ISSN: 1680-4023

An Introduction to Cambodia's Inland Fisheries

Mekong Development Series No. 4
November 2004

Mekong River Commission

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Published in Phnom Penh in November 2004 by the Mekong River Commission.

This document should be cited as: Hortle, K.G., S. Lieng and J. Valbo-Jorgensen. 2004. An introduction to Cambodia's inland fisheries. Mekong Development Series No. 4. Mekong River Commission, Phnom Penh, Cambodia. 41 pages. ISSN 1680-4023

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Acknowledgements

This report was prepared with financial assistance from the Government of Denmark (through Danida) by staff and counterparts of the Assessment of Mekong Capture Fisheries Component (AMCF) of the Mekong River Fisheries Programme, and other sources as acknowledged.

We are grateful to Chris Barlow, Nao Thouk, Sam Nuov, Srun Limsong, Touch Seang Tana, Pierre Dubeau and Joseph G. Garrison for reviewing drafts of the paper. Ouk Vibol supplied aquaculture figures, and the Aranya Prathet import figures were kindly supplied by Ubolratana Suntornratana of the Thai Dept of Fisheries.

Foreword

Cambodia's inland fisheries are among the world's largest and most diverse, and have long played a key role in Cambodian life and culture. While the country relies heavily on its natural resources and agricultural land to provide food and livelihoods for its 13.4 million people, the inland fisheries sector is perhaps the most vibrant and valuable, accounting for a large proportion of the fish and other aquatic animals produced from the Lower Mekong Basin. The fisheries sector officially accounts for about 12% of GDP, and provides most Cambodians with their key source of animal protein, calcium and vitamin A.

Cambodian fisheries products are also exported to many other countries, providing much-needed revenue. Migration of river fish across national boundaries in the Lower Mekong Basin increases the international importance of the fisheries.

In common with many developing countries that have rapidly growing populations, Cambodia is facing the challenge of balancing economic needs with environmental safeguards. The country needs to develop its water resources in order to increase the delivery of goods and services to its people. In this regard, the task of the Mekong River Commission is to determine and then promote development alternatives that maximise beneficial outcomes for the people of the region.

This report synthesises much of the relevant research on Cambodia's inland fisheries and aims to provide an introduction and overview which is accessible to general audiences. By publishing Development Series reports such as this, the fourth in the series, the MRC intends to summarise and disseminate key findings on the state of the Mekong Basin as widely as possible, particularly for consideration by those involved in working toward our mutual goal of sustainable development and economic harmony.

Dr Olivier Cogels
Chief Executive Officer
Mekong River Commission Secretariat

Fish and fisheries were central to life in the ancient Khmer Empire.

The walls of many temples are decorated with scores of bas-reliefs showing fish and other aquatic animals and fisheries-related activities. Shown here are some scenes from the Bayon Temple.

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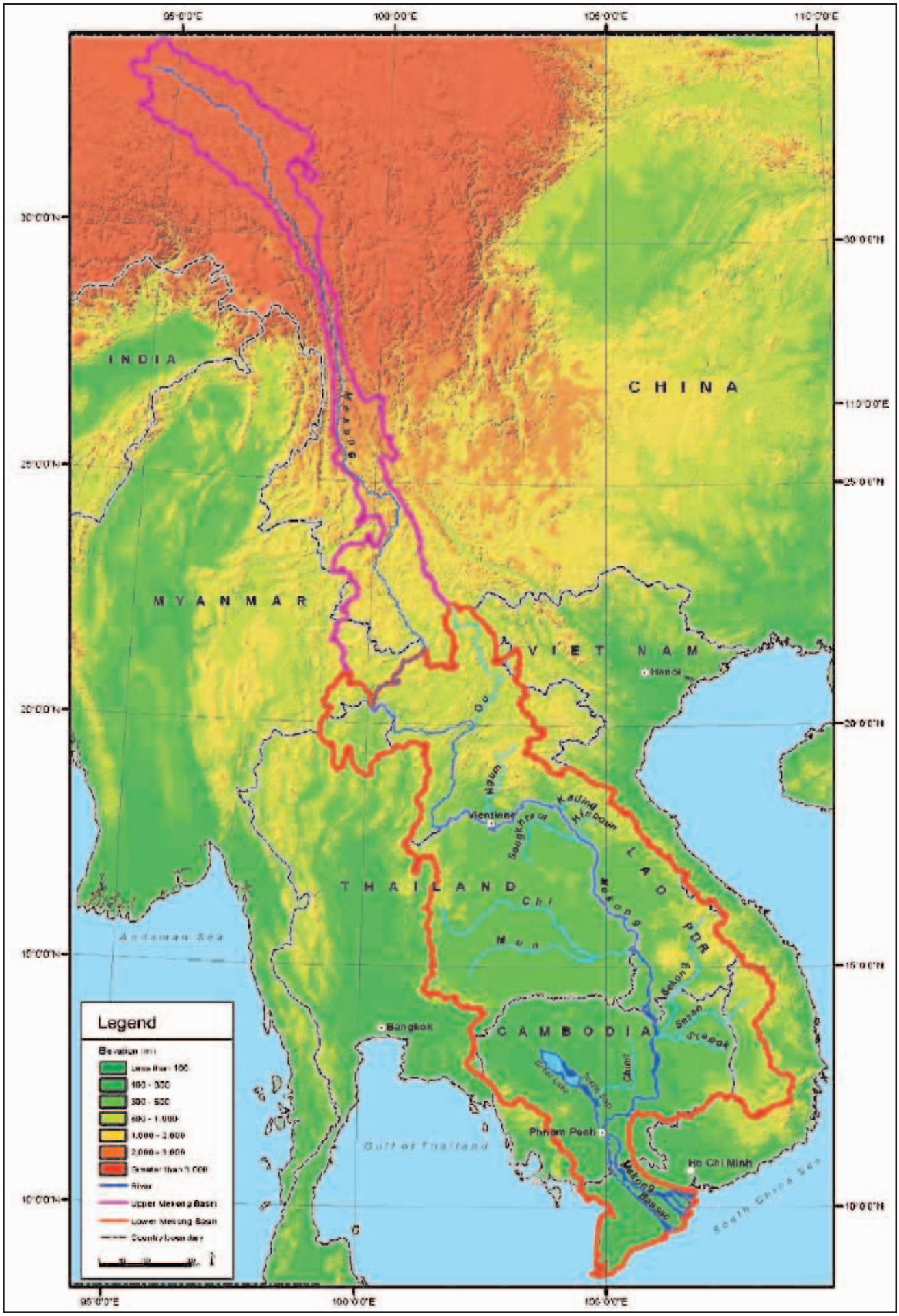
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MYANMAR
VIET NAM
Hanoi
THAILAND
Bangkok
LAO PDR
Vientiane
CAMBODIA
Phnom Penh
Ho Chi Minh
Andaman Sea
Gulf of Thailand
South China Sea
Mekong
Salween
Legend
Elevation (m)
Less than 100
100 - 300
300 - 500
500 - 1,000
1,000 - 2,000
2,000 - 3,000
Greater than 3,000
River
Upper Mekong Basin
Lower Mekong Basin
Country boundary

Summary

Fish and fishing have been central to Cambodian culture since ancient times. Cambodia's inland fisheries are among the largest and most significant in the world, based on hundreds of species which are caught using at least 150 kinds of gear. The fish catch is conservatively estimated at over 400,000 tonnes per year, worth some US$300 million, and the catch of other aquatic animals (OAAs) such as shrimps, crabs, snails, frogs, insects, snakes and turtles is at least 60,000 tonnes per year. Millions of people work full- or part-time in fisheries-related activities, and fish and rice remain the nation's staple foods. Fish and OAAs are crucial for nutrition and food security because they provide Cambodian people with 80% of their animal protein and much of their essential vitamins and minerals, particularly calcium and vitamin A, as well as fish oils.

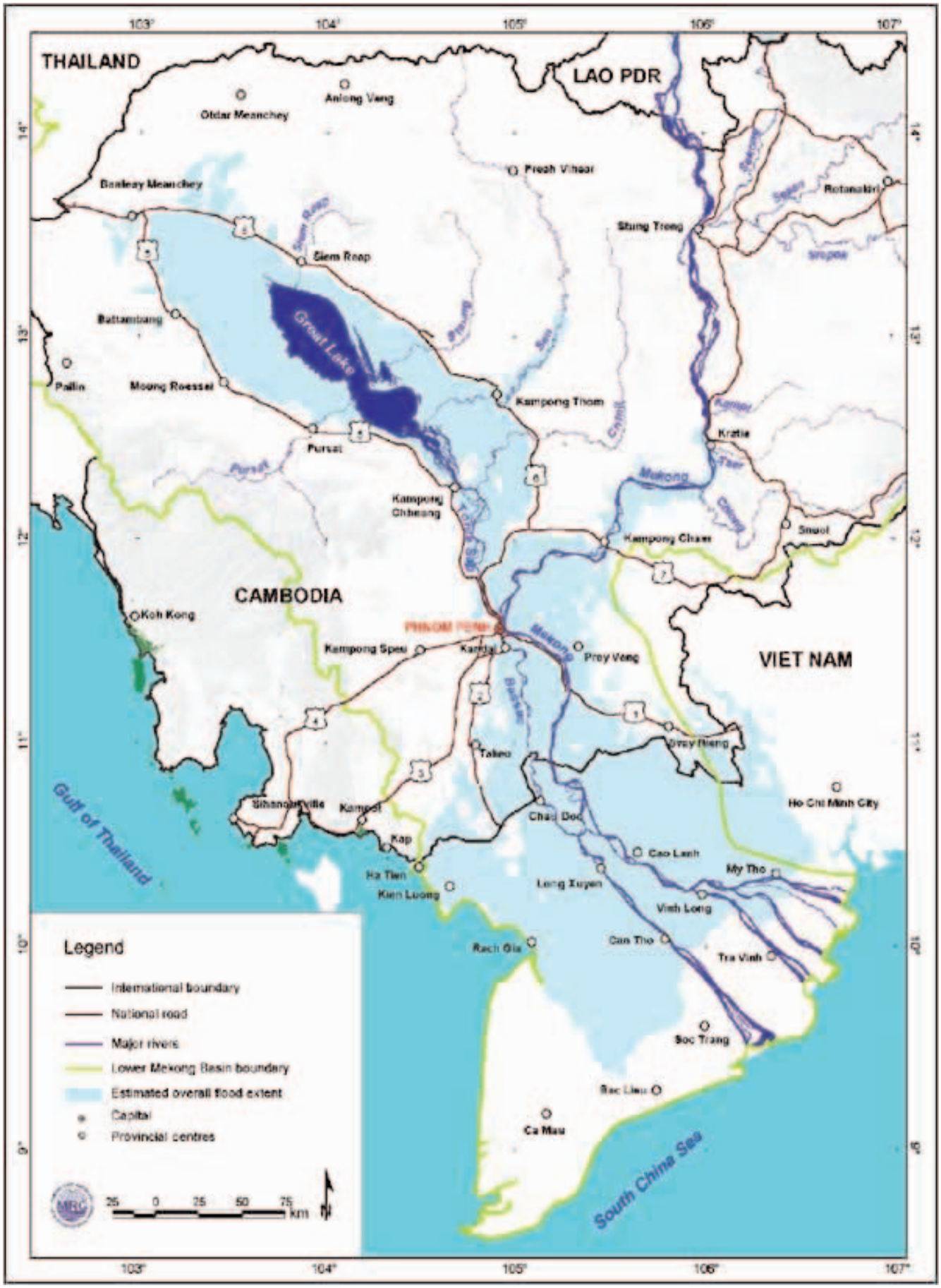
Fisheries production depends primarily upon annual flooding of the plains and wetlands around the Tonle Sap and Great Lake system and along the lower Mekong. Dry-season refuges for fish are also important, the most notable being the deep pools of the Mekong and its tributaries upstream of Kratie. Many fish found in Cambodia's inland waters cross international borders during their massive seasonal migrations, so some fish which originate in Cambodia are caught in the Lao PDR, Thailand or Viet Nam, the other countries of the Lower Mekong Basin (LMB). Conversely some of the fish caught by Cambodians originate in these other countries, so Cambodia's fisheries are of international significance. Moreover, Cambodia exports considerable quantities of inland fish to the other lower LMB countries and elsewhere.

Catches of larger species have declined and, as more people fish each year with increasingly efficient gear, there are signs of overfishing of even the smaller fast-growing fishes. Fisheries management aims to ensure that sufficient stocks of fish and OAAs survive, reproduce and grow each year, and that the benefits are distributed efficiently and equitably. Conserving and managing Cambodia's fisheries will benefit all countries of the lower Mekong Basin and will help to maintain livelihoods and food security for millions of rural people. Fisheries management is the responsibility of the Cambodian Department of Fisheries, working with fishers and local communities. Successful management of such large and diverse fisheries requires improved governance and concerted, ongoing support from donors as well as the fishing industry.

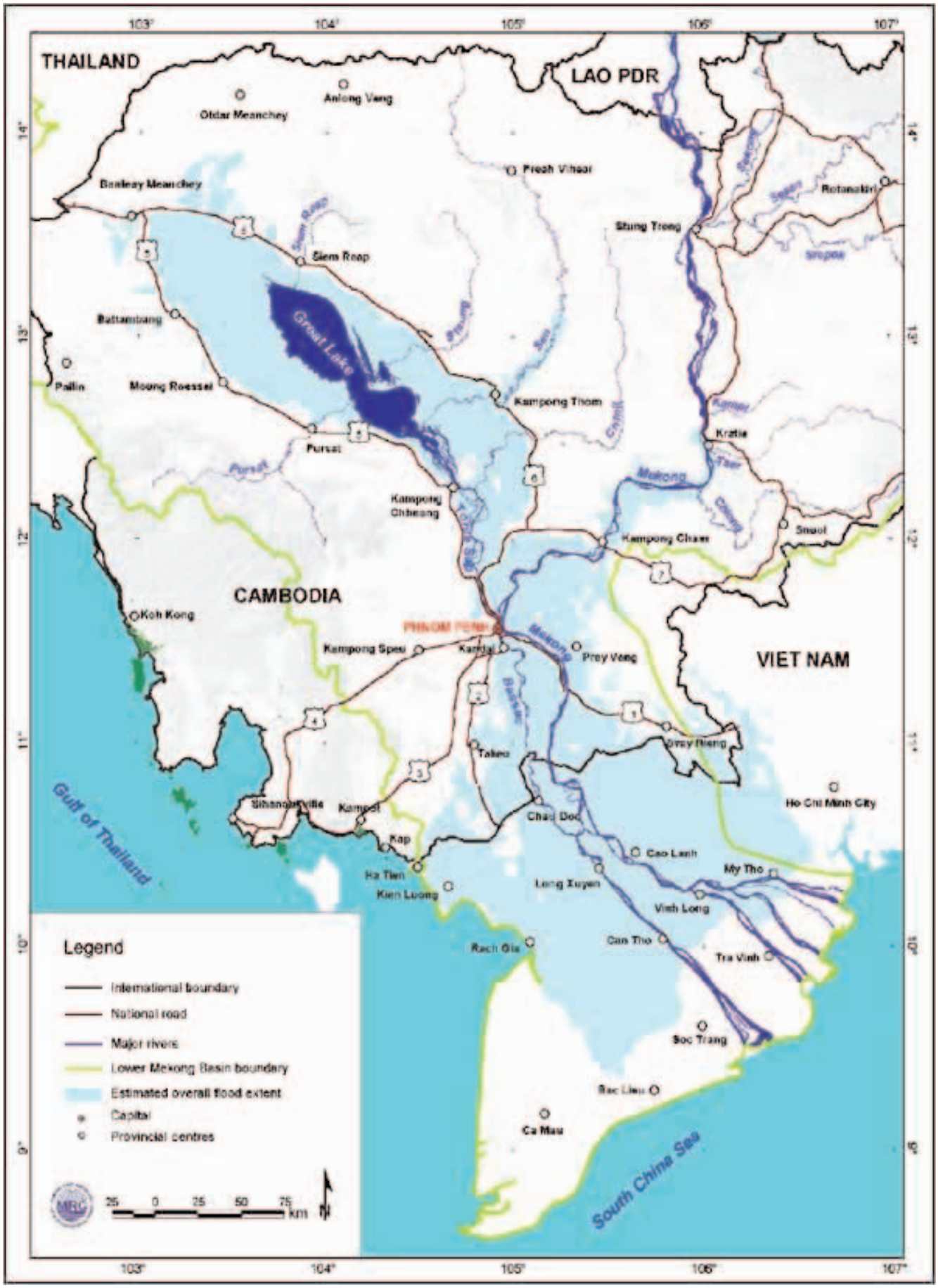
Although fisheries management is important, the long-term future of Cambodia’s fisheries depends primarily on activities which affect the quantity and quality of water and habitat within the aquatic environment. The Fisheries Department has little or no direct jurisdiction over the aquatic environment or the many .upstream. uses. Other agencies have other priorities for water and land use, and in particular, developments for irrigation, water supply and hydroelectricity can damage river fisheries by changing the amount and timing of flooding, blocking fish migrations, polluting water or damaging fish habitats. Private interests also continue to convert productive fish habitats for alternative uses, particularly agriculture.

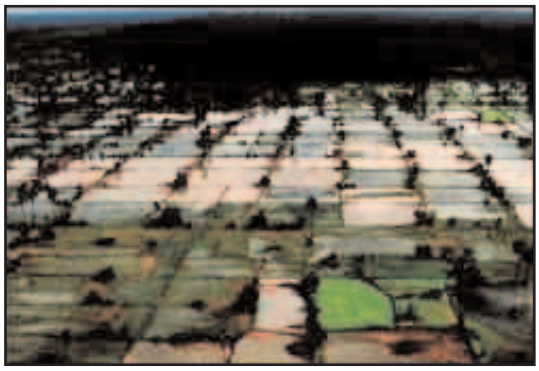
Those responsible for development in other sectors should consider the size and importance of Cambodia’s fisheries and they should fully evaluate costs, benefits and mitigation measures when planning projects. Development may bring improvements, for example in agricultural production, water supply, sanitation and electricity supply, but if this is at the expense of inland fisheries production there may be no overall benefit. Fisheries deserve special consideration as they are central to Cambodian traditional life and culture and they continue to provide many benefits to a broad spectrum of people. In particular, inland fisheries are vital for poor people who can readily harvest fish and other aquatic products for food and income, and who may have no other opportunities for employment.

Map 2 **Extent of flooding in Cambodia and the Viet Nam Delta in 2000, a high-flood year**



Map 3 **Fishing lots of Cambodia, showing those released for community fisheries in 2000-2001**
Note that lot numbers repeat in each province





Lowland forest and typical ricefields, flooded by recent rain, near Siem Reap, July 2004

Ploughing recently-flooded fields prior to planting

Planting a ricefield near Siem Reap

Rice and fish

Rice is a wetland grass which originated in Asia, so it is perfectly adapted to the floodplains of Cambodia. Cambodian farmers have cultivated rice for at least 2,000 years (Helmers,1997) and fish and rice are the Cambodian staples.

Ricefields occupy about 23,000 km 2 in Cambodia, and include rainfed wet-season lowland rice (83% of the area), dry-season irrigated rice (11% of the area), and small areas of rainfed upland rice and deepwater floating rice (McKenney and Prom, 2003). Rainfed irrigated rice allows settled agriculture, because blue-green algae grow in the flooded paddies and fix atmospheric nitrogen, which then becomes available as a nutrient for the rice; thus repeated cropping does not rapidly deplete the soil of this primary nutrient.

Traditional rice agricultural systems incorporate fish, which eat the insect pests of the rice and fertilise the paddies. Fish and OAAs that remain in small ponds in the dry season spawn during the rainy season, so their fry or larvae colonise adjacent paddies. Broodstock were traditionally maintained by farmers (Heckman, 1979). Fish fry are also carried into ricefields when they are flooded by or connected to naturalriver systems.

Fish and many OAAs (including crabs, shrimps, clams, snailsand insects) harvested from ricefields make a major contribution to people's nutrition, with a typical estimated yield of 50-100 kg/ha/year of animal protein worth up to about 40% of the value of the rice produced (Guttman, 1999). Systems for rice-fish culture have been developed and rainfed lowland and irrigated rice ecosystems offer potential for further improvements in yield (Gregory, 1997).

High-yield strains of rice require high nutrient inputs and measures to control pests. Managing use of fertilisers and integrated pest management (which limit pesticide use) have been developed and promoted in Cambodia to reduce damage to the environment and fisheries (Nesbitt, 1996). Dikes and floodgates used to control water flows may isolate rice fields from natural waterways, preventing fish colonisation and reducing the input of nutrient-rich silt, so these are factors to be considered in design and management of irrigation systems.

Women in fisheries

Most rural Cambodians fish at some, and nearly all eat fish and OAAs. Women play an important role in inland fisheries and are often involved with other family members in fishing, in processing fish and in marketing. Women tend to use small-scale gear, fish near their house, and process fish for the household, whereas men dominate other types of fishing, particularly where hard manual labour is involved, such as in the large-scale fisheries.

In a study of four provinces, Kaing and Ouch (2003) found that about 20% of fishers were female, over half of aquaculturists were female, and 85% of fish traders were women.

Women dominate marketing of fishery products throughout the country; Deap (1998) found that up to 90-95% of sellers in rural fish markets were women, and Khay and Hortle (2004) reported that Phnom Penh's 29 main fish markets support over 2,000 fish sellers, of which 90% are women. Small markets are the primary supplier of fish to cities or towns, providing significant employment opportunities for women in an environment where they can manage their own businesses.

A typical fish seller, Bang Keng Kong market, Phnom Penh

Introduction

Cambodia is a tropical country, centrally located in Indochina, between Thailand, Viet Nam and the Lao PDR, the other countries of the Lower Mekong Basin (LMB). The country has only recently emerged from decades of war and internal upheaval. During the Khmer Rouge rule (1975-79) much of Cambodia's economy and infrastructure were destroyed and a large proportion of the population died. Civil war continued to hinder reconstruction and development from 1979 to 1991. A post-war baby boom has led to the current population of around 13.4 million, most of whom are under 20 years of age, and the annual population growth rate of 2.5% is high for the region (Hook *et al*., 2003). Average population density is moderate, at 74 people/km^2, but most areas of productive floodplain are relatively densely populated, whereas more elevated or mountainous areas are lightly populated. Cambodia is now a democracy and with support from international donors the economy improved greatly during the 1990s, when annual GDP growth was 4 to 7%. Despite recent economic development, levels of education, health, gender equality and life expectancy remain relatively low. Many people continue to live in poverty and are unable to access basic services, so the need for economic development is everywhere apparent (Hook *et al*., 2003).

Links between the four LMB countries continue to strengthen, with development of roads, electrical systems and other infrastructure, and increasing trade in natural resources and agricultural products. International cooperation between government agencies is facilitated by the Mekong River Commission, which was established in 1995 to promote sustainable development in the catchment of the Lower Mekong, the region's largest river. Among the possible uses of river systems, fisheries tend to be neglected, even though they are very important throughout the Mekong Basin, particularly in Cambodia, where fish and fishing are central to the economy and traditional life and culture.

Cambodia relies on inland fisheries perhaps more than any other country in the world. Officially, Cambodia's inland fisheries produce about 400,000 t/yr (tonnes per year), the world's fourth-largest inland fisheries production, after China, India and Bangladesh, countries with much larger populations (see www.fao.org). However, the actual yield from the fisheries may be much higher. Fisheries-related activities are evident throughout the country to even the most casual observer: small children collecting snails or fishing in ponds; farmers with traps and nets in ricefields; ubiquitous river fishers on boats; people drying fish by the roadside; spectacular catches from commercial fisheries; and all manner of aquatic animals sold by the many women in the country's markets.

This report aims to provide an introduction to this important industry by synthesising information which is widely-scattered and mostly unpublished. It is intended to aid those involved in development planning to gain some appreciation of Cambodian fisheries and their importance for food security, for nutrition, as a basis for many people's livelihoods and as a key element of the economy. Maintaining fisheries should be a prime consideration in all development planning, particularly where management of water is involved.

For those intending to study fish and fisheries in Cambodia, this report provides a listing of much of the relevant literature.

The report first covers the dependence of fisheries on the environment and the natural flow regime of rivers and describes the main features of Cambodia's inland waters. The discussion then covers the diversity of species, some aspects of inland capture fisheries and aquaculture, and current fishery management and law. Finally we discuss the main threats to fisheries and the ways they should be addressed by those involved directly in fisheries, by those in other sectors and by those responsible for development planning.

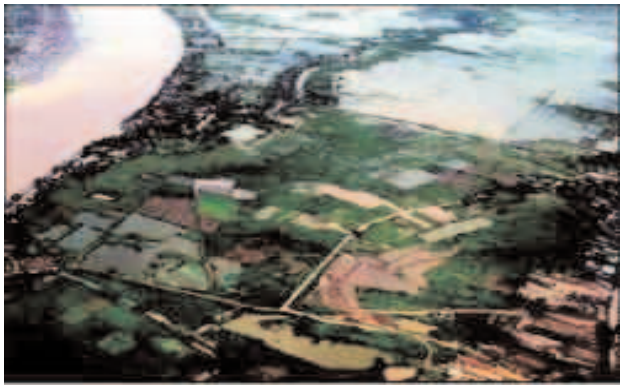
Habitat

A branch of the Mekong near the Lao border, with traps set to catch migrating fish

Deep pool in the Sesan River, northeast Cambodia

Flooded forest near deep pools of the Mekong River upstream of Kratie

Typical lowland ricefields and pools in lowland river, Kampong Chhnang Province



Flooded land near Phnom Penh

Brush parks (built to attract fish) and cage culture along the Tonle Touch, Prey Veng Province

Fisheries **production depends** on a **healthy** environment

In tropical river systems, production and catches of fish and other aquatic animals (OAAs) depend largely on the extent, duration and timing of flooding, and access to productive floodplain habitats (Welcomme, 1985).

Flooding liberates nutrients from inundated sediments, so there is an explosive growth of microscopic plants (phytoplankton) and the tiny animals which eat them (zooplankton). This simple food chain develops rapidly - days to weeks - after flooding and provides the basis for much of the early growth of fish fry, which themselves serve as food for many predatory fishes. Terrestrial insects, worms and other invertebrates, as well as plants, seeds, and fruits that were previously out of reach, are also flooded, providing a gourmet feast for fish, which grow rapidly. Many OAAs, including both invertebrates and vertebrates, also feast in the flooded areas and either prey on or provide food for fish.

Other things being equal, more fish will be produced during a larger flood, which lasts for a longer period and which occurs when fish are ready to reproduce. But productivity declines if a floodplain is permanently inundated (e.g. in a large reservoir), as the plants which are adapted to seasonal inundation die and the recycling of nutrients from sediments - which is driven by wetting and drying - decreases.

In the Mekong River system monsoon rains cause a large annual flood, with most discharge from July to October. For example, over these four months the discharge at Phnom Penh comprises about 74% of the annual flow (MRC, 2003). The ecology of fish and other aquatic organisms is adjusted to and depends upon this variation. The Mekong's flood is relatively predictable and of similar size each year compared with rivers elsewhere, so aquatic communities and the people who depend on them have been able to adapt to take advantage of the benefits of the flood.

Of Cambodia's land area of 181,031 km, up to 40,000 km^2 (or 22%) floods each year (MRC, 2003). Of this flooded area, about 22,000 km^2 comprises forests, grassland or agricultural land, and about 18,000 km^2 is wetlands, of which about 5,000 km^2 is permanent water (Ahmed *et al.*, 1998; McKenney and Prom, 2003). The main flooded areas extend down the delta into Viet Nam, so many fish and OAAs in this region cross the border along river channels or by swimming through seasonally flooded areas (Map 2).

Cambodia's **Inland Waters**

About 86% of Cambodia's land area is within the Mekong catchment, and about 20% of the Mekong River's catchment is within Cambodia (see Map 1). Several small rivers which run to the sea in south-west Cambodia lack extensive floodplains, so they are relatively unproductive.

Cambodia was formerly cloaked in heavy forest which protected catchments, regulated hydrology and provided fish with habitat and food in areas which flooded. In the 1950s and 1960s forest cover was estimated at about 70%, but by 1997 this had officially declined to about 60% (MRC, 2003). Much of this 'forest' was actually disturbed or regrowth forest or had been converted for agriculture. Clearing has accelerated in recent years, and flooded forests - important fish habitats - have been particularly affected because they grow in or near the most heavily populated areas. Loss of forests in Cambodia and in upstream countries has undoubtedly caused a wide range of impacts to hydrological and aquatic ecological systems, but the actual extent of losses and their

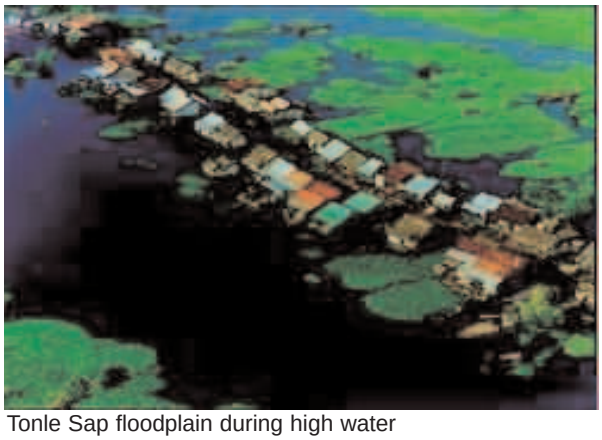
Habitat

Children fish everywhere, even near Cambodia's most famous temple, Angkor Wat

The Tonle Sap near the mouth of the Great Lake. July 2004. Sediment-rich Mekong 'white' water running into the lake is joined by black water from wetlands. Chnouk Trou in the foreground

Flooded land along the Tonle Sap

Chnok Trou, an important fishing centre at the entrance of the Great Lake



Tonle Sap floodplain during high water

Boys catching fish in a forest pond, Ratanakiri Province

Typical floodplain lake with lotus plants in the dry season

The **Mekong** River

The Mekong is the largest river in southeast Asia, flowing over 5,000 km from its source in Tibet to its mouth in Viet Nam (MRC, 2003). Its catchment is about 795,000 km^2 and its mean discharge is about 15,000 m^3/s. The Mekong enters northeast Cambodia downstream of Khone Falls in Lao PDR, over which its level drops from 95 m to 65 m above sea level. From the border to Kratie Town, the Mekong is a large braided river, with a variety of habitats: rapids, pools, rock bars and sandbars, as well as fringing seasonally-flooded forests. Rapids with fast-flowing oxygen-rich water are important spawning habitats for fish. Deep pools, some up to 80 m deep, offer refuge to many large fish during the dry season (Chan *et al*., 2004). This section of the river is rather inaccessible by road, so fishing pressure has been relatively light, but is intensifying as boat access and gear availability have increased. A section of river upstream of Stung Treng is one of two sites in Cambodia which are classed as wetlands of international significance under the Ramsar Convention (www.ramsar.org); the other site is near the Great Lake (see below).

At Stung Treng the Mekong is joined by the combined flow of three major tributaries, the Sesan, Sekong and Srepok, which flow from southern Lao PDR and the central highlands of Vietnam. These tributaries are essential in the life cycle of many migratory Mekong fishes and are among the few areas in the system where large fish remain fairly abundant. Near Kratie, the Mekong becomes a meandering lowland river with a slower current, a muddy/sandy bed, less variation in depth, and fringing wetlands and floodplains. The river drops only 20 m between Kratie and the sea, a distance of some 500 km.

Near Phnom Penh, at the head of its delta, the river divides into a larger eastern branch, the Mekong, and a smaller western branch, the Bassac River. Both branches flow southeast and divide further, before emptying into the South China Sea through several distributaries and through canals which have been constructed in Viet Nam to regulate flooding. Near Phnom Penh the Mekong is joined by the Tonle Sap, a large tributary with its origin in the Great Lake.

The Mekong delta is a large estuary system that is highly modified in Viet Nam by a complex canal network. The delta is subject to pronounced tidal fluctuations during much of the year. Saline water intrudes up the system during the dry season, to an extent which depends on the opposing river flow and tidal height, but saline water does not reach Cambodia to any degree.

The **Great Lake** and **Tonle Sap**

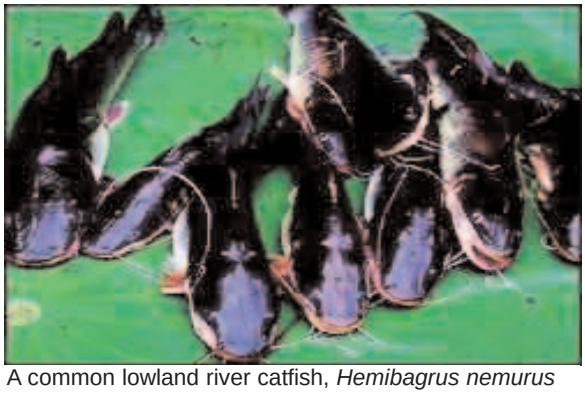
The Great Lake - or Tonle Sap Lake - is the largest lake in southeast Asia and is connected to the Mekong by the Tonle Sap (Sap River) (see Maps 1 and 2). The lake was formed by subsidence about 5,700 years ago (Carbonnel, 1963; Tsukawaki, 1997). The Tonle Sap-Great Lake system is the centre of Cambodian fishery production and it is globally significant, being nominated as a Biosphere Reserve in 1997 under the Man and Biosphere Program of UNESCO. Boeng Tonle Chma, a wetland northeast of the lake, is one of two Cambodian inland wetland sites of international significance under the Ramsar Convention.

The Tonle Sap-Great Lake system expands and contracts seasonally in response to rainfall and the flow of the Mekong, thereby acting as a storage which regulates flooding. When the level of the Mekong rises, water runs north-west ‘up’ the Tonle Sap towards the lake, which may increase from its dry-season (Dec-June) depth of 1-2 m up to about 10 m at the peak of the flood. The lake’s area expands from 2,500-3,000 km^2 in the dry season to 10-14,000 km^2 during the flood season, when it covers about 5-8% of the land area of Cambodia (MRC, 2003). Inundated forests and fields become a vast productive habitat for fish and other aquatic life. At the end of the flood season, the level of the Mekong falls, so the Tonle Sap flows towards the Mekong, taking with it

White fishes

When floodplains drain at the end of the wet season, water remains in lakes and scattered depressions, which continue to shrink in size and number during the dry season. Floodplain waterbodies become hot, oxygen is depleted and food and shelter diminish, with many ponds drying-out completely. So the fish which feed and grow on flooded areas must either return to the river as the waters recede, or remain and endure the poor conditions on the floodplain.

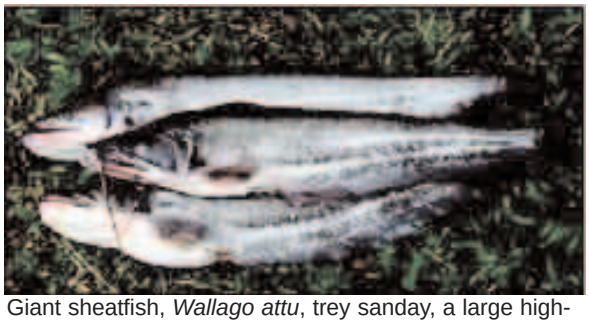
Species which leave flooded areas and return to rivers are referred to as 'white fishes', as they spend most of their lives in turbid (white) river water. Many of these white fishes migrate long distances to dry-season refuges. Shown below are some of the more common white fishes of Cambodian rivers.



A common lowland river catfish, *Hemibagrus nemurus*
Trey chhlang

Many kinds of flatfish are found in lowland Cambodia rivers, like this sole *Euryglossa* species, trey andat chhke

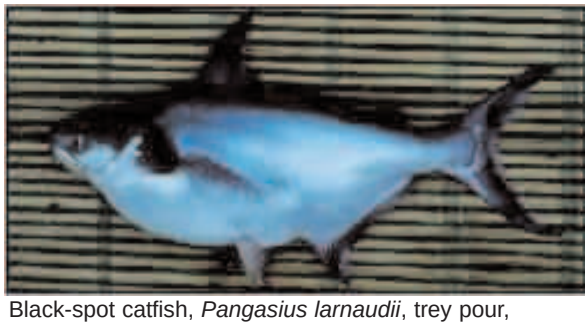
River catfish, *Pangasius hypophthalmus,* trey pra, a species prized in catches and used extensively in aquaculture



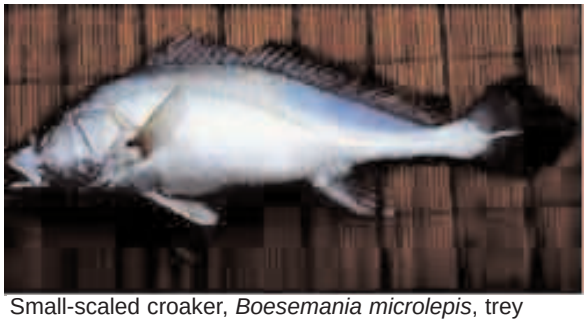
Giant sheatfish, *Wallago attu*, trey sanday, a large high-value predatory species

Red-tailed tinfoil, *Barbonymus altus*
Trey kahe

Marbled goby, *Oxyeleotris marmorata*, trey damrei, a high-value fish which is often exported



Black-spot catfish, *Pangasius larnaudii*, trey pour, a river fish which grows fat when aquacultured like this specimen



Small-scaled croaker, *Boesemania microlepis*, trey promah, a species often dried or salted

Black fishes

The species of fish which remain on the floodplain are known as 'black fishes', as they spend their lives in relatively clear water that is tea-coloured by chemicals dissolved from floodplain vegetation. Decomposition of vegetation causes floodplain water to be acidic and depleted in oxygen, stresses which black fishes can tolerate. Most black fishes can breathe air, and common species such as those shown below can survive out of water for long periods, and most can move overland in search of new waterbodies. A few species can bury themselves deep in the mud and wait until thenext flood. Many black fishes are used in aquaculture and are transported alive to markets.

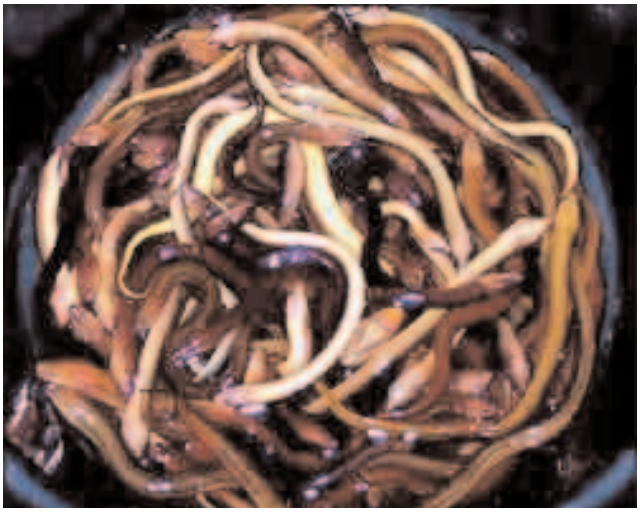
Black swamp water (foreground) contrasts with 'white' river water

Striped snakehead, *Channa striata,* trey roh, one of the most commonly seen black fishes

Walking catfish, *Clarias batrachus*
Trey andaing

Snakeskin gouramy, *Trichogaster pectoralis*
Trey kanto

Climbing perch, *Anabas testudineus*
Trey kranh



Swamp eels, *Ophisternon bengalense*
Ontoong

Giant snakeheads, *Channa micropeltes*
Trey chdao

Upper Cambodian fishes

Red-finned catfish, *Hemibagrus wyckioides*, 3 kg
Trey chhlang thmor

Sheatfish, *Micronema apogon*, 7 kg
Trey kes

River catfish, *Pangasius hypophthalmus*, 15 kg
Trey pra

Goonch, *Bagarius yarrelli*, 20 kg
rey krawbey

The large fish shown above were all caught in the Mekong in upper Cambodia in 2004 and exported to the Lao PDR or Thailand, as part of an increasing trade in large fish

Two-headed carp, *Bangana behri,* trey pava mookpee, and *Mekongina erythrospila*, trey pa s'ee (on the right), both species found in the Cambodian upper Mekong and large tributaries, which host many different fishes compared to the lowland rivers

Inland fish diversity in Cambodia

The Mekong hosts over 1,000 species of fish, one of the highest species counts of any river system in the world (Coates *et al.*, 2003). This richness in species has arisen from evolution in a wide range of habitats available in many river systems that were fragmented and re-joined over recent geological time (Rainboth, 1996). The continuing variation in hydrology and the variety of habitats allow the persistence of many species which all require different conditions. Some species are most abundant on the floodplain and its wetlands, some favour lowland rivers and some are found mainly in tributaries, but all migrate within or between habitats to complete their life cycles. About 500 species are found in the Mekong system in Cambodia, but for any particular fishery most of the catch usually comprises 10 species or less, as shown in Table 1.

Table 1. **Composition of catches in Cambodian commercial inland fisheries, 1995-96**
Catch % by weight, from van Zalinge and Nao (1999); other fisheries have different species compositions, totals are weighted means

English Name	Khmer Name	Scientific Name	Type of fishery			% of total catch	% of total value
			Lot	Dai	Middle		
Small river carp	Riel	*Cirrhinus lobatus/siamensis*	11	40	20	21	9
Giant snakehead	Chdeo	*Channa micropeltes*	18	0	8	9	19
Soldier river barb	Chhkok	*Cyclocheilichthys enoplos*	8	1	13	8	6
River barbs	Ach kok	*Labiobarbus* spp.	5	6	7	6	2
Shark minnows	Kroh	*Osteochilus* spp.	2	10	2	4	2
Small-scale carp	Pruol	*Cirrhinus microlepis*	5	3	2	3	4
River catfish	Pra	*Pangasius* spp.	6	0	1	3	3
Tawes	Chhpin prak	*Barbonymus gonionotus*	3	0	4	3	2
Pelagic river carp	Siak russey	*Pareisubuca typus*	1	11	0	3	1
Striped snakehead	Roh	*Channa striata*	5	0	1	2	6
	Other species		38	30	42	37	44
	Number of species recorded		75	44	82	-	-

The Mekong has some of the smallest and largest freshwater fishes in the world, from the minute ricefish *Oryzias mekongensis* (maximum size 2 cm), to huge species such as the Mekong giant catfish (*Pangasianodon gigas*), the giant barb (*Catlocarpio siamensis*) and giant stingrays (*Himantura chaophraya* and other species) (Rainboth, 1996; www.fishbase.org). As well as the more familiar groups such as catfishes, river carps, snakeheads and climbing perch, Cambodian rivers and wetlands are home to garfish, longtoms, frogfish, pipefish, pufferfish, eels, sharks, rays, flounders and many others. The many species encompass many families with a diversity of form, feeding habits and modes of reproduction.

As a result of the high diversity, fish occupy all available aquatic habitats and exploit many kinds of foods. Biodiversity is a crucial element in high fishery production, providing to some extent a 'safety-valve' each season, so that loss of any species (for example from a disease or overfishing) will be compensated for by increased production of other species. The high diversity of species, the great range of habitats, and the variation in catches over time and space make wild inland fish available to a wide range of people, thus ensuring a high degree of participation in Cambodian fisheries.

Apart from fish, inland waters support many kinds of OAAs including vertebrates - reptiles, birds, mammals and amphibians, and invertebrates, such as insects, crustaceans and molluscs, all of which depend upon maintenance of aquatic ecosystems. People throughout Cambodia catch and eat all kinds of OAAs, which are all considered part of the fishery.

Giant species

The Department of Fisheries purchases, tags and releases large endangered species when notified by fishers.

Giant freshwater stingray, trey bobel, *Himantura chaophraya*, 4 m long, released in December 2002

Mekong giant catfish, trey riech, *Pangasianodon gigas,* 171 kg caught in mid-2002

Giant River Carp, *Catlocarpio siamensis,* trey kool rieng,102 kg, caught and released in December 2002

Other aquatic animals




As well as fish Cambodians eat at least 50-100,000 t/yr of other aquatic animals, including clams, snails, snakes, turtles, frogs, tadpoles and shrimps




Dolphins of the Mekong

Irrawaddy dolphins, *Orcaella brevirostris*, were formerly common and widespread in the lower Mekong, but now only 60-100 remain, mainly as a result of massive killing during the Khmer Rouge period (Beasley *et al.*, 2003). In Cambodia, dolphins are found now only from the Lao border down to Kratie, where they support a small ecotourism industry. Deep pools along this stretch provide shelter for the dolphins and also harbour the fish upon which they feed. During the annual flood, the dolphins enter large tributaries, the Sesan and Sekong, probably pursuing migrating fish. Dolphins play an important part in Mekong folklore, so usually people will not deliberately hurt them, but some are killed by boat propellers, by gill-nets, or by explosives or electricity used illegally for fishing. Modifications to habitat - from dams or catchment changes - could have negative impacts on the dolphins. The Cambodian government has recently declared protected zones and has banned the use of large-mesh gill-net nets. These measures will require ongoing support for implementation.

Trey Riel

The small fishes called trey riel are probably the most abundant fish in the Mekong system, and are the most important fish in Cambodia's inland fisheries. Trey riel feed on microscopic plants. They breed when one year old, with each female fish producing thousands of eggs. In heavily-fished areas most fish are caught before they reach one year of age.

Trey riel are also the main food for many predatory fishes, including snakeheads. Floodplains along the Tonle Sap River and the Great Lake are very important feeding areas, from where many trey riel migrate back to the Tonle Sap and the Mekong when water levels fall.

Thousands of tonnes of trey riel are caught each year between December and March along the Tonle Sap. Dais catch many species, but the proportion of trey riel is increasing and is now about 50% of the catch in the Tonle Sap. Trey riel are also caught by many other kinds of gears along their migration route, from the Tonle Sap up the Mekong River to Khone Falls, and into tributaries. Some fishers follow the schools as they move along the river.

Trey riel, *Cirrhinus lobatus* (above) and *Cirrhinus siamensis*

Prahoc

During the peak catch period (December to March) thousands of people travel to the Tonle Sap, the Mekong and other waterways to trade rice for fish or to fish themselves. For a few months the river banks are lined with temporary shelters while fish are made into prahoc or preserved in other ways.

Prahoc is fermented fish paste made from small low-value fishes such as trey riel. The fish are thoroughly washed; the heads and scales are removed, and the fish are then salted and dried for a few days, after which they are stored in large ceramic pots to ferment. During fermentation, bacteria hydrolyse protein into its constituent amino acids, at the same time producing lactic acid which prevents further decomposition. The protein in prahoc is more digestible than in fresh fish, so prahoc is excellent food for the elderly or small children.

By-products of prahoc-making are fish-fat, which is collected and sold for making soap, and heads and guts, which are used as fish feed, animal feed or fertiliser.

Prahoc is the main product in which the seasonal excess of fish is stored. Entire families work together, and businesses whichsell prahoc hire many temporary labourers to assist with processing. Prahoc and other forms of preserved fish are vital for nutrition and food security for the rural poor, especially during the closed season.

Water Festival

During the flood millions of fish migrate up the Tonle Sap and the Great Lake and move onto floodplains to feed and grow, returning when the water recedes. These migrations are the basis for the centuries-old Water Festival (Bon Om Teuk). During the full moon in October or November, when the flow of the Tonle Sap reverses, thousands of people from all over Cambodia gather for the three-day festival along the river's banks in Phnom Penh.

The festival marks the beginning of the fishing season, and aims to propitiate the river spirits so that there will be good fishing and a bountiful rice harvest. The next three months are crucial, because people must store enough fish to provide protein in their diet during the dry season.

The highlight of the festival is a race by hundreds of longboats, each beautifully carved and decorated to represent its village, and powered by up to 100 rowers. The boat race is said to commemorate the naval victory of the great Cambodian king, Jayavarman VII over a fleet of Cham warships on the Tonle Sap in 1177 AD, probably near Kampong Cham (Groslier, 1973).

Fish migration and spawning

Some fish species spawn on floodplains, but many migrate upstream at the start of the flood to spawn in tributaries such as the Sesan, Sekong and Srepok Rivers, and rapids in the Mekong mainstream between Kratie and the Lao border (Poulsen *et al*., 2002). The rising rivers carry the fish larvae and fry downstream and onto the productive floodplains.

Sampling upstream of Phnom Penh shows that tens of millions of juvenile fish drift downstream each day during the peak spawning season (Hortle *et al*., 2004a). After spawning, many adult fish also swim into flooded areas where they can gorge on the abundant food, until falling water forces them to return to the main rivers and their dry season refuges. Many fish migrate across international borders to spawning, feeding or refuge areas, both upstream to Lao PDR and downstream to Viet Nam. Some species of fish and shrimps migrate to spawn in estuarine areas, while others spend part of their life in the sea.

Fishing is focused on migrations

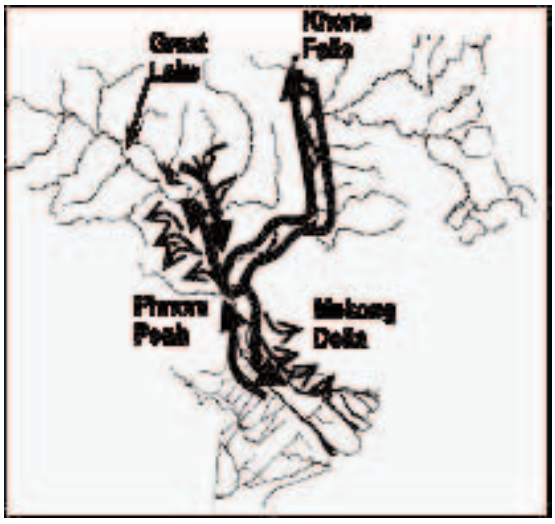
During the flood, fish are dispersed in a large volume of water and many have not yet grown to a catchable size, so use of medium and large-scale gears is prohibited during the official closed season (1 July to 31 October south of Phnom Penh, and 1 June to 30 September in the north). When water levels recede, fish are forced off the floodplain and become concentrated in channels, streams and rivers, through which they migrate to dry-season refuges. Migrating, fish are more vulnerable to capture, especially by any gears that filter the water. Various kinds of traps and large stationary trawls (dais) set across flowing waters in the flood recession season catch many fish and OAAs. Those which remain on the floodplain become concentrated in a few wetland refuges where they are more vulnerable to fishing. As the dry season progresses their stocks become increasingly depleted, with relatively few surviving to spawn and repopulate newly-flooded areas during the wet season.

Migration routes in Cambodia

Important spawning areas for migratory fish are located in northeast Cambodia, while the most significant feeding grounds are the floodplains along the Tonle Sap, Great Lake and in the Mekong Delta.

During the dry season, fish find refuge in deep pools along the Mekong River, particulary upstream of Kratie to the Lao Border.

Migratory fish stocks are thus shared between Viet Nam, Cambodia and Lao PDR, and some species probably migrate into Thailand as well.



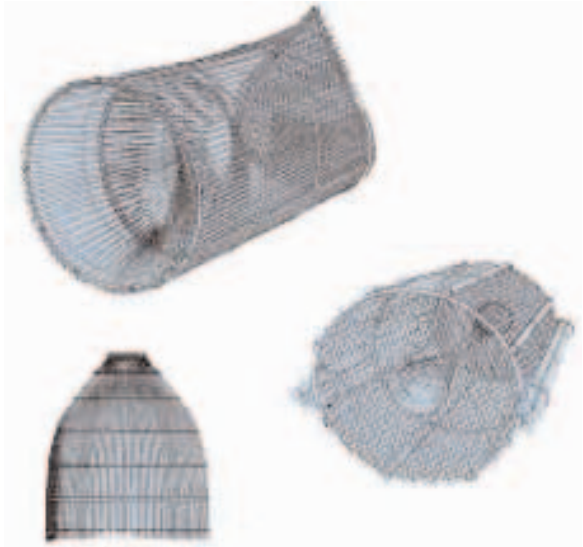
Large arrows show mainstream migrations between the major habitats. Small arrows illustrate movements between river and floodplain.

Fishing gears

Barrage with traps on the Tonle Sap, a gear which filters the falling river waters

A barrage in flooded forest, built to catch migrating fish

Gill-nets are now very common and effective gears



Traditional traps are widely used

A typical large liftnet, an effective traditional gear

Fishing gears

Cambodians use an amazing variety of gears of all sizes, many of which were developed to suit local conditions. Many gears and methods reflect the accumulated knowledge of generations of Cambodian fishers. The largest gears, such as dais and barrages, are rather non-selective and target fish which are migrating in large numbers. Most smaller traditional gears are specialised for fishing particular habitats in a particular way to catch a few target species. The diversity of gears parallels the diversity of fish - more than 150 types of gears are known from Cambodia (Deap *et al*., 2003). Gears are discussed further on page 28.

Historical importance of Cambodia's fisheries

Until about 5,000 years ago the lower Mekong Basin was inhabited by small groups of hunter gatherers. Neolithic farming began to develop as people settled on the most fertile areas. Civilisation developed in the delta region during the Funan period, 1st -7th Century AD (Chandler, 2003). Excavations of old settlements at Angkor Borei in Takeo Province were dated from 1,600-2,400 years ago and included the bones of hundreds of species in at least 17 families of fish, showing their importance as food for the early Cambodians (Voeun, 2001). As the population grew, people migrated inland to settle around the productive Great Lake-Tonle Sap system. Rich inland fisheries supported the great Angkor Empire (9th-15th Century AD), which was centred on Siem Reap, and many reliefs of the Bayon and other temples depict fish and fisheries (Roberts, 2002).

Zhou Daguan, a Chinese visitor to Cambodia in 1296-7 AD, commented on the richness of aquatic resources of the Great Lake, noting the abundance of many kinds of fish as well as frogs, tortoises and turtles, lizards, large prawns, crocodiles and molluscs (Zhou, reprinted in 2002). French explorers during the 19th Century also noted the abundance of fish and the ease of catching very large fish, or large quantities of fish along the Mekong and its tributaries, and how for example the Vietnamese exploited the fruitful fisheries of the Tonle Sap (Garnier, reprinted in 1996).

Inland fish products have long been an important export. In 1910 about 50,000 tonnes of fish were exported as dried or salted fish, fish oil, fish paste or live fish (Petillot, 1911). During the 1930s, about 100,000 t/yr of fish were processed from the Great Lake to produce about 25,000 t/yr of mostly dried or salted fish, of which 23,000 t/yr was sent to Java (Chevey, 1935). Later Chevey and Le Poulain (1940) estimated commercial fish production at about 120,000 t/yr. Bardach (1959) estimated inland fish production in 1939 was 147,000 t/yr and in 1957 was 130,000 t/yr. In 1973 the total Cambodian catch was conservatively estimated at 125-160,000 t/yr, with commercial production officially comprising 85,000 t/yr (Lagler, 1976).

The Khmer Rouge regime (1975-79) disrupted infrastructure and trade systems and forced most of the population into rice production (Degen and Nao, 2000). Fishing pressure and production reduced greatly, although export of fish to Thailand and import of salt for fish-preservation continued on a large scale (Kiernan, 1996). Fishing activity increased again between 1979 and 1991, but due to the disruption of infrastructure and the ongoing civil war, production was probably much less than in the 1940s; official figures - of limited accuracy - for catches by commercial gears were 18-66,000 t/yr over the period 1979-1988 (Nguyen and Nguyen, 1989). Since stabilisation of the country in the 1990s all forms of economic activity have gradually increased, so fishing has once again become a major industry and a vital occupation for many Cambodians.

Tonle Sap dai fisheries

A row of dai bagnets in the Tonle Sap

Dai owner weighing catches

Transporting trey riel to shore for processing

Sorting trey riel and other fish

The dai catch is emptied into a sampan

Ethnic Vietnamese (Khin) and Chams, the largest minority groups in Cambodia, are disproportionately represented in the fishing industry, particularly in the larger licensed operations (Degen and Nao, 2000). Many Chinese-Khmers lease commercial fishing lots or are involved in trading of fishery products or other commercial activities. Most ethnic Khmers in rural areas own land and see themselves as farmers, with fishing or fishing-related activities as secondary but vital occupations. These ethnic differences and their implications for management are reviewed in detail by Gum (2000). Although readily apparent in the field, the ethnic dimension of inland fisheries in Cambodia has not been well-quantified in any large-scale surveys.

Size and value of Cambodia's fisheries

As mentioned earlier, historical records show that Cambodia's inland fisheries have been of major importance for centuries. Almost all Cambodians eat fish, and most participate in fishing and fishing-related activities. Many also depend on the industry for their livelihood. In one survey (Ahmed *et al.*, 1998) more than one million out of 4.2 million people living in eight fishing provinces were either fully or partly dependent on fisheries for their income.

Table 2. **Estimated annual inland catches in Cambodia, based on mid-1990s figures**
Note that consumption figures suggest these are underestimates

Type of Fishery	Annual Catch (tonnes/year)
Large scale fishery - Fishing lots - Dais (large bagnets)	 25,000 - 75,000 14,000 - 16,000
Middle scale fisheries	85,000 - 100,000
Family fisheries	115,000 - 140,000
Ricefield fisheries	50,000 - 100,000
Total	**289,000 - 431,000**

Collecting comprehensive data on catches is difficult because the fisheries are very dispersed in space and time, registered fishers have no incentive to accurately report catches, and most of the catch is made by the millions of small-scale fishers who are very difficult to survey quantitatively. The most recent country-wide estimates of the size of the fisheries were made based on field research by the Department of Fisheries and the Mekong River Commission (MRC). Production of inland fish was estimated at 289-431,000 t/yr for the entire country by van Zalinge and Nao (1999) based on catch surveys (1994-97), socioeconomic surveys (1995-6) and estimated yields from ricefields (Table 2). Allowing for population growth of about 2.5% per year since then, and assuming increasing average age, fish consumption and fishing intensity, the figures should be increased by at least 20% to estimate current production. An economic survey in 1999 (NIS, 2000) found that Cambodians spent on average 6,386 Riels/person/month on fish, which at the time corresponded to about 2 kg/month, or 240,000 t/yr. As many - perhaps most - fish are eaten by those who catch them or are bartered, these retail figures suggest that the estimates in Table 2 are conservative.

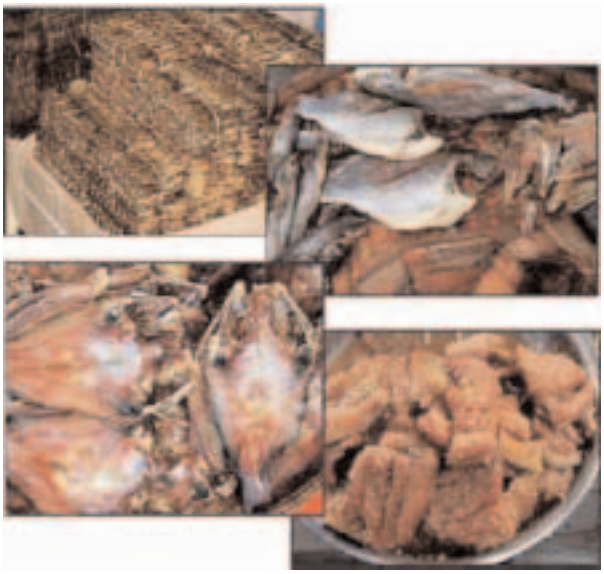
In the eight provinces around the Tonle Sap and Great Lake in 1995-96, rural people in fishing communes reportedly ate between 22-68 kg/yr of fresh fish and 10-24 kg/yr of preserved fish

Processing fish

Filleting snakeheads, *Channa micropeltes*

Smoked sheatfish, *Micronema sp.*

Snakeheads fillets being sun-dried



Preserved fish are sold in many forms: salted, fermented, smoked or dried

The ovaries of snakeheads are removed and sold separately

Bulk sale of fermented fish products at Oresey Market, Phnom Penh

products, including fermented fish, fish paste, smoked fish, salted dried fish and fish sauce (Ahmed *et al*., 1998), so total consumption was 34-92 kg/person/yr, with a mean of 75.6 kg/person/yr, as actual weight eaten. In dry areas which are further from rivers people eat less fish; for example Setboonsarng *et al*., (2001) found mean consumption of fish and fish products of 22, 15 and 17 kg/person/yr in Kandal, Prey Veng and Takeo respectively. If we convert the figures for preserved fish to the equivalent weight of fresh fish needed to make the products - for example, 1 kg of salted dried fish is made with about 3 kg of fresh fish - then the consumption of fish as 'fresh-fish equivalent' is even higher.

Hortle and Bush (in prep.) extrapolated from these and other data (Touch *et al*., 1994), and based on a mid-2000 population of 11 million, estimated total inland fish consumption of 661,400 t/yr as equivalent whole fresh-fish, or a mean of 60.3 kg/person/year for the Cambodian part of the LMB. Cambodians also eat many OAAs, such as shrimps, crabs, molluscs, frogs, turtles, and insects. Based on very limited data, Hortle and Bush (in prep.) estimated such consumption at about 60,000 t/yr, or 5.2 kg/person/yr, although the quantity could be much greater. Some authors argue for lower total catch estimates (see review by Touch and Todd, 2001), but the mean inland fish and OAA consumption figure of 65.5 kg/person/yr is in the mid-upper level of world ranges of 15-90 kg/person/yr (Hortle and Bush, 2003). The estimate presented here seems plausible, given the very obvious importance of aquatic products in Cambodia, although further work is needed to confirm consumption estimates, which are based primarily on interviews with consumers.

No other kind of food could readily replace fish in the diet of Cambodians. Fish is currently cheap by world standards, generally averaging about $0.75/ kg in markets; nevertheless it is still worth at least $300 million based on this average sale price. But such a simple valuation does not take into account the replacement costs and the effect of varying supply and demand. For example, the catch of the Tonle Sap dai fishery in 2003-4 was about half of that in 2002-3, so the price of the most common fish, trey riel, rose more than three-fold. Moreover, many other industries depend upon fishing: gear-making, supply of boats, fuel, ice and preservatives, and transportation and marketing, as well as some downstream industries. Better information on the value of these industries and the degree of employment they provide is urgently needed, as even allowing for underestimates, the fisheries industry is estimated to account for about 12% of Cambodia's GDP, ahead of rice production, which contributes 10% to GDP (Starr, 2003).

Most fish caught in Cambodia are consumed locally, but fish and fish products are also exported to many other countries, especially Thailand, Viet Nam and Lao PDR, with minor quantities exported to other Asian and to some Western countries. So although Cambodia's fish and OAA consumption is about one quarter of the total of the LMB, its share of LMB fisheries production would be greater, due to exports to the other LMB countries (Hortle and Bush, in prep). Officially, Cambodia exported about 23,690 tonnes of inland fish in 2001 (Nao *et al*., 2001), but a large unofficial and untaxed trade could be several times higher than this figure. In 2003, official border trade to Thailand alone via Aranya Prathet was 9,564 tonnes exported (valued at US$7.5 million) and 443 tonnes imported (valued at US$200,000) (based on Thai customs figures), but unofficial trade may be much greater. Touch and Todd (2001) review trade figures in more detail, providing estimates of size and value for many species.

In summary, an official catch figure of about 400,000 t/yr, valued at US$300 million, probably under-estimates the size and value of the catch, as it is based on incomplete and outdated figures. Unfortunately, there are no monitoring systems in place which can show accurately total production each year, or how the catches are changing from year to year countrywide.

Marketing

Live fish in baskets are transported to markets

Giant freshwater shrimps *Macrobrachium rosenbergii* are now one of most expensive inland fishery products

This seller retails a range of fish including large river barbs *Cyclocheilichthys enoplos* in the foreground, caught in the Mekong downstream of Phnom Penh in early 2004

Live fish are commonly sold, here walking catfish, *Clarias* sp.

Nutrition

Fish is the most important source of animal protein for people in Cambodia, contributing about 80% of the average daily intake. Fish protein is balanced - i.e. it contains all essential amino acids - and is among the most easily digestible of protein foods (Haas, 1992). An adequate daily intake of balanced protein is essential for normal tissue growth and development, and any deficit has secondary effects on the absorption or metabolism of other nutrients or micronutrients.

In Cambodia, as in most other Asian countries, people do not traditionally eat dairy products, but they eat small fish whole, providing much of the calcium required for bone development. Fish also provides other essential minerals, including iron and zinc (Roos, 2003) and vitamins, especially vitamin A. Fresh fish is about 75% water, most of the remainder is protein, and oils are the third-largest component of fish tissue, providing an important source of energy. Fish oils include some essential polyunsaturated fatty acids, such as Omega-3 PUFA, which are increasingly recognised as providing other health benefits such as reducing the risk of heart disease (AHA, 2002), promoting brain function (Kalmijn, 2004) and reducing the effects of arthritis (Larsen, 2004).

Fisheries management

Formal fisheries management dates from the reign of King Norodom (1863-1897), who leased fishing rights to certain areas. French colonial administrators passed the first fisheries laws of the country (Petillot, 1911), which formalised this lease system with the primary aim of maximising tax revenue. The current Fisheries Management and Administration Law of 1987, which is under review, states that all living animals and plants within waterbodies are the property of the State, enabling the state to set conditions for their exploitation.

Department of Fisheries and IFReDI

The Department of Fisheries (DoF) administers Fisheries Law and regulations and employs about 1,350 staff at national, provincial and district levels. The DoF's main responsibilities are licensing, enforcement of regulations, research, and community fisheries management. Research capacity is being developed particularly within the Inland Fisheries Research and Development Institute of Cambodia (IFReDI), which was recently created with support from the MRC and Danida. The objective of IFReDI is to carry out research that provides information which can be used to manage fisheries. Priority areas include fish habitats, migration, consumption and marketing, export of fisheries products, classification of freshwater fishing gear, valuation of fisheries and resource management systems.

Inland fisheries categories

Capture fisheries

Capture fisheries are categorised as small-scale or subsistence, as middle-scale, or as commercial-scale. Small-scale fisheries are family fisheries, based on small gears such as castnets, dipnets, small gill-nets and traps. Anybody can fish, and a licence is not needed, but it is illegal to fish in fishing lots during the open season (October-May). Most Cambodians fish for some time each year on land they own, or in nearby waterbodies, flooded forest and floodplain areas. Production from ricefields fisheries is very important to most rural families (Gum, 2000).

Aquaculture

In cage culture the most popular species are carnivorous high-value snakeheads (Channidae), but river catfishes (Pangasiidae), walking catfish (*Clarias* species) and introduced fishes such as Nile tilapia (*Oreochromis niloticus*) are also commonly grown, being fed on fishmeal and rice bran. Pond culture is also expanding, based on these species as well as some herbivorous fishes, but is still of very minor importance compared with the wild fishery. Aquaculture mostly entails grow-out (i.e. rearing) of wild-caught fish or fingerlings, which are themselves fed with small wild fish. For carnivorous species, typically 5 kg of fish as feed produces only 1 kg of fish as product, consequently the industry is a nett consumer of fish which cannot replace the wild fishery upon which it depends.

Fish fry are currently produced from 13 government hatcheries spread throughout the country, supported by several aid programs, with minor production from some small private hatcheries. Total government hatchery production in 2003 was 13.2 million fry, mainly comprising two native fishes: the red-tailed tinfoil (*Barbonymus gonionotus*), a river catfish (*Pangasianodon hypopthalmus*) and two exotic species: Chinese bighead and silver carp (*Hypophthalmichthys* species), and Nile tilapia. The Aquaculture of Indigenous Mekong Species Component of the MRC Fisheries Programme currently supports research and development on other native fishes, which are more culturally acceptable and less likely to cause ecological problems if they escape to the wild.

Fish fry are sold in bulk to middlemen, who then sell them to growers. Fish are raised in ponds, or in natural waterbodies in bamboo cages or pens made from nets. Official figures for 2003 for the facilities devoted to aquaculture countrywide were: 9,425 ponds with a total area of 224 ha, 3,784 cages with an area of 5.6 ha, and 240 pens with an area of 3.8 ha.

Ponds for adult broodstock, Bati Station, south of Phnom Penh

Native river catfish *Pangasius hypophthalmus*

Fry from successful breeding of river catfish

Chinese bighead carp *Hypophthalmichthys nobilis*

Stripping eggs from river catfish

Introduced carp, *Cyprinus carpio,* a very common aquaculture fish

Red tilapia, a popular aquaculture fish, a hybrid of two African species, *Oreochromis niloticus and Oreochromis mossambicus*

Cage culture of tilapia along the Tonle sap

Middle-scale fisheries are based on larger gears, of at least 40 types, with the most popular being gill-nets and seines. Anybody can fish, but a licence is required. Middle-scale fisheries are not permitted inside commercial fishing lots (see Map 3).

Commercial-scale fishing is based on 'lots', fishing areas which are auctioned every two years. Large-scale fishing gears are only permitted in fishing lots, which can only be fished in the open season (October to May in most areas). Such gears include dais, fences with traps, and barrages. A dai is a stationary trawl or bagnet which filters the current, and is typically 25-45 m wide and 100 m long. Fences, up to several kilometres in length, are built across flooded areas or lakes to direct fish into traps. Barrages are smaller gears that block a stream and direct fish into traps.

The area of inland fishing lots in Cambodia was formerly 9,537 km^2, but in October 2000, as a result of conflicts between lot lessees and communities over access to fish (Gum, 2000), most lots - 56% of the area - were released for public access by a decree from the Prime Minister. The 82 remaining lots now cover 4,175 km^2 and provide lease revenue of about US$1.2 million per year.

Released fishing lots have been transferred to community fisheries, for which management is being promoted by the DoF, under a new Community Fisheries Development Office, which aims to improve management through broader participation of villagers. This work is aided by NGOs under an Asian Development Bank (ADB) loan, and by the MRC Fisheries Programme, but the task is huge. The actual measures to be implemented - e.g. closed seasons, gear restrictions, conservation zones, habitat management and stocking - can conserve fish stocks, but all cause hardships to individuals. To be effective, implementation requires education, consultation and enforcement. The dominance of migrating fishes causes particular ownership problems, because fish conserved in one area may be caught when they move to another area.

The relative merits of large commercial lot-based fisheries versus community-managed fisheries have been discussed by many authors (reviewed by Degen *et al.*, 2002; Gum, 2000; and McKenney and Prom, 2002). While the lot system tends to favour the rich and powerful, it provides revenue for the government and a potential mechanism for co-management with lot lessees, who have an incentive to conserve fish within lots, allowing them time to grow during the flood. The lots also provide stable jobs for many people, and for local fishers who sub-lease parts of the lots (Degen and Nao, 2000). The lot lessees have access to capital for boats and fishing gear, and to buy the equipment for processing and transporting the fish in good condition.

The debate over the relative merits of lots versus community fisheries will continue. Although eliminating lots provides an opportunity for villagers to better share the benefits of the fisheries, in the absence of management and enforcement of regulations such open access will lead to overfishing. Designated areas may be accessed by outsiders, causing conflict with communities and commercial fishers. Despite these difficulties, by April 2004 there were 329 community fisheries established throughout the country, and most have made some progress in implementing measures to conserve fish stocks (Kaing *et al.*, 2004). Experiences from Lao PDR suggest that community fisheries management can be effective in conserving fish stocks, if ownership of resources is clear and the process is supported by the government (Baird and Flaherty, in press).

Aquaculture

The wild fishery in Cambodia has been so productive that there has been little incentive for development of aquaculture. Moreover, until recently, poor infrastructure limited the distribution of fish feed, fingerlings and the products of the industry. Cage-culture expanded greatly in the last decade; for example fish are held in hundreds of floating cages in the Great Lake and along the Tonle Sap and the Mekong near Phnom Penh. These fish are fed on the flood-recession excess of cheap wild fish, either directly or in fishmeal, which is one way of storing fish during times of

EIAs protecting the environment

All development causes positive and negative effects on the environment, which for large projects are usually assessed and managed through Environmental Impact Assessment (EIA) processes. In Cambodia EIA was established with the first law on Environmental Protection and Natural Resource Management in 1996, and the Sub-decree on the EIA Process in 1999. If implemented properly, an EIA assesses different options for a project, allows a determination of whether a project should proceed, and aims to enhance positive and to mitigate negative impacts. Negative impacts and their mitigation could include: hydrological impacts (mitigated by re-regulating ponds and riparian flows), poor water quality (mitigated by aeration, de-stratification and catchment management), and blocking of fish passage (mitigated by fishways and management of water gates).

The EIA process is managed by the Ministry of Environment (MoE). Fisheries biologists can be involved as consultants to developers, or as advisers to the MoE via a referral process.

Most environmental changes are caused by smaller developments which do not require an EIA, so other measures are needed to improve outcomes for fisheries. One approach to improving the outcomes of development is by implementing industry Codes of Practice (CoPs) which aim to achieve engineering objectives more cost-effectively and sustainably, and to mitigate negative environmental effects.

For example, typical surface drainage systems cause rapid flushes of water down streams, which lead to the need for further engineering of water courses to prevent flooding and erosion. Better engineering incorporates retarding basins and absorption drains to store runoff and reduce flood peaks, as well as planting of vegetation and catchment management to limit erosion and pollution and retard runoff. To mitigate impacts on fisheries, CoPs can be applied to most types of development, including irrigation or hydroelectric schemes, navigation improvements, road and culvert design, and forestry and land management.

Nam Ngum Dam, Lao PDR, has formed the largest Mekong Basin reservoir

Irrigation weir on the Stung Chinit, a tributary of the Tonle Sap. Built under the Khmer Rouge, this defunct weir will soon be rehabilitated and will incorporate a fishpass for migrating fish, and a continuous release of water to the river downstream

A small drop-structure, a barrier which with better design could allow migrating fish to pass

A nature-like fishway built to allow fish to pass a small weir in Australia, successful mitigation in practice

Threats to inland fisheries

Fisheries may be damaged by actions which change the environment, or by overfishing or illegal fishing. Among these threats, environmental changes are of most concern.

Environmental changes

Fish need water and habitats, and they need clear passage between habitats. So the main threats to fish production are activities that affect the natural hydrological regime, damage fish habitats, or restrict or prevent the movement of fish. Dams and flood control schemes in particular diminish river-floodplain fisheries, as they cause all of these impacts.

Large dams have had well-documented negative impacts on inland fisheries throughout the world (e.g. Goldsmith and Hildyard, 1993; Marmulla, 2001). Such impacts are also documented for some dams in the Lower Mekong Basin (e.g. Baird *et al*., 2002; Roberts, 1993; Watson and Schouten, 2001), but impacts from most dams have not been assessed. Dams create reservoirs that may support large fisheries, but the overall effect of large dams is usually a loss of fish production. Most dams store wet-season water so they delay and attenuate flooding, which reduces fish production downstream on floodplains. To generate peak-load hydroelectricity some dams release water in short-duration flushes each day, so rivers downstream are exposed to rapidly fluctuating flows unsuitable for most aquatic life. Downstream, fish spawn at the wrong time when they receive false stimuli from release water, or do not spawn at all. Fish eggs and larvae may be stranded by fluctuating flows or may not develop at the right time to enter the flooded nursery habitats with rising waters. Dams also prevent migrating fish from reaching the habitats they need to access for spawning or feeding. Dams trap nutrients and sediment, and may release deoxygenated stagnant bottom water which is toxic to fish and other aquatic life. Abstraction of water for other uses reduces the amount available for the fishery.

No major dams have been constructed in Cambodia, but there are at least 669 smaller dams (mostly flooding areas of less than 500 ha) which are used for irrigation and water supply (DoF, 1999), and their impacts on fisheries are unknown. Many large dams have been built in the upstream countries, and many more dams are planned for the coming decades. The total water storage in large Mekong dams was estimated at 2.5% of wet season flows in 1995, which would cause little reduction in flood levels (Kreuze, 1998), but water abstraction and ongoing dam construction in upstream countries is likely to progressively reduce flooding and associated fisheries production in Cambodia, as well as causing other impacts as mentioned above. In particular, damming of the Sesan-Sekong-Srepok System upstream of Cambodia is likely to progressively degrade this system, which is noted as a source of large fish and a spawning area for floodplain species. The first large dam, the Yali Falls Dam on the Sesan in Viet Nam, has caused economic, social and environmental impacts downstream in Viet Nam and Cambodia (RMR, 2000).

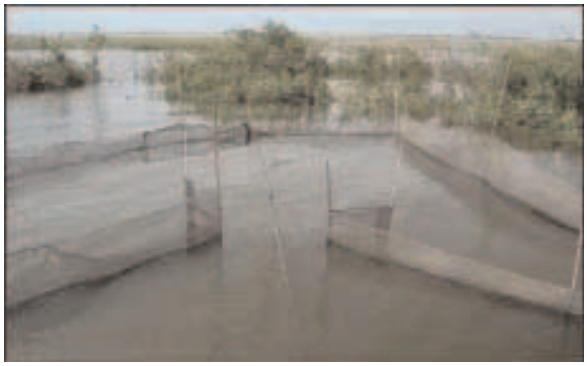
As well as dams, many other kinds of structures change hydrology. Irrigation and flood control schemes incorporate dykes and floodgates which restrict the access of fish to tributaries and the floodplain and so reduce fisheries production. Many such schemes have already been constructed in the Mekong Basin, with documented adverse effects on fisheries productivity and diversity (e.g. Suntornratana and Thalengkieaatleela, 1996).

Fishing pressure

Remnant waterbodies are heavily fished at the end of the dry season, in this case using traditional traps

A typical drift gill-net in the Tonle sap, catching many fish with little effort. Gill-nets are comon everywhere nowadays

Catches in the Tonle Sap dai fishery contain fewer and fewer large fish, like this *Cirrhinus microlepis*, trey p'roul



Nylon mosquito-netting is used widely on floodplains to make fences with traps, an illegal gear known as *say yoeun,* which catches very small fish of all species

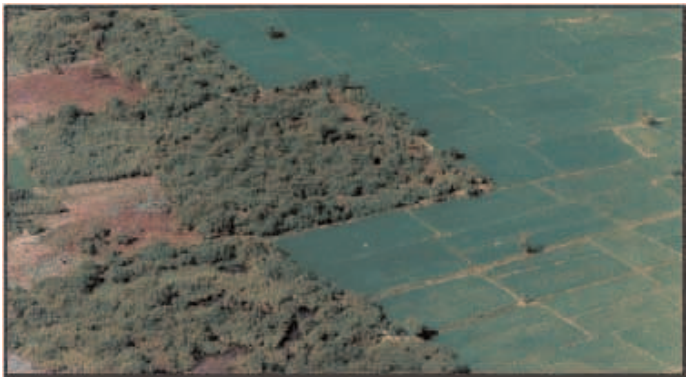
Catches in the dai fisheries near the Viet Nam border now comprise virtually all very small fish, due to heavy fishing pressure on floodplains upstream

Destruction of natural habitats also impacts fisheries. The flooded forests along rivers and around the Great Lake are being cleared for firewood and converted to rice paddies. As well as the loss of shelter for fish, the loss of forest increases soil erosion, causing silt to fill-in and simplify the habitat in waterways.

Water pollution has affected many river fisheries, but despite local impacts Cambodian rivers are not yet significantly polluted because industrial development is limited. Also, the large volumes of water greatly dilute wastes in Cambodian river systems.

People need improved roads and other infrastructure in floodplain areas, but increased accessibility facilitates destruction of valuable habitats, which reduces fish production. Measures are needed to limit impacts on the best fish-producing areas of floodplains. Navigation improvements also potentially affect flow patterns and the dispersal of fish eggs and larvae.

Introduction of exotic species causes irreversible alteration of the aquatic environment, so should be done with great care. Ironically, despite the high fish diversity of the Mekong System, much aquaculture depends upon exotic species, and a large aquarium trade also distributes fish which originate from many continents. About 17 exotic species are known to have established wild populations in the LMB (Welcomme and Vidthayanon, 2003). All these species potentially compete with, prey upon, or may transmit diseases to more valuable native fish. The Cambodian DoF recently prohibited aquaculture of one exotic species, the red-bellied pacu, *Piaractus brachypomus*, but without similar action in other countries, this ban cannot be effective in limiting its spread in the wild.



Ricefields replacing flooded forest near the Great Lake

The red-bellied pacu, *Piaractus brachypomus*, a member of the piranha family from South America

Overfishing and illegal fishing

Floodplain fisheries are extremely resilient to fishing pressure because floodplain fish have high reproductive rates, producing large numbers of rapidly-developing juveniles which colonise and grow in flooded environments. Most fish are destined to be killed by starvation, disease or predation each year when the flood recedes, as they are crowded into an ever-diminishing volume of water. Consequently, fishing which removes a large part of the stocks each year may have little or no impact on the catch in the subsequent year. As fishing pressure increases, larger predatory species are ‘fished-down’ first, allowing survival of their prey, which can then be caught by people, so the total catch increases (Figure 1).

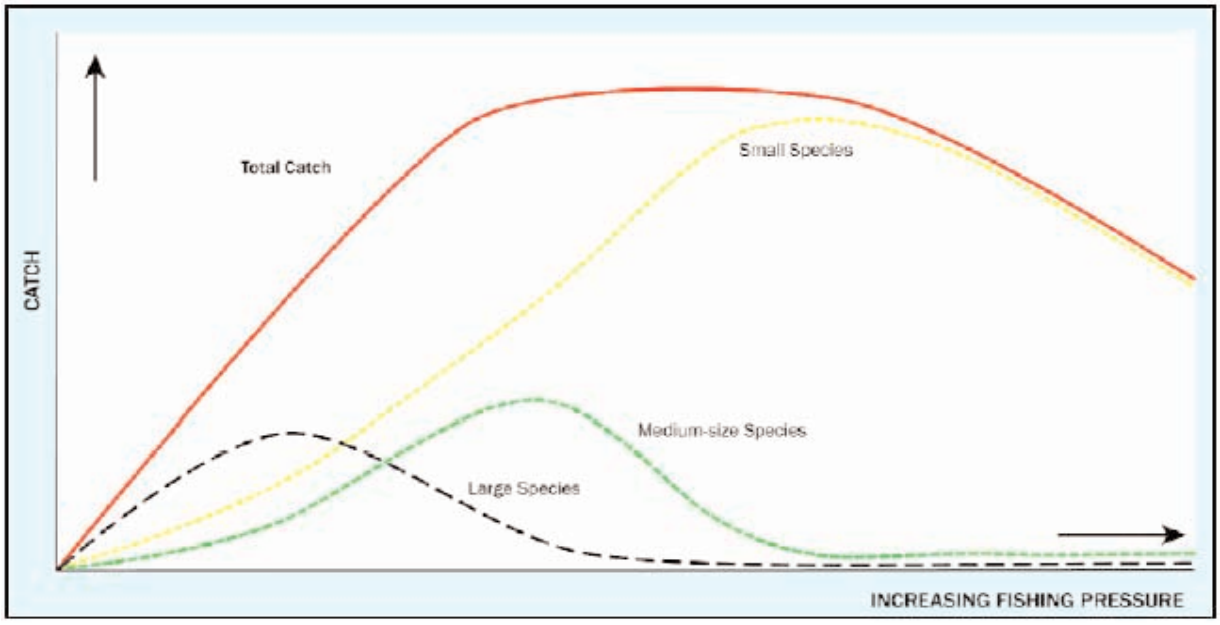


Figure 1. **How fisheries respond to fishing pressure.**
The larger and more valuable species are overfished first, but total production increases despite increasing fishing pressure, as more medium-sized and small fishes are caught.

Increasing fishing pressure can be caused by more fishers, use of more or better gears, or both. In Cambodia the number of fishers increased greatly between the 1940s and mid-1990s, and the amount caught by each fisher fell, although the total catch actually increased (Table 3). So it is primarily the increasing number of people fishing which has led to lower individual catches.

Table 3. **Changes in population size and fish catch in the Great Lake, Cambodia, between 1940 and 1995-96**
(Data from van Zalinge, Nao and Sam, 2001).

Period	Fishing commune inhabitants (11.2% of total popn)	Great Lake fish catch (tonne)	Fish catch / fishing commune inhabitant / year	Decline in catch / fisher
1940	0.36 million	125,000 t	347 kg	
1995-6	1.20 million	235,000 t	196 kg	44%

Over the last decade, fishing gear has become much cheaper and more efficient. Formerly, most people used traditional gears which were time-consuming to make and could only be used over relatively small areas. Two kinds of gear are largely supplanting traditional gears: nylon monofilament gill-nets and fine-mesh fences with traps. Nylon monofilament gill-nets have become widely available and are very cheap. They are highly efficient for catching a wide range of species and can be set and left untended to fish continuously. The Fisheries Law limits gill-nets for personal use to 10 metres in length, but most nets are 50 metres or longer. A typical 50-metre net retails for $3-5, a cost that may be recovered in less than a day in some areas, so now most families living along waterways own many gill-nets. There are many thousand of such nets used each day in Cambodian waterways, forming a 'wall-of-death' for migrating species. Fine-mesh fences with traps (*say yoeun*) are another type of gear made from a modern material, plastic mosquito netting. A wall or fence of netting is set across flooded areas to direct fish into a trap, also made of mosquito netting. These illegal gears are also very cheap; the mesh sells for about US$0.50 per metre, so a typical gear with a 50-metre fence costs less than $30, an outlay that may be repaid in a few days. These gears prevent fish from moving across the floodplain and catch very small fish of all species before they can grow, thereby reducing the total catch each season. Much of the catch of very small fish is sold to feed snakeheads held in cages. About 5 kg of feed is required to produce 1 kg of snakeheads, so much of the catch from this fishery is wasted.

Electrofishing, poisoning and use of explosives are illegal fishing methods, but all are widespread and add to fishing pressure, as well as killing non-target species and damaging habitats.

Some researchers believe many fisheries in Cambodia are already overfished (e.g. Touch and Todd, 2001), but is there hard evidence for overfishing? The only accurate long-term monitoring data on catches are from the Tonle Sap dai fishery (Hortle *et al*., 2004b). These data support the idea that fish production depends primarily on the extent of flooding (Figure 2), because the annual catches 1995-6 to 2000-1 correlate well with river height, which is itself correlated with flood area. But over the last three years catches have declined below the levels which would be predicted from flood heights, with the catch for the 2003-2004 season being the lowest on record. Thousands of additional people using more gear are fishing each year, so it is not surprising that catches from the dais are decreasing, if only as a result of competition with other fishers.

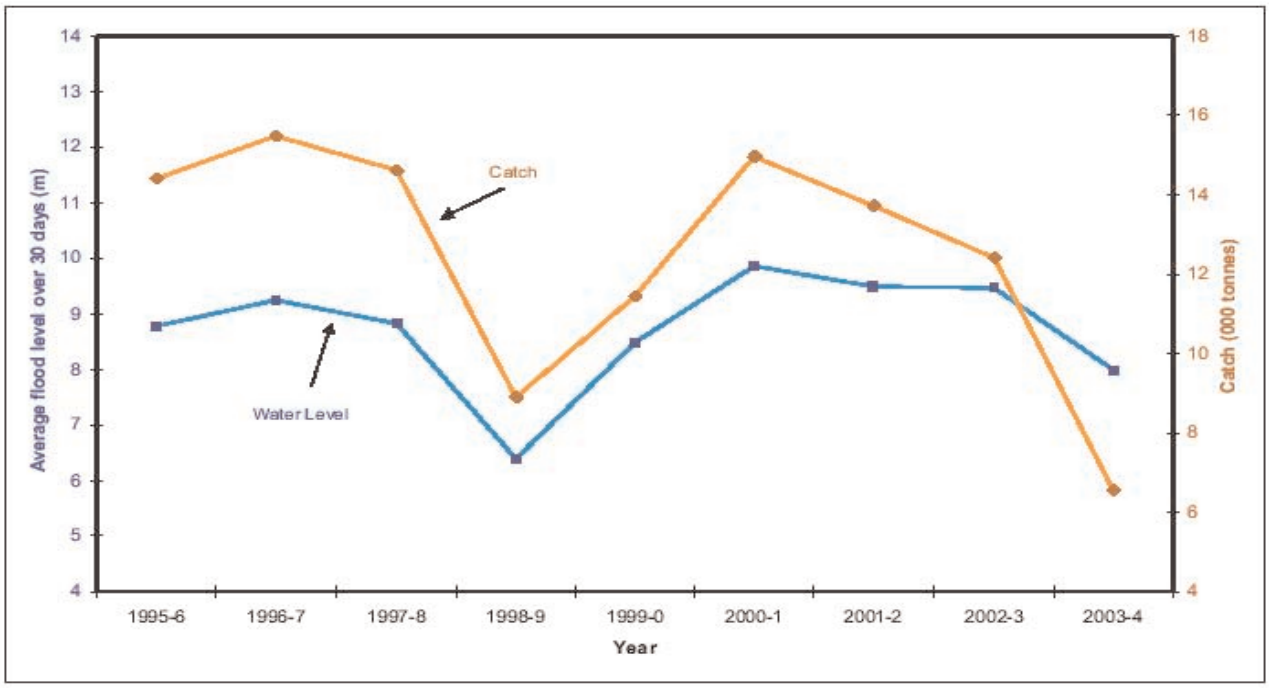


Figure 2. Catches in the Tonle Sap dai fishery
The graph shows the positive relationship with water levels and the recent decline in catches

However, the contribution of very small species to the catch has increased, and the average size of these small fish has also declined, both signs indicating overfishing in this intensively-fished area.

Management measures are urgently needed to prevent overfishing and to protect aquatic habitats. A recently formulated General Fisheries Plan for the Tonle Sap system - prepared under ADB funding - aims to address this need (ADB, 2002; ADB, 2003). Further research on fisheries and management is being carried out by the DoF. The Mekong River and its tributaries in upper Cambodia are still comparatively under-fished, but pressure continues to increase and management is also needed, particularly as this area contains many large fish which are the broodstock for production of the fish larvae and fry that drift downstream to colonise flooded areas.

Conclusions

With an annual fish harvest of at least 400,000 tonnes, and a significant harvest of other aquatic animals, Cambodia's inland fisheries are of overriding importance to the livelihoods of rural people and to the national economy. Because many fish stocks are shared with neighbouring countries and because many fishery products are exported, Cambodian fisheries are of regional importance.

Fishing pressure in the country is generally high and increasing. Larger and more valuable fish species are becoming less abundant in catches, but for most species this trend is reversible as long as adequate habitats are available. Fisheries management needs to be improved to reduce the impacts of illegal fishing and overfishing. In particular, the larger fish - the broodstock - in critical upstream habitats need to be conserved so they can spawn to maintain catches downstream.

The waters of the Mekong and its tributaries could be put to many uses: irrigated agriculture, potable domestic supply, hydroelectricity production, navigation and fisheries. In Cambodia, fisheries production is primarily from the wild capture fishery. Developments in other sectors will become increasingly common in the future and the wild fishery is likely to decline as a consequence. Actions to mitigate and manage the impacts of water management projects will minimise this decline; such actions depend upon an effective engagement of fisheries managers with planners in other sectors. Only through this approach can we have truly sustainable development for the people using the resources of the Mekong.

The following specific suggestions are made from the viewpoint of management of Cambodia’s inland fisheries, but they also need to be considered in the context of overall development of the resources of the Mekong.

- All sectors should cooperate in integrated water resources management.
- Development planning should recognise the value of fisheries and their importance in the livelihoods of Cambodians.
- Environmental Impact Assessments should consider all options for development, as well as the costs and benefits of competing uses of water.
- Plans for water management projects should include consideration of sustaining, and where possible, increasing fish production.
- The main elements of the flooding cycle and important fish habitats should be maintained where possible; if water management projects are designed to reduce flood levels then the consequences for fisheries production should be appraised and appropriate substitutes for livelihoods and income for those affected should be available.
- Any evaluation of dams proposed for the Mekong mainstream and major tributaries should consider the consequences for fish migrations and floodplain production downstream, and should recognise that impacts could not be fully mitigated.
- Mitigation measures should be incorporated in the design and operation of dams, including low-level weirs; these could include fish passes, maintenance of riparian flows, re-regulation of discharges and measures to improve water quality.

- Communities should be empowered to manage and conserve fish at a local level and deal with illegal fishing practices and habitat destruction.

- Fish habitats on floodplains should be enhanced; for example by maintainingor creating dry-season refuges and channels for migrating fish.

- Dialogue should be maintained between LMB countries on mitigating transboundary impacts from water management projects, fishing activities and exotic species, both up-and downstream of Cambodia.

More information is required on the ecology, value and importance for livelihoods of Cambodian fisheries. But enough is known to provide clear directions for management of the country's inland fisheries. It is time to adopt an integrated approach to conserving and enhancing fisheries for the continuing well-being of Cambodia and its neighbouring countries.

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