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Tagging fish — a case study from the Tonle Sap, Cambodia

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Summary

The Mekong River system supports one of the world's largest and most diverse inland fisheries. It includes a broad assortment of operations, ranging from solitary fishers to large-scale commercial enterprises. The catch contains a high proportion of fishes whose life-cycles involve migrations between feeding and spawning grounds and dry season refuges. The preservation of the river's fisheries, therefore, partly depends on keeping the migration routes these fish use free from obstructions and barriers that could critically disrupt their life-cycles. However, the details of these migration routes are not well understood.

Accordingly, many of the fish biologists who work in the Lower Mekong Basin now focus their research on understanding the migratory behaviour of the Mekong's most commercially important species of fish. Their research relies heavily on local ecological knowledge (LEK) gathered from fishers rather than data obtained from conventional 'tag-and-recapture' methods, which, they argue, will be ineffective in a species-rich, heavily-fished system, such as the Mekong. However, data from LEK studies may be misleading, because the 'migration waves' that fishers observe, can result from several phenomena, and in some instances they may even be artefacts. Therefore, this study set out to test if 'tag-and-recapture' methods will work in the Mekong River system. It also investigates whether the method can be used to supplement, and possibly validate, information acquired during LEK surveys.

In all, 15 species of migratory Mekong fish (total number = 2825) were tagged and released between October 2003 and January 2005. The fish were caught in commercial *dais* (stationary trawls) in the Tonle Sap River, a tributary of the Mekong. Local fishers, operating gillnets along the main river systems up- and downstream of the tagging site, were paid for the tags they recovered and returned. As of March 2005, the tag-return rate was 16% (total number = 445). The high rate of returns shows that fishing pressure is very severe in this system.

Most of the returned tags were taken from fish that were recaptured within five kilometres of the tagging site. However, tags were returned from seven species of fish that had travelled more than 5 km and four species of fish that had migrated over 100 km. These recaptures provide hard evidence of long-distance migration. Indeed, three species of fish, *Pangasianodon hypophthalmus*, *Pangasius larnaudiei*, and *Probarbus jullieni*, were recaptured as far away as Viet Nam. The study also confirms some of the information about migrations that previous workers had obtained during interviews with local fishers. In particular, it provides confirmation that many species of fish migrate out of the Tonle Sap system and into the main-stem of the Mekong during the dry season.

The study demonstrated that tagging is a viable, and useful, method for recording fish movements and migrations in the Mekong River system, providing, that is, the tagging sites and the fish tagged are chosen with care and that fishers are given suitable incentives to return tags and to record accurately the time and the location of fish-recaptures.

KEY WORDS: Mekong; Tonle Sap River; Tonle Sap Great Lake; fish-tagging; migration

1. Introduction

Migration is a key factor in the life-cycle of many Mekong fish species. These migrations typically take three forms: (i) movement from a flooded (wet season) habitat to the main river channel; (ii) movement of adults up and down the main river channel and (iii) migration of young fish downstream. Poulsen *et al.* (2002) recognised three distinct migration systems in the Lower Mekong Basin:

1. The Lower Mekong Migration System; from the Khone Falls, in Cambodia, downstream to the mouth of the Mekong in Viet Nam. It also includes the Tonle Sap system.

2. The Middle Mekong Migration System; from just above the Khone Falls upstream to the Loei River in Thailand, including the major tributaries, the Mun, Songkhram, Xe Bang Fai and Hinboun rivers as well as a number of other, smaller, tributaries.

3. The Upper Mekong Migration System; from the mouth of the Loei River upstream towards the border between Lao PDR and China.

Other migration patterns, such as those involving anadromy (fish migrations from the sea to the river), occur in the Mekong but appear to be rare (Hogan *et al.,* 2004).

Identifying migration patterns and the cues that trigger migration are two of the most immediate challenges facing biologists who study Mekong fishes (Hill and Hill, 1994). There already is some evidence that many fish that are native to the Mekong migrate long distances. Baird *et al*. (2004) documented regular, seasonal, fish movements over the Khone Falls in southern Lao PDR; Lenormand (1996) described changing seasonal fish distribution and abundances in Viet Nam; Ngor (1999) observed seasonal fisheries for drifting fry in central Cambodia; Hogan *et al.* (2004) provided evidence of long-distance migration from the South China Sea to Lao PDR; and Poulsen *et al.* (2000) conducted local knowledge surveys (LEK) to gather basin-wide information about fish migration patterns.

While these studies show that over 30 species of commercially important fish migrate long distances, there is little or no information on the remaining 74 per cent of species that are known to live in the Mekong (Baran, 2006). Furthermore, much of what is known comes from interviews with local fishers. While LEK is valuable data, it is limited to the factors that these fishers can observe and that are important to their livelihoods, such as the size and composition of their catches, the habitats and localities that particular species prefer and the flow of the river. They do not record the movements of individual fish. Therefore, LEK surveys cannot provide conclusive information on fish migrations, because the features that they record, such as apparent ‘migration waves’ (abundances of fish at particular times and places), may be accounted for by several other phenomena (such as fishing effort), or may even be artefacts.

Nevertheless, migrations are critical passages in the life-cycle of many species as they move between feeding grounds, spawning grounds and dry season refuges. Clearly, any disruption

of these migration routes, or obstacles placed in the path of migrating fish, will disrupt the life-cycles of fish with unknown consequences on fish stocks and the people who depend on fishing, or associated industries, for their livelihoods. Therefore, detailed knowledge of fish migrations and their migration routes is needed to help manage the development of the Mekong's water resources in ways that will not harm the river's fisheries. However, information on fish migrations at the level of detail needed to do this is not yet available. This is largely because tracking fish movements in an extensive, and complex river system, such as the Mekong, is difficult.

'Tag-and-recapture' is a standard method fish biologists use to record the movements of individual fish. However, until recently fish biologists researching into the behaviour of fish in the Mekong have been reluctant to use this method. They felt that, whilst tagging itself was straightforward, it was unlikely they could recover a statistically meaningful proportion of the tags from the large population of Mekong fishers who potentially could catch the tagged fish.

This report documents the results of a tagging programme undertaken in the Tonle Sap River between October 2003 and January 2005. One of the programme's objectives was to validate the results of the LEK studies conducted by Poulson *et al.* (2000) and other researchers. Another was to test the effectiveness of external plastic tags and the willingness of local fishers to return tags from recaptured fish.

There are a number of reasons why the Tonle Sap is a suitable location to test the tag-and-release method. Firstly, many fisheries, particularly the large *dai* fisheries, that operate in this stretch of the river system use bag-nets rather than gillnets as their major gear. These bag-nets catch fish alive and in good condition and as a result post-tagging mortality is comparatively low. Secondly, the bag-net fisheries catch a wide variety of fish species, allowing researchers to tag a diverse range of fish at one time. Finally, although it was not an original objective of the exercise, the percentage of returned tags gives an indication of the level of exploitation in the Tonle Sap; a river that contains one of the most important fisheries in the Lower Mekong Basin.

2. Materials and methods

We bought fish for the tagging study from commercial bag-net operators who work the Tonle Sap River. This bag-net fishery, which is located in the southern-most stretch of the river (Figure 1), comprises 14 rows. Each row contains between one and seven nets. Each individual net is cone-shaped, being 25 metres in diameter at the mouth and 120 metres in length. Almost all the fish we tagged during this study were collected from bag-net row numbers two, three, and four, which are approximately 4-6 km upstream of Phnom Penh. The bag-net fishery is a large seasonal fishery that targets fish moving out of the Tonle Sap Great Lake (Hortle *et al*., 2005), making it an appropriate source of fish. With the cooperation of the bag-net operators, we were able to collect, tag, and release fish with ease.

Figure 1. Location of the tagging site and the major rivers in the Mekong River system

The Tonle Sap River is a tributary of the Mekong River, connecting the Tonle Sap Great Lake with the main Mekong River. The flow of the Tonle Sap River is seasonal; from October to June water flows out of the Tonle Sap Lake and its tributaries, down the Tonle Sap River, and into the Mekong River. From about July to September (during the height of the rainy season), the flow of the river reverses and water flows from the Mekong River into the Tonle Sap Great Lake. Thus, the Tonle Sap Great Lake functions like a vast floodplain, and the Tonle Sap River connects this floodplain with the Mekong River.

Tagging and release took place during the October 2003–March 2004 and the October 2004–March 2005 *dai* open seasons. Fifteen species of fish were tagged in total (Tables 1, 2, 3 and 4). We chose these species on the basis of three criteria: (i) because we understood that they were migratory species; (ii) the availability of suitably sized fish, and (iii) the fish vendors'

willingness to sell the fish. However, as a result of this selection, the size distribution of the tagged-fish was not necessarily representative of the size distribution of fish in the total catch.

We collected fish either directly from the bag-net or, more often, from a holding cage adjacent to the bag-nets. Every effort was made to tag fish in good condition (we ignored those with cuts and abrasions) and to release fish downstream of the nets.

We attempted to tag mainly adult fish, but because of the scarcity of large fish, younger fish were also tagged. The minimum weight of tagged-fish was about 100 grams. Before tagging, we weighed each fish and measured its length. We tagged the fish with plastic disc and 'spaghetti' tags (Figure 2). These were applied, either manually or using a tagging gun, to the base of the dorsal fin, so that the nickel pin/T-bar attachment fixed firmly behind the dorsal fin rays of the fish (Figure 3). We labelled each tag with an identification number, instructions (in Khmer) to return the tags to the Department of Fisheries and the size of the reward for returning the tag. The tagged-fish were placed in fresh water for a short period, and then released approximately 50 metres downstream of the tagging site. On average, the tagging process, including the time necessary for the fish to recover and their release, took ten minutes per fish.

In order to gather information on returns, we interviewed Department of Fisheries staff and local fishermen once every ten days or so, starting from 1st February 2004. This report documents the returns up to the 1st April 2005, however surveys in selected parts of the Tonle Sap Great Lake, the Tonle Sap River, the Bassac River, and the Mekong River, are ongoing.

Figure 2. Study tags: red and green FD-68BC T-bar anchor tags and fluorescent yellow Peterson disc tags

Figure 3. Photographs of *P. larnaudiei* (top), *C. microlepis* (middle) and *C. siamensis* (bottom) with disc and T-bar tags

3. Results

A total of 1845 fish, belonging to 13 species, were tagged and released during the 2003–2004 bag-net fishery season (Table 1). By the 1st April 2004, fishers had returned tags from 243 fish that had been caught and tagged earlier that season (Table 2). This represents a recapture rate of 13 per cent. Fishers caught 209 of these within five kilometres of the release site (in the Tonle Sap River). Thirty-eight fish were caught more than five kilometres from the release site; one fish in the Tonle Sap River (upstream), 14 from the Mekong River downstream of Phnom Penh, 4 from the Bassac River downstream from Phnom Penh, and 19 from the Mekong River upstream of Phnom Penh.

Table 1. *Fish tagged and released, October 2003 to March 2004*

Species	Number
Pangasius larnaudiei	476
Cirrhinus microlepis	457
Cyclocheilichthys enoplos	277
Morulius chrysophekadion	185
Probarbus jullieni	121
Pangasius conchophilus	108
Pangasianodon hypophthalmus	108
Wallago attu	51
Helicophagus waandersi	29
Catlocarpio siamensis	17
Pangasianodon gigas	8
Chitala ornata	5
Boesemania microlepis	3
Total	**1845**

Table 2. *Recaptured tagged-fish, October 2003 to March 2004*

Species	Number
Pangasius larnaudiei	91
Cirrhinus microlepis	58
Cyclocheilichthys enoplos	14
Morulius chrysophekadion	15
Probarbus jullieni	26
Pangasius conchophilus	10
Pangasianodon hypophthalmus	21
Wallago attu	2
Helicophagus waandersi	1
Catlocarpio siamensis	0
Pangasianodon gigas	4
Chitala ornata	1
Boesemania microlepis	0
Total	**243**

Seven species of fish (*Pangasianodon hypophthalmus, Pangasius larnaudiei, Pangasius conchophilus, Cirrhinus microlepis, Probarbus jullieni, Morulius chrysophekadion* and

Cyclocheilichthys enoplos) were recaptured more than five kilometres from the release site Table 5). Recaptures of four species (*P. hypophthalmus, P. larnaudiei, C. microlepis,* and *M. chrysophekadion*) were reported more than 100 kilometres from Phnom Penh, all these were from the Mekong River upstream of its confluence with the Tonle Sap River. (Appendix 1 gives the recapture sites and the length distribution of individual species.)

In the case of four species, *Pangasianodon gigas*, *Catlocarpio siamensis*, *C. microlepis* and *P. hypophthalmus*, only adult specimens were caught, suggesting that these fish were undergoing a spawning migration. Catches of other species comprised fish of all age-classes.

An additional 980 fish, belonging to 11 species, were tagged and released during the 2004–2005 season (Table 3). During this period, fishers returned 202 tags (Table 4).

Table 3. *Fish tagged and released, October 2004 to March 2005*

Species	**Number**
Pangasius larnaudiei	524
Pangasianodon hypophthalmus	263
Probarbus jullieni	121
Morulius chrysophekadion	36
Pangasius bocourti	11
Catlocarpio siamensis	9
Pangasianodon gigas	6
Pangasius conchophilus	5
Lates calcarifer	2
Wallago attu	2
Pangasius krempfi	1
Total	**980**

Table 4. *Recaptured tagged-fish, October 2004 to March 2005*

Species	**Number**
Pangasius larnaudiei	87
Pangasianodon hypophthalmus	60
Probarbus jullieni	22
Morulius chrysophekadion	10
Cirrhinus microlepis[*]	9
Pangasius conchophilus	2
Pangasianodon gigas	2
Cyclocheilichthys enoplos[*]	1
Wallago attu	1
Unknown	8
Total	**202**

Note: [*] Species not tagged during 2004–2005

Interestingly, three species, *P. hypophthalmus*, *P. larnaudiei*, and *P. jullieni* were recaptured in Viet Nam (Table 6). Fishers also reported the recapture of some fish in the 2004–2005 season that were tagged the previous season. These included two species (*C. microlepis* and *C. enoplos*) that were not tagged at all during the 2004–2005 season.

Spreadsheets containing details of all the fish captured and tagged can be obtained by visiting the MRC web site at www.mrcmekong.org.

Table 5. *List of notable migrations in 2003–2004*

Species	Tag #	Tag Date	Recapture Date	Recapture Location
Pangasianodon hypophthalmus	1181	Nov 10, 2003	Feb 12, 2004	MU 300 km from PP
Pangasius larnaudiei	1201	Dec 4, 2003	Dec 27, 2003	MU 180 km from PP
Cirrhinus microlepis	00266	Dec 6, 2003	Jan 11, 2004	MU 150 km from PP
Morulius chrysophekadion	1938	Dec 22, 2003	Feb 1, 2004	MU 110 km from PP
Pangasius larnaudiei	1287	Dec 3-4, 2003	Dec 7, 2003	MD 63 km from PP
Cyclocheilichthys enoplos	1377	Dec 6, 2003	Dec 7, 2003	MD 63 km from PP

Note: MU = Mekong Upstream, MD = Mekong Downstream, PP = Phnom Penh. The recapture date is approximate, it may be the date that the tag was returned to the Department of Fisheries rather than the date that fishers caught the fish.

Table 6. *List of notable migrations in 2004–2005*

Species	Tag #	Tag Date	Recapture Date	Recapture Location
Pangasianodon hypophthalmus	2186	Oct 31, 2004	Dec 3, 2004	Angiang Province, Viet Nam
Pangasius larnaudiei	2730	Dec 3, 2004	Jan 14, 2004	Dong Thap Province, Viet Nam
Probarbus jullieni	2383	Dec 17, 2004	Jan 1, 2005	Dong Thap Province, Viet Nam
Morulius chrysophekadion	2214	Dec 18, 2004	Jan 24, 2004	MU 135 km from PP
Probarbus jullieni	2258	Dec 19, 2004	Jan 12, 2005	MU 135 km from PP

Note: MU = Mekong Upstream, MD = Mekong Downstream, PP = Phnom Penh. The recapture date is approximate, it may be the date that the tag was returned to the Department of Fisheries rather than the date that fishers caught the fish.

4. Discussion

Methodology

Poulsen *et al.* (2000) argue that conventional methods for studying migrations (notably fish tagging) are not appropriate for the multi-species fisheries of the Mekong. However, the results of our study indicate that in the correct circumstances, tagging can provide valid and useful information. Methods such as tagging may be the best way to validate LEK surveys and gather definitive evidence on the long-distance migration of Mekong fish.

Tagging should be conducted at sites that have a steady supply of fish and a reasonably well understood fishery — otherwise, there is a risk that the tagging operation will be inefficient. The high rates of recapture (16%) that we recorded may have occurred simply because tagged-fish are easy to catch, and the fisheries a short distance downstream of release-sites picked up most of the newly released fish. Therefore, every effort should be made to release healthy fish at locations where they can continue their natural migration. On the positive side, the high rate of recapture recorded in this study indicates that fishers were willing to report the recaptures to the DOF, allaying the concerns expressed by Poulsen *et al.* (2000).

We had hoped that the information provided by fishers would help shed light on other aspects of the life-cycles of fish, such as their growth rates. Unfortunately, many fishers were rather lax when recording information about the fish from which they returned tags. While an untrained fisher is likely to keep a tag, he or she is less likely to record other information about the tagged-fish, such as the date it was caught, the fishing gear they used and the length and the weight of the fish. Therefore, as long as the recapture programme relies on untrained fishermen to return tags, tagging will provide only limited additional reliable information.

Migrations

Our study focuses on the Lower Mekong Migration System, notably the migrations of fish from the flooded habitats of the Tonle Sap Great Lake to the mainstreams of the Mekong and Bassac Rivers. Poulsen *et al.* (2002) defined the Lower Mekong Migration System as the stretch of the river from the Khone falls downstream, through southern Cambodia (including the Tonle Sap system), to the Mekong Delta in Viet Nam. It also includes the Sesan – Sekong – Srepok system in northern Cambodia, Viet Nam and the Lao PDR.

The locations of the sites where fishers recaptured of nine of the most important fish species we tagged during the 2003–2004 season are given in Appendix 1. Of the fifteen species studied, four species followed the basic pattern described by Poulsen *et al.* (2002), that is they migrated out of the Tonle Sap River and up the Mekong River. These four species (*P. hypophthalmus, P. larnaudiei, C. microlepis,* and *M. chrysophekadion*) migrated over 100 kilometres within two months of their release. It seems likely that other species migrate similar distances as well, but due to the preliminary nature of these results, we were not able

to define clearly the movement patterns of all species, nor document the movement of fish between the Mekong and its tributaries in northeastern Cambodia. Nonetheless, our results indicate that Mekong species move long distances and utilise a variety of habitats, including floodplains/flooded forests, tributary streams, and the main river channels.

To summarise, individual fish of all the species we tagged moved down the Tonle Sap River and into the Mekong. Once in the Mekong, fish moved both up- and downstream, and fishers recaptured tagged-fish throughout the Cambodian Mekong, from Stung Treng to the Vietnamese border. The broad distribution of recaptures indicates that several species of fish migrate through the system, and that this behaviour is a critical activity in their life-histories. The large number of tag recaptures downstream of Phnom Penh (to the Vietnamese border) may indicate that this area is an important habitat for fish. Alternatively, the high recapture rate in this section of the river could be the result of either higher fishing pressure or injuries that caused fish to drift passively downstream where they were caught.

Giant and endangered species

Over the period of the survey, a large number of specimens of the 'Mekong's giant and endangered fish species' (Matson *et al.*, 2002) were tagged and released (Figure 4). However, none of these fish were recaptured upstream of the tagging site and none had made a long-distance migration. Several tagged Mekong giant catfish (*Pangasianodon gigas*) were

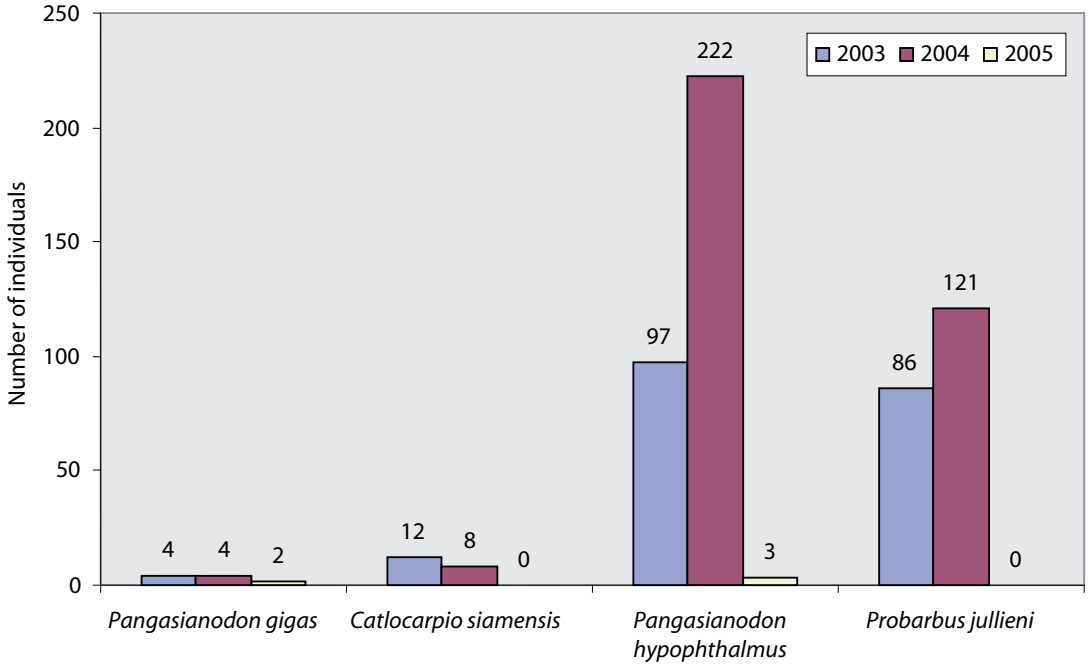

Figure 4. Threatened species tagged at bag-net row #2, 2003-2005 (as of 1st December 2005)

Note: Although *P. hypophthalmus* is not a threatened species it is a commercially important fish and there is concern that stocks of the species are suffering from over-exploitation — for this reason *P. hypophthalmus* is included on this chart. Large *P. hypophthalmus* were once a common catch throughout the Mekong and Chao Phraya Rivers, as well as in the Tonle Sap Lake and in the *dai* fisheries of the Tonle Sap River. Recently catches of *P. hypophthalmus* have declined dramatically — very few are now caught in the Chao Phraya or in the Mekong above Khone Falls. Fishers also report steep declines in catches of larval *P. hypophthalmus*.

recaptured downstream of the tagging site, but all of these fish were already dead when they were recovered.

There are several possible explanations for the low number of recaptures of giant fish. Firstly, relatively few giant fish were tagged. Secondly, giant fish seem more vulnerable to capture-stress and many die as a result of capture. And thirdly, large-bodied fish have a high market value, meaning that fishers likely view returning tags as less financially rewarding and more risky (relative to the overall value of the fish). Therefore, in future studies of large-bodied fish, efforts should be taken to ensure that fish are not injured during capture and recapture. In any case, the risk to the fish during tagging and recapture means that this method is probably not the best way to study the migratory behaviour of giant fish species.

Management and conservation

Because they are so important to the health of the Mekong's fisheries, fish migrations and migration routes are factors that decision makers, managers and developers should take into account when planing activities that may alter the natural condition of the river and its ecosystems. These activities include establishing fish conservation zones, assessing the potential impacts of dam constructions, drafting agreements on international water-resource management, implementing local control of fisheries resources, assessing fish stocks and modelling fish populations (Bartham and de Brito Ribeiro, 1991).

For example, the region of the Mekong River between Pakse, Lao PDR, and Stung Treng, Cambodia, has been designated as a Ramsar Wetland of International Importance[1]. This section of the river is thought to be an important spawning site for pangasiid catfish and other migratory species (Bardach, 1959; Roberts, 1993a; Roberts and Baird, 1995; Lenormand, 1996). However, protecting spawning habitats will do little to conserve catfish populations if the fish are over-exploited in rearing areas and along migration corridors. Similarly, 59 communities in southern Lao PDR have established local fish conservation zones to protect fisheries from over-fishing (Hogan, 1997), yet the effectiveness of these zones is doubtful because protected fish may migrate to other locations where they are harvested freely. Population modelling and population viability analyses are also difficult without knowledge of stock mobility (Burgman *et al.,* 1993). Finally, models of environmental flows that incorporate the impacts of dams and other human interventions are not realistic if they do not take into account fully the migratory behaviour and movement patterns of fish.

It is also important that planners recognise that the connection between the Tonle Sap Lake and the Mekong River and the reversal of the flow of the Tonle Sap River are vital to fish migrations and to the overall functioning of the riverine ecosystems (Lim *et al.,* 1999). Obstructing the connection between the Tonle Sap Great Lake and the Mekong River (via the Tonle Sap River) would likely block dry season migrations of adult fish out of the Tonle Sap Great Lake, and rainy season movement of young fish back into the lake (Roberts, 1993b).

1 The Ramsar Convention on Wetlands was signed in Ramsar, Iran, in 1971, providing a framework for the conservation and sustainable use of wetland environments. Cambodia has designated three areas as sites of international importance under the Ramsar Convention on Wetlands, including the middle stretches of the Mekong upstream of Stung Treng. This section of river is believed to be an important spawning habitat for several species of migratory fish.

Modification of the flow of the Tonle Sap River could disrupt the timing of migrations and the proper functioning of fishing gears, as well as altering the amount of habitat available to fish during the rainy season.

Finally, the rates of recapture we recorded, which reached 16 per cent during the 2004–5 season, were extremely high, particularly bearing in mind the huge size of the fishery and the large number of fishers who work this stretch of the Mekong. Although it was not one of the original objectives of the tagging exercise, this high rate of returns clearly shows the high fishing pressure fisheries in the Tonle Sap River (and in the adjacent stretches of the Mekong and Bassac Rivers) are under at this time.

5. Recommendations

1. The results of previous research, especially the LEK surveys of Poulsen *et al.* (2000), should be used as a starting point for future tagging studies. Tagging studies (and other common techniques for studying dispersal, such as genetic analysis and isotope studies) have a much greater chance of success when basic data already exists on the life-history of, and fisheries for, the target species.

2. The movement of fish out of the Tonle Sap Great Lake, down the Tonle Sap River, and into the Mekong River needs further study. This system is arguably the ideal site for studying the causes and patterns of movements of the majority of the migratory species that live in the Mekong River Basin.

3. The importance of the Khone Falls as a barrier to migration needs further investigation. While Poulsen *et al*. (2000) contend that the migration patterns of many species of fish differ above and below the falls, other researchers (such as Singhavong *et al.*, 1996; Baird *et al.,* 2001; Baird *et al.*, 2004) report that large numbers of fish move over the falls every year. Some of the species, such as the anadromous catfish *P. krempfi*, originate in the South China Sea and presumably migrate hundreds of kilometres to spawning grounds above the falls. The fishermen of Khone Falls are well-organised, friendly, and have been involved in previous studies of fish migration (Baird *et al.*, 2004). It is highly likely that they will cooperate with any future tag-and-recapture study.

4. The significance of deep pools in the life-cycle Mekong fishes should be examined in greater detail. Deep pools are believed to be important dry season refuges for over 60 species. The use of the pools during the dry season, as well as movement of fish out of the pools during the wet season, could be studied using tag and recapture techniques or underwater bio-telemetry.

5. The influence of flow on fish movement needs to be better defined (Singanouvong *et al*., 1996). Currently, almost no information exists on the effect of flow on fish behaviour and yet Poulsen *et al*. (2000) suggest that fish migrations can be categorised according to the time of year and the prevailing hydrological conditions. As mentioned previously, the Tonle Sap River system — most notably the commercial barrage and bag-net fisheries — provide a unique opportunity to record fish movements closely and to monitor the levels of exploitation of these fisheries.

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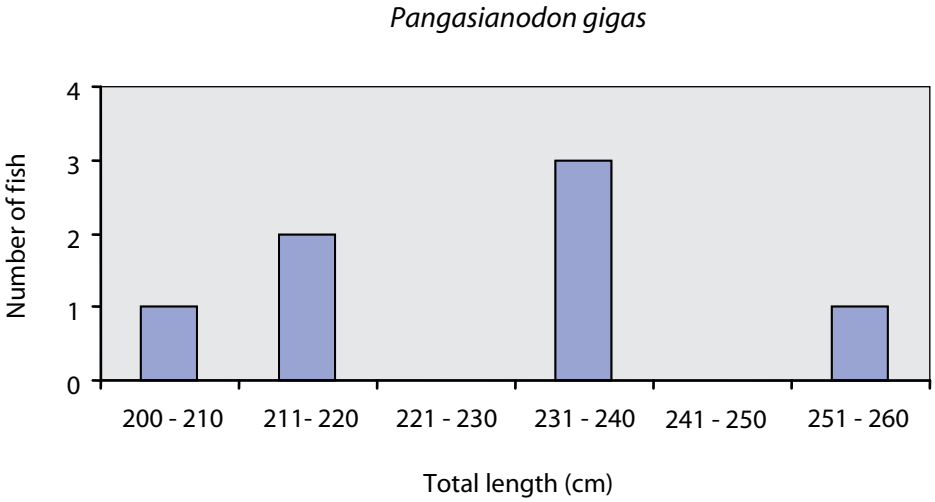
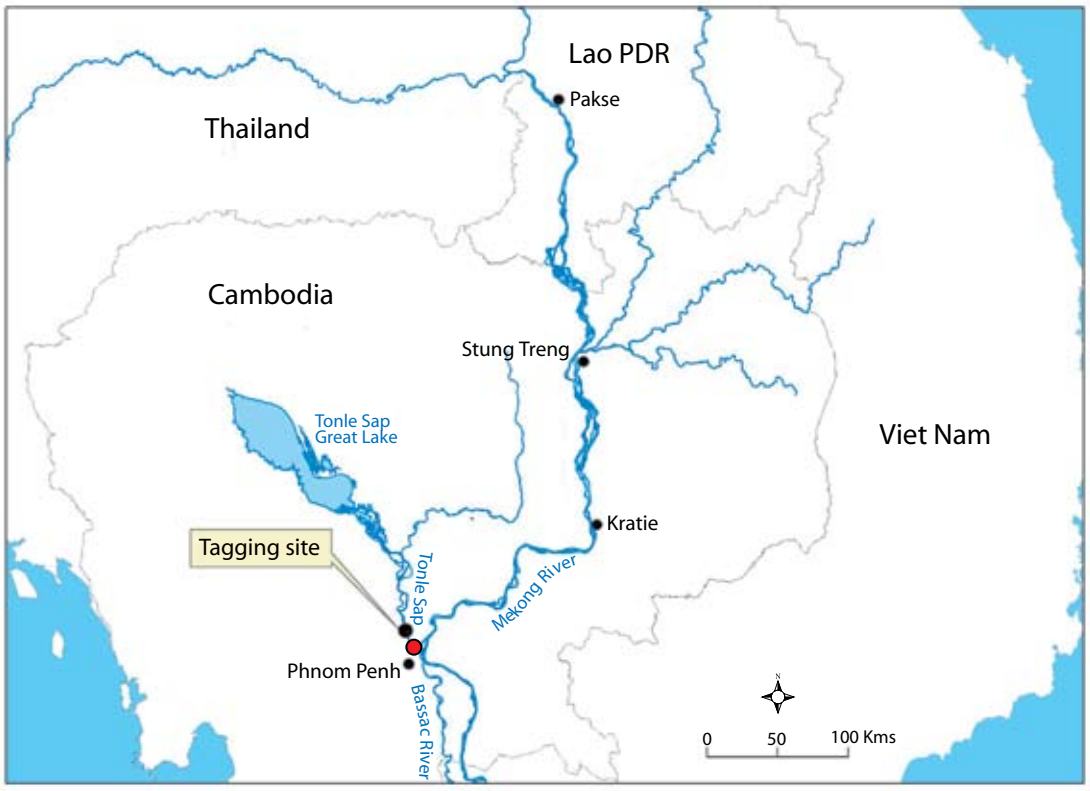
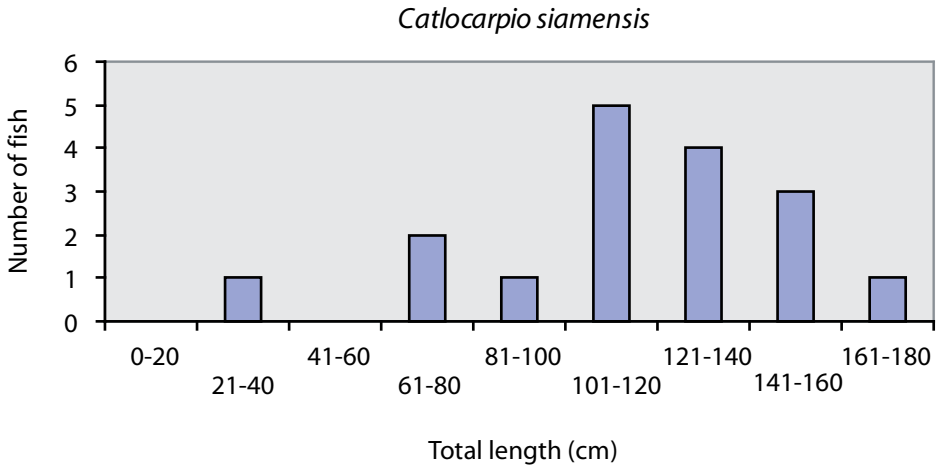
Appendix 1. Locations of the recapture sites of some significant species



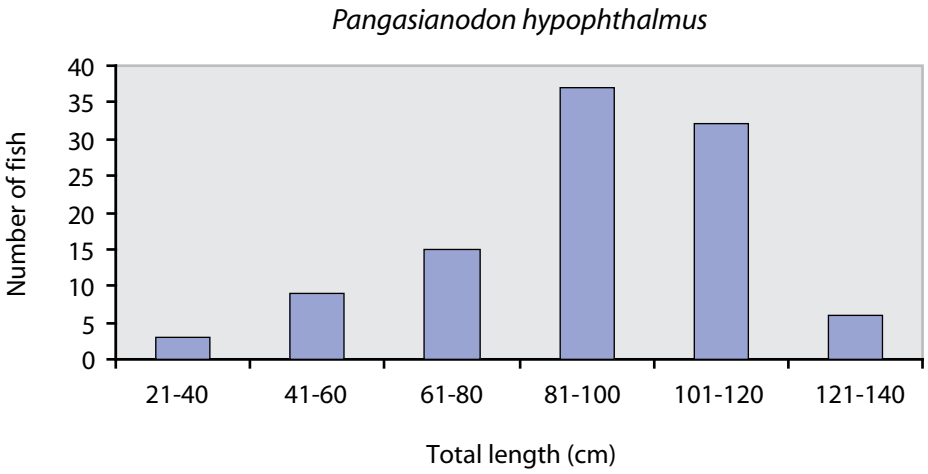
Length distribution of *Pangasainodon gigas* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



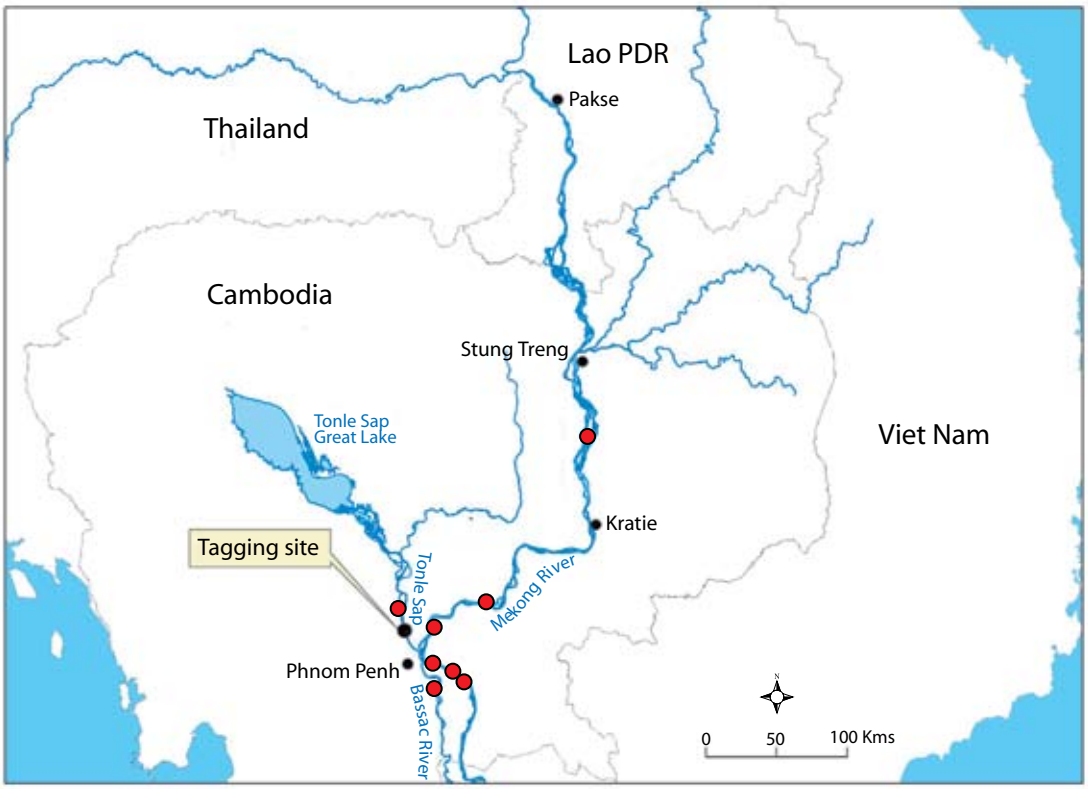
Location of recaptures of *P. gigas*, October 2003–March 2004



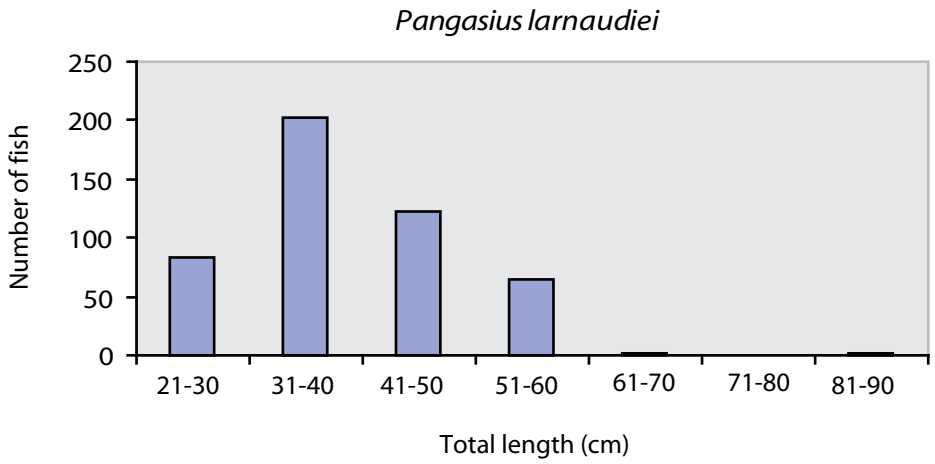
Length distribution of *Catlocarpio siamensis* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



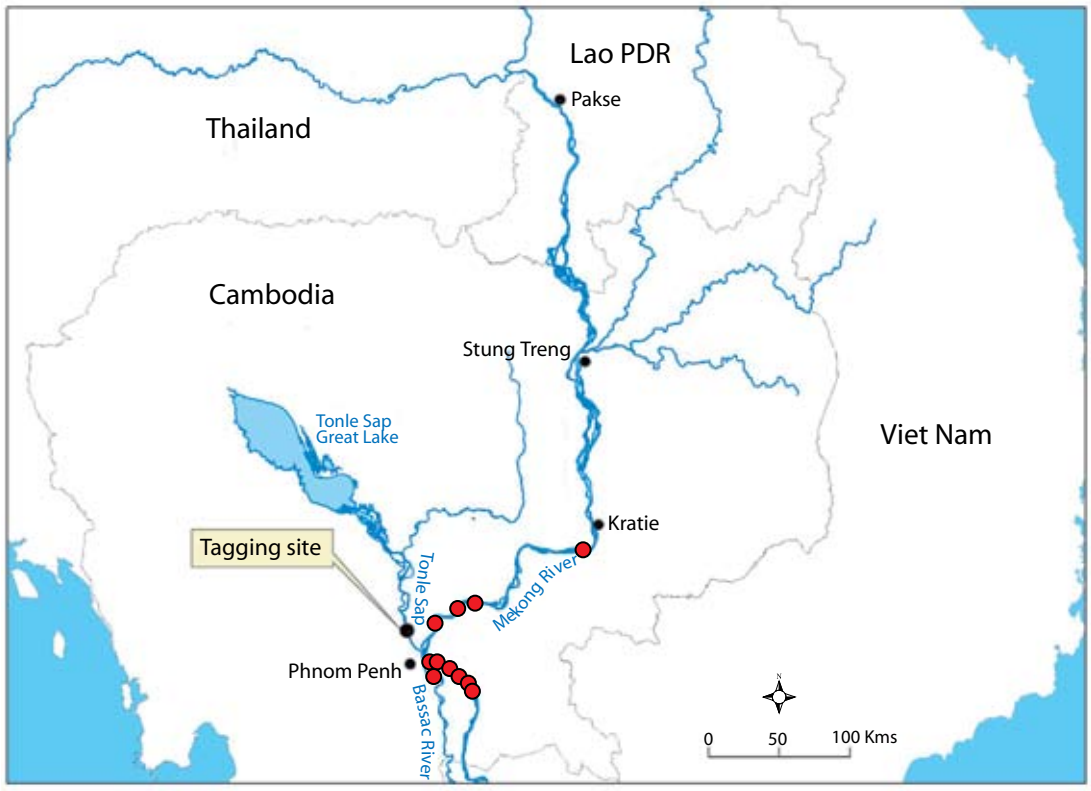
Length distribution of *Pangasianodon hypophthalmus* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



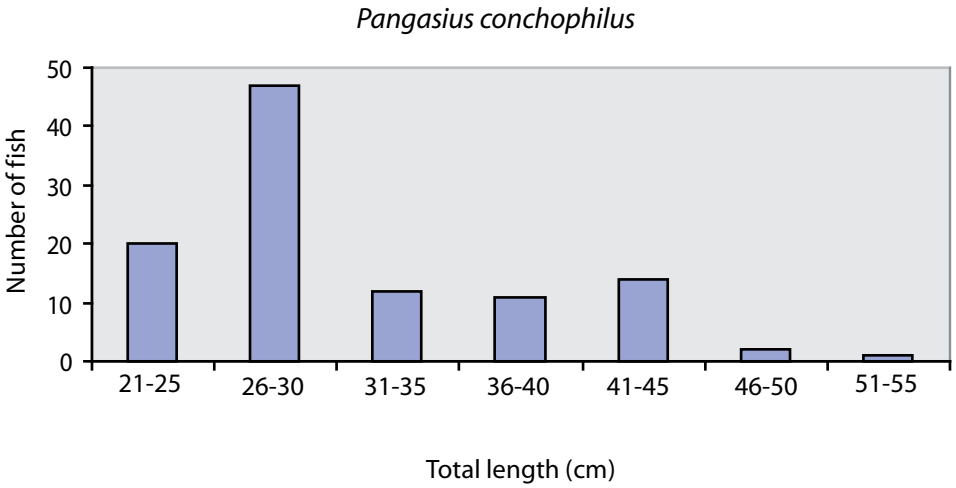
Location of recaptures of *P. hypophthalmus*, October 2003–March 2004



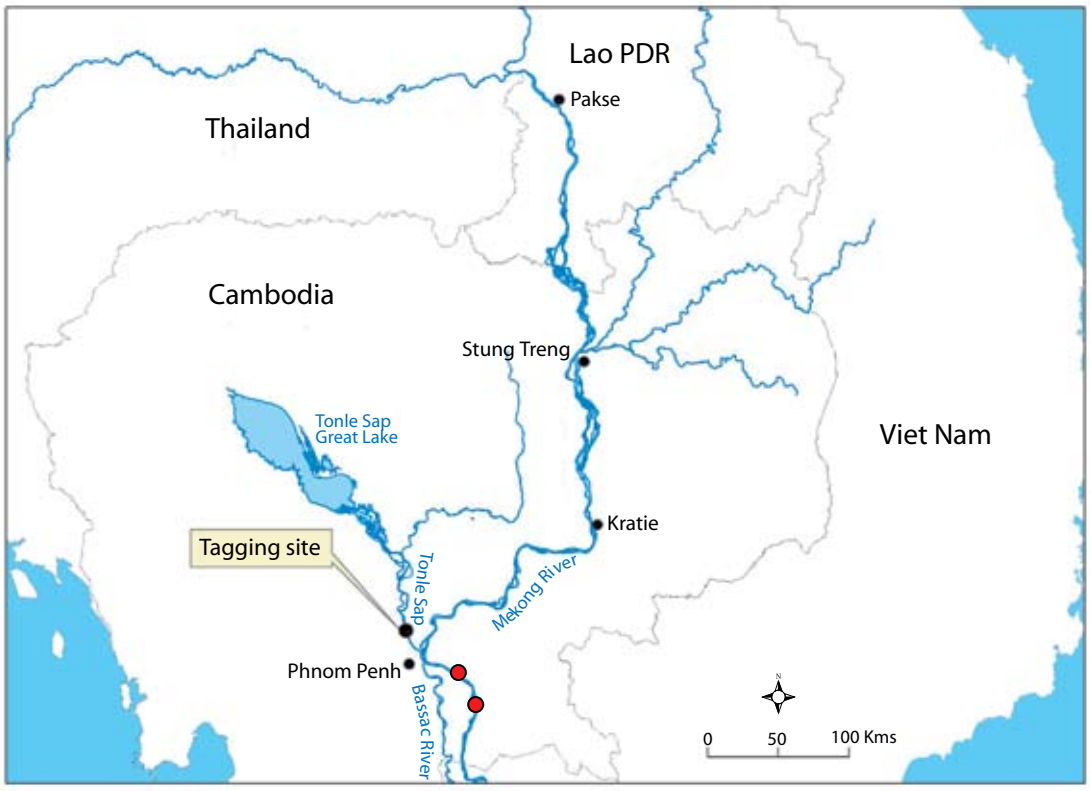
Length distribution of *Pangasius larnaudiei* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



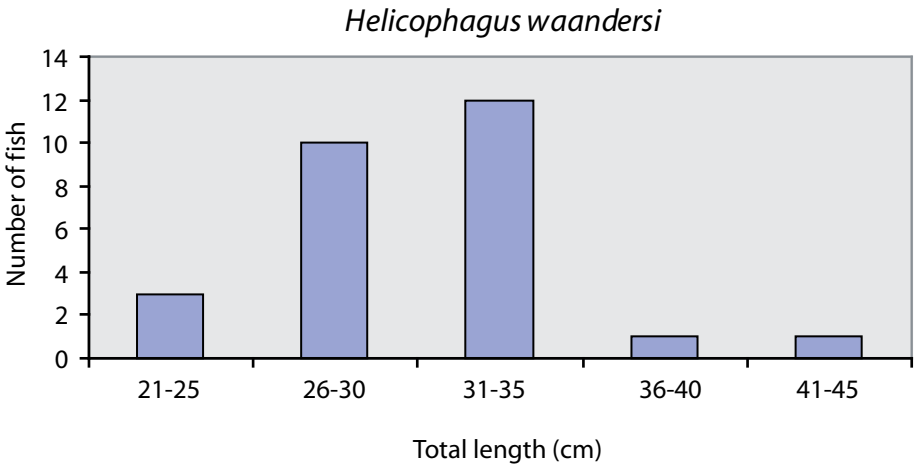
Location of recaptures of *P. larnaudiei*, October 2003–March 2004



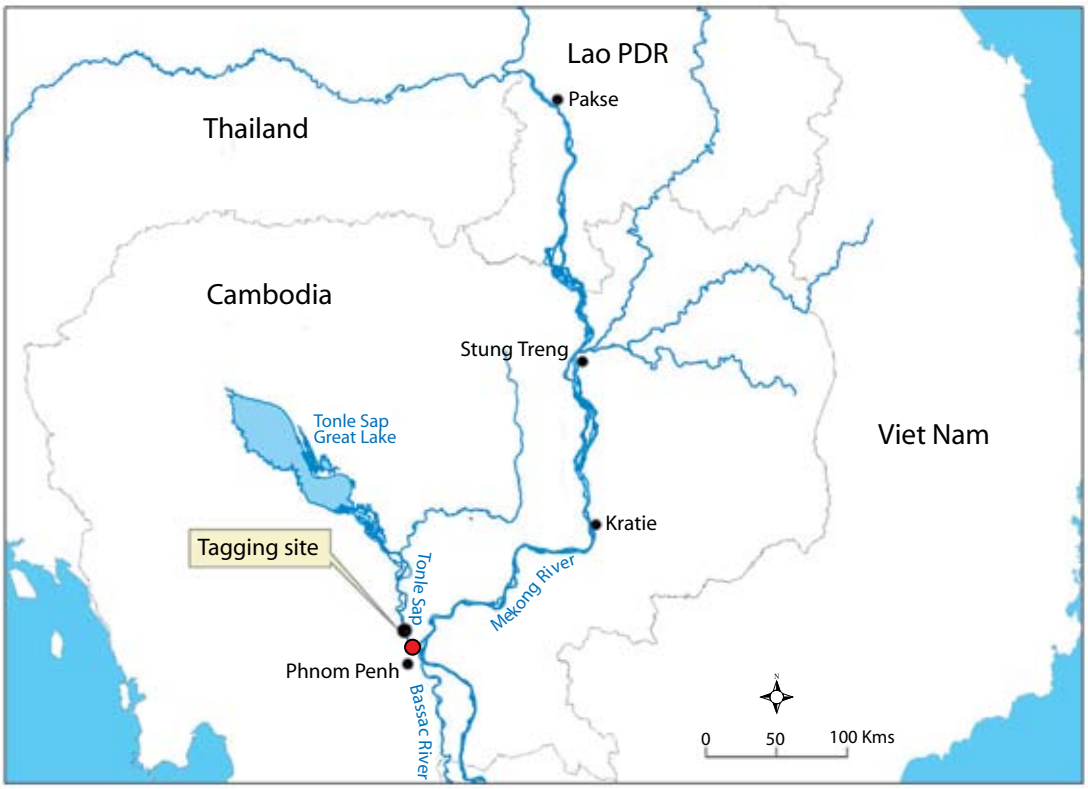
Length distribution of *Pangasius conchophilus* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



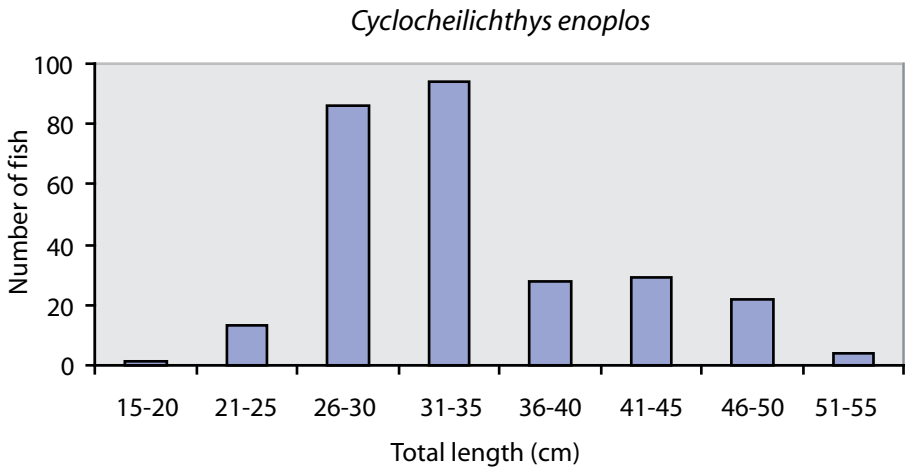
Location of recaptures of *P. conchophilus*, October 2003–March 2004



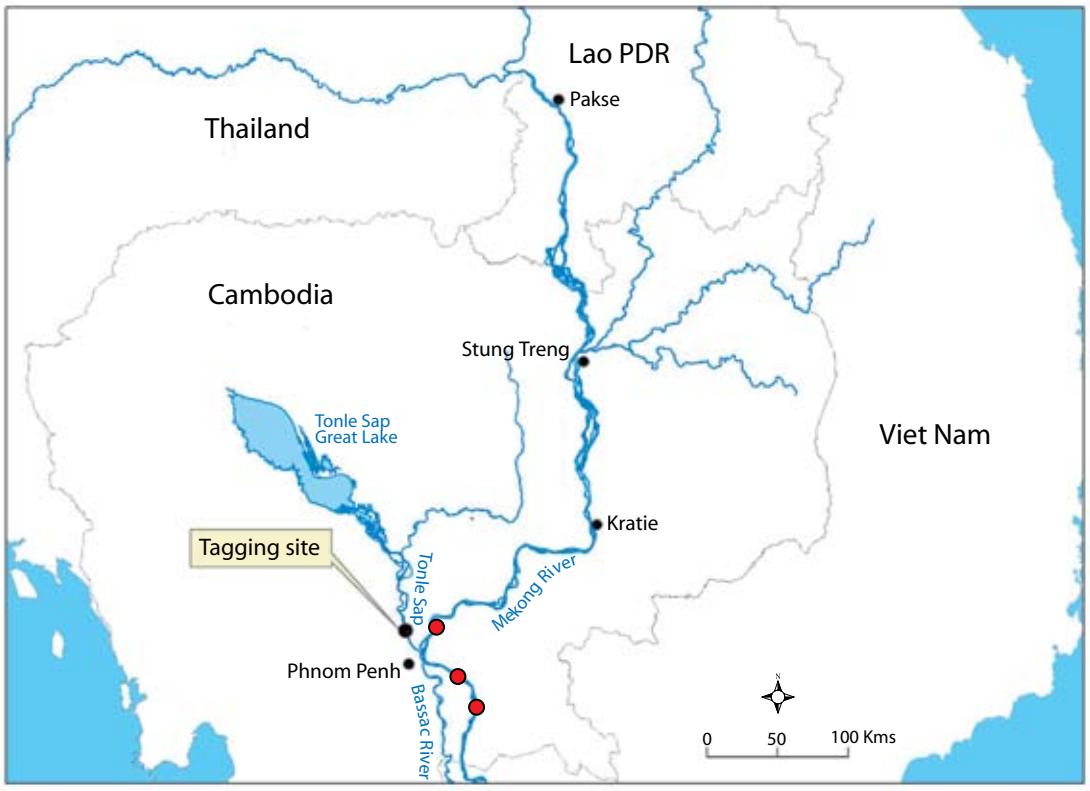
Length distribution of *Helicophagus waandersi* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



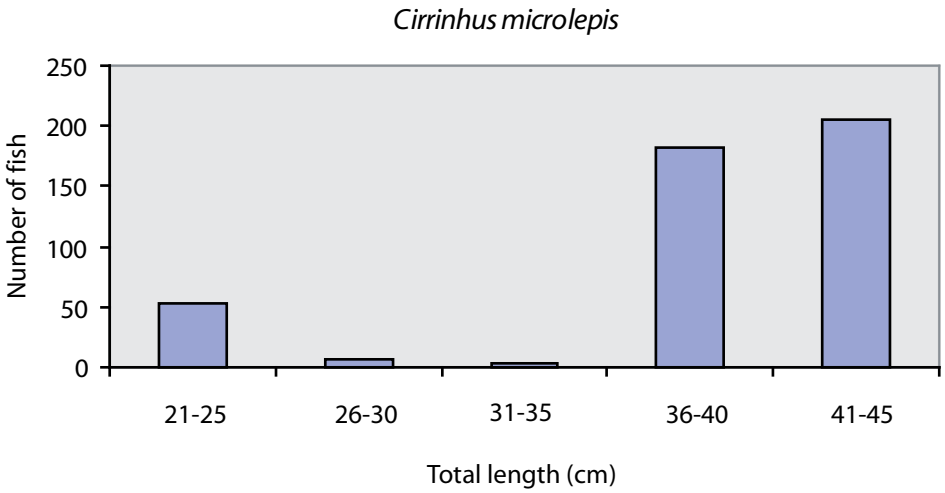
Location of recaptures of *H. waandersi*, October 2003–March 2004



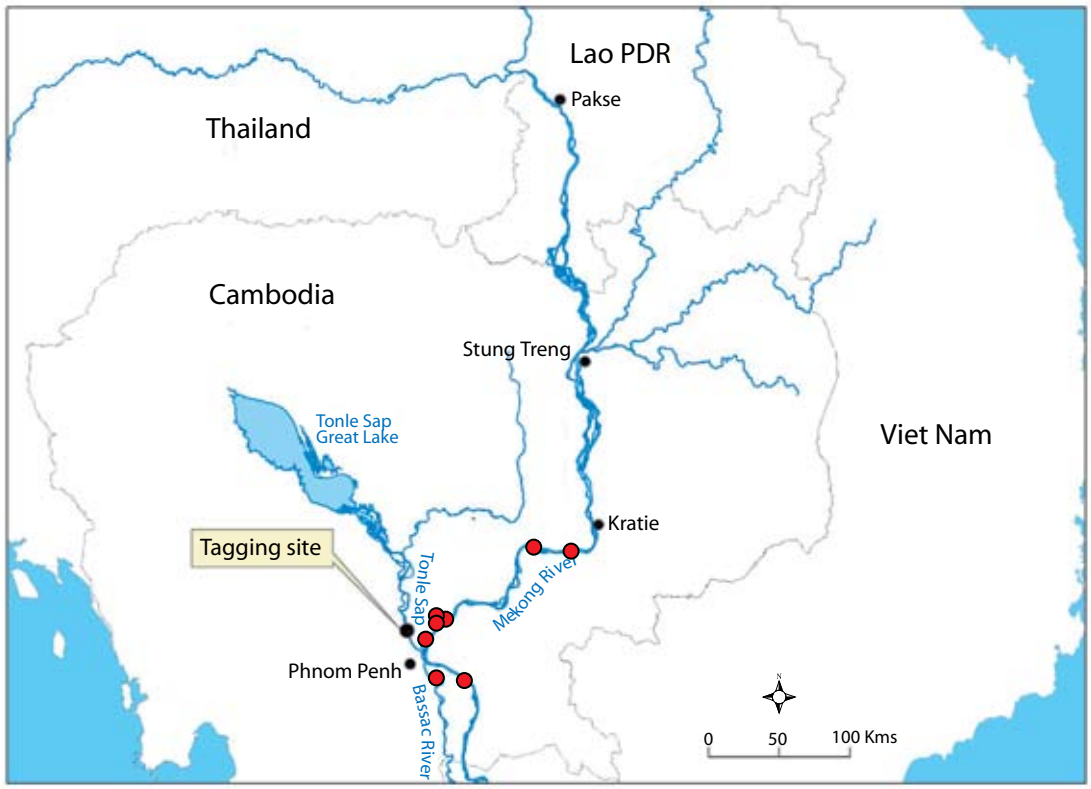
Length distribution of *Cyclocheilichthys enoplos* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



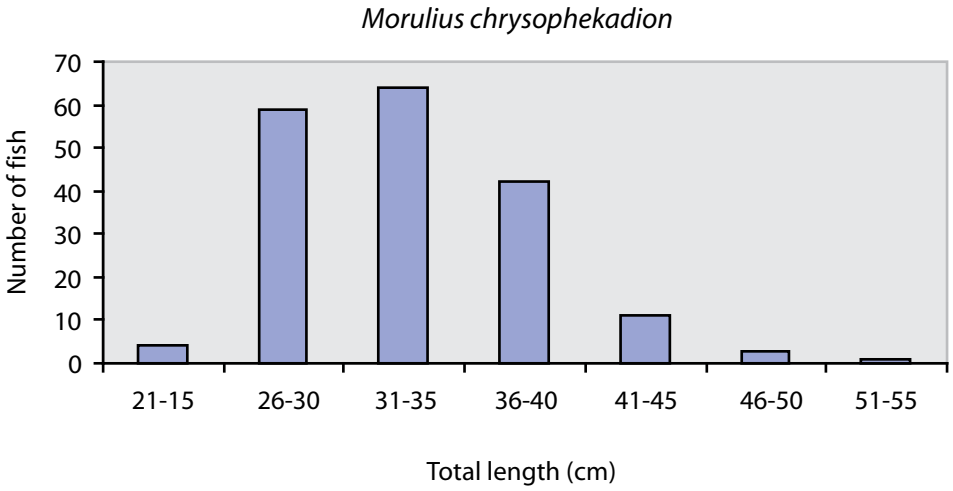
Location of recaptures of *C. enoplos*, October 2003–March 2004



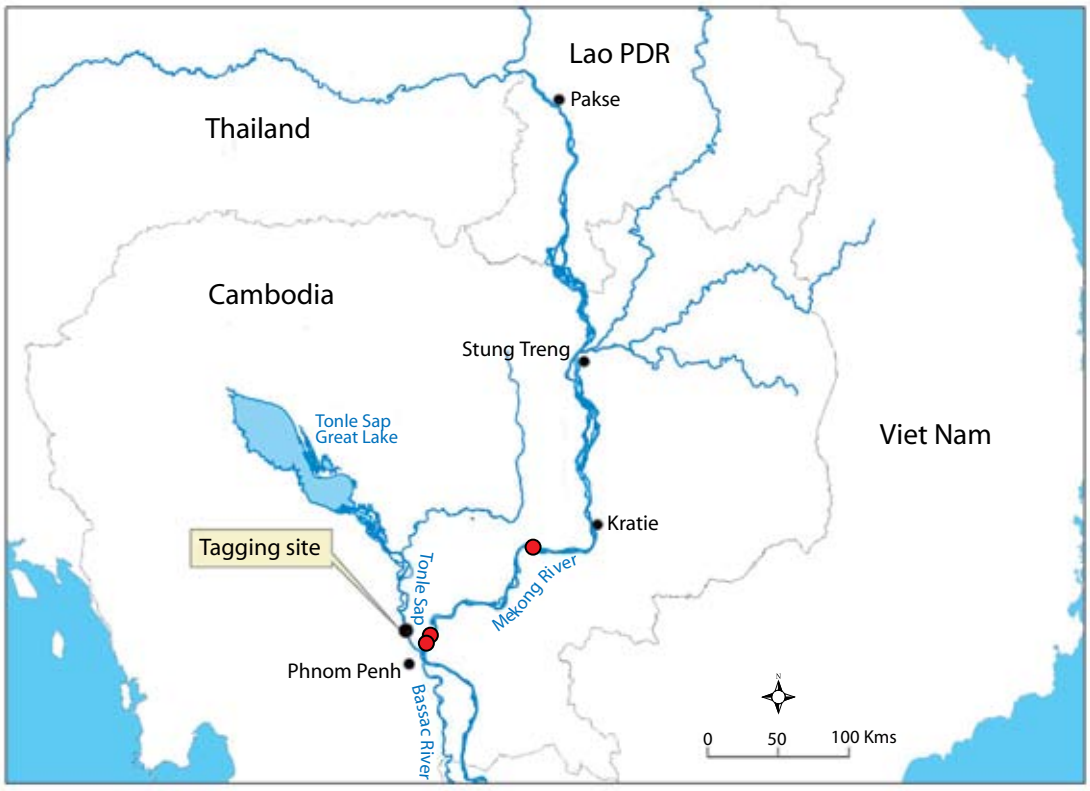
Length distribution of *Cirrinhus microlepis* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004



Location of recaptures of *C. microlepis*, October 2003–March 2004

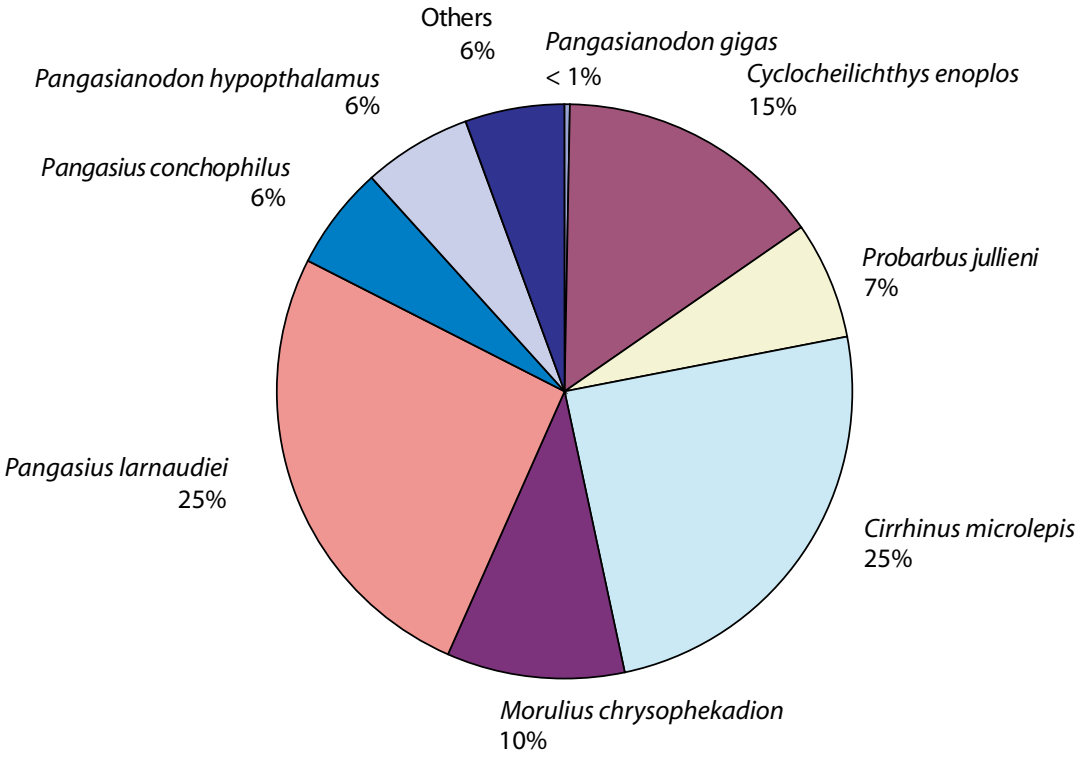


Length distribution of *Morulius chrysophekadion* tagged and released at the Tonle Sap River bag-net fishery, October 2003–March 2004

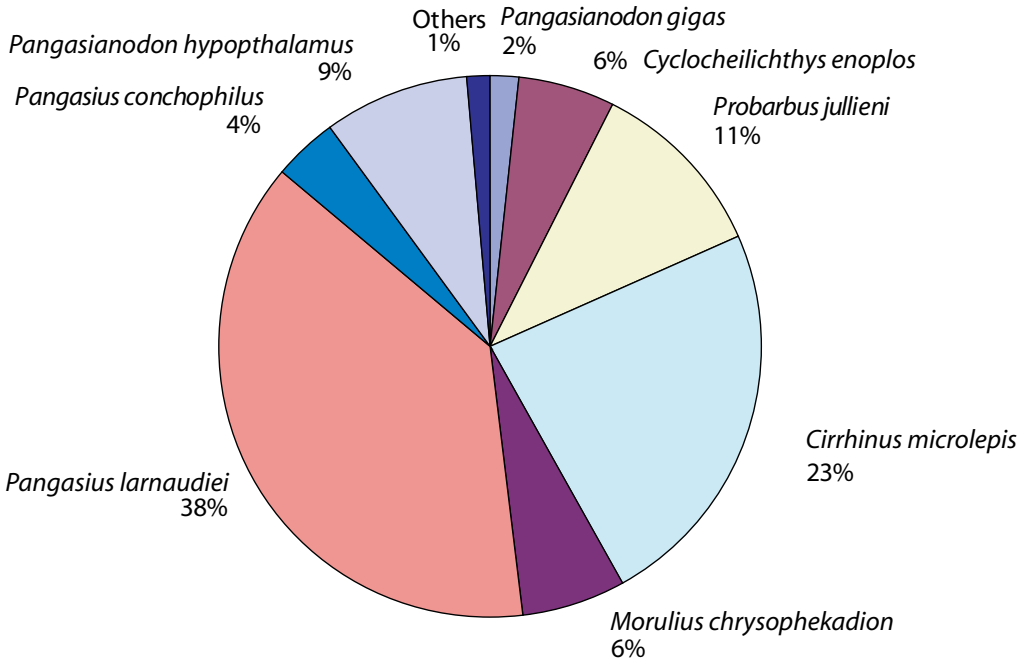


Location of recaptures of *M. chrysophekadion*, October 2003–March 2004

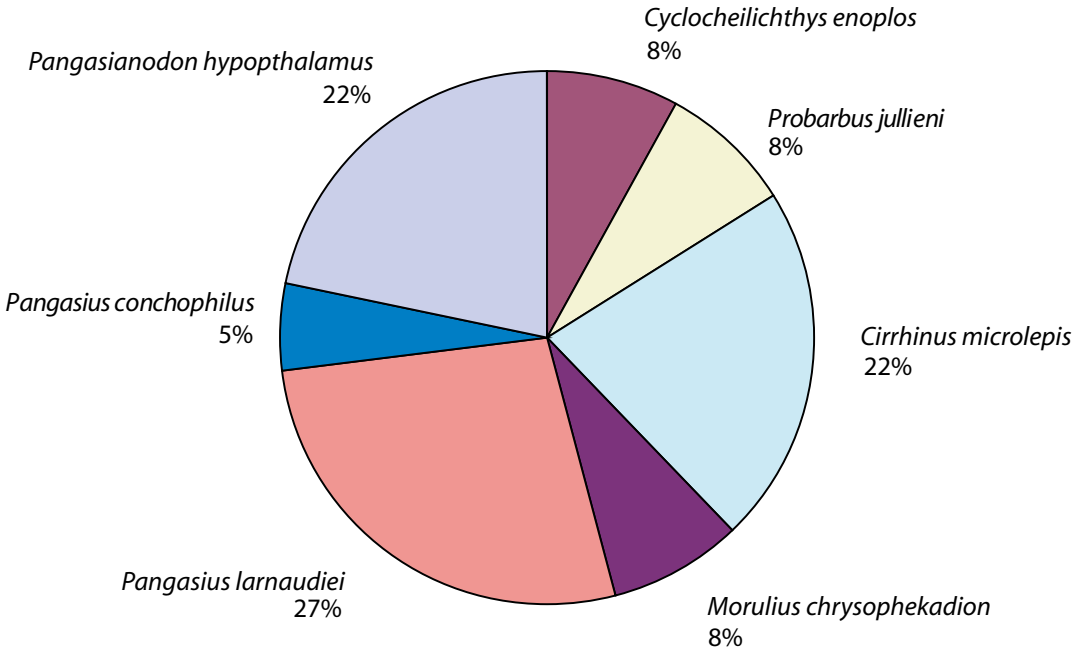
Appendix 2. Species compositions of tagged and recaptured fish



Species composition of tagged fish, October 2003–March 2004



Species composition of recaptures, October 2003–March 2004



Species composition of recaptures located more than five kilometres from the site of release, October 2003–March 2004

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