# USING LOCAL KNOWLEDGE AS A RESEARCH TOOL IN THE STUDY OF RIVER FISH BIOLOGY: EXPERIENCES FROM THE MEKONG

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**Abstract.** River fisheries are extremely important for food-security among the rural poor in many tropical countries. The growing populations and rapid industrialisation of these countries require that appropriate action should be taken to sustain the resources for future generations. However, an incomplete understanding of river fisheries biology, at the managerial level, often hampers proper planning and management. This is partly due to the difficult access to large parts of such river basins, the complex nature of the fisheries, and in many cases a severe lack of research funds. In contrast, the thousands, or often millions of people who live along the shores of the rivers and rely on the fishery for their daily survival, have a very intimate knowledge of the behaviour and biology of the fish. In this situation, gathering the knowledge of the fishers may provide politicians or planners with baseline knowledge in a relatively quick and cheap way.

This paper discusses two years of research using local knowledge in the study of fish migration and spawning in the Lower Mekong Basin. The study involves semi-structured interviews with 355 expert fishermen in four countries along 2,400 km of the Mekong mainstream. By piecing together information from fishermen in different areas, we were able to construct migration maps, and provide rough estimates of the spawning period for 50 fish species. We conclude that river fisheries research can benefit significantly from local knowledge as the basis for future research.

**Key words:** local knowledge, river fisheries, Mekong, fish migration.

## 1. Introduction

The Mekong is the largest river in South-East Asia and is among the largest flowing waters in the world. From its sources 5,000 meters above sea level, in the Tibetan plateau, to the outlet in the South China Sea, the river has a total length of 4,200 km (Pantulu, 1986) (Figure 1). The Basin covers an area of 783,000 km$^2$ (ICCILMB, 1992), and is shared by six countries: China 20 per cent, Myanmar 2 per cent, Thailand 24 per cent, Laos 26 per cent, Cambodia 20 per cent, and Vietnam 8 per cent (University of Michigan, 1976; Pantulu, 1986). The Mekong is a typical tropical river with pronounced seasonal differences in water level, and in the lowland (i.e.,

*Environment, Development ans Sustainability* **2:** 253–276, 2000.

Cambodia and Vietnam) some areas are flooded for more than six months every year (Pétillot, 1911; Pedersen, 1999).

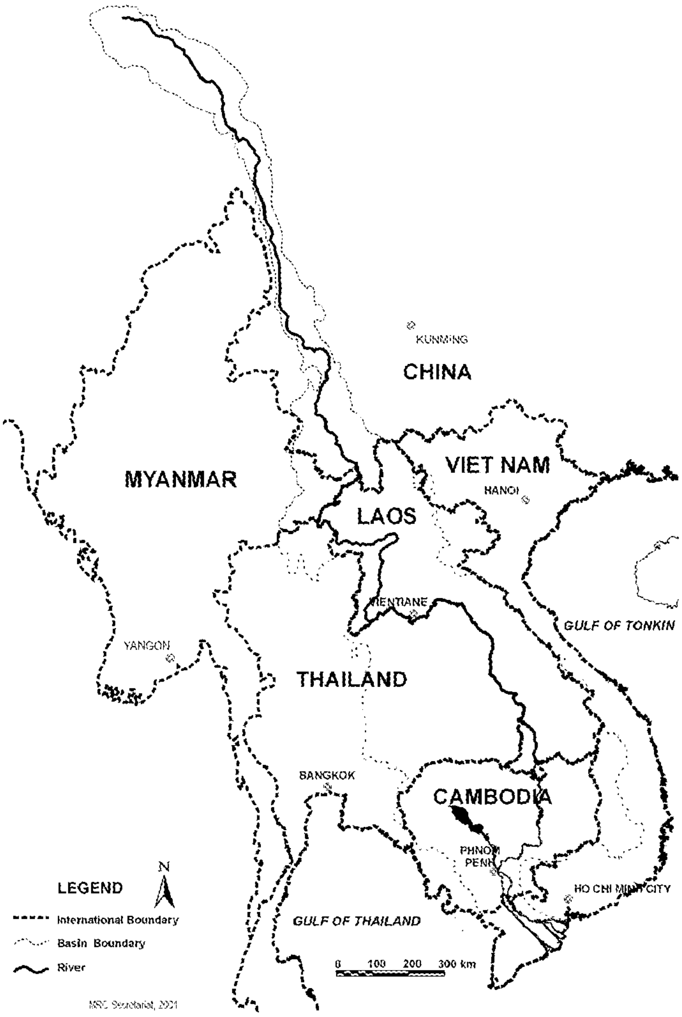


*Figure 1.* The Mekong Basin (map provided by the MRC Secretariat).

The diversity of fish species in the Mekong Basin is breathtaking with more than 1200 species recorded until now, and large parts of the basin have still not been surveyed in detail by fish taxonomists. Dominating fish orders include Cypriniformes, Perciformes and Siluriformes with respectively 34 per cent, 26 per cent and 12 per cent of the species (Rainboth and Chavalit Vidthayanon, pers. com.).

Along its entire length, the Mekong River is heavily exploited for its fish, and the basin sustains one of the largest freshwater fisheries in the world, with an annual yield in excess of 1 million tonnes (Jensen, 1996;

2000; Sjørslev and Bamrungrach, 2000). Most of this catch is harvested by small-scale fisheries and consumed locally. Every river, lake, stream, ditch, canal (even the sewers in the cities) is fished. Various bas-reliefs, showing both fish and fishing activities, on the walls of the ancient Cambodian temple complex of Angkor Wat, underline that this importance of the fisheries is not a new feature in the region. The Cambodian currency, the *riel*, is also named after a fish species group (*Henicorhynchus* spp.), which constitutes the majority of the catch in this part of the basin.

Most of the current knowledge on the biology of fish in tropical floodplain rivers is derived from research in some of the major South American and African rivers (see for instance reviews by Welcomme, 1979; 1985; and Lowe-McConnell, 1987). In spite of having one of the most significant inland fisheries in the world, knowledge on the fishery in the Mekong Basin has only recently begun to accumulate, and the knowledge on the lifecycles of even the most important commercial Mekong species is still very fragmentary. This may have serious implications for the ability to predict impacts of proposed water utilisation or management projects on the ecosystem. For the riparian countries to be able to manage their fisheries appropriately in the future, fundamental biological and ecological knowledge about the resource is crucial.

Due to the current lack of basic ecological and biological knowledge, environmental impact assessments (EIAs) of development schemes are based on very little data, which is often of low quality. EIAs most often only take the local impact in the vicinity of the proposed scheme into consideration. The fieldwork on which an EIA is based normally covers only a short period, and fish data is usually restricted to a list of species without considering any ecological aspects. However, due to the migratory habits of most Mekong fish species, the fish community at any particular place is constantly changing, and the data should cover at least an entire year. Implicit in the migratory nature of the fish is also that damage to a fish habitat or blockage of a migration corridor in one area may be felt far away from where it occurred, sometimes even in another country (Coates *et al.*, 2000).

Given all these limitations and constraints, is it then possible to carry out a proper fisheries impact assessment, when not even the basic ecological parameters are known?

In order to answer this question, we have to realise that lack of knowledge and understanding among administrators and researchers does not necessarily mean that the knowledge does not exist. The millions of people who live along the shores of the rivers and rely on the fishery for their daily survival have a very intimate knowledge of the behaviour and biology of the fish. Gathering the fishers' knowledge may provide politicians or planners with baseline knowledge in a relatively quick and cheap way.

This paper discusses the application of local knowledge in the study of river fisheries exemplified by the biological studies of fish that were carried out under the auspices of the Mekong River Commission[1]. Although the foci of these studies were on certain ecological features, in particular fish migrations, there is no reason to believe that the method cannot be applied to other aspects of fish or river biology.

In the following sections, we present an example of the kind of detail that can be obtained using local knowledge through a case study dealing with the migration and spawning of commercial fish species in the Mekong mainstream.

## 2. Objectives

The objectives of the study were:

i) to provide lifecycle information, in particular on migration and spawning, for important Mekong fish species;
ii) to provide basin-wide information on key fish habitats;
iii) to provide directions towards future research needs and priorities.

## 3. Methods

In view of the study being the first of its kind where local knowledge has been used as a tool in a basin wide river fisheries biological study, we feel that an account of some of the main considerations that influenced the design of the survey is justified.

### 3.1. Considerations Taken into Account in the Design of the Survey

Our main research subject, fish migrations, often covers large distances - sometimes of a basin-wide scale. On the other hand, local knowledge is by definition area specific and fishermen are not likely to have detailed knowledge about the species outside the area where he/she is normally fishing. A fisher in Laos, for example, cannot possibly know whether a fish is migrating to the South China Sea. All inquiries should therefore be area specific. Only when information from fishers from many different places all over the basin is correlated a substantial amount of information on life cycles for the concerned species will emerge.

Geographical coverage was not considered an aim in itself; the priority was given to *ecological coverage.* Upland as well as lowland parts of the basin and river segments above and below zoogeographical barriers (i.e., rapids or waterfalls) had to be included. Sections where major tributaries join the mainstream were also given special attention.

[1] MRC Fisheries Programme: Assessment of Mekong Fisheries - Fish Migrations and Spawning and the Impact of Water Management Component.

We needed species-specific information. This posed a particular problem in a Mekong context, because local names of fish species are highly variable - even among people speaking the same language. Extreme examples include fishermen from three Laotian villages, located few kilometres apart, who were using three different names for the same species of fish. This complicates biological interviews for which taxonomic accuracy is necessary. It is obviously difficult to interview fishers by referring to local names, especially if the interviewer is from a different part of the country. It is also not possible to request villagers to list *important species in their catch* and later translate the names into scientific names.

Another problem arose from the fact that local names are often given to species groups rather than individual species. The fishers will often know, however, that the species in concern are in fact different species, and may eventually also be able to differentiate them, if they are asked to do so. This will sometimes be with a supplementary name (e.g., several species of pangasiid and schilbeid catfishes are referred to as Pa Njon in Laos, but if a fisher is asked a second time, *Pangasius pleurotaenia* will be Pa Njon Thong Khom, and *P. polyuranodon* will be Pa Njon Hang Hian etc.).

The opposite problem, where several names are applied to the same fish, for example distinct names to different lifestages, is also widespread (e.g., in Cambodia juvenile *Catlocarpio siamensis* is called Trey Kahao, while the adults are named Trey Kolreang). It can also happen that fishers insist that two species are in fact male and female of the same species.

In order to ensure that reliable species-specific information was obtained, we decided to use photos of fishes as the main conversation object during the survey.

Fishers demonstrate an enormous ingenuity in constructing fishing gears. Fishing gears are always improved through modifications, and new gears are constantly invented. Each gear is used to target certain species or species groups so the diversity of fishing gears parallels the diversity of fish species (the Department of Fisheries in Cambodia has for example catalogued 180 kinds of fishing gears [Component for the Management of the Freshwater Capture Fisheries of Cambodia, in prep.]). The fishery is so closely adapted to the local situation that it is extremely unlikely that a species inhabiting the area or passing by on a regular basis can avoid being caught by somebody. So, while the diversity of fishing gears is a nightmare for researchers undertaking studies of total catch using catch per unit effort (CPUE); it is actually the best guarantee for the local knowledge researcher that all species are being caught.

Interviews should be carried out in the fishers' own languages without any translations. It turned out to be necessary to compromise on this in some areas, however, because the Mekong region is home to such a diversity of ethnic groups speaking their own languages - the other alternative, eliminating these people completely from the survey, was considered as even less attractive.

We considered that people who are ready to provide information free of charge because they are interested in the survey, are more motivated and thus more likely to provide good information. Interviewees were therefore never rewarded individually for their information, also because promises of rewards tend to attract more people - also people who are less knowledgeable. If a reward is promised, the fisher may also get the impression that the size of it will be proportionate with the amount of information he/she can provide (e.g., the number of species they can identify). Instead, we sometimes invited all the interviewees for dinner when all interviews in an area were done.

In the Mekong countries, like in many other countries, officers from the department of fisheries carry out fisheries surveys. It is thus the same people who are responsible for the enforcement of the fisheries law and sometimes for the collection of taxes or fees. This is not a good foundation for mutual trust. Fisheries officers sometimes consider the fishers liars and cheaters, and fishermen often accuse the officers of being corrupt. It was therefore extremely important that the purpose of the survey was explained thoroughly, and that participating fishermen were guaranteed that the information they provided would not be used against them. The survey should be purely biological, and more sensitive issues such as income that are also important in a fisheries impact assessment, should be left out of the survey and gathered separately.

Religion and superstition are still integrated parts of everyday life in the riparian countries and sometimes involve certain species of fish. In the Mekong, the Mekong giant catfish (*Pangasianodon gigas*) is considered holy, and is surrounded by myths and traditions. In Cambodia, it means bad luck to catch a Mekong giant catfish, and fishers will often release it if they catch it by accident. In Laos, some people believe that the giant mottled eel (*Anguilla marmorata*) eats people, and they do not like to talk about it. It is often seen that women and children leave the meeting if the eel is mentioned.

### 3.2. Outline of the Survey Method

Equipped with these initial considerations, we developed, tested and modified the survey methodology. In the following, we provide an outline of the survey method, which has been described in more detail by Poulsen and Valbo-Jørgensen (1999).

In each country, an interview team consisting of two to three experienced fisheries scientists carried out the interviews[2]. Several workshops and training sessions were held with the interview teams before,

[2] Interviews were carried out by staff from the following counterpart institutions: Research Institute for Aquaculture No. 2, Ho Chi Minh City, Vietnam; Department of Fisheries, Thailand; Department of Livestock and Fisheries, Vientiane, Laos PDR; and Department of Fisheries, Phnom Penh, Cambodia.

during and after the fieldwork. During these workshops, preliminary data were analysed, problems and progress were elaborately discussed, and methods were modified accordingly.

The survey was carried out in fifty-one areas distributed along the Mekong and Bassac rivers from Ban Sop Kok in North-East Thailand, located 2,403 km from the river mouth, to Long Binh commune in Vietnam, positioned only eleven kilometres from the sea. 113 villages were visited and interviews carried out (Figure 2). The stations were chosen based on a combination of the knowledge of experienced departments of fisheries staff, information gathered during extensive pre-survey travelling in the region, review of scientific papers, and finally by spotting distinctive ecological reaches on detailed maps.

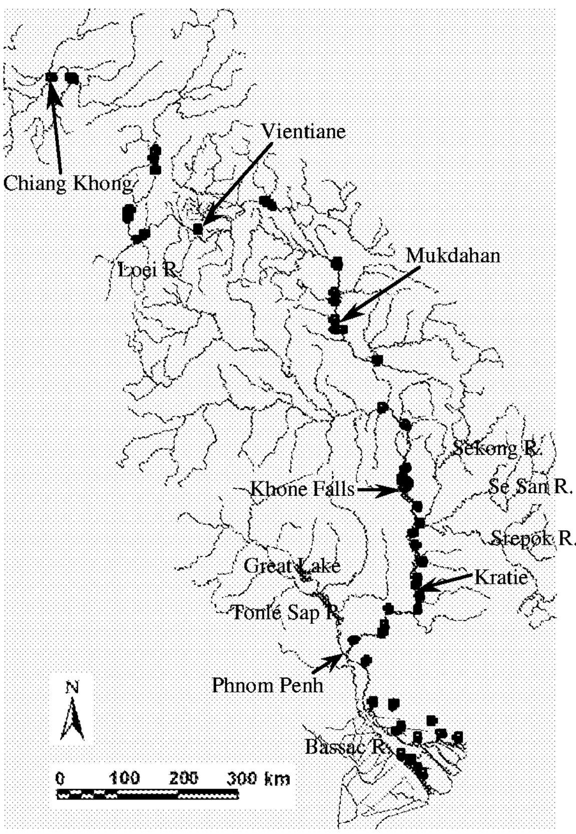


*Figure 2.* The 51 areas (dots) along the Mekong where interviews were carried out.

The survey comprised two types of interviews: fisher group interviews and individual interviews. In total, 120 fisher groups were interviewed during the survey. From these groups, 355 *expert fishers* were selected and interviewed individually.

*3.2.1. Fisher Group Interview*

The group interviews had the following purposes:

First, to get as much detail about the fishery and the fish habitats as possible; this was done by letting the fishers draw a map of the fishing ground including - but not restricted to - the following:

i) the location of the village in relation to the fishing ground,
ii) exact place(s) for fishing activities on the fishing ground (which gears are used where),
iii) river width (for riverine fishing grounds),
iv) depth,
v) bottom conditions,
vi) vegetation,
vii) seasonality.

Second, a list of the fish species occurring at the fishing ground was obtained by letting the fisher group go through photographs of 174 species, confirm the presence or absence of each species, and identify them by their local names.

Third, the group interview provided an indication of the level of knowledge of each group member, and thus helped the interview team to select expert fishers for individual interviews.

*3.2.2. Individual Interview*

It was during these interviews that detailed species-specific ecological information was obtained for fifty out of the 174 species included in the photo flipchart. These species were selected based on their importance in the fisheries, both in terms of occurrence on landing sites and fish markets, and in terms of experienced fisheries staff's perceived importance; with due consideration also given to endangered species (e.g., *Aaptosyax grypus*), and species of cultural significance (e.g., the Mekong giant catfish). At the same time, we aimed at getting a broad taxonomic coverage (i.e., eighteen fish families) (for a list of species and families refer to Table 1).

It was normally not difficult to find people who were willing to be interviewed. However, one of the most crucial points for a successful outcome of the survey was the selection of the interviewees. For surveys requiring detailed biological information interviewees should never be selected at random, interviews should instead focus on expert fishers (Johannes, 1993; Johannes *et al.*, 2000). An expert fisher, for our purpose, is 'anybody who possesses detailed knowledge about the habits of one or more species of fish in a particular area', and thus not necessarily a professional full time fisherman. We thus needed to ensure, as much as possible, that the right persons were interviewed.

A team of two researchers carried out the interviews, one of these was doing the talking (interviewing), whereas the other was noting down the answers as they appeared during the interview. Although datasheets were used to facilitate the entry of the data into the database, rigid questionnaires were avoided to make interviews more conversational and interesting for both the interviewer and the fisher being interviewed. There was thus an infinite number of ways of getting the information, and the whole interview was more like a talk between friends with a common interest. This approach demanded a substantial amount of skills from the interviewer, in terms of conversational skills as well as knowledge and interest in the subject.

*Table 1.* The species included in the survey (nomenclature follows Rainboth, 1996).

| | |
|---|---|
| **Notopteridae** | **Schilbeidae:** |
| *Chitala blanci* | *Laides hexanema* |
| *Chitala ornata* | *Laides sinensis* |
| *Notopterus notopterus* | **Pangasiidae** |
| **Clupeidae** | *Helicophagus waandersi* |
| *Tenualosa thibeaudeaui* | *Pangasianodon gigas* |
| **Engraulidae** | *Pangasianodon hypophthalmus* |
| *Lycothrissa crocodylus* | *Pangasius bocourti* |
| **Cyprinidae** | *Pangasius conchophilus* |
| *Aaptosyax grypus* | *Pangasius krempfi* |
| *Bangana behri* | *Pangasius larnaudiei* |
| *Barbodes gonionotus* | *Pangasius macronema* |
| *Catlocarpio siamensis* | *Pangasius pleurotaenia* |
| *Cirrhinus microlepis* | *Pangasius polyuranodon* |
| *Cyclocheilichtys enoplos* | *Pangasius sanitwongsei* |
| *Hampala dispar* | *Pangasius siamensis* |
| *Hampala macrolepidota* | **Sisoridae** |
| *Henicorhynchus siamensis* | *Bagarius yarelli* |
| *Hypsibarbus malcolmi* | **Clariidae** |
| *Mekongina erythrospila* | *Clarias batrachus* |
| *Morulius chrysophekadion* | **Mastacembelidae** |
| *Osteochilus hasselti* | *Mastacembelus armatus* |
| *Paralaubuca typus* | **Sciaenidae** |
| *Probarbus jullienni* | *Boesemania microlepis* |
| *Probarbus labeamajor* | **Nandidae** |
| *Puntioplites falcifer* | *Pristolepis fasciata* |
| **Cobitidae** | **Anabantidae** |
| *Botia modesta* | *Anabas testudineus* |
| **Bagridae** | **Belontiidae** |
| *Mystus nemurus* | *Trichogaster trichopterus* |
| **Siluridae** | **Osphronemidae** |
| *Micronema bleekeri* | *Osphronemus exodon* |
| *Wallago attu* | **Channidae** |
| *Wallago leeri* | *Channa striata* |

Before the interview about the fish started, each fisher was asked about his fishing activities and experience in order to get a profile of the fisher, which could later be used in the interpretation of the ecological data the fisher provided.

Only one species was discussed at the time. The information the fisher was requested to provide mainly focused on which periods of the year the concerned species normally is present, whether there tend to be peaks in the abundance of the fish, and the length of any such peaks. If the fisher had observed any spawning activity, he was asked to draw a map of the spawning ground. Many fishers also provided information about the period when the fish had eggs in the abdomen.

Size specific information was obtained by using *cut-out fish-size series* consisting of: three series of fish sizes, one for *normal-shaped* fish, one for *deep-bodied* fish and one for *eel-shaped* fish. Each series had eleven different sizes from two to ninety centimetres long (if fish grew larger, fishers were allowed to refer to weight).

*3.2.3. Validation Procedures*

To ensure the quality of the information provided several validation procedures were built into the survey. Although none of these measures by themselves gave a hundred percent guarantee, in concert they did provide a reasonable check on the quality of the data. The procedures included comparing biological information and local names provided at closely situated stations, and matching new information with the interviewers background knowledge. The photo-flipchart for example contained photographs of a number of species with limited distribution so if a fisher for instance indicated that a primary freshwater species occurred in the brackish water delta, or that an estuarine species occurred in the upper reaches, this was taken as a strong indication that the information he provided was not one hundred percent reliable.

Whenever possible, the interview data were also supplemented with personal observations by the interviewers during the time of the interview, although these observations of course were severely biased because of the seasonal variations in the fishery. If a fisher for instance referred to an unusual species, he was normally asked whether it was possible to provide a specimen. The local fish markets were always visited. Fish sellers often proved to be the best of all in identifying species, and they were able to provide exact local names of the fish. It was also often the fish vendors, rather than the fishers, who knew when certain fish have eggs, because the fish sellers clean the fish for their customers, while fishers often do not cut the fish open.

*3.2.4. Data Storage and Analysis*

The information provided by the fishers can be grouped in three categories: their own observations, conclusions based on their own observations, and traditional knowledge. As scientists, we are obviously most interested in the first type of information, although the value of the second and third type cannot be disputed, but clear distinctions were made between the three types of information.

Biologists as representatives for the natural sciences are used to deal with quantitative data, which can be analysed by an ever-increasing amount of sophisticated software. Data gathered through local knowledge in most situations is qualitative and therefore demand a different approach to analyse. There is in fact no, and never will be, any software that will be able to analyse the raw data gathered during our Mekong surveys. Particularly, because the field with *additional information* (i.e., all the things we did not think about asking when the data sheets were designed), often turned out to be the most interesting when the data were analysed.

Both qualitative and quantitative data were stored in a tailor made database in Microsoft Access 97 (Visser, 1999). This approach allowed for a query based analysis of the data. In this way the data was analysed species by species for the entire basin or for an entire ecological reach at the same time, thereby allowing the broad picture to emerge.

While the analysis of the data indeed was a slow process, it was impossible not being fascinated of all the information that was provided. Seeing the picture that gradually emerged, when all the pieces in the jigsaw were put together, was no less satisfying than getting a statistically significant outcome of a probability analysis.

## 4. Results and Discussion

### 4.1. THE FISHERS

The interviewed fishers aged between fifteen and eighty years, with the majority between thirty-one and forty-five years. Although it was not intentional, all the interviewees were men, and they had from two to sixty years of fishing experience, with the majority having from eleven to thirty years of experience.

*Table 2.* The gears and methods used by the interviewed fishers, and the number of individuals using them (from Poulsen and Valbo-Jørgensen, 2000).

| Gear name | Cambodia | Lao PDR | Thailand | Vietnam | Total |
|---|---|---|---|---|---|
| Stationary gill-net | 120 | 205 | 8 | 16 | 349 |
| Drifting gill-net | 23 | 173 | 62 | 5 | 263 |
| Cast-net | 98 | 130 | 11 | 4 | 243 |
| Longline | 67 | 153 | 5 | 12 | 237 |
| Miscellaneous traps | 84 | 106 | 6 | 3 | 199 |
| Hook and Line | 8 | 69 | 16 | 2 | 95 |
| Small scoop-net | 24 | 3 | | 2 | 29 |
| Seine net | 17 | 2 | 5 | | 24 |
| Trawl | 9 | | | 10 | 19 |
| Beach seine - with brush park | 7 | 2 | | 3 | 12 |
| Unspecified | 9 | 2 | | | 11 |
| Large dai | | | | 10 | 10 |
| Large scoop-net | | | 10 | | 10 |
| Small dai | 1 | 1 | | 5 | 7 |
| Purse seine | | | 1 | 5 | 6 |
| Spear (incl. bow and arrow) | 3 | 2 | | | 5 |
| Barrages | | 2 | | | 2 |
| Large lift-net | | | | 2 | 2 |
| Collection | | | 1 | | 1 |
| Small lift-net | | 1 | | | 1 |

The interviewed fishers were using more than twenty different fishing gears (Table 2). The most widely used were stationary and drifting gillnets, castnets, longlines and traps.

### 4.2. MIGRATIONS

Although the survey produced migration maps for 50 species, we are only including two examples here to demonstrate the nature of the obtained information (for the results of the remaining species refer to Poulsen and Valbo-Jørgensen, 2000). In addition, some more general results of the survey are presented.

#### *4.2.1. Example 1 - Redtail Botia*

The redtail botia (*Botia modesta*) is a small strongly migratory loach that occurs throughout the survey area, from the Mekong Delta to Chiang Saen near the border between Laos, Thailand and Myanmar. It was reported from all the surveyed stations.

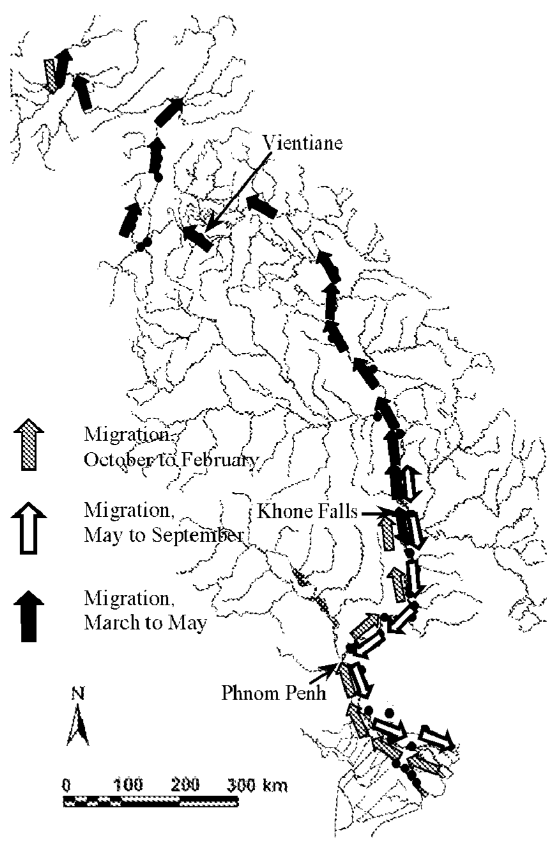


*Figure 3.* Migration pattern of redtail botia (*Botia modesta*) (modified from Poulsen and Valbo-Jørgensen, 2000).

The migration pattern of redtail botia is illustrated in Figure 3. An upstream migration was reported from around the saline intrusion zone in the Mekong Delta, to just below the Khone Falls in southern Laos from November to March (reported from 16 out of 18 mainstream stations in this area). This migration was reported to be triggered by receding water levels (reported from 8 of the stations). At four stations from Kandal to Kompong Cham, it was reported to migrate during full moon (or just before full moon at Kandal).

From May to July, the species migrates the opposite way, downstream from the Khone Falls, apparently to flooded areas in Southern Cambodia and the Mekong Delta (i.e., this migration was reported for all three floodplain stations in the Mekong Delta).

Above the Khone Falls, redtail botia migrates upstream during February to May (reported for 12 stations out of 14). At five stations, it was reported to migrate together with *Henicorhynchus* spp. However, at the northern station at Chiang Khong, it was reported that redtail botia does not migrate together with other species. It was reported to migrate into small streams, e.g., at Huai Noi and Huai Kum, near Mukdahan-Savannakhet. At Chiang Khong, it was reported to go into a tributary, Nam Ing, from where the young-of-the-year return to the Mekong during September-November (indicating that spawning occurs in Nam Ing).

One station just above the Khone Falls reported the main upstream migration period to be June-July. This is the only station above the Falls, which reported migration during this period. However, the timing coincides with the downstream migration reported below the Falls. At the same station, it was reported that redtail botia does not migrate into tributaries and smaller streams.

Eggs were reported to occur from February to July throughout the distribution range (17 stations). Most reports concentrated on May-June (11 stations), indicating that spawning takes place during this period.

Based on the above we hypothesise that redtail botia should be spawning during the early flood season. Above the Khone Falls spawning apparently occurs in tributaries and streams, from where eggs and larvae are swept into flooded areas, where they spend the flood season. Below the Khone Falls, spawning may be limited to the Mekong mainstream between Kratie and the Falls, and to the Se San, Sre Pok, Sekong tributary system in the northern part of Cambodia. This implies that the population occurring in southern Cambodia and the Mekong Delta (and possibly in the Tonle Sap/Great Lake system) originates from this area.

*4.2.2. Example 2 - Henicorhynchus siamensis*

*Henicorhynchus siamensis* is a small cyprinid, which, according to the survey, is distributed from the Mekong Delta all the way along the Mekong to Chiang Khong, near the border between, Thailand, Laos and Myanmar. The migration pattern of *H. siamensis* is shown in Figure 4.

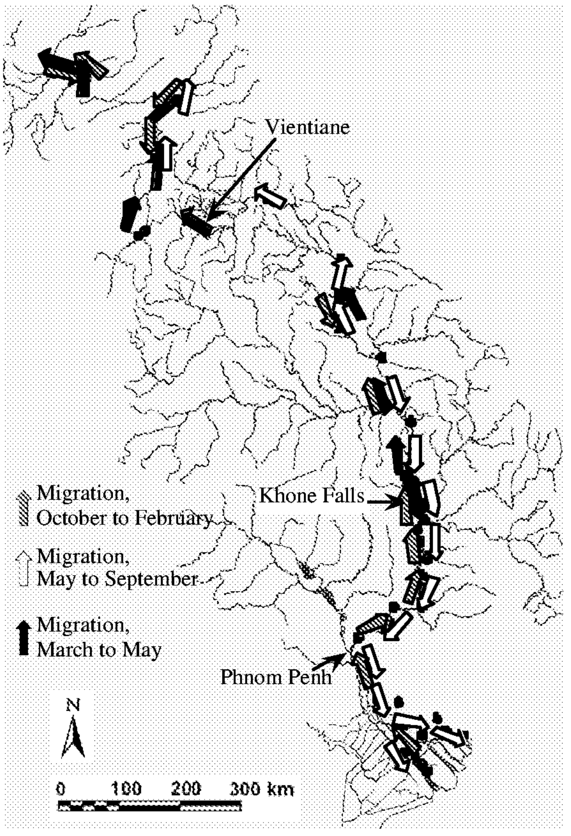


*Figure 4.* The migration pattern of *Henicorhynchus siamensis* (modified from Poulsen and Valbo-Jørgensen, 2000).

All the stations from just upstream Phnom Penh to the Khone Falls reported that *H. siamensis* migrates upstream during the period October to February. At Muk Kompul District in Kandal Province, the species was reported to migrate upstream just before full moon. Further upstream, at two stations near Kratie, it was reported to migrate during full moon, and at Sambor, a little further upstream, it migrates immediately after full moon. Some fishermen who exploit this migration and migrate together with the fish all the way to Stung Treng, reported that the species migrates approximately seventeen kilometres per day.

Near the Khone Falls, the migration pattern is less obvious. Upstream movements continue through March, but in April fish are apparently moving both up and downstream. From May to July, at the onset of the rainy season, fish migrate downstream from the Khone Falls, a movement reported for all the stations right down to the Mekong Delta. Here, the fish migrate out of the Mekong into canals and flooded areas during August-September. This migration includes movement of very small fishes (young of the year) as well as mature fishes of about 20 cm. During receding water (November-December), the fish again migrate out to the mainstream.

Upstream of the Khone Falls, the movements are also less well defined. Near Ubolratchatani, *H. siamensis* migrates upstream from February to June. In February-March, this movement consists mainly of juveniles, whereas from April to June, it consists of adults (15-20 cm).

Further upstream, from Xayaboury to Chiang Khong, upstream migrations occur from March to July, first by juveniles, later by adults.

Observations of mature eggs were reported from April to July with a strong peak during May-June (i.e., during the upstream migration). Nearly all stations downstream from Savannakhet-Mukdahan reported May-June as the spawning period. At Sambor, a fisherman reported observing mature females 'releasing eggs which then flowed downstream' during the month of May. At Chiang Khong, fish were reported to migrate up into tributaries to spawn from May to July. At Loei, spawning was reported to occur in July-August in a tributary (Loei River) in a small pool with slow current. In general, spawning seems to occur over a longer period and extend into August-September from Loei and upstream.

The limited information obtained about the species from the stretch from Savannakhet-Mukdahan to Loei may indicate the occurrence of two different populations, or even species, upstream and downstream of this stretch.

*4.2.3. Overall Migration Patterns*

It is not possible to give a detailed account of all the species covered by the survey, but there are some generalities that can be pointed out.

First of all there are two main migration periods. The first is from May to July when the water is rising. During this migration most fish are full of eggs, implying that this is a migration towards the spawning grounds.

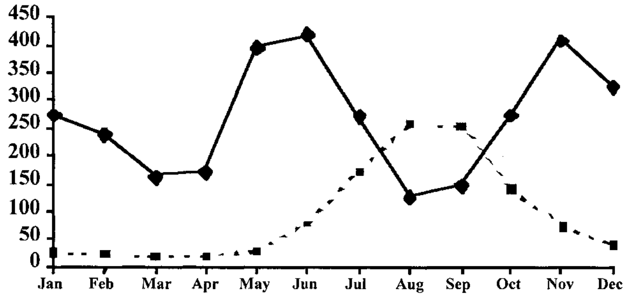


*Figure 5.* The relationship between fish migration and hydrology (modified from Bouakhamvongsa and Poulsen 2000).
Dotted line: Average monthly discharge ($m^3$/sec./100) of the Mekong River at Pakse, Southern Laos (data provided by the MRC Secretariat).
Solid line: Number of migration reports (all stations and all species).

The second migration period happens October to December when the water level is falling rapidly thereby pushing the fish out of the nursery and feeding areas on the floodplain, from where they migrate to their dry season refuges. Figure 5 shows all migration reports per month for all fifty species, together with the monthly discharge of the Mekong River.

For species reproducing outside the feeding areas, there must also be a migration between spawning and feeding habitats, but this migration has almost not been reported on. This is probably because the migrations towards the spawning grounds are massive movements of huge quantities of fish, going in the same direction and thus easily observable by the fishers. Conversely, spent fish often move individually or pair-wise towards the feeding areas with many stops for feeding on the way, and the fishers do not always perceive this as a migration.

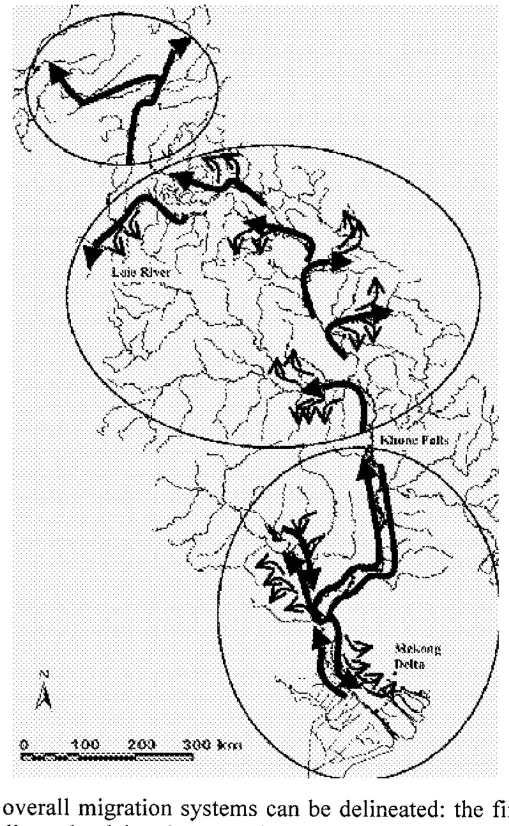


*Figure 6.* Three overall migration systems can be delineated: the first extends from Khone Falls to the delta, the second from Khone Falls to Loei River, and the third upstream Loei River. Large arrows symbolises longitudinal migrations small arrows indicate lateral migrations.

It also becomes apparent that three different migration systems can be delineated (Figure 6). The Khone Falls in southern Laos appears to play a central role in delineating the two first systems. Khone Falls is not a big waterfall, but consists of a series of canals and rapids, of which most are passable for fish, and there is plenty of documentation of fish actually crossing the Falls (e.g., Singhanouvong *et al.*, 1996a; 1996b). Khone Falls does not seem to form a zoogeographical barrier either (i.e., most of the species we recorded just below the Falls were also reported above, and *vice versa*).

The first migration system covers the stretch from around the Khone Falls to the Mekong Delta in Vietnam, and includes the Tonlé Sap–Great Lake system. It is the huge annual flood pulse, in southern Cambodia and in the northern Mekong Delta in Vietnam, which drives this system. Species spawning in the mainstream probably spawn in the area between Kratie and Khone Falls, while others migrate into the Se San, Sre Pok and Sekong tributaries. Floodplain spawners spawn from downstream of Kratie to the saline intrusion zone in the delta.

During the flood season larvae, juveniles or adults of most species enter the floodplains, where they take advantage of the productive environment. As the water begins to recede at the beginning of the dry season, the fish move back out into permanent water bodies, and eventually distribute themselves within dry season refuges, often associated with deep pools in the main river channels.

In the second system, extending from just above the Khone Falls to the area where Loei River joins the Mekong, migrations appear to be determined by the presence of large tributaries with extensive floodplains. During the early flood season, fishes move upstream within the Mekong until they reach a tributary, from where they can get access to floodplains. Some migrating fishes may spawn on the floodplain itself, whereas others spawn in the tributary mainstream. Larvae and juveniles of the latter species reach their floodplain nursery areas passively (i.e., drifting with the current), or actively (i.e., as juveniles swimming in from the river). At the end of the flood season, fishes move from flooded areas back to the main river channel. Many species move all the way back to the Mekong mainstream, where they spend the dry season in certain deep pools.

Lateral movements to floodplains is a less prominent feature of the third system, which starts upstream of Loei, because floodplains become very scarce and are limited mainly to fringing floodplains adjacent to the main river channel. The most conspicuous species involved with this migration system is the Mekong giant catfish (*Pangasianodon gigas*). This species is caught every year in northern Laos and Thailand during its upstream spawning migration and its migration is believed to extend into China.

### 4.3. Spawning Grounds

Many fishers were able to provide information about the periods where the fish have eggs in the abdomen, and in doing so giving us an indication of the spawning period. However, exact spawning grounds turned out to be much more difficult to identify than we expected, probably because the Mekong is very turbid - especially during the flood season when most species are spawning.

This also explains why the spawning grounds that were reported were mainly for species spawning in shallow water on the floodplain. One example is the catfish *Wallago attu*, for which a fisherman in Chiang Khong, Thailand reported the following: 'In June-July groups of fishes larger than 2 kg spawn in shallow water on flooded grassland. The eggs stick to the substrate and hatch within 3 days.' Another Thai fisherman, in Loei Province, reported that *W. attu* is spawning in Huai Kid reservoir near the mouth of the Huai Kid stream, and a Vietnamese fisher reported that it breeds in rice fields.

Other floodplain spawning fish, for which spawning grounds were reported, are the bronze featherback (*Notopterus notopterus*), cyprinids of the genus *Hypsibarbus*, the walking catfish (*Clarias batrachus*), *Wallago leeri*, and the chevron snakehead (*Channa striata*).

Several spawning grounds could be identified for the mainstream spawning sevenline barb (*Probarbus jullieni*) and thicklip barb (*P. labeamajor*), probably because these species are spawning in the dry season, when the water is clearer, and also because they make a lot of noise during the spawning performance. A fisherman in Mukdahan, Thailand, for instance reported observing 'hundred fish gathering near two islands named *Don Son Korn* and *Don Nang Nean*'. In Sungkom district, Thailand, three *Probarbus* species were reported to migrate together, but spawn separately, during January-February.

## 4.4. Deep Pools - Important Mainstream Fish Habitats

The so-called *deep pools* within the Mekong mainstream have been identified as important dry season refuge habitats for fishes of the Mekong (e.g., Hill and Hill, 1994). Although the question of deep pools was not specifically raised as an issue during the survey interviews, more than 230 records from the survey refer to deep pools as being important habitats for certain fishes. A list of species reported using deep pools is provided in Table 3, where also the numbers of reports per species are included.

The list includes both relatively sedentary species like the clown featherback (*Chitala ornata*), the catfish *Wallago attu,* the zigzag eel (*Mastacembelus armatus*) and the goonch (*Bagarius yarelli*), and highly migratory species, such as the river catfishes (Pangasiidae), and the cyprinids *Probarbus* spp., giant barb (*Catlocarpio siamensis*), *Cirrhinus microlepis,* and *Cyclocheilichthys enoplos.*

*Table 3.* Species reported to be using deep pools as dry season habitat (numbers refer to number of times mentioned in interviews) (from Poulsen, in prep.).

| Species | Reports | Species | Reports |
|---|---|---|---|
| *Chitala ornata* | 12 | *Botia modesta* | 3 |
| *Helicophagus waandersi* | 10 | *Cirrhinus microlepis* | 3 |
| *Paralaubuca typus* | 10 | *Cosmochilus harmandi* | 3 |
| *Wallago attu* | 10 | *Hemibagrus nemurus* | 3 |
| *Mastacembelus armatus* | 9 | *Pangasius sanitwongsei* | 3 |
| *Micronema sp* | 9 | *Pangasius siamensis* | 3 |
| *Puntioplites falcifer* | 9 | *Wallago leeri* | 3 |
| *Morulius chrysophekadion* | 8 | *Hypsibarbus malcolmi* | 3 |
| *Bagarius yarelli* | 7 | *Pangasius djambal* | 2 |
| *Pangasius macronema* | 7 | *Tenualosa thibeaudeaui* | 2 |
| *Pangasius polyuranodon* | 7 | *Trichogaster trichopterus* | 2 |
| *Probarbus jullieni* | 7 | *Bagarius bagarius* | 2 |
| *Probarbus labeamajor* | 7 | *Bangana behri* | 1 |
| *Cyclocheilichthys enoplos* | 6 | *Botia helodes* | 1 |
| *Hampala dispar* | 6 | *Channa striata* | 1 |
| *Hampala macrolepidota* | 6 | *Chitala lopis* | 1 |
| *Henicorhynchus siamensis* | 6 | *Cirrhinus molitorella* | 1 |
| *Pangasianodon hypophthalmus* | 6 | *Hemibagrus wycki* | 1 |
| *Pangasius conchophilus* | 6 | *Laides hexanema* | 1 |
| *Pangasius krempfi* | 6 | *Lycothrissa crocodylus* | 1 |
| *Pangasius pleurotaenia* | 6 | *Mekongina erythrospila* | 1 |
| *Catlocarpio siamensis* | 5 | *Osphronemus exodon* | 1 |
| *Chitala blanchi* | 5 | *Osteocheilus hasselti* | 1 |
| *Pangasius larnaudiei* | 5 | *Pristolepis fasciata* | 1 |
| *Barbodes gonionotus* | 4 | *Puntioplites proctozysron* | 1 |
| *Notopterus notopterus* | 4 | *Boesemania microlepis* | 1 |
| *Pangasius bocourti* | 4 | | |

### 4.5. EXPERIENCES

The complex migration patterns that were uncovered during the survey, illustrated here by the redtail botia and *H. siamensis* (Figures 3-4), show that a large amount of detailed lifecycle information can be obtained through semi-structured interviews with local fishermen. The critical issue here is that the survey is designed in a way that makes data collected from a number of sites comparable, so that each site act as one piece in the puzzle and when putting all pieces together, migration patterns for the species emerge.

The results on overall migration reports and migration patterns demonstrate that by combining results from a large number of species, it is possible to make conclusions about more general ecological parameters, such as determining the effect of hydrological factors on the fisheries ecology, or indicating the borders between different eco-regions. This would not have been possible through more conventional biological surveys like sampling or tagging.

Although a certain rigidity of the survey is important, in order to be able to compare results from station to station, it is equally important to allow room to include information, which the survey designers did not take into account during the design of the survey. The issue about deep pools, for instance, was not considered specifically when designing the survey. However, the development of co-management systems for deep pool habitats may be a priority for future fisheries management in the Mekong Basin, and the survey provided an unexpected opportunity to map out important *deep-pool areas* and indicate which species are using deep pool habitats.

If biological information provided at closely situated stations is contradictory, it is necessary to further explore the reasons. While it is possible that one of the fishers was misunderstood or provided erroneous information, it is in fact also possible that all fishers are right! Rivers constitute extremely heterogeneous environments and it is entirely possible that fish behave differently even at two closely situated fishing grounds. It is therefore central to get as much detail about the environment at each station as possible (depth, current, bottom types, tributaries etc.).

One of the areas where local knowledge proved to be superior to any other methodology is in mapping the distribution of endangered species. Rare species are not likely to show up in any sampling study of limited duration. But fishers, who set their gear in the same place day after day, will almost certainly know whether a particular species is there or not, and the fishers can also provide historical information about species that have disappeared within their lifetime.

The migratory nature of most fish species for instance makes the identification of stocks difficult. In order to get more detail it will be necessary to resort to supplementary methods such as sampling at fixed stations along the river, tagging (including electronic tags), and genetic population studies. Common for all these methods is that they are extremely expensive and near worthless without baseline data. Local knowledge data will play a key-role in the formulation of hypotheses to be tested with these methods in the years to come.

### 4.6. How Can the Mekong Fisheries be Managed Based on Local Knowledge?

The intensity of the fishery in the Mekong Basin has led to the popular belief that the fish stocks are suffering from over fishing. However, several hundred thousand tonnes of fish have been extracted annually for many decades, and there is currently no evidence of any decline in the fishery yield (Jensen, 1996) - only a few of the large and slow growing species are now decreasing in numbers (Lieng *et al.*, 1995; Jensen, 1996; Van Zalinge *et al.*, 2000). This is because most species are adapted to high natural mortalities in floodplain rivers by early sexual maturation (after one or two years), and by laying a high number of small eggs with a rapid development (r-strategy) (Welcomme, 1985; Lowe-McConnell, 1987). Species with such a life strategy can be exploited very intensively without serious impact to the stocks (Welcomme and Hagborg, 1977; Bayley, 1995), because recruitment and mortality of these species is much more dependant on the size and duration of the flood than on the intensity of the fishery (Welcomme and Hagborg, 1977). Nearly all species are much more sensitive to environmental changes than to over-fishing. This implies that it is more important to manage the environment than to manage the fisheries *per se*, in order to sustain the fisheries.

Overall the Mekong Basin is still relatively unaffected by pollution, and except for a few spots, near major cities, the water quality is good. However, increased industrial development and rapidly growing human populations will inevitably lead to a considerable rise in the demand for water, energy and arable land, and the pressure on the natural resources in the region is quickly building up.

Destruction of aquatic habitats is already widespread, and mainly consists in the conversion of natural floodplains into paddy fields and cutting down trees and bushes for firewood and for use in brush parks in the fisheries (Troeung, 2000; Van Zalinge *et al.*, 2000). Improving navigation through dredging of the riverbed and removal of rocks, like it is being considered for some sections of the river, will change water flow and may also affect spawning grounds of many species (Coates *et al.*, 2000).

Currently a number of dams in the Mekong Basin are being planned, some of these are for flood-control, others for irrigation and hydropower (ICCILMB, 1992; Hill and Hill, 1994). Migratory fish species depend on free movement during their seasonal migrations, and any construction that hinders the migrations will prevent these fish from completing their lifecycles, thus leading to the gradual disappearance of the affected stocks or in some cases even the species. Even if it were possible to design a fish ladder which allowed the passage of all species, it still would not be able to cope with the enormous quantities of fish during the times of peak migration.

The cumulative effect of dams on tributaries, and extraction of water for irrigation and other purposes, will in addition affect the duration and size of the floods as well as their timing. The flood size and duration determines the size of the feeding areas on the floodplain, and the time these are available for fish. The timing of the flood is crucial for the transportation of eggs and larvae from spawning grounds to feeding areas. If the flood size or timing deviate too much from the normal, the larvae will risk ending up in the wrong place (Welcomme, 1985).

Appropriate management must therefore take the ecology of the individual species into account rather than using simplistic parameters like fish stock sizes, which does not convey any information about the health of riverine fish stocks unless a long series of data is available. Important ecological parameters are distribution, spawning grounds, migration patterns (including distance, timing and migration corridors).

As already mentioned, the diversity of fish is high, and it is impossible to continuously monitor the status of all the stocks, even if we did manage to get sufficient information on status quo. The only option is to group the fishes according to their ecology, and develop management strategies for each group. In a first attempt, one hundred species, recorded from the Tonlé Sap floodplain, were grouped based on lifecycle information gathered through local knowledge and sampling (Chan *et al.*, 2000).

For management purposes, one or several indicator species should be identified in each group. The indicator species is not necessarily an important commercial species, but should be easy to monitor and a good representative of its group and thereby be able to provide information about the situation for the entire group.

## 5. Conclusions

Riverine fish stocks are extremely resilient and can sustain incredibly high fishing pressures, but these stocks are vulnerable to environmental degradation and especially to water management projects. The lack of detailed knowledge on the ecology, and sometimes even the taxonomy of most species, makes it is very difficult to get a manageable picture of the fisheries situation in a vast basin like the Mekong. The majority of Mekong fish species are migratory and are dependant upon both longitudinal and lateral connectivity in order to complete their lifecycles. Most fishery impacts will therefore be of much more than a localised scale, and EIAs must consequently cover all ecological units of the basin.

It is concluded that local knowledge will have a significant position in the study of river ecology in the years to come, because gathering fishermen's knowledge is a quick way to obtain baseline information about the biology of fish. The method is also sustainable in developing countries because it is cheap and requires limited training if carried out by experienced fisheries people. However, the method cannot, and should not, stand alone, but should rather be used as the first step in a process enabling researchers to ask more specific questions, which can be answered through more focused studies.

## Acknowledgements

We would like to acknowledge the contributions by counterparts at all levels, and provincial and district officers in the four riparian countries, who willingly assisted us during the survey.

Dr. Niek Van Zalinge and Mr. Peter Degen from the Component for the Management of the Freshwater Capture Fisheries of Cambodia, and Dr. Chris Barlow at the MRC Secretariat kindly commented on the manuscript. Mr. Sou Virak, at the MRC Secretariat, assisted in designing the map of the Mekong.

Basin and Mrs. Cheap Sotheavy helped formatting several of the figures.
However, most of all we wish to thank the fishermen, who spend hours of their valuable time, sharing their knowledge with us. Without their voluntary collaboration, this survey could not have been realised.

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