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FISH MIGRATIONS AND SPAWNING HABITS IN THE MEKONG MAINSTREAM: A SURVEY USING LOCAL KNOWLEDGE

(BASINWIDE)

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Assessment of Mekong Fisheries: Fish Migrations and Spawning and the Impact of Water Management Project

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Foreword

This report is based on local knowledge possessed by fishers living along the shores of the Mekong in the four Riparian countries of the Mekong River Commission (MRC). The information was compiled during a survey facilitated by the ***Component of the Assessment of Mekong Fisheries: Fish Migrations and Spawning and Impact of Water Management*** (AMFC) and implemented jointly by staff from: Department of Fisheries Cambodia, Living Aquatic Resources Research Centre (LARReC) of Lao PDR, Department of Fisheries Thailand, and Research Institute for Aquaculture No. 2 (RIA-") of Vietnam.

The AMFC is a regional component (Cambodia, Lao PDR, Thailand and Vietnam) and has offices in each country. The objective of the component is that improved quantitative and qualitative information of fisheries ecology and socio-economics is provided and (a) taken into account in fisheries management pratices, and (b) incorporated into planning of water management projects in order to sustain and optimise fisheries productivity and socio-economic benefits from potentially affected water bodies.

Preparation of this report

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I. INTRODUCTION

A. Background

The Mekong River is the largest river in South-East Asia. From its source in China, it flows through six countries and covers a distance of more than 4,200 km, to discharge approximately 475,000 million m^3 of water into the South China Sea. The river enters its lower basin at the border point between China, the Lao People's Democratic Republic (Lao PDR) and Myanmar, some 2,380 km from the sea. This point also marks the entry of the river into the jurisdiction of the Mekong River Commission (MRC).

The Mekong River is enriched with a remarkable diversity of fish. The river basin is inhabited by an estimated 1,200 species, many of which are still awaiting taxonomic identification. On a per unit area basis, this is possibly unrivalled by any other river basin.

In fact, the Mekong River is unique not only in terms of diversity. The river basin supports what is probably the largest inland fishery in the world. The total annual catch of the lower Mekong (covering Cambodia, the Lao PDR, Thailand and Viet Nam) is conservatively estimated at about 1 million tons[1] (Jensen, 1996). Approximately 60 million people live within the basin, most of whom, directly or indirectly, depend on the fisheries resources of the Mekong River for their income and food security.

For any Mekong fish species, minimal and fragmentary biological and ecological information exists. Most of the available information originates from studies at Khone Falls in southern Lao PDR on the border with Cambodia (Singanouvong *et al.,* 1996a and 1996b; Baird 1998, Roberts 1993, Roberts and Warren 1994, Roberts and Baird 1995). That area is clearly a key site within the Mekong River and the results of the studies are extremely valuable. However, by their nature, they are local studies. As is discussed below, some ecological events in rivers occur at the basinwide level. Therefore, in order to describe such ecological events, it is necessary to include the basin as a whole in such studies.

In order to improve the information base on Mekong fisheries, the Assessment of Mekong Fisheries – Fish Migrations and Spawning Habits and Impacts of Water Management Component of the MRC Fisheries Programme (AMFC) was initiated in 1997. One of the important activities of AMFC is to "describe fish migrations and spawning habits, and identify key habitats, for a selected number of important Mekong fishes". Initially, 45 species were tentatively proposed for detailed studies in the project document. The list has since been modified by the project (see box 1).

This report presents the first research findings of AMFC on fish migrations and spawning habits in the Mekong mainstream. The findings are based on a basinwide survey carried out DURING 1999 by AMFC along the Mekong mainstream. The survey produced a large amount of data, of which only a fraction is included here. The

[1] References to tonnage in this publication are given in metric tons.

data are stored in an ACCESS database, which will be published together with this report.

Box 1. List of priority fish species

Cyprinidae:

Aaptosyax grypus
Bangana behri
Barbodes gonionotus
Catlocarpio siamensis
Cirrhinus microlepis
Cyclocheilichtys enoplos
Hampala dispar
Hampala macrolepidota
Henicorhynchus siamensis
Hypsibarbus malcolmi
Mekongina erythrospila
Morulius chrysophekadion
Osteochilus hasselti
Paralaubuca typus
Probarbus jullienni
Probarbus labeamajor
Puntioplites falcifer

Notopteridae

Chitala blanci
Chitala ornata
Notopterus notopterus

Clupeidae

Tenualosa thibeaudeaui

Engraulidae

Lycothrissa crocodylus

Cobitidae

Botia modesta

Mastacembelidae

Mastacembelus armatus

Belontiidae

Trichogaster trichopterus

Osphronemidae

Osphronemus exodon

Nandidae

Pristolepis fasciata

Pangasiidae:

Helicophagus waandersi
Pangasianodon gigas
Pangasianodon hypophthalmus
Pangasius bocourti
Pangasius conchophilus
Pangasius krempfi
Pangasius larnaudiei
Pangasius macronema
Pangasius pleurotaenia
Pangasius polyuranodon
Pangasius sanitwongsei
Pangasius siamensis

Schilbeidae:

Laides hexanema
Laides sinensis

Siluridae

Micronema bleekeri
Wallago attu
Wallago leeri

Bagridae

Mystus nemurus

Clariidae

Clarias batrachus

Sisoridae

Bagarius yarelli

Sciaenidae

Boesemania microlepis

Anabantidae

Anabas testudineus

Channidae

Channa striata

However, before presenting and discussing the results, fish migrations (including their implications for fisheries) are discussed. Furthermore, the initial considerations within AMFC are discussed, including their implications in relation to the research methodology that was applied.

B. Fish migrations and their implications

Fish migrations are an important feature of river ecology in most major tropical rivers. Often, fishes migrate several hundred kilometres in order to reach spawning sites or fertile feeding grounds (Bayley, 1973). In spectacular cases such migrations can cover distances of several thousand kilometres (Barthem and Goulding, 1997).

The long-distance migrations within main river channels and their main tributaries are normally referred to as "longitudinal migrations". Fish migrations from the main river and tributaries into flood-plain areas during the flood season and back again during the dry season, are referred to as "lateral migrations". Another important type of fish movement in rivers is the downstream passive movement by fish larvae, or "larval drift". During the flood season, larvae of some species may drift several hundred kilometres from upstream spawning areas to downstream nursery areas in the flood plain. All the different movements are integrated components of the life cycle strategies for riverine fishes. Many species, at different times and life stages, undertake all the above movements. For example, for many species, lateral migrations from flood plains back to the river are often followed by longitudinal migrations within the main river channel.

Essentially, these migrations are adaptations to life in running water. Within each river system, fish have adapted to the particular hydrological conditions associated with that river. For example, in a tropical flood-plain river like the Mekong, the life cycles of many fish species are adapted to ensure that newly hatched fish larvae and juveniles are brought into the highly productive flood-plain areas at the onset of the flood season.

The life cycles of migrating fish ecologically connect different areas and habitats of rivers. Although rivers and their associated flood plains encompass a wide range of different habitat types, they are all ecologically linked in a complex "fish migration network". Therefore, from the point of view of migrating fish species, the river basin functions as one ecological unit.

In the Mekong River, fish migrations have great implications for fisheries because a substantial part of the fisheries are based on catching migrating fish. Good examples are the *dai* (bag net) fisheries in Cambodia (Lieng *et al.,* 1995), and the Khone Falls fishery, one of the most important fisheries in the Lao PDR (Baird, 1998; Singanouvong *et al*., 1996a; Singanouvong *et al*., 1996b). Even the larval drift is exploited. In the Mekong delta in Viet Nam, millions of *Pangasianodon hypophthalmus* larvae are caught every year and stocked in ponds and cages.

Fish migrations also have great implications for regional development planning and management. Many important fish stocks are shared between riparian countries and, therefore, call for regional management strategies. They are, in fact, transboundary

resources. Requirements for, and development of, joint management approaches by the four countries of the lower Mekong River basin is a primary reason for the existence of MRC, in accordance with the Mekong Agreement 1995, and MRC Strategic Plan, 1999-2003. The fact that a river basin can be regarded as one single ecological unit implies that holistic (i.e., basinwide) resource management strategies should be developed and implemented.

A prerequisite to efficient and appropriate planning is the availability of high-quality information. This, in essence, is the main reason for the existence of AMFC, i.e., to increase the ecological knowledge, on a basinwide scale, about fish and fisheries of the Mekong River with a view to the inclusion of such information in future development plans for the basin.

Many previous studies of fish migrations in rivers have focused on one or a few species in smaller areas, using "conventional biological" methods such as tagging and sampling (Bayley, 1973; Quiros and Vidal, 1998). However, with few exceptions, those methods have provided only fragmentary information on the life cycles of the studied target species (Welcomme, 1985, Barthem and Goulding, 1997). Barthem and Goulding (1997) concluded that "the value of tagging experiments in an area as large and unknown as the Amazon is doubtful". Instead, they based their hypotheses about the migration of two important catfish species in the Amazon River on more than 15 years of studies that compared the composition of fish lengths and species in various rivers of the Amazon basin during different seasons of the year.

Given the basinwide, multi-species approach of AMFC, conventional research methods are not appropriate. In effect, no standard method that is ready to be "picked from the shelf", exists for basinwide, multi-species studies in major river systems.

Based on these considerations, AMFC decided that the best approach would be to tap into the vast source of ecological information that exists among the peoples and communities who, in every sense, are closest to the resource: the local fishermen and fishing communities of the Mekong basin.

C. Local knowledge as a tool in ecological research

In recent years, local knowledge has been recognised as a valid and important source of ecological information (Huntington and Mymrin, 1996; Johannes, 1993). This development has coincided with an increased call for local participation in natural resources management, triggered by a general realisation of the limitations of conventional, centralised management strategies (Hoggarth *et al*., 1999).

As a consequence, local knowledge (often referred to as traditional ecological knowledge or TEK) is now increasingly being promoted and used as a tool in natural resources management. This approach refers to both its use in terms of acquiring detailed, ecological knowledge related to natural resources, and in terms of the involvement of local people in the process of developing and implementing management strategies (Price, 1995, Hoggarth *et al*, 1999). In fact, many experts

argue that it is not possible to separate the use of local people's knowledge from the involvement of those same people in the process of managing local resources.[2]

Box 2. Examples of recognition of local knowledge by international Conventions and Agreements under the United Nations system

Rio Declaration on Environment and Development

Principle 22

Indigenous people and their communities and other local communities have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognise and duly support their identity, culture and interests, and enable their effective participation in the achievement of sustainable development.

Agenda 21

Chapter 26: **Recognising and Strengthening the Role of Indigenous People and Their Communities**.

Article 26.1 (Basis for action):

Indigenous communities have developed over many generations a holistic traditional scientific knowledge of their lands, natural resources and environment.

Article 26.3 (Objectives):

Recognition of their values, traditional knowledge and resource management practices with a view to promoting environmentally sound and sustainable development.

Article 26.5 (Activities):

Achieving a better understanding of indigenous people's knowledge and management experience related to the environment, and applying this to contemporary development challenges.

Convention on Biological Diversity

Article 8j:

Each contracting party shall respect, preserve and maintain knowledge of indigenous and local communities, promote their wider application with the approval and involvement of the holders of such knowledge and encourage the equitable sharing of benefits arising from the utilisation of such knowledge

Article 17:

The contracting parties shall facilitate the exchange of information, including information on indigenous and traditional knowledge.

Food and Agriculture Organisation Code of Conduct for Responsible Fishing

Article 12, paragraph 12:

States should investigate and document traditional fisheries knowledge and technologies, in particular those applied to small-scale fisheries…

[2] Wolf Hartman, personal communication.

The recognition of traditional ecological knowledge is a global trend, which is reflected in a number of important international Conventions and Agreements (see box 2).

One of the major strengths of local ecological knowledge is that it is based on everyday observations, which often reach beyond the lifetime of the individual. Such intimate knowledge about the local environment, and the resources contained within it, is virtually impossible to acquire through conventional research surveys, which very rarely cover even one complete annual cycle. In line with this, Freeman (1999) argued that local knowledge in many cases was superior to traditional scientific methods. He, furthermore, provided four examples, where knowledge possessed by Inuit hunters in Canada had proved superior to conventional scientific research findings.

Such examples serve to demonstrate that local knowledge should at least be viewed on.equal terms with conventional scientific knowledge. In fact, it could be argued that local knowledge and scientific knowledge are basically the same; both attempt to make predictions based on careful observations. Whether such observations are undertaken by using expensive electronic equipment or the naked eye does not change their basic aim. Therefore, the strongest foundation for the collection of quality fisheries ecological information is to establish a system through which both local and scientific knowledge can contribute, on equal terms, towards the formulation of basin development plans and environmental impact assessments (EIAs).

Johannes (1993) elaborated on the potential for integrating TEK into EIAs. He suggested that for traditional ecological knowledge to be useful for EIAs, research should include four perspectives:

(a) A taxonomic perspective (i.e., the study of local, indigenous naming systems and their significance in relation to the role of natural resources);

(b) A spatial perspective (i.e., spatial distribution of natural resources);

(c) A temporal perspective (i.e., timing of certain ecological events, such as migrations and spawning aggregations, related to living natural resources);

(d) A social perspective (i.e., how will local people respond to changes caused by environmental impacts).

Concern is often raised about the use of local knowledge is linked to the issue of validation. Johannes (1993) stated that “a flagrant deficiency in much of the literature describing traditional ecological knowledge is the absence of any effort to determine its validity”. Furthermore, he provided some suggestions for validation procedures that can be incorporated into the survey process.

Although a local fisherman is just as keen to get the facts right as any scientist, cultural and communicative barriers between fishermen and interviewers may easily lead to misunderstandings. We therefore agree on the importance of incorporating validation procedures into the survey. The validation procedures applied during this survey are described in section F of this chapter.

D. Use of local knowledge in the study of river fisheries

Despite the recent recognition of local knowledge, very few studies have focused any attention on it in the context of river fisheries. However, in one interesting study, Poizat and Baran (1997) compared the knowledge of fishermen with gill-net sampling in the Fatala River estuary, in Guinea, West Africa. They found that there was "good coherence between fishermen's answers and gill-net sampling results" and supported the idea of using fishermen's knowledge as a source of ecological information.

According to Dr. Michael Goulding, a leading expert on the ecology of the Amazon River, "indigenous and local natural history represents the true 'El Dorado' of the Amazon" (ECT, 1998).

In the Mekong River, local knowledge on fish ecology has been included in studies and conservation work near the Khone Falls in southern Lao PDR. For example, the recent establishment of fish conservation zones in Khong District, just above the Khone Falls, was based largely on local knowledge (Baird *et al*., 1999). Roberts (1993) supplemented his fish sampling at the Khone Falls during June-July 1993 by interviewing some of the experienced fishermen in that area. He recommended that "the interviews should be extended to other times of the year and other places". Roberts and Warren (1994) based an important part of their account of the migration and spawning of *Probarbus jullieni* in and around the Khone Falls on interviews with local fishermen.

E. Survey method

AMFC has developed a methodology for the use of local knowledge[3] in the study of fish migrations and spawning habits in the Mekong basin. The methodology was tested through a trial survey during June-September 1998 in a small area of the basin in each of the four riparian countries (Jørgensen *et al*, 1998). The main objectives of the trial were to test the methodology and to build up experience in carrying out such type of survey.

Based on the trial survey, the methodology was refined (Jørgensen *et. al*., 1998), and the survey of the Mekong mainstream (on which this report is based) was carried out from February to July 1999. Since the methodology is described in detail in the Survey Manual (Poulsen and Jørgensen, 1999), only the main points are mentioned here. The overall approach of the survey was to gather specific information, focusing on three main perspectives of local knowledge:

(a) Taxonomic. All information compiled was related to a specific taxonomic group or species. Links between local names and taxonomic names were established;

[3] Although the term TEK is now a recognised acronym, AMFP prefers to use the broader term "local knowledge" because the objective is to obtain information related to local ecological events. This may or may not be based on traditional (i.e., inherited) knowledge.

(b) Spatial. All information compiled from one fisherman for a particular species (or species group) was related to a specific fishing ground (and therefore a specific habitat);

(c) Temporal. Information about a particular species at a particular place (habitat) was correlated with timing of occurrence and certain natural events (seasonal as well as diurnal).

Local knowledge is area specific, and a fisherman living in the upper reaches of a river cannot be expected to know about occurrence and timing of species in the lower reaches. Since fish migrations often occur at the basinwide level, it is not possible to learn every aspect of the lifecycle of any species by talking with one or a few fishermen only. Information is required from many fishermen located all over the basin before it becomes possible to map out lifecycle patterns of migrating fish. Although this fact complicates things, it is at the same time a major strength; it gives the data a more solid foundation when they are based on the knowledge of many people rather than only a few.

Therefore, one fisherman provides information from his/her local area only. When information from different places along the Mekong River is correlated, a substantial amount of data on life cycles for the concerned species emerges.

The main tool used during the survey was a photo flipchart of about 150 selected species. Of those species, 49 were selected as target species for more detailed ecological information gathering. The selection was based on their importance in fisheries as well as in the context of biodiversity (according to anecdotal indications as well as observations by component staff). In addition, the selection aimed at a broad taxonomic coverage, e.g., including representatives from as many different fish families as deemed possible (see box 1).

Apart from providing the focal point during interviews, the photo flipchart also served to “breaking the ice”. Often, villagers gathered around the interview spot and the photos became the centre of attention, triggering discussions between villagers and interviewers. Thus, a relationship was established that would otherwise have taken much longer to achieve.

Prior to the start of each interview, the fishermen were informed about the purpose of the visit and the intended use of the information provided by them.

In each country, a two-person team undertook the survey. One person carried out the conversation with the fishermen while the other extracted data from the conversation, using pre-designed survey formats. Experience from the trial survey demonstrated clearly that as the survey team became more familiar with the situation and the methodology, the quality of the survey increased substantially. Therefore, emphasis was placed on maintaining the same survey teams throughout the survey.

Several workshops and training sessions were held for the interview teams before, during and after the fieldwork. During the workshops, methods were discussed in detail and modified, progress and problems in relation to ongoing fieldwork were reviewed, and collected data were analysed and discussed.

F. Validation

The survey operated with several layers of validation, which are detailed below.

First, substantial effort was put into selecting the right fishermen. This approach was very important because not only do the more knowledgeable and experienced fisherfolk provide more information, they are also better motivated to participate and therefore less likely to exaggerate and/or provide false information. In addition, in many villages, certain persons have the reputation of being "expert fishermen" and often it has been a matter of pride for villagers to get these experts to provide information to the survey team.

Second, on-the-spot validation occurs during interviews. The survey teams quickly develop experience in assessing the quality of information provided by fishermen. Especially during the initial group interviews (see Poulsen and Jørgensen, 1999, for methodological details), quality and reliability were checked by the interview team. For example, at each location, it was known that certain fish species in the photo flipchart were not found in that area. If a fisherman from the upper reaches of the Mekong River in northern Lao PDR claimed to recognise an estuarine species such as the tarpon (*Megalops cyprinoides*), it was a sign that caution was needed with the information provided by him. In such cases, the interview team did not select that fisherman for further individual interviewing.

Sometimes, there were reasons for misidentification. For example, during the trial survey, the giant Mekong barb, *Catlocarpio siamensis*, a typical mainstream long-distance migrant, was identified by fishermen from Nong Houm Reservoir near Vientiane. One of the most common species introduced into the reservoir was the Bighead carp (*Hypophthalmichthys nobilis*), which was not included in the photo flipchart. Although the resemblance between the two species is not obvious, they are both big-sized fish with large heads. The Bighead carp is obviously a prominent feature in the Nong Houm reservoir fisheries and the Giant Barb, which is not found there, is the species bearing closest resemblance to the Bighead carp in the photo flipchart.

Another common misidentification occurred between the two *Notopterid* species, *Notopterus notopterus* and *Chitala lopis*. The latter is a large species that grows to 150 cm whereas *Notopterus notopterus* only reaches 40 cm. However, in the photo flipchart they appear to be of equal size.

It is important that interviewers are aware of such potential misidentification and, where needed, can provide the fishermen with additional information about the fish in the photos.

According to experience gained during the survey, most of the interviewed fishermen provided reliable data. Again, this was often a matter of pride for both the individual person as well as the village as a whole.

Third, validation occurs during data analysis when data from all the interviewed fishermen are correlated. Any "faulty" data will normally fall out of context with other data. However, any dismissal of seemingly "wrong" data should be done with care. Data that appear to contradict overall trends may not necessarily be wrong. For example, it could reflect the occurrence of different stocks with different ecological habits.

As a final note on the methodology, it should be mentioned that the authors regard this survey as the beginning, not the end, of a more active involvement of resource users in the research process. The aim is that this process will eventually lead to the development of strategies and recommendations for future resource use planning and management.

To that end, the results of the survey will be presented to, and discussed with, the participating fishermen, some of whom have already shown interest in participating further in the research. A logbook monitoring system will be set up in co-operation with those fishermen, whereby they will monitor their own catches on a daily basis over one year.

II. DESCRIPTION OF PARTICIPATING FISHERMEN

A. Study area

During the migration and spawning survey, 120 fishing groups from 113 villages were interviewed about the absence or presence of 175 fish species in their fishing grounds. The villages were distributed along the Mekong and Bassac rivers, from Ban Sop Kok located in north-eastern Thailand, 2,403 km from the river mouth, to Long Binh commune in Viet Nam, which is only 11 km from the sea.

A total of 355 "expert" fishermen were interviewed individually with regard to a subset of the species encountered in their area. The ages of the interviewees ranged between 15 and 80 years, with the majority aged from 31 to 45 years (figure 1). Although it was not intentional, all the interviewees were male with between 2 and 60 years of fishing experience (figure 2), with the majority having from 11 to 30 years of experience.

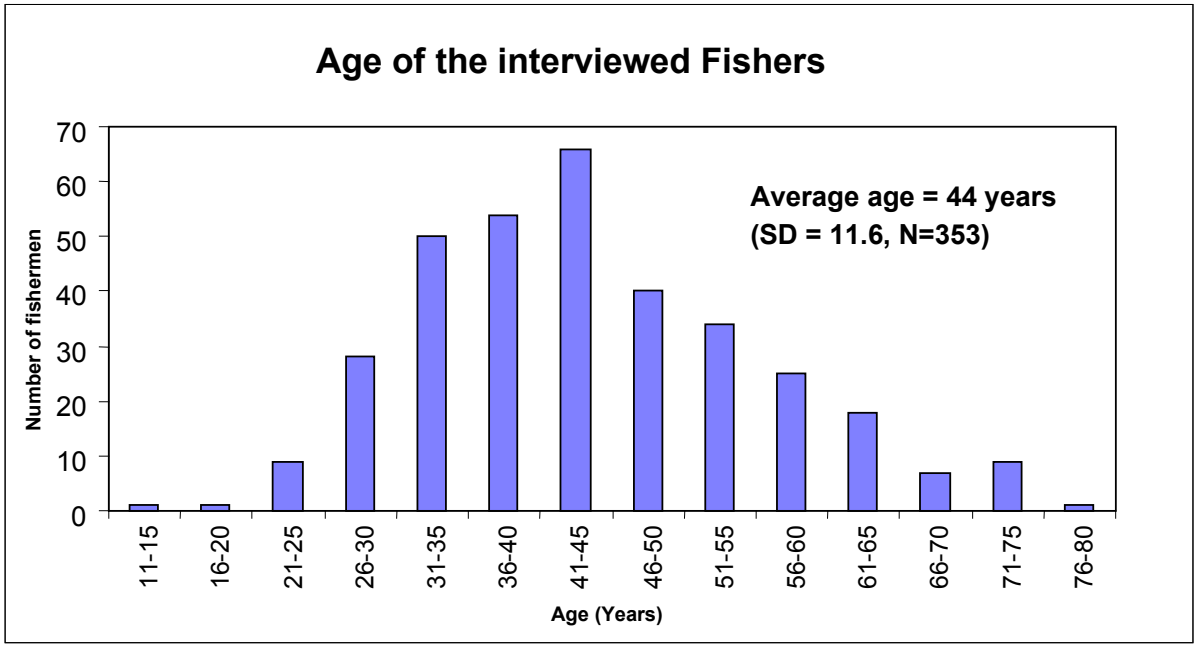


Fig. 1: The age of 353 interviewed fishers (for two fishers no age data was available).

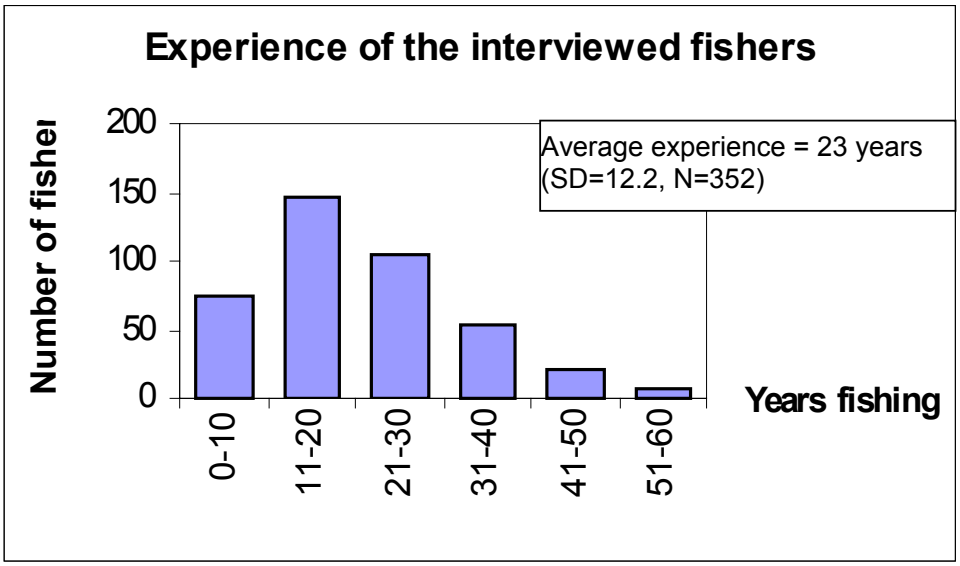


Fig. 2: The fishing experience of the interviewed fishers (for three fishers no data on fishing experience was available).

B. Types of fishing gear and methods used

The interviewed fishermen used more than 20 different types of fishing gear and methods (see table). The most frequently used methods were stationary and drifting gill net (used by 349 and 263 fishermen, respectively), longline (237 fishermen), cast-net (243 fishermen) and "other traps" (199 fishermen).

Types of fishing gear and methods used by number of fishermen interviewed in each country

Type of gear	Cambodia	Lao PDR	Thailand	Viet Nam	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
Other traps	84	106	6	3	199
Hook and line	8	69	16	2	95
Small scoop net	24	3		2	29
Trawl	7			10	17
Seine net	17				17
Beach seine – with brushpark	7	2		3	12
Unspecified	9	2			11
Large *dai*				10	10
Large scoop-net			10		10
Small *dai*	1	1		5	7
Beach seine – without brushpark		2	5		7
Purse seine			1	5	6
Spear (including bow and arrow)	3	2			5
Trawl (unspecified)	2				2
Barrages		2			2
Large lift net				2	2
Collection			1		1
Small lift net		1			1

III. RESULTS

A. Introduction

In this chapter, some of the main findings of the Mekong mainstream survey will be discussed. All the primary data on which this report is based are stored into a Microsoft ACCESS database developed by AMFC (Visser, 1999).[4] The database contains a large amount of data, of which only a fraction is included in this report. The remaining data will be analysed and published in subsequent reports, i.e., together with data obtained in the survey of major tributaries carried out in 2000.

The report is intended to provide: (a) lifecycle information for important Mekong fish species; (b) basinwide information on key fish habitats; and (c) the direction to be taken towards future research needs and priorities

The findings are discussed, species by species, in section B of this chapter. First, the species of the most diverse family, *Cyprinidae*, are described, followed by the families of *Cobitidae, Clupeidae, Engraulidae, Bagridae, Clariidae, Pangasiidae, Schilbeidae, Siluridae, Sisoridae, Notopteridae, Channidae, Anabantidae, Belontiidae, Osphronemidae, Mastacembelidae, Nandidae* and *Sciaenidae*. Within each family, the species are covered in alphabetic order.

In order to visualise distribution ranges and migratory patterns, the report includes maps of occurrence and migration patterns for most species. The maps are based on information provided by fishermen during the survey. At each station, groups of fishermen were asked whether or not each species occurred at that site. In addition, the fishermen were asked about the migration timing and direction (i.e., upstream or downstream) of each species.

In addition to creating information, species by species, looking at all the species together will be very helpful in identifying different migration patterns as well as key geographical areas and habitats. In section C, the general aspects and trends of the findings are discussed.

[4] The database will be published on CD-ROM together with this report.

B. Migration patterns for important Mekong fish species

1. Family: *Cyprinidae*

(a) Aaptosyax grypus

Aaptosyax grypus has previously been reported to be a rare endemic species of the Mekong region with distribution limited to large rivers in the middle Mekong (Rainboth, 1996). It is, furthermore, listed as "Data deficient" on the IUCN List of Endangered Animals.

The survey indicated a distribution range within the Mekong mainstream from Sambor in Cambodia to Loei in Thailand. However, one of the reports from Loei stated that the species was no longer found there, indicating that present-day distribution may have become significantly reduced.

Detailed migration information was obtained from four stations from O Krieng in Sambor district, Cambodia, to Klong Kaem in Ubon Ratchatani province, Thailand.

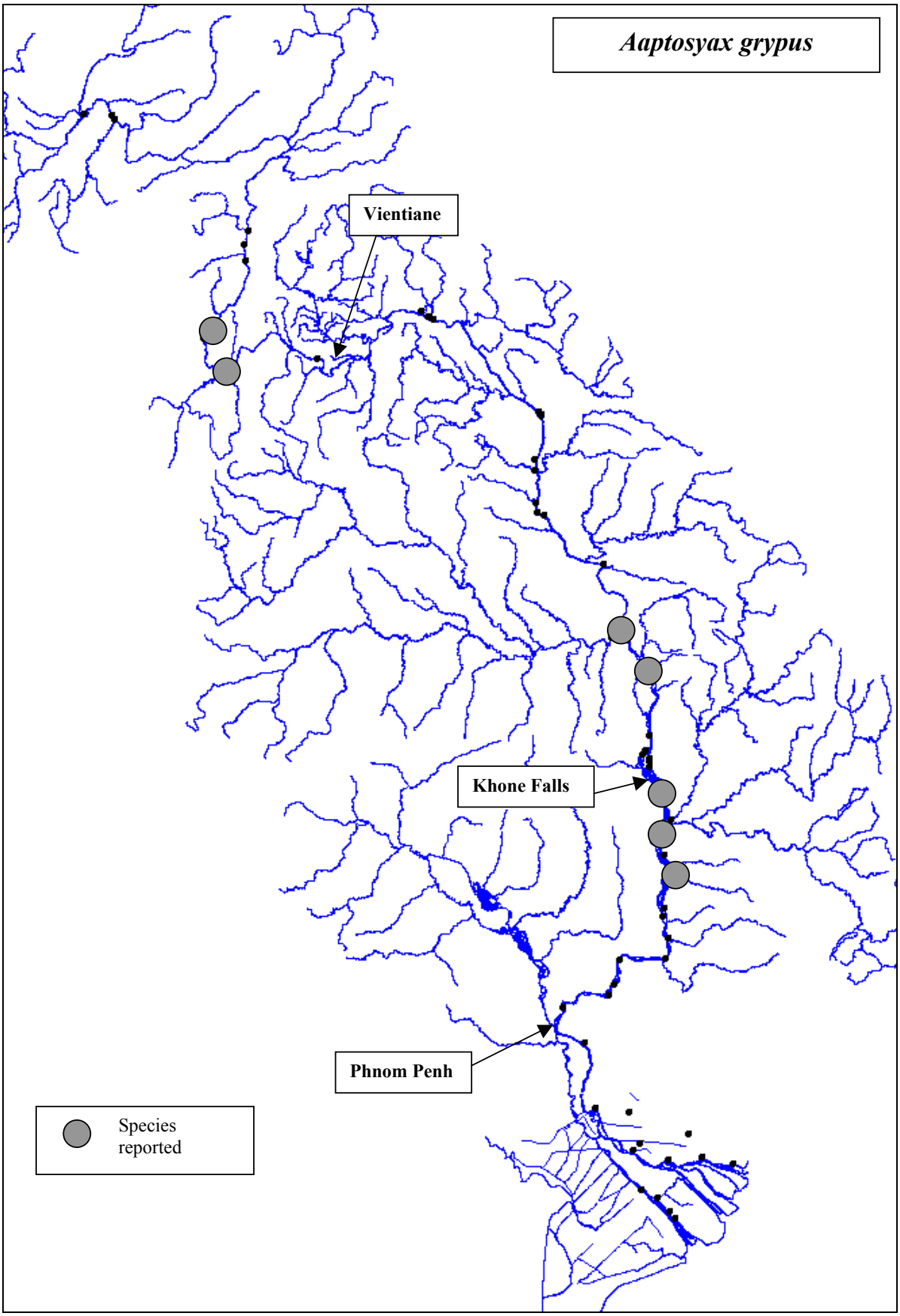
Aaptosyax grypus is reported to be a pelagic species that migrates at the same time as *Probarbus*, i.e., from December to February. This movement coincides with the timing of the reported upstream migration of small cyprinids in the same stretch of the Mekong River. Since *Aaptosyax grypus* is a predatory species, it could be hypothesised that it migrates upstream in order to follow its prey comprising smaller migratory fishes.

Roberts (1993) suggested that the upstream migration starting from late December might be a spawning migration. According to Dr. Chavalit Vidthayanon of the Department of Fisheries in Thailand, the species spawns during the dry season (April) in pools near rapids in the Mekong mainstream. However, no information was obtained on spawning during the survey.

Migrating *Aaptosyax* are all big fish and no information has been obtained on smaller specimens. The only existing report of juveniles is that of two specimens weighing 100 g, which were caught by gill nets in June 1996 at Ban Hang Khone, southern Lao PDR, just south of the Khone Falls (Baird 1998). Specimens have also been caught in the Songkhram and Moon rivers.[5]

The survey confirmed that *Aaptosyax grypus* is an extremely rare species. All the interviewed fishermen agreed on this conclusion and one of them even reported that it had been three years since he had last seen any of this species.

[5] Dr. Chavalit Vidthayanon, personal communication.


Aaptosyax grypus
Vientiane
Khone Falls
Phnom Penh
Species reported

(b) Bangana behri

Bangana behri is found from Sambor, Cambodia, in the south to Chiang Khong, Thailand, in the north. According to Rainboth (1996), this species occursin rocky stretches of the mainstream during the dry season and moves to tributary streams during the high water period. During the present survey, several fishermen reported that the fish lives in association with rocky parts of the Mekong River. Since rocky stretches do not occur downstream of Sambor, the distribution pattern does, in fact, appear to be determined by the presence of rocky habitats. However, records from two stations in the Mekong delta in Viet Nam suggest that the species occurs there, thus contradicting the above theory. From the records of the two stations, *Bangana behri* are reported to be non-migratory, which is also contradictory to the above theory and to previous studies. These reports may be the result of misidentification and therefore need re-checking.

The migration pattern below the Khone Falls appears to be somewhat contradictory. At two stations in Stung Treng province, fishermen reported that the species migrates upstream at the onset of the monsoon season (May-June) and downstream in the dry season from November to February. At other stations in Sambor and Kratie, as well as two stations just south of the Khone Falls, the species was reported to migrate downstream at the onset of the monsoon season and upstream in the dry season. The reason for that movement appears to be the presence of the important tributary system comprising the Sekong-Sesan-Srepok rivers. Fishermen at stations near the tributary system reported that fish migrate from this system into the Mekong River during periods of receding water, and then migrate upstream in the tributaries during the monsoon season, possibly to spawn.

Upstream of the Khone Falls, this species begins migrating upstream in the dry season (February to May) and continues into the beginning of the monsoon season. This movement may, in fact, be two separate migrations: a dry season, non-reproductive migration of smaller fish, and an early monsoon season migration of larger fish in spawning condition.

Non-reproductive, dry-season migrations of *Bangana behri* have previously been reported from just above the Khone Falls between December and February, at which time it becomes one of the most important fish in the fisheries (Warren *et al*., 1998). These are mainly small specimens with a mean body weight of 275 g. Juveniles of the species, with mean sizes around 100 to 150 g (Baird, 1998), have also been reported by dry season fisheries at Ban Hang Khone, immediately downstream of the Khone Falls.

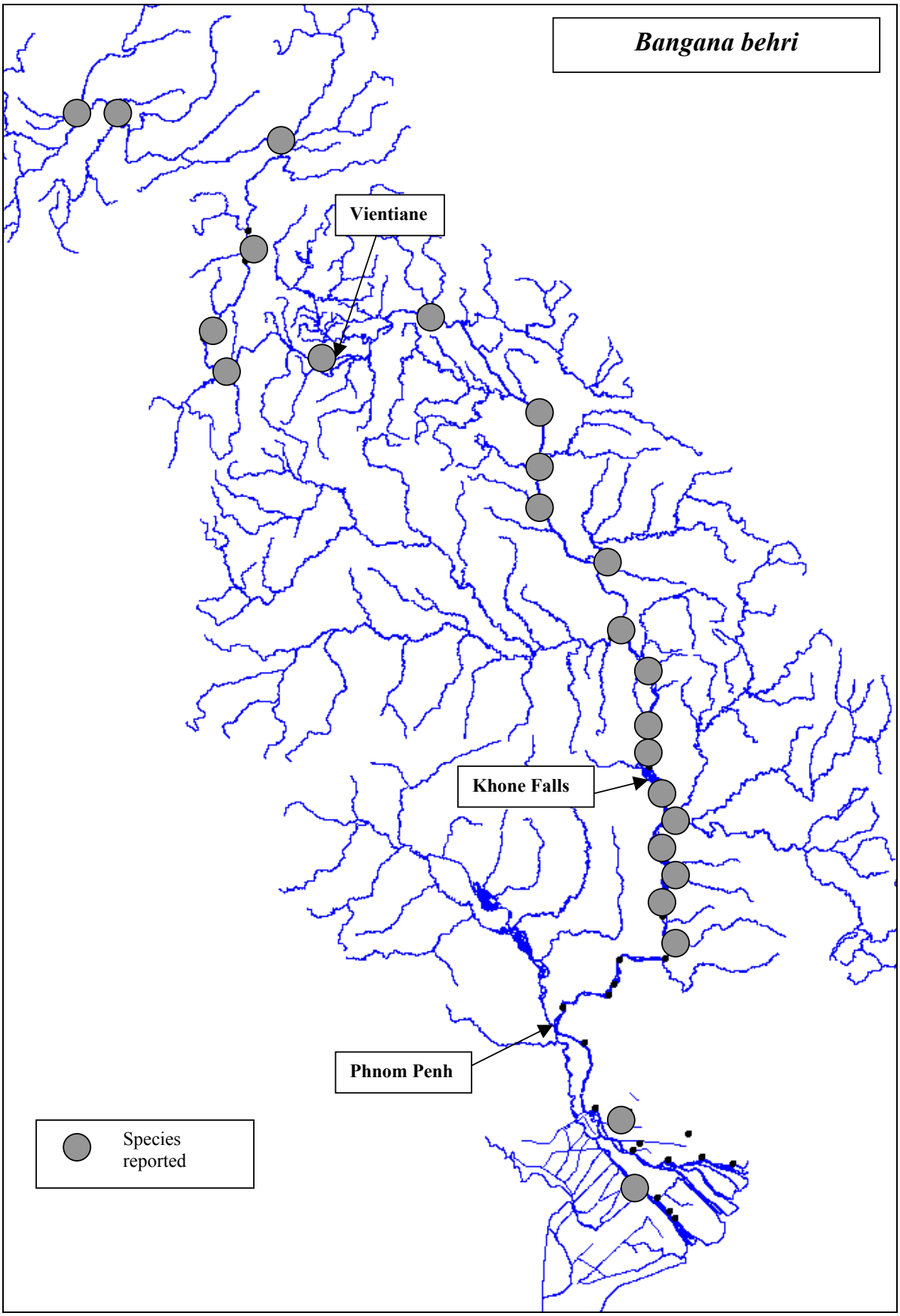
There were no reports during the two studies, both above and below the Khone Falls, on upstream migrations of this species during the early monsoon season.

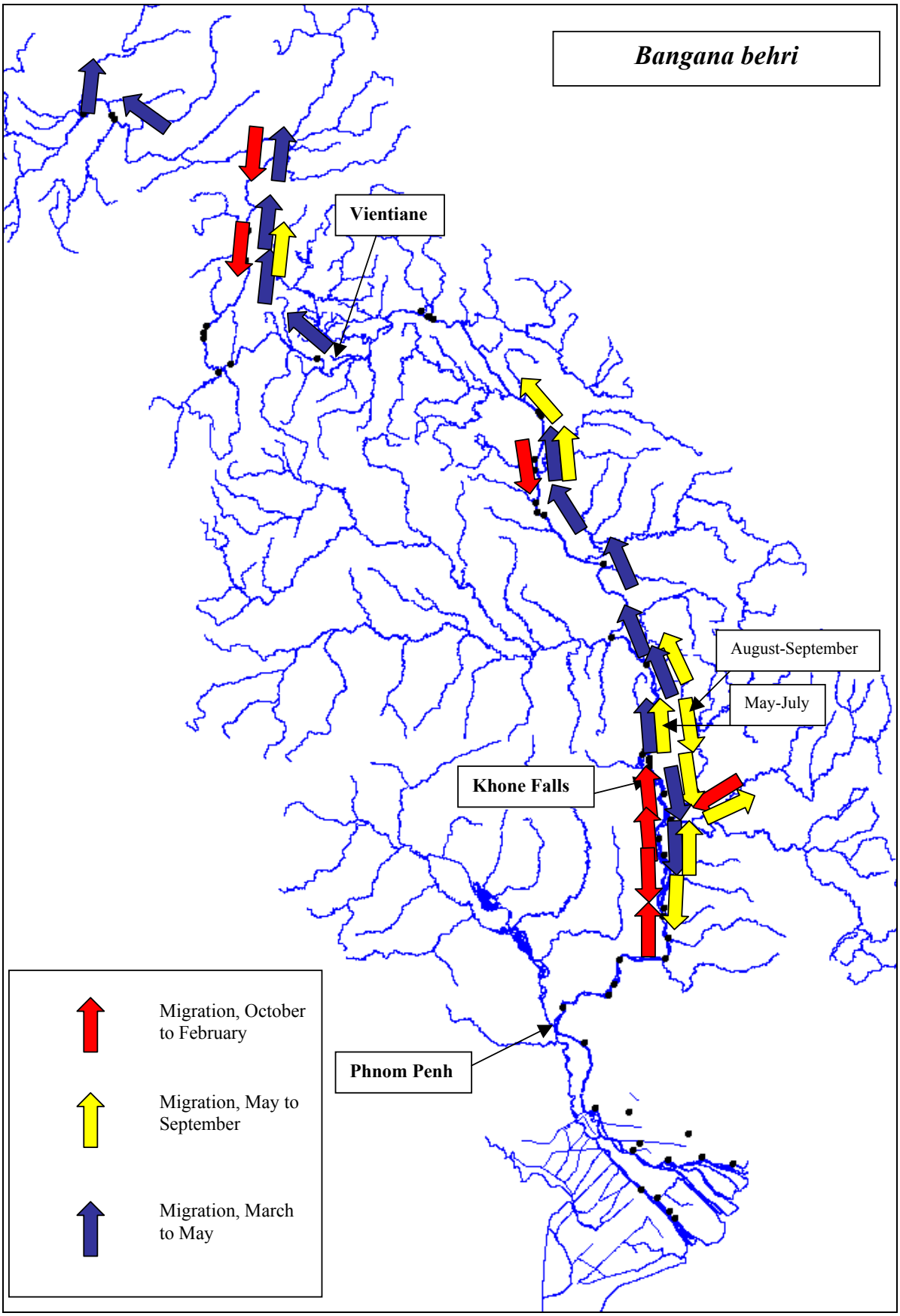
Several accounts received during the survey indicated that the upstream migrations occurring from the Khone Falls all the way to Chiang Khong in northern Thailand are triggered by increasing water levels and changes in water colour (from clear to red-brown). The species was reported to migrate upstream in schools together with other

cyprinids such as *Labeo cf. pierry*, *Cirrhinus microlepis*, *Morulius chrysophekadion* and *Cyclocheilichthys enoplos,* as well as the loach, *Botia modesta*.

These monsoon season migrations appear to comprise larger fish compared to the dry season migrations, and at Paksan and Xayaboury, in the Lao PDR, the fish were reported to have mature eggs during June-July migrations.

Hypothesis:
The distribution of *Bangana behri* is determined by the occurrence of rocks and boulders in the Mekong River.


Bangana behri
Vientiane
Khone Falls
Phnom Penh
Species reported


Bangana behri
Vientiane
August-September
May-July
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(c) Barbodes gonionotus

Barbodes gonionotus occurs throughout the whole freshwater stretch of the Mekong River, from the saline intrusion zone of the delta to the northernmost stations at Chiang Khong and Bokeo in Thailand and the Lao PDR, respectively.

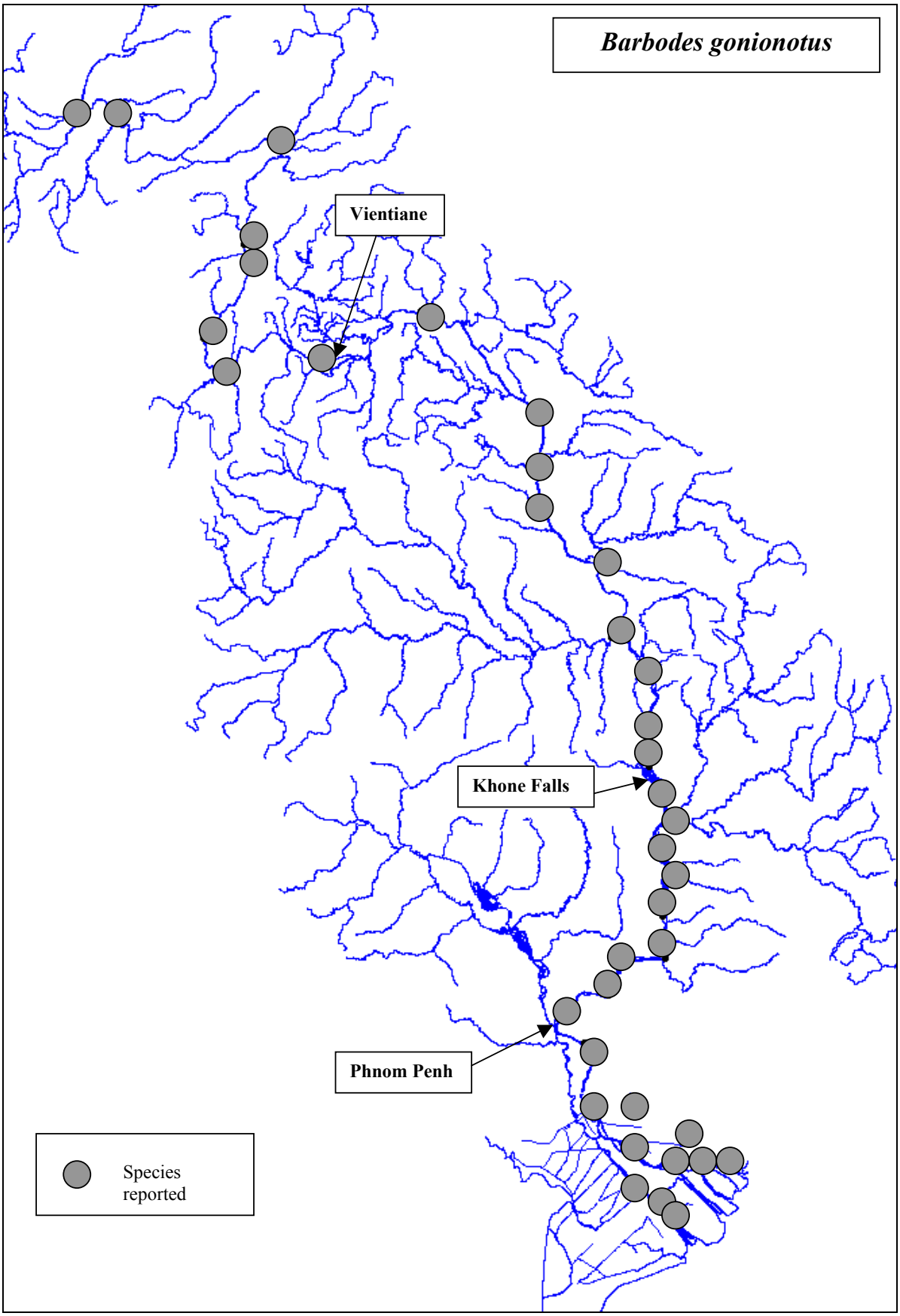
In Cambodia, this species has the same name as the *Hypsibarbus* species, so some confusion may have occurred in the information provided about these two genera (see below).

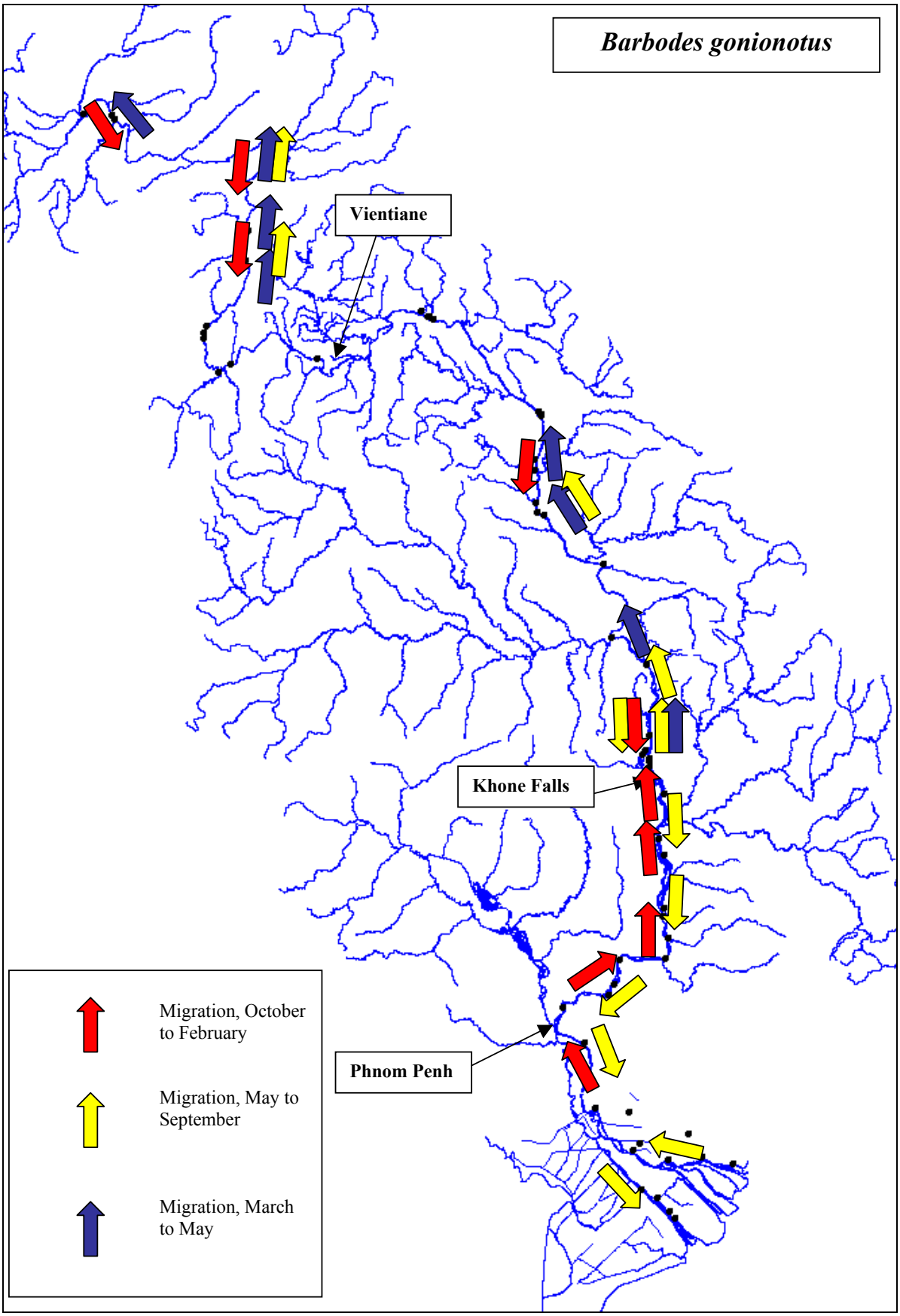
Barbodes gonionotus is not considered to be a long-distance migratory species. Most fishermen reported that it was a "local migrant", meaning that it migrates from the Mekong River up into small streams and canals and into flooded areas during the monsoon season, and back down during periods of receding water (lateral migration). This observation was confirmed at most of the stations during the survey.

Some reports indicated that the upstream migration of the fish was triggered by the first rains and rising water levels. When the fish find a tributary, a canal or a small stream they migrate upstream and eventually into flooded areas. Receding water triggers the movement back into the canals and streams and into the Mekong.

Most fishermen reported developed eggs during the period from March to June, although others reported that eggs can be found all year round.

The above information indicates that *Barbodes gonionotus* is an opportunistic spawner and that the species probably has numerous local populations with some degree of overlap.


Barbodes gonionotus
Vientiane
Khone Falls
Phnom Penh
Species reported


Barbodes gonionotus
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(d) Catlocarpio siamensis

Catlocarpio siamensis is the largest of the Mekong cyprinids. It is said to grow to a length of up to three meters (Smith, 1945; Rainboth, 1996). In this survey the largest reported size weighed 150 kg.

Catlocarpio siamensis is now a rare fish species. However, the species is apparently encountered regularly at several stations ranging from Nong Khai, Thailand, and further north up to Chiang Saen, both on the Thai and the Lao sides of the Mekong River. It has also been recorded at stations in Nakhon Phanom and Ubon Ratchathani, Thailand. It is more common in Cambodia and Viet Nam, where it is encountered all the year at many stations.

Juveniles (2 to 6 cm in length) were reported by three locations in Thailand: Chiang Saen (Chiang Rai province), Tad Phanom (Nakhon Phanom province) and Khemmaratch, (Ubon Ratchathani province). In Cambodia, juveniles of the same size were reported in Sray Son Thor (Kompong Cham province) and Muk Kompul (Kandal province). In Viet Nam, juveniles have been recorded in Can Tho (Can Tho province) and Cao Lanh (Dong Thap province) in the Mekong River and in some canals.

Juveniles of 10-14 cm in length were also reported in the Songkhram River, Thailand, in November during the Phase I (trial) of the survey.

While the adults have a preference for large pools in the Mekong River, at least during part of the year, juveniles are mostly seen in floodplain habitats and small tributaries, from where they are sometimes collected and stocked in ponds. This is consistent with information given by Smith (1945), that "this is a fish of the large streams" but that "it breeds in Bung Borapet and other *bungs* (swamps) into which the floodwater of the river flows". However, large mature fish have not been observed in floodplain habitats and it is more likely that Catlocarpio spawns in certain habitats within the main river channel, from where eggs and/or larvae reach rearing habitats on the floodplain partly by passive drift.

Eggs are seen from January to August, but most fishermen reported finding eggs from May to July. This is consistent with the presence of juveniles, 2-4 cm in length, from July to November.

Hypothesis:
Above the Khone Falls, there are at least three populations of *Catlocarpio siamensis*. All three populations migrate into tributaries to spawn either in the tributary itself or within the associated floodplain.

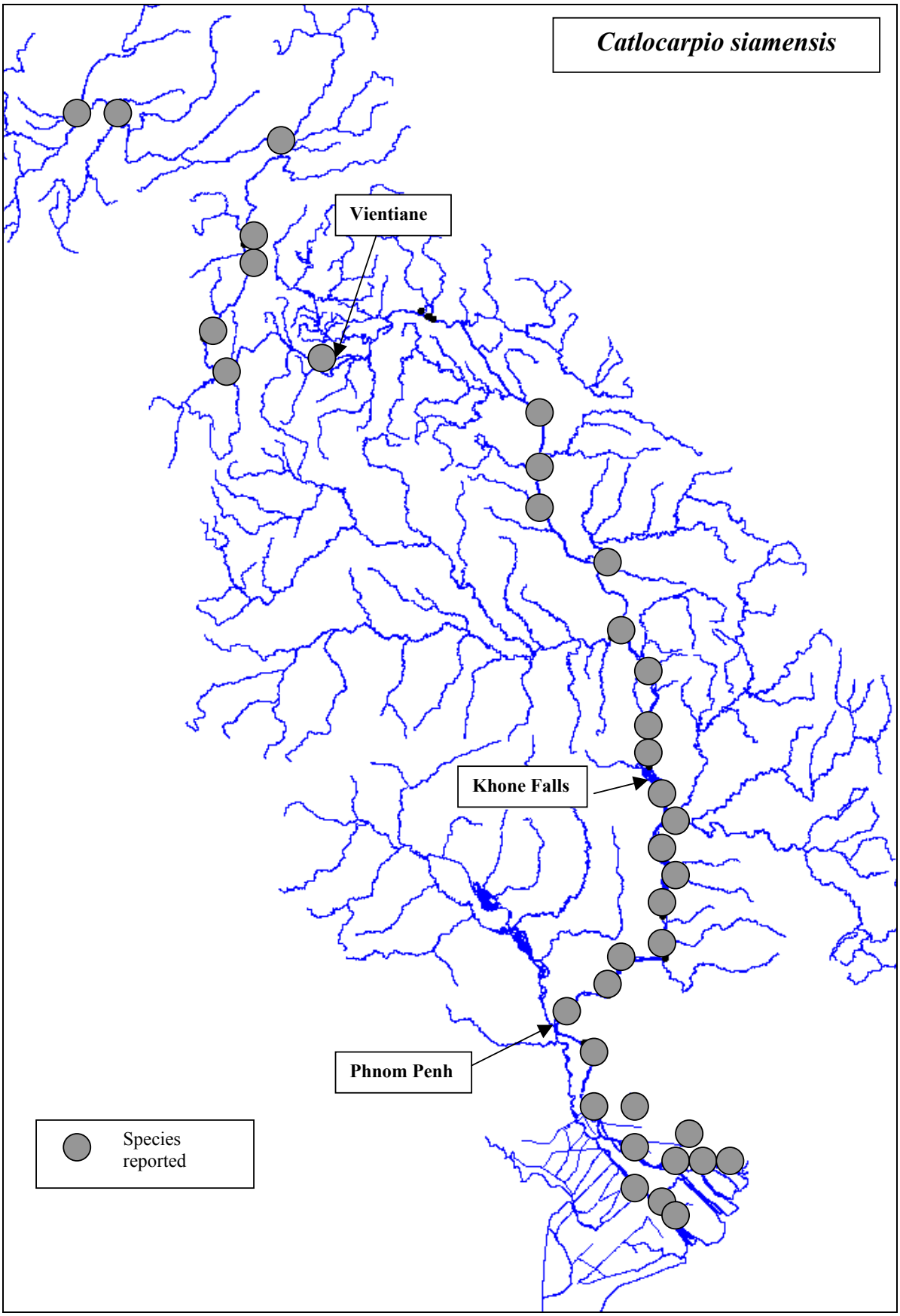
One population occur in the upper part of the survey area and migrate from the Mekong mainstream to tributaries, e.g., in Chiang Rai province.

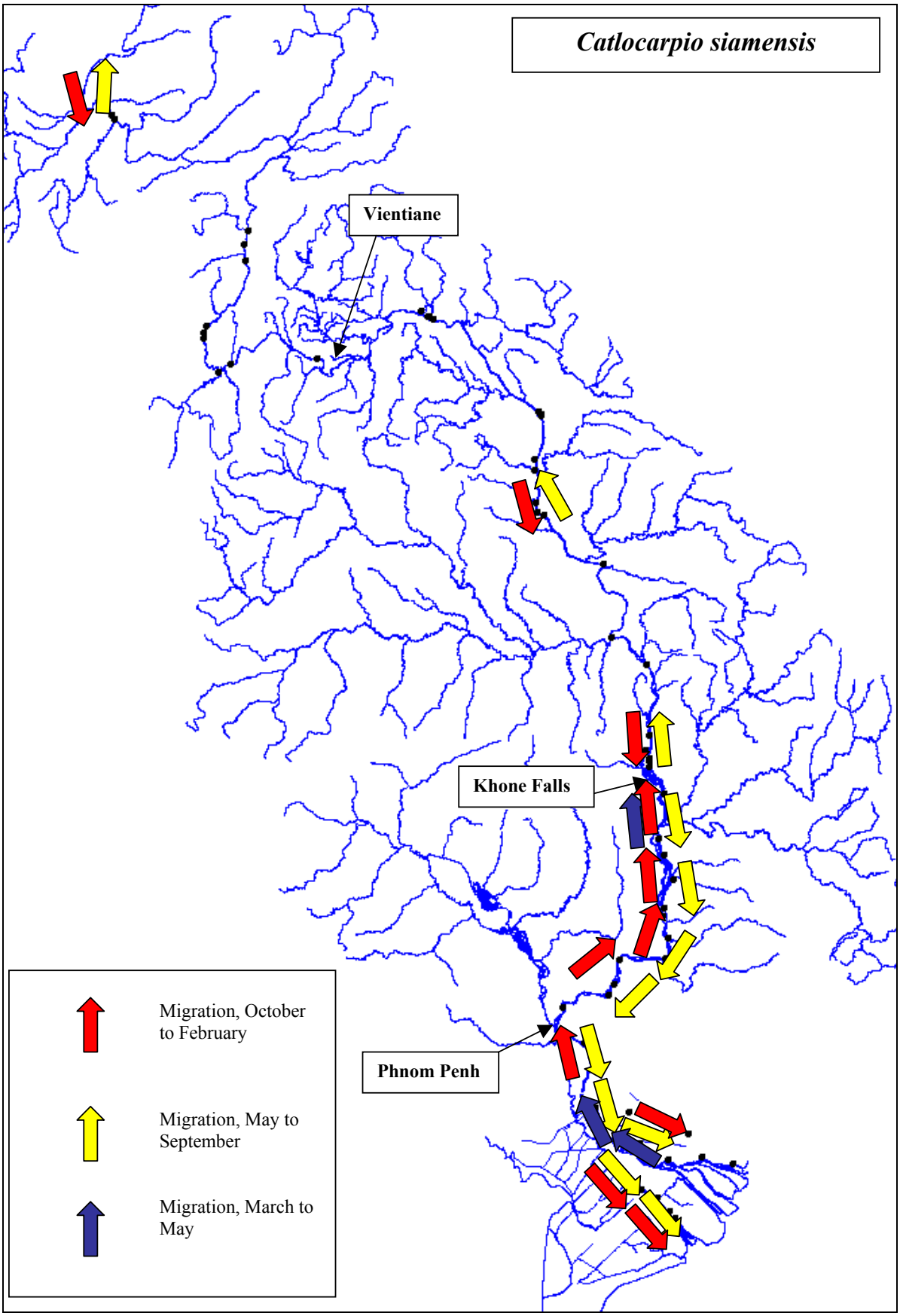
Further downstream, a population occurs around Nakhon Phanom province from where it migrates into tributaries, e.g., the Songkhram River.

Finally, there appears to be a population in and around Ubon Ratchathani province, which also migrates into tributaries to spawn.

Below the Khone Falls, there appears to be only one population. Spawning occurs mainly in the upper part of the stretch in the Mekong (i.e., upstream from Phnom Penh) and possibly also in the Sesan tributary system.

When the water begins to recede at the end of the flood season, the young-of-the-year and sub-adults migrate from flooded areas back into the main river channels and tributaries. During the dry season, *Catlocarpio siamensis* lives in deep pools associated with the main river channels.


Catlocarpio siamensis
Vientiane
Khone Falls
Phnom Penh
Species reported


Catlocarpio siamensis
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(e) Cirrhinus microlepis

Cirrhinus microlepis can be found throughout the survey area, from the Mekong delta to Chiang Saen near the border between the Lao PDR, Thailand and Myanmar.

Its migration patterns are markedly different above and below the Khone Falls. Below the Falls, an upstream migration from Phnom Penh to the Khone Falls occurs between November and February, consisting mainly of sub-adult fish of sizes from 10 to 50 cm.From April to July, *Cirrhinus microlepis* migrate in the opposite direction, downstream from the Khone Falls. That migration, which also comprises mainly sub-adults up to about 50 cm in size, appears to be less conspicuous as no reports of downstream migration were made by some stations along that stretch of the river.

In the Mekong delta, only downstream migrations were reported, comprising mainly juveniles sized between 2 and 20 cm. The smallest fish were mainly reported from June-July, whereas *Cirrhinus microlepis* sized between 10 and 20 cm were mainly reported from September to November.

The migration pattern above the Khone Falls is less clear. From Klong Kaem district, Ubon Ratchatani, *Cirrhinus microlepis* migrate upstream in February, while further upstream in Ubon Ratchatani, at Khemmaratch, they migrate upstream during March-April. At Mukdahan, they migrate upstream in May. However, during June-July, they migrate downstream at Klong Kaem. During that period, fish in reproductive condition are reported.

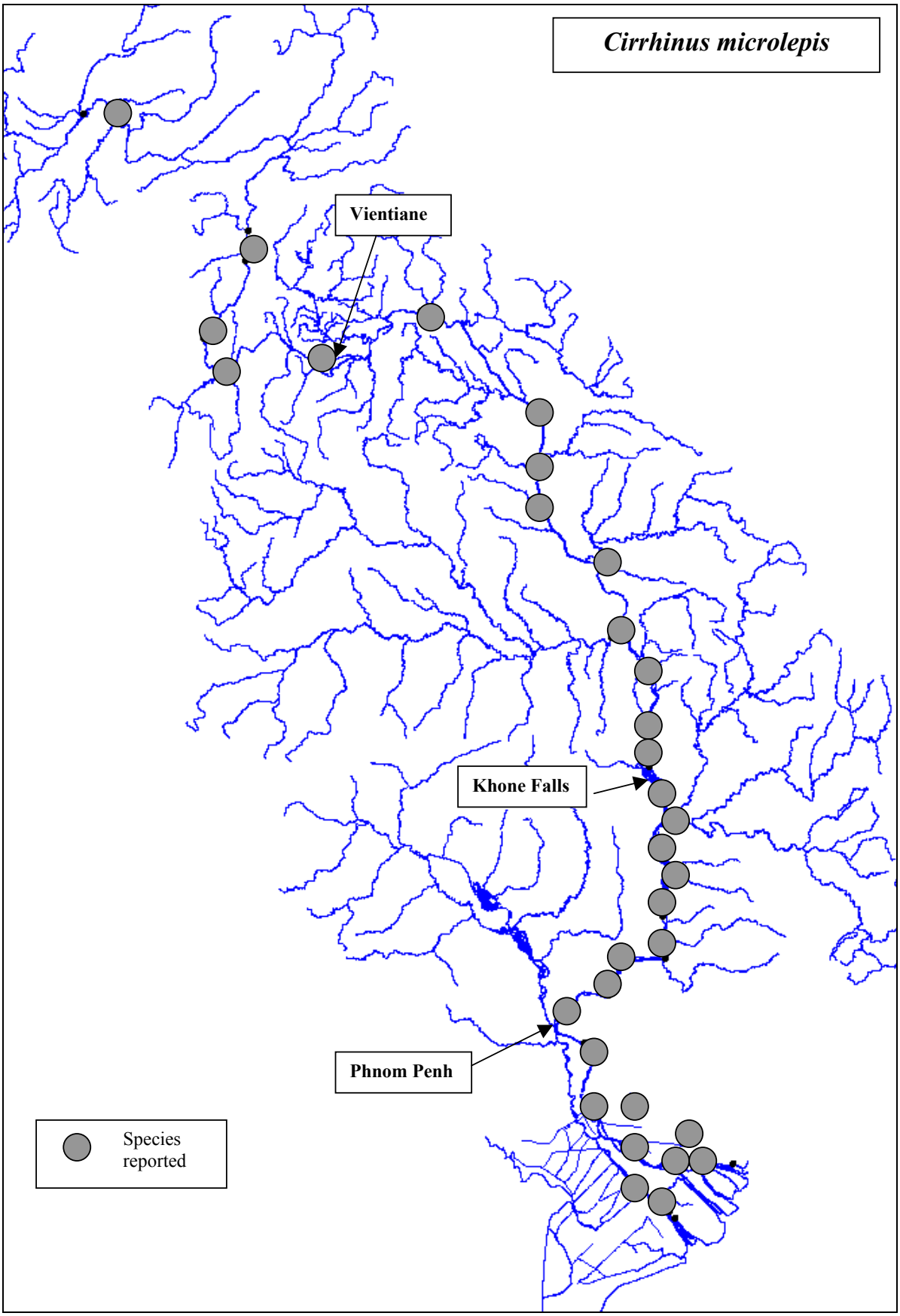
Along the river stretch from Savannakhet to Xayaboury, no migration was reported. At Loei, the species is found throughout the year. From Xayaboury to Chiang Saen, upstream migrations occur from March to August. Again, there appear to be two distinct migrations, one of sub-adults (ranging from 15 to 50 cm) during March and April, and a second migration during June and July that comprises large *Cirrhinus microlepis* within the range of 40 to 90 cm. The latter movement appears to be a spawning migration as mature fish bearing eggs were reported during July-August.

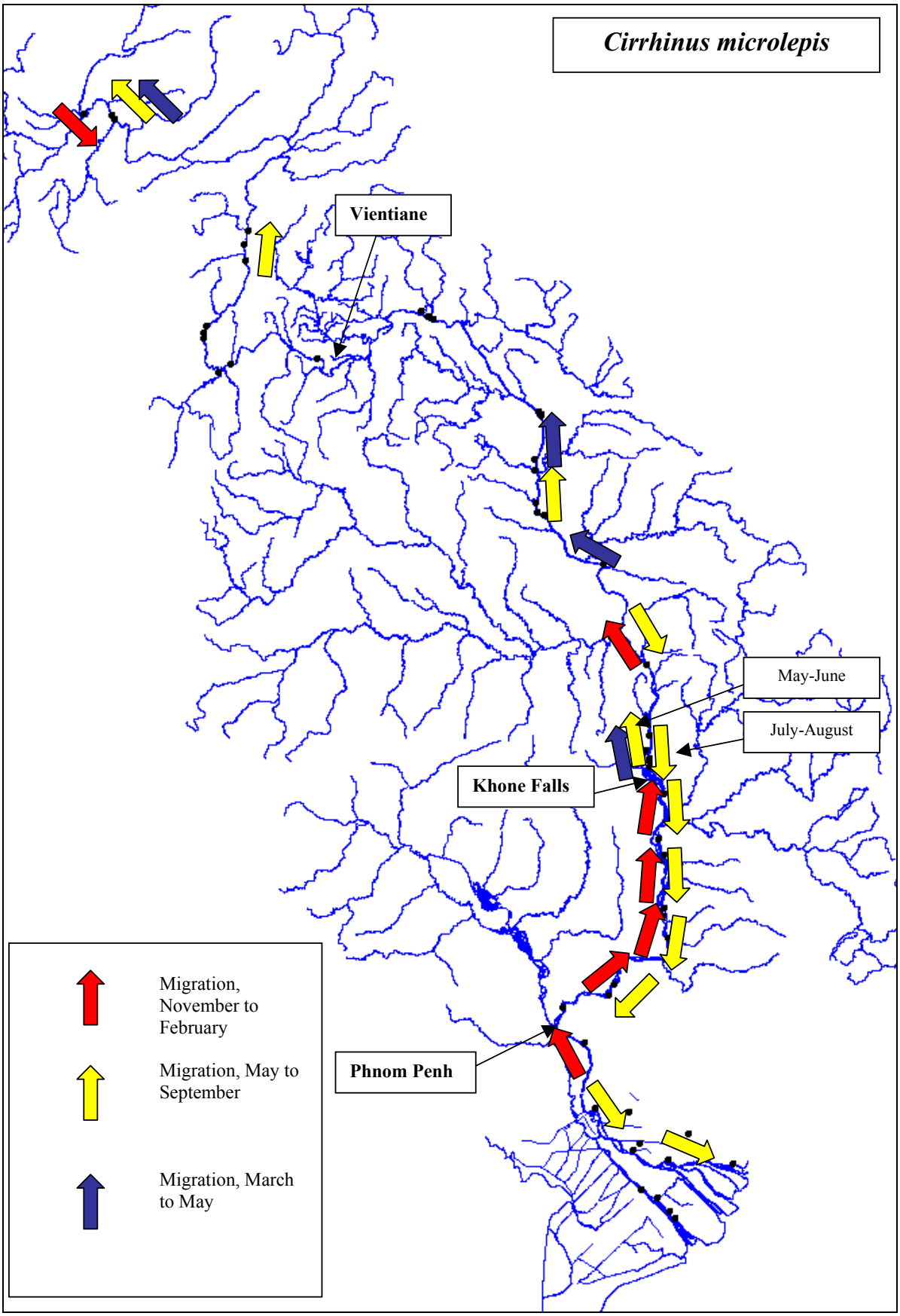
Previous studies at the Khone Falls have indicated that *Cirrhinus microlepis* is one of the most important fish for the local fisheries during the dry season from January to March, when it migrates upstream (Warren *et al*, 1998; Baird, 1998). From December to February it is also an important species for the *dai* fisheries in the Tonle Sap River when it migrates downstream into the Mekong River (Lieng *et al*., 1995).
Artificial spawning has been induced in *Cirrhinus microlepis* at Pakse, in Champassak province, the Lao PDR (Bouakhamvongsa *et al*., 1994). Local fishermen reported that in June they would catch broodstock 52 km south of Pakse town at what they believed to be a spawning site. They reported the spawning migration to be a downstream one and indicated that its origin might be as far upstream as Khammouan.

Hypothesis:
There are at least two populations of *Cirrhinus microlepis*:

(a) One population from Loei to Chiang Saen undertakes upstream spawning migrations from May to August to spawning grounds within the main river channel, where spawning occurs in June-July.

(b) The second population occurs in the stretch of the river from Boulikhamxay in the north to the Mekong delta. In fact, it may be two populations with some degree of overlap, since spawning was reported to occur in the Mekong mainstream, both above and below the Khone Falls (July-August). The eggs and larvae drift downstream and out into the flooded areas. Juveniles and adults also move downstream and out into the floodplains during the flood season, particularly in southern Cambodia and Viet Nam, and up through the Tonle Sap River system. When the water begins to recede at the end of the flood season, the fish move back into rivers where they start a non-reproductive upstream dispersal migration.


Cirrhinus microlepis
Vientiane
Khone Falls
Phnom Penh
Species reported

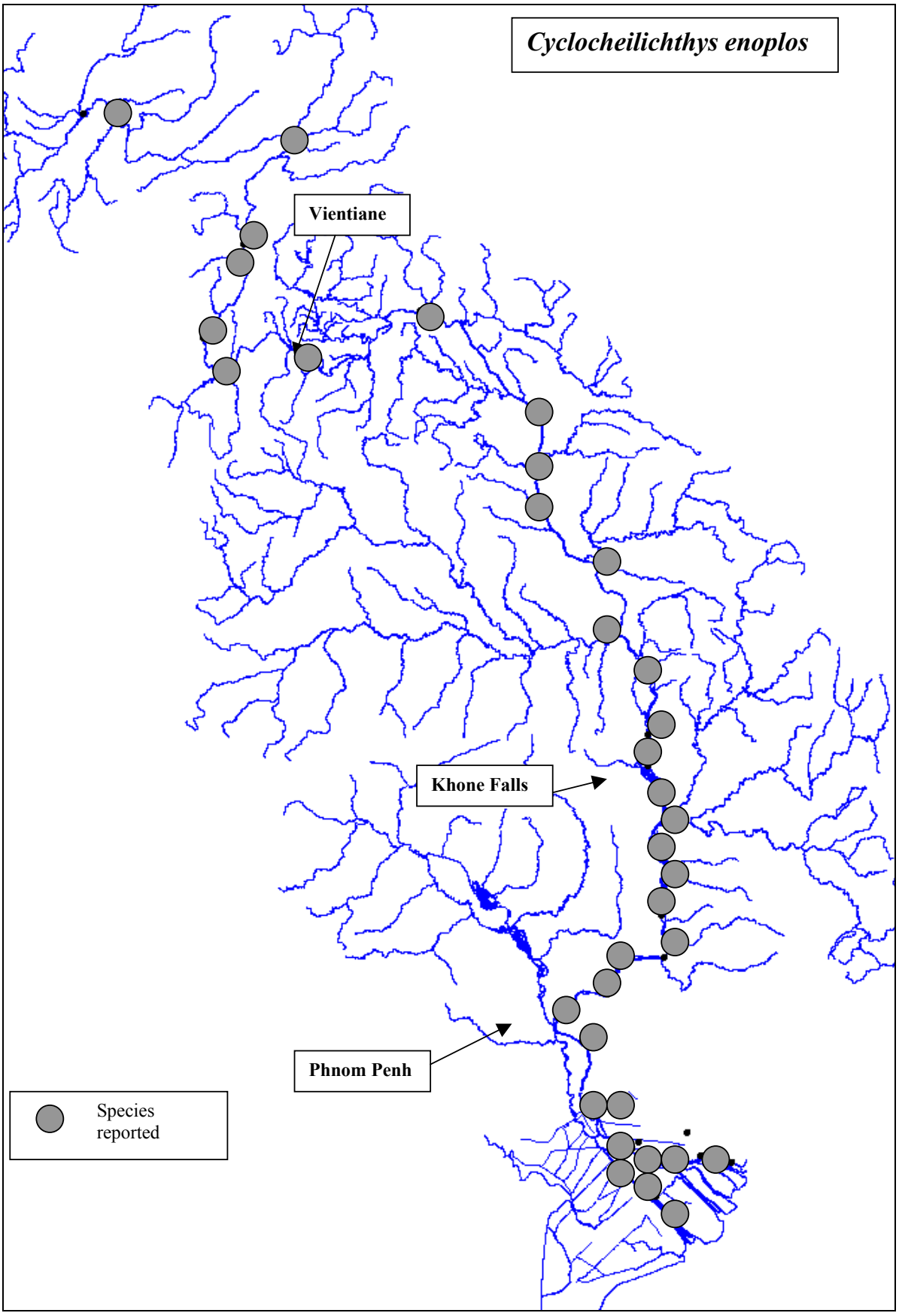

Cirrhinus microlepis
Vientiane
May-June
July-August
Khone Falls
Phnom Penh
Migration, November to February
Migration, May to September
Migration, March to May

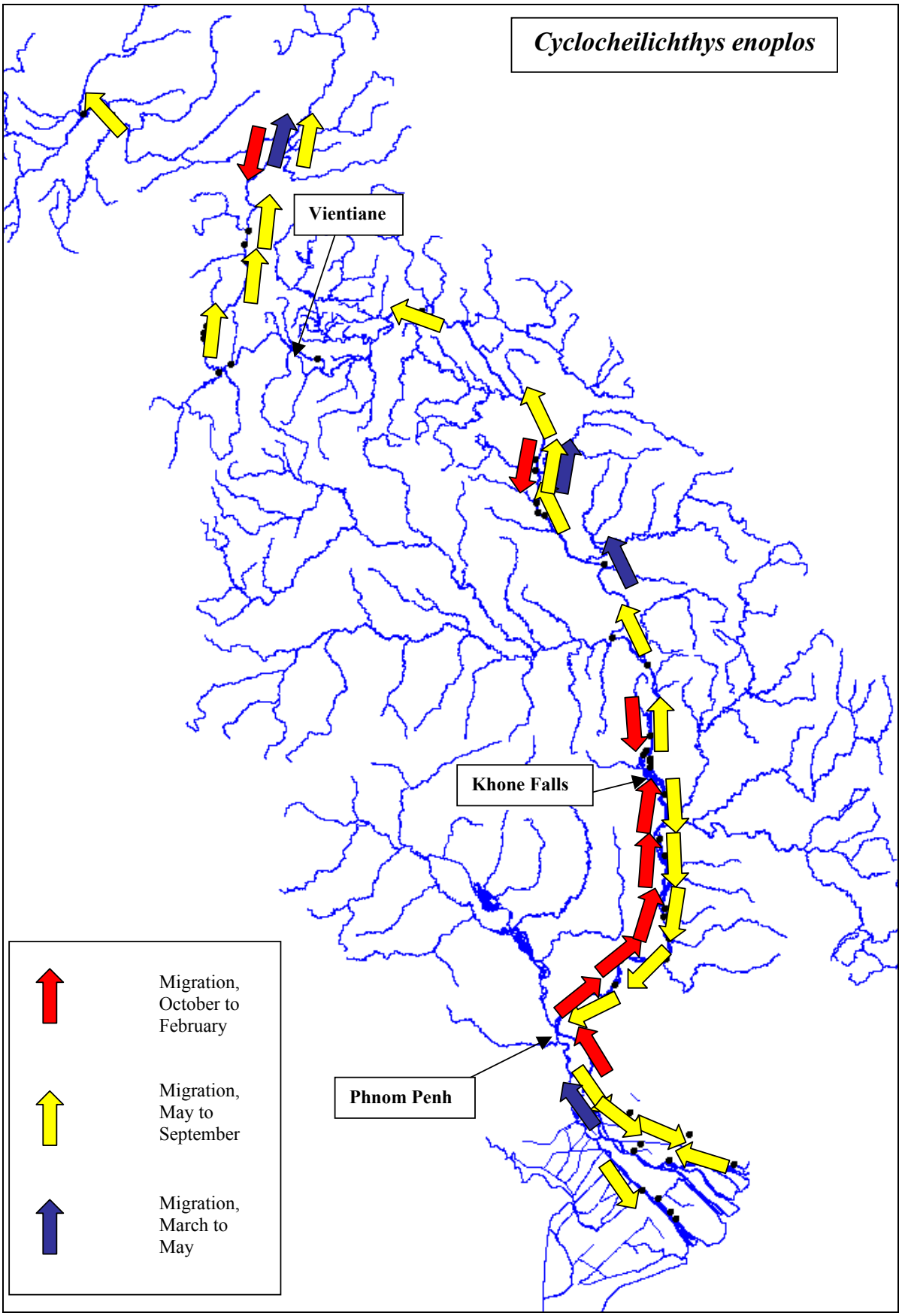
(f) Cyclocheilichthys enoplos

Cyclocheilichthys enoplos was reported throughout the survey area, from Bokeo in the Lao PDR in the north to the Mekong delta.

The migration pattern was found to be similar to *Cirrhinus microlepis*, with an upstream migration from Phnom Penh to the Khone Falls from November to February, and a downstream migration from May to August. The latter migration continues down into the Mekong delta area in Viet Nam until peak flooding in October-November. The two migrations mainly comprise juveniles and sub-adults, although the three stations closest to the Khone Falls have reported adults of 90 cm.

Above the Khone Falls, *Cyclocheilichthys enoplos* migrate upstream from April to September. It is probably a spawning migration as the fish are dominated by adults; also, mature *Cyclocheilichthys enoplos* bearing eggs were reported during that period by three stations in Xayaboury province. Juveniles and sub-adults are also caught in that section of the river.


Cyclocheilichthys enoplos
Vientiane
Khone Falls
Phnom Penh
Species reported


Cyclocheilichthys enoplos
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

Several reports from Cambodia stated that the juveniles and sub-adults[6] migrated out of flooded areas and back upstream into the Mekong River during the period of receding water. At two stations, reports indicated that *Cyclocheilichthys enoplos* migrated down from the Tonle Sap River into the Mekong River. That information corresponds with the results of previous studies on the Tonle Sap River, where the species constitutes an important part of the catch between December and February (Lieng *et al.*, 1995).

Above the Khone Falls, the first rainfall at the end of the dry season, as well as rising water levels and higher turbidity, were all reported to contribute to triggering the onset of the upstream migration.

The larger fish were reported to live in big pools at certain places along the Mekong (e.g., Boulikhamxay and Xayaboury provinces), whereas smaller fish occur near the riverbank, in particular around flooded/submerged shrubs.

Information was not received on spawning habits of this species, apart from egg-bearing upstream migrating fish reported by Xayaboury. Previous work under the aegis of the Department of Fisheries in Thailand concluded that the spawning season is July/August, that *Cyclocheilichthys enoplos* is a total spawner, and that both eggs and larvae are pelagic.

Hypothesis:
Cyclocheilichthys enoplos spawns during the early flood season in the main river, and eggs and larvae drift downstream and out into flooded areas or stagnant, shallow segments of the mainstream. Juveniles and adults also move out into the flood plains during the flood season. When the water begins to recede at the end of the flood season, the fish migrate back into rivers where they start a non-reproductive upstream dispersal migration.

(g) Henicorhynchus siamensis

There appears to be some taxonomic confusion regarding the genus *Henicorhynchus*. In a recent taxonomic revision of the cyprinid genus, *Cirrhinus*, *Henicorhynchus* was treated as a junior synonym of *Cirrhinus* (Roberts, 1997). We choose to follow the nomenclature of Rainboth (1996) and therefore, at least for the time being, use the name *Henicorhynchus siamensis*.

Together with another species from the same genus, *Henicorhynchus lobatus*, *Henicorhynchus siamensis* may be the most abundant fish species in the middle and lower Mekong (Roberts, 1997). It has been suggested that *Henicorhynchus lobatus* is an ecological keystone species (Roberts and Baird, 1995; Roberts, 1997). The information provided by fishermen during the AMFC survey was based on a photograph of *Henicorhynchus siamensis*. Roberts (1997) indicated that it might be difficult to distinguish between specimens of the two species and, therefore, some of the information provided by fishers may possibly be related to either, or both, species.

[6] The term "sub-adults" in this document means immature fishes older than "young-of-the-year" fish.

According to the present survey, the distribution of *Henicorhynchus siamensis* ranges from the Mekong delta all the way along the Mekong River to Chiang Khong, near the border between the Lao PDR, Thailand and Myanmar.

This species is well known for lateral migrations into the floodplains during the flood season and then returning to the rivers when the floodwater begins to recede (Rainboth, 1996). The genus *Henicorhynchus* is the most important group of fish in the *dai* fisheries of the Tonle Sap River, constituting more than 60 per cent of the catch from November to February (Lieng *et al*., 1995). During that period, the fish move into the Tonle Sap River from flooded areas along the river as well as the Great Lake. After reaching the Tonle Sap, they migrate down to the Mekong River and continue their journey upstream, at least until they reach the Khone Falls (Lieng *et al*., 1995; Baird 1998).

The results of the present survey support the above findings. All the stations from just upstream of Phnom Penh to the Khone Falls reported that *Henicorhynchus siamensis* migrated upstream between October and February. At Muk Kompul district in Kandal province of Cambodia, the species was reported to migrate upstream just before the full moon. Further upstream, at two stations near Kratie, it was reported to migrate during full moon and at Sambor, a little further upstream, they were reported to migrate immediately after the full moon. Some fishers exploit that migration by following the fish all the way to Stung Treng.

Near the Khone Falls, the migration pattern appears to be less conspicuous. Upstream movements continue through March, but in April the fish apparently move in both directions. From May to July, with the onset of the monsoon season, the fish migrate downstream from the Khone Falls, a movement reported by all the stations down to the Mekong delta. Here, the fish migrate into canals and flooded areas during August-September (e.g., as reported from Cay Lai, Tien Giang province, in Viet Nam). This migration includes the movement of very small fish, (young-of-the-year) as well as mature fish measuring about 20 cm. As the water recedes (November-December), the fish migrate back to the Mekong.

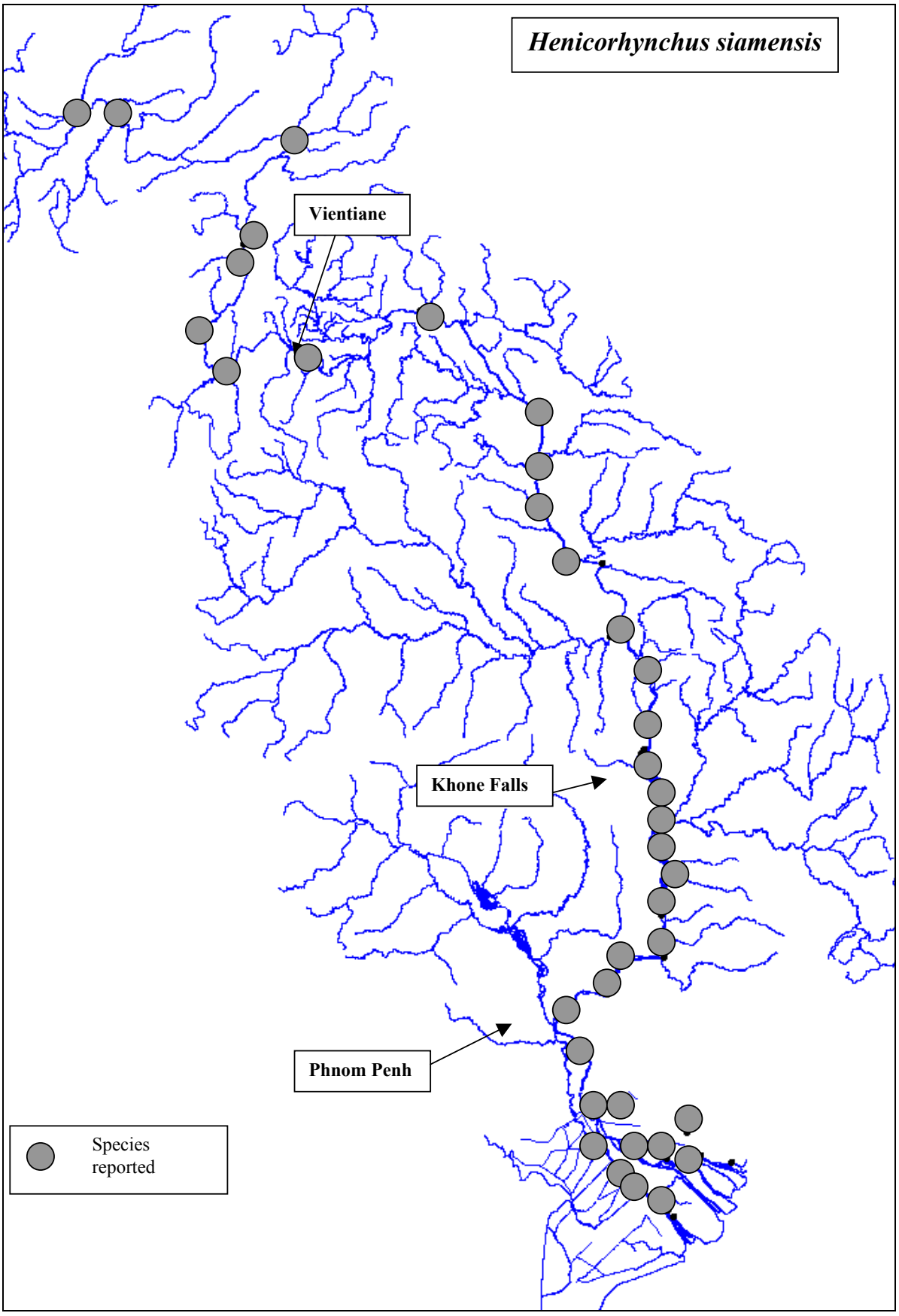
Upstream of the Khone Falls, migratory movements are also less conspicuous. Near Ubon Ratchatani, *Henicorhynchus siamensis* migrate upstream from February to June. In February and March, that movement consists mainly of juveniles, whereas from April to June, it comprises adults (15-20 cm). Further north, from Xayaboury to Chiang Khong, upstream migrations occur from March to July, first by juveniles and later by adults.

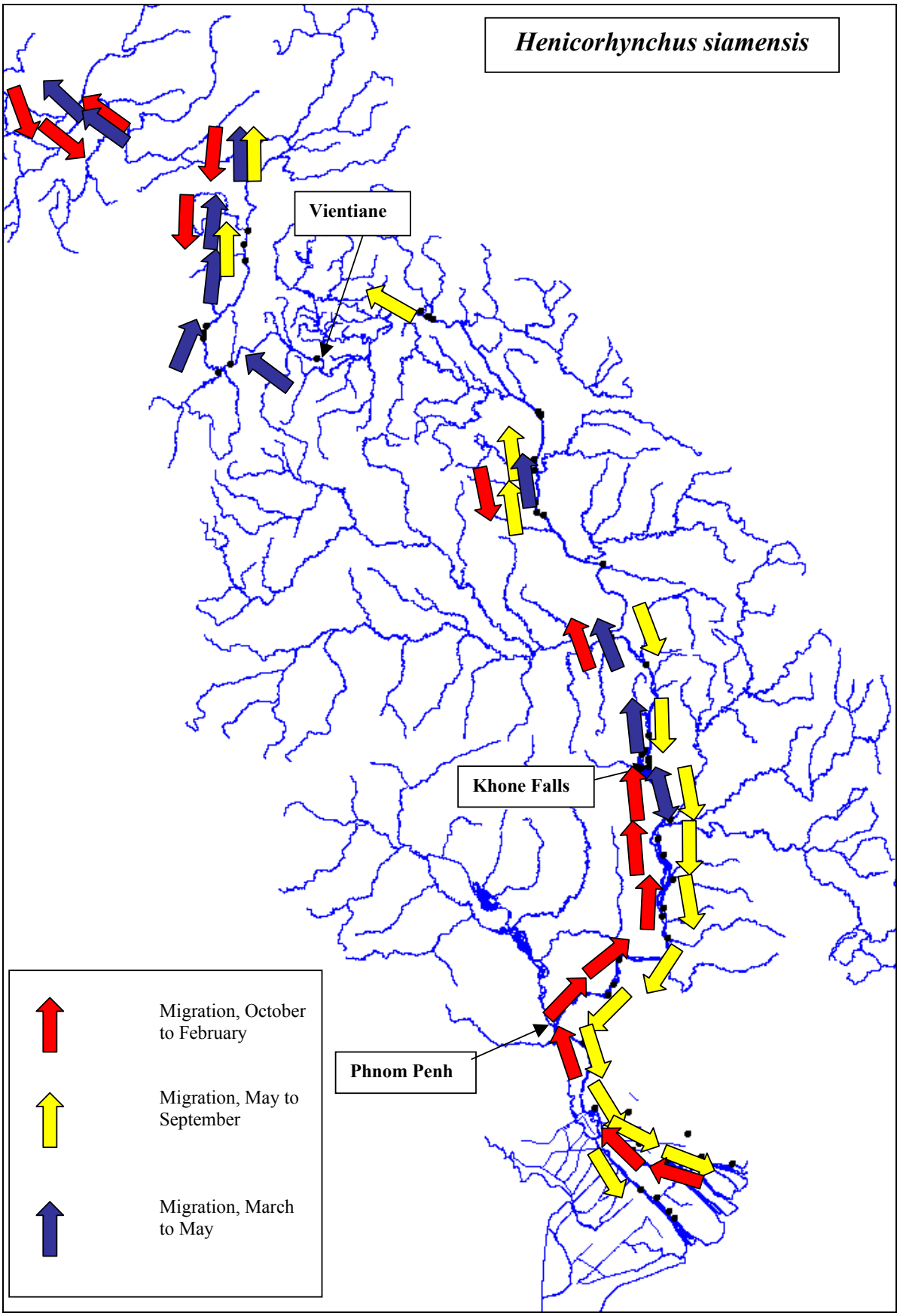
Observations of mature eggs were reported from April to July, with a strong peak during May and June. Nearly all stations downstream from Savannakhet-Mukdahan reported that May and June was the spawning period. At Sambor, one fisherman reported observing mature females “releasing eggs that then flowed downstream” during May.

At Chiang Khong, the fish were reported as migrating into tributaries to spawn from May to July. At Loei, spawning was reported to occur in July and August in a Mekong tributary (Loei River) in a small pool with a slow current. In general,

spawning apparently occurs over a longer period and extends into August and September from Loei and upstream.

The limited information obtained for the stretch from Savannakhet-Mukdahan to Loei may indicate the occurrence of two different populations, or even species, above and belowthat stretch, respectively.


Henicorhynchus siamensis
Vientiane
Khone Falls
Phnom Penh
Species reported


Henicorhynchus siamensis
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(h) Hypsibarbus spp.

Rainboth (1996) included six species of the genus *Hypsibarbus* in his book, *Fishes of the Cambodian Mekong,* and further indicated that seven species might occur within the Mekong River. Since species within this genus are difficult to separate just by looking at photographs, they are covered here as a single group. Local names reflect the similarities between the species, i.e., the same local name is often used for all species within the genus (e.g., in Cambodia it is *trey Chhpin*). In fact, in Cambodia, *Barbodes gonionotus* is also called *trey Chhpin*, indicating that there would even be some confusion in information between the two genera, *Hypsibarbus* and *Barbodes*. Similar problems probably occur in the Lao PDR, Thailand and Viet Nam. This obviously limits the species-specific conclusions that can be drawn for *Hypsibarbus* species. Therefore, only some general trends are discussed here for this group of fish.

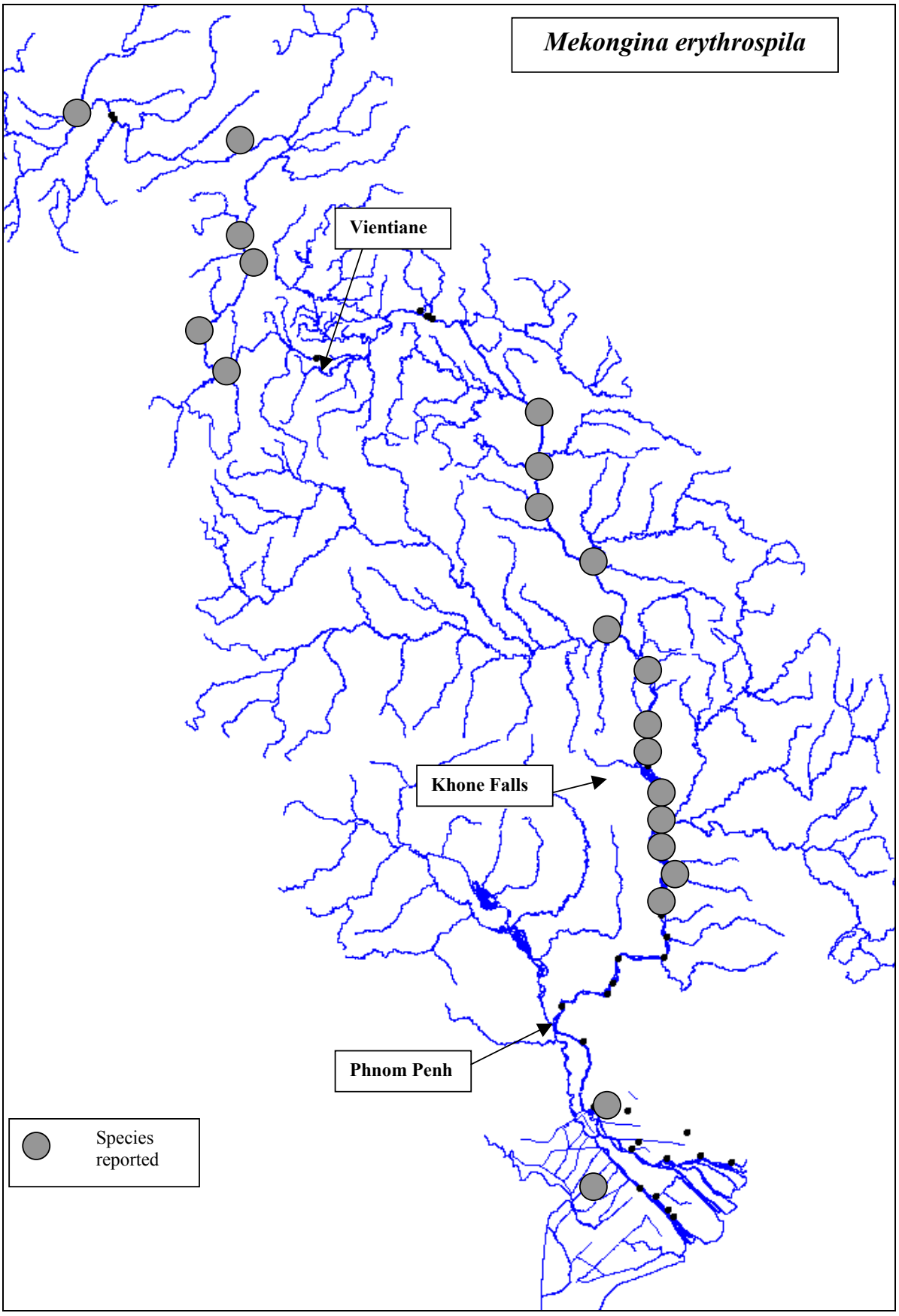
Below the Khone Falls, fishermen reported that this species group undertook short local migrations, including lateral migrations. The migrations were reportedly triggered by rising and receding water levels, respectively. At three stations, migration from flooded areas and back to the main river was reported to occur just before the full moon.

Above the Khone Falls, in the Lao PDR and Thailand, there was contradictory information regarding migratory patterns, i.e., both upstream and downstream movements were reported during the onset of the monsoon season. Such movements probably reflect different species within the group.

Two fishermen from Chiang Khong and Loei, respectively, reported spawning behaviour in May. They both observed fish gathering in large groups in shallow waters near a sandy beach in the Mekong mainstream. April to June is the peak period for observing eggs in the fish, which further indicates a spawning period within that period.

The spawning behaviour of *Hypsibarbus malcolmi* was previously studied at the Khone Falls (Baird and Phylavanh, 1999c). This species vocalises during its spawning season in November and December; based on these vocalisations, three spawning grounds were identified just below the Khone Falls, near the border between Cambodia and the Lao PDR (Baird and Phylavanh, 1999c).

Hypsibarbus malcolmi is thus one of the few species to have a distinct spawning season in the early dry season.


Mekongina erythrospila
Vientiane
Khone Falls
Phnom Penh
Species reported

(i) Mekongina erythrospila

Mekongina erythrospila is a cyprinid species endemic to the Mekong Basin. Some fishermen complained about the quality of the flipchart picture of this species, and misidentification by some fishermen may have occurred.

Fishermen from Chiang Saen district in northern Thailand and downstream to Pak Lay (Lao PDR) identified this species. There were no reports of the species from Chiang Khan in Thailand to Paksan in the Lao PDR. *Mekongina erythrospila* was, however, identified at all three stations in Thakhek, the Lao PDR. It was not noted at Tad Phanom or the northernmost station in Mukdahan (both in Thailand).

Fishermen between the downstream station in Mukdahan to Sambor (Cambodia), were familiar with the fish. South of Sambor, only fishermen at the Ap Tan My and Phu Hiep stations (Viet Nam) identified the species; however, those reports were probably due to misidentification and thus need verification. A southern distribution limit at Sambor coincided with earlier reports by Roberts and Warren (1994). One fisherman at Klong Kaem in Thailand mentioned that the species never migrates into small streams. It was also recorded at Xe Bangfai, Nam Theun (Kottelat, 1998) and Xe Done (Noraseng *et al.*, undated). Rainboth (1996) also stated that the species only inhabits medium and large-sized rivers.

It is interesting to observe that in Stung Treng, Cambodia, near the Lao border this species is called by its Laotian name (*Trey Pa Sa-ee*). Further south, in Kratie, fishermen were unable to identify it by name although they recognised the fish, indicating that the species was rarer in that area. The distribution pattern indicates that the species prefers rocky stretches with rapids and a fast current, and concurs with observations by Rainboth (1996).

The maximum weight of fish reported during the survey was 3 kg in Mukdahan district and 2 kg in Chiang Saen district of Thailand. The two reports were almost certainly based on misidentification, since fishermen at the remaining stations reported a maximum size of about 40 cm or weight of up to 1 kg. Rainboth (1996) mentioned 45 cm as the maximum length for the species. In a survey in southern Lao PDR, Baird (1998) reported the largest individual as weighing 1.2 kg.

Mekongina erythrospila was reported to migrate upstream from Pak Lay to Chiang Khong between March and May. Many Lao fishermen in that area reported that the migrations start when the first heavy rains of the monsoon season occur, or when the river water change from being relatively clear to a reddish or brown colour. Only one report of downstream migration from Pak Lay was received from fishermen who observed *Mekongina erythrospila* migrating downstream in October-November.

From Klong Kaem to Mukdahan in Thailand, *M. erythrospila* migrates upstream from February to April; however, none of the fishermen at those stations knew about downstream migrations. Noraseng *et al*. (undated) reported upstream migrations in the Xe Done River between December and March. South of the Khone Falls, upstream migrations were generally reported to occur from November to February, while downstream migrations occur from April to June. One Thai fisherman mentioned that *Mekongina erythrospila* has black fins when it migrates downstream.

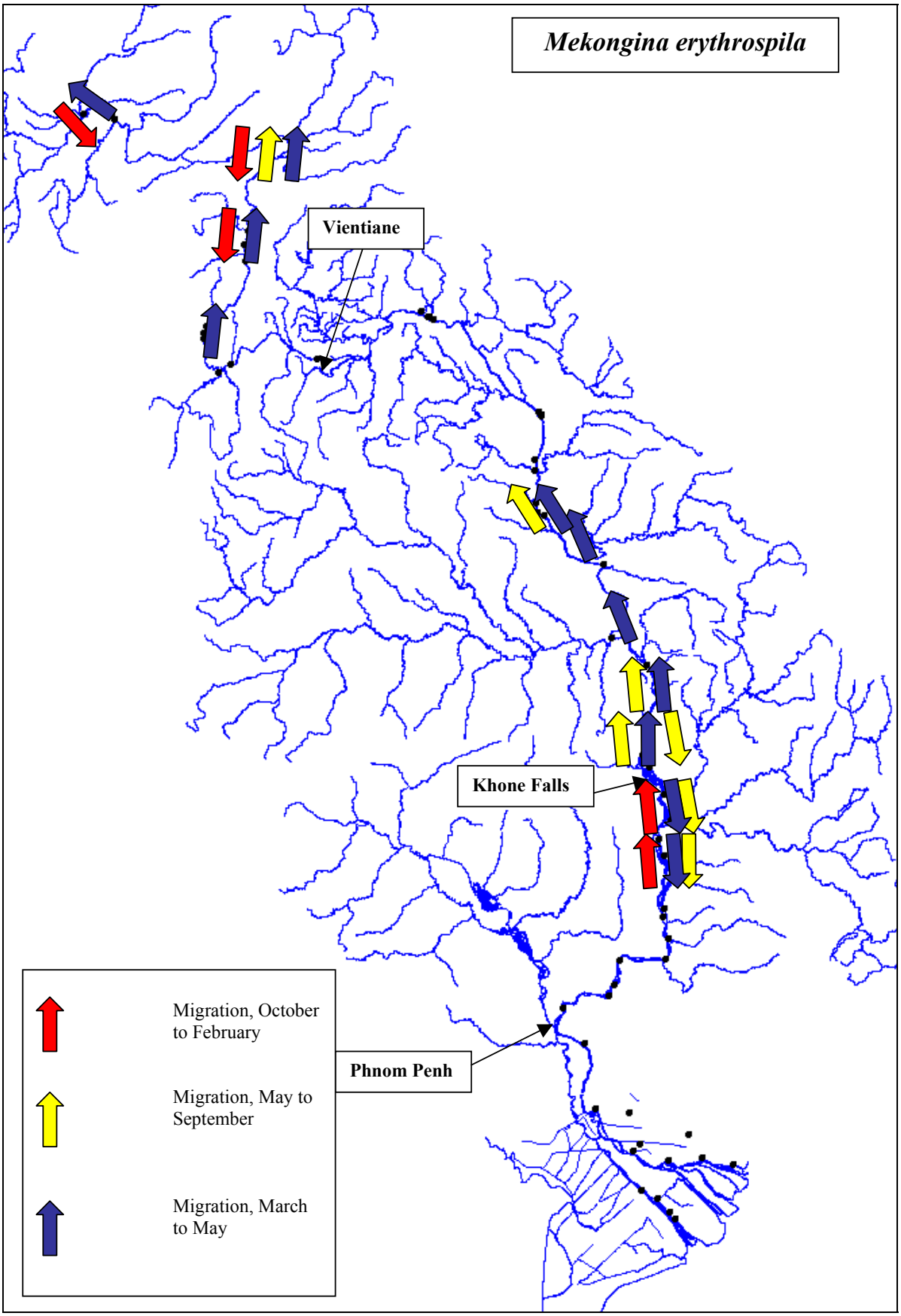
Mekongina erythrospila migrates in big schools comprising several hundred fish, often together with other cyprinids and loaches such as *Hypsibarbus* spp., *Scaphognathops* spp., *Henicorhynchus siamensis* and *Botia modesta*. One Thai fisherman reported that the juveniles are also migratory.

Few fishermen were able to give any detailed information about the reproduction habits of this species. One fisherman from Xayaboury, Lao PDR, reported seeing eggs in the abdomen of the fish during May and June. In Stung Treng and Kratie provinces, some fishermen said they had observed eggs from January to June, with most observations occurring in June. Those observations are consistent with a spawning time from June to August as reported by Noraseng *et al*. (undated).

The smallest juveniles, around 6 cm, were reported from the southern areas in Khammouan, Ubon Ratchathani, Champassak and Stung Treng provinces. One fisherman at Kemmaratch, Thailand, explained that he caught juveniles in the mouth of a stream and stocked a pond with them.

Hypothesis:
Two main populations of *Mekongina erythrospila* exist in the Mekong mainstream. A northern population occurs between Pak Lay and Chiang Khong, while a southern population is distributed between Sambor and Mukdahan.

There also appears to be a small population in the Thakhek area. Those fish may belong to a stock in one of the larger tributaries in the area, from where the fish only occasionally venture out into the Mekong mainstream.


Mekongina erythrospila
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(j)Morulius chrysophekadion

Morulius chrysophekadion is one of the large cyprinids. The survey confirmed its distribution throughout the basin, from the northernmost stations in the Lao PDR and Thailand to the southernmost stations in Bassac and the Mekong delta in Viet Nam.

There is some variation in the maximum size attained by this fish in the four countries. In Viet Nam, maximum reported size of *Morulius chrysophekadion* was 40 cm, while in Cambodia and the Lao PDR it was 70 cm. In Thailand, fishes of 90 cm were reported (about 7 kg), which is considerably higher than the maximum size of 60 cm, reported by Rainboth (1996).

Spawning behaviour had not been directly observed by any of the interviewed fishermen. Although eggs were reported to have been observed in the abdomen of the species between February and October, there are significantly more reports on such observations from April to July. It thus appears that the species has a relatively long spawning season. This assumption is supported by the fact that small juveniles (2-4 cm) were reported year-round, with the highest number of reports being made for the October-November period. This indicates a main spawning period around August. Bardach (1959) reported the occurrence of spawning in Cambodia during June-July. Juvenile *Morulius chrysophekadion* were also recorded in small numbers during the juvenile study carried out by AMFC in An Giang province, Viet Nam, in June-July 1999.

One fisherman in Viet Nam suggested that *Morulius chrysophekadion* spawns in flooded ricefields and grasslands. That suggestion is consistent with Smith (1945), who indicated that the species had an important spawning ground in the Bung Borapet swamp in the Chao Phraya catchment in Thailand.

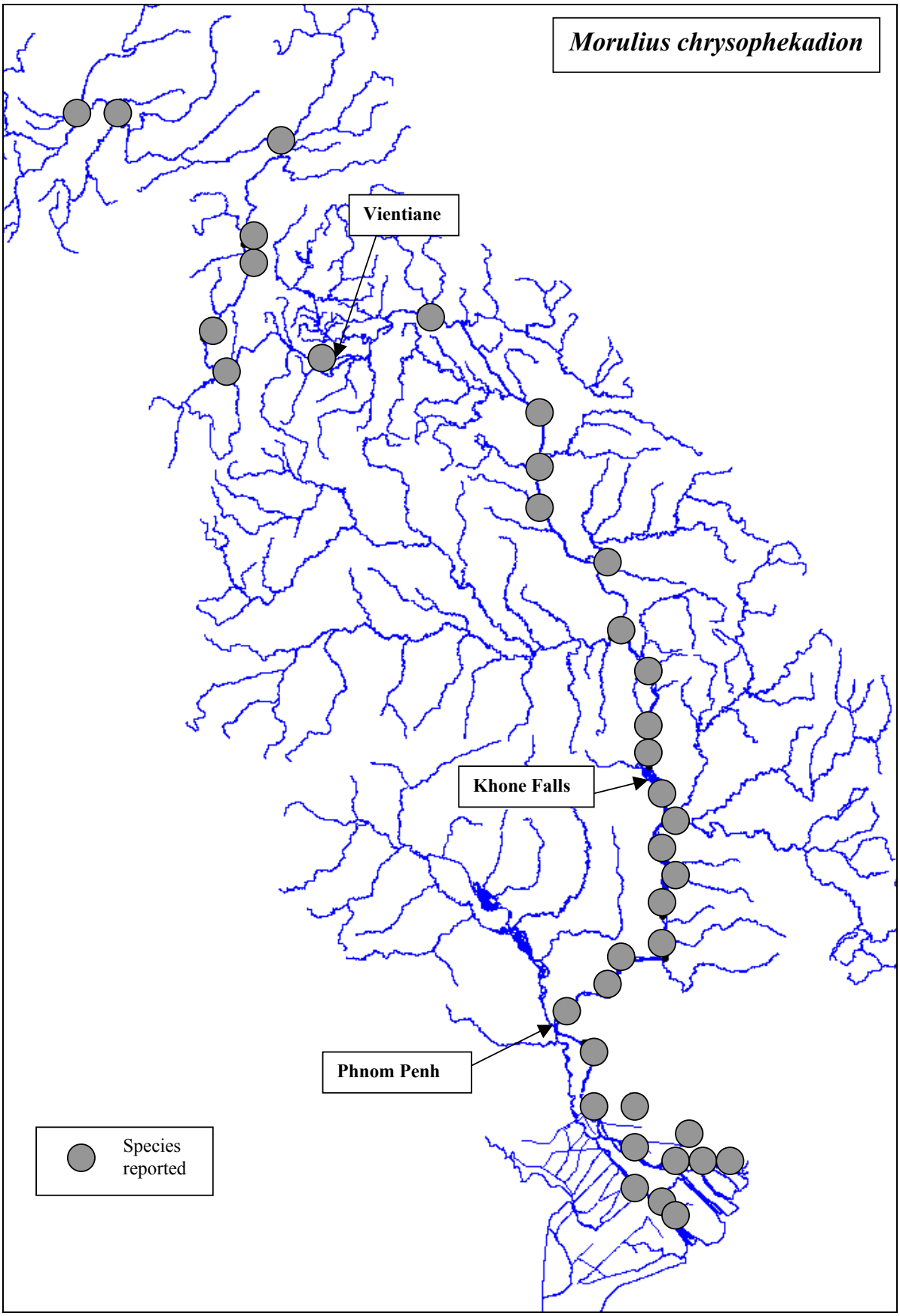
Fishermen in the Lao PDR and Thailand agreed that *Morulius chrysophekadion* migrates upstream from March to August. Downstream migration in October was only reported by one fisherman in northern Thailand.

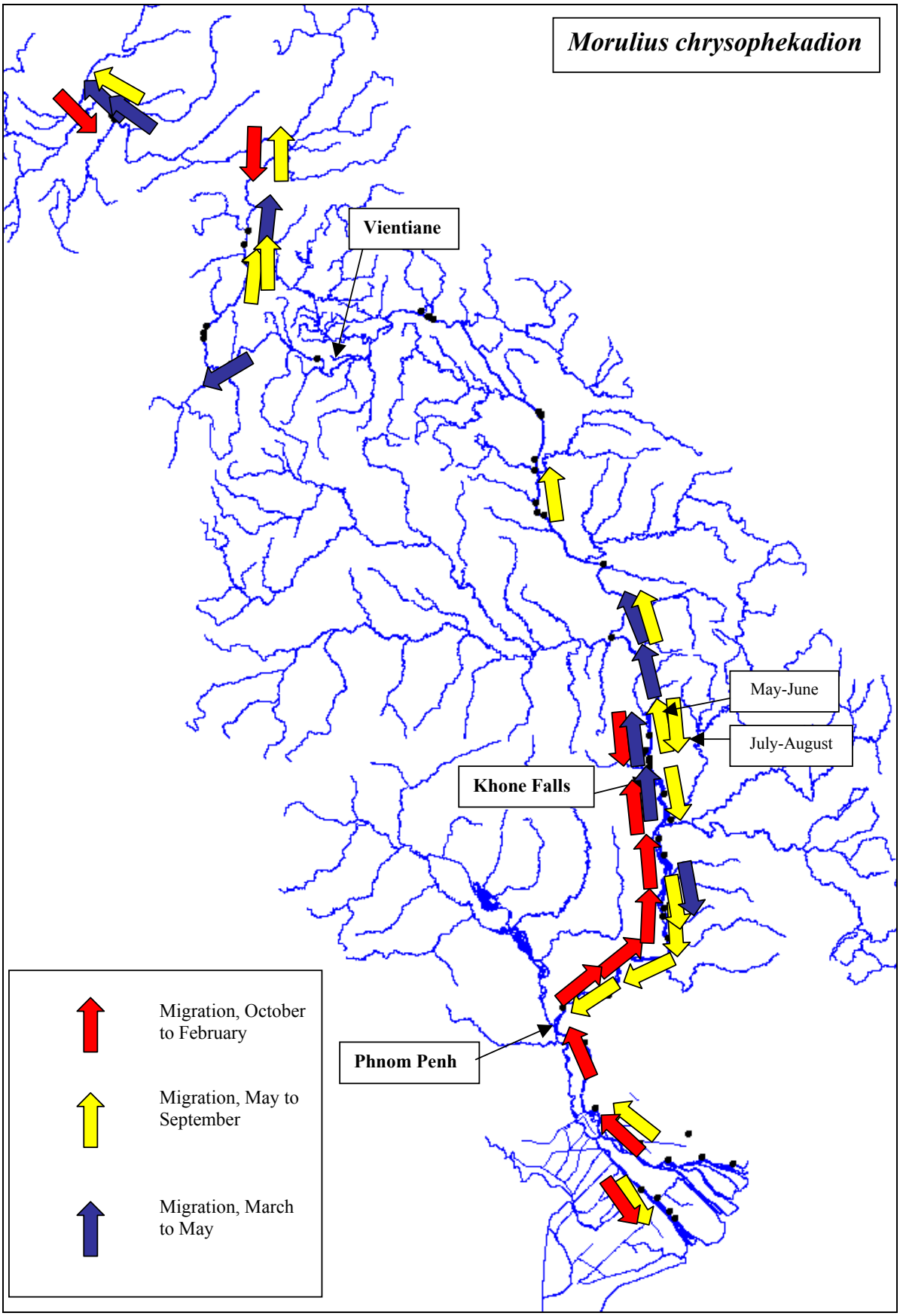
In Cambodia, upstream migration was reported from October to March, while the downstream migration was observed from March to August. In Viet Nam, there is very little information on migrations in the mainstream of the Mekong and Bassac rivers. The information that does exist is contradictory.

There were several reports of the species migrating into tributaries, small streams and canals. In the Lao PDR and Thailand, the species apparently starts migrating when the water changes from being clear to a reddish-brown colour (at the start of the monsoon season) or when the water level begins to rise.

Hypothesis:
Multiple populations of *Morulius chrysophekadion* exist along the Mekong River. In the Lao PDR and Thailand, the species starts its upstream migration at the onset of the monsoon season, and continues to move into tributaries and flood-plain areas to spawn. In northern Cambodia, the species migrates downstream at the same time and

moves into the floodplains to spawn further downstream, with some specimens even travelling all the way to the Great Lake.


Morulius chrysophekadion
Vientiane
Khone Falls
Phnom Penh
Species reported

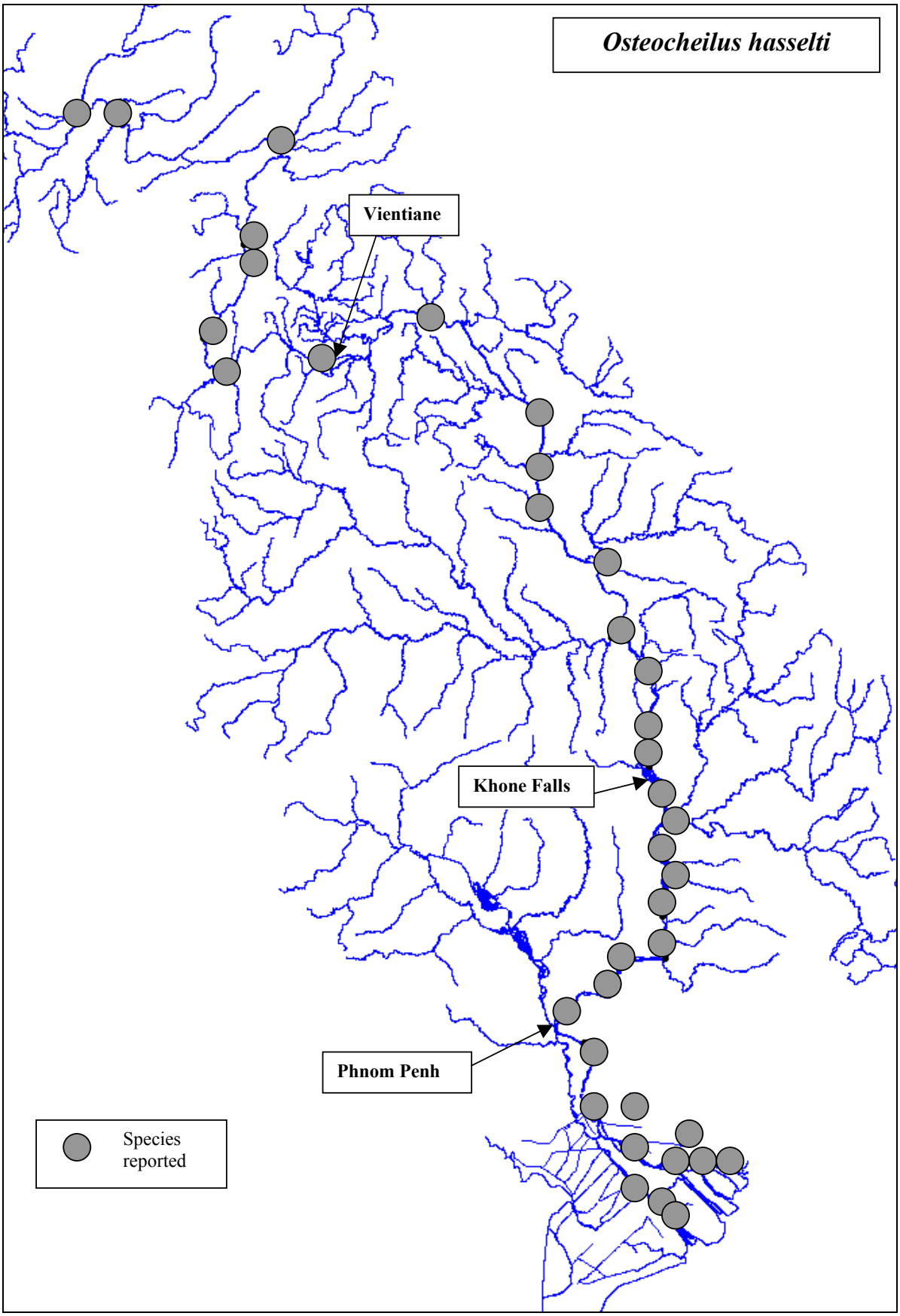

Morulius chrysophekadion
Vientiane
May-June
July-August
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(k)Osteocheilus hasselti

Osteochilus hasselti is a common species that occurs throughout the survey range from the Thai-Lao-Myanmar border in the north, to the Mekong delta in the south. It appears to be a species that mainly lives in smaller tributaries and, during the onset of the flood season, migrates to flooded areas. At the end of the monsoon season, the species migrates back to its river habitats in tributaries and, to a lesser extent, the Mekong mainstream.

The number of developed eggs peaks in May-June, indicating that spawning occurs during the period of rising waters at the onset of the flood season.

Hypothesis:
Osteocheilus hasselti appears to constitute many subpopulations throughout the Mekong basin, each undertaking short migrations from rivers to flood-plain habitats at the onset of the flood season, and returning to river habitats at the end of that period.


Osteocheilus hasselti
Vientiane
Khone Falls
Phnom Penh
Species reported

(l) Paralaubuca typus

Paralaubuca typus occurs throughout the survey area, from the Mekong delta to Chiang Saen near the border between the Lao PDR, Thailand and Myanmar. It was reported by all the surveyed stations.

Below the Khone Falls, two distinct and conspicuous migrations occur. From November to February, a non-reproductive upstream migration is undertaken all the way from Kandal, near Phnom Penh, to the Khone Falls (reported by all 13 stations throughout Cambodia).

One Cambodian fisherman from Kompong Cham reported that the fish comes from Tonle Sap as well as from small canals into the mainstream. Two fishermen from Kandal and Kompong Cham reported that the migration occurs at about the time of the full moon.

From May to July, the fish migrate downstream (also reported by all stations). At that time, the fish were reported to be in reproductive condition. Twenty-two reports confirmed that mature eggs were observed from May to July. Two fishermen from Sambor reported observing fish releasing eggs in May. The eggs were reported to have drifted downstream with the current.

In the Mekong delta, rising water appears to trigger a migration up into canals and then into flooded areas. When the water recedes, the fish return through canals to the mainstream (reported by all three flood-plain stations in Viet Nam).

Spawning was observed by fishermen at two stations in Dong Thap province (Hong Ngu and Tam Nong). At Hong Ngu, spawning was observed in the Mekong mainstream in May, whereas at Tam Nong it was observed in a flood-plain area in June.

Above the Khone Falls, the upstream migration was somewhat delayed compared to below the Khone Falls, occurring from March to July (reported by 14 stations). The migration is apparently triggered by a combination of "the first strong rain", rising water, changes in water colour/turbidity and the appearance of insects (reported by six stations). Several fishermen along this stretch reported observing the fish feeding on insects in shallow water near the riverbank. Six stations reported that the species migrates together with several other species, in particular *Henicorhynchus* sp. (*pa* [*pla*] *soi*), but also *Botia modesta*, small *Pangasius* sp. (*pla yon*) and *Micronema* sp.

Eggs were observed (10 stations) in the abdomen of fish from April to July, with a strong peak in May-June, indicating that spawning occurs during that period. One fisherman (Loei, Thailand) reported observing developed ova during August-November. That report is inconsistent with all other reports and should therefore be further investigated.

At Loei and Chiang Khong (Thailand), *Paralaubuca typus* was reported to occur all year round, migrating up into tributaries (e.g., the Loei River) and into flooded areas at both locations.

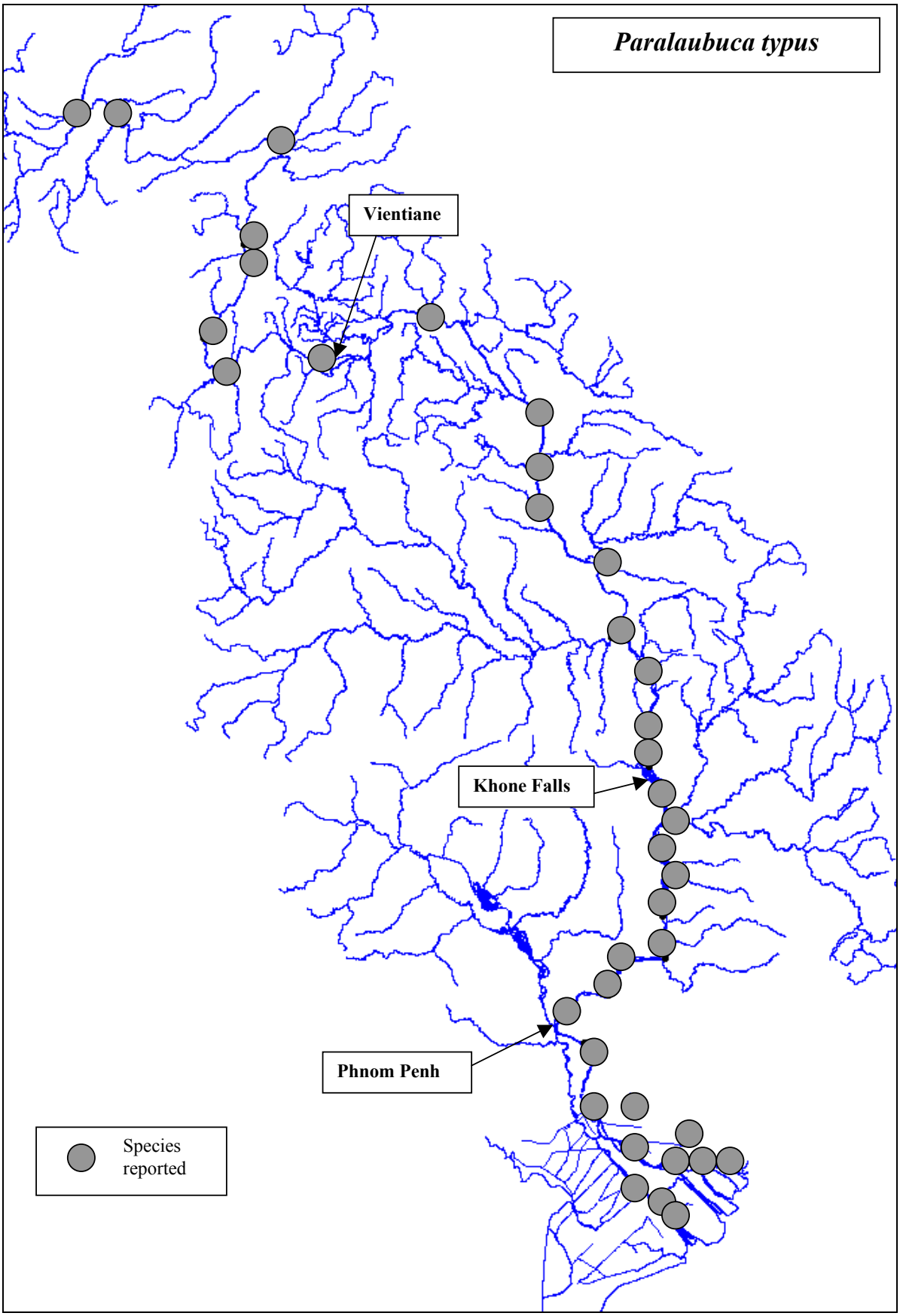
Paralaubuca typus in one of the most important fishes in the specialised *tone* trap fishery at Ban Hang Khone from January to March (Baird, 1998). This fishery mainly targets small, highly migratory cyprinids.

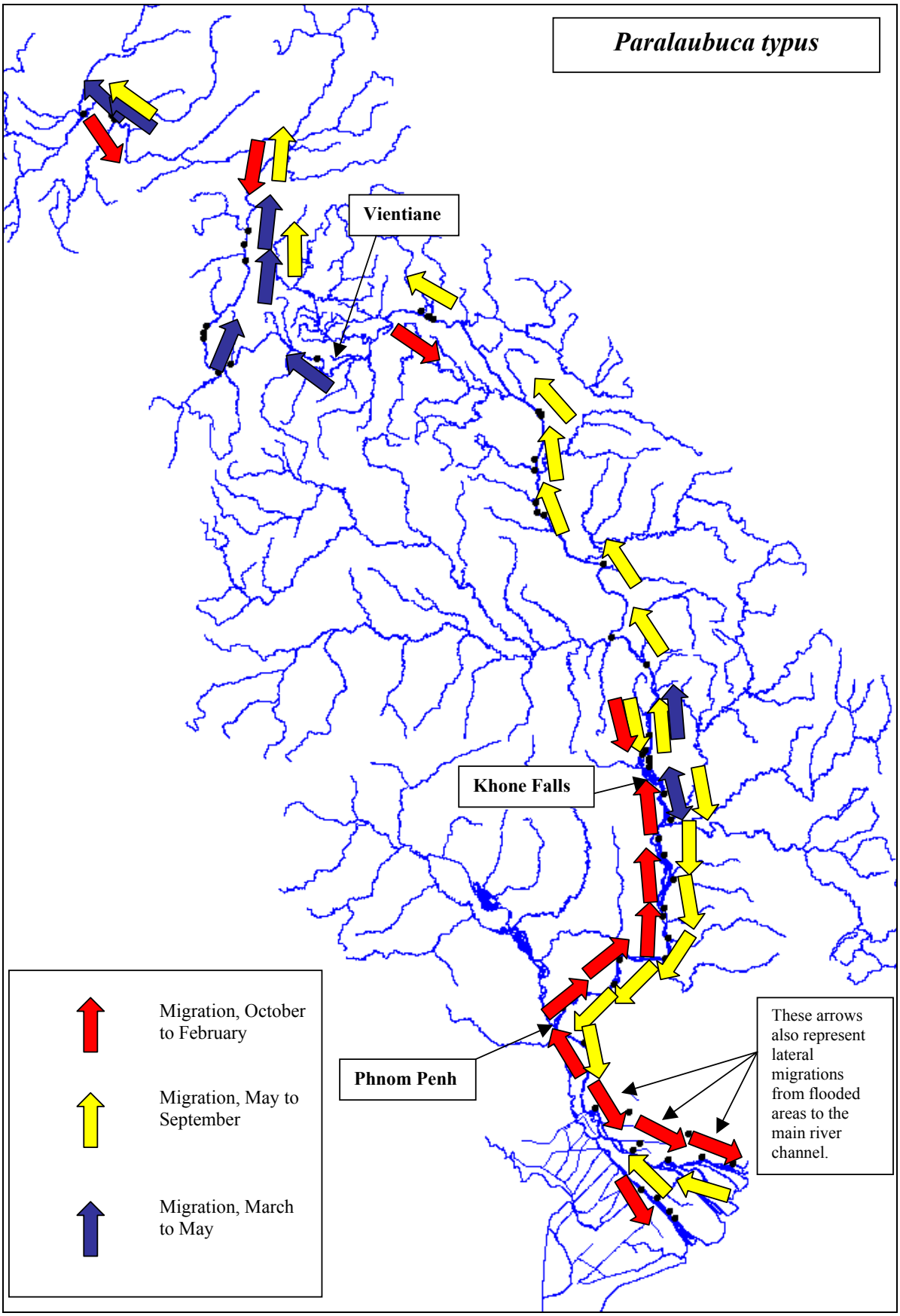
The species was also recorded in market surveys at Stung Treng during February 1994 and Kratie during January-February, where it was considered part of a group of "small non-reproductive fish migrating upstream from downriver" (Roberts and Warren, 1994). This information is in line with the finding of the current survey.

Hypothesis:
Paralaubuca typus spawns at the onset of the flood season (May to July), and the eggs and larvae are swept downstream and out into flooded areas. Juveniles and adults also spend the flood season on the floodplain. When the water begins to recede, the fish (young-of-the-year as well as adults) migrate back into tributaries (e.g., the Tonle Sap River) and eventually back into the Mekong mainstream. Together with other small migratory fishes, *Paralaubuca typus* takes part in a dispersal migration all the way from the Great Lake/Tonle Sap River system to the Mekong and upstream to the Khone Falls between November and February.

Upstream of the Khone Falls, there are at least two populations, one from the Khone Falls to somewhere above Vientiane/Nong Khai, and one further upstream from Loei to Chiang Saen near the border between the Lao PDR, Thailand and Myanmar.

Downstream from the Khone Falls, *Paralaubuca typus* constitutes one single population with multiple spawning sites. Alternatively, there may be more than one population, with substantial overlapping.


Paralaubuca typus
Vientiane
Khone Falls
Phnom Penh
Species reported


Paralaubuca typus
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May
These arrows also represent lateral migrations from flooded areas to the main river channel.

(m) Probarbus jullieni and *Probarbus labeamajor*

Three species have been described within the genus: *Probarbus jullieni, Probarbus labeamajor* and *Probarbus labeaminor* (Roberts 1992). All three are included in the IUCN List of Endangered Animals, the first as "Endangered", and the latter two as "Data deficient". In addition, *Probarbus jullieni* is listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Appendix I.

Probarbus jullieni and *Probarbus labeamajor* appear to have very similar migratory habits, and although fishermen at many places can distinguish between the two species (e.g., they have different local names), they are reported to migrate together. A third species (*Probarbus labeaminor*?) was reported at Sungkom district, Nong Khai province (Thailand) with similar migratory habits to *Probarbus jullieni* and *Probarbus labeamajor*. Since the two first species appear to be very similar with respect to migratory habits, they are considered together in this publication.

The two species occur throughout the survey area, from the Mekong delta to the border between the Lao PDR, Thailand and Myanmar. As with most of the other migrating species covered by the current survey, the migrations of *Probarbus* can be divided into spawning migrations and trophic migrations.

Upstream spawning migrations occur between October and February from Kompong Cham (Cambodia) to the northernmost station of Chiang Khong (Thailand). Above the Khone Falls, the main spawning period was reported to be January to February, sometimes extending into March-April. At Chiang Khong, fishermen reported that *Probarbus* migrates up the Nam Ta tributary in the Lao PDR to spawn during March-April. A spawning site was described.

At Loei (Thailand), a site named Bung Ghang was reported to be a spawning ground. At Mukdahan (Thailand), spawning was reported at two Mekong sites named Don Son Korn and Don Nang Nean (the fisherman reported observing "a hundred fish gathering there"). Another fisherman at Mukdahan reported mature male fish with milt and seeing fish swimming near the surface during October-November.

In Sungkom district, Nong Khai province, three *Probarbus* species were reported to migrate together but spawn separately during January-February. Early-stage eggs were observed during October-November.

At Paksan (Lao PDR), ripe females were reported in March-April.

However, a report from Pak Lay, Xayabouri province in the Lao PDR, did not adhere to the information given in the other spawning reports. The report noted that eggs were observed in August, but the development stage of the observed eggs was not described. Further investigation is therefore needed to verify that observation.

There were no reports on actual spawning sites below the Khone Falls. Furthermore, reports on the occurrence of eggs in that stretch were less clear compared to reports

from above the Khone Falls. Four reports, covering the stretch from Thalabovirrat near the Khone Falls to Sambor, stated that eggs were observed from November to March. However, at four stations from Sambor to Kandal, eggs were reported to occur from May to August, at a time when the fish were reported to migrate downstream. Since the development stages of the eggs were not mentioned, they could have been in a very early stage of development. The information could also indicate the presence of a different population (or even species) from further upstream. Further investigations are therefore needed for verification.

There were no reports on spawning or occurrence of eggs in the Mekong delta. In the delta, *Probarbus* sp. occur mainly as juveniles up to 40 cm. Only one station, Hong Ngu in Dong Thap province, reported fish of up to 90 cm.

Spawning of *Probarbus* has been quite well documented in previous studies. Roberts and Warren (1994) described the upstream spawning migration at the Khone Falls from October to January. They also reported that *P. jullieni* and *P. labeamajor* migrated together. A spawning site near Don Hee was identified.

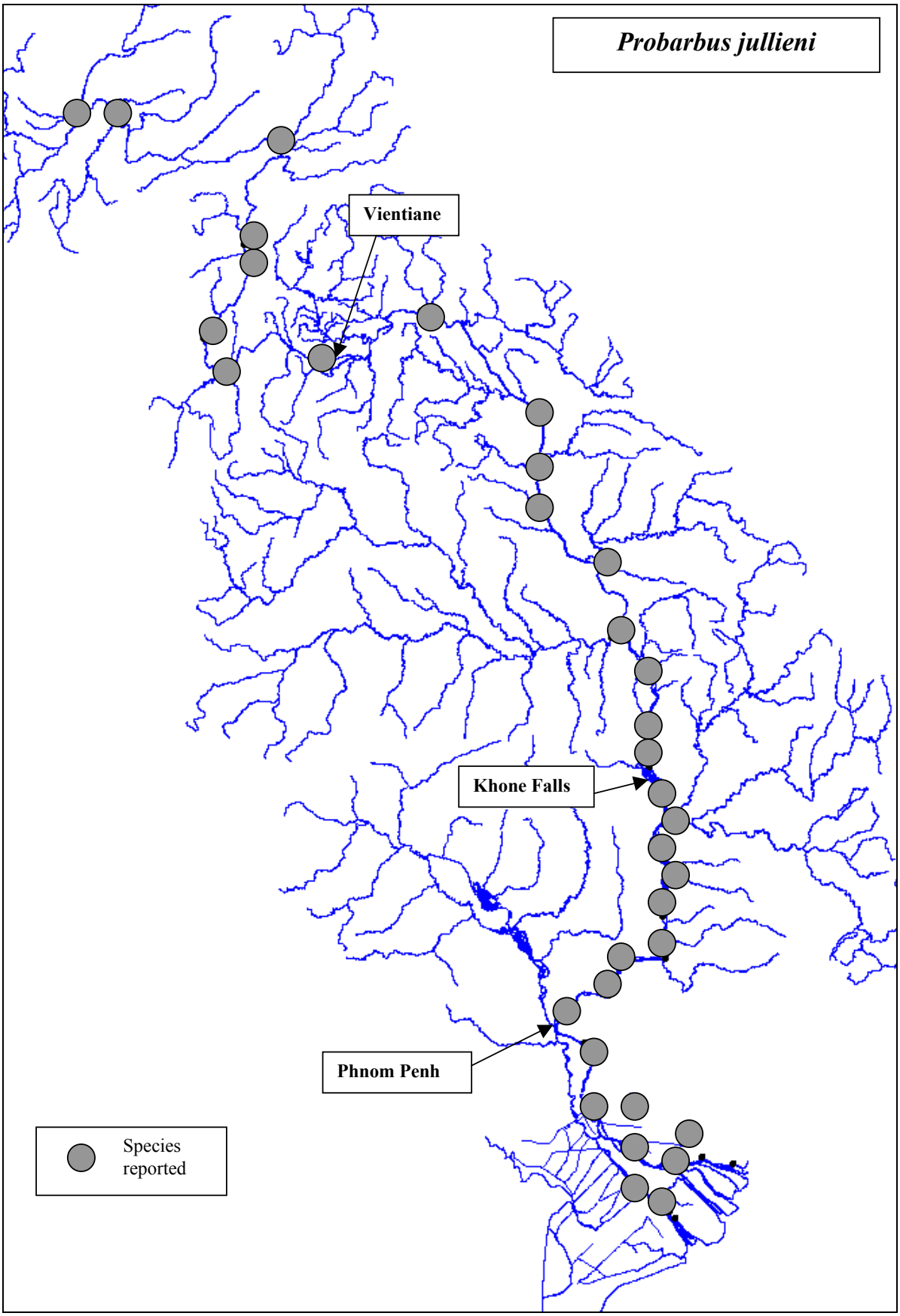
Baird (1998) documented the *Probarbus* fisheries from October to January at Ban Hang Khone, just below the Khone Falls. Virtually all *Probarbus spp*. caught were in reproductive condition. The main species was *Probarbus jullieni* accounting for more than 65 per cent of the catch during that period, with *Probarbus labeamajor* accounting for just over 12 per cent.

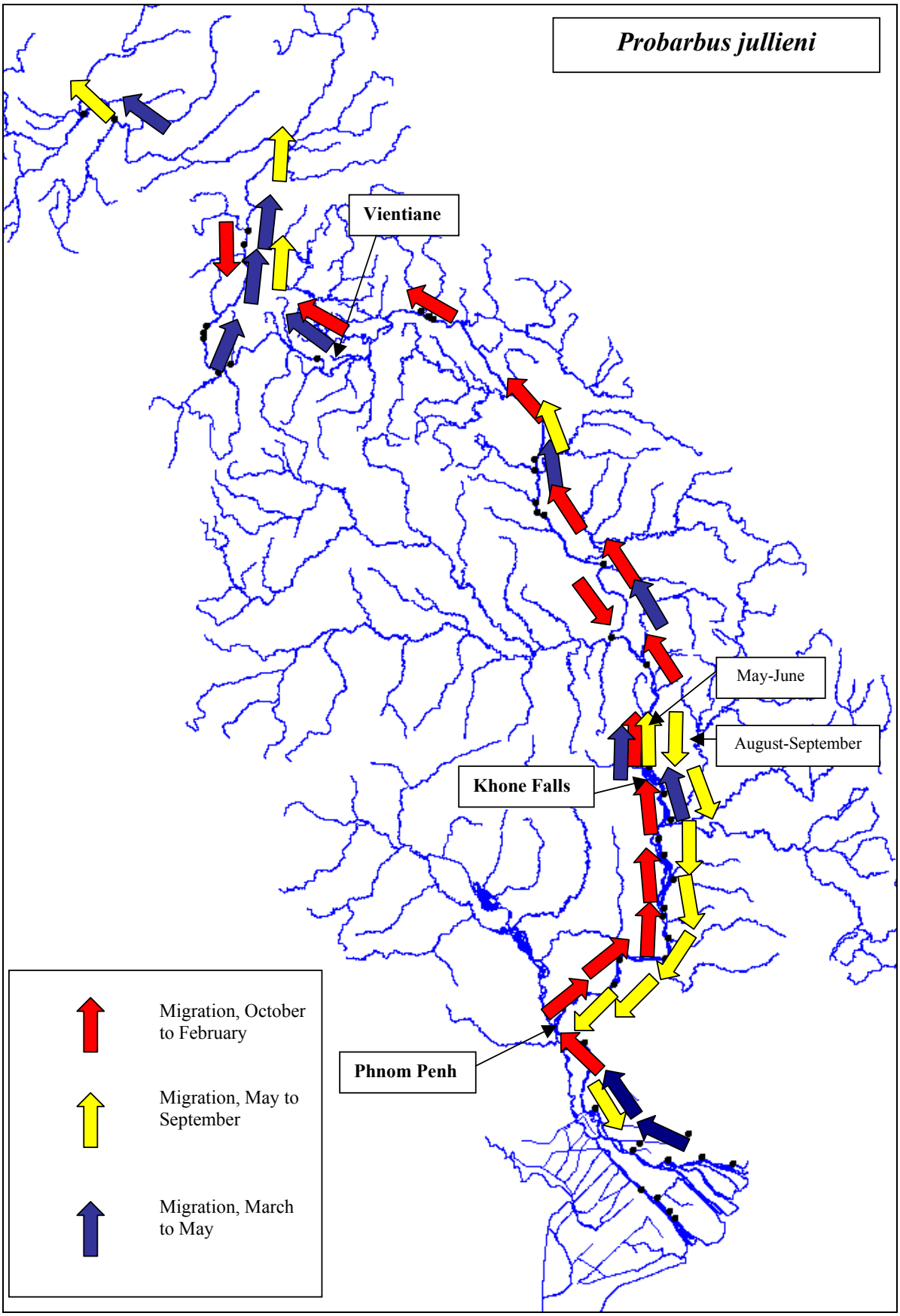
Viravong (1996) documented a spawning ground in the Ou River in northern Lao PDR, and described in detail the spawning behaviour of *Probarbus jullieni*, during February 1995.

Finally, a *Probarbus* spawning ground in the Nam Lik River, in the Nam Ngum River catchment area, was documented during phase I of the present survey (Trial Survey) in 1998.

Trophic migrations were reported throughout the occurrence range. They occur mainly at the onset of the flood season and are mainly undertaken by juveniles and sub-adults. At a station at Nakhon Phanom (Thailand), juveniles of about 6 cm were reported to live “near the beach, and when the beach begins to be covered with water, they migrate upstream”. They apparently spend the flood season in flooded areas. The same station reported observing juveniles of about 2 cm from March to May.

At Loei, the fish were reported to move up the Loei River and into flooded areas. At that time, juveniles “cannot be seen in the Mekong”. From Cambodia, there were several reports of lateral migrations from the Mekong into smaller streams and flooded areas, mainly comprising smaller fish of 20 to 60 cm. At Sambor, juveniles were reported from Lake Sandan, a flood-plain lake.


Probarbus jullieni
Vientiane
Khone Falls
Phnom Penh
Species reported


Probarbus jullieni
Vientiane
May-June
August-September
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(n) Puntioplites falcifer

According to the data gathered during the survey, *Puntioplites falcifer* is a common species in the Mekong mainstream all the way from Chiang Rai province in northern Thailand to the southernmost station in Viet Nam. Although relatively easy to identify because of its very long dorsal fin, it is possible that the identity of the species has been confused with other *Puntioplites* spp., especially *P. proctozysron*, which is another common species.

The maximum reported size was around 40 cm, which is slightly larger than the maximum size of 35 cm reported by Rainboth (1996).

Several fishermen mentioned that *Puntioplites falcifer* has a preference for deep pools in the river. It was also mentioned that the fish migrate to streams, canals and lakes during the flood season. The last statement is not in agreement with Rainboth (1996), who specifically stated that *Puntioplites. falcifer* has a preference for large rivers and avoids standing water. *Puntioplites proctozysron*, on the other hand, reportedly has a preference for lentic environments.

Puntioplites falcifer is a social species that migrates in large schools. It was also reported to migrate together with a number of other species, in particular *Cosmochilus harmandi*, *Cirrhinus* spp., *Morulius chrysophekadion* and *Bangana* sp.

It is difficult to summarise the migration patterns of this species because the migrations are spread out over a long period. However, it appears that the basin can be divided into four parts:

- Northern Lao PDR and Thailand (from Loei and Chiang Rai provinces). Upstream migrations there were reported to occur from February to May and July to August, but the main period of upstream migration is during March-April. Downstream migrations occur from September to November.

- Champassak (Lao PDR) to Nakhon Phanom province (Thailand). Upstream migrations are concentrated during May-June. Downstream migrations occurduring November-December.

- Northern Cambodia (Stung Treng to Kratie). *Puntioplites falcifer* was reported to migrate upstream in this river stretch during November-December, and downstream during April-June.

- The Mekong mainstream in Viet Nam. Only one report was received, from Tien Giang province, on upstream migration in July and downstream migration during October-December.

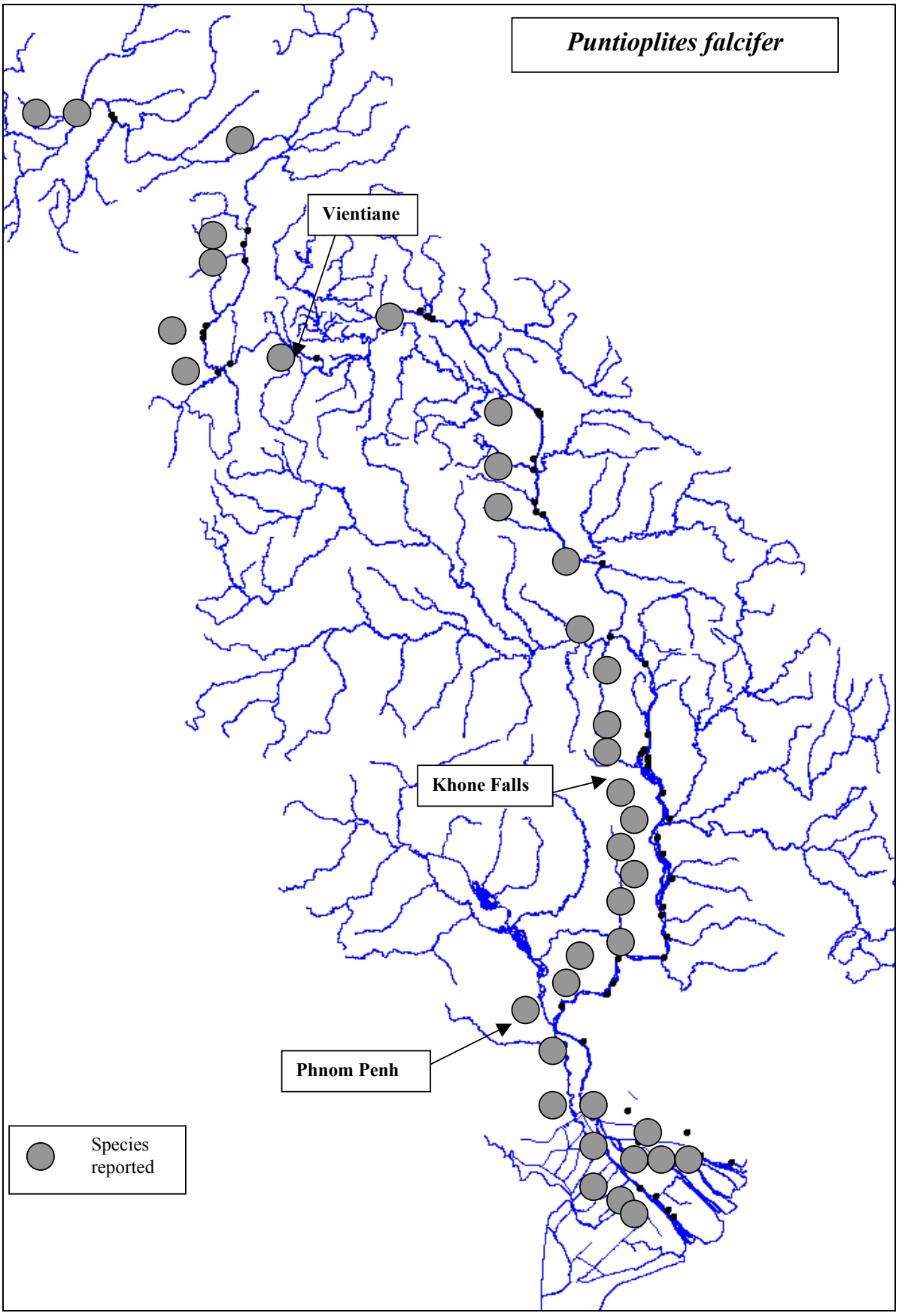
From Nong Khai to Thakhek, and from Kompong Cham to Tra Vinh in Viet Nam, no indications were given on the direction of the migrations. Similarly, no information was provided on the direction of migrations in the Bassac River.

A number of environmental factors and events have been connected with the migrations of this species, with some of them being, to a certain extent, contradictory.

Fishermen at five stations in the Lao PDR, for example, mentioned that *Puntioplites falcifer* occur in large numbers when the water is reddish in colour, while fishermen at two other Lao stations mentioned that clear water is indicative of a high concentration of this species. Water level appears to be a very important factor, since migration activities of this species intensify when the level rises or falls.

Some fishermen reported that periods of upstream migration and good catches are associated with the occurrence of water temperature changes and strong winds. In Cambodia, both upstream and downstream migrations are associated with a full moon. One Thai fisherman in Mukdahan reported that *Puntioplites falcifer* attains sexual maturity at about 0.3-0.4 kg. In all four countries, eggs were reported during March-December, with most reports giving May-June as the peak period. However, there were many more reports from Cambodia than from the other countries. The reason could be due to the low occurrence of the species in the Mekong mainstream in the Lao PDR and Thailand during the spawning season. Juveniles measuring 2 cm were observed throughout the year, with peak occurrence from May to November. Vietnamese fishermen reported that *Puntioplites falcifer* spawnsin small streams and ricefields.

Hypothesis:
During the first heavy rains of the monsoon season, *Puntioplites falcifer* migrates to the nearest large tributary, and spawns in tributaries and canals and associated flood-plain areas. The juveniles spread out along the riverbank, and some of them enter the Mekong mainstream. When the river level falls, adult and juvenile *Puntioplites falcifer* move back to the Mekong River, where they stay in deep pools until the next flood season.


Puntioplites falcifer
Vientiane
Khone Falls
Phnom Penh
Species reported

2. Family: *Cobitidae*

Botia modesta

Botia modesta was reported by all the surveyed stations throughout the survey area, from the Mekong delta to Chiang Saen, near the border between the Lao PDR, Thailand and Myanmar.

An upstream migration by *Botia modesta* was reported by 16 out of 18 Mekong stations in the Mekong delta, from around the saline intrusion zone to just below the Khone Falls between November and March. Migration was reported to be triggered by receding water levels (reported by eight stations). Four stations, from Kandal to Kompong Cham, reported a migration during the full moon (just before the full moon at Kandal).

From May to July, the species migrates the opposite way, downstream from the Khone Falls, apparently all the way 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, *Botia modesta* was reported by 12 out of 14 stations to migrate upstream from February to May. Five stations reported that this species migrates together with *Henicorhynchus* sp. (*Pa* [*pla*] *soi*). However, the northernmost station in Chiang Khong (Thailand) reported that *Botia modesta* does not migrate together with other species, that the fish entered the tributary, Nam Ing, and that the young-of-the-year return from the Nam Ing to the Mekong during September-November (indicating that spawning occurs in the Nam Ing). Further downstream, near Mukdahan-Savannakhet, *Botia modesta* was also reported to migrate into small streams, e.g. at Huai Noi and Huai Kum.

One station just above the Khone Falls (Khong Island) reported that the main upstream migration period occurred in June-July. This was the only station above the Khone Falls that reported any migration during that period. However, the timing coincides with the downstream migration reported below the Khone Falls. The same station reported that *Botia modesta* does not migrate into tributaries and smaller streams.

Eggs were observed from February to July throughout the distribution range (17 stations) with a strong peak in May-June (reported by 11 stations), indicating that spawning occurs during that period.

Juveniles of about 2 cm in length were reported at several places throughout the range. At Chiang Khong and Chiang Saen in the north, they were observed between March to May, and again from September to November. At Xayaboury, they appear from March to May, while in Mukdahan they were seen in November (reported by two stations). In Cambodia, three stations reported that 2-cm juveniles were observed between November and February from Stung Treng to Sambor, and from July to October between Kratie and Kandal. In the Mekong delta, eight stations observed 2-cm juveniles between June and November.

Between January to March, *Botia modesta* is one of the most important species in the specialised *tone* trap fisheries area at Ban Hang Khone, immediately downstream from the Khone Falls (Baird, 1998).

Botia modesta is a popular species in the aquarium trade, particularly in Thailand.[7] Since breeding in captivity is still in the experimental stage, the trade is based on the capture of specimens from the wild. One of the most important areas for the capture of aquarium specimens is the Songkhram River in north-eastern Thailand, where the species is believed to spawn in, or near, flood-plain areas at the onset of the flood season.

Hypothesis:

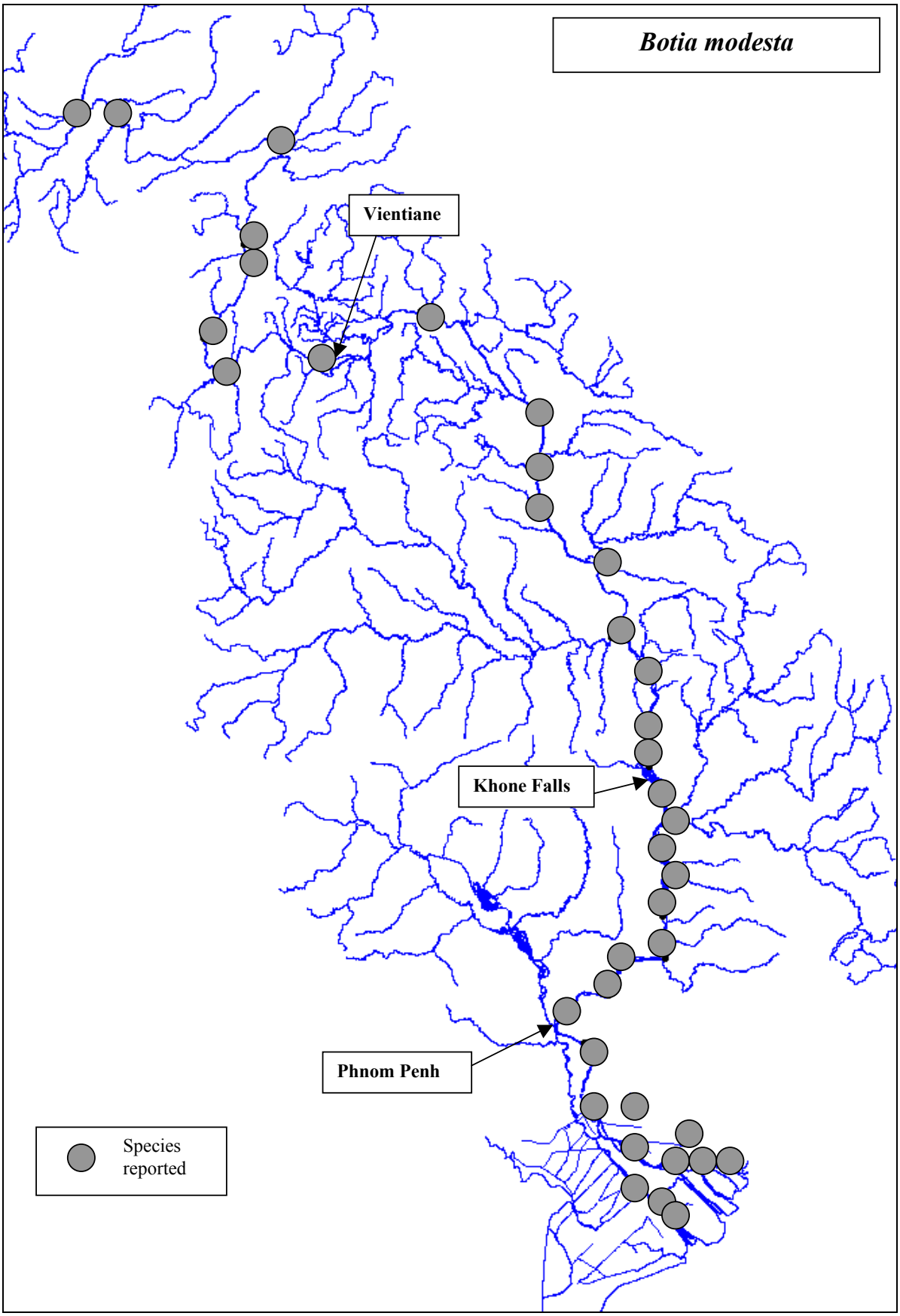
Several (multiple?) populations of *Botia modesta* exist in the Mekong.

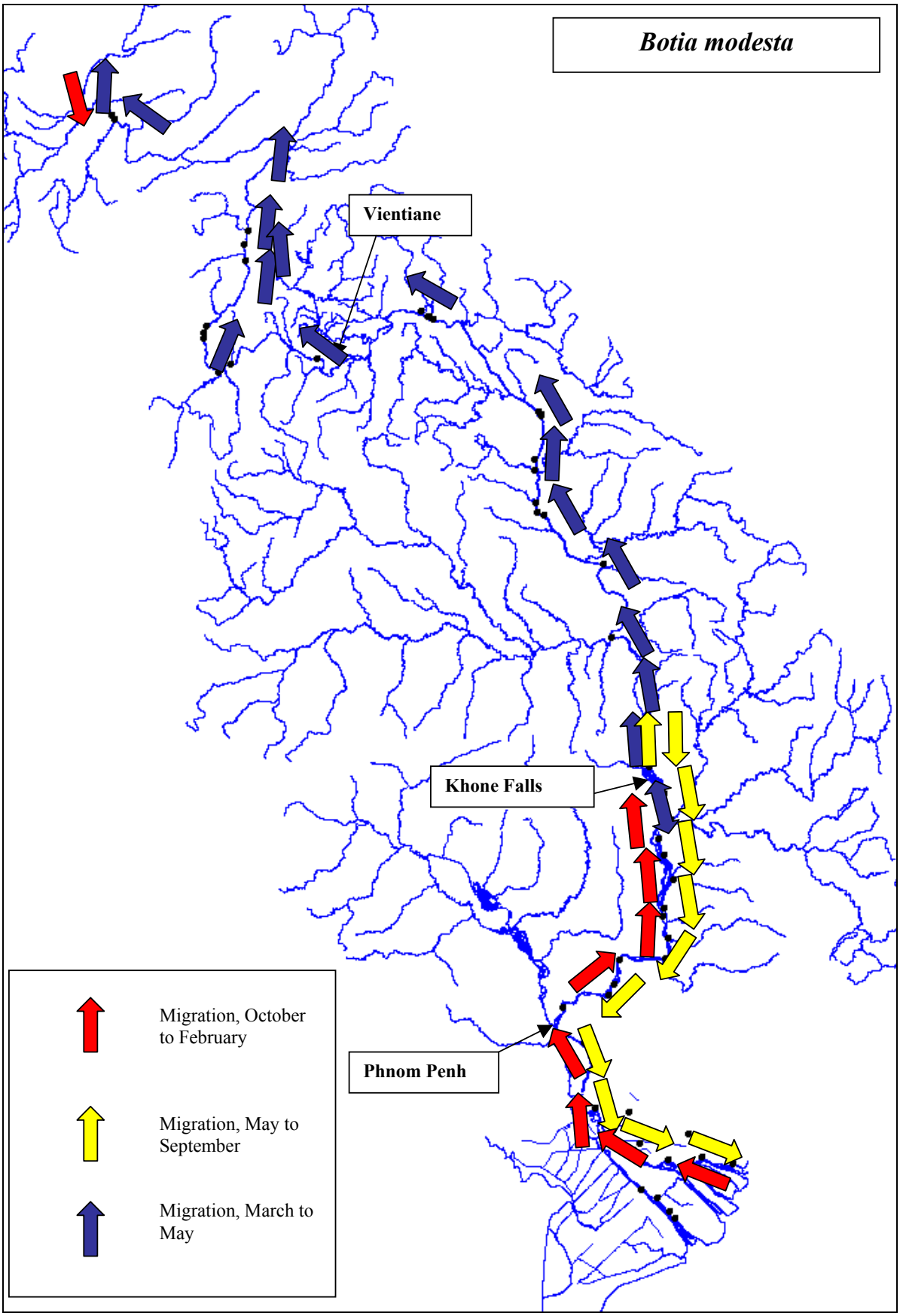
Above the Khone Falls, *Botia modesta* migrate into tributaries and streams, where they spawn during the early flood season. Eggs and larvae are swept onto flooded areas, where they develop during the flood season. When the water begins to recede, the fish move back into the main tributaries and the Mekong mainstream. There may be a limited overlap between different populations in that stretch of the river.

Below the Khone Falls, *Botia modesta* also spawns at the onset of the flood season, and eggs and larvae are carried into flooded areas in southern Cambodia and the Mekong delta. Spawning may be limited to the northern part of Cambodia, between Kratie and the Khone Falls. Consequently, the population that inhabits southern Cambodia and the Mekong delta (and possibly the Tonle Sap/Great Lake system) originates from the area that stretches from Kratie upstream towards the Khone Falls. Separate populations may exist in large tributaries, e.g., the Sesan system.

The fact that 2-cm juveniles can be found for an extended period throughout the survey area suggests a long spawning period or, alternatively, different spawning periods for different populations. Different species of the genus may also be involved.

[7] Dr. Chavalit Vidthayanon, personal communication.


Botia modesta
Vientiane
Khone Falls
Phnom Penh
Species reported


Botia modesta
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

3. Family: *Clupeidae*

Tenualosa thibeaudeaui

Tenualosa thibeaudeaui occurs in the stretch of river from the Mekong delta to Chiang Khong in the northern Thai province of Chiang Rai. However, throughout its range it appears to be rare. For example, 10 reports from Cambodia stated that very few fish of this species are now observed at the respective stations. Also, the limited information provided by fishermen suggests that it is rare. One fisherman in Paksan, Boulikhamxay province of the Lao PDR, stated that he recognised the fish but did not know much about it. He then referred to the fact that some elder members of his family know the fish, since "the species was much more common in the past". This statement corresponds with the findings of Roberts (1993) who reported that the species was previously one of the most important in the Khone Falls fisheries, but that it had undergone a drastic decline in recent years.

Eight stations in Cambodia reported an upstream migration from Kandal province, near Phnom Penh, to the Khone Falls from October to February (with a peak during November-December). From April to July, the fish migrate downstream from the Khone Falls, at least as far as Kompong Cham province. The station at Sray Son Thor, in Kompong Cham province, reported that the species migrates from the Tonle Sap River. At one station near Stung Treng (Siem Bok), the fish were reported to make local migrations into, and out of, small streams and flooded areas (lateral migration) during periods of rising and receding water levels, respectively.

Four stations in the Mekong delta reported seeing *Tenualosa thibeaudeaui*. Three of the stations are located near the saline intrusion zone in Tien Giang and Tra Vinh provinces, and the fourth is at Hong Ngu, near the border with Cambodia. At Go Cong Tay, the species was reported to be found all year round. It appears that the species is not particularly migratory in that part of the river, since no information on migration was reported from the Mekong Delta.

Eleven stations above the Khone Falls reported that *Tenualosa thibeaudeaui* migrates upstream from March to June. The main factors triggering this migration were reported to be a combination of: (a) the first rainfall; (b) increased water levels; and (c) increased turbidity.

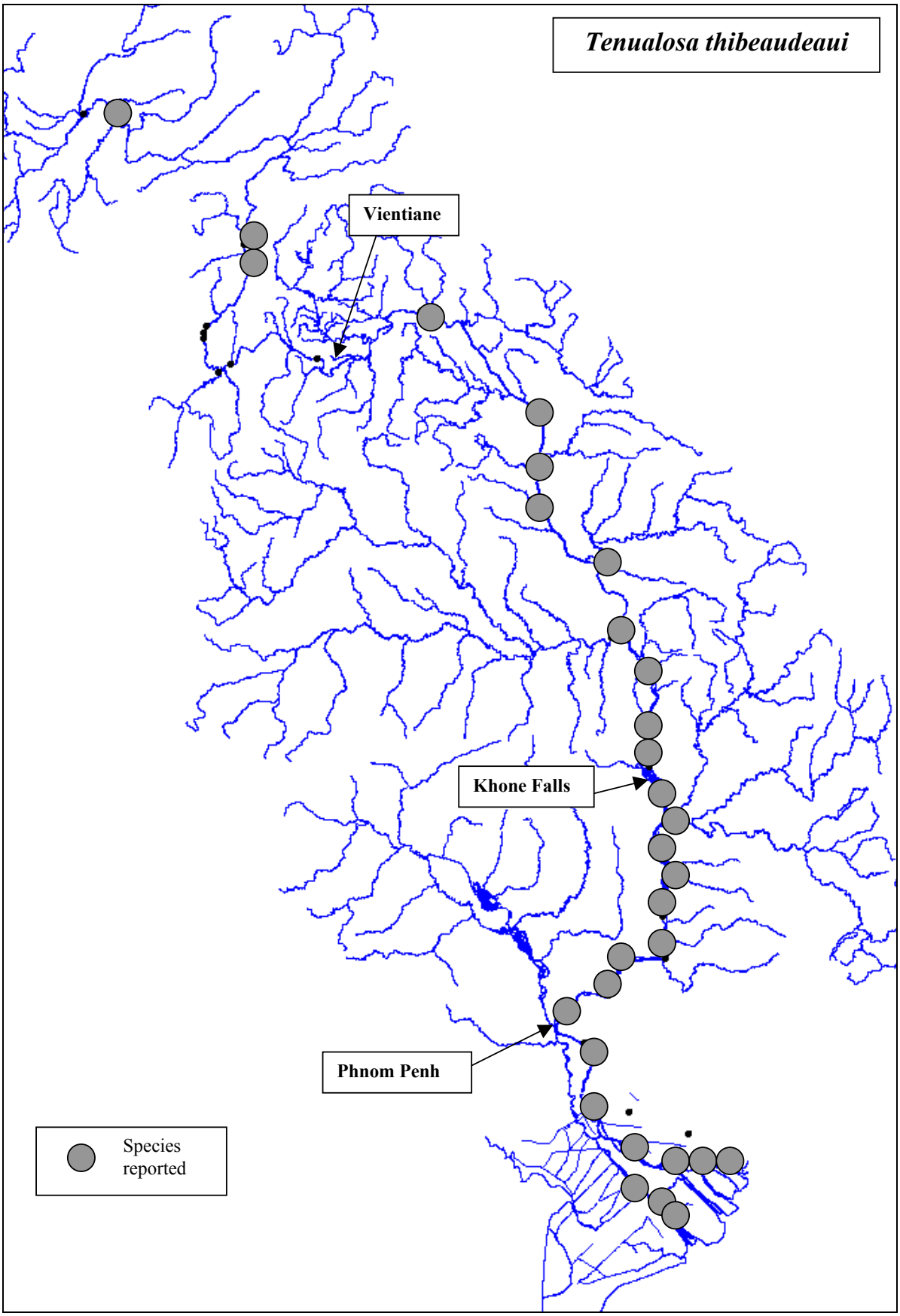
Six reports were received on observations of eggs in the abdomen of the fish. Five stations reported that developed eggs appear during May-June. Three of the stations were in Cambodia, from Stung Treng to Kandal, while the other two stations were in Xayabouri province of the Lao PDR. Eggs were reported at Khemmaratch, in Ubon Ratchatani province of Thailand, during March-April.

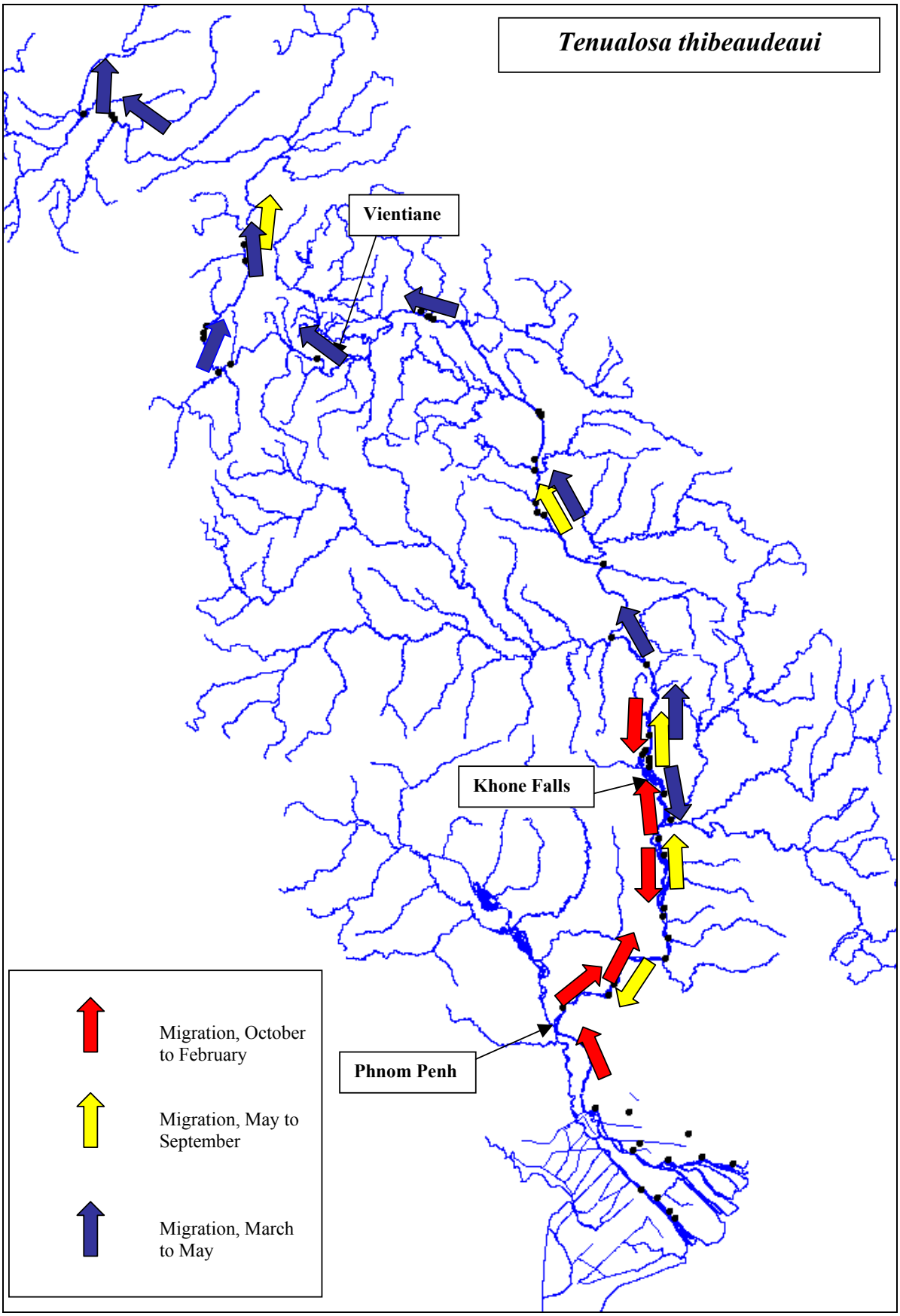
Hypothesis:
At least two populations of *Tenualosa thibeaudeaui* exist in the Mekong River. One is found around Xayaboury and upstream, and the other in the lower Mekong River from the Mekong delta to Paksan in the Lao PDR. The latter may represent more than one population, e.g., one above and one below the Khone Falls.

Tenualosa thibeaudeaui spawns at the onset of the flood season (mainly during May-June). The eggs and larvae are carried into flooded areas by the rising waters. Adults also move into flooded areas. When the water recedes at the end of the flood season, the fish (adults and young-of-the-year) return to the main rivers and tributaries, and begin a dispersal migration.

Below the Khone Falls, the species migrates from flooded areas in southern Cambodia and the Mekong delta, as well as from the Tonle Sap system, into the Mekong mainstream, where the fish then migrate upstream to the Khone Falls.

Above the Khone Falls, a combination of the first rainfall, rising water and increased turbidity triggers the fish into migrating upstream to spawning sites associated with flooded areas in tributaries of the Mekong, where they spawn during May-June. When the water begins to recede, the fish move back to the mainstream, where they spend the dry season.


Tenualosa thibeaudeaui
Vientiane
Khone Falls
Phnom Penh
Species reported


Tenualosa thibeaudeaui
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

4. Family: *Engraulidae*

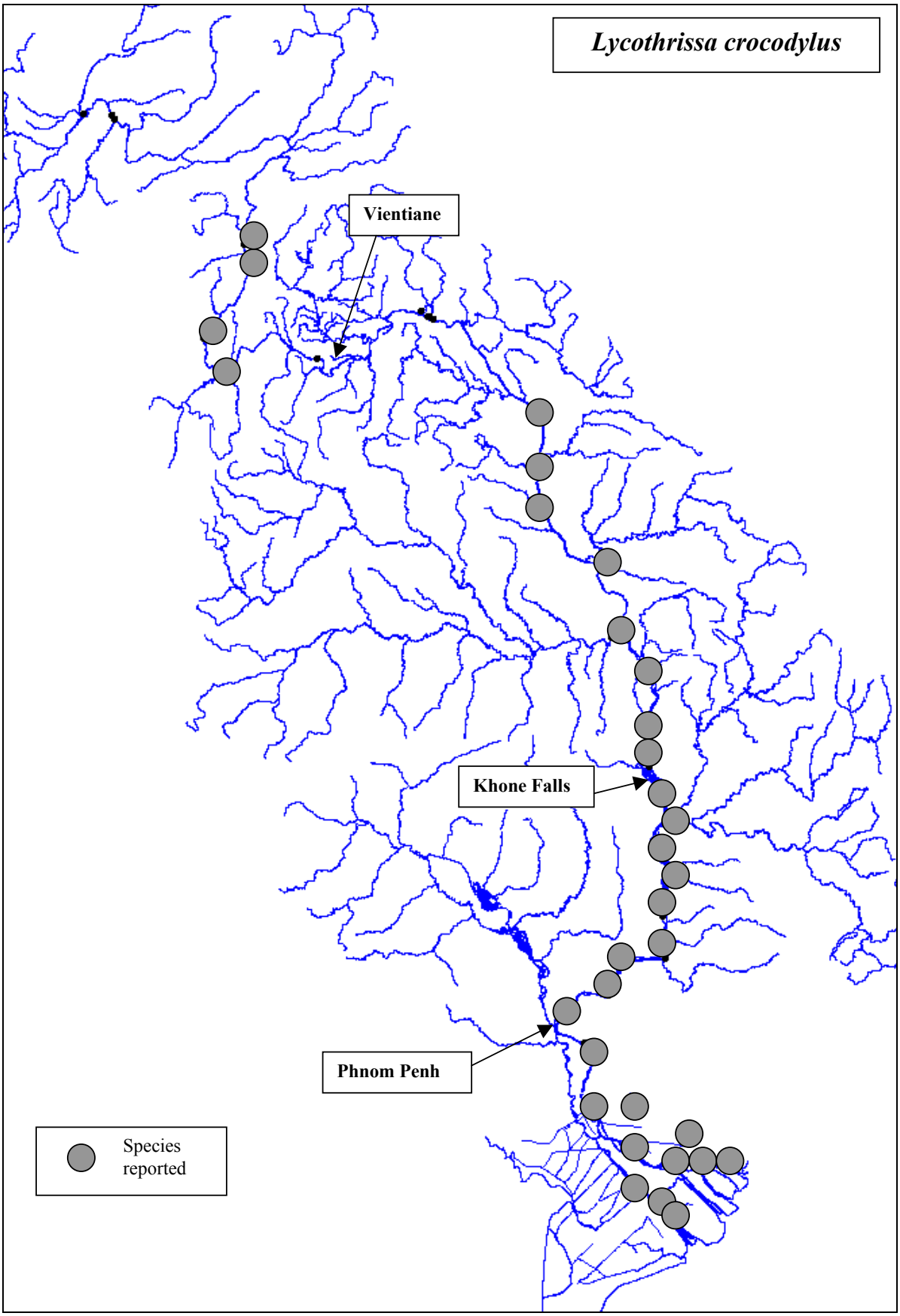
Lycothrissa crocodylus

According to Rainboth (1996), *Lycothrissa crocodylus* is found in the estuaries of large rivers from Indonesia to Thailand, usually in brackish water, but often ascending into freshwater. It is common in the Mekong delta up to the Tonle Sap and the Great Lake.

In the present survey, *Lycothrissa crocodylus* was reported by all stations in Cambodia, from just downstream of the Khone Falls to Kandal province. Above the Khone Falls, it was reported as far upstream as Xayaboury in the Lao PDR. Given its preference for brackish water, the reports from above the Khone Falls could be misidentifications. The most likely candidate for such misidentifications is another engraulid species, *Setipinna melanochir*, which is found further upstream from the estuary of large rivers and, in the Mekong, has been reported by Thailand (Rainboth, 1996). Some of the reports from Cambodia may also involve misidentification between these two engraulids.

From the Khone Falls to the Mekong delta, 14 fishermen reported an upstream migration during the dry season, from October to March. Downstream migrations were reported to occur at the onset of the monsoon season, from May to July. Several reports suggested that changes in the water level (receding or rising) trigger the migrations. At the station in Kandal, the upstream migrations occur when the water recede, just before the full moon.

Reports on developing eggs peaked around March to April (four reports for each month). One report was received each for February, May and June, suggesting that eggs develop during the dry season, and that spawning occurs either late in the dry season or at the onset of the flood season.


Lycothrissa crocodylus
Vientiane
Khone Falls
Phnom Penh
Species reported

5. Family: *Bagridae*

Hemibagrus filamentus (formerly *Mystus nemurus*)

Mystus nemurus was recently renamed *Hemibagrus filamentus*.[8] *Hemibagrus filamentus* occurs throughout the Mekong mainstream, from the Mekong delta to Bokeo and Chiang Saen in the north. Many fishermen reported that the species is very common and can be found throughout the year.

There was consensus among the fishermen all along the Mekong that this species undertake shorter local migrations within the Mekong mainstream at the onset of the flood season. With the rise in the water level, the fish migrate into smaller tributaries and out into flooded areas. When water levels start to recede at the end of the flood season, the fish return to the main river channel where they remain during the dry season.

Five stations along the stretch from Kandal province to the Khone Falls reported upstream migrations occurring just before, and during, the full moon. At Loei, the species migrates during the waning-moon phase.

Spawning was observed to occur in flood-plain areas. Three fishermen reported directly observing spawning of *Hemibagrus filamentus* associated with flood-plain habitats. At Chiang Saen in the far north of the survey area, one fisherman observed spawning in a flooded swamp near Ban Saew village in July. In Klong Kaem district of Ubon Ratchatani province in Thailand, a fisherman observed spawning in the flooded fringe of a small stream, Huai Ton, during May-June. The flooded spawning area contained mainly trees and shrubs. Finally, in Cao Lanh district, in Dong Thap province of Viet Nam, a fisherman observed spawning in a flood-inundated wet rice-growing area.

Almost all stations provided several reports on observations of eggs in the fish. The reports were distributed as follows (number of reports in bracket): February (2 reports), March (4), April (17), May (30), June (26), July (15), August (4), September to December (1 per month). One fisherman from Paksan had observed big, red-brown eggs during June-July.

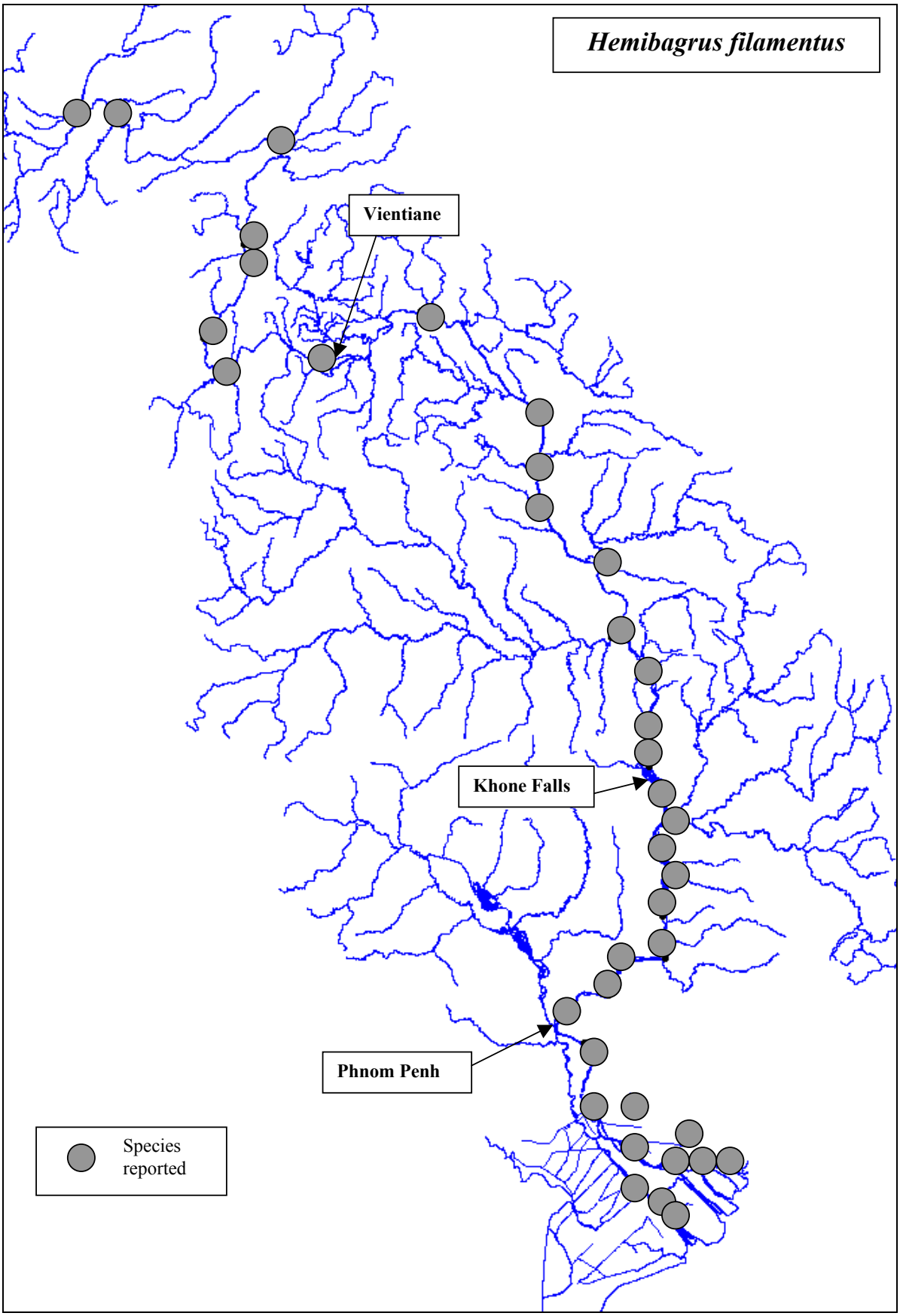
Juveniles, 2 to 4 cm in size, were reported from all over the survey area, from Chiang Khong in the north to the Mekong delta.

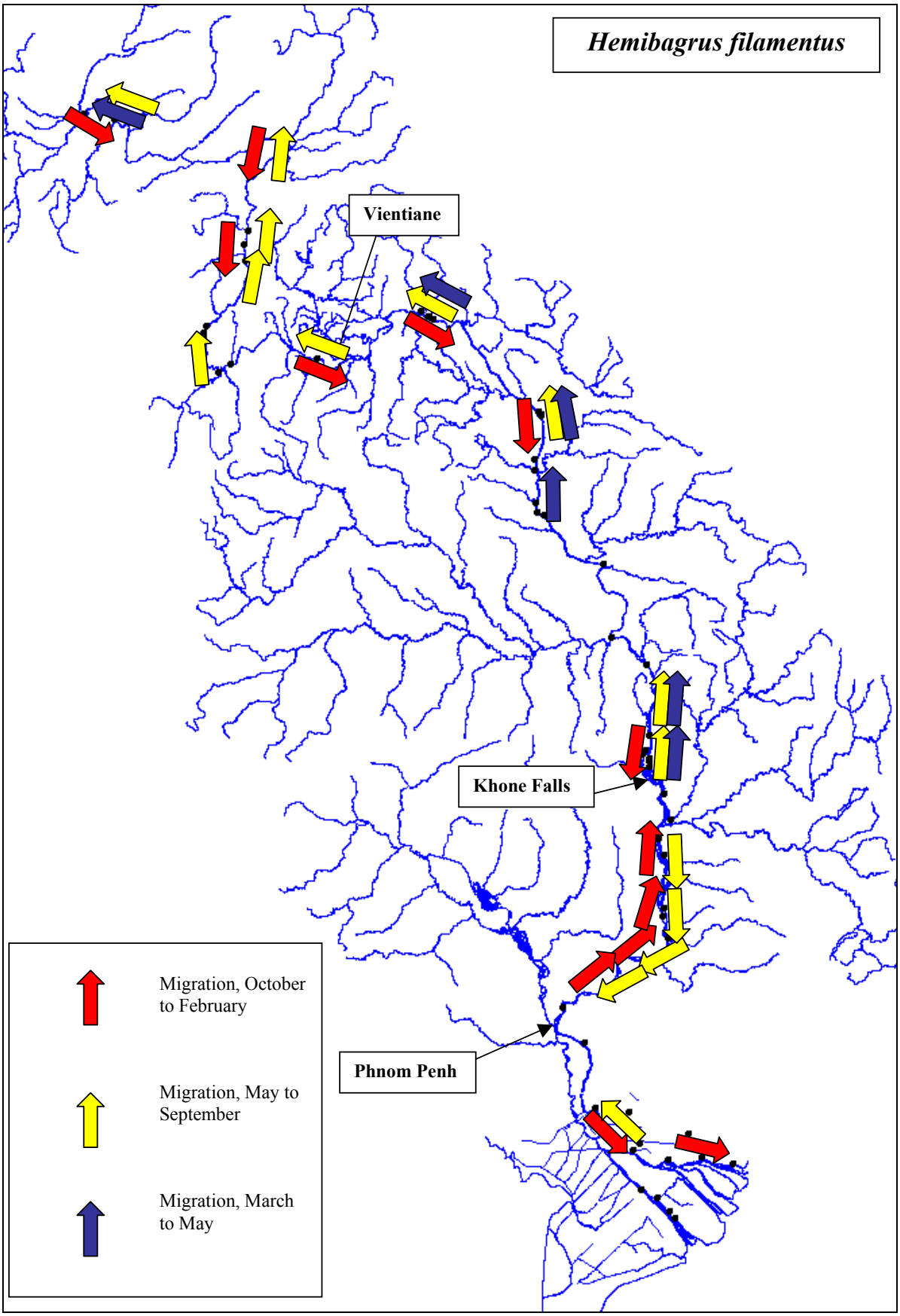
Hemibagrus filamentus was previously recorded in fisheries around the Khone Falls (Baird, 1998). In a gill-net fishery at Ban Hang Khone, which mainly target small cyprinids such as *Scaphognathops* spp., *Hemibagrus filamentus* ranked as tenth in terms of total weight. In the dry season, *tone* trap fishery, which targets highly migratory cyprinids (e.g., *Henicorhynchus* spp. and *Papalaubuca typus*), the species was ranked 35 in terms of total biomass. *Hemibagrus filamentus* were also caught during the flood season, where it ranked twelfth and eighteenth in *chan* trap and *kha* trap fisheries, respectively (Baird, 1998).

[8] Dr. Chavalit Vidthayanon, personal communication.

Singanouvong *et al.* (1996a) also reported *Hemibagrus filamentus* from gill-net catches at the Khone Falls, but did not consider it to be migrating over the Khone Falls during the dry season. However, during the monsoon season, the same authors listed the species as an upstream migratory species, based on catch records from the highly specialised *lee* (wing) trap fisheries right at the centre of the Khone Falls.

Hypothesis:
Mystus nemurus comprises multiple populations that undertake short local migrations at the onset of the flood season. The migrations are triggered by a combination of changes in water level and turbidity as well as the first rainfall. Spawning occurs in the early flood season, during May-June, and adults and young-of-the-year move out into the flood-plain areas, where they spend the flood season. When water begins to recede at the end of the flood season, the fish return to the river channels.


Hemibagrus filamentus
Vientiane
Khone Falls
Phnom Penh
Species reported


Hemibagrus filamentus
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

6. Family: *Clariidae*

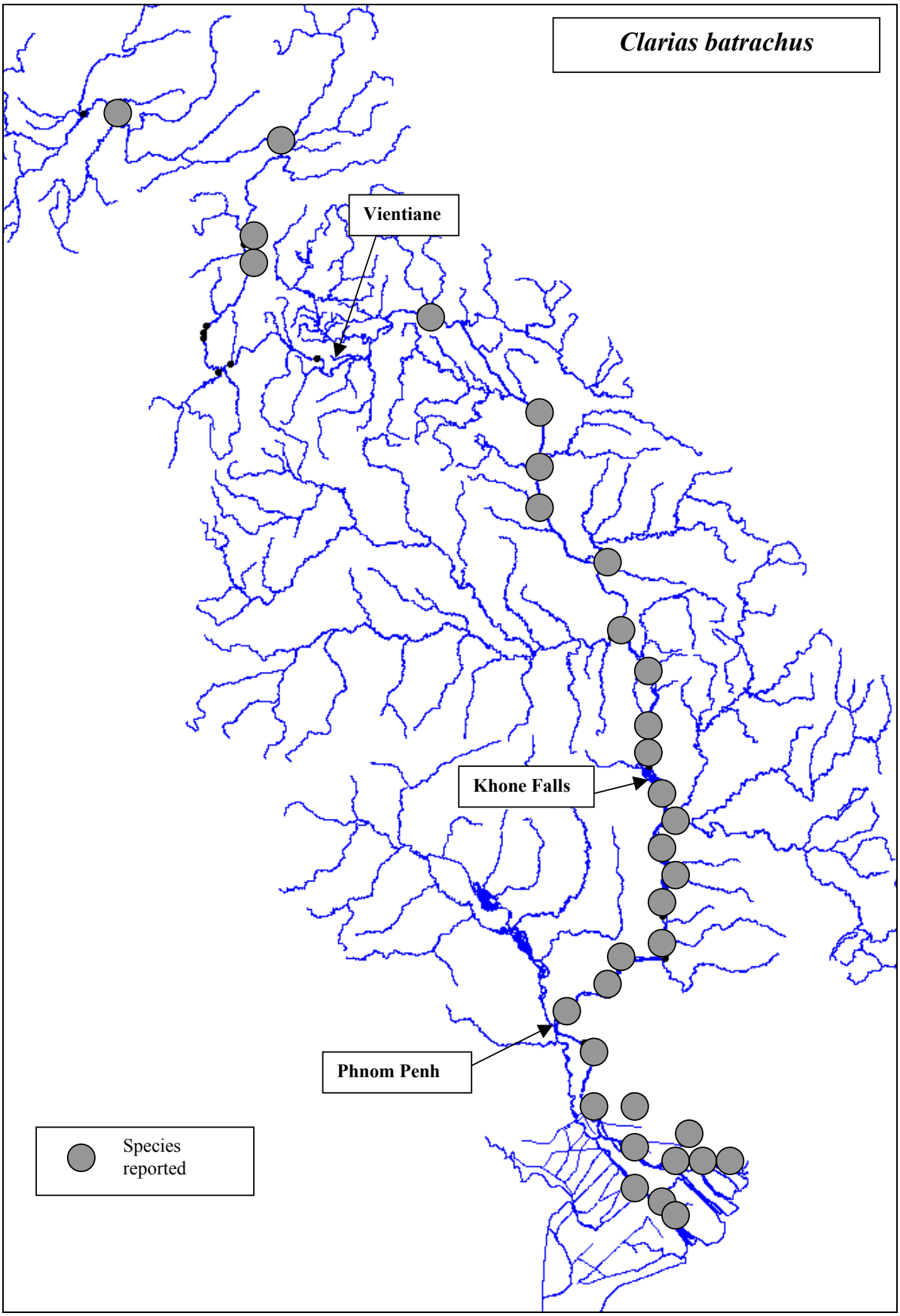
Clarias batrachus

Clarias batrachus occurs throughout the survey area, from Chiang Saen in the north to the Mekong delta. Fishermen throughout its distribution range agreed that the species mainly undertakes lateral migrations from the main river, or other permanent water bodies, to flooded areas during the flood season, and returns to the permanent water body at the beginning of the dry season.

Most fishermen, particularly in Cambodia, reported that the species is much more common in flood-plain lakes than in the main river. That view concurs with Rainboth (1996), who stated that *Clarias batrachus* is "found in standing water or sluggish flowing water habitats, from Sri Lanka to Indonesia and the Philippines. Usually found in flood plains and flooded forests". It is well adapted to withstand the harsh conditions of flood-plain habitats and is even able to move over dry land in search of new habitats.

According to a fisherman in Khammouan province, in the Lao PDR, the first heavy rains at the end of the dry season trigger *Clarias batrachus* to move into small streams. The fish spend the dry season living around rocks in the main river.

Eggs were reported as follows (number of reports in brackets): March (4 reports), April (9), May (10), June (9), July (3) and October (1). In addition, two fishermen in the Mekong delta reported seeing eggs throughout the year. One of the fishermen, from Tien Giang province, had observed *Clarias batrachus* spawning in paddy fields during April-May.


Clarias batrachus
Vientiane
Khone Falls
Phnom Penh
Species reported

7. Family: Pangasidae

(a) Heligophagus waandersi

In the Mekong mainstream, *Heligophagus waandersi* is distributed from the Mekong delta to Bokeo in northern Lao PDR. Apart from the Mekong River, the species also occurs in the Chao Phraya basin in Thailand and in rivers on the island of Sumatra, Indonesia (Roberts and Vidthayanon, 1991; Rainboth, 1996).

The Khone Falls appear, to a great extent, to act as a barrier for this species, i.e., migration patterns above and below the Khone Falls are significantly different.

Below the Khone Falls, *Heligophagus waandersi* migrates upstream from October to February. From May to July, the species migrates downstream, at least from Sambor to Muk Kompul in Kandal province of Cambodia. Interestingly, there were no reports on migratory behaviour from Sambor to the Khone Falls, although the species was reported to be common along that stretch. Similarly, there were no reports from the Mekong delta on migratory behaviour, although five stations reported that the species occurs in the delta area.

Above the Khone Falls, there appear to be two upstream movements, one during the late dry season from March to May (mainly along the stretch from Paksan to Loei) and one during the early rainy season, from May to August.

Fifteen reports were received on eggs having been observed in the abdomen of fish: nine reports in June, seven in May and five each in March, April and July. The reports provided an indication that the main spawning season is from May to June. There were no indications of differences in the timing of spawning, except for one report from Dong Thap province in Viet Nam noting that the species spawned locally throughout the year as "fry are observed all year round".

South of the Khone Falls, five stations reported juveniles of 2-4 cm size from Kompong Cham province, Cambodia, to Can Tho and Dong Thap provinces in Viet Nam.

Above the Khone Falls, 2-4 cm juveniles were reported in Nong Khai, Mukdahan and Ubon Ratchatani provinces of Thailand. There were no reports from either the Thai or Lao side on juveniles upstream of Nong Khai province

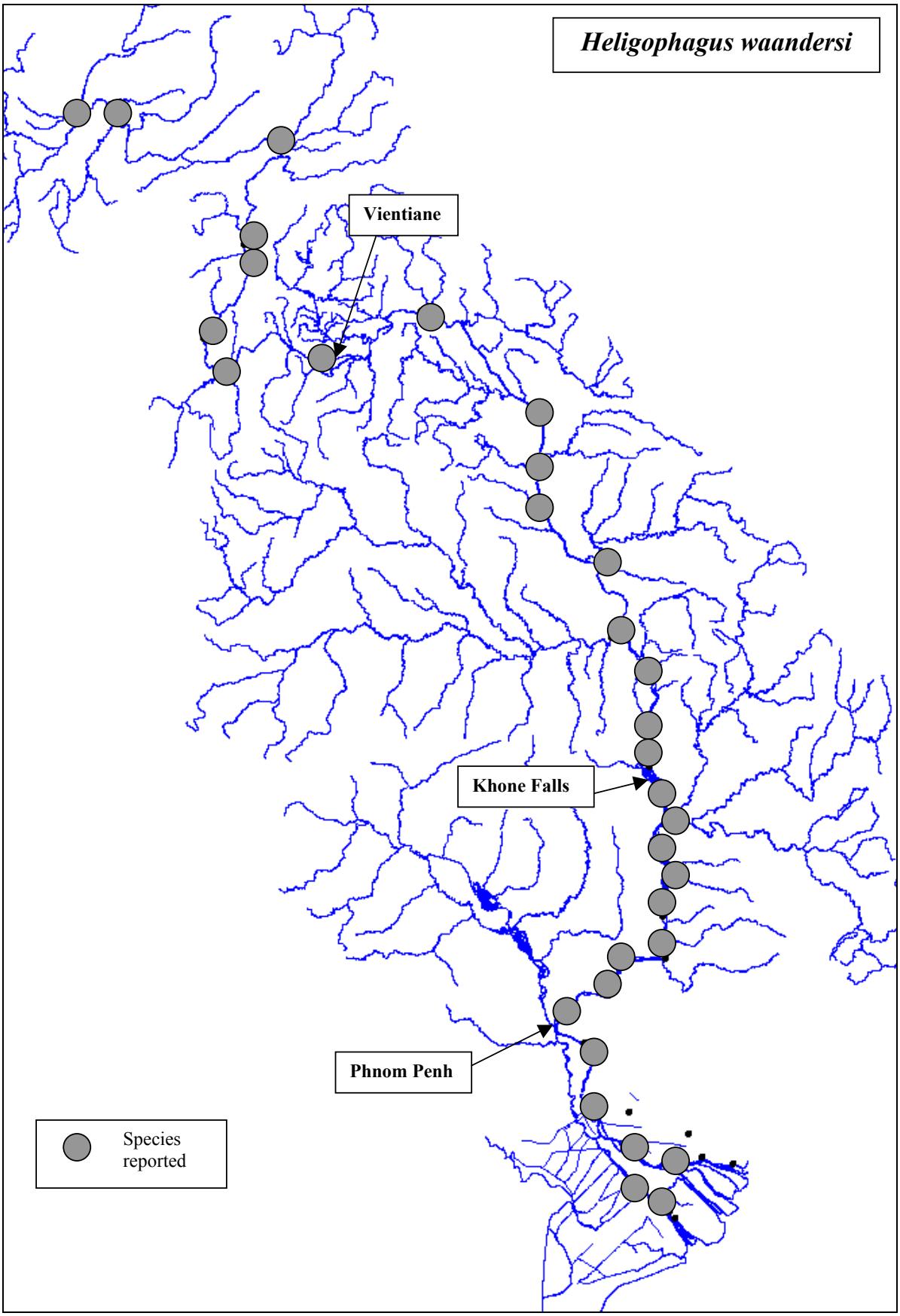
Hypothesis:
There are several populations of *Heligophagus waandersi* in the Mekong River, especially above the Khone Falls.

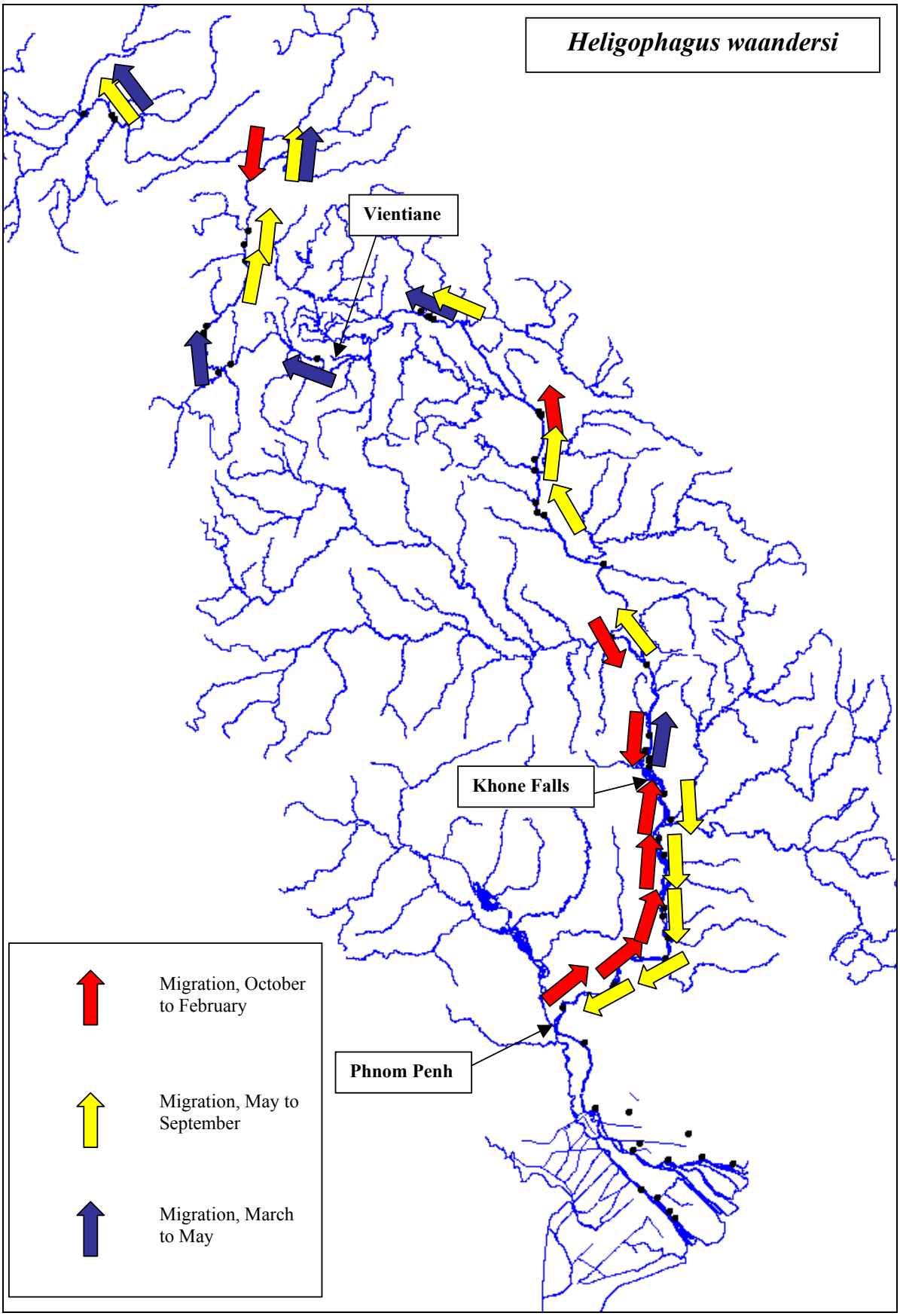
The Khone Falls forms a barrier to the movement of this species and the migration patterns below and above that point are significantly different.

Above the Khone Falls, several populations exist, each undertaking a relatively short upstream migration during the late dry season and/or early flood season. Those movements appear to be spawning migrations, although they may also involve trophic

migrations of sub-adults. Some of the migrating populations migrate into major tributaries (e.g., the Nam Ngum and Songkhram rivers, as confirmed during the trial survey of the tributaries).

Below the Khone Falls, *Heligophagus waandersi* migrates upstream from the onset of the dry season until the late dry season, and downstream during the onset of the flood season. There may also be several sub-populations along that stretch, e.g., a relatively sedentary population may exist in the Mekong delta


Heligophagus waandersi
Vientiane
Khone Falls
Phnom Penh
Species reported


Heligophagus waandersi
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(b) Pangasianodon gigas

Stations in all four countries recorded the famous giant catfish. However, its occurrence was not reported by several stations, and only fishermen at the northern stations of Bokeo and Chiang Rai provinces (the Lao PDR and Thailand, respectively) provided records on the migration of this species.

In Cambodia, it was only recorded from Kratie to Stung Treng, and local fishermen emphasised that it was very rare.

Pangasianodon gigas is occasionally caught by the *dai* fisheries in the Tonle Sap River during their migration out of the Tonle Sap into the Mekong during the period of receding water.[9] However, it has not been recorded by the Khone Falls fisheries in recent years (Baird, 1998; Singanouvong *et al,*, 1996b).

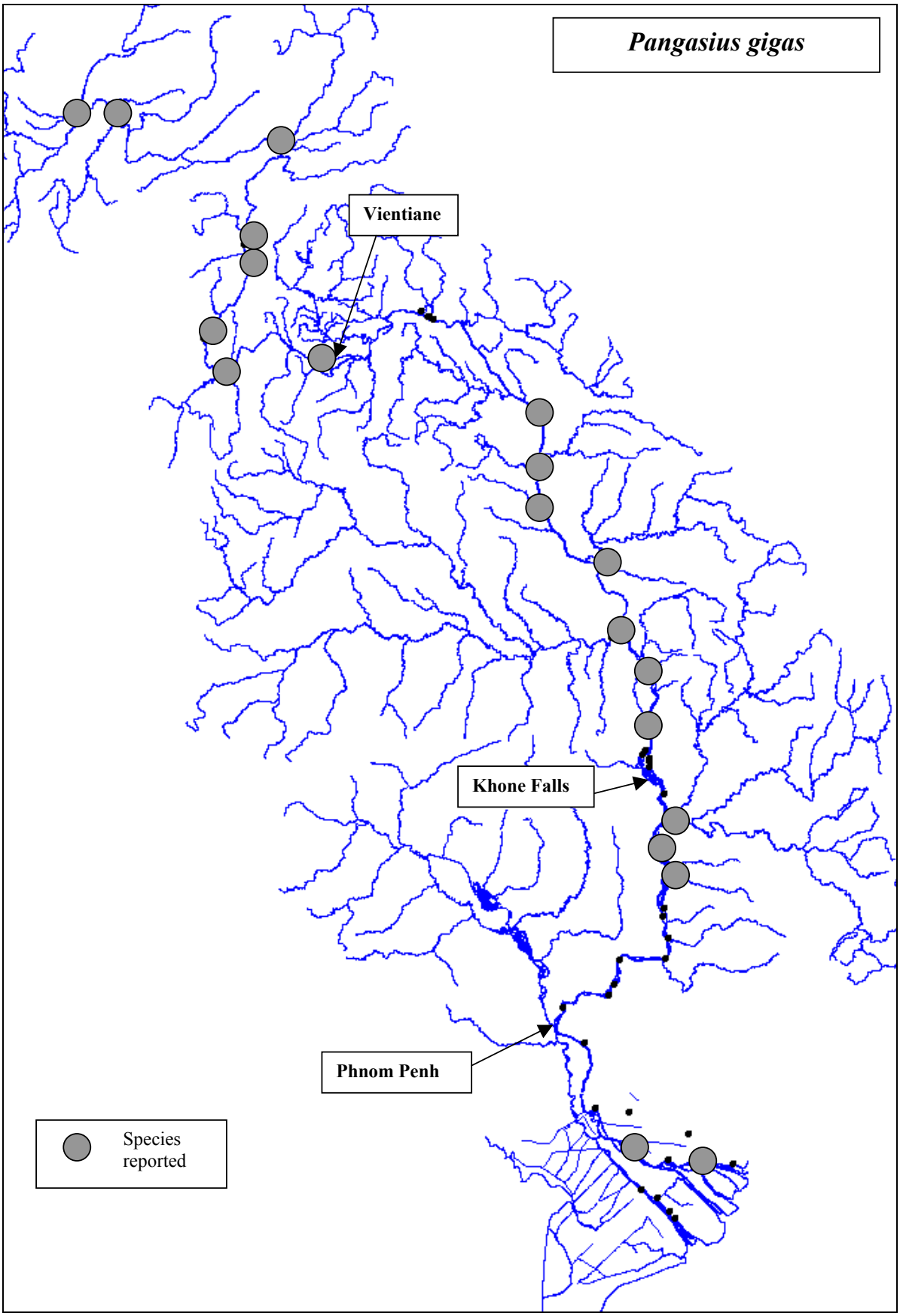
In northern stations, on the border between the Lao PDR and Thailand, *Pangasianodon gigas* migrate upstream during April-May. That is also the time when fishermen from that area traditionally catch giant catfish. Fishermen from Bokeo stated that they caught the fish at a certain site with strong current near a beach. The migration is triggered by the first rain and the resultant increase in turbidity (e.g., mentioned independently by all three interviewed fishers from Bokeo Province).

Some fishermen from Xayaboury Province in Lao PDR reported that giant catfish spend the dry season in certain deep pools in the Mekong mainstream in that province.

Although *Pangasianodon gigas* appears to have previously been relatively common in other parts of the Mekong River along the Lao-Thai border (e.g., in the area of Nong Khai), the giant catfish is now extremely rare along that stretch.

Hypothesis:
There are two remaining populations of *Pangasianodon gigas*, one below the Khone Falls (i.e., in Cambodia and Viet Nam), and one in the northern stretch of the river.

[9] Nao Thouk, personal communication.


Pangasius gigas
Vientiane
Khone Falls
Phnom Penh
Species reported

(c) Pangasianodon hypophthalmus

According to the present survey, the distribution range for *Pangasianodon hypophthalmus* is from the Mekong delta all the way up the Mekong to Chiang Khong and Bokeo in the north. However, it was not recognised at Chiang Saen, near the border between Thailand, the Lao PDR and Myanmar.

Four stations in the middle Mekong, from Mukdahan in the south to That Phanom in the north, did not report observing this species. Information from Khammouan and Boulikhamxay provinces in the Lao PDR was also very limited. However, from Sungkom district (Nong Khai province of Thailand) to Chiang Khong, upstream migration was reported from May to July. Two of those stations (Loei and Xayabouri) reported eggs and milt during the migration. At Loei, the fish were reported to "swim upstream near the surface, early in the morning".

In general, this species appears to be very rare above the Khone Falls. Furthermore, in that stretch of the river, mainly large-sized individuals were seen (e.g., 90 cm and above). Juveniles were not observed in that stretch, except at one place (Loei) where sizes of 15 to 30 cm were reported.

South of the Khone Falls, a pronounced upstream migration was reported from October to February (peaking in November-December). All stations from Kandal to Stung Treng (where it extends into April) consistently reported this migration. It is apparently triggered by receding water levels and appears to be a dispersal migration, following the lateral migration from flooded areas back into the Mekong River at the end of the flood season. Two stations (Kratie and Kompong Cham) reported that the migration occurs during the full moon.

From May to August, a migration takes place in the opposite direction, downstream from Stung Treng to Kandal and into the Mekong delta, at least as far as Cai Be. This movement was reported by 13 stations, including a flood-plain station in Tien Giang province of Viet Nam.

Eggs were reported from Stung Treng to Kandal between March and August, with a strong peak during June-July. Thus, the downstream migration is both a spawning migration and a trophic migration that eventually brings the fish into flood-plain areas in Cambodia and Viet Nam during the flood season.

In An Giang and Dong Thap provinces of Viet Nam, larvae of *Pangasianodon hypophthalmus* are caught every year in June-July during their downstream drift from spawning site(s) somewhere upstream in Cambodia. They are caught in specialised larvae *dai* nets just south of the Cambodian-Vietnamese border, and are used as stocking material in the cage culture industry in Viet Nam. According to one "larvae" fisherman from the Chao Doc area, at least four species of pangasiids were caught in the larval stages at Chao Doc during June-July until 1998, when the activity was banned at that site. The most important species were *Pangasianodon hypophthalmus* and, to a lesser extent, *Pangasius bocourti* (see below). The two other species were not identified. During the two-month period of operation, several (usually three) peaks of *Pangasianodon* larvae occur.

The occurrence of larvae (or young-of-the-year) was also reported during the present survey. At three stations in Kompong Cham province and one station in Kandal province in Cambodia, as well as two stations in Viet Nam, fish larvae of a size of 2 cm were reported from May to July.

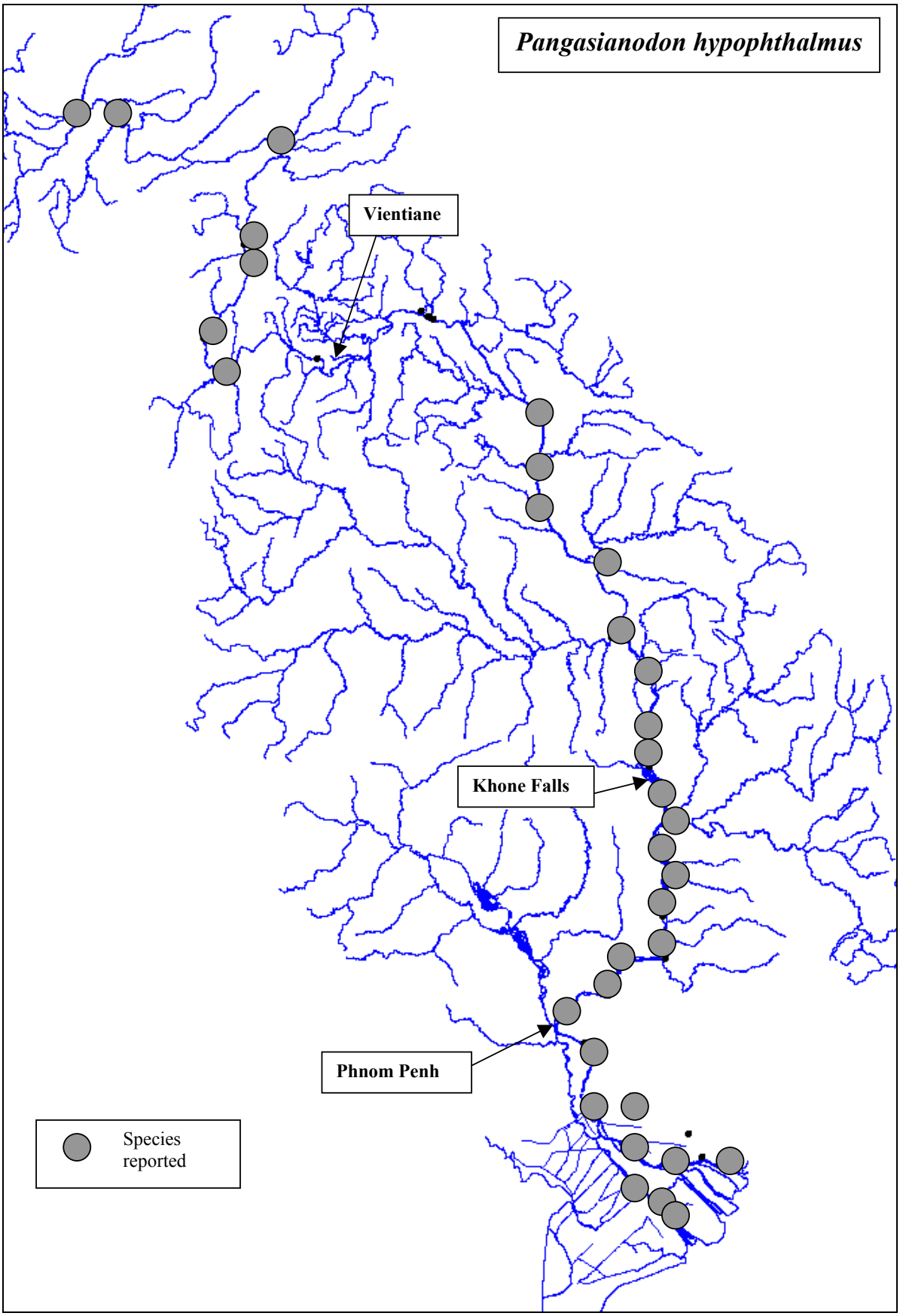
In general, the fish from the Mekong delta are below 50 cm, with the majority being below 30 cm.

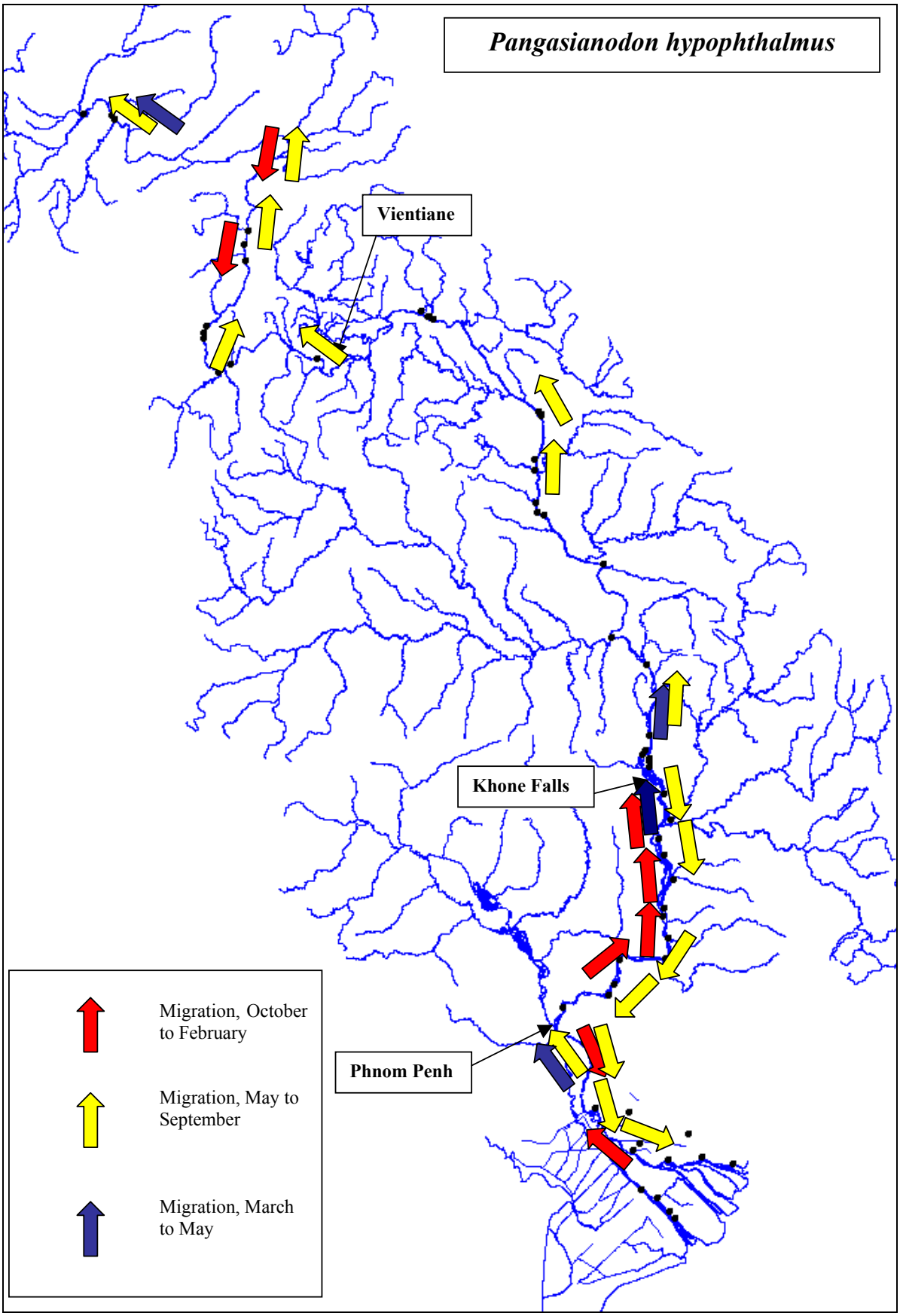
Pangasianodon hypophthalmus is one of five pangasiid species considered important in the Khone Falls *lee* trap fishery industry from May to July each year (Baird, 1998). The wing trap is designed to catch fishes when they migrate over the waterfalls. However, in 1994, the species was not found in *lee* catches.

The same study described a gill-net fishery operation at Ban Hang Khone, just south of the Khone Falls during the same period, which targeted *Pangasius krempfi* (see below). This fishery recorded 28 species over a four-year period (1993-1997). However, *Pangasianodon hypophthalmus* was not among them (Baird, 1998).

Hypothesis:
Pangasianodon hypophthalmus spawns in deep pools in the Mekong mainstream somewhere between Kratie and the Khone Falls at the beginning of the flood season. When the eggs hatch, the larvae drift downstream until they are swept out into flood-plain areas in southern Cambodia and Viet Nam. At that time, the current in the Tonle Sap River reverses, resulting in a proportion of the larvae drifting up the Tonle Sap and out into flooded areas along the Tonle Sap River and the Great Lake. When the water level begins to recede at the end of the monsoon season, the fish return to the Mekong mainstream and begin a dispersal migration upstream through Cambodia to near the Khone Falls.
Therefore, from the Khone Falls and downstream, *Pangasianodon hypophthalmus* consists of one singlepopulation .

Another distinct population spawns at an, as yet, unidentified spawning ground(s) further upstream, at least as far as Xayabouri. There may be some degree of overlap between the two populations, although the lack of reports from the stretch in the middle Mekong from Mukdahan to Nakhon Phanom suggests that any such overlap is limited.


Pangasianodon hypophthalmus
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasianodon hypophthalmus
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(d) Pangasius bocourti

According to Rainboth (1996), this species bears a strong resemblance to *Pangasius djambal* (see below), a fact that was also observed by some of the fishermen contributing to the present survey. A fisherman from Chiang Khong, Thailand, stated that the two species are the same, whereas a fisherman from Nakhon Phanom, Thailand, mentioned that the two species are very similar in appearance and behaviour.

However, some problems still exist with the taxonomy of this species,[10] particularly in the case of the upper stretch of the survey area along the Lao-Thai border. Rainboth suggested that the species currently believed to be *Pangasius bocourti* along that stretch could in fact be another, so far undescribed, species. As with many other Mekong fish, there is an urgent need to clarify the taxonomy of this species in the Mekong context (i.e., many type specimens on which identifications are made, originate from relatively few sites within the Mekong). This problem should be kept in mind when analysing the data for this species.

According to the present survey, *Pangasius bocourti* occurs throughout the survey range, from Chiang Saen in the north to the Mekong delta.

Again, the area around the Khone Falls appears to be a borderline between two different migration patterns. Below the Khone Falls, an upstream migration begins in November when the water level within the river decreases and continues well into the dry season, at least until February. This migration was reported by all stations, from the Cambodia-Viet Nam border to just south of the Khone Falls. In the late dry season, or the beginning of the monsoon season, a downstream migration occurs along the same stretch, from the Khone Falls to the Mekong delta.

From just below the Khone Falls, an upstream migration begins at the onset of the flood season. This migration was reported by eight stations, from just below the Khone Falls all the way to Chiang Saen in the north. From Boulikhamxay province and upstream, the migration occurs a little earlier, from April to June; however, nearer the Khone Falls, in Mukdahan and Ubon Ratchatani provinces, it occurs in July-August. The migration appears to be triggered by a combination of rising water levels, strong rain and increased turbidity.

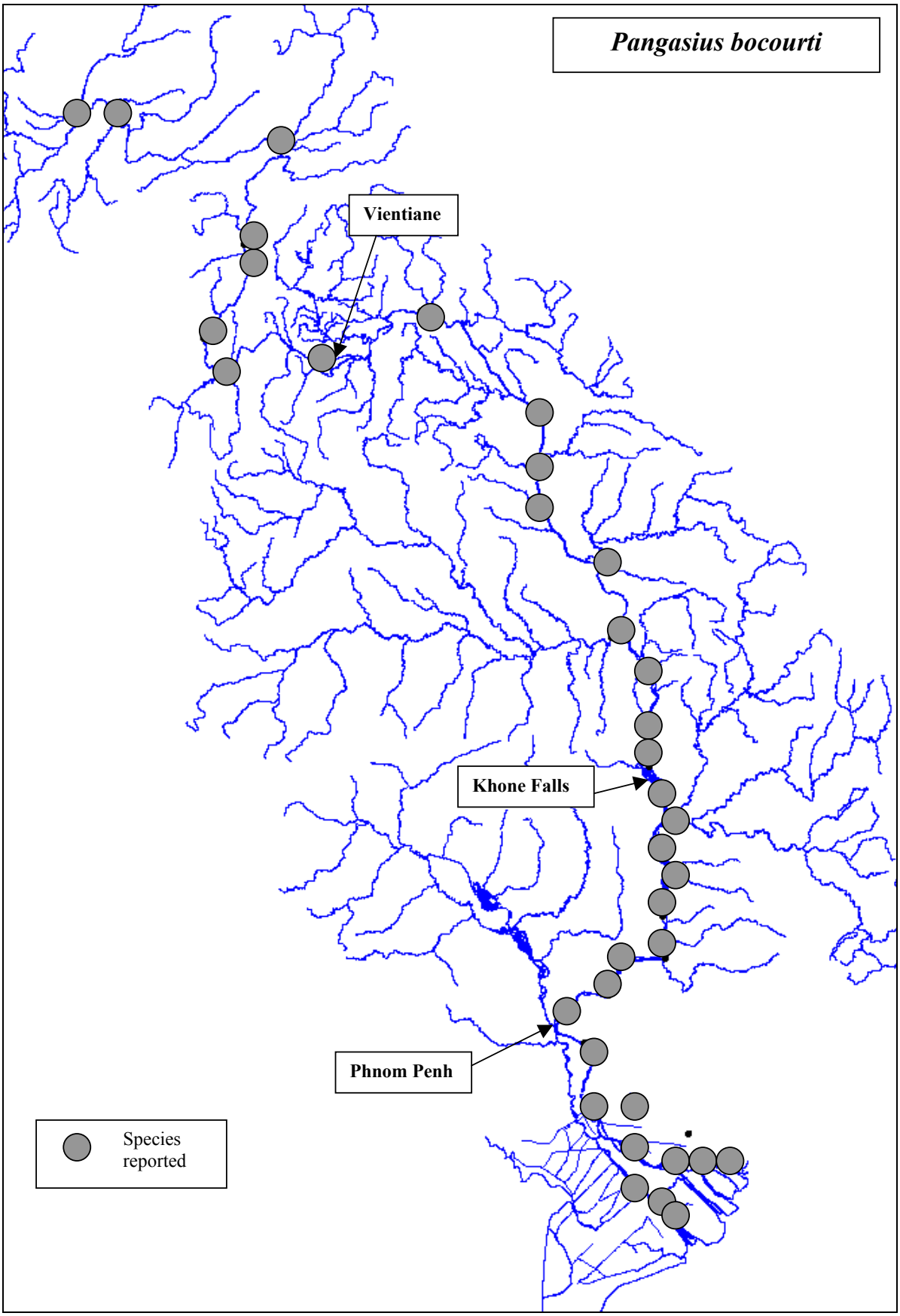
Observations on mature eggs were scattered evenly over a long period, from March to August. This pattern may indicate different populations, separated genetically by the timing of their reproductive behaviour. Considering the taxonomic confusion that still exists over *Pangasius bocourti*, it could also reflect the fact that two different species are involved.

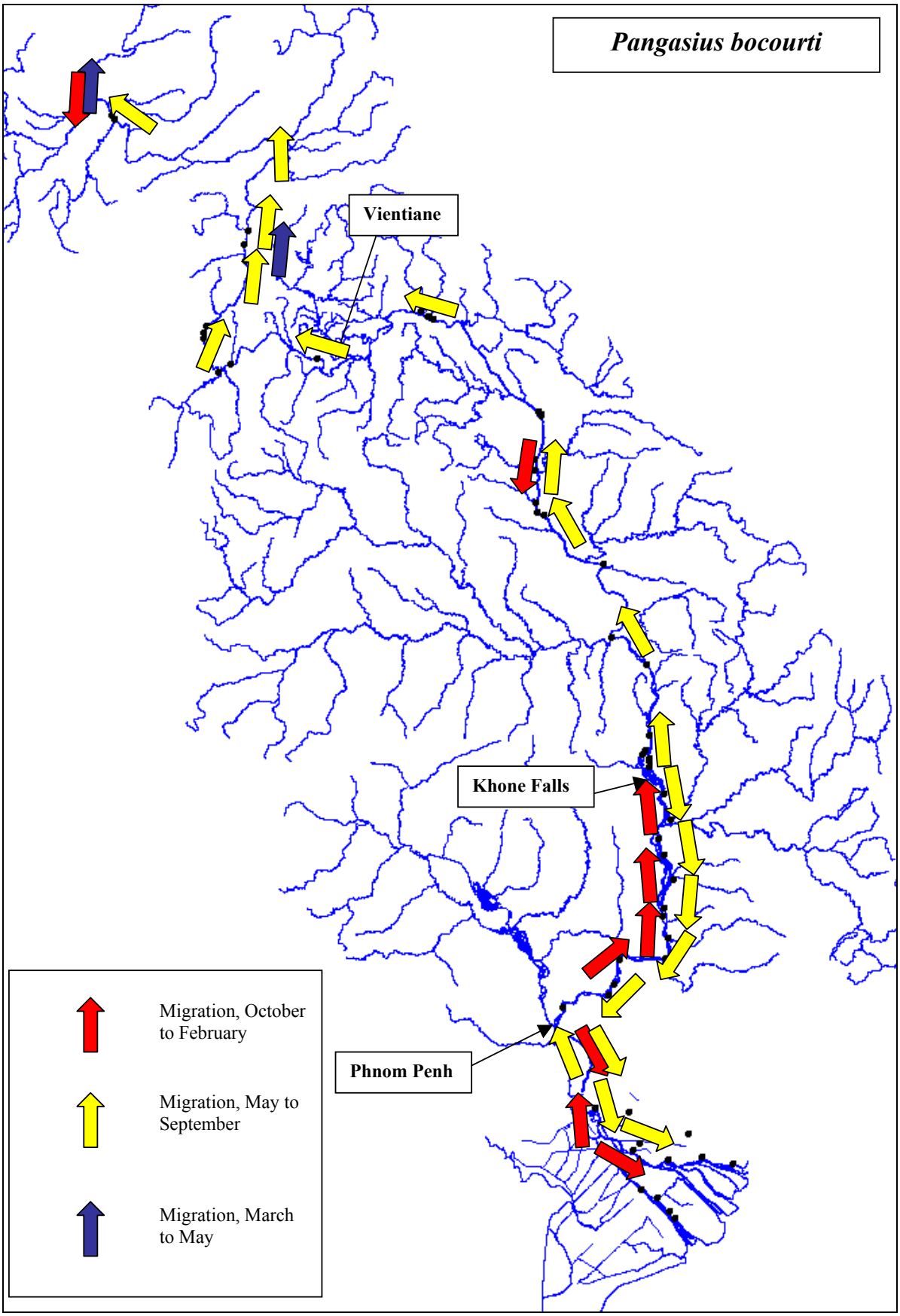
Previous studies at the Khone Falls identified *Pangasius bocourti* as one of the migratory pangasiid catfishes that migrate over the Khone Falls (Baird, 1998; Singanouvong *et al*., 1996b).

[10] Rainboth, personal communication.

Hypothesis:
There are two different populations of *Pangasius bocourti* in the Mekong River. One occurs from the Mekong delta to the Mukdahan-Savannakhet area upstream from the Khone Falls. This population may consist of two sub-populations with some degree of genetic overlap.

Another population occurs from the area around Boulikhamxay-Nong Khai provinces to the area around Chiang Rai-Bokeo provinces in the north. This population may constitute a separate species.


Pangasius bocourti
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius bocourti
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(e) Pangasius conchophilus

According to the present survey, the distribution range for *Pangasius conchophilus* is from the Mekong delta along the Mekong River to Chiang Saen, near the border between Thailand, the Lao PDR and Myanmar.

Between March and August, *Pangasius conchophilus* migrates upstream from Khong Island, just upstream of the Khone Falls, to the northernmost station at Chiang Saen. All surveyed stations along that stretch reported this movement, which appears to constitute two separate migrations: (a) a non-spawning (trophic?) migration from March to May, comprising sub-adults within the size range of 10 to 40 cm; and (b) a spawning migration from May to August, comprising fish of sizes 40 to 90 cm.

Along that stretch, eggs were reported from May to August, with a strong peak in June-July. Juveniles of 4 cm were reported at two Thai stations, one at Klong Kaem district, Ubon Ratchatani province, and one at That Phanom district, Nakhon Phanom province.

From the Khone Falls to Kandal, near Phnom Penh, eggs were observed between March and August (12 reports), with a peak during May-June (9 reports). At that time, the fish are migrating downstream (reported by all 13 Cambodian stations). Juveniles (young-of-the-year) were also reported at several places along this stretch. For example, at Kratie and Kandal, fish of 2 cm were observed during June-August and July-August, respectively. At both places, they appear in peaks of 3-5 days, which corresponds with a spawning time around May to June and would indicate that spawning occurs somewhere upstream between Kratie and the Khone Falls, or in the Sesan tributary system.

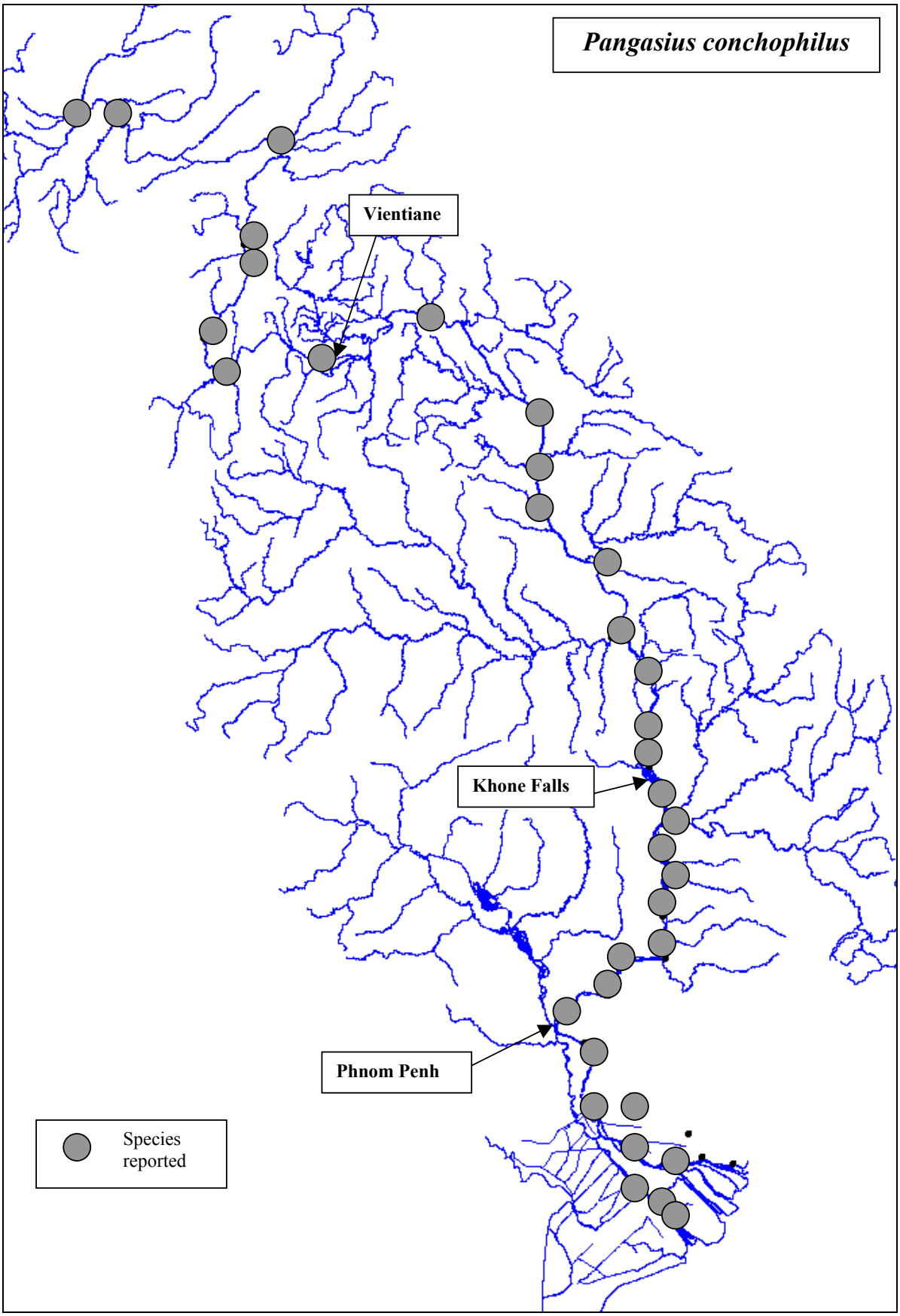
In the Mekong delta, mainly juveniles were reported. Almost all stations reported fish smaller than 30 cm. Only one station (Hong Ngu, Dong Thap province) reported fish of up to 90 cm and weighing up to 35 kg, which may indicate misidentification. Since *Pangasius conchophilus* is not believed to reach such sizes, further verification is needed. Also in the Mekong delta, 2 cm juveniles appear in June (e.g., Thot Not, Can Tho province; Hong Ngu, Dong Thap province). At the end of the year they have grown to about 20 cm.

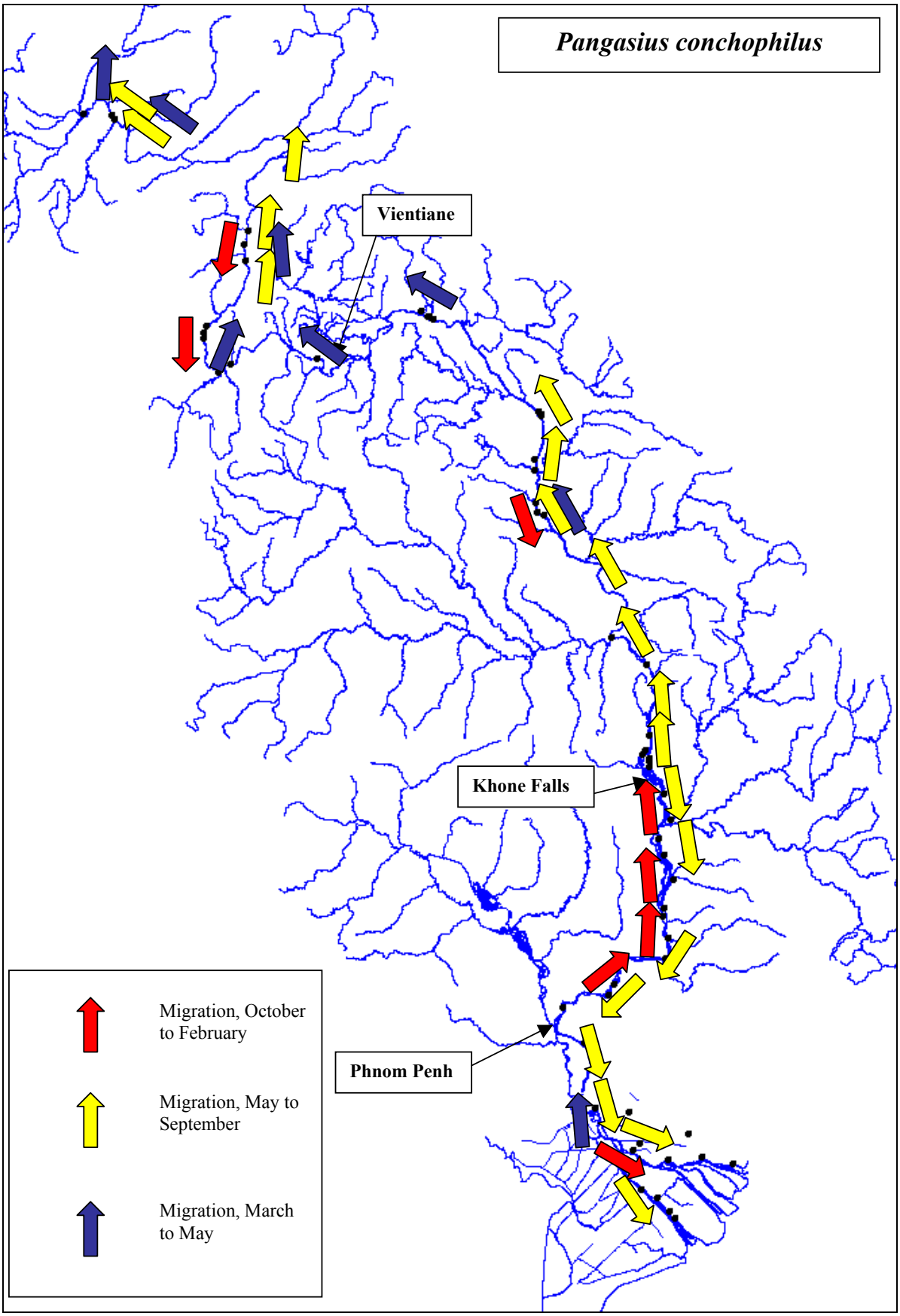
Hypothesis:
Pangasius conchophilus spawns in the Mekong mainstream somewhere between Kompong Cham and the Khone Falls at the beginning of the flood season. When the eggs hatch, the larvae drift downstream until they are swept out into flood-plain areas in southern Cambodia and Viet Nam. At that time, the current in the Tonle Sap River reverses, resulting in a proportion of the larvae drifting up the Tonle Sap and out into flooded areas along the Tonle Sap River and the Great Lake.

Pangasius conchophilus consists of one downstream population, from the Khone Falls on the Lao/Cambodian border, and one or more distinct population(s) in the Mekong mainstream above the Khone Falls. They spawn during the same period (i. e., at the onset of the flood season, from May to July, at as yet unidentified spawning grounds, at least as far as Chiang Saen near the border between the Lao PDR,

Thailand and Myanmar. If more than one population exists, they may overlap to some extent.

When the water level begins to recede at the end of the monsoon season, the young-of-the-year return to the main river and begin a dispersal migration. For the population bwlow the Khone Falls, this dispersal migration is an upstream migration, from Viet Nam through Cambodia to near the Khone Falls, wheras above the Falls, it is a downstream migration.


Pangasius conchophilus
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius conchophilus
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(f) Pangasius djambal

Pangasius djambal is very difficult to separate from *Pangasius bocourti* without a close examination of the gill rakers (Rainboth, 1996).[11] Therefore, some reports provided in the present survey may be based on misidentification of *Pangasius bocourti* (see above).

The northern distribution boundary for *Pangasius djambal* is Chiang Khong in Thailand. The species was not identified at Nong Khai and the three upper stations at Paksan in the Lao PDR. At the downstream stations in Paksan and Thakhek it was present, but only in small numbers. Except for one of the stations at Mukdahan, the species was reported to be present from Nakhon Phanom all the way to Muk Kompul, in Kandal province of Cambodia. It was also identified by one of the canal stations in Viet Nam. Although the presence of the species in the Lao PDR and Thailand is limited to a few months, it is present throughout the year at most stations in Cambodia.

According to the results of the present survey, the maximum size and weight of the species is around 90 cm and 16 kg, which is larger than the maximum size of 50 cm and 60 cm given by Roberts and Vidthayanon (1991) and Rainboth (1996), respectively.

In the Lao PDR and Thailand, *Pangasius djambal* starts its upstream migration in May, when the water level rises, and it continues until August. One fisherman from Mukdahan mentioned that the species migrates upstream several times every year, and that the duration of each migration period is one or two days.

Downstream migration in October-November was reported by stations in Loei and Savannakhet. In Cambodia, *Pangasius djambal* migrates downstream over an eight-month period; however, the main migration period is during June-July. Upstream migration mainly takes place from December to February.

Spawning activity in this species was not observed. There were also no indications of the location of the spawning habitat. One fisherman in Thailand reported that the species attainssexual maturity when it reaches a weight of about 1 kg. Eggs were observed in the abdomen of the fish from March to August, but most fishermen reported that eggs are present from April to July.

Small juveniles (2-4 cm) were observed at Nakhon Phanom and Savannakhet, and from Kratie to Kompong Cham, between May and November.

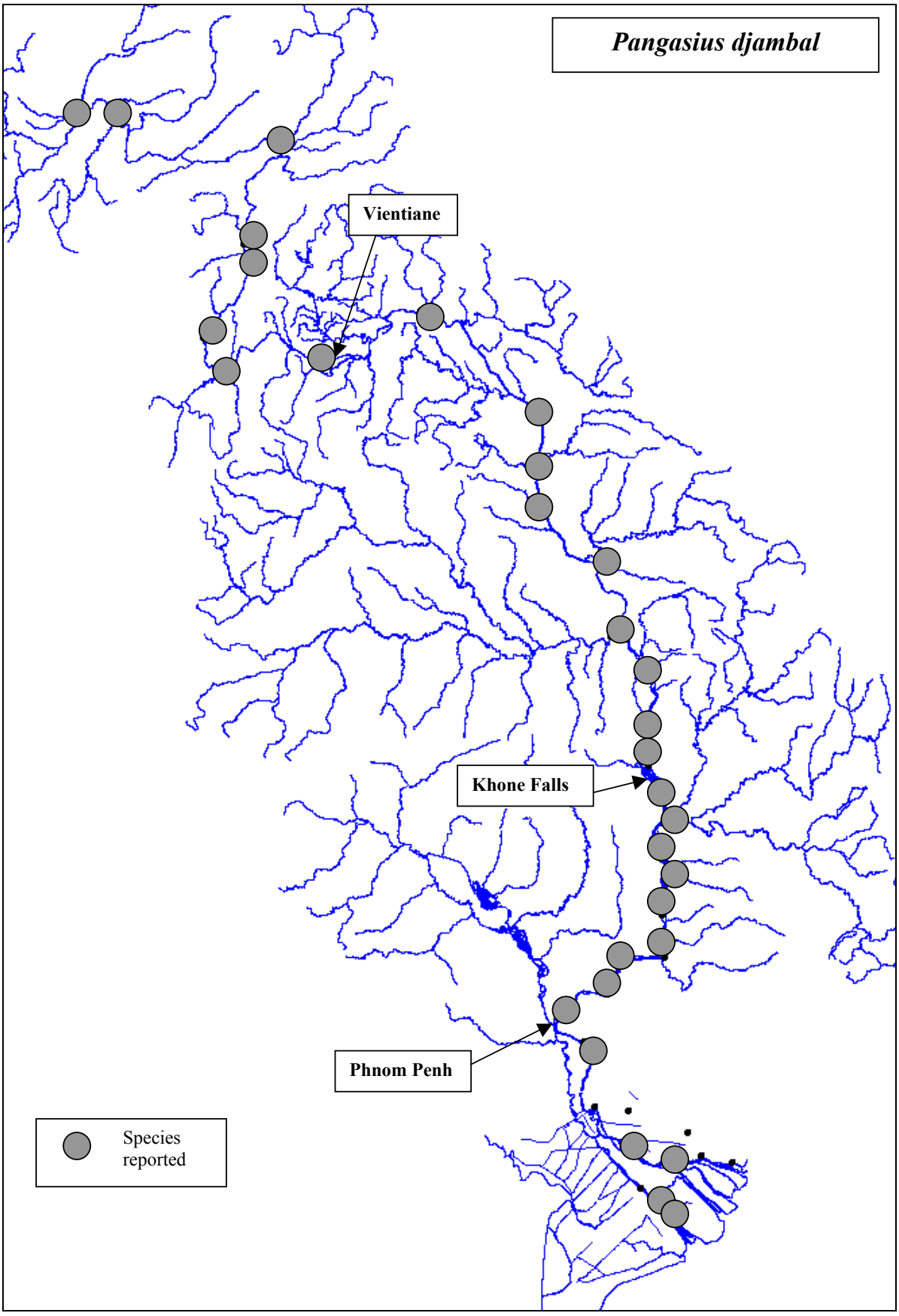
Hypothesis:
There appears to be one population of *Pangasius djambal*, distributed within the area between Loei and Chiang Khong. That population most probably spawns in the Ing River.

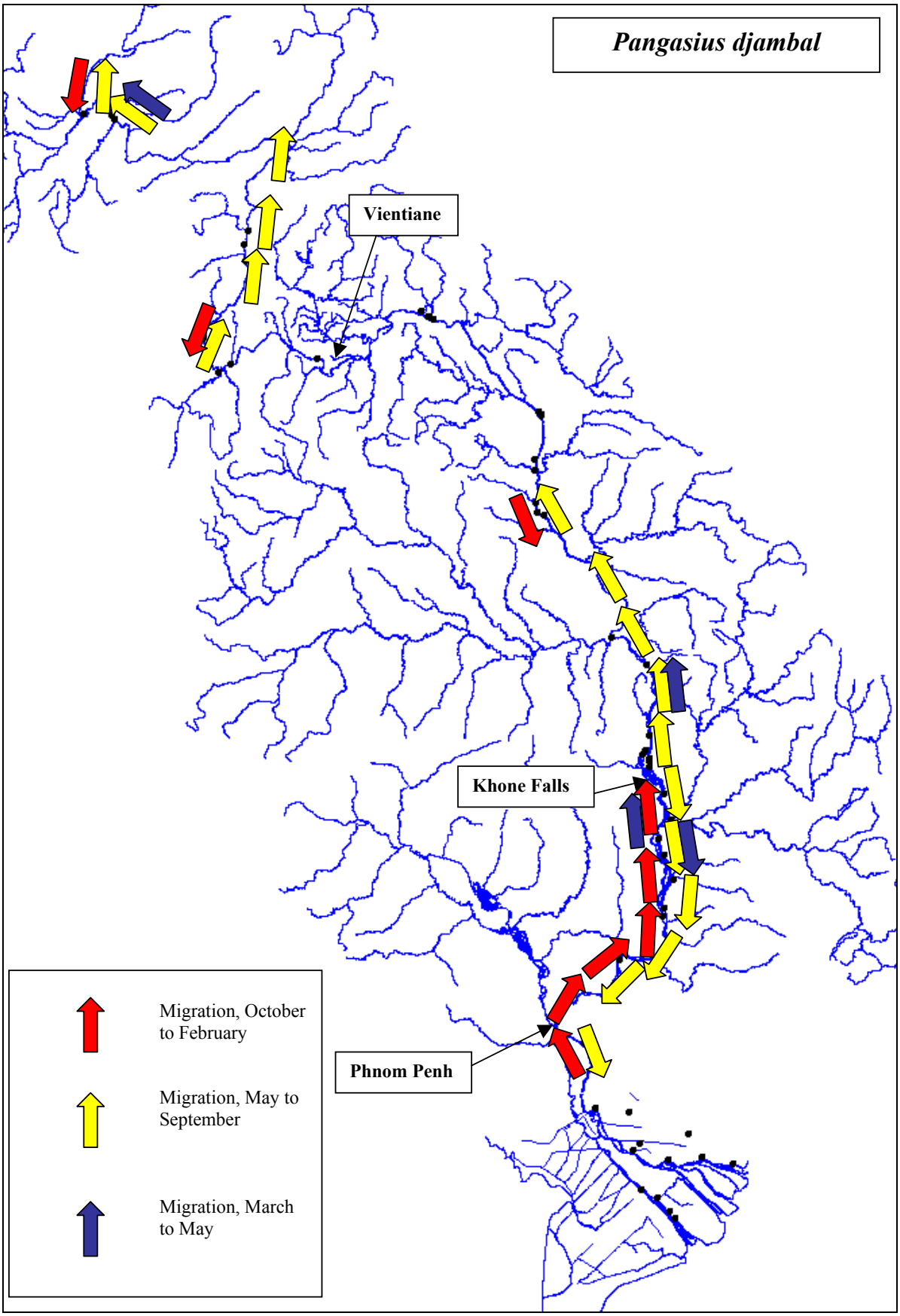
It is not possible to conclude whether *Pangasius djambal* in the remainder of the Lao PDR, Thailand and Cambodia belong to the same population. Those fish most

[11] Also Vidthayanon, personal communication.

probably spawn in the Songkhram and Mun rivers as well as in some tributaries in the Lao PDR. If they comprise a distinct sub-population, there may be a substantial overlap with the sub-population further upstream.

There may be a distinct population south of the Khone Falls that spawns in the Se San tributary system. Adults and juveniles (including larvae) migrate downstream to areas with more extensive floodplains below Kratie.


Pangasius djambal
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius djambal
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(g) Pangasius krempfi

According to the present survey, the distribution range for *Pangasius krempfi* is from the Mekong delta and along the Mekong to Chiang Saen, near the border between Thailand, the Lao PDR and Myanmar.

Upstream of the Khone Falls, *Pangasius krempfi* is mainly seen during its upstream migration from May to September (12 out of 15 stations reported that migration; the remaining three stations did not report on this species). The migration is dominated by fish in spawning condition. Seven stations above the Khone Falls reported eggs occurring during the migration in June-September, with a peak in July. One station (Sungkom district, Nong Khai in Thailand) reported that fish releasing eggs were caught during July-August near Pa Sak Neua village. At the same village, the species was also reported during October-November. At that time, the fish do not have eggs.

The upstream migrations occur several times, in peaks of 3-5 days, during the migration period.

Only two reports of downstream movement were received from above the Khone Falls, both during October. According to the fishermen, downstream movements are much less conspicuous because, unlike upstream migrations, they are not undertaken in big schools within short peak periods.

Below the Khone Falls, eggs were observed (six reports) in the abdomen of *Pangasius krempfi* during May-August, with a peak in June-July. However, the migration pattern during that period is less clear. At Thalabovirrat, near the Khone Falls, the fish migrate upstream in May-June, in line with the reported migration further upstream.

From Stung Treng to Kompong Cham provinces in Cambodia, the fish migrate downstream during the same period, although less conspicuously (several stations did not report downstream migrations). At Sambor, one fisherman reported catching fish that were releasing eggs in June-July.

In Kandal province, near Phnom Penh, *Pangasius krempfi* was reported to migrate upstream from Viet Nam, from March to May. This migration occurs in peaks of up to five days and involves sizes between 40 to 90 cm. There were no reports on spawning condition.

Almost all the stations above the Khone Falls reported that most fish are within the range of 40 to 90 cm, with the majority measuring above 70 cm. At Chiang Khong in the north, fish weighing 7-10 kg were reported during the monsoon season migration. Most of the stations reported that they had never seen juveniles of this species. However, one station (Mukdahan, Thailand) reported seeing juveniles as small as 4 cm during May-June. Juveniles of such a size would appear to be at least two months old, which would thus imply a spawning time during March-April. As this information does not concur with the other reports on spawning for this species, it could be a case of misidentification and should be verified.

South of the Khone Falls, in Cambodia and Viet Nam, several reports on juveniles were received. Thalabovirrat, near the Khone Falls, reported fish of 6 cm, while Sambor reported sizes of 10 cm. In Sray Son Thor district of Kompong Cham province (Cambodia), 2-cm juveniles were reported from August to October.

In Viet Nam, most reports were of fishes of 10 to 70 cm. In Vinh Huu sub-district, Tien Giang province (near the saline intrusion zone), juveniles sized between 6 and 50 cm were reported in February, with sizes increasing as the dry season progresses (e.g., in April, the size range was reported to be between 20 and 50 cm). Only one station in Viet Nam (Cao Lanh, Dong Thap province) reported that the species undertakes migrations (upstream from November to February, and downstream from April to July, with both movements mainly involving large fish of 70 to 90 cm). There were no reports from the Mekong delta on spawning or the occurrence of eggs.

The results of previous studies at the Khone Falls support the findings that *Pangasius krempfi* spawn during the early flood season from May to July (Roberts and Baird, 1995). At Ban Hang Khone, from May to July, *Pangasius krempfi* is one of the most important species in the monsoon season for the wing trap fishery (Baird, 1998). All the fish migrating during that period were in reproductive condition, with the smallest weighing about 1.2 kg. The Ban Hang Khone study concluded that only reproductive individuals were thought to make the annual migration. The present survey supports that finding.

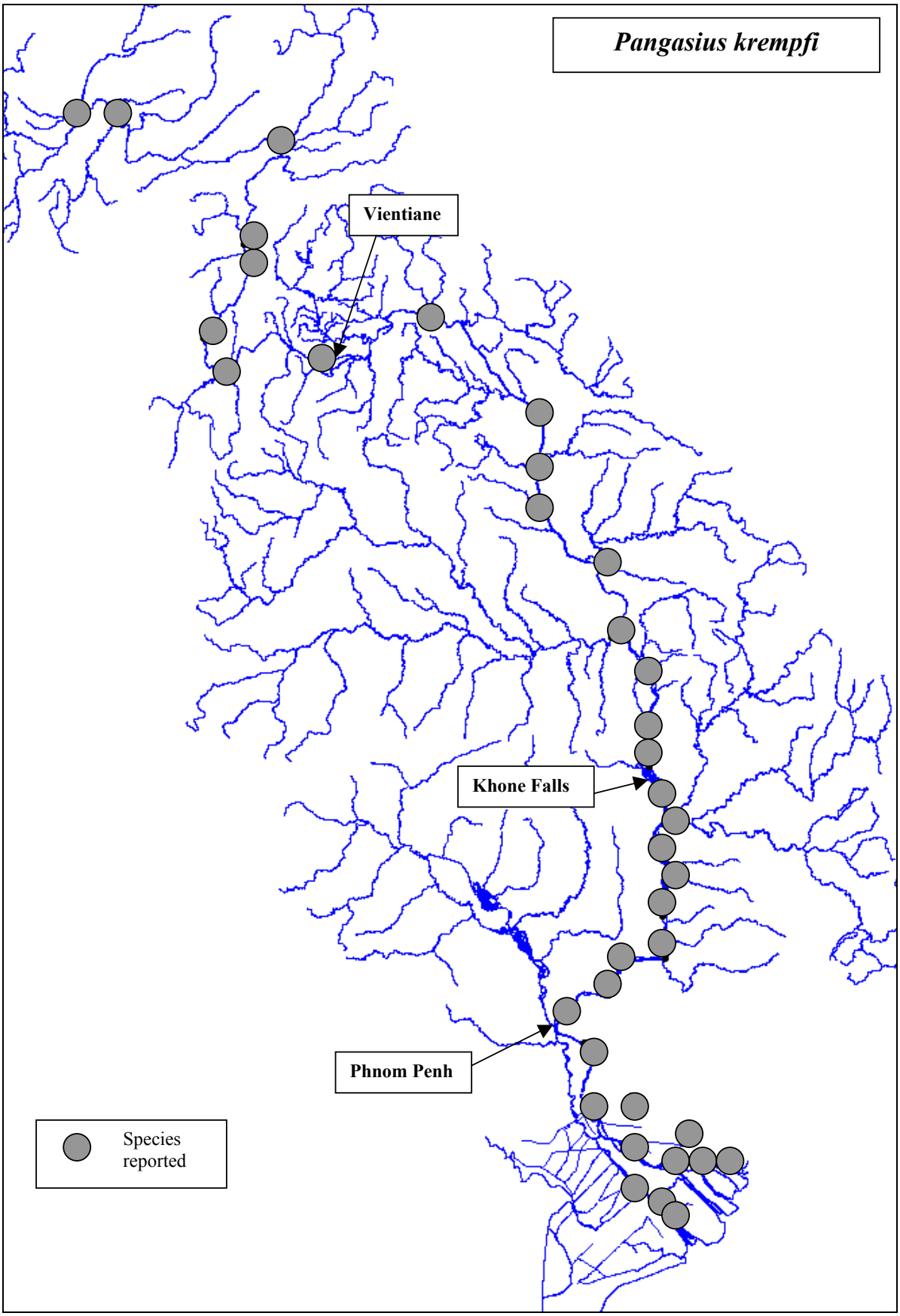
According to the Ban Hang Khone study, local fishermen believed that the migrations were triggered by rising water levels in the Mekong River (Baird, 1998). That view is supported by the findings of the present survey for below the Khone Falls, as well as above, in the Lao PDR and Thailand.

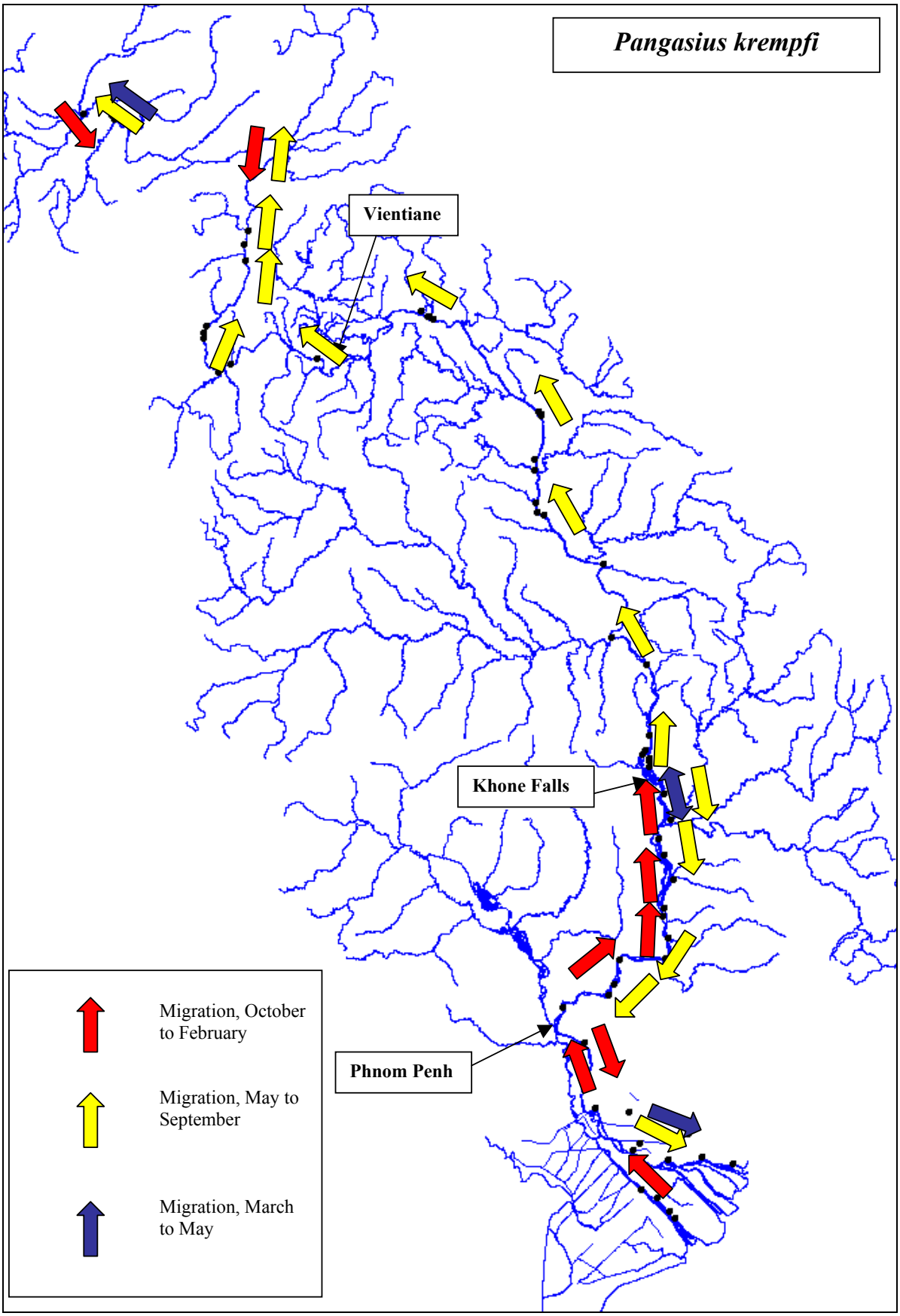
Pangasius krempfi is believed to spend part of its life in the sea (Roberts, 1993; Roberts and Baird, 1995). In fact, Roberts and Baird (1995) stated that *Pangasius krempfi* was an "anadromous fish with a life story resembling that of salmon". The present survey is obviously not able to verify this (i.e., marine fishermen were not interviewed). The occurrence throughout the year in the delta region, as well as several reports that juveniles were observed in the same area, indicate that at least part of the population remains within fresh water and brackish-water for most, if not all, of their lifecycle.

Some doubt remains about the status of the taxonomy of the species. Rainboth (1996) indicated that there might be two different species involved, one in the middle Mekong (based on specimens caught at Nong Khai) and one in the lower Mekong (Cambodia-Viet Nam).

Hypothesis:
There are two populations of *Pangasius krempfi* in the Mekong River. One population is centered in the upper reaches in Xayaboury and Luang Prabang provinces in Lao PDR. This population migrates upstream during May to September from downstream sites, possibly all the way from just south of the Khone Falls to spawning grounds along the mainstream Mekong all the way to Chiang Khong, near the Lao-Thai-Myanmar border. The larvae drift downstream with the current to unidentified nursing areas.

Another population migrates downstream from around Stung Treng to unidentified spawning grounds somewhere between Stung Treng and Kompong Cham during the spawning season, from May to August. The larvae drift downstream to nursing grounds in the flood plains in the Mekong delta. When the water level begins to recede in October, the fish migrate back to the main river and begin an upstream dispersal migration, reaching the stretch just below the Khone Falls. *Pangasius krempfi* spend the dry season in deep pools within the mainstream.


Pangasius krempfi
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius krempfi
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(h) Pangasius larnaudiei

Pangasius larnaudiei occurs throughout the Mekong mainstream, from the Mekong delta to Chiang Saen near the border between the Lao PDR, Thailand and Myanmar.

Together with *Pangasius conchophilus*, this species is the most important in the wet season fishery (May to June) during its migration through Hoo Som Yai, a steep-gradient channel at the fault line of the Khone Falls (Singanouvong *et al*., 1996b). Unlike *Pangasius conchophilus*, however, these upstream migrations by *Pangasius larnaudiei* are more protracted, with regular smaller movements taking place over a number of weeks. Singanouvong *et al*. (1996b) considered the ultimate purpose of the migrations to be reproduction. In the *tone* trap and *lee* trap fisheries at Ban Hang Khone (Khone Falls), *Pangasius larnaudiei* ranked third after *Pangasius conchophilus* and *Pangasius krempfi* (Baird, 1998).

Again, for this species, the Khone Falls forms a borderline between two different migration patterns.

Below the Khone Falls, the species migrates upstream at the beginning of the dry season, triggered by receding water levels. This migration was reported by all the stations from Dong Thap province in Viet Nam to the Khone Falls. At the onset of the monsoon season, the species migrates in the opposite direction, downstream from the Khone Falls. The downstream migration was also reported by all stations except those in Chloung and Prek Pra Soup districts of Kratie Province, Cambodia.

Above the Khone Falls, the species migrates upstream at the onset of the monsoon season (reported by seven stations). Only one station (Loei, Thailand) reported a downstream migration, which occurs during August-September. Two Thai stations, in Mukdahan and Ubon Ratchatani provinces, respectively, reported that *Pangasius larnaudiei* is the last species to undertake the upstream migrations at the onset of the monsoon season. A fisherman at Ubon Ratchatani mentioned that *Pangasius larnaudiei* migrates just after the upstream migration of *Pangasius krempfi*.

The main trigger of these migrations appeared to be a combination of changes in water levels (12 reports) and changes in water colour (seven reports).

Pangasius larnaudiei is apparently one of the few species of the pangasid family that can be seen near the water surface. This fact was confirmed by at least two stations, located at Chiang Saen and Ubon Ratchatani, where fishermen reported observing them at the surface. Four stations (three in Thailand, one in Cambodia) specifically reported that the species lives in deep pools in the river.

From Kratie and downstream, *Pangasius larnaudiei* was reported moving between the Mekong River and smaller streams. However, at Loei, the species apparently remains in the Mekong throughout the year.

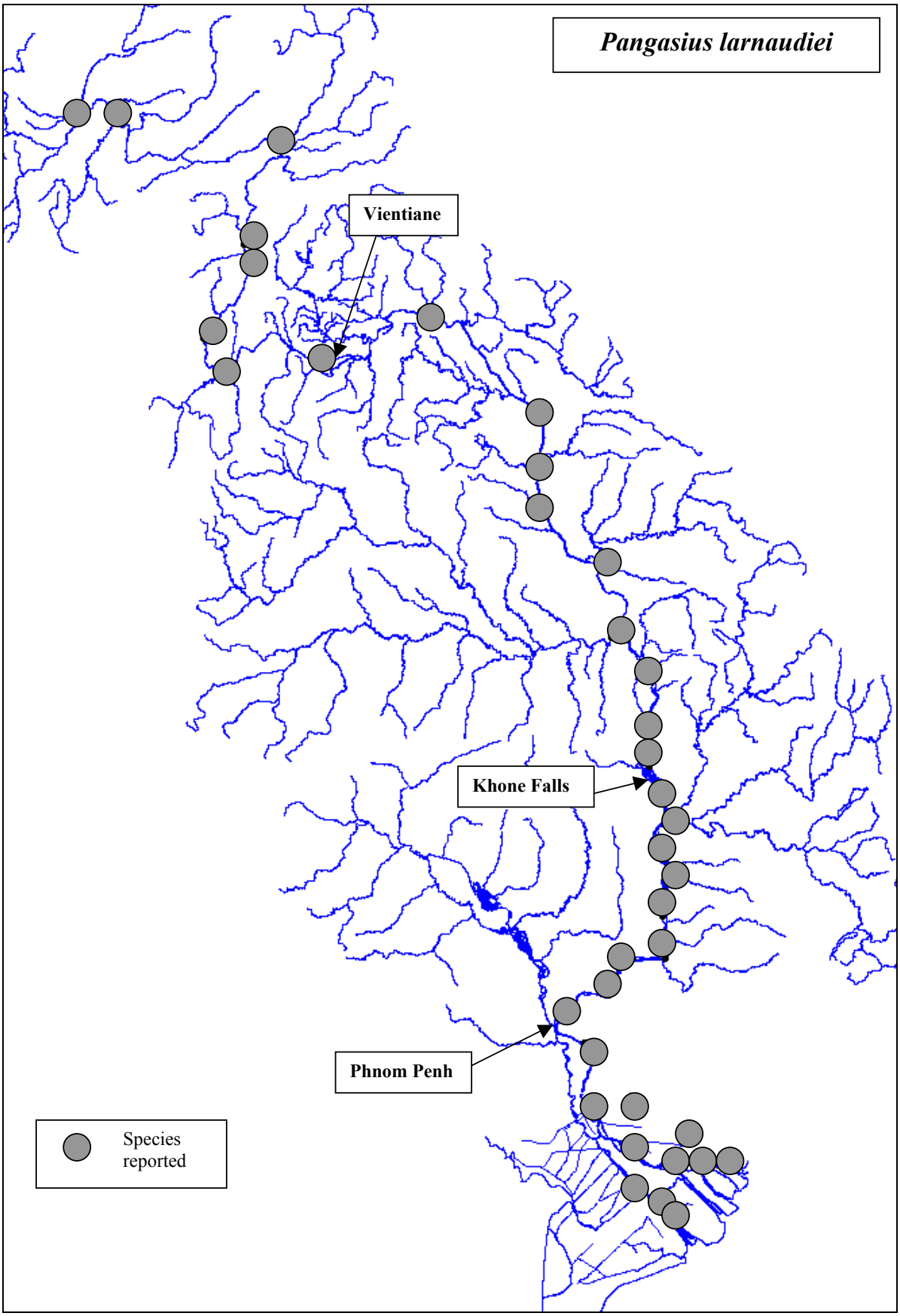
Eggs and/or milt were reported by 12 stations throughout the survey area during the following months: March (2 reports), April (1), May (6), June (7), July (4), August (1) and September (1). This pattern indicates a peak spawning time from May to August.

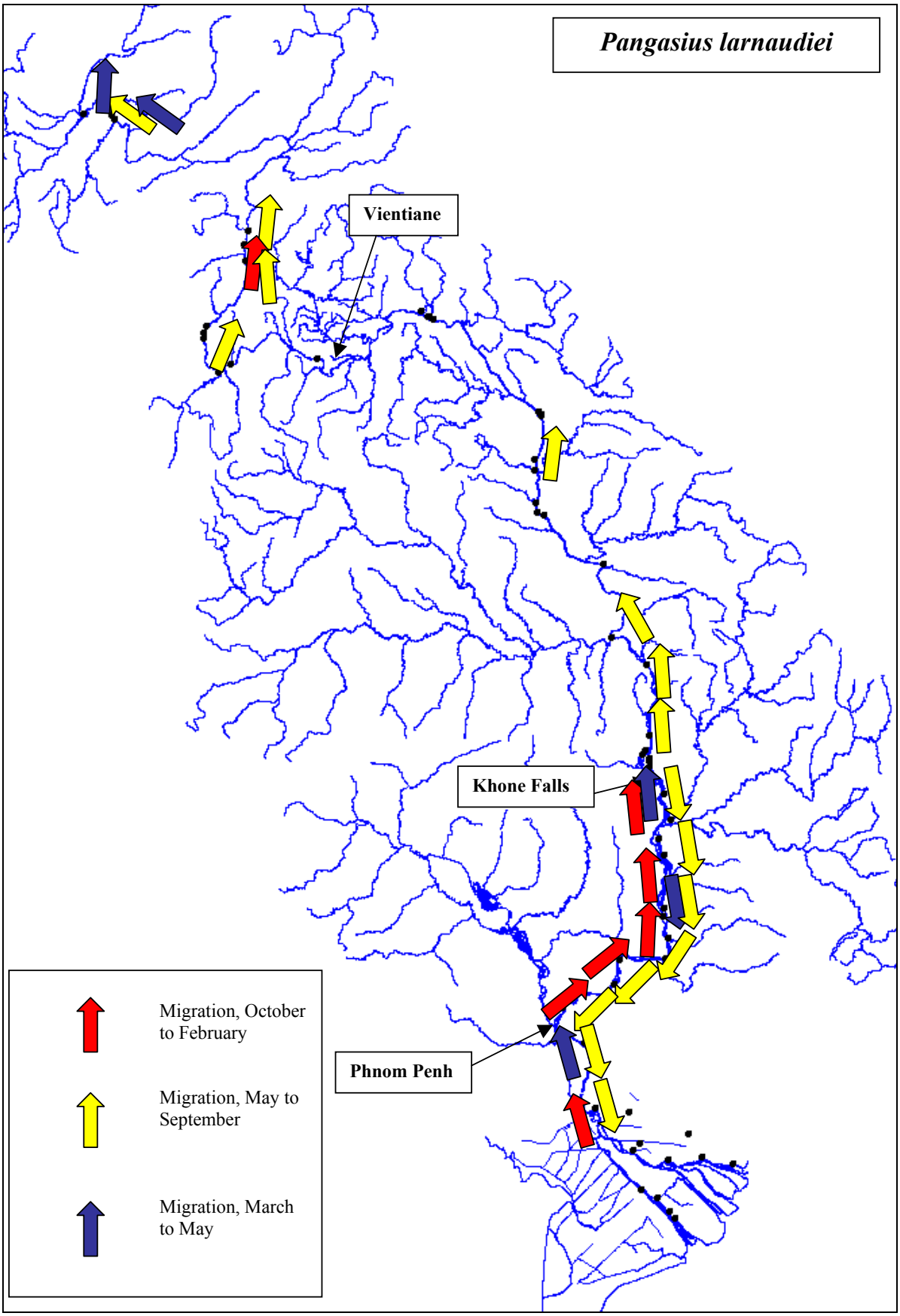
Below the Khone Falls, juveniles of 2-4 cm were reported by six stations, from Kompong Cham downstream to the Mekong delta (four stations in Cambodia and two in Viet Nam). All the stations reported observing juveniles from June to October, peaking between June and August. Above the Khone Falls, the smallest sizes were recorded by one station in Xayabouri, which reported juveniles of 6 cm from June to August. At Ubon Ratchatani (Klong Kaem), juveniles of 10-14 cm were reported during June-July. Apart from those stations, only large fish (30 to 90 cm) were reported from upstream of the Khone Falls.

Hypothesis:
Pangasius larnaudiei spends the dry season in deep pools at several places within the Mekong, both upstream and downstream from the Khone Falls. Below the Khone Falls, the stretch down to Kompong Cham constitutes a particularly important dry-season habitat.

The onset of the monsoon season and associated rises in the water level in the Mekong trigger the migration of *Pangasius larnaudiei* to as yet unidentified spawning grounds where it spawns from May to August. The occurrence of 6-cm juveniles indicates that spawning takes place somewhere further upstream. Below the Khone Falls, juveniles are only recorded from Kompong Cham to the Mekong delta, indicating that spawning takes places somewhere further upstream, above and/or just below the Khone Falls (e.g., from Kratie to Stung Treng).

Juveniles and adults move into the flooded areas and return to the Mekong River when water levels start to recede at the end of the monsoon season. Some of the bigger individuals, especially in the upper sections of the Mekong, may remain in the main channel during the monsoon season.


Pangasius larnaudiei
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius larnaudiei
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(i) Pangasius macronema

According to the findings of the present survey, the maximum size of *Pangasius macronema* is about 28 cm, which is somewhat larger than 18 and 20 cm reported by Rainboth (1996) and Roberts and Vidthayanon (1991), respectively. In spite of being one of the smallest pangasiid species, it is very important to local fisheries, a fact that is reflected in the number of fishermen that were able to provide information about the habits of the species. *Pangasius macronema*, however, is very similar to several other schilbeid and pangasiid species, and cases of misidentification may have occurred.

The principal habitat of this species appears to be the Mekong mainstream; only one fisherman, in Khammouan province of the Lao PDR, reported that it migrates up into small streams. The distribution range covers most of the Mekong except for a short stretch covering Nakhon Phanom and Mukdahan provinces in Thailand.

In Cambodia and Viet Nam, the species is generally present throughout the year, although in varying degrees of abundance. During the period when it is migrating it is more abundant.

Northwards from Boulikhamxay province in the Lao PDR, the species migrates upstream during April to August. The survey data indicate, however, that May and June comprise the main period of upstream migration in that region. Fishermen in Loei province of Thailand and Xayaboury province in the Lao PDR concurrently reported downstream migration during October-November (another fisherman in Xayaboury, however, reported upstream migration during the same period).

In Cambodia, an upstream migration starts in November and continues until January/February. One fisherman in Stung Treng province also reported that *Pangasius macronema* migrates upstream during May-June, while fishermen at four stations reported the fish moving downstream during the same period.

Very little information was provided on the direction of the migrations in Viet Nam, but at the two lowermost stations in the Mekong delta, *Pangasius macronema* were reported to migrate downstream from July to November.

Pangasius macronema has previously been reported to have passed the Khone Falls in southern Lao PDR during April-May, when it forms the basis for one of the most important fisheries in that region (Roberts and Baird, 1995; Baird et. al., 1999).

Limited information only is available about the breeding habits of this species. Only one fisherman from Tien Giang province in Viet Nam reported that the species spawns in the Mekong mainstream during August-September. This was later than the period reported by Bardach (1959), who stated that *Pangasius macronema* spawned in Cambodia in June.

Eggs were observed in the abdomen of this species throughout the year except in February. The largest number of reports was for April to June. One fisherman in Cambodia reported that *Pangasius macronema* carried eggs twice a year, during May-

June and November-December. Since he was the only person to have reported that fact, it is possible that there was confusion between two species, and further verification is needed. One fisher in Loei province of Thailand reported that the fish migrates downstream during October-November.

Juveniles sized 2-4 cm were observed throughout the year in all countries except the Lao PDR, where juveniles smaller than 6 cm were not reported. The average of all the minimum sizes reported for all countries, month for month, indicates that spawning mainly takes place between August and October.

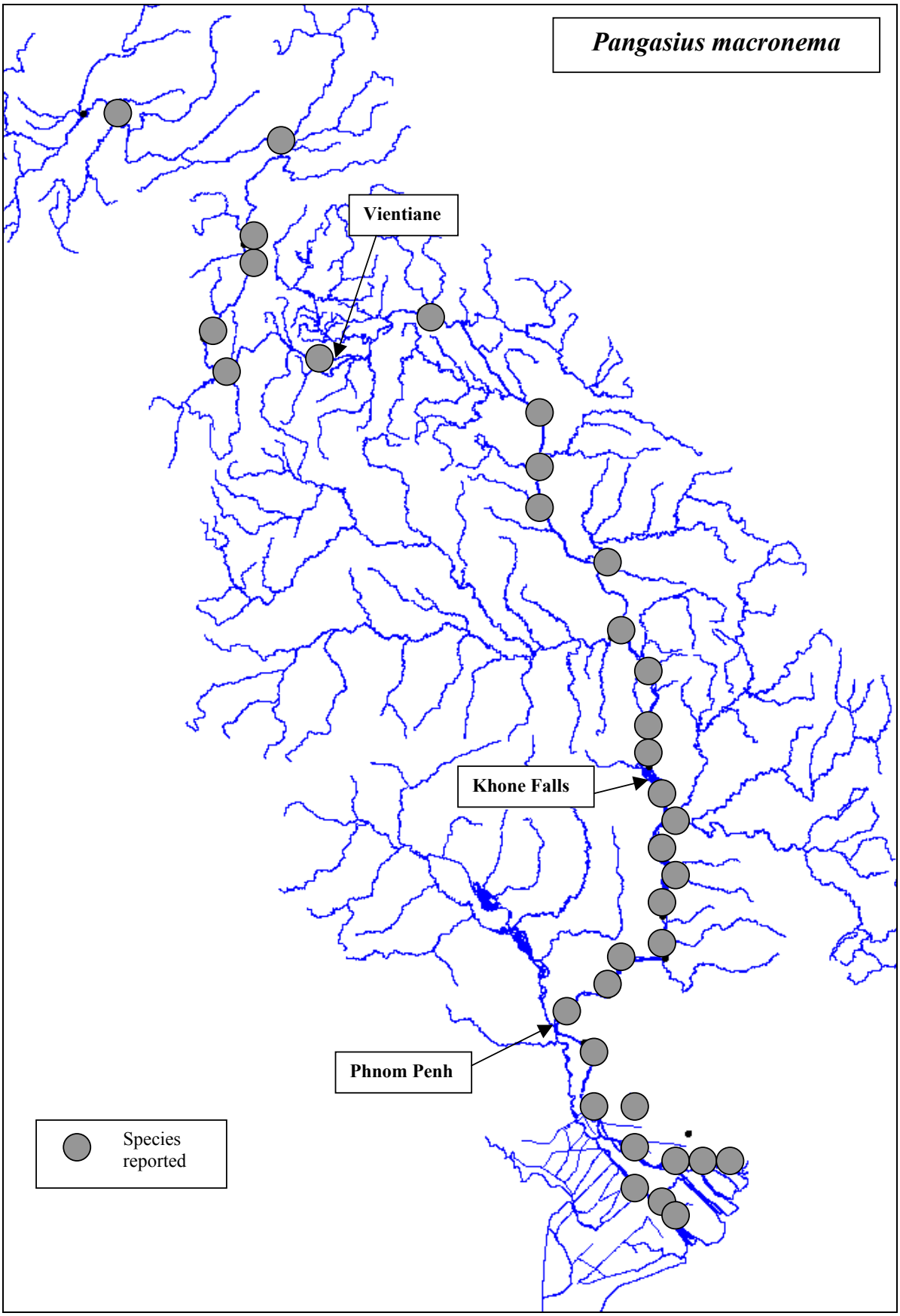
Many fishermen provided information about natural events that coincides with the migrations of *Pangasius macronema*. Changes in water level appear to have an influence on the movements of this species.. Seven Lao fishermen mentioned changes in the colour of the water as an important indicator of peak occurrence.. Eight fishermen in the Lao PDR and two in Thailand affirmed that the peak occurrence of this species coincided with the emergence of insects. Most of the fishermen identified dragonflies, while one mentioned termites and stoneflies.

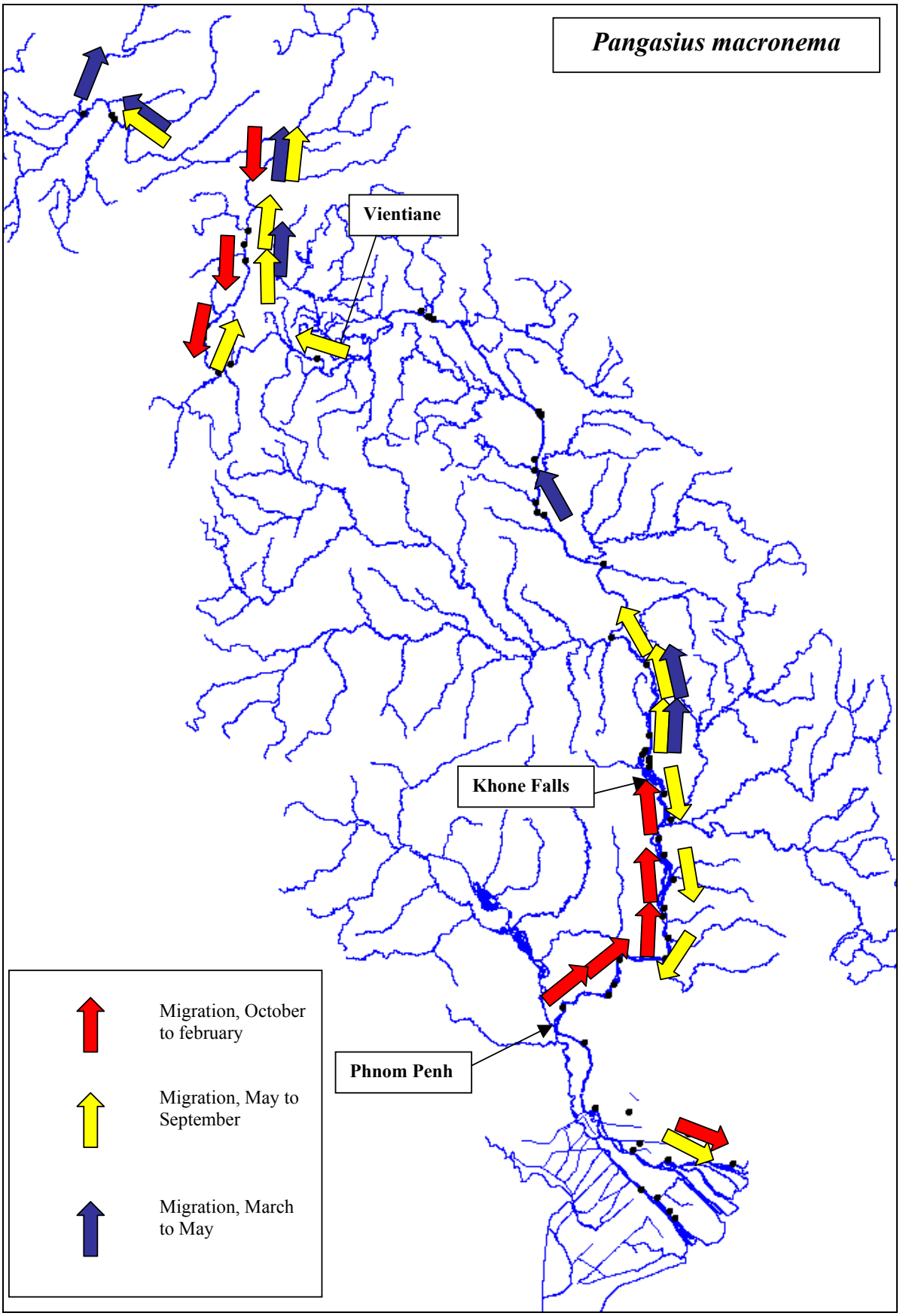
Hypothesis:
Three populations of *Pangasius macronema* exist.

The distribution range of the first population is from Thakhek, Khammouan province of the Lao PDR to Chiang Saen, in Chiang Rai province of Thailand. This population migrates upstream during May-June at the onset of the flood period, to spawn in the upper reaches of the Mekong River. After spawning, adults and juveniles spread out through the area.

The second population is distributed from Khemmaratch, Ubon Ratchathani province of Thailand in the north, down to Kratie province in Cambodia. This population breeds above the Khone Falls. After spawning, juveniles and adult fish disperse throughout the area. When the water level starts decreasing in November, *Pangasius macronema* migrates to some of the deep pools (e.g., near Kratie), where they stay until the next flood.

The third population partly overlaps with the second one. It is distributed from Stung Treng in Cambodia, down to the Bassac River in Can Tho province and to the Mekong delta. This population spawns in the area around Quatre Bras at the confluence of the Tonle Sap and Mekong rivers. These fish migrate to, and remain in, the same area as the second population during the dry season.


Pangasius macronema
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius macronema
Vientiane
Khone Falls
Phnom Penh
Migration, October to february
Migration, May to September
Migration, March to May

(j) Pangasius pleurotaenia

Pangasius pleurotaenia occurs throughout the survey area, from the northern station of Chiang Saen to the Mekong delta, although apparently the species is rare both in the far north and far south.

According to Rainboth (1996), this species prefers greater water clarity than most other pangasiids and, based on the size of its eyes, it may rely more on its vision for catching its prey than other pangasids. Many fishermen (i.e., at least seven fishermen from Thailand and the Lao PDR) mentioned that the occurrence of *Pangasius pleurotaenia* coincides with high incidence of certain insects near the water surface, in particular dragonflies. Some of the same fishermen said they had observed the fish coming to the surface to catch insects, confirming that the species relies on vision to catch its prey.

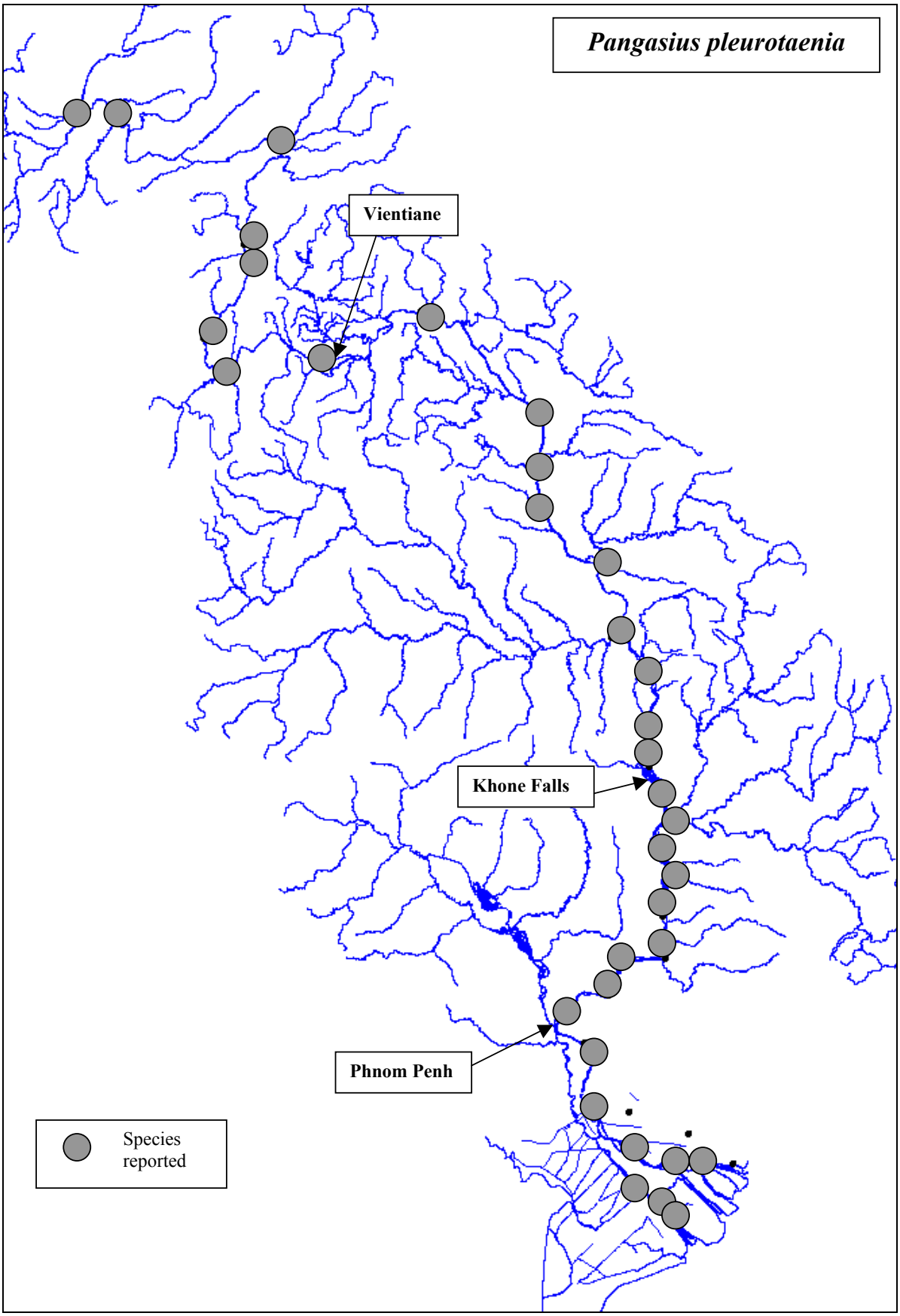
Below the Khone Falls, *Pangasius pleurotaenia* migrates upstream at the beginning of the dry season, a movement that continues in waves until March. These migrations are triggered by receding/low water levels. Late in the dry season, probably induced by the first rain showers, the species migrates downstream from the Khone Falls, at least as far as Kandal province. Migratory behaviour in the Mekong delta appears to be less clear, and none of the fishermen in that area reported any migratory activity by *Pangasius pleurotaenia*.

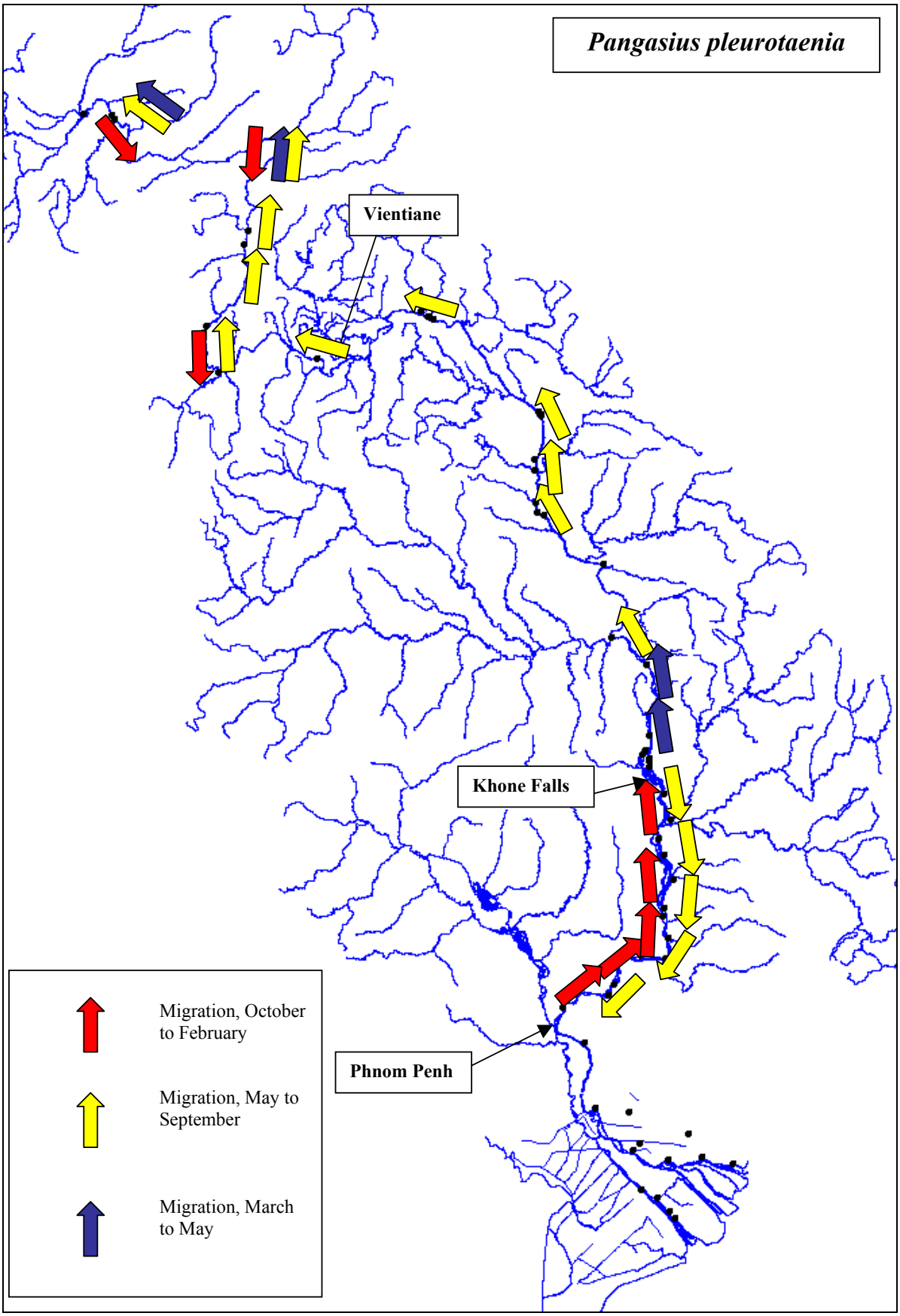
Along the stretch from Khone Falls and up to Chiang Rai Province, the first heavy rains, marking the end of the dry season, triggers *Pangasius pleurotaenia* to migrate upstream.. From the Khone Falls to Loei province in Thailand, the migration occurs over a relatively short period, typically during May-June. Further upstream, from Xayaboury to Chiang Rai, the migration tends to take place over a longer period, from March to August.

Several fishermen in Thailand and the Lao PDR reported that *Pangasius pleurotaenia* migrates into tributaries and small streams. One fisherman stated that it spawns in tributaries.

Reports of eggs being observed were made in March (1 report), April (4), May (11), June (12), July (4), August (2), September (1), October (1), November (1) and December (1). One fisherman in Stung Treng province, near the Khone Falls, observed eggs twice per year, during May-June and November-December. Based on these observations, the peak spawning period can be taken as May-June, coinciding with the onset of the flood season.

Pangasius pleurotaenia has previously been identified in the *tone* trap fishery at the Khone Falls, which targets highly migratory small cyprinids during the dry season from January to March (Baird, 1998). Singanouvong *et al.* (1996b) also sampled the species during the flood season over a three-year period and found that most migratory activity took place when the water flow volume was increasing rapidly. That increase occurred within a short time span, from early to mid-June in all three years.


Pangasius pleurotaenia
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius pleurotaenia
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(k) Pangasius polyuranodon

According to Rainboth (1996), *Pangasius polyuranodon* occurs in the Mekong as far upstream as Stung Treng. The present survey indicates that the species can be found all the way to Xayaboury in the Lao PDR. However, none of the stations in Thailand reported the species, indicating that it is rare in the middle Mekong, from the Khone Falls and upstream.

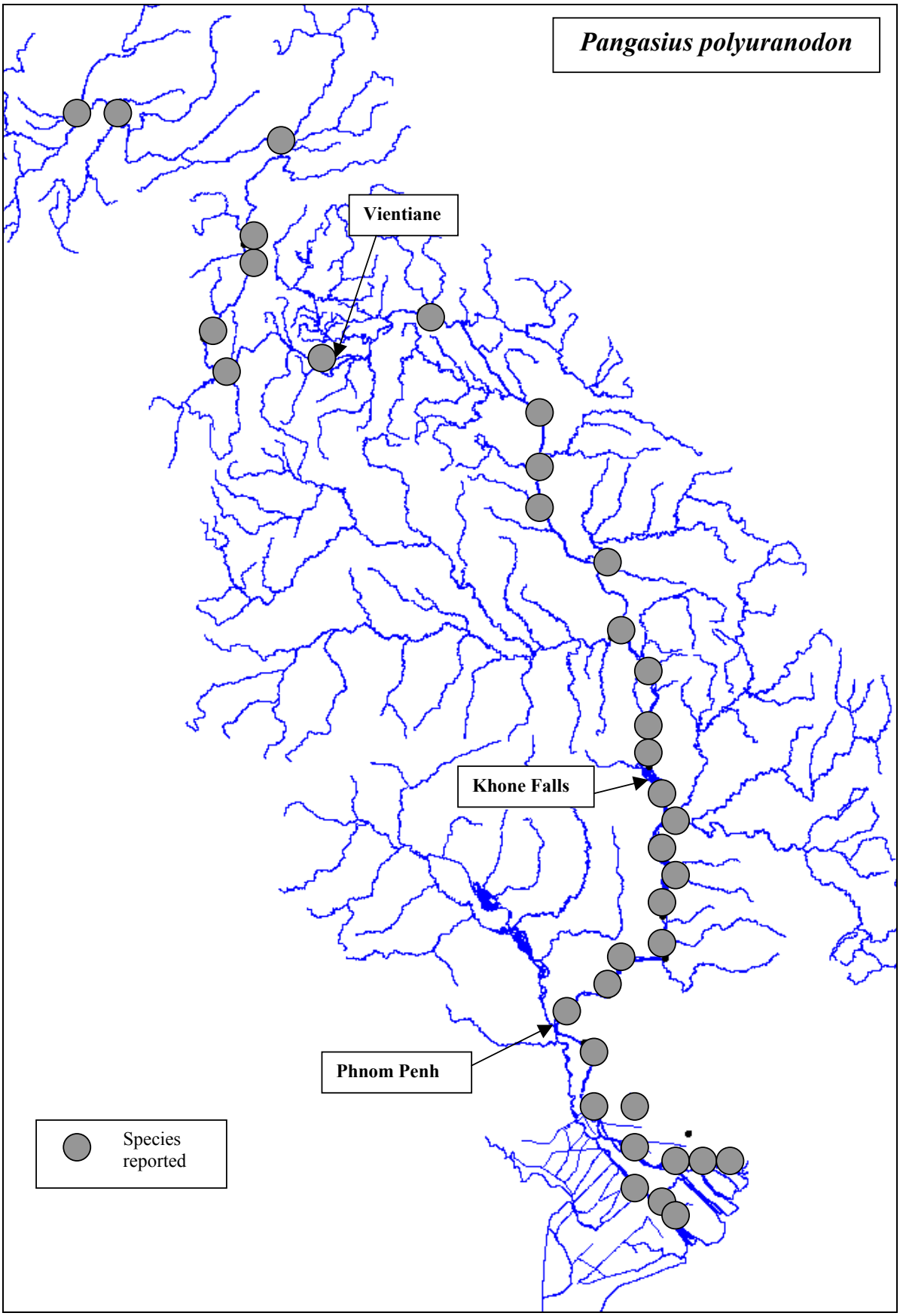
Below the Khone Falls, the migration pattern of *Pangasius polyuranodon* is similar to other migratory fishes. It undertakes upstream migrations from Kandal province in Cambodia to the Khone Falls, mainly triggered by receding water levels at the end of the flood season. This migration may take place all the way from the Mekong delta; however, only one station reported this movement in Viet Nam (My Tho town, Tien Giang province). Although the species appears to be common in the Mekong delta, (i.e., it was reported by most stations in Viet Nam), Vietnamese fishermen do not consider it to be a long-distance migratory species.

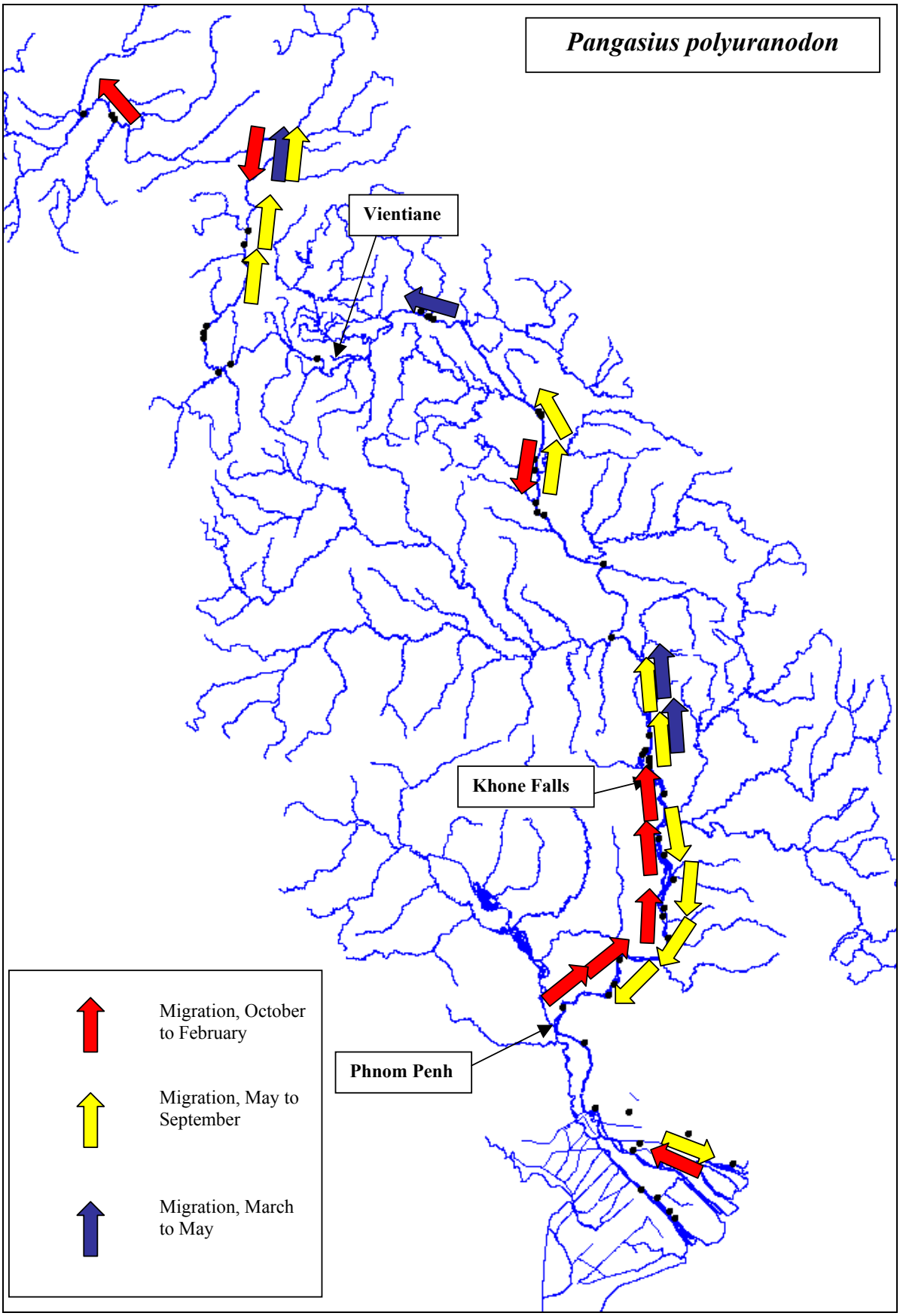
Downstream migrations during the onset of the flood season, triggered by a combination of early rainfall and rising water levels, were reported by stations from Thalabowirrat in Stung Treng province, to the Mekong delta. These are reproductive migrations, i.e., the reports of eggs indicate a spawning period from May to August.

Above the Khone Falls, the species migrates upstream at the onset of the flood season. This migration is also triggered by a combination of water level changes, the first rainfall and changes in water colour (turbidity). Many fishermen along that stretch use the appearance of certain insects, especially dragonflies, as an indication that migrations are underway.

One fisherman in Khanthaboury, Savannakhet province, reported that *Pangasius polyuranodon* migrates upstream in schools together with other species. However, the downstream migrations are more sporadic and not with other species.

Pangasius polyuranodon, of a sizes within the range of 20 to 345 g, have previously been reported in the dry season gillnet fisheries at Ban Hang Khone, just below the Khone Falls, during December-February (Baird, 1998). Onle few specimen were reported by the same author in the ‘tone’ fishery during the beginning of flood season (Baird, 1998).


Pangasius polyuranodon
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius polyuranodon
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

(l) Pangasius sanitwongsei

In terms of size and weight, *Pangasius sanitwongsei* is second only to the giant Mekong catfish, *Pangasianodon gigas*. However, at Loei in the upper part of the Mekong, one fisherman reported a *Pangasius sanitwongsei* weighing 300 kg, indicating that the species may, in fact, rival the size of the "real" Mekong giant.

According to the present survey, its distribution range is from the upper Mekong delta near the border between Cambodia and Viet Nam to at least Chiang Saen, near the border between Thailand, the Lao PDR and Myanmar.

Although Rainboth (1996) stated that this species is common in the middle Mekong, upstream from the Khone Falls, there are indications that it is becoming increasingly rare. For example, according to one fisherman near Loei, the species has all but disappeared, whereas previously 11-12 specimens were caught every night during the 30-day peak period during April-May. A Lao fisherman in Ban Don Kho, about 10 km upstream from Pakse, confirmed this information. As a specialist *Pangasius sanitwongsei* fisherman, he often caught about 20 fish per season; however, he said, he no longer sees this species.

Downstream from the Khone Falls, *Pangasius sanitwongsei* is also rare (according to reports by 10 fishermen during the present survey).

Within the whole survey area, two stretches of the Mekong mainstream show clear migration patterns: (a) the stretch from Kompong Cham to the Khone Falls; and (b) the stretch from Loei to Chiang Saen. Stations along the other stretches of the Mekong did not report on the migratory habits of this species. The reason could be that the fish is now so rare that it is difficult to observe any migratory patterns. On the other hand, a fisherman at Khemmaratch in Thailand reported that the species appears to be non-migratory in that area.

From Kompong Cham to the Khone Falls, the species migrates upstream from October to February during receding water levels, and then downstream from June to August during rising water levels. As opposed to many other large pangasid catfishes, *Pangasius sanitwongsei* does not appear to migrate over the Khone Falls. Previous studies in the Khone Falls area support this observation (Baird, 1998; Singanouvong *et al*., 1996b).

The main trigger of these migrations is changes in water level (or associated factors such as rainfall and water colour). Only one station, near Phnom Penh, mentioned a lunar effect, with upstream migrations occurring during receding water levels just before a full moon. More reports are needed before lunar effects on migration patterns can be confirmed for *Pangasius sanitwongsei*.

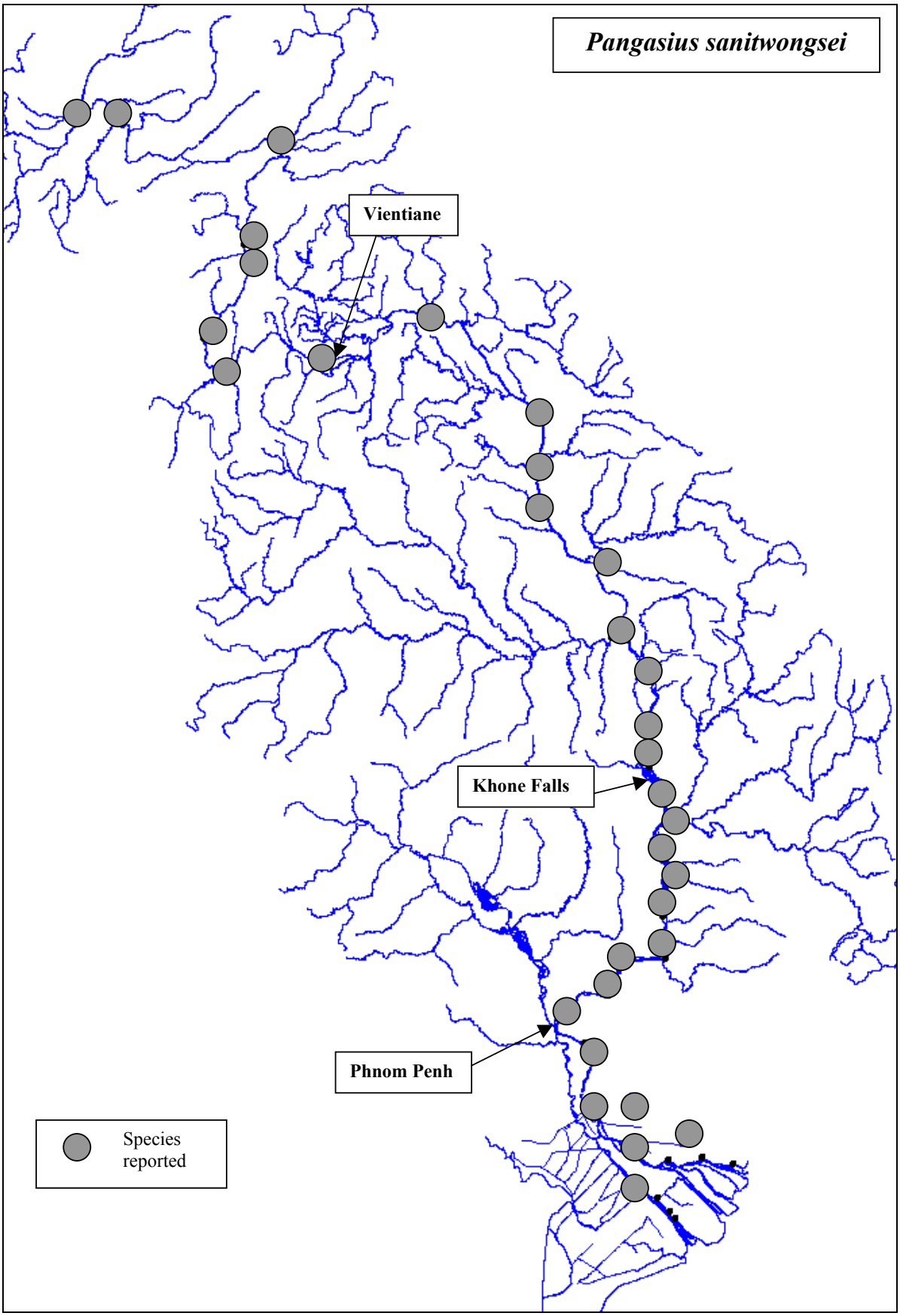
Below the Khone Falls, juveniles of 4 to 6 cm were reported from Kratie and downstream to the upper part of the Mekong delta. In Viet Nam, the maximum reported size was 14 cm. Above the Khone Falls, juveniles of 4-6 cm were reported from Loei, Nakhon Phanom, Thakhek and Ubon Ratchatani. Upstream from Loei, no juveniles were reported.

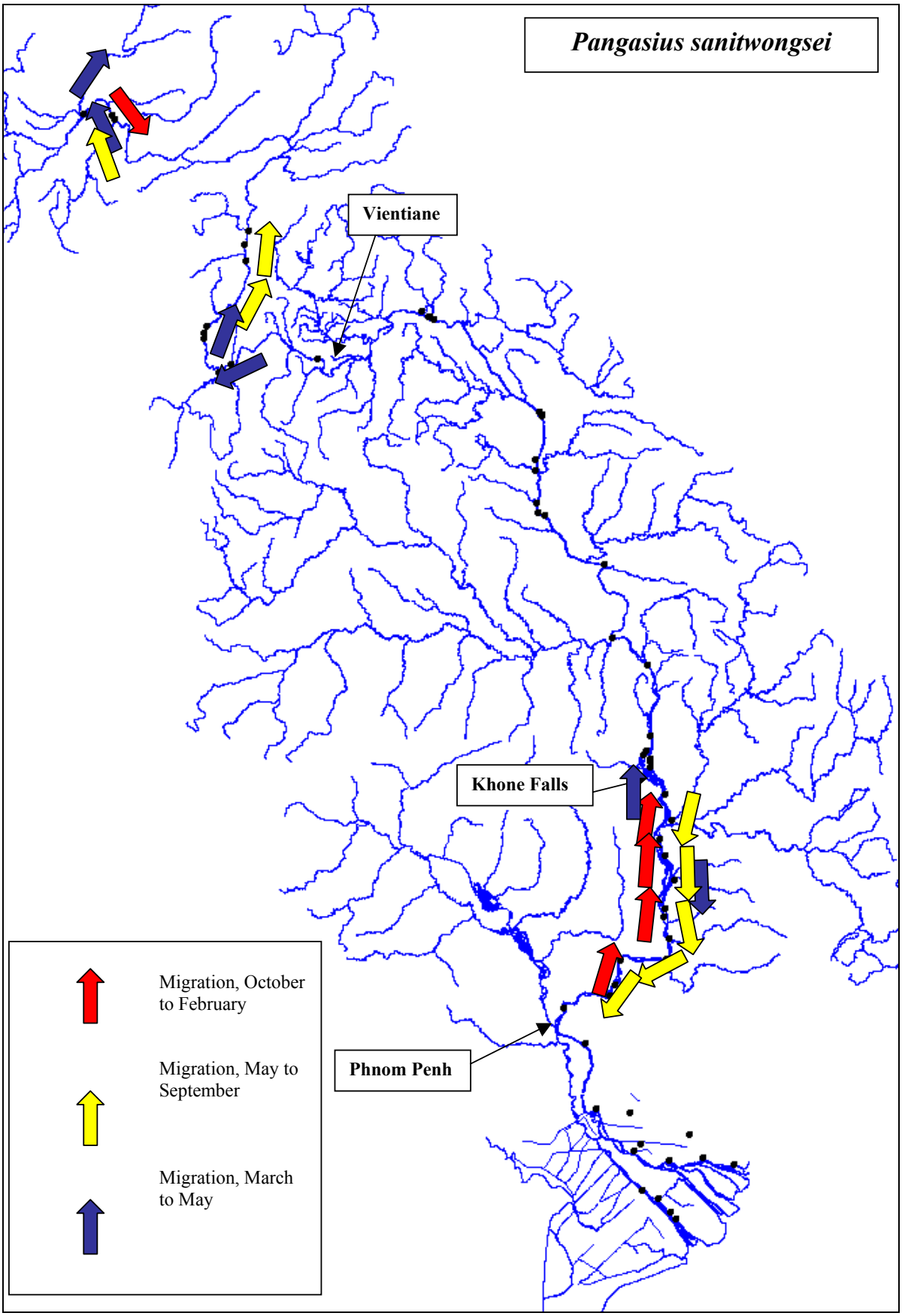
Hypothesis:

Pangasius sanitwongsei encompass two distinct sub-populations in the Mekong mainstream. One population occurs along the stretch from the upper Mekong delta (i.e., just downstream of the Cambodian-Vietnamese border) to the Khone Falls. The other population is confined to the Mekong mainstream above the Khone Falls, but is mainly distributed along the stretch from Vientiane to the border between the Lao PDR, Thailand and Myanmar.

Both sub-populations spawn in the upper sections of their respective stretches during May to July. Larvae and juveniles drift downstream until they reach their nursing areas. The southern population (below Khone Falls) migrates upstream at the end of the flood season, triggered by receding water levels.

As one of the few pangasid catfishes, *Pangasius sanitwongsei* does not migrate over the Khone Falls. However, it is caught at Ban Hang Khone just downstream from the Khone Falls (Baird, 1998; Singanouvong, 1996b), where it presumably preys on migrating fish, especially small cyprinids undertaking their dry-season upstream migrations.


Pangasius sanitwongsei
Vientiane
Khone Falls
Phnom Penh
Species reported


Pangasius sanitwongsei
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

8. Family: *Siluridae*

(a) Micronema bleekeri (and Micronema apogon)

Three species of the genus *Micronema* have been recorded in the Mekong (Rainboth, 1996). Two of those species, *Micronema apogon* and *Micronema bleekeri*, resemble each other strongly and they probably have similar ecological characteristics (Rainboth, 1996). They may therefore both have been covered, although the photograph used during the survey was of *Micronema bleekeri*.

Micronema bleekeri is distributed throughout the survey area, from Chiang Saen in the north to the Mekong delta.

Twelve fishermen specifically reported that *Micronema bleekeri* undertakes lateral migrations from the Mekong River into smaller tributaries and into the floodplains at the onset of the flood season, returning to the main river channel when the water starts to recede at the beginning of the dry season. Several fishermen from all the four countries reported that the first rainfall at the end of the dry season, as well as water level changes, trigger the migrations. In addition, four stations in Stung Treng and Kandal provinces of Cambodia reported a lunar influence. Fishermen in those provinces reported that the species returns to the river from the floodplains and tributaries on, or immediately before, the full moon.

Below the Khone Falls, these lateral migrations are followed by a longitudinal migration within the mainstream (reported by 11 Cambodian fishermen). One fisherman mentioned that the purpose of the upstream migration is to find a deep pool where the fish can spend the dry season. Deep pools within the Mekong mainstream were also reported by at least four Lao and Thai fishermen to be the dry season habitat above the Khone Falls.

The peak period for observing eggs in the fish of this species is May (16 reports) and June (17 reports). Eggs were also reported four times each in April and July. One fisherman in Xayaboury observed eggs during May-June and November-December. A few other fishermen also reported eggs during the dry season.

(b) Wallago attu

The distribution of *Wallago attu* is from the Mekong delta up to northern Lao PDR and Thailand. Reported to grow to over 90 cm, it is one of the large Mekong species. Rainboth (1996) stated that the fish reach a size of 200 cm.

There is some confusion as to what degree the species migrates in the Mekong mainstream. However, there appears to be consensus between fishermen in the four survey countries that the species migrates to smaller streams, canals and the floodplain at some stage during the flood season. During the dry season, this species lives in deep pools. The migration appears to have the dual purpose of (a) pursuing food, especially at the time where smaller fishes are migrating, and (b) spawning.

Eggs were reported to be present in the abdomen of *Wallago attu* from March to October, with most fishermen reporting eggs from May to July. Juveniles smaller than 4 cm are found from June to December, with an apparent peak during October-November. One fisherman in Chiang Khong, northern Thailand, reported that: "In June-July, groups of fish larger than 2 kg spawn in shallow water on flooded grassland. The eggs attach to the substrate and hatch within three days." Another Thai fisherman in Loei province reported personally observing spawning in the Huai Kid reservoir near the mouth of the Huai Kid stream. Small juveniles were also observed in a swamp in Chiang Rai province of Thailand. One Vietnamese fisherman reported that the fish breed in ricefields.

The timing of spawning coincides with that reported by Bardach (1959), who stated that *Wallago attu* spawns from May to October, with peak activity from July to September.

Hypothesis:
Wallago attu only undertakes short longitudinal migrations to the nearest stream, as well as some localised movements to pursue schools of smaller fish on which it preys. During the flood season it stays in swamps, canals and streams on the flood plain, where it also spawns. When the water level in the Mekong mainstream drops and the floodwater recedes, *Wallago attu* migrates to the Mekong River or larger tributaries, where it lives in deep pools until the next inundation period.

(c) Wallago leeri

Although *Wallago leeri* appears to be less common than the congeneric *Wallago attu*, it has almost the same distribution range, i.e., from about 50 km from the Mekong delta to the northernmost stations in Thailand.

Like its relative, *Wallago leeri* attains sizes larger than 90 cm. One fisherman in Chiang Khong, northern Thailand, said the species attains a maximum weight of 80 kg. The maximum size recorded by Rainboth (1996) was 145 cm.

The present survey produced limited data on the migrations of this species. The data on downstream migrations nevertheless follows a general pattern. In Cambodia, downstream migrations begin in May and end in July. Fishermen at one station in the Lao PDR and one station in Thailand concurrently reported that *Wallago leeri* migrates downstream during October-November. The data for the timing of upstream movements are too sparse to allow any interpretation.

Fishermen in the Lao PDR and Thailand agreed that *Wallago leeri* migrated into smaller streams to spawn. One Lao fisherman reported that the fish migrated in groups. One Thai fisherman explained that the species could normally be found in small Mekong tributaries when the water level started rising, especially after heavy rain. Detailed information on the movements of this species in Cambodia and Viet Nam is not available.

Eggs were observed in the abdomen of the fish from April to October, with the majority of observations being reported between May and July.

One fisherman in Chiang Khong reported personally observing the spawning of *Wallago leeri*. He also reported that *Wallago leeri* spawns in flooded grassland in July, that it spawns at night, and that it breed in deeper water than *Wallago attu*. When breeding, the fish swim in pairs, and the eggs are spawned near the surface.

9. Family: *Sisoridae*

Bagarius yarelli

Bagarius yarelli grows to more than 90 cm, and can attain a weight of around 50 kg. Rainboth (1996) indicated a maximum size of 200 cm. Interestingly, the largest individuals reported by Vietnamese fishermen were no bigger than 20 cm. There are several possible explanations for this difference: (a) misidentification; (b) the larger individuals have habitat requirements that cannot be met in Viet Nam (see below); or (c) greater pressure from fishing activities in the lowermost part of the Mekong River.

Except for a few locations in the southern part of the Mekong delta, *Bagarius yarelli* was identified at all the stations where interviews were carried out. Although Rainboth (1996) stated that it is a relatively unimportant food fish, the species was recorded at five markets during the present survey.

This species appears to be more common in the river stretches from Kratie and upstream, probably because of a preference for rocky areas with a strong current, a fact that was mentioned by a number of fishermen, and concurred with by Rainboth (1996). One Thai fisherman in Chiang Saen stated that *Bagarius yarelli* never enters small streams, which is consistent with Rainboth (1996).

It was mentioned at least twice that the species migrates in schools, and one Thai fisherman in Nong Khai mentioned that it follows *Catlocarpio siamensis* during its upstream migration. Some fishermen reported that the fish migrates to follow their prey.

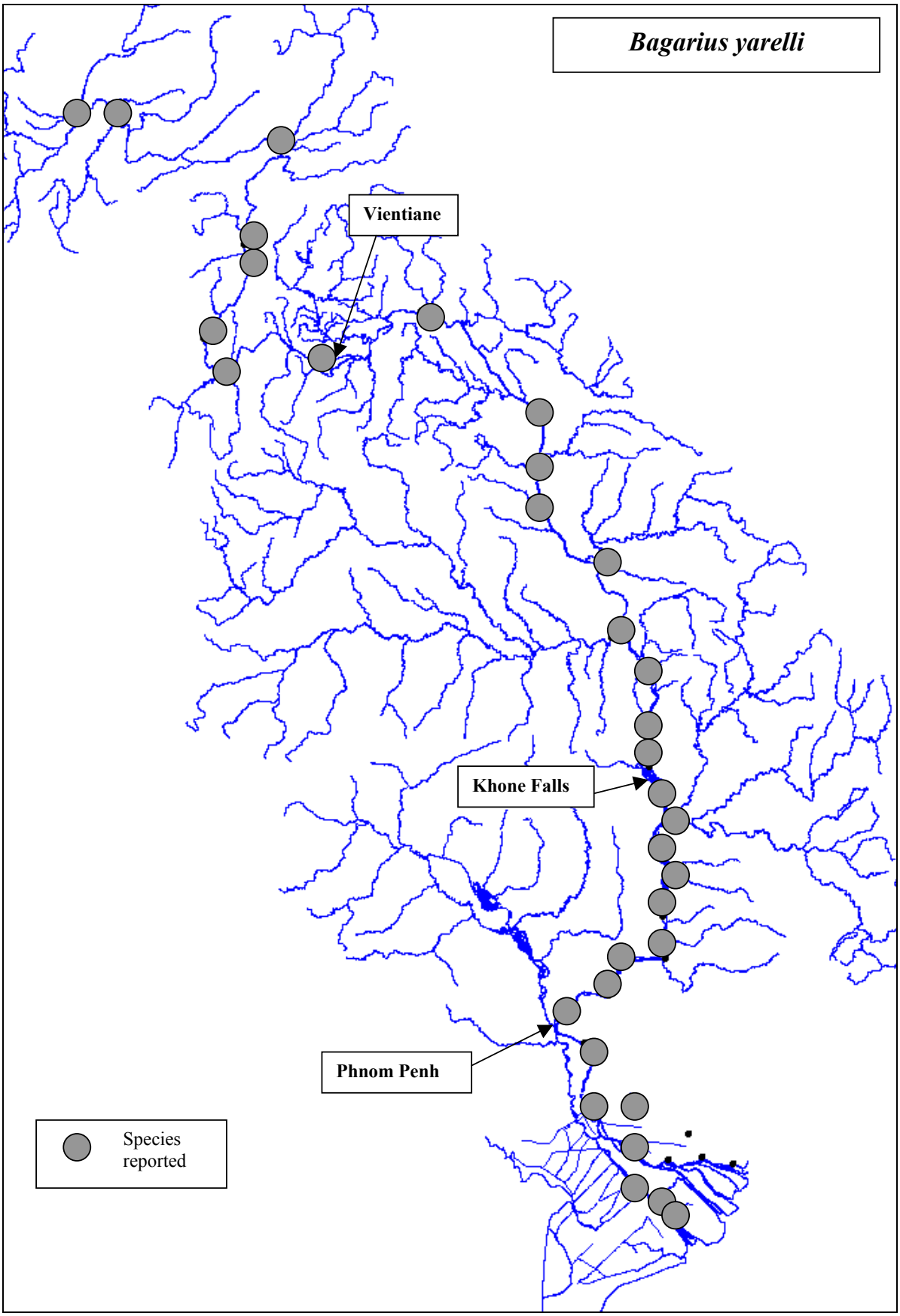
During the upstream migration, which occurs from March to August in the area upstream from the Khone Falls, the fish leave the rocky areas where they live during the rest of the year. The main migration apparently starts close to the peak flood when the current is very strong and the water is still turbid.

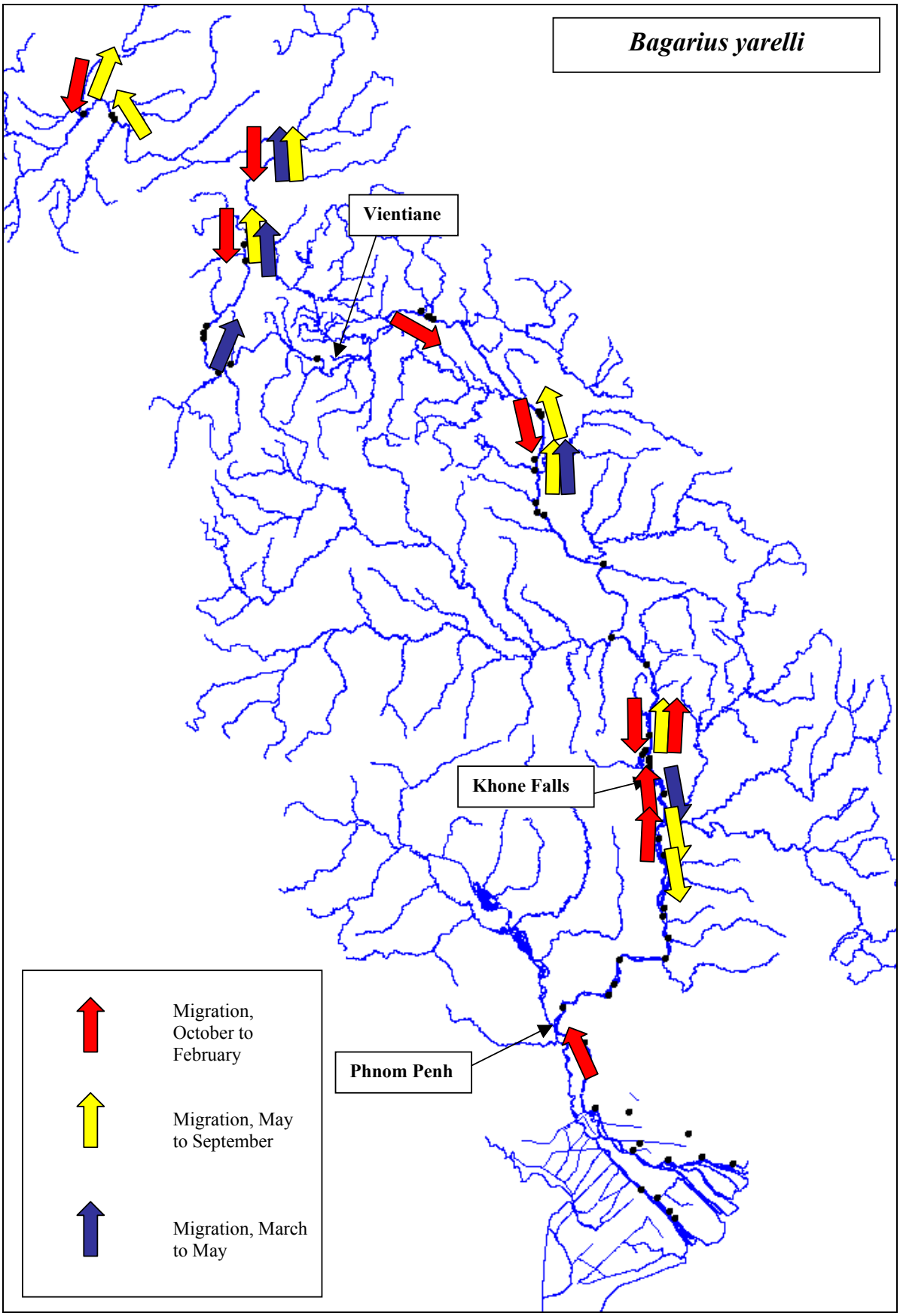
Bagarius yarelli is one of the few species for which several reports were made on downstream migration along the stretch from just above the Khone Falls to the northern station of Chiang Saen. The downstream migration in that area takes place from October to December. One fisherman in Chiang Saen reported that the fish arefatter during their downstream migration.

In the case of migrations below the Khone Falls, information is available only for localities in Kratie and Stung Treng provinces. The fish migrate upstream from October to February and downstream from April to September.

Fishermen at nine sites in Cambodia, the Lao PDR and Thailand reported seeing eggs in the abdomen of this species. Apart from a report in December by one fisherman from Xayaboury in the Lao PDR, all the fishermen maintained that the eggs were observed between April and September, with a peak during June-July. The peak spawning period thus coincides with the upstream migration period above the Khone Falls and with the downstream period below the Khone Falls. Juveniles of only 2 cm in length were seen throughout the year, however, indicating that the spawning period is more protracted than demonstrated by the data on the occurrence of eggs.

None of the fish seen by the survey teams in markets in Kratie, Loei and Boulikhamxay from March to June had eggs or milt.


Bagarius yarelli
Vientiane
Khone Falls
Phnom Penh
Species reported


Bagarius yarelli
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

10. Family: *Notopteridae*

(a) Chitala blanchi

The distribution range of *Chitala blanchi* has previously been stated to be between Khemmaratch in Thailand, and Kratie in Cambodia (Rainboth, 1996). The restricted range, caused by the preference of this fish for mainstream habitats containing rocks and boulders, has resulted in the species being included in the IUCN Red List of Threatened Animals (listed as "lower risk/near threatened"). The species is endemic to the Mekong River.

The present survey indicates that the distribution range is somewhat larger, from Xayaboury in the Lao PDR to Kompong Cham in Cambodia. All three stations in Kompong Cham province reported that the species is rare, confirming the preference of this species for habitats associated with rocky substrates.

There is broad consensus among fishermen throughout the survey area that *Chitala blanchi* only undertakes short, local migrations. From Kratie downstream to Kompong Cham, the species was reported to migrate into smaller tributaries when the water level starts to rise, returning to the Mekong mainstream when water level begin to recede. At several places, from Kratie to the Khone Falls, the species was reported as common throughout the year. Further upstream (e.g., Xayaboury and Thakhek), water level changes were reported to be the main trigger of the local migrations.

Most fishermen reported that the species spends the entire year in deep pools in the main river channel. However, at a few places (e.g., Klong Kaem in Ubon Ratchatani province in Thailand), the fish were reported to enter tributaries during the flood season.

Eggs were observed in the fish during February (1 report), March (4), April (14), May (8), June (2), July (2), August (1), September (2), October (2), November (1) and December (1). This pattern indicates that spawning occurs over an extended period from the late dry season to the early flood season (March to June). According to one fisherman in Nakhon Phanom (Thailand), he had observed spawning activity of *Chitala blanchi* at several places in the Mekong during March and April in the main river channel in areas containing submerged wood and rocks. He said the female guards the fry.

Juveniles measuring 2-6 cm were reported at several places, e.g., Stung Treng, Kratie and Kompong Cham provinces in Cambodia, and Ubon Ratchatani and Nakhon Phanom provinces in Thailand. The smallest sizes, around 2 cm, were observed from March to July, again an indication of an extended spawning period from March to June.

(b) Chitala ornata

Within the Mekong River, *Chitala ornata* has a larger distribution range than *Chitala blanchi*, from Chiang Khong near the border between the Lao PDR, Thailand and

Myanmar, to the Mekong delta. In Viet Nam, it was recorded by all stations except those in My Tho, Tien Giang province, and Cau Ke and Tieu Can districts, both in Tra Vinh province. Furthermore, as opposed to *Chitala blanchi*, this species is not endemic to the Mekong River, but is found throughout mainland South-East Asia (Rainboth, 1996).

Throughout its range, *Chitala ornata* was reported to migrate locally into smaller tributaries and flooded areas during the flood season, returning to the main river channel when water levels start to recede. Within the Mekong mainstream, it lives in pools. Several fishermen mentioned that the habits of *Chitala ornata* and *Chitala blanchi* were the same within the mainstream, including spawning habits. One fisherman in Mukdahan was able to distinguish between the two species by observing them when they surfaced, e.g., during spawning. There were more direct observations of spawning among this species, i.e., from Loei, Paksan, Nakhon Phanom and Ubon Ratchatani provinces. As with *Chitala blanchi*, eggs were laid on submerged wood from March to July, with the female guarding the fry. Smith (1945) stated that after spawning the female departs and the male guards the eggs.

(c) Notopterus notopterus

Notopterus notopterus is distributed throughout the area of the present survey, from the Mekong delta to Chiang Saen in Chiang Rai province, Thailand. Fishermen throughout its distribution range reported that the species only undertakes localised lateral migrations from the Mekong River to floodplains during the flood season, and back to the main river or other permanent water bodies during the dry season. Many fishermen, especially in Cambodia, stated that the species was more common in permanent lakes than in the main river channel.

Further upstream, in the Lao PDR and Thailand, the species is common in the Mekong mainstream as well as its tributaries, living in pools with submerged wood and shrubs. At several places, it was reported to move into tributaries during the flood season, where it apparently spawns.

Reports on eggs showed a strong peak in May (14 reports) and June (11 reports). Two fishermen in Viet Nam also reported observing eggs from September to November. Furthermore, two fishermen (one from Khemmaratch in Thailand, and one from Sambor in Cambodia), reported separately that the species spawns twice per year.

Three fishermen reported spawning behaviour. Two fishermen in Viet Nam observed spawning in flood-plain habitats (flood-plain grassland and flood-irrigated ricefields, respectively). One fisherman in Khemmaratch observed spawning in mainstream pool habitats, with the eggs attached to submerged vegetation.

11. Family: *Channidae*

Channa striata

Channa striata occurs throughout the area of the present survey, from Chiang Saen in the north to the Mekong delta. Fishermen throughout its distribution range agreed that the species does not undertake longitudinal migrations within the Mekong River. They also agreed that the species undertakes lateral migrations from the mainstream, or other permanent water bodies, to flooded areas during the flood season, and that the fish returns to the permanent water bodies at the beginning of the dry season.

Fishermen throughout the present survey area, but in particular in Cambodia and Thailand, reported that the species is much more common in flood-plain lakes and smaller streams than in the Mekong mainstream. That information is supported by Rainboth (1996), who stated that *Channa striata* was "found in sluggish or standing water, from Sri Lanka to Indonesia".

Eggs were observed in January (2 reports), February (2), March (7), April (13), May (15), June (9), July (1), August (0), September (1), October (1), November (3) and December (3). Interestingly, two fishermen, both from Cambodia, reported observing eggs during May-June and November-December.

Three fishermen from Chiang Rai province in Thailand observed spawning *Channa striata* during June-July in ricefields (two reports) and a natural swamp (one report). Two of those fishermen also reported that the fish guarded the newly hatched fry. A fisherman from Khemmaratch, Thailand, observed spawning *Channa striata* in the Mekong mainstream in May, in an area with sluggish water. He said that the "brood-fish made up the spawning ground and then guarded its young for about a month". One fisherman in Sambor, Cambodia, also observed fish guarding their fry during June-July. Finally, a fisherman in Dong Thap province, Viet Nam, observed spawning during December-January in an irrigated paddy field.

12. Family: *Anabantidae*

Anabas testudineus

Anabas testudineus occurs throughout the area of the present survey, from Chiang Saen in the north to the Mekong delta. Fishermen throughout its distribution range agreed that the species does not undertake longitudinal migrations within the Mekong River. They also agreed that the species undertakes lateral migrations from the Mekong mainstream, or other permanent water bodies, to flooded areas during the flood season, and returns to the permanent water bodies at the start of the dry season.

Most fishermen, particularly in Cambodia, reported that the species is much more common in flood-plain lakes than in the Mekong River. This information is supported by Rainboth (1996), who stated that *Anabas testudineus* is "found in sluggish, standing, or even stagnant water, often with dense vegetation". Further upstream in the Lao PDR and Thailand, the species was reported to return to the Mekong mainstream during receding water levels, where the fish spent the dry season in pools associated with submerged wood and shrubs. The fish are well adapted to withstand the harsh conditions in flood-plain habitats and they are even able to move over dry land in search of new habitats.

Eggs were observed in March (4 reports), April (10), May (17), June (11), July (3), August (1), September (1) and October (1). In addition, two direct spawning observations were reported, one from Chiang Khong province, Thailand, from May to July, and one from Dong Thap province, Viet Nam, from March to May. The two observations were made in rainfed paddy and irrigated ricefields, respectively.

13. Family: *Belontiidae*

Trichogaster trichopterus

Trichogaster trichopterus occurs throughout the area of the present survey, from Chiang Saen in the north to the Mekong delta. Fishermen throughout its distribution range agreed that the species does not undertake longitudinal migrations within the Mekong mainstream. They also agreed that the species undertakes lateral migrations from the mainstream, or other permanent water bodies, to flooded areas during the flood season, and returns to the permanent water bodies at the start of the dry season.

Most fishermen, particularly in Cambodia, reported that the species is much more common in flood-plain lakes than in the Mekong River. This information is supported by Rainboth (1996), who stated that *Trichogaster trichopterus* is "found in shallow, sluggish or standing-water habitats with a lot of aquatic vegetation". In Thailand, fishermen from Chiang Khong and Nong Khai provinces stated that the species is not common in the Mekong River, but common in small streams and swamps. One fisher from Mukdahan in Thailand reported that the species migrates from the Mekong River into its tributaries.

Eggs were observed in March (2 reports), April (8), May (12), June (7), July (2), August (1), September (2), October (1), November (1) and December (1). Furthermore, a fisherman in Can Tho province, Viet Nam, reported that eggs could be seen throughout the year. At Chiang Khong, one fisherman reported seeing nests in rainfed paddy fields during June-July.

14. Family: *Osphronemidae*

Osphronemus exodon

Osphronemus exodon was described as a new species as recently as 1994 (Roberts, 1994). Misidentification between this species and *Osphronemus gouramy* may have occurred during the present survey, although photographs of both species were shown to, and discussed with, fishermen. According to Rainboth (1996), the species occurs in the middle Mekong in a stretch from just upstream of the Khone Falls in southern Lao PDR southward to Kratie.

According to the present survey, *Osphronemus exodon* occurs from Xayaboury (Lao PDR) to Kompong Cham province (Cambodia). Furthermore, 11 fishermen recognised the species in the Mekong delta. However, those reports may be misidentifications involving *Osphronemus gouramy* and should therefore be further verified.

Osphronemus exodon migrates laterally from the Mekong mainstream into flood-plain areas during the flood season, and returns to the Mekong River or other permanent water bodies during the dry season. The migration is triggered by changes in water levels.

According to one fisherman in Thakhek (Lao PDR), the species lives under shrubs in pools of the main river, near the mouths of tributaries.

Eggs were reported to occur over a long period during the dry season and into the flood season, with a peak around March-April. Eggs were also reported during November-December. Furthermore, one fisherman from Sambor (Cambodia) stated that the species spawns twice per year, indicating that *Osphronemus exodon* is an opportunistic breeder.

15. Family: *Mastacembelidae*

Mastacembelus armatus

Mastacembelus armatus is one of the largest species of spiny eels and, as such, is relatively easy for most fishermen to identify. The maximum size is somewhat more than 90 cm, which is larger than the 80 cm maximum size reported by Rainboth (1996).

All stations in the present survey identified the species. At many of the stations, this species is observed throughout the year. The abundance of *Mastacembelus armatus*, however, is highly variable, even between closely situated stations. In Cambodia, south of Kratie, fishermen reported that it is a rare species.

Some fishermen indicated that *Mastacembelus armatus* lives in crevices and under rocks in the Mekong mainstream during the dry season, but enters canals, lakes and other flood-plain areas during the flood season. The species was reported to develop eggs throughout the year, although most fishermen said they had observed eggs from April to June. One Thai fisherman reported observing spawning in a whirlpool during April-May, in which the eggs were adhered to filamentous algae. One fisherman in Viet Nam reported that *Mastacembelus armatus* spawns in ricefields.

Hypothesis:
Mastacembelus armatus is a relatively stationary species that only undertakes short local migrations, and which has very strict habitat requirements (at least with regard to its dry-season habitat). In the dry season, it is only found in areas with a rocky bottom. Spawning also appears to take place in the habitat. During the flood season, part of the population moves to flood-plain habitats in the vicinity of the dry-season refuges, mainly to feed. Some individuals may also spawn on the flood plain.

16. Family: *Nandidae*

Pristolepis fasciata

Pristolepis fasciata is found throughout the area of the present survey, from Chiang Saen in the north to the Mekong delta.

Fishermen throughout the area covered by the survey, particularly in Cambodia, reported that the species is more common in permanent lakes than in the Mekong mainstream. This finding is supported by Rainboth (1996), who reported that this species occurs "in sluggish or standing waters, including reservoirs, from Burma to Indonesia". Within the main river, the species lives in areas containing submerged wood and shrubs, from where it enters into smaller streams at the onset of the flood season (e.g., reported by fishermen in Khammouan and Xayaboury provinces of the Lao PDR and Chiang Rai province in Thailand).

Fishermen throughout the survey area agreed that *Pristolepis fasciata* does not undertake longitudinal migrations, but makes lateral migrations from the Mekong River to the floodplains during the flood season, and back again at the onset of the dry season. These migrations are triggered mainly by changes in water levels.

Eggs were observed in March (3 reports), April (9), May (12), June (9), July (4), August (1), September (1) and October (1). The reports for August and September were of specimens caught in a flood-plain lake in Cambodia. In addition, one fisherman from Can Tho province, Viet Nam, reported that eggs could be seen throughout the year, indicating that while *Pristolepis fasciata* is an opportunistic breeder its main spawning period is at the beginning of the flood season.

17. Family: *Sciaenidae*

Boesemania microlepis

According to the findings of the present survey, *Boesemania microlepis* is distributed from the Mekong delta to Xayabouri in the Lao PDR. However, the one report received from Xayabouri was the only one to mention the species upstream from Paksan in Boulikhamxay province, indicating that it is extremely rare along that stretch of the river. Other fishermen in the area reported that although the species could previously be found there, it has not been seen for many years.[12]

Although the map indicates that the species undertakes migrations, the movement appears to be sporadic and covers only a short distance. Above the Khone Falls, the migrations usually take place around the onset of rising water levels at the beginning of the flood season. Downstream movements above the Khone Falls were not reported.

Below the Khone Falls, these short-distance upstream movements are usually seen during receding water levels at the end of the flood season. Downstream movements

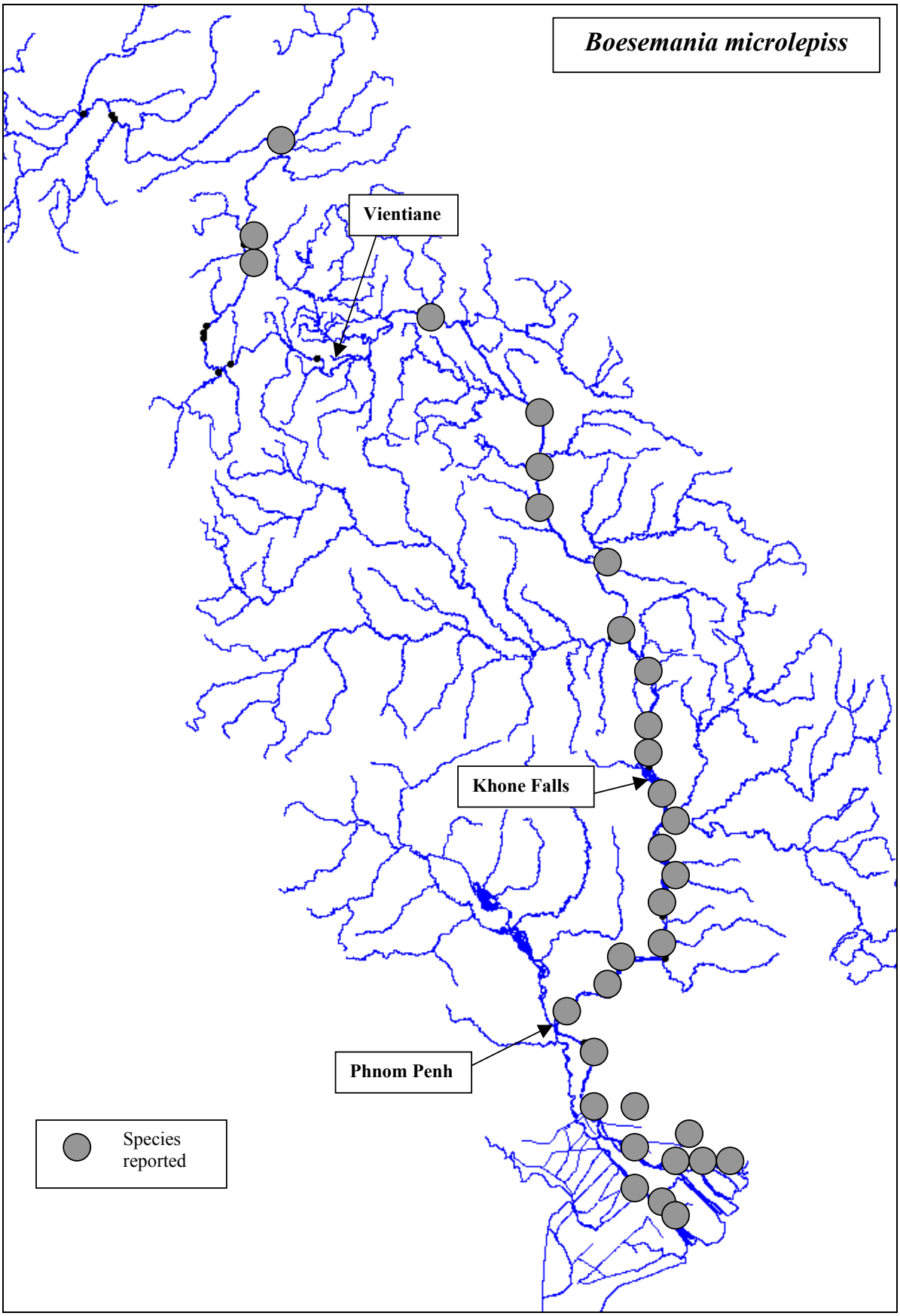
[12] Kongpeng Bouakhamvongsa, personal communication.

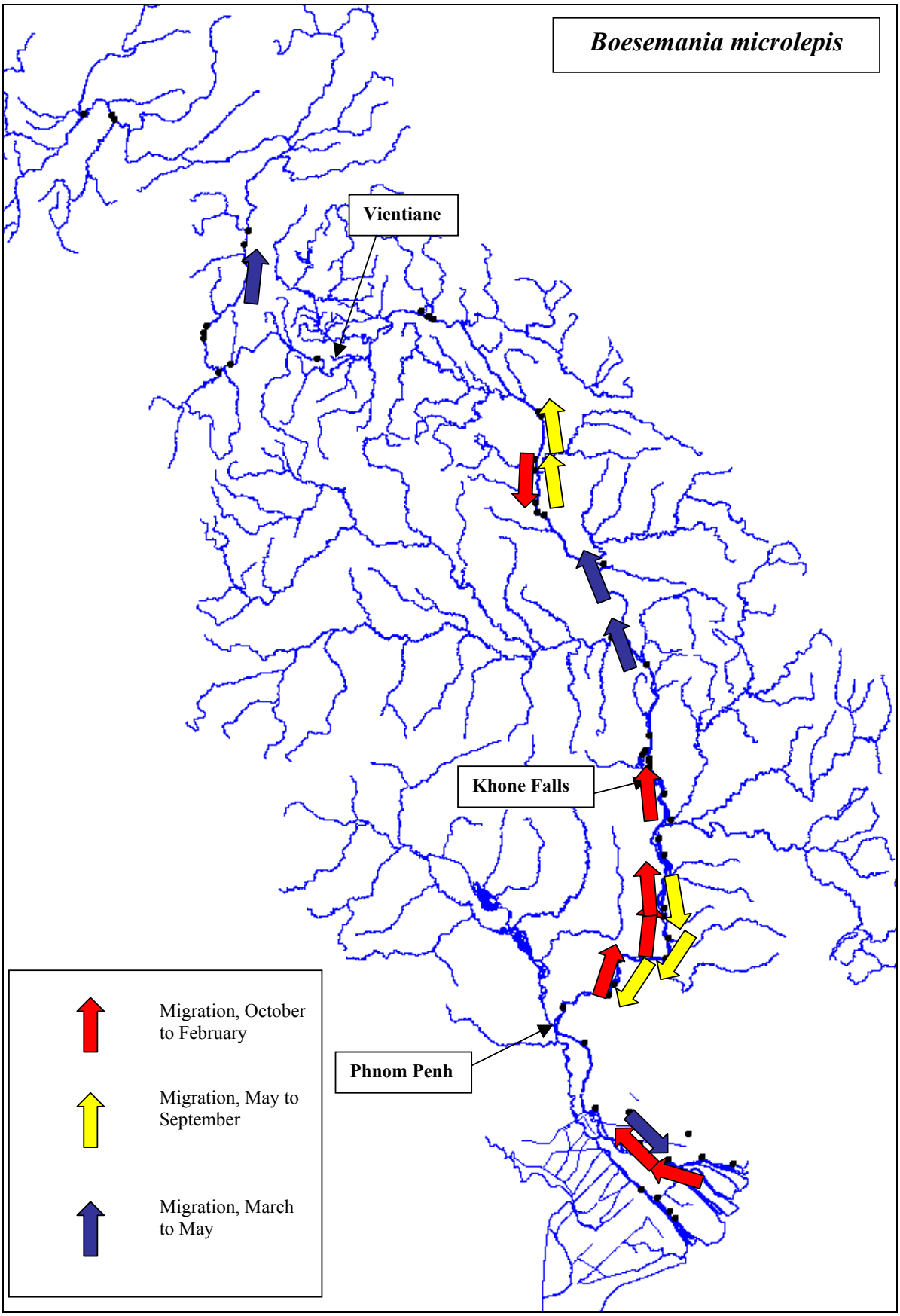
occur during the period of rising water levels. The lunar cycle also appears to effect migration, i.e., three fishermen, all from the Kompong Cham to Kandal stretch, mentioned that the movements occur on, or just before, a full moon.

Two fishermen, one from Xayaboury and one from Stung Treng, reported that the species migrates solitarily rather than in schools. One fisherman in Kompong Cham province stated that the fish migrate in order to follow their prey, which comprises small migrating fishes. Previous reports support this finding, although shrimps appear to be the main food source of this species (Rainboth, 1996, Baird and Phylavanh, 1999a and 1999b).

Eggs were only observed between April and July (two reports in April, five in May, three in June and one in July), indicating that the peak spawning period is in May. Baird and Phylavanh (1999a) found that spawning occurs in deep water sections of the Mekong River during the height of the dry season between March and early May. Bardach (1959) suggested that the spawning period occurs during May-June in Cambodia.

Boesemania microlepis has been reported to make loud croaking vocalisations during its spawning period (Baird and Phylavanh, 1999a). Based on the recording of the croaking, seven spawning grounds associated with deep pools in Khong district, just above the Khone Falls, were confirmed (Baird and Phylavanh, 1999a).


Boesemania microlepiss
Vientiane
Khone Falls
Phnom Penh
Species reported


Boesemania microlepis
Vientiane
Khone Falls
Phnom Penh
Migration, October to February
Migration, May to September
Migration, March to May

GENERAL DISCUSSION

Although this report has focused on migration patterns at the level of individual species, some more general ecological characteristics of the Mekong system can be made, based on the findings of the present survey. When migratory patterns and reproductive strategies for all the described species are put together, some important ecological indications emerge. These indications are described below.

A. Khone Falls

The Khone Falls in southern Lao PDR clearly emerge as a key area of the Mekong River. Although not appearing to present a physical barrier for most of the described species (e.g., most species live both below and above the Khone Falls), the migratory patterns of most of the species differ significantly below and above the Khone Falls. Many species make an upstream dry-season migration from the south up to the Khone Falls, as well as a downstream migration from the Khone Falls during the onset of the flood season. On the other hand, above the Khone Falls, many of the same species migrate upstream during the onset of the flood season. In other words, the same species migrate at the same time, in opposite directions. The timing of the migrations coincides with the main spawning periods for most species, both below and above the Khone Falls.

B. Deep pools within the Mekong mainstream acting as dry-season refuges

Throughout the Mekong mainstream, fishermen emphasise deep pools as habitats for fish. In particular, the stretch of the Mekong from Kratie, Cambodia, to the Khone Falls appears to be very important as a dry-season habitat for almost all the surveyed species. Numerous deep pools are situated within that stretch of the Mekong (Hill and Hill, 1994). Furthermore, the area contains rapids and flooded vegetation, which may be exploited by fish (Baird and Phylavanh, 1999b). The present survey confirms that many of the important migratory species spend the dry season in deep pools within that stretch of the river.

Further upstream, deep pools also play an important role as dry season habitats. Most of the large migratory species within that stretch migrate from the Mekong up into tributaries during the flood season, returning to the Mekong mainstream at the beginning of the dry season, and typically spend the dry season in deep pools. Many fishermen are aware of the importance of deep pools as a habitat for fish. Often they know where the pools are and, in some cases, even how deep they are (i.e., most species can be found in that stretch throughout the year).

C. Importance of floodplains

With few exceptions, the species covered in this report depend on flooded areas at some stage during their lifecycle, and especially during the larval/juvenile stages. Many longitudinal migrations appear to be adaptations to ensure that offspring are eventually brought into the productive flooded areas, where they can capitalise on the fertile environments associated with flood plains. This is particularly apparent in

southern Cambodia and the Mekong delta, where the movement into, and out of, the flooded areas during rising and receding water levels, respectively, is a common feature among most species. However, such movement was also reported regularly further upstream, e.g., in flooded areas along the Loei River and even at the northern station in Chiang Khong.

There is a major difference between flood-plain areas in the lower Mekong River (i.e., below the Khone Falls) and the middle Mekong. In the lower Mekong (southern Cambodia, which includes the Tonle Sap catchment and the Mekong delta) the flood plains are directly connected to the Mekong mainstream, whereas in the middle Mekong, the flood plains are mainly associated with tributaries.

Therefore, in the middle Mekong, fish can only gain access to the flood plains through tributaries and smaller streams. The upstream migrations reported for many species from the middle Mekong just before, and during, the onset of the flood season appear to be an adaptation for "finding" a tributary from which the fish will be able to reach flooded areas (or get their offspring into flooded areas).

On the other hand, below the Khone Falls, particularly downstream from Kratie, the flood plains are accessible directly from the Mekong mainstream. Therefore, they can be reached more easily, simply by moving downstream (actively or passively) until the extensive flood plains in southern Cambodia and the Mekong delta, and in the Tonle Sap system, are reached. The migratory patterns of most species covered in the present survey appear to be an adaptation to these environmental circumstances.

D. Hydrological factors

According to reports from fishermen along the whole stretch of the river, the main trigger of fish migrations is changes in water levels (or related factors such as rainfall, turbidity and water colour). For all the species covered in the survey, the most important trigger of migratory behaviour (longitudinal and/or lateral) was water level changes. Consequently, the main periods for migratory activities occur when the water level begins to rise at the onset of the flood season, and again when the water level begins to recede at the onset of the dry season, respectively (figure 3). Furthermore, the peak spawning period for most species coincides with the start of rising water levels at the beginning of the flood season (with a few spectacular exceptions such as the *Probarbus* species).

In other words, the life cycles of these fish are adapted to the hydrological conditions determined by the conspicuous annual flood pulse of the Mekong River.

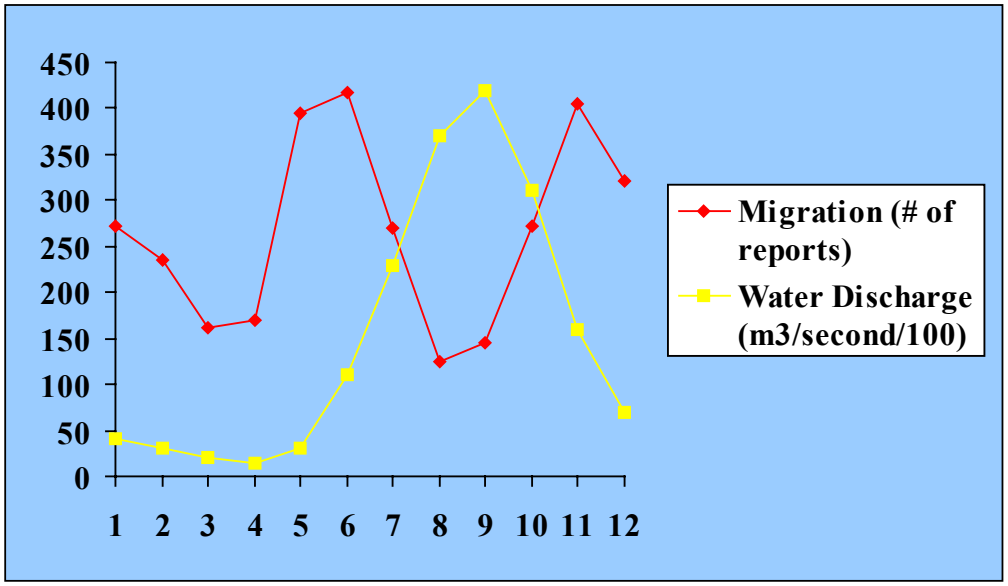


Figure 3. Total numbe of reports of fish migrations (red graph) vs. water discharge (yellow graph)

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