smaller fish. Larger specimens of the air-breathing black fishes (including *Clarias*, *Channa*, and *Anabas*) can be kept alive for extended periods out of water, so are easy to transport and sell. Data on catch disposal were incomplete, either because fishers did not supply the information or it was not accurately recorded by data collectors, so a detailed analysis could not be undertaken. Up to about 70% of catches at any time were reported to be sold by fishers, with generally higher proportions sold at times of higher catches. Fishers at Sites 1–4 appeared to be mainly fishing for income, and sold 50–70% of their catches, fishers at Sites 5–7 (close to houses and with more children fishing) sold only about 10–15% of their catches, and at Sites 8 and 9 fishers sold 15–60% of their catches, with higher percentages at times of larger catches. From these data it would be reasonable to estimate that about half of the weight of all the catches was sold. Thus the value of sales may also be estimated as about half of the total value of the catch, or about US$11,456—or about US$51 per hectare as actual sales. Allowing for the fact that larger and higher-value fish tend to be sold preferentially, the value of sales is probably higher than this figure. Catches which are not sold are either eaten in the fishers' households, preserved, or given away or bartered with other households.

3.7 Comparison between sites

Total catches at each site varied between about 67 and 162 kg/ha, with a mean value of 119 kg/ha, and the value of catches ranged from about $61/ha to $148/ha, with a mean value of $102/ha, as shown in Table 11.

The variation between sites was not large, so the relative error for the estimate of mean catches was only +21%. Fish made up about 77% of the total catch, but about 89% of the total value, because fish were generally more valuable than OAAs. The variation in catches between sites may be a consequence of the differences in extent and duration of inundation, which were greatest at Sites 1 to 4, corresponding to the highest catches. In addition, catches were correlated with fishing pressure, but this could be simply a consequence of the fact that people fished more on those sites that were inundated for a longer period.

The number of species recorded was greatest at Sites 8 and 9, which appeared to be a result of the capture (in relatively small quantities) of several species of grey or white fish that probably swam into the sites from their dry-season refuge areas in the nearby Sangke River, which is close to these sites (see Figure 2).

Table 11. *Summary statistics for catches, value, no. of taxa and effort at each site. Weight and value converted to kg/ha. Value converted from Riel, US$1 = R4000. CLs denotes 95% confidence limits. RE (relative error) = CLs/mean.*

Statistic	Site1	Site2	Site3	Site4	Site5	Site6	Site7	Site8	Site9	Mean	CLs	RE
Total catch (kg/ha)	132.4	140.5	162.0	161.0	121.0	66.6	91.0	98.6	96.0	118.8	25.4	21.4%
Catch of fish (kg/ha)	105.8	115.7	133.4	114.4	97.6	54.3	62.6	69.0	65.9	91.0	21.9	24.1%
Catch of OAAs (kg/ha)	26.6	24.8	28.6	46.6	23.4	12.3	28.4	29.6	30.1	27.8	6.8	24.6%
Fish as percent of catch	79.9%	82.3%	82.3%	71.1%	80.7%	81.5%	68.8%	70.0%	68.6%	76.6%	18.4%	24.1%
OAAs as percent of catch	20.1%	17.6%	17.7%	28.9%	19.3%	18.5%	31.2%	30.0%	31.4%	23.4%	5.8%	24.6%
Total value (US$/ha)	109.40	127.18	148.13	126.86	119.41	70.37	82.25	72.30	60.62	101.84	23.88	23.5%
Value of fish (US$/ha)	99.02	120.19	135.80	111.27	111.39	63.82	73.78	54.17	45.12	90.51	24.68	27.3%
Value of OAAs (US$/ha)	10.38	6.99	12.33	15.59	8.02	6.55	8.47	18.13	15.50	11.33	3.27	28.8%
Fish as percent of value	90.5%	94.5%	91.7%	87.7%	93.3%	90.7%	89.7%	74.9%	74.4%	88.9%	24.2%	27.3%
OAAs as percent of value	9.5%	5.5%	8.3%	12.3%	6.7%	9.3%	10.3%	25.1%	25.6%	11.1%	3.2%	28.8%
No. of taxa recorded	19	21	21	22	17	17	19	36	32	22.7	5.2	22.8%
Species of Fish	14	16	16	17	12	11	13	30	26	17.2	5.0	29.0%
Taxa of OAAs	5	5	5	5	5	6	6	6	6	5.4	0.4	7.4%
Fisher days per site	13,480	16,532	15,100	20,012	14,392	9666	12,940	10,120	11,693	13,771	2443	17.7%

The composition of catches was rather similar at each site; for example the six most-abundant fish species overall were also among the most abundant species at each site, making up 67 – 97% of the fauna at a site (see also Figure 12 below). Most species were present at all sites; Sorensen's index varied from 0.58 to 0.98. There was a significant rank correlation between the abundance at each site with every other site (Rho = 0.40-0.95 for all site comparisons, $p<0.05$) with one exception; Site 3 compared with Site 5 (Rho = 0.36, $p>0.05$). Based on the composition of catches, despite general similarities, the sites appeared to fall into three main groups, as is evident in Figure 11. These are also the three site groups that could be readily identified in the field as differing in gross hydrological characteristics. Sites 1 to 4 were inundated to the greatest depth and for the greatest duration; Sites 5 to 7 were shallow and inundated for the shortest period, while Sites 8 and 9 were intermediate and were located close to the Sangke River. The proximity of each site to others in its group, as well as the partial separation of each group by physical barriers, would also lead to relatively greater interchange of fauna between the sites within each group, which would tend to result in a similar fauna within each group.

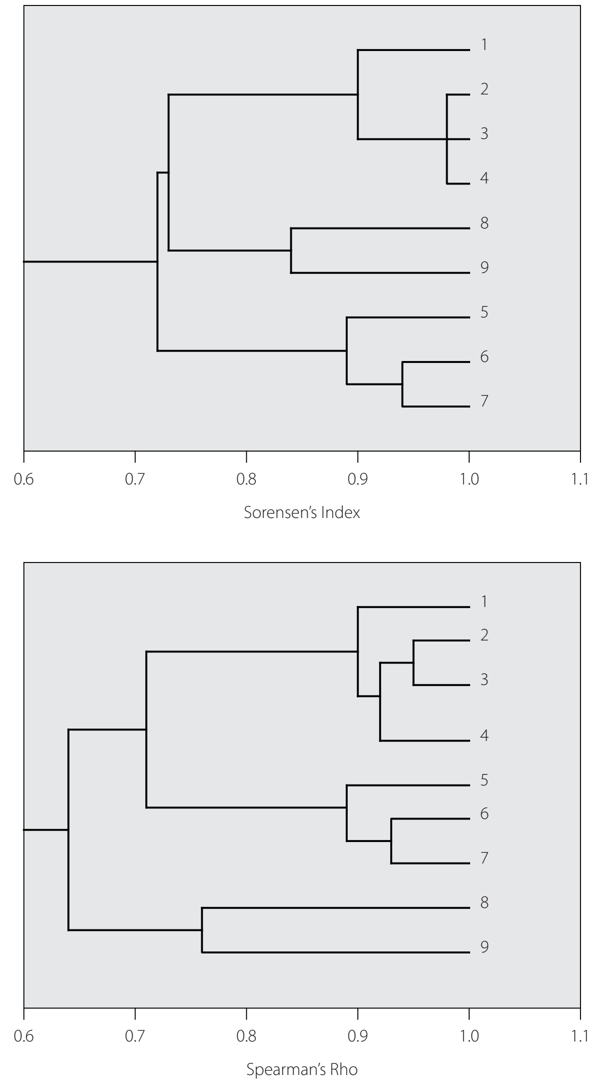


Figure 11. Dendrograms of site similarity based on total catches. Sorensen's index is based on presence/absence of taxa, Spearman's Rho on relative ranking of taxa.

3.8 Relationship to habitat variables

There was no correlation between the total catch or total taxa recorded at the nine sites with any of the general features of the habitat listed in Table 2 — altitude, brush cover, size or mean area of paddy fields, number of temporary or permanent ponds or both, and distance to a river (Spearman's Rho, $p>0.18$ for all comparisons). The lack of relationships does not mean that these variables are not important, but probably reflects the generally narrow range of variation between the sites and the limited extent of any features that might affect yield. For example, six of the nine plots had ponds. Of these, five plots had two ponds and one had three ponds and the mean density of ponds was 0.06 ponds/ha. By comparison, in other regions, where trap-ponds are used to enhance fish production, there may be one or more ponds per hectare. Another possible reason for the lack of any apparent relationship with habitat variables is the ability of animals to move freely into the plots from other areas, so that the effects of brush (which might provide spawning habitat), or refuge aquatic habitats (ponds and watercourses) might be apparent, but only at a landscape scale. For example, only plot 3 had significant coverage of brush, and although the catch at that site was the highest, the catch at the nearby plot 4 was almost identical, despite an almost complete absence of brush at that site. If brush does increase fishery production, the effects may extend some distance from the immediate area. More fish species were caught at Sites 8 and 9 than at the other sites, which is thought to be a result of better access of white/grey fish to this plot from nearby rivers. However, in the absence of a detailed assessment of the hydrology at each site this interpretation is speculative.

3.9 Standing Crop

On the first occasion that fields were pumped, mean standing crop was 58 kg/ha, and on the second occasion mean standing crop was about 72 kg/ha (Table 12). This increase was significant (paired t-test, $t=3.97$, $df=8$, $0.001<p<0.01$) and at all sites, except Site 1, the standing crop increased. The standing crop of fish increased significantly between occasions (and also at all sites except 1), but the mean standing crop of OAAs fell significantly, and fell at all sites. These changes would be consistent with growth of fish during this period and cropping of invertebrate biomass by the fish. There was no relationship between the standing crop at a site on the first pumping occasion and on the second occasion ($r^2=0.094$, $p>0.05$). In general, the overall density between pumping occasions was increasing to be within the relatively narrow range shown for Occasion 2 in Table 12, with also a lower relative error of the mean (+5.6%) on the second occasion (Table 12).

The composition of the fauna from pump samples was generally similar to the fauna of catches in terms of ranking of dominant taxa, but *Channa striata* made up over half of the biomass of fish in standing crop samples, compared with about 28% in fisher catches and *Clarias meladerma* which was relatively rare in catches, was among the more common species (Figure 12, see also Figure 6 and Table 13). There were also fewer species recorded at every site; of the 35 species of fish recorded from catches, only 19 were recorded from the rice fields pumped for standing crop estimation.

Table 12. *Summary statistics for standing crop on the first and second occasions of pumping 1-ha plots in rice fields.*

CLs denotes the 95% confidence limits. RE (relative error) = CLs/mean.

Site	Total Wt (kg/ha)		Fish (kg/ha)		OAAs (kg/ha)		Mean Standing Crop (kg/ha)		
	Occ. 1	Occ. 2	Occ. 1	Occ. 2	Occ. 1	Occ. 2	Total	Fish	OAA
1	86	69.4	66.7	56.1	19.4	13.4	77.7	61.4	16.4
2	64.8	66.8	31.6	49.7	33.3	17.1	65.8	40.7	25.2
3	51.2	69.1	26.4	52.2	24.8	16.9	60.2	39.3	20.9
4	39.7	78.1	21.3	60.4	18.5	17.6	58.9	40.9	18.1
5	54	80.7	32	59.7	22	20.9	67.4	45.9	21.5
6	67.4	74	40.7	52	26.7	22.1	70.7	46.4	24.4
7	47.8	66.7	31.4	53.9	16.4	12.8	57.3	42.7	14.6
8	50.8	71.7	31.1	60.9	19.6	10.8	61.3	46	15.2
9	60.5	66.6	34	53.6	26.5	13.1	63.6	43.8	19.8
Mean	58.0	71.5	35.0	55.4	23.0	16.1	64.8	45.2	19.6
Min	39.7	66.6	21.3	49.7	16.4	10.8	57.3	39.3	14.6
Max	86.0	80.7	66.7	60.9	33.3	22.1	77.7	61.4	25.2
CLs	10.4	4.0	10.0	3.1	4.1	3.0	5.0	5.1	2.9
RE	18.0%	5.6%	28.5%	5.7%	17.7%	18.4%	7.7%	11.2%	15.0%

The composition of the fauna from pumping at each site was very similar; Sorensen’s index varied from 0.73 to 0.97 for all site comparisons, and the rank order of the fauna at each site was very similar to that at every other site (Spearman’s Rho for all site comparisons: range 0.68-0.92, all $p<0.001$). Hence there is no basis for separating the site groups based on variation in faunal composition. Figure 12 illustrates the relative similarity of the composition of the standing crop at each pumping site, showing for example the similar level of importance of *Channa striata* and the other common fish species, in contrast to the more variable proportions in catches.

To compare the fauna of the 25-ha catch assessment sites with the fauna of the adjacent 1-ha sites pumped for standing crop estimation, multi-dimensional scaling (MDS) was used as a technique to reduce the data to two dimensions[1]. In Figure 13, the standing crop sites are clearly clumped together and consistent with the general similarity of their fauna, with the exception of Site 1 which had a much higher proportion of *Channa striata* and a lower proportion of crabs than the other sites. The catch assessment sites are relatively separate from each other and generally distant from the standing crop sites.

1 The Proxscal scaling procedure in SPSS was used based on Euclidean distances. Stress-1=0.15, Stress-2=0.33. S-stress=0.05; the procedure accounted for 98% of dispersion in the data.

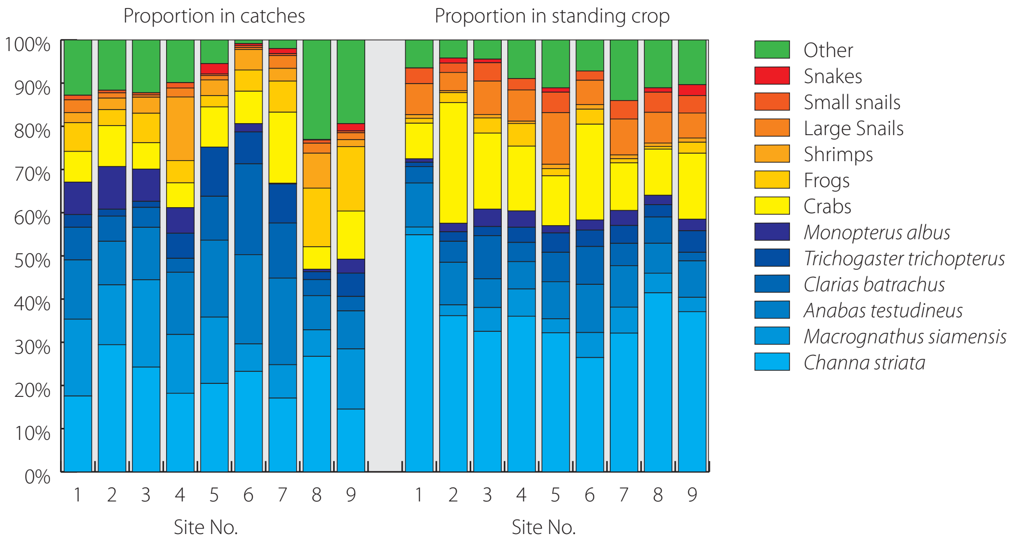


Figure 12. Proportional composition by weight of the dominant fauna in catches compared with the fauna recorded by pumping rice fields to estimate standing crop. The figures include all six taxa of OAAs and the six most abundant species of fish.

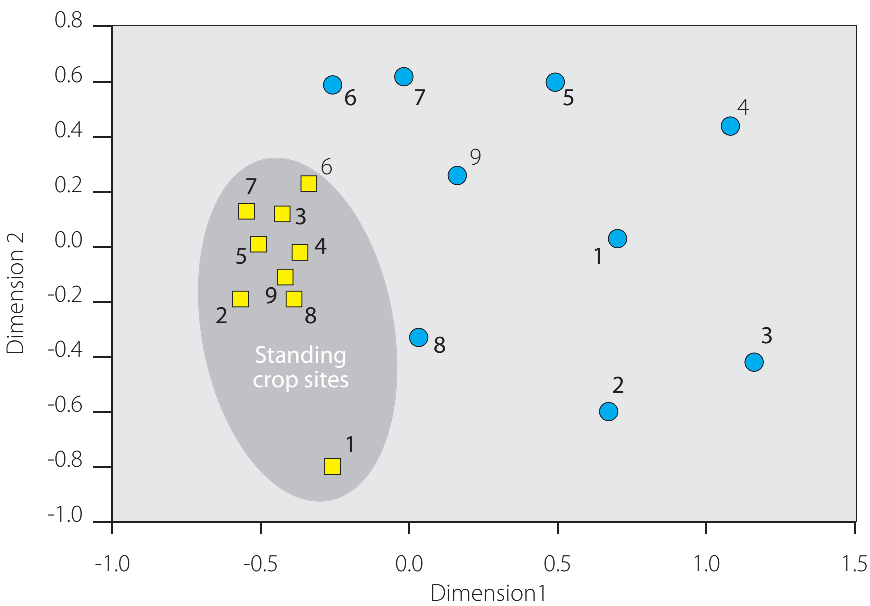


Figure 13. Ordination of sites based on multi-dimensional scaling of faunal composition. Sites with square symbols inside the ellipse are 1-ha standing crop sites, others are 25-ha catch assessment sites.

Table 13 shows that four taxa (*Anabas testudineus*, *Macrognathus siamensis*, frogs and shrimps) were present in significantly higher proportions in catches, whereas five taxa (*Channa striata*, *Clarias meladerma*, crabs, large snails and small snails) were relatively more abundant in pump samples as a proportion of the entire assemblage (i.e. fish plus OAAs). These differences in composition are a consequence of the pump samples being taken from

1-ha plots of rice fields, whereas catches were made from all habitats within each 25-ha study plot: including rice fields and adjacent canals, ponds and seasonal watercourses. In the pump samples, black fish made up virtually all (97%) of the biomass of fish, and purely carnivorous fish made up 75% of the biomass; the comparable proportions from fisher catches were 88% black fish and 63% carnivores; therefore rice fields *per se* are characterised by a very high proportion of carnivores and black fish.

Table 13. *Comparison of the proportions of the main taxa in catches and pump samples at each site. Paired t-tests for the six most abundant fish (by weight) in catches and in pump samples, and the six taxa of OAAs. * p<0.05, ** .01<p<0.05, *** P<0.001>.*

Taxon	Mean percentage of fauna in catches	Mean percentage of fauna in pump samples	t	Significance
Anabas testudineus	14.0%	8.6%	3.826	**
Channa striata	21.3%	36.5%	-4.505	**
Clarias batrachus	8.0%	5.8%	1.275	
Clarias meladerma	1.6%	4.9%	-2.694	*
Macrognathus siamensis	12.8%	4.3%	4.294	**
Monopterus albus	4.1%	2.5%	1.180	
Trichogaster trichopterus	5.2%	3.2%	2.136	
Crabs	8.7%	15.5%	-2.770	*
Frogs	7.3%	2.4%	3.018	*
Large Snails	1.7%	7.2%	-7.229	***
Shrimps	4.9%	0.8%	2.932	*
Small snails	0.6%	3.6%	-7.663	***
Snakes	0.6%	0.7%	-0.272	

3.10 Catches as a proportion of standing crop

Standing crop estimates were compared with those for fisher catch at each site by testing for correlations as shown in Table 14. Fisher catches from the same month as the first and second pumping occasions were included as well as total catches and total (average) standing crop estimates. There were no significant relationships between standing crop and fisher catches in any of the comparisons, a somewhat surprising result which could be attributable to several causes. Firstly, as noted above, fishers catch fish and OAAs from all habitats, not just rice fields. Secondly, a high standing crop in any area might lead to more fishing effort, which would tend to reduce the standing crop, so reducing any correlation. Finally, the 1-ha sites pumped for standing crop assessment might not be entirely representative of the adjacent 25-ha sites assessed for fisher catch.

Table 14. *Correlation matrix for comparison of total catches with total standing crop from pumping. N=9 sites. SP = mean standing crop estimate from two occasions. Catch-catch and pump-pump comparisons not shown.*

Variable		C1	P2	C2	SC	SP
P1 (pumping 1st occasion)	Rho	0.15		-0.20	-0.18	
	Sig. (2-tailed)	0.70		0.61	0.64	
C1 (catch 1st occasion)	Correlation Coefficient		0.03			0.23
	Sig. (2-tailed)		0.93			0.55
P2 (pumping 2nd occasion)	Correlation Coefficient			-0.03	0.15	
	Sig. (2-tailed)			0.93	0.70	
C2 (catch 2nd occasion)	Correlation Coefficient					-0.25
	Sig. (2-tailed)					0.52
SC (sum of all catches, Aug-Feb)	Correlation Coefficient					-0.17
	Sig. (2-tailed)					0.67

Mean standing crop estimates overall varied from about 57-78 kg/ha (Table 12) and mean standing crop varied from about 37% to 106% of catches at a location.

3.11 Length-frequency data

Fisher catches

From the fisher catches across the nine the sites, a total of 11,309 specimens of the five most abundant fish were measured as summarised in Table 15. The maximum lengths for each of these species were less than recorded in literature, and the majority of fish were small; about half of all the fish were less than 10 cm in length and the overall range across the five species was 2 – 32 cm. The data were cross-tabulated by week and length to determine whether length modes indicative of cohorts could be used to estimate growth rates. Appendix 6 shows the tabulations for the sites at which the greatest numbers of each species were measured. Fish in the smaller size classes were present throughout the fishing season, suggesting continuous breeding and recruitment, with fishers continually cropping excess fish.

For four species (*Anabas testudineus*, *Clarias batrachus*, *Macrognathus siamensis* and *Trichogaster trichopterus*) it was not possible to interpret length frequency data, because length modes did not appear to coincide in any meaningful way between sampling occasions. Possibly, distinct cohorts were present in the populations of fish, but were obscured because the fishers did not use the same types of gear throughout the sampling period, thereby introducing artefacts. Fishers also focus on different habitats at different times, which would also obscure evidence of cohorts if, as is likely, fish select different habitats at different sizes. For *Channa* *striata*, the length-frequency data at some sites suggested distinct cohorts, as shown in Figure 14 for Site 1. One cohort appears to have grown 2 cm (from 18 to 20 cm) in 9 weeks, and smaller fish appear to have grown 1 cm (from 17 to 18 cm) in 2 weeks. The data therefore suggest that growth for *Channa striata* within the measured length range was in the range of 1–2 cm per month. More than half of the *Channa* caught were 18 cm or less, and the maximum length recorded was 32 cm, so most *Channa* are probably caught in their first or second year of life.

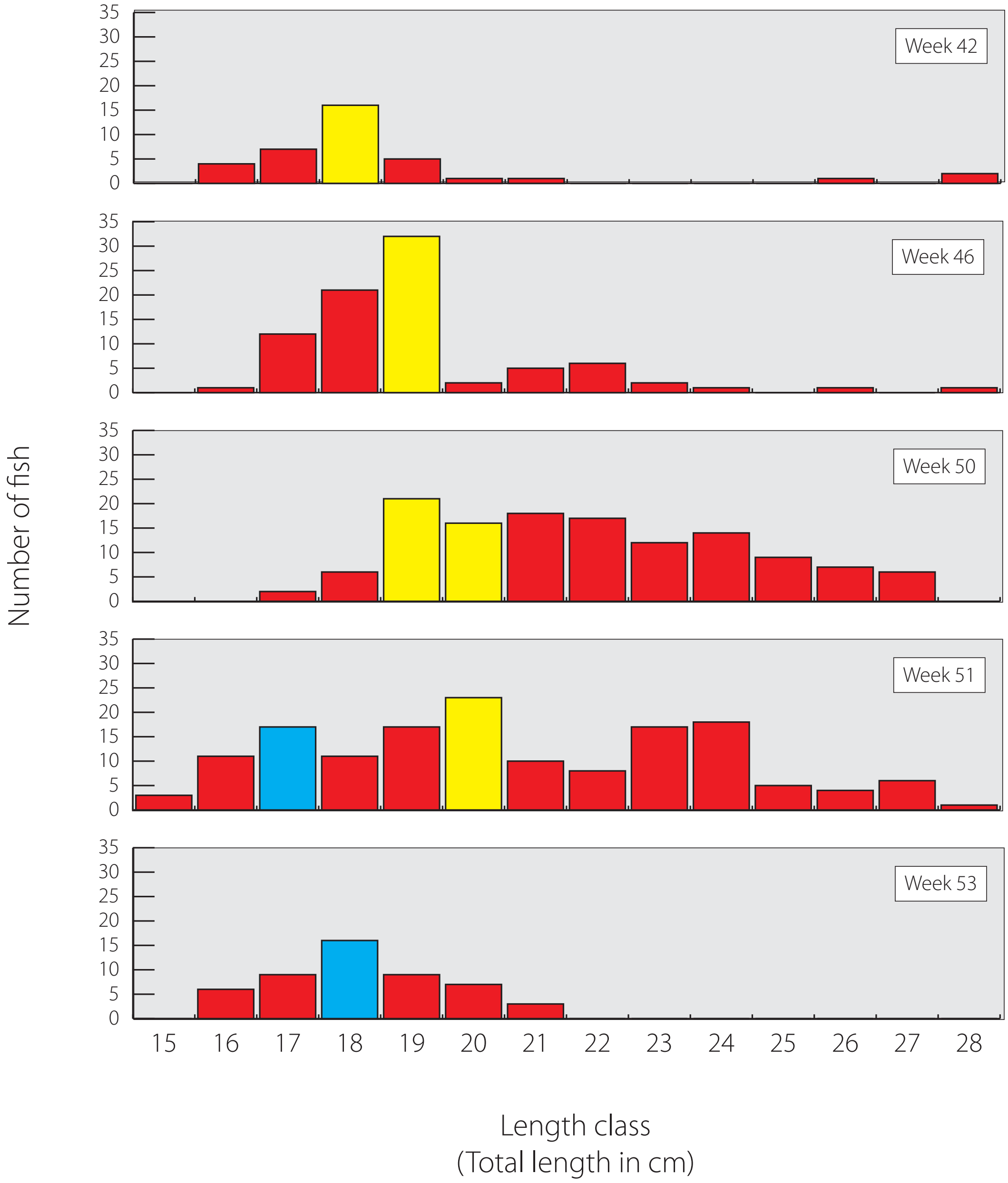


Figure 14. Length-frequency for catches of *Channa striata* at Site 1.
Length classes on horizontal axes are total length in cm. The modes of two probable cohorts are highlighted in yellow and blue. Week 42 is 12th to 18th October 2003; Week 53 is 28th December 2003 to 3rd January 2004.

Pumping data

Data from pumping are more likely to be useful for size frequency analysis because the same sampling method was used in the same location each of the two times that pumping was carried out. A total of 4858 fish in five common species was measured across the nine sites (Table 15).

Table 15. *Summary of fish measured from sub-samples of fisher catches and from pumping on two occasions for standing crop estimation.*

Lengths are all cm total length; Maximum length recorded in world literature is from Appendix 3.

Species	Fisher Catches			Pumping			Max length in world literature
	N	Min Lth	Max Lth	N	Min Lth	Max Lth	
Anabas testudineus	3526	3	14	1462	3	12	25
Channa striata	2060	6	32	1128	9	29	115
Clarias batrachus	856	5	26	305	13	25	47
Macrognathus siamensis	2247	6	27	861	12	23	35
Trichogaster trichopterus	2620	2	11	1102	3	11	17
Total	11,309	2	32	4858	3	29	

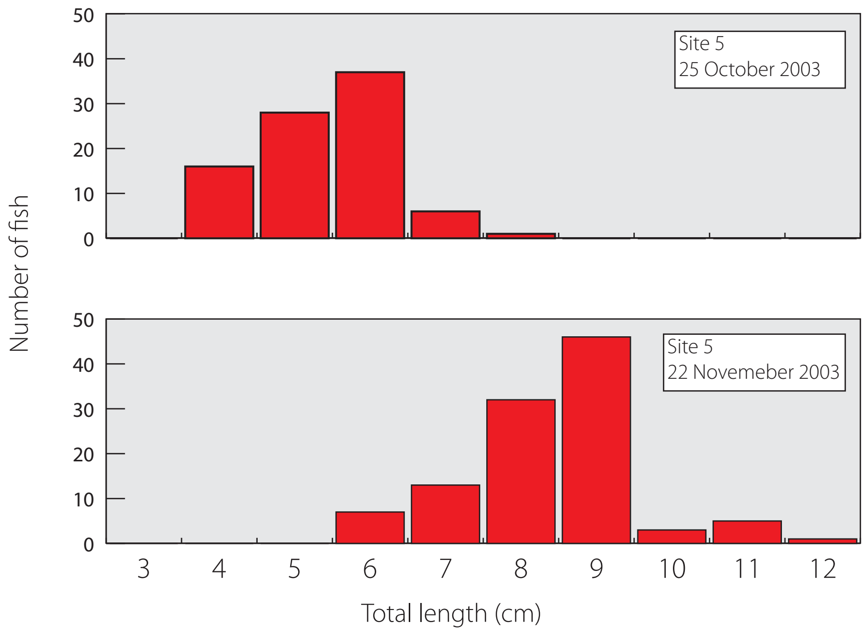


Figure 15. Apparent changes in length, as exemplified by *Anabas testudineus* at Site 5. Pump samples, occasions 28 days apart.

For each of these species the length range was less than in fisher catches, as would be expected when fewer fish are measured during a more restricted time period in only one habitat.

Well-defined modes which appeared to represent one or two cohorts and which show growth between the sampling occasions were evident for three species, as exemplified in Figure 15.

For these three species (Table 16), the mean length of fish within an apparent cohort was calculated and used to estimate daily change in length for that cohort based on the number of days which had elapsed between occasions.

Table 16. *Increase in total length of identifiable cohorts of three common species between pumping occasions Lengths are cm total length.*
At most sites that are not shown too few fish were measured on at least one occasion. For Anabas at Site 1 modes were present but could not be clearly related.

Anabas testudineus

Site	No. of fish on occasion		Mean length (cm) of main cohort on occasion		Increase in length (cm)	Elapsed days	Increase (cm/month)
	1	2	1	2			
2	88	80	5.41	8.08	2.67	54	1.50
3	58	74	5.41	8.14	2.72	46	1.80
4	48	106	6.04	8.23	2.18	46	1.44
5	85	107	4.79	8.41	3.62	28	3.94
6	84	79	5.60	8.10	2.51	30	2.54
7	109	52	4.96	7.48	2.52	29	2.64
8	107	41	4.17	7.54	3.37	40	2.56
9	54	24	4.29	6.75	2.46	40	1.87
Mean increase (rounded)							2
Maximum length recorded in this study							14

Trichogaster trichopterus

Site	No. of fish on occasion		Mean length (cm) of main cohort on occasion		Increase in length (cm)	Elapsed days	Increase (cm/month)
	1	2	1	2			
5	48	94	4.81	7.16	2.35	28	2.55
6	45	84	4.93	6.77	1.84	30	1.87
7	45	84	4.36	6.20	1.85	29	1.94
8	57	31	4.23	6.58	2.35	40	1.79
9	82	45	4.96	6.60	1.64	40	1.24
Mean increase (rounded)							2
Maximum length recorded in this study							11

Clarias batrachus

Site	No. of fish on occasion		Mean length (cm) of main cohort on occasion		Increase in length (cm)	Elapsed days	Increase (cm/month)
	1	2	1	2			
5	7	22	15.43	20.86	5.44	28	5.90
6	7	38	15.14	18.63	3.49	30	3.54
7	3	50	15.50	17.78	2.28	29	2.39
Mean increase (rounded)							4
Maximum length recorded in this study							26

Table 16 summarises the estimated change in mean length of apparent cohorts; when rounded to the nearest cm (the unit of the original measurements) the increase in length was about 2 cm per month for *Anabas testudineus* and *Trichogaster trichopterus* and about 4 cm per month for *Clarias batrachus*. For these three species it is apparent that the growth rates and maximum recorded lengths are consistent with most fish being caught within their first year of life.

For *Channa striata* and *Macrognathus siamensis* (as exemplified in Figure 16) there were no clear patterns that would enable identification of particular cohorts. Possible explanations for the lack of a pattern include the following.

- Some size classes within these two species could be quite mobile, actively moving within rice fields and between rice fields and canals and channels. This would explain, for example, the appearance of larger fish (>20 cm) in Figure 15.

- Fishers could be selectively removing certain size classes in these two species; which would explain the apparent loss of the strong mode at 13 cm on the first sampling occasion.

- The distribution of cohorts of these fish may be patchy, with samples reflecting the presence of single broods of fish spawned in the sampled area. This explanation is particularly likely to apply to *Channa*, in which both parents protect their young in one locality until they are fingerlings. Such an explanation would also explain the mode at 13 cm on the first sampling occasion in Figure 15, but the absence of this size class on the second.

4. Discussion

4.1 Comparison with rice-field fisheries elsewhere

The general features of the Battambang rice fields fishery resemble those reported for a similar rain-fed rice field environment in Kampong Thom, north-east of the Tonle Sap system by Balzer *et al*. (2005). There, 25 fish species were abundant and 12 more were commonly seen; a total of 37 species compared with 35 in this study. In Kampong Thom, four fish species were abundant and favoured; these were all carnivorous black fishes, which were also among the top five species recorded in catches in Battambang – *Channa striata*, *Clarias macrocephalus*, *Clarias batrachus* and *Monopterus albus*. Other aquatic animals such as snakes, crabs, shrimps, amphibians, molluscs and insects were also important, as in this study. In Svay Rieng south-east Cambodia, Gregory *et al*. (1996), found a similar proportion (18%) of OAAs in the catch as found in this study (24%) and also found that carnivorous or primarily carnivorous blackfishes – *Channa striata*, *Anabas testudineus* and *Clarias macrocephalus* were also caught most frequently. In another study of rain-fed rice field habitat in Svay Rieng, Shams *et al*. (2001) found that *Channa striata*, *Clarias* spp. and *Anabas testudineus* comprised 89% of the total catch of 12 farmers who were monitored. In north-east Thailand these same three taxa comprised about 79% (*C. striata* comprised 60%) of the total catch of 123 farmers' trap ponds in the Chi valley (Saengrut, 1998). Middendorp (1992) found these three black fish taxa comprised on average 91% of the wild fish catch (43% was *Channa striata*), and wild fish dominated the yield from stocked trap-pond culture systems. Angporn *et al*. (1998) similarly found that the same three black fish taxa produced 95% of the yield from the trap-pond systems of 35 farmers. In a coastal poldered system in southern Cambodia, 31 fish species were caught; the most important taxa were also *Channa striata*, *Clarias* spp., *Anabas testudineus* and the featherback, *Notopterus notopterus*, a grey fish which depends upon large permanent water bodies as dry-season refuges (Lim *et al*., 2005).

Balzer *et al*. (2005) recorded 26 techniques of catching fish; Gregory *et al*. (1996) recorded 23 techniques and in this study in Battambang 26 techniques were recorded. The seasonal pattern of fishing activity, peaking in the period when rice is in the vegetative stage (October-November in this study), is probably the general pattern in much of Cambodia, as described in Svay Rieng by Gregory *et al*. (1996). In Kampong Thom, Balzer *et al*. (2005) estimated mean consumption would be about 1 kg/family during the fishing season; in this study catches averaged about 1 kg/fisher/day. Allowing for two fishers per family (typically of 5 or 6 people), and sale of about half of the fish caught, the two estimates are quite similar. In Svay Rieng, Shams *et al*. (2001) found over a nine-month period, mean catches of about 585 kg/household, or about 2 kg/household/day/year and Gregory *et al*. (1996) found a similar mean catch rate of 681 kg/household over ten months; in both studies these higher catch rates were apparently associated with the use of household trap ponds (not present in Battambang), which increased yield by providing dry-season refuges and increasing capture efficiency. In Svay Rieng, lower rainfalls, poorer soils and below-average rice production, coupled with an expanding population and reduction of the wild fishery, have made investment in and management of trap ponds attractive for farmers looking to supplement their livelihoods. Similarly, in north-east Thailand, trap ponds are widespread and their production appears to compensate for losses of wild fish, and perhaps leads to higher yields than were obtainable without management. Saengrut (1998) found that in rain fed rice farming areas in the lower Chi Valley in northeast Thailand, 54% of catches were from trap ponds; the yield per fisher was similar to that of the more natural floodplain-rice field fisheries of the lower Songkhram River Basin (Hortle and Suntornratana, 2008). Catches of fish from typical trap-pond systems in rain-fed wet-season rice fields in north-east Thailand averaged 209 kg/ha, more than double the fish yield (91 kg/ha) found in this study in Battambang (Middendorp, 1992). Further intensification to a double-cropping rice system can be expected to create conditions which are much less favourable for many aquatic organisms; for example only seven fish species were present in an intensive rice-growing area in Malaysia, nevertheless trap ponds produced a mean yield of fish of 129 kg/ha/season and a maximum yield of 202 kg/ha/season (Ali, 1990).

The highest yield reported for a wild fishery in rice fields is about 630 kg/ha/year[1], in a coastal area of Cambodia where levees (polders) have been built to raise and stabilise seasonal water levels and prevent seawater intrusion (Lim *et al*. 2005). This high yield is likely a result of the high water levels in the wet season (average 2 m depth), the presence of permanent water bodies within the polders, and immigration of fish from rivers and streams, which run through the poldered area. Achieving such a high yield shows the potential for fisheries to be the primary output from agricultural land with improved environmental management.

The mean yield estimate for fish and OAAs of 119 kg/ha/year reported here is consistent with ranges previously reported for lowland rice field habitats, as shown in Table 17. The yield is within the range reported by de Graaf and Chinh (2000) for a non-acid floodplain site in the Mekong Delta, and the yield of fish of 91 kg/ha/year is within the range reported by Little *et al*. (1996) for wild fish yield in rain-fed rice-field habitat in northeast Thailand. The yield of 50 – 100 kg/ha/year estimated by Guttman (1999) for a rice field fishery in Prey Veng province, southeast Cambodia, is less than that that found in this study, as might be expected because Prey Veng is drier and less productive than Battambang. An estimate of 125 kg/ha by Gregory *et al*. (1996) in Svay Rieng, also a dry province, was based on only three villages which might not have been representative. It is interesting to note that the rice field fishery in Battambang appears to be more productive on an areal basis than the notable fishery of the lower Songkhram River Basin in Thailand. Probably the yield from the highly productive floodplain-based portion of the fishery of the Songkhram is diluted by the yield from relatively unproductive but spatially extensive rice fields, which in the lower Songkhram River Basin are shallower and inundated for shorter periods than those in Battambang.

1 The yield reported was based on a flooded area of 5500 ha, but flooded area may have reached 10,000 ha or more, so the yield per unit area may be overestimated.

Table 17. *Estimates of yields from rain-fed rice fields and floodplain habitat.*

Location	Habitats	Yield (kg/ha/year)	Composition	Comment	Source
Battambang, this study	Rice fields, single crop rain-fed	119	Fish 76% OAAs 24%	Yields from 10 plots of 25 ha each, monitoring of all catches	This study
Prey Veng, Cambodia	Rice fields, single crop rain-fed, low yield	50 – 100	Fish	Estimates based on catches, villages may not be representative, approximate area	Guttman (1999)
Svay Rieng	Rice fields, single crop rain-fed, low yield	125	Fish 82% OAAs 18%	Estimates from 3 villages only and approximate areas	Gregory *et al.* (1996)
Mekong system, northeast Thailand	Rice fields, single crop rain-fed	25 – 125	Fish	Range from one study in Khu Khat	Little *et al.* (1996)
Mekong system, northeast Thailand	Rice fields, single crop rain-fed	209	Fish	Mean with trap ponds, wild fish only	Middendorp (1992) 20 farmers and 16 farmers over 2 years
Malaysia - nr Penang	Rice fields, double-cropping irrigated	129 (57 – 202)	Fish	Double rice cropping, artisanal fishery	Tan et al. (1973), cited in Fernando (1993) Table 3 and Ali (1990)
Mekong system, northeast Thailand	Rain-fed and recession rice fields and floodplain	79	Fish and OAAs	Based on catches, consistent with consumption estimates	Hortle and Suntornratana (2007)
Mekong Delta Floodplain, Viet Nam	Rice fields, deep water floodplain, acid soils	63	Fish 47%, OAAs 53%	Intensive monitoring at one site	de Graaf and Chinh (2000)
Mekong Delta Floodplain, Viet Nam	Rice fields, deep water floodplain, non-acid	119	Fish 89%, OAAs 11%	Intensive monitoring at one site	de Graaf and Chinh (2000)
Prey Veng, Cambodia	Floodplain - rice fields, single-crop, former forest	55	Fish	Includes only commercial arge and middle-scale catches in fishing lots, does not include artisanal catch	Troeung *et al.* (2003)
Prey Veng, Cambodia	Floodplain - degraded flooded forest 31% cover and rice fields, single crop	92	Fish		
Battambang, Cambodia	Floodplain - flooded forest	95	Fish		
Tonle Sap, Cambodia	Mostly floodplain with recession rice, rain-fed rice fields, permanent water bodies about 5% of area	243 – 532	Fish and OAAs	Study area 8252 ha, max flooded area 6732 ha. Based on fisher logbooks plus commercial catches which were 4 – 9% of total	Dubeau *et al.* (2000)
Prey Nup, Cambodia (coastal)	Artificial deep floodplains behind polders	630	Fish	May include fish migrating in from rivers	Lim *et al.* (2005)
Floodplains, Bangladesh	Unregulated Floodplains 8 studies	24 – 574	Wild fish only	Intensively fished	Ali (1997) Tables 31 – 33
Floodplains, Bangladesh	Floodplain – Natural	104 – 130	Fish	Intensively fished	Halls *et al.* (1999)
Tonle Sap System	Floodplain, total	230	Fish?	Crude estimate	Baran *et al.* (2001)
Tonle Sap Floodplain	Floodplain, total for 1995-99	139 – 190	Fish?	Crude estimate	Lieng and van Zalinge (2001)

4.2 Significance to livelihoods and food security

The peak fisher density of 2 persons per hectare, if representative for Cambodian rice fields, suggests that about 7.2 million people (or about half of the current population of 13.4 million) could be active in the rain-fed wet-season rice-field fishery at its peak each year. The significance of rice-field fisheries for Cambodia's population lies not only in their yield and contribution to nutrition, but also the dispersal of benefits through the population, particularly to the rural poor, many of whom are landless and have limited opportunities for employment. Evaluation of the merits of changes to farming systems should include assessments of their overall socio-economic effects, particularly on the more vulnerable segments of the population. It should also be noted that if wild capture fisheries are affected by agricultural intensification, attempts to compensate by developing aquaculture face not only impediments related to land-holding size and location as discussed below, but may tend to shift the workload onto women and children (Hatha *et al*., 1995; So *et al*., 1998).

4.3 Implications for fishery yield estimates

Fisheries yield depends largely upon the extent of seasonally inundated land, which in the lower Mekong Basin includes both floodplains and a much larger area of wetlands, most of which are 'rain-fed' rice field habitats that are inundated by rain directly or by diversion of small local watercourses. The lower Mekong Basin covers an area of about 639,000 km^2, of which about 30% is classed as wetlands (permanently or seasonally inundated areas), and of this about 86% is classed as rice fields, based on MRC land-use databases (Table 18). In Cambodia (i.e. the whole country) there are about 47,000 km^2 of wetlands of which about 34,000 km^2 are classed as rice field habitats. About 41,000 km^2 of Cambodia's wetland area is within the LMB, and comprises about 70% rice field habitats (Table 18).

Table 18. *Estimated wetland areas in the LMB and Cambodia.*
Based on MRC land-use databases post 2000, which are more comprehensive and accurate than wetland databases used to estimate similar areas by Hortle (2007).

Wetland type	Cambodia		Total LMB	
	Area (1000 km^2)	% of total	Area (1000 km^2)	% of total
Ricefield habitats	28.5	69.4%	159.2	86.1%
Flooded forest/grassland/shrub	7.3	17.7%	7.3	3.9%
Natural swamp	0.3	0.8%	2.2	1.2%
Aquaculture	0.0	0.0%	2.4	1.3%
Permanent water bodies	5.0	12.1%	13.8	7.5%
Total wetlands	41.0	100.0%	184.9	100.0%

The annual catch figures produced by the Department of Fisheries in Cambodia include an estimate for rice field fisheries of 50 – 100,000 tonnes/year (or 17 – 23% of the total catch) based on a rice field area of 1.8 million hectares (the 1992 planted area estimate) and a literature-based yield estimate of 25 – 62 kg/ha (Table 19)[1]. These catch estimates have been subsequently quoted by many authors, but are subject to great uncertainty, as stressed by Sensereivorth *et al*. (1999). Moreover, the figures are out-of-date, as increasing fishing pressure and a greater area under rice cultivation would certainly have led to an increased rice field catch since the 1990s

Table 19. *Estimated annual inland catches for Cambodia, based on information from 1994 – 1997. From van Zalinge* et al. *(2000).*

Type of fishery	Annual Catch (tonnes/year)
Large scale fishery	
Fishing lots	25,000 – 75,000
Dais (large bag nets)	14,000 – 16,000
Middle scale fisheries	85,000 – 100,000
Family fisheries	115,000 – 140,000
Rice-field fisheries	50,000 – 100,000
Total	289,000 – 431,000

The discrepancy in rice field areas between Table 1 (planted area of about 24,000 km^2 in 2004) and the area estimated from land-use mapping of 34,000 km^2 arises because ‘rice field habitats’ includes many smaller areas of other kinds of habitat (such as small swamps, ponds, canals and remnant forest) that are not discriminated from actual rice fields. Moreover the area actually planted each year (Table 1) is less than the total area. The ‘rice field habitat’ area is a more appropriate measure to use to estimate total yield, because areal yield estimates (as in this report) are based upon large blocks of habitat, rather than just rice fields per se.

The national estimates for yield from rice field habitats should be revised based on the more accurate estimates of area and an improved areal yield estimate. The estimate from this study of 119+25 kg/ha/year under-estimates the areal yield from Battambang rice field habitat, because dry-season catches and some illegal gear catches were not recorded. On the other hand, rice field habitats in Battambang might be more productive than in Cambodia generally, so a conservative assumption for mean rice field yield in Cambodia is about 100 kg/ha, of which about 24% is OAAs. A figure of 100 kg/ha for rain-fed rice fields is within the lower range of yields for floodplains (discussed below) and appears reasonable, because the effect of the relatively short duration and shallow inundation of rain-fed rice fields may be offset by their greater fertility, high biological productivity (Heckman, 1974; 1979) and high fishing pressure. Multiplying the areal yield of 100 kg/ha/year by the area of rice field habitats provides an estimate of 285,000 tonnes per year for rain-fed rice field habitats in the LMB in Cambodia, or about 340,000 tonnes per year from such habitats in the whole of Cambodia. The catches from

1 Based on the stated area and yields, the range is 45,00-112,000 tonnes/year, which was apparently rounded to a very approximate range

middle-scale and family fisheries may also derive partly from rice fields, but can be separately accounted as the areal yield estimate is based only on the small-scale or household catch

Substituting the rice field yield figure of 285,000 tonnes in Table 19 increases the fishery yield from the Cambodian part of the LMB to 524,000 – 616,000 tonnes/year, a range consistent with the figure of 587,004 tonnes/year estimated for Cambodia by Hortle (2007) based on consumption surveys. The apparently large contribution from the 'invisible' rice field fishery may allay concerns over the credibility of the consumption-based estimates that have been expressed by Baran and Myschowoda (2008, p. 59).

Floodplains are often cited as the driver of fishery productivity in the lower Mekong basin. Based on MRC GIS data, the maximum extent of annually flooded area in the LMB is about 28% of the total wetland area; the remainder is mainly rice fields or associated habitats. In Cambodia, about 30% of the wetland area is above the maximum annually flooded area. Wet season, rain-fed rice farming extends into the periphery of the floodplain, where rice that has been growing for 2 – 3 months may be exposed to floodwaters for days to weeks during large floods. Therefore about half of the wetland area in Cambodia is outside what might be defined as the average 'active floodplain' and most of this area is rain-fed rice fields.

Comparing fisheries yield from rain-fed rice fields (as estimated in this study) with yield from floodplains is constrained by the paucity of accurate data, especially for yields from defined areas of floodplains. Available data are summarised in Table 17. Cambodian fishing lots had commercial-fishing yields of 55 – 95 kg/ha/year of fish, but unmeasured subsistence catches could greatly increase these values (Troeung *et al*., 2003). An estimate of 245 – 532 kg/ha (mid-value 388 kg/ha) (Dubeau *et al*., 2001) from 'floodplain' near the Tonle Sap showed that small-scale catches made up 91-96% of the total, but much of the study area was actually rain-fed rice fields. The estimates of 139 – 190 kg/ha/year and 230 kg/ha/year for the entire Tonle Sap system (Lieng and van Zalinge, 2001; Baran *et al*. (2001) suffer from imprecise definition of the area of floodplains, possible inaccuracies in the underlying catch or consumption data, and the incorrect assumption that the catch was entirely from floodplains and none was from the surrounding area of rain-fed rice field habitat. An estimate of 630 kg/ha/year from a coastal system (Lim *et al*., 2005) probably reflects deep-water flooding and the presence of large permanent shallow water bodies. Floodplains of Bangladesh, which have a similar fauna and hydrology to those in Cambodia, yield 2 – 574 kg/ha/year (Table 17); low yields derive from enclosed, relatively dry floodplains, whereas the highest yields derive from open, natural floodplains that have large permanent water bodies. Based on these data, Cambodian floodplains are likely to produce areal yields that are much higher than areal rice field yields, as they are inundated for longer and to a greater depth, are generally open, have many water bodies, and are subject to moderate-to-high fishing pressure.

A yield figure of about 100 kg/ha/year was used as a medium-level to estimate total yield based on the area of all Cambodian wetlands by Hortle (2007). In the LMB generally, rice field habitat dominates land-use classes within wetlands, so that rice field yield estimates are critical to estimating the yield of the basin; research on areal yields basinwide would greatly aid efforts to improve the overall LMB estimate.

4.4 Integration of fisheries and agriculture

Rice farming throughout most of Cambodia is relatively non-intensive and unproductive; about 86% of wet-season rice land is still farmed using traditional varieties which are relatively slow-growing, producing only one crop per year (ACI and CamConsult, 2006). The traditional farming system uses comparatively low inputs of chemical fertilisers and pesticides and entails prolonged inundation of fields. This also allows a diverse native aquatic fauna to persist and this forms the basis of an important fishery. This fishery is, however, based on common property; the fish and OAAs. Based on surveys in 2004, farmers who own the land earned about $150/ha on average as a gross income[1] from wet-season rain-fed rice farming (ACI and CamConsult, 2006). The fishery in its current undeveloped state is worth about US$102/ha as a gross value, based on this study. But farmers do not directly benefit from this output from their land so they have no direct incentive to conserve the fishery, and may also be dissuaded from investing in simple measures such as trap ponds that would greatly increase fish production and capture efficiency. Even if ownership of the fishery were to be changed so that farmers owned the wild fish and OAAs on their land, security is a further constraint to better management of the fishery. Farm holdings are generally small - about 1 ha/household on average — and many households own two or more plots (ACI and CamConsult, 2006), which are usually not close to the owners' houses. The lack of security for fishery production (rather than the technical issues commonly considered) could be a very most significant factor constraining fishery conservation and aquaculture development.

Unfortunately, agriculture has been managed as a separate sector to fisheries, so for example, in a major review, ACI and CamConsult (2006) made no reference to the importance of the rice-field fishery or the possibilities it offers for improving livelihoods. Rather, following general practice, to improve farm incomes they recommended an increase in dry-season irrigation to increase rice production, as well as crop diversification. Dry-season irrigation potentially affects fisheries on floodplains (Shankar *et al*., 2004), but may have little or no effect on fishery production in rain-fed habitats (Khoa *et al*., 2005), depending on the actual management practices. However, intensification of rice cultivation typically involves increased use of pesticides, which may reduce the food supply for fish, and may kill fish and amphibians that could be significant agents in controlling the pests of rice. Research on management of insect pests of rice has focused on invertebrates as control agents (as reviewed by Way and Heong, 1994 and Matteson, 2000), but some research using introduced omnivorous fish has confirmed their potential for controlling important pests (Xiao, 1992), as reviewed in Frei and Becker (2005). In one study in the Mekong Delta, fish reduced rice caseworm populations in rice by 93% (Vromant *et al*., 1998). Rural people may also perceive the importance of wild fish in this context. For example, in one study villagers believed that fish controlled harmful insects (Shams *et al*., 2001). Gregory (1997) cautions that some rice pests may be unpalatable to fish and suggests the main benefit of fish is to raise the economic threshold at which farmers must spray; under IPM the yield of fish is posited to compensate for the loss of income from pests. However, the value for pest control of indigenous carnivorous air-breathing black fish

1 Nett of costs but prior to taxes.

and predators such as frogs and toads has never been scientifically evaluated. Unlike the introduced species (common carp, Nile tilapia and silver barb), which are commonly used in rice-fish culture, the native species can all move freely through rice fields as they are essentially amphibious and do not require oxygenated water to survive. These indigenous fish do not require the same level of management as the commonly used introduced fish, which cannot tolerate deoxygenation and usually require that some rice-growing area is sacrificed to make refuges. Food supply may also be limiting; when rice plants are actively growing, shading virtually eliminates other macrophytes and plankton, forcing fish to feed on poor-quality detritus, leading Vromant *et al*. (2004) to conclude that 'from an aquaculture point of view, the rice field is not an ideal place for fish production'. Of course, this conclusion does not apply to the indigenous fish that are abundant in traditionally managed rice fields.

A focus on introducing exotic herbivorous or omnivorous species in 'rice-fish' systems (reviewed in Halwart and Gupta, 2004) stems perhaps from a belief that carnivorous fish should not be aquacultured because of the loss of yield which results from their position higher in the food chain. However, in the rice field environment it may be more relevant to consider that carnivorous fish and amphibians harvest and concentrate a range of other organisms, including insects, crabs and snails which would otherwise be inaccessible for human consumption, and in the process may control many pests of rice. It should also be noted that carnivorous fish are generally better food fish, preferred by villagers, and they fetch a higher price than omnivorous or herbivorous fish. Overall, the comparative economics of using indigenous carnivorous fish in rice-fish systems should be given more consideration, and integrating the rice field fishery with agricultural development should be thoroughly researched and developed as a high priority, as the benefits are now well known (Frei and Becker, 2005).

5. References

ACI and CamConsult (2006) *Cambodia Agriculture Sector Diagnostic Repor*t. A report prepared for AusAID by Agrifood Consulting International and CamConsult. 214 pages + Annexes.

Ali, A.B. (1990) Some ecological aspects of fish production in ricefields. *Hydrobiologia* **190**: 215–222.

Ali, Y. (1997) *Fish, Water and People. Reflections on Inland Openwater Fisheries Resources of Bangladesh.* The University Press Ltd., Dhaka, Bangladesh. 126 pages.

Angporn, P,, Guttman, H., Turongruang, D., Mingkano, P, and H. Demaine (1998) *Survey of Trap Pond Owners in Sisaket and Roi Et Provinces, Thailand.* AIT Aqua Outreach, Working Paper T–6. 45 pages. Asian Institute of Technology, Bangkok, Thailand.

Anonymous (1999) *General Population Census of Cambodia* 1998. Final Census Results. National Institute of Statistics, Ministry of Planning, Phnom Penh, Cambodia. 299 pages.

Balzer, P,, Balzer, T. and S. Pon (2005) Traditional use and availability of aquatic biodiversity in rice-based ecosystems. 1. Kampong Thom Province, Kingdom of Cambodia. pp. 1-16 in: Halwart, M. and Bartley, D. (Eds) Recent Initiatives on the Availability and Use of Aquatic Organisms in Rice-based Farming. CD-ROM, FAO, Rome. ftp://ftp.fao.org/FI/CDrom/AqBiodCD20Jul2005/Start.pdf

Baran, E. and Myschowoda, C. (2008) Have fish catches been declining in the Mekong River Basin? Pages 55-64 in: *Modern Myths of the Mekong* (eds M. Kummu, M. Keskinen and O. Varis) Helsinki University of Technology, Helsinki, Finland. 187 pages.

Baran, E., van Zalinge, N., Ngor, P.B., Baird, I. and D. Coates (2001) *Fish Resources and Hydro-biological Modelling Approaches in the Mekong Basin*. ICLARM, Penang, Malaysia, and the Mekong River Commission, Phnom Penh, Cambodia. 61 pages.

de Graaf, G. J. and N. D. Chinh (2000) *Floodplain Fisheries in the Southern Provinces of Vietnam*. www.nefisco.org. 9 pages.

Deap, L., Degen, P, and N.P. van Zalinge (2003) Fishing gears of the Cambodian Mekong. *Inland Fisheries Research and Development Institute of Cambodia (IFReDI), Technical Paper Series* **4**: 1–269.

Dubeau, P., Ouch, P. and J. G. Sjorslev (2001) Estimating fish and aquatic animal productivity/yield per area in Kampong Tralach: an integrated approach. Cambodia Fisheries Technical Paper Series **3**: 143–164.

Fernando, C.H. (1993) Rice-field ecology and fish culture - an overview. *Hydrobiologia* **259**: 91–113.

Frei, M. and K. Becker (2005) Integrated rice-fish culture: coupled production saves resources. *Natural Resources Forum* **29**: 135–143.

Froese, R. and D. Pauly (2007) (Eds) *FishBase*. World Wide Web Electronic Publication. www.fishbase.org, version (08/2007).

Gregory, R., Guttman, H., and T. Kekputherith, (1996) *Poor in All But Fish. A Study of the Collection of Ricefield Foods from Three Villages in Svay Theap District, Svay Rieng*. Working Paper No. 5. 1–27. AIT Aqua-Outreach Programme, Phnom Penh, Cambodia.

Gregory, R.S. (1997) *Ricefield Fisheries Handbook*. Cambodia-IRRI-Australia Project, Cambodia. 38 pages.

Guttman, H. (1999) *Rice Field Fisheries—A Resource for Cambodia*. AIT Aqua Outreach, Bangkok, Thailand. 4 pages.

Halls, A.S, Hoggarth, D.D, & Debnath, K. (1999) Impacts of hydraulic engineering on the dynamics and production potential of floodplain fish populations in Bangladesh. *Fisheries Management and Ecology* **6**: 261–285.

Halwart, M. and M.V. Gupta (2004) *Culture of fish in rice fields*. FAO and the WorldFish Center, Rome, Italy and Penang, Malaysia. 77 pages.

Halwart, M. (2006) Biodiversity and nutrition in rice-based aquatic ecosystems. *Journal of Food Composition and Analysis* **19**: 747–751.

Hatha, P., Narath, S. and R. Gregory (1995) A study of the roles and responsibilities of Cambodian women and children in small-scale aquaculture. Working Paper C-2 in *Regional Workshop on the Role of Women in Fisheries Development*, 17-21 July 1995, Iloilo City, Philippines. 6 pages.

Hellawell, J.M. (1978) *Biological Surveillance of Rivers*. Water Research Centre. Stevenage, UK. 332 pages.

Heckman,W.C. (1974) The seasonal succession of species in a rice paddy in Vientiane, Laos. *Internationale Revue der Gesamten Hydrobiologie* **59**: 489–507.

Heckman, W. C. (1979) Rice field ecology in Northeastern Thailand. *Monographiae Biologicae* **34**: 1–227.

Hortle, K.G,, Roth, T., Garrison, J. and G. Cans (2005) Harvesting insects—a growing industry in Cambodia. *Catch and Culture* **11**: 9–10.

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. 88 pp.

Hortle, K.G and U. Suntornratana (2008) Fisheries of the lower Songkhram River Basin northeast Thailand: report on a baseline survey. *MRC Technical Paper No. 17*. Mekong River Commission, Vientiane. 85 pp.

IRC (2002) *Twentieth Session of the Commission, 23-26 July Bangkok, Thailand. Major Recommendations*. International Rice Commission website. www.fao.org/ag/agp/agpc/doc/field/commrice/pages/sessions.html#01

Khoa, S.N, Lorenzen, K., Garaway, C., Cahmshing, B., Siebert, D, and M. Randone (2005) Impacts of irrigation in rain-fed rice-farming landscapes. *Journal of Applied Ecology* **42**: 892–900.

Lieng, S. & N.P. van Zalinge (2001) Fish yield estimation by habitat in the floodplains of the Great Lake, Cambodia. *Cambodia Fisheries Technical Paper Series No 3* 18–26.

Lim, P., Villavueva, M.C., Chhouk, B., Chay, K.K., Brun, J.M. and J. Moreau (2005) Fish assessment in the rehabilitated polders of Prey Nup (Cambodia). *Asian Fisheries Science;* **18**; 241–253.

Little, D.C, Surintaraseree, P, and N. Innes-Taylor, (1996) Fish culture in rainfed rice fields of northeast Thailand. *Aquaculture* **140**: 295–321.

Matteson, P.C. (2000) Insect pest management in tropical Asian irrigated rice. *Annual Review of Ecology and Systematics* **45**: 549–574.

Middendorp, H.A.J. (1992) Contribution of stocked and wild fish in ricefields to fish production and farmer nutrition in northeast Thailand. *Asian Fisheries Science* **5**: 145–161.

MRCS (1994) Cambodia: Agricultural Development Options Review. Land Cover Mapping Component (1973/76, 1985/87 and 1992/93). Technical Report Volume 1 and 2. Report to the Food and Agriculture Organisation of the United Nations. 17 page + annexes

Poulsen, A.F., Hortle, K.G, Valbo-Jorgensen, J, and S. Chan (2004) Distribution and ecology of some important riverine fish species of the Mekong River Basin. *MRC Technical Paper 10*: 1–116.

Rainboth, W.J. (1996) *Fishes of the Cambodian Mekong*. FAO, Rome. 265 pages + plates.

Saengrut, T. (1998) *Role of Wild fish in Aquatic Resource Development in the Lower Chi Valley of Thailand*. MSc Thesis. Asian Institute of Technology. Bangkok, Thailand. 100 pages.

Sensereivorth, T., Diep, L, and T. Nao (1999) Freshwater capture fisheries data collection in 1998. pp. 40–53 in van Zalinge, N. P, Nao, T, and Deap, L. (Eds) *Present Status of Cambodia's Freshwater Capture Fisheries and Management Implications*. Department of Fisheries & MRC/Danida Program for Fisheries Management and Development Cooperation, Phnom Penh, Cambodia.

Shams, N., Tuy, S., and D. Gutierrez (2001) *Much More Than Rice: Rice Field Biodiversity and Food Security in Southeastern Cambodia*. Catholic Relief Services (CRS). Phnom Penh, Cambodia. 18 pages.

Shankar, B., Halls, A., and J. Barr (2004) Rice versus fish revisited: on the integrated management of floodplain resources in Bangladesh. *Natural Resources Forum* **28**: 91–101.

So, N., Ouch, V., Hao, V. and M.C. Nandeesha (1998) Women in small-scale aquaculture development in Cambodia. *Aquaculture Asia* **3**: 20–22.

Troeung, R., Aun, S., Lieng, S., Deap, L. and N. van Zalinge (2003) A comparison of fish yields and species composition between one fishing lot in Battambang province and two fishing lots in Prey Veng Province. *MRC Conference Series* 4: 9–16.

van Zalinge, N.P., Nao, T., Touch, S.T. and L. Deap (2000) Where There is Water, There is Fish? Cambodian Fisheries Issues in a Mekong River Basin Perspective. I*CLARM Studies Review* **26**: 37–48.

Vromant, C., Nam, C.Q., Chau, N.T.H., and F. Ollevier (2004) Survival rate and growth performance of *Cyprinus carpio* L. in intensively cultivated rice fields. *Aquaculture Research* **35**: 171–177.

Vromant, N., Rothuis, A.J., Cuc, N.T.T. and F. Ollevier (1998) The effect of fish on the abundance of the rice caseworm *Nymphula depunctalis* (Guenée) (Lepidoptera: Pyralidae) in direct-seeded, concurrent rice-fish yields. *Biocontrol Science and Technology* **8**: 539–546.

Way, M.J. and K.L. Heong (1994) The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice—a review. *Bulletin of Entomological Research* **84**: 567–587.

Welcomme, R.L. (1985) River fisheries. *FAO Fisheries Technical Paper* **262**: 1–330.

Xiao, Q.Y. (1992) Role of fish in pest control in rice farming. *ICLARM Conference Proceedings* **24**: 235–243.

Appendix 1. Effort, total catches and CPUE for all gears and sites combined

Sum of fisher-gear days all sites

Khmer Name	Gear	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Total	Percent
Santuch Bongkai	Single-hook set pole and line	912	904	1466	1025				4307	18.8%
Tru	Horizontal rice field cylinder trap	648	684	785	544	556			3217	14.0%
Lop Phsom Pruol	Horizontal cylinder trap with bamboo fences	48	12	240	884	652	24		1860	8.1%
Lop Nhek Sre	Vertical rice field cylinder trap		452	642	336	168	24		1622	7.1%
Santuch Phlay Muoy	Hand-held single hook and line			947	816	208			1971	8.6%
Mong Reay Sre	Gill net			712	732				1444	6.3%
Samnanh	Cast net			711	1228	80			2019	8.8%
Anchorng	Small-handle seine net			160	144	216	24		544	2.4%
Chongnoum	Bamboo funnel basket trap			152	392				544	2.4%
Tom	Vertical bamboo vase trap			144	80				224	1.0%
Lu Sbai Mong	Fyke net (fine mesh)			50	560				610	2.7%
Anlung Ungkoup	Hole trap				1052	72			1124	4.9%
Lawn Antong	Bamboo tube trap for eels				528	228			756	3.3%
Lop Kongkaep	Horizontal cylinder trap for frogs				132	428	24		584	2.5%
Santuch Bobok Kongkaep	Pole and line for catching frogs				348		80		428	1.9%
Kangva Trey Chhlonh	Eel clamp				48	148	80	80	356	1.6%
Bach Bat Pralay	Capture by hand by pumping out canal					164	152	32	348	1.5%
Kangva Kongkaep	Frog gaff						220	128	348	1.5%
Chheub	Hand-held scissors push net					112	132		244	1.1%
Chamrob	Two-pronged eel fork						96	99	195	0.8%
Chhnieng Chunhchoat	Wedge-shaped scoop basket							80	80	0.3%
Chap Dai	Capture by hand in water						16	48	64	0.3%
Kantrup Kongkaep	Frog trap net			40					40	0.2%
Thnorng Moul	Long-handled circular scoop bag			12					12	0.1%
Lop Rungvel	Big horizontal cylinder trap				16				16	0.1%
Uon Hum	Small hand-dragged seine net						8		8	0.03%
Total		1608	2052	6061	8865	3032	880	467	22965	100.0%

Sum of catches (kg) by gear, all sites

Khmer Name	Gear	Aug 03	Sep 03	Oct 03	Nov 03	Dec 03	Jan 04	Feb 04	Total	Percent
Santuch Bongkai	Single-hook set pole and line	382	791	1402	2103				4678	17.5%
Tru	Horizontal ricefield cylinder trap	1041	465	1126	427	771			3831	14.3%
Lop Phsom Pruol	Horizontal cylinder trap with bamboo fences	29	20	263	1958	993	45		3308	12.4%
Lop Nhek Sre	Vertical ricefield cylinder trap		492	1375	350	244	7		2468	9.2%
Santuch Phlay Muoy	Hand-held single hook and line			351	1015	87			1452	5.4%
Mong Reay Sre	Gill net			808	643				1451	5.4%
Samnanh	Cast net			972	1595	56			2623	9.8%
Anchorng	Small-handle seine net			158	203	150	7		518	1.9%
Chongnoum	Bamboo funnel basket trap			105	404				509	1.9%
Tom	Vertical bamboo vase trap			261	30				291	1.1%
Lu Sbai Mong	Fyke net (fine mesh)			173	847				1020	3.8%
Anlung Ungkoup	Hole trap				482	121			603	2.3%
Lawn Antong	Bamboo tube trap for eels				600	170			770	2.9%
Lop Kongkaep	Horizontal cylinder trap for frogs				292	520	11		823	3.1%
Santuch Bobok Kongkaep	Pole and line for catching frogs				314		93		407	1.5%
Kangva Trey Chhlonh	Eel clamp				6	160	62	72	300	1.1%
Bach Bat Pralay	Capture by hand by pumping out canal					131	89	30	250	0.9%
Kangva Kongkaep	Frog gaff						219	196	415	1.6%
Chheub	Hand-held scissors push net					96	432		529	2.0%
Chamrob	Two-pronged eel fork						34	114	148	0.6%
Chhnieng Chunhchoat	Wedge-shaped scoop basket							178	178	0.7%
Chap Dai	Capture by hand in water						8	27	35	0.1%
Kantrup Kongkaep	Frog trap net			49					49	0.2%
Thnorng Moul	Long-handled circular scoop bag			30					30	0.1%
Lop Rungvel	Big horizontal cylinder trap				38				38	0.1%
Uon Hum	Small hand-dragged seine net						7		7	0.0%
Total		1452	1767	7073	11307	3500	1015	617	26730	100.0%

Appendix 2. Total effort, catch and CUPE for all gear types

Gear	Total fisher-days	Total catch (kg)	CPUE (kg/fisher/day)
Small-handle seine net	544	518	0.95
Hole trap	1124	603	0.54
Capture by hand in dried ditch or canal	348	250	0.72
Two-pronged eel fork	195	148	0.76
Capture by hand in water	64	35	0.54
Hand-held scissors push net	244	529	2.17
Wedge-shaped scoop basket	80	178	2.23
Bamboo funnel basket trap	544	509	0.93
Frog gaff	348	415	1.19
Eel clamp	356	300	0.84
Frog trap net	40	49	1.23
Bamboo tube trap for eel	756	770	1.02
Horizontal cylinder trap for frogs	584	823	1.41
Vertical rice field cylinder trap	1622	2468	1.52
Horizontal cylinder trap with bamboo fences	1860	3308	1.78
Big horizontal cylinder trap	16	38	2.38
Fyke net (fine mesh)	610	1020	1.67
Gillnet	1444	1451	1.00
Cast net	2019	2623	1.30
Pole and line for catching frogs	428	407	0.95
Single-hook set pole and line	4307	4678	1.09
Hand-held single hook and line	1971	1452	0.74
Long-handled circular scoop bag	12	30	2.50
Vertical bamboo vase trap	224	291	1.30
Horizontal rice field cylinder trap	3217	3831	1.19
Small hand-dragged seine net	8	7	0.86
Total	22,965	26,730	1.16

Appendix 3. List of species of fish and taxa of OAAs recorded, with proportions of total weight in catches and standing crop estimation, and categorisation by diet and as black or white/grey fishes

Family	Species	English name	Khmer name	Black or Grey/White	Dietary category	Max total Lth (cm) in literature	% of fish in catches	% of all fish and OAAs in catches	% of fish in standing crop	% of all fish and OAAs in standing crop
Anabantidae	*Anabas testudineus*	Climbing perch	*Kranh srai*	Black	Omnivorous	25	17.71%	13.56%	12.5%	8.7%
Bagridae	*Hemibagrus nemurus*	White-whiskered river catfish	*Chhlang*	Grey/White	Carnivorous	65	0.01%	0.00%		
Bagridae	*Heterobagrus bocourti*	Bocourt's catfish	*Kanchos kdaung*	Grey/White	Carnivorous	24	0.01%	0.01%	0.0%	0.0%
Bagridae	*Mystus atrifasciatus*	Silver mystus catfish	*Kanchos chhnoht*	Grey/White	Omnivorous	15	1.74%	1.33%	0.4%	0.3%
Bagridae	*Mystus singaringan*	Grey mystus catfish	*Kanchos*	Grey/White	Omnivorous	30	0.03%	0.03%		
Bagridae	*Mystus* sp. *cf. wolffi**	Wolff's mystus catfish	*Kanchos*	Grey/White	Carnivorous	20	0.29%	0.22%		
Belonidae	*Xenentodon cancila*	Freshwater garfish	*Phtoung*	Grey/White	Carnivorous	40	0.04%	0.03%		
Belontiidae	*Trichopsis vittata*	Talking gourami	*Kroem kdah*	Black	Carnivorous	7	1.38%	1.06%	0.5%	0.3%
Channidae	*Channa striata*	Chevron snakehead	*Raws*	Black	Carnivorous	100	28.01%	21.45%	52.9%	36.9%
Clariidae	*Clarias batrachus*	Walking catfish	*Andaing roueng*	Black	Omnivorous	47	9.24%	7.08%	8.2%	5.8%
Clariidae	*Clarias macrocephalus*	Broad-headed walking catfish	*Andaing toun*	Black	Carnivorous	120	2.30%	1.77%	0.6%	0.5%
Clariidae	*Clarias meladerma*	Blackskin walking catfish	*Andaing toun*	Black	Carnivorous	35	1.86%	1.42%	6.9%	4.9%
Clupeidae	*Clupeoides borneensis*	River sprat	*Bawndol ampou kontoi khmao*	Grey/White	Carnivorous	8	0.40%	0.31%		
Cyprinidae	*Crossocheilus* sp.		*Changwa*	Grey/White	Omnivorous		0.14%	0.11%		
Cyprinidae	*Cyclocheilichthys apogon*	Beardless barb	*Srawka kdam och*	Grey/White	Omnivorous	25	0.10%	0.08%		
Cyprinidae	*Cyclocheilichthys lagleri*	Lagler's silver barb	*Srawka kdam*	Grey/White	Carnivorous	15	0.11%	0.09%	0.6%	0.4%
Cyprinidae	*Cyclocheilichthys repasson*	River barb	*Srawka kdam khmao*	Grey/White	Omnivorous	28	0.01%	0.00%		
Cyprinidae	*Dangila* sp. *cf. cuvieri**	Cuvier's barb	*Khnawng veng*	Grey/White	Omnivorous		0.01%	0.01%	0.1%	0.0%
Cyprinidae	*Esomus longimanus*	Mekong flying barb	*Changwa phlieng*	Grey/White	Carnivorous	8	0.97%	0.74%	1.4%	1.0%
Cyprinidae	*Hypsibarbus lagleri*	Lagler's barb	*Chhpin kbal touch*	Grey/White	Omnivorous	40	0.26%	0.20%		
Cyprinidae	*Labiobarbus siamensis*	Black spot barb	*Ach kok*	Grey/White	Omnivorous	22	0.00%	0.00%		
Cyprinidae	*Puntioplites falcifer*		*Chrakaing kontoi veng*	Grey/White	Omnivorous	40?	0.00%	0.00%		
Cyprinidae	*Puntius brevis*		*Angkat prak*	Grey/White	Omnivorous	12	0.19%	0.14%	0.6%	0.4%
Cyprinidae	*Rasbora daniconius*	Slender rasbora	*Changwa chhnot*	Grey/White	Carnivorous	15	0.03%	0.02%		
Cyprinidae	*Rasbora myersi*	Myer's rasbora	*Changwa*	Grey/White	Omnivorous	10	0.62%	0.48%		

Family	Species	English name	Khmer name	Black or Grey/White	Dietary category	Max total Lth (cm) in literature	% of fish in catches	% of all fish and OAAs in catches	% of fish in standing crop	% of all fish and OAAs in standing crop
Cyprinidae	*Rasbora pauciperforata*	Redstripe rasbora	*Changwa*	Grey/White	Carnivorous	7	0.13%	0.10%	0.2%	0.1%
Cyprinidae	*Rasbora tornieri*	Yellowtail rasbora	*Changwa mool*	Grey/White	Carnivorous	17	2.12%	1.62%	0.0%	0.0%
Mastacembelidae	*Macrognathus siamensis*	Peacock eel	*Chhlonh chhnoht*	Black	Carnivorous	30	17.95%	13.75%	6.1%	4.2%
Nandidae	*Pristolepis fasciata*	Malayan leaf fish	*Kantrawb*	Black	Omnivorous	20	0.39%	0.30%		
Osphronemidae	*Trichogaster microlepis*	Moonlight gourami	*Kawmphleanh phluk*	Black	Carnivorous	13	0.79%	0.60%	0.3%	0.2%
Osphronemidae	*Trichogaster trichopterus*	Three spot gourami	*Kawmphleanh sor*	Black	Carnivorous	15	6.32%	4.84%	4.6%	3.2%
Siluridae	*Kryptopterus hexapterus*	White sheatfish	*Kamplieu*	Grey/White	Carnivorous	24	0.10%	0.08%		
Siluridae	*Ompok bimaculatus*	Butter catfish	*Ta aun*	Grey/White	Carnivorous	45	0.01%	0.01%		
Synbranchidae	*Monopterus albus*	Swamp eel	*Antung*	Black	Omnivorous	100	6.17%	4.72%	3.5%	2.5%
Synbranchidae	*Ophisternon bengalense*	Onegilled eel	*Antung*	Black	Carnivorous	100	0.54%	0.41%	0.6%	0.4%
TOTAL FISH							100.00%	76.58%	100.0%	69.8%

Notes: Fish names and most details follow Froese and Pauly (2007), except * after Rainboth (1996). Maximum recorded lengths in literature include some standard lengths that were converted to total lengths by multiplying by 1.15. MRC (2003) and other sources also used for classification as black or grey/white and for dietary category.

Family	Species	English name	Khmer name		Dietary category		% of OAAs in catches	% of all fish and OAAs in catches	% of OAAs in standing crop	% of all fish and OAAs in standing crop
Parathelphusidae	*Sommaniathelphusa* spp.	Crabs			Omnivorous		35.49%	8.31%	22.2%	15.5%
Palaeomonidae	*Macrobrachium* spp.	Shrimps			Omnivorous		29.58%	6.93%	1.2%	0.8%
		Frogs			Carnivorous		22.49%	5.27%	3.4%	2.3%
		Big water snails			Herbivorous		7.15%	1.67%	10.4%	7.2%
		Small water snails			Herbivorous		2.91%	0.68%	5.1%	3.6%
		Snakes			Carnivorous		2.39%	0.56%	1.0%	0.7%
TOTAL OAAs							100.00%	23.42%	43.3%	30.2%
TOTAL FISH and OAAs							100.00%	100.00%	143.3%	100.0%

Appendix 4. Total catch of each species by each type of gear

Cat No.	1	1	2	2	3	3	3
Category	Capture by hand		Scoop nets		Wounding gear		
Gear	Capture by hand	Capture by hand by pumping out canal	Long-handled circular scoop bag	Wedge-shaped scoop basket	Eel clamp	Frog gaff	Two-pronged eel fork
Channa striata	9.0	98.5	2.0				
Macrognathus siamensis	1.0	13.6			300.3		
Anabas testudineus	20.8	40.1	3.0	49.0			
Clarias batrachus		22.3					
Trichogaster trichopterus		3.6	3.0	50.2			
Monopterus albus							148.3
Clarias macrocephalus							
Rasbora tornieri	1.0	5.2		4.9			
Clarias meladerma							
Mystus atrifasciatus		2.5					
Trichopsis vittata			22.0	8.1			
Esomus longimanus							
Trichogaster microlepis	0.3						
Rasbora myersi	0.5	4.0					
Ophisternon bengalense							
Clupeoides borneensis							
Pristolepis fasciata		0.6					
Mystus sp. cf. *wolffi*		0.7					
Hypsibarbus lagleri		0.4					
Puntius brevis		1.6		0.2			
Crossocheilus sp.							
Rasbora pauciperforata							
Cyclocheilichthys lagleri	0.2	2.4		16.1			
Cyclocheilichthys apogon							
Kryptopterus hexapterus		2.0					
Xenentodon cancila		1.0					
Mystus singaringan							
Rasbora daniconius							
Dangila sp. cf. *cuvieri*		0.0					
Heterobagrus bocourti							
Ompok bimaculatus							
Cyclocheilichthys repasson							
Mystus nemurus							
Dangila spilopleura							
Puntioplites falcifer							
Fish Total	32.6	198.6	30.0	128.5	300.3		148.3
Crab	1.0	26.6		42.6		28.8	
Shrimp		3.0		1.7			
Frog	1.0	2.0				385.8	
Big water snail		14.2		3.1			
Small water snail		1.6		2.3			
Snake		4.3					
OAA Total	2.0	51.6		49.8		414.6	
TOTAL	34.6	250.3	30.0	178.2	300.3	414.6	148.3

Cat No.	4	4	4	5	5	5	5
Category	Hook & line			Traps			
Gear	Hand-held hook and line	Pole and line for catching frogs	Single-hook set pole and line	Bamboo funnel basket trap	Bamboo tube trap for eel	Big horizontal cylinder trap	Hole trap
Channa striata	85.0		2781.7			12.0	258.0
Macrognathus siamensis	425.4						
Anabas testudineus	860.3		594.1	60.0		4.0	105.4
Clarias batrachus			676.9			4.0	139.0
Trichogaster trichopterus				60.0			
Monopterus albus			14.1		741.2		
Clarias macrocephalus			311.2	43.0			38.0
Rasbora tornieri				128.4			
Clarias meladerma	7.0		231.9			3.0	27.0
Mystus atrifasciatus	45.1		19.3				
Trichopsis vittata				76.2			
Esomus longimanus							
Trichogaster microlepis							
Rasbora myersi							31.0
Ophisternon bengalense			46.8		29.1		
Clupeoides borneensis							
Pristolepis fasciata							
Mystus sp. cf. *wolffi*	22.0		0.5				
Hypsibarbus lagleri							
Puntius brevis							
Crossocheilus sp.							
Rasbora pauciperforata							
Cyclocheilichthys lagleri							
Cyclocheilichthys apogon							
Kryptopterus hexapterus							
Xenentodon cancila	7.0						
Mystus singaringan							
Rasbora daniconius							
Dangila sp. cf. *cuvieri*							
Heterobagrus bocourti							
Ompok bimaculatus			1.3				
Cyclocheilichthys repasson							
Mystus nemurus							
Dangila spilopleura							
Puntioplites falcifer							
Fish Total	1451.8		4677.8	367.6	770.3	23.0	598.4
Crab						11.0	5.0
Shrimp				140.9			
Frog		407.0					
Big water snail						4.0	
Small water snail							
Snake							
OAA Total		407.0		140.9		15.0	5.0
TOTAL	1451.8	407.0	4677.8	508.6	770.3	38.0	603.4

Cat No.	5	5	5	5	5	6
Category	Traps					Gill nets
Gear	Horizontal cylinder for frogs	Horizontal rice field cylinder trap	Horizontal cylinder trap with bamboo fences	Vertical bamboo vase trap	Vertical rice field cylinder trap	Gill net
Channa striata		666.1	823.5	47.0	320.4	310.4
Macrognathus siamensis		231.5	701.1	36.0	214.8	147.6
Anabas testudineus		348.8	334.3	97.0	344.5	354.5
Clarias batrachus		282.0	193.0		254.2	258.6
Trichogaster trichopterus		219.1	75.9	72.0	171.4	133.9
Monopterus albus		199.8	141.5		4.4	
Clarias macrocephalus		9.6	42.0			28.0
Rasbora tornieri		8.5	11.9			
Clarias meladerma		10.6	51.0		12.0	11.0
Mystus atrifasciatus		100.8	54.0			7.8
Trichopsis vittata		20.1	2.2		9.8	
Esomus longimanus		128.9	11.3		22.7	
Trichogaster microlepis		39.2	7.2		28.4	70.0
Rasbora myersi			63.0		26.0	
Ophisternon bengalense		33.7	0.7			
Clupeoides borneensis						
Pristolepis fasciata		6.8	57.0			
Mystus sp. cf. *wolffi*			0.4			
Hypsibarbus lagleri		1.0	11.3		26.3	
Puntius brevis		35.1	1.1			
Crossocheilus sp.		29.4				
Rasbora pauciperforata		4.4			22.7	
Cyclocheilichthys lagleri		1.9	1.3			
Cyclocheilichthys apogon		18.1	2.0			
Kryptopterus hexapterus		1.0	6.1		5.9	2.0
Xenentodon cancila						
Mystus singaringan		1.2			5.5	
Rasbora daniconius		3.6				
Dangila sp. cf. *cuvieri*		0.5	0.6			
Heterobagrus bocourti						
Ompok bimaculatus						
Cyclocheilichthys repasson		1.3				
Mystus nemurus						
Dangila spilopleura						
Puntioplites falcifer						
Fish Total		2403.0	2592.5	252.0	1468.8	1323.7
Crab		887.2	453.8	4.0	613.2	103.0
Shrimp		207.1	20.0	22.0	134.7	
Frog	823.0	84.3	6.0	12.0	80.6	
Big water snail		183.1	139.0	1.0	67.2	
Small water snail		61.8	59.3		24.0	
Snake		4.0	37.1		80.0	24.0
OAA Total	823.0	1427.6	715.2	39.0	999.6	127.0
TOTAL	823.0	3830.5	3307.7	291.0	2468.4	1450.7

Cat No.	7	7	9	11	11	12	Total
Category		Seine nets		Covering nets		Bagnets	
Gear	Gill net	Small hand-dragged seine net	Small-handle seine net	Hand-held scissors push net	Cast net	Frog trap net	
Channa striata	310.4	4.0	5.0	1.0	287.5	23.0	5734.0
Macrognathus siamensis	147.6	1.0		1.0	1598.7	2.0	3674.1
Anabas testudineus	354.5	0.3	2.9	6.0	281.5	119.0	3625.3
Clarias batrachus	258.6				61.9		1891.8
Trichogaster trichopterus	133.9	0.3	80.9	132.0	196.4	94.0	1292.6
Monopterus albus				13.6			1262.8
Clarias macrocephalus	28.0						471.8
Rasbora tornieri			29.0	136.4		108.0	433.4
Clarias meladerma	11.0				1.7	25.0	380.1
Mystus atrifasciatus	7.8			5.3	121.9		356.8
Trichopsis vittata			76.7			67.5	282.6
Esomus longimanus				1.2		34.2	198.4
Trichogaster microlepis	70.0			1.2	2.9	11.6	160.8
Rasbora myersi					3.4		127.9
Ophisternon bengalense							110.3
Clupeoides borneensis						82.8	82.8
Pristolepis fasciata		0.3	0.1		16.0		80.8
Mystus sp. cf. *wolffi*			22.0	0.4	13.1		59.1
Hypsibarbus lagleri			0.3		13.9		53.2
Puntius brevis							37.9
Crossocheilus sp.							29.4
Rasbora pauciperforata							27.1
Cyclocheilichthys lagleri					1.3		23.2
Cyclocheilichthys apogon				0.8	0.5		21.4
Kryptopterus hexapterus	2.0				4.0		21.0
Xenentodon cancila		1.0					9.0
Mystus singaringan			0.1				6.7
Rasbora daniconius					1.8		5.4
Dangila sp. cf. *cuvieri*					1.4		2.5
Heterobagrus bocourti					1.3		1.3
Ompok bimaculatus							1.3
Cyclocheilichthys repasson							1.3
Mystus nemurus					1.3		1.3
Dangila spilopleura					0.8		0.8
Puntioplites falcifer					0.6		0.6
Fish Total	1323.7	6.9	216.8	299.0	2611.9	567.1	20468.9
Crab	103.0		14.0		2.0	30.0	2222.1
Shrimp			286.0	229.6		363.0	1408.1
Frog			1.2				1851.8
Big water snail					3.0	33.0	447.6
Small water snail					6.0	27.0	182.0
Snake	24.0						149.4
OAA Total	127.0		301.2	229.6	11.0	453.0	6261.1
TOTAL	1450.7	6.9	518.0	528.6	2622.9	1020.1	26730.0

Appendix 5. Taxa recorded in this study with total catch quantities and value

Black or Grey/White	Dietary category	Taxon	Total Weight (kg)	Total Value		Price (US$/kg)			No. of site-month values
				Riel	US$	Min.	Weighted Mean	Max.	
	Herbivorous	Small water snail	182	38017	$9.50	$0.03	$0.05	$0.11	32
	Herbivorous	Big water snail	448	111,113	$27.78	$0.04	$0.06	$0.07	36
	Omnivorous	Crab	2222	617,873	$154.47	$0.05	$0.07	$0.08	48
	Carnivorous	Snake	149	255,276	$63.82	$0.27	$0.43	$0.49	8
	Omnivorous	Shrimp	1408	2,702,968	$675.74	$0.24	$0.48	$0.80	43
	Carnivorous	Frog	1852	6,469,512	$1617.38	$0.55	$0.87	$1.17	36
Black	Omnivorous	*Anabas testudineus*	3625	8,825,956	$2206.49	$0.37	$0.61	$0.89	48
Black	Carnivorous	*Channa striata*	5734	28,127,666	$7031.92	$0.84	$1.23	$1.37	46
Black	Omnivorous	*Clarias batrachus*	1892	10,056,433	$2514.11	$1.15	$1.33	$1.58	36
Black	Carnivorous	*Clarias macrocephalus*	472	2,343,495	$585.87	$1.05	$1.24	$1.29	6
Black	Carnivorous	*Clarias meladerma*	380	1,329,871	$332.47	$0.78	$0.87	$1.41	16
Grey/White	Carnivorous	*Clupeoides borneensis*	83	115,573	$28.89	$0.35	$0.35	$0.35	3
Grey/White	Omnivorous	*Crossocheilus* sp.	29	13,880	$3.47	$0.12	$0.12	$0.12	1
Grey/White	Omnivorous	*Cyclocheilichthys apogon*	21	22,305	$5.58	$0.06	$0.26	$0.39	4
Grey/White	Carnivorous	*Cyclocheilichthys lagleri*	23	21,321	$5.33	$0.08	$0.23	$0.48	7
Grey/White	Omnivorous	*Cyclocheilichthys repasson*	1	433	$0.11	$0.08	$0.08	$0.08	1
Grey/White	Omnivorous	*Dangila* sp.cf.*cuvieri*	3	2996	$0.75	$0.07	$0.29	$0.49	5
Grey/White	Carnivorous	*Esomus longimanus*	198	285,037	$71.26	$0.26	$0.36	$0.42	24
Grey/White	Carnivorous	*Hemibagrus nemurus*	1	1028	$0.26	$0.19	$0.19	$0.19	1
Grey/White	Carnivorous	*Heterobagrus bocourti*	1	2021	$0.51	$0.38	$0.38	$0.38	1
Grey/White	Omnivorous	*Hypsibarbus lagleri*	53	125,728	$31.43	$0.37	$0.59	$0.63	9
Grey/White	Carnivorous	*Kryptopterus hexapterus*	21	37,545	$9.39	$0.39	$0.45	$0.46	4
Grey/White	Omnivorous	*Labiobarbus siamensis*	1	1026	$0.26	$0.31	$0.31	$0.31	1
Black	Carnivorous	*Macrognathus siamensis*	3674	18,064,194	$4516.05	$0.96	$1.23	$1.41	40
Black	Omnivorous	*Monopterus albus*	1263	6,203,947	$1550.99	$0.58	$1.23	$1.50	25
Grey/White	Omnivorous	*Mystus atrifasciatus*	357	579,675	$144.92	$0.36	$0.41	$0.48	22
Grey/White	Omnivorous	*Mystus singaringan*	7	19,844	$4.96	$0.65	$0.74	$0.76	5
Grey/White	Carnivorous	*Mystus* sp. cf. *wolffi*	59	80,744	$20.19	$0.09	$0.34	$0.97	7
Grey/White	Carnivorous	*Ompok bimaculatus*	1	3032	$0.76	$0.57	$0.57	$0.57	1
Black	Carnivorous	*Ophisternon bengalense*	110	601,705	$150.43	$1.25	$1.36	$1.50	7
Black	Omnivorous	*Pristolepis fasciata*	81	83,793	$20.95	$0.25	$0.26	$1.21	10

Black or Grey/White	Dietary category	Taxon	Total Weight (kg)	Total Value		Price (US$/kg)			No. of site-month values
				Riel	US$	Min.	Weighted Mean	Max.	
Grey/White	Omnivorous	*Puntioplites falcifer*	1	1026	$0.26	$0.42	$0.42	$0.42	1
Grey/White	Omnivorous	*Puntius brevis*	38	37,699	$9.42	$0.08	$0.25	$0.35	5
Grey/White	Carnivorous	*Rasbora daniconius*	5	6,082.39	$1.52	$0.28	$0.28	$0.29	1
Grey/White	Omnivorous	*Rasbora myersi*	128	369,403	$92.35	$0.06	$0.72	$0.74	6
Grey/White	Carnivorous	*Rasbora pauciperforata*	27	41,644	$10.41	$0.08	$0.38	$0.40	6
Grey/White	Carnivorous	*Rasbora tornieri*	433	598,110	$149.53	$0.28	$0.35	$0.40	18
Black	Carnivorous	*Trichogaster microlepis*	161	206,053	$51.51	$0.11	$0.32	$0.62	13
Black	Carnivorous	*Trichogaster trichopterus*	1293	2,865,914	$716.48	$0.35	$0.55	$0.70	40
Black	Carnivorous	*Trichopsis vittata*	283	357,423	$89.36	$0.16	$0.32	$0.42	22
Grey/White	Carnivorous	*Xenentodon cancila*	9	23492	$5.87	$0.16	$0.65	$0.79	2
		TOTAL	26,730	91,650,857	$22,912.71	$0.03	$0.86	$1.58	647

Appendix 6. Length frequency distributions for the five most abundant species of fishes

Data includes the catches at those sites at which the most measurements were made for each of the species.

Channa striata
Site 1

Week	Total Length (cm)														Total
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
42		4	7	16	5	1	1					1		2	37
46		1	12	21	32	2	5	6	2	1		1		1	84
50			2	6	21	16	18	17	12	14	9	7	6		128
51	3	11	17	11	17	23	10	8	17	18	5	4	6	1	151
53		6	9	16	9	7	3								50
Total	3	22	47	70	84	49	37	31	31	33	14	13	12	4	450

Clarias batrachus
Site 7

Week	Total Length (cm)												Total
	10	12	13	14	15	16	17	18	19	20	21	23	
36			1	1			2	1			1	1	7
41					1	6	1	5	3	4			20
42					1	5	9	16	4				35
44				2		3	7	11	9	7			39
45	1	2			11	7	5	8	4	1			39
47				5	5	6	2	1	2	1			22
48				1	2	2				1			6
49				5	10	2	3	1					21
51				1	3	1	1	1					7
52						3	7	1					11
53				1	3	1							5
54				2	3	2							7
Total	1	2	1	18	39	38	37	45	22	14	1	1	219

Macrognathus siamensis
Site 8

Week	Total Length (cm)										Total
	12	13	14	15	16	17	18	19	20	21	
39		2	2	1							5
41			1	2	3						6
43				2	2	1	2	3	2	1	13
45		4	22	27	33	35	13	5	2	4	145
47	9	28		52							89
52		24	32								56
55	3	4	21	2							30
56		4	3								7
58		6	11	6	2	3	1				29
Total	12	72	92	92	40	39	16	8	4	5	380

Trichogaster trichopterus
Site 5

Week	Total Length (cm)						Total
	6	7	8	9	10	11	
39	25	31	43	35			134
41	10	80	111	85	18	6	310
42	31	37	26				94
45	11	35	19	10			75
47		4	6	2	1		13
48		7	12	2			21
51	2	3	1				6
53	2	6	3				11
55		3	2				5
Total	81	206	223	134	19	6	669

Anabas testudineus
Site 7

Week	Total Length (cm)										Total
	5	6	7	8	9	10	11	12	13	14	
36				5	9	2	10	11	5		42
41		4	22	21	15	11				1	74
42		42	47	36	24	16	6				171
44		7	16	16	13	12	4	3		1	72
45	6		6	42	31	22	8				115
47			22	26	11	1					60
48				2	4	2	1				9
49		4	11	10	3						28
51			5	7	2						14
52			4	6							10
53		3	9	6	7	4					29
54			9	5							14
55			2	3							5
57			2	5	3						10
Total	6	60	155	190	122	70	29	14	5	2	653

Other papers in the MRC Technical Paper series:

MRC Technical Paper No.1 Status of the Mekong Pangasianodon hypophthalmus resources with special reference to the stock shared between Cambodia and Viet Nam.

MRC Technical Paper No.2 Status of Pangasiid aquaculture in Viet Nam.

MRC Technical Paper No. 3 Mekong giant fish species: on their biology and management.

MRC Technical Paper No. 4 Deep pools as dry season fish habitats in the Mekong Basin.

MRC Technical Paper No. 5 Financial analysis and risk assessment of selected aquaculture and fishery activities in the Mekong Basin.

MRC Technical Paper No. 6 Fisheries in the Lower Mekong Basin: status and perspectives.

MRC Technical Paper No. 7 Freshwater aquaculture in the Lower Mekong Basin.

MRC Technical Paper No. 8 Fish migrations of the Lower Mekong Basin: implications for development, planning and environmental management.

MRC Technical Paper No. 9 The impacts of introductions and stocking of exotic species in the Mekong Basin and polices for their control.

MRC Technical Paper No. 10 Distribution and ecology of some important riverine fish species of the Mekong River Basin.

MRC Technical Paper No. 11 Hydro-acoustic survey of deep pools in the Mekong River of southern Lao PDR and northern Cambodia.

MRC Technical Paper No. 12 Tagging Fish - a case study from the Tonle Sap, Cambodia.

MRC Technical Paper No. 13 Biomonitoring of the lower Mekong River and selected tributaries.

MRC Technical Paper No. 14 Fish Migration Triggers in the Mekong River and other freshwater tropical systems.

MRC Technical Paper No. 15 Diagnostic study of water quality in the Lower Mekong Basin.

MRC Technical Paper No. 16 Fish Consumption and the Yield of Fish and Other Aquatic Animals from the Lower Mekong River Basin.

MRC Technical Paper No. 17 Socio-economics of the fisheries of the lower Songkhram River Baisn, northeast Thailand.

Mekong River Commission
P.O.Box 6101,Vientiane 01000,
Lao PDR.Telephone: (856) 21 263 263 Facsimile: (856) 21 263 264
E-mail: mrcs@mrcmekong.org
Website: www.mrcmekong.org