Monitoring of fish larvae during the annual flood of the Mekong and Bassac rivers, Mekong Delta, Viet Nam

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ABSTRACT

Many Mekong fish species spawn in Cambodia at the beginning of the annual flood, after which their fry drift down the Mekong and its tributary rivers into the Mekong Delta. During the flood, fish fry move from the main rivers to flooded areas where they can feed and grow, and as flood levels fall they move back to the main river systems. Pangasiid catfish are a particularly important component of the fry drift, as they were the target of a large stationary bagnet (Dai) fishery along the Mekong and Bassac Rivers in Cambodia and Viet Nam. The fry were sold to aquaculturists, but the fishery was outlawed in Viet Nam in 2000 when fry from hatcheries became available.

In 1999 and 2000, catches by the Dai fishery were studied, and later on samples (up until 2003) were taken with Bongo nets to monitor fry as a general indicator of the status of fish stocks. Samples were taken in the Mekong and Bassac Rivers in Viet Nam close to the border with Cambodia. A total of 4,535 samples have been taken and processed: 3,018 samples from Vinh Xuong (Mekong River) and 1,517 samples from Quoc Thai station (Bassac River). A total of 201 fish species were identified.

The highest numbers of fish larvae occurred in 2000 when 148 species were recorded, and the lowest catches were in 2002 when only 59 species were recorded. The hydrological regime of the Mekong River profoundly influences the distribution of fish larvae and juveniles. The fry samples confirmed that most Mekong River fish spawn at the beginning of the flood season and fewer fish spawn during or after peak water levels. Fish larvae/fry in samples are derived from spawning several days or weeks before they are caught; highest densities were 0.98 individuals/m3 in the early flood season, 1.2 individuals/m3 in the mid-flood season, and 0.09 individuals/m3 at the end of the flood season. Water levels fluctuated by about 3m during a large flood in 2000, from June (1.77m) to September (4.78m) at Tan Chau.

The studies show that water management in the delta could be improved to allow better recruitment of fry to seasonally flooded areas to support fisheries production. Monitoring of fry drift should continue as a useful general indicator of the status of the fishery.

INTRODUCTION

Many fish species of the Mekong River migrate upstream for spawning during the flood season. However, the exact spawning sites of most fish species has yet to be determined. For some inland freshwater species, some knowledge of spawning sites is available, such as in shallow rice fields or similar flooded areas. Some of species of the Pangasiidae family, such as *Pangasius hypophthalmus* and *Pangasius bocourti* are thought to spawn somewhere in the mainstream of the river. However, this is still not clear due to strong flows and turbidity during the flood season, making research difficult. From the spawning grounds, larvae drift into flooded areas of the lower basin, and fish larvae develop there in inundated swamps and other wetland areas until the end of flood season. When floodwaters recede, fish migrate back to the mainstreams via small rivers or canals.

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Very few studies have been completed on the larval stages of Mekong fishes due to difficulties in sampling, and also the technical problem involved with identifying fish larvae looking at morphological and meristic characteristics. So far, most studies and documents on fish taxonomy in the Mekong in general have dealt with adult fish.

The migratory behaviour of most fish species are in tune with annual flood patterns, but not always so for all species. Many egg-laying fish species spawn in the main flows of Northern Cambodia and Southern Laos and fish larvae are then carried into Southern Cambodia or into the Mekong Delta in Viet Nam up to distances of 500km away. If spawning is delayed late into the wet season, fish larvae may not reach Tonle Sap Lake due to back flows coming from the Great Lake. Under these conditions fish larvae may therefore drift into the lower Mekong Basin of Viet Nam. So, the stages of the flood cycle, and the timing of spawning, regulate what actually happens in any one given year. Environmental changes, such as alterations to the beginning of the time of the flood cycle and its duration, together with total annual flow volume of the Mekong River are of major importance and ultimately have consequences for fisheries.

Submerged areas in the Mekong Delta of Viet Nam and the areas surrounding the Tonle Sap Lake are very important nursery sites for fish. Many commercially important fish species migrate hundreds of kilometres across international borders from the Mekong Delta of Viet Nam up to Cambodia, Thailand and Laos via the Mekong mainstream channel. Fish larvae of some fish species drift several hundred kilometres from spawning grounds in upstream areas back downstream into inundated areas where they grow and develop. Some other fish species migrate only short distances into nearby flooded areas, and it is there that they reproduce and the young fish develop.

MATERIALS AND METHODS

Study sites

Two study sites were chosen, just about 1km away from the border with Cambodia. One was at the Hau River located at Hamlet 1, Quoc Thai village, An Phu district at 177°5’49,2’’E and 10°55’13,2’N, and the second one was at the Tien River located at Hamlet 1, Vinh Xuong village, Tan Chau district, at 177°10’52,4’ E and 10 °54’11.9’N (Figure 1).

Sampling methods

Sampling nets used during the study

Three types of nets were used for sampling. The first type was a simple bag net (called ‘*Dai*’ for larvae sampling). It is a traditional fishing gear used by farmers when they want to collect fish larvae (*Pangasius hypophthalmus*) in An Giang and Dong Thap Provinces. The objective of using (Figure 2).

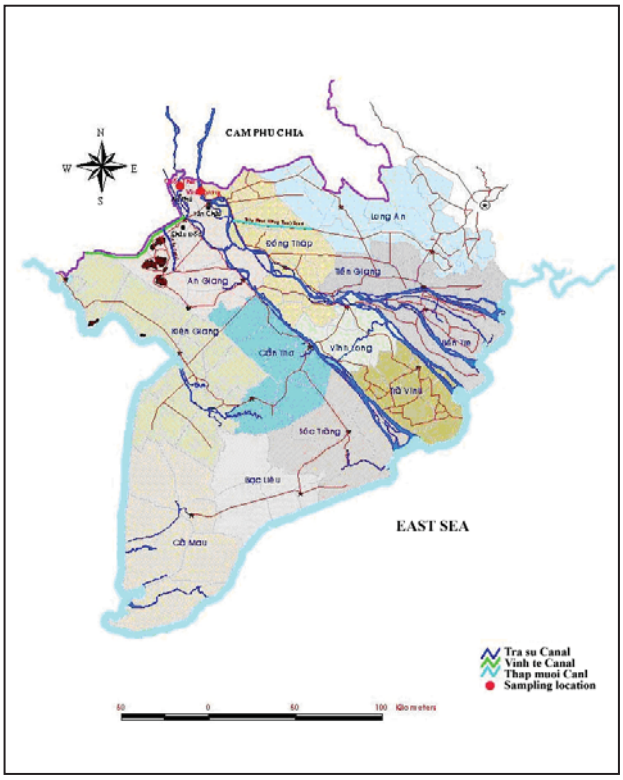

Figure 1. Map of sampling sites

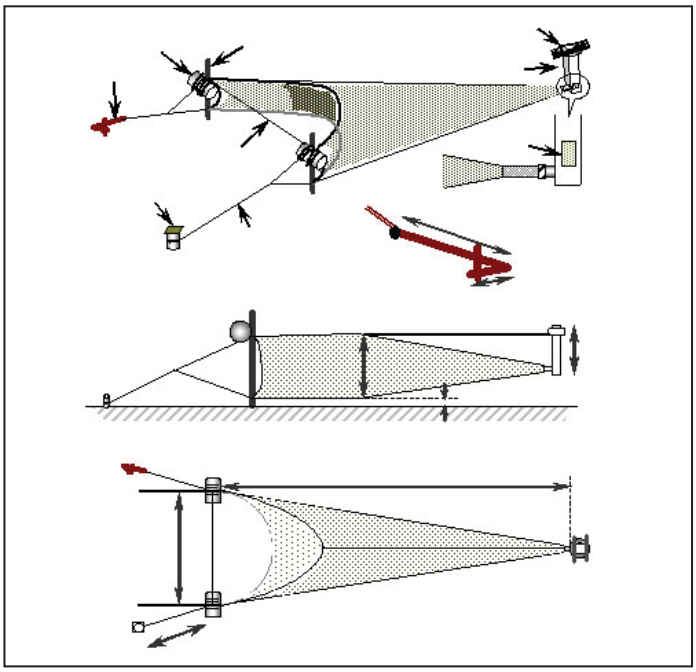

Figure 2. Nets used for sampling.

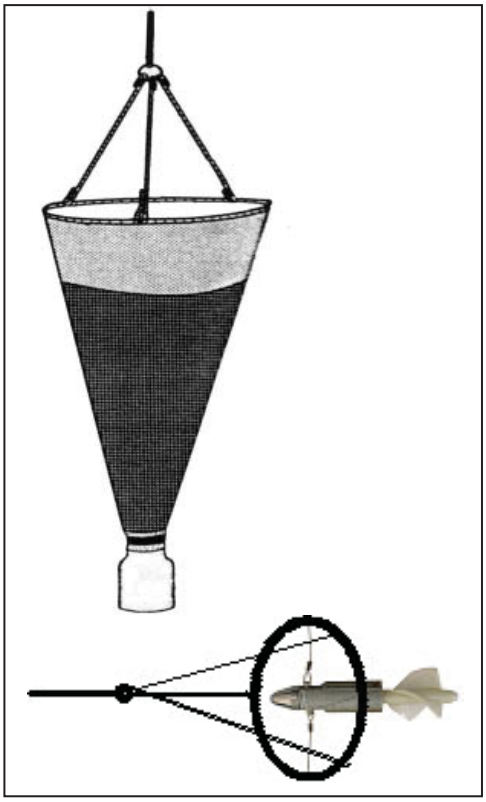

Figure 3. A second type of sampling net.

this sampling net was to qualitatively sample fish species and to identify them to genus or species. The second type of gear used for sampling was to determine species composition and density of fish larvae and juveniles at different sampling sites (Figure 3).

Sampling methods

- Regular samplings. Four samplings per month. Samples collected on two days with an interval of three hours between sampling.
- Other sampling techniques. Samplings over almost one complete day. Sampling began at 6:00am in the morning and continued until 5:00am the next morning. The duration of sampling was over a time period of 60 minutes. This took place during every hour, on one day each week. Samples were immediately fixed in 5 per cent formalin solution.
- Sampling took place during the main spawning period from May to September in the Mekong mainstream.

Number of samples

From 1999 to 2003, a total of 5,498 samples were collected (3,501 samples from Mekong River and 1,997 samples from the Bassac River).

Methods of sample analysis and taxonomy

Fish classification

Fish were classified using published literature by Rainboth (1996), Termvidchakorn (2003) and Pinder (2001).

All samples were deposited at the Division of Fisheries Resource, Research Institute for Aquaculture No.2, Ministry of Fishery, 116 Nguyen Dinh Chieu Street, District 1, Ho Chi Minh City.

Quantity of species composition

All fish species present in the samples were separated and counted by species type. In some cases there were thousands of fish larvae mixed with organic debris in samples. In these cases we took sub-samples using the following steps:

- Total weight of main sample (original sample) was measured
- Take out 3 sub-samples from different sampling sites
- Weight of sub-sample was measured
- Identifying species and counting number of larvae in each sub-sample
- Number of fish species is calculated by using following formula:

$$N_{tot} = \left(\frac{N_1}{W_1} + \frac{N_2}{W_2} + \frac{N_3}{W_3} \right) \times \frac{W_{tot}}{3}$$

Where:

N_{total} = number of larvae in the sample

W_{total} = total weight of main sample

N_1 = number of larvae in sub-sample1 W_1 = weight of sub-sample 1

N_2 =: number of larvae in sub-sample 2 W_2 = weight of sub-sample 2

N_3 = number of larvae in sub-sample 3 W_3 = weight of sub-sample

Data storage and analysis

All data were stored in MS Access and analyzed using Excel software.

Data on relationship of individual and species composition depends on different times in samplings. All data is converted by sampling or fishing time based on the formula:

Formula 1: *Identical- Index Jaccards*

J percentage of identical level, a similar number of fish in two different environments , b number of fish in environment 1 and c number of fish in environment 2.

$$J = \frac{a}{a+b+c} * 1($$

Formula 2: *Biological diversifying Index Shannon – Wiener*

H' = diversity of species composition P: probability of species I (abundant relationship) and S: total number of species.

$$H' = -\sum_{i=1}^{S_{obs}} p_i \text{ h } p_i$$

Where: CSC : later measuring value
CSD: previous measuring value
t : measuring time (unit: second)

RESULTS AND DISCUSSION

Species composition of fish larvae and juveniles and fluctuation of their production.

Species composition

During 1999 to 2003 a total of 5,948 samples were collected (3,501 samples collected at Vinh Xuong in the Mekong River, and 1,997 samples at Quoc Thai in The Bassac River). One hundred and thirty fish species belonging to 31 families and 11 orders were found. One hundred and thirty species were found in the Tien River and 125 species were found in the Hau River. The majority of the fish species were from Cyprinidae (actually occupying about one third of the total number of species). This family was the most diverse of all the families encountered in the in the Mekong Delta.

Results from Figure 6 showed that three orders have the largest number of species. These were Cypriniformes (53 species, and representing 40 per cent of the total), Siluriformes (27 species and representing 20 per cent of the total), and Perciformes (23 species and representing 17 per cent of the total). Other orders included Clupeiformes (6 species and representing 5 per cent of the total), Pleuronectiformes (6 species and representing 5 per cent of the total), and Synbranchiformes

(5 species and representing 4 per cent of the total). Four orders (Anguilliformes, Beloniformes, Tetraodontiformes and Osteoglossiformes) each had 3 species, and each represented 2 per cent of the total. Lastly, there was the order Syngnathiformes and species in this order represented only 1 per cent of the total.

In terms of orders, Perciformes had the highest number (9 families, 30 per cent), followed by Siluriformes (6 families, 20 per cent), and then Cypriniformes (4 families, 13 per cent). The family *Cyprinidae* had the highest number of species (44 species, 35 per cent), followed by the families of *Siluridae* (8 species, 6 per cent), *Gobiidae* (8 species, 6 per cent), *Pangasiidae* (8 species, 6 per cent), *Bagridae* (7 species, 5 per cent), and *Cobitidae* (6 species, 4 per cent). Four species in both the *Belontiidae* and *Clupeidae* (3 per cent). Three species in both the *Mastacembelidae* and *Cynoglossidae* (2 per cent). Thirty-two species were found in other families (25 per cent).

Our results on species composition are similar to previous studies on fish species composition in the Mekong Delta.

Several species found in the Mekong Delta are important for inland fish culture. Two of the most important of all are *Pangasius hypophthalmus* and *Pangasius bocourti*. Commercial export of several fish species from An Giang Province reached 100,000 tons in 2002 and 130,000 tons in 2003. From Dong Thap Province 30 tons were exported in 2002 and 33,000 tons in 2003. These two provinces border the Mekong and Bassac rivers providing good advantages for cage-culture activities. Recently, several provinces without the right conditions for cage-culture have developed river-catfish / pond-culture with very high yields of up to 200-300 tons/ha/crop on average. Other fish species used in aquaculture are also of high economic value and include: P*angasius larnaudii, Pangasius conchophilus, Labeo chrysophekadion, Osteochilus melanopleurus*, *Cyclocheilichthys enoplus, Silver barb Barbodes gonionotus, Barbodes altus, Micronema bleekeri*, *Anabas testudineus,* Sand goby *Oxyeleotris marmorata, Channa micropeltes, Channa striata, Clarias batrachus, Notopterus notopterus, Chitala ornata, Monopterus albus, Mystus filamentus,* and *Catlocarpio siamensis*. Of all the species found in Vinh Xuong and Quoc Thai, there are 19 species that are commonly cultured species in the Mekong Delta, and 6 species are recorded in the Red book of Viet Nam.

Species composition fluctuation of fish larvae and juveniles by years

During our 5-year study (1999 to2003) we found that the highest number of species of all were found in the year 2000 (130 species). This was followed by 125 species in 1999, 92 species in 2003, 77 species in 2002 and the lowest in 2001 (71 species) (Figure 4).

We examined the fluctuation in flooding in the Mekong Delta in relation to species composition. The crest of the flood was highest in 2000, with 490cm of flood water level. Generally, water levels fluctuated between 350 to 447cm in other years. The highest record we obtained was at Chau Doc in 2000 (506 cm), but during other years, the flood water level fluctuated between 406 to 482cm.

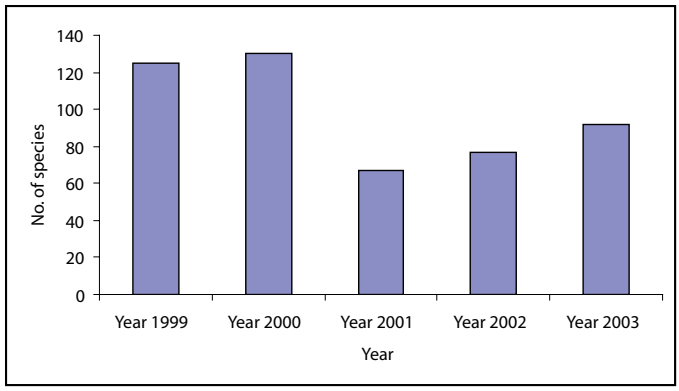

Figure 4. Species composition changes of fish larvae and juveniles by years

It appeared to us that the flood regime significantly influenced both spawning success and species composition in the lower Mekong Basin. In the year 2000 the strongest flood was recorded within 70 years of records being taken. It was also during this year that we found the largest number of species.

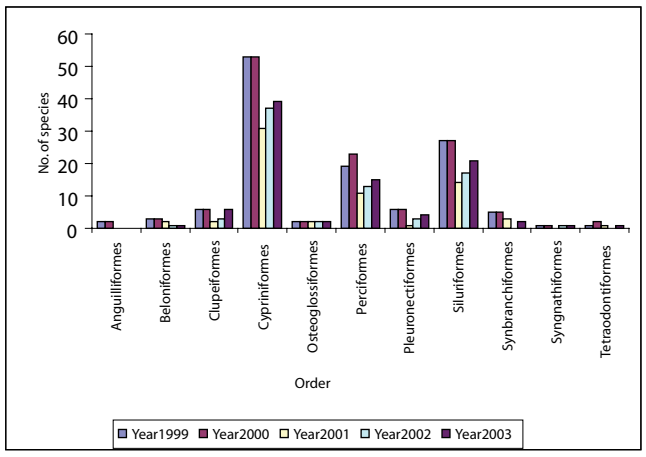

Figure 5. Variation in species composition during the 1999 to 2003 study

Figure 5 shows that the highest number of species appeared in three orders; Cypriniformes, Siluriformes and Perciformes. Previous studies have also confirmed these three orders contain the highest number of species.

Species composition fluctuation of fish larvae and juveniles by seasons

Species composition of fish larvae and juveniles clearly fluctuated during different seasons. At the beginning of the flood season, many species spawned resulting in more species appearing during this time. The number of species decreased at the end of the flood season (Figure 6). The annual flood causes many areas to become submerged. Fish move to these areas to spawn and grow. At the end of flood season they migrate back to canals and rivers.

- Species often appear at high density at the beginning of the flood season such as *Pangasianodon hypophthalmus, Clupeoides borneensis* and other species.
- Some species appear in the middle of the flood season such as *Henicorhynchus siamensis* and *Paralaubuca riveroi*.
- Some species appear at the end of flood season including *Rasbora daniconius* and *Pangasius siamensis*. Certain species often appeared in all samples, and at all times of the year such as *Henicorhynchus siamensis.*

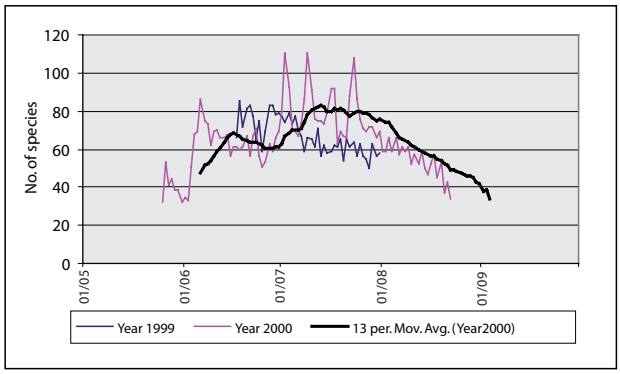

Figure 6. Changes in species composition by sampling period

In general, the number of species appears to be highest at the beginning of June until July.

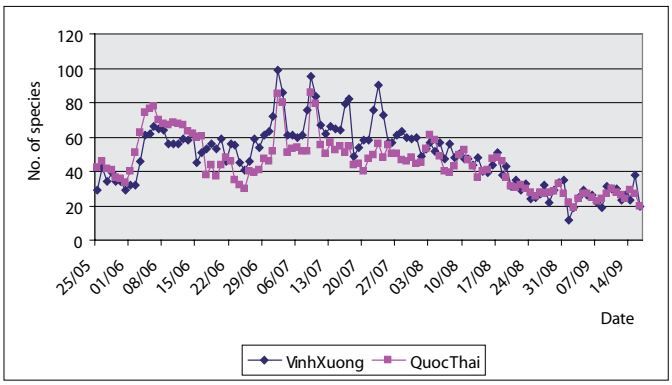

Figure 7. Changes in species fluctuation at two study stations

The fish species composition at two stations where the study took place (Vinh Xuong of Mekong River and Quoc Thai of Bassac River) were found to be similar. That is, more species at the beginning of flood season and then a gradual decline. By the end of the flood season the species composition was the lowest of all. Family composition also varied over the different seasons (Figure 7). This was probably due to the favourable spawning conditions at the start of the flood season in the Mekong Delta.

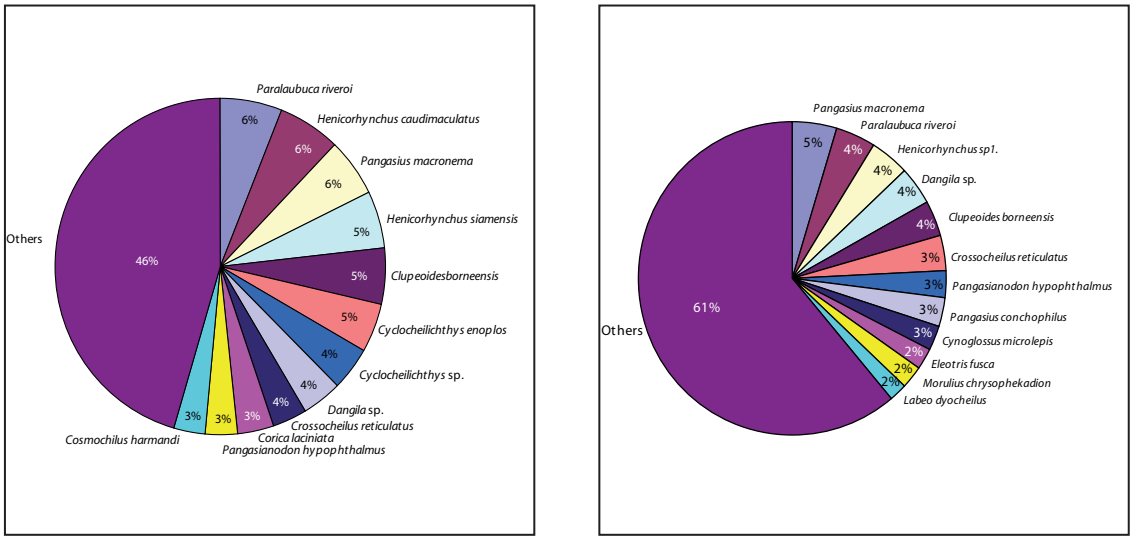

Figure 8. Species fluctuation of fish larvae and juvenile by day and night

Clearly there is a difference in species composition between day and night. Species appearing at night are mainly scale-less fish species and, in contrast, species appearing during the daytime were mainly fish species with scales. Some species show different frequencies of capture between day and night. Species that mainly appeared during the day included *Corica laciniata*, *Paralaubuca riveroi*. Species that mainly appeared during night included *Rasbora daniconius*, *R. myersi*, *Labeo chrysophekadion*, *Pangasius conchophilus*, *Pangasius macronema*, *Mastacembelus favus* and *Eleotris fusca* (Figure 8).

Light intensity also influences the distribution of fish species during day and night. Many catfish species live deep in the water column, coming up to the surface at night. The studies of Paller (1987) and Marchetti and Moyle (2000) also indicated that fish larvae and juveniles often appear more during the night than during the day. They also appear at different depths in the water column. Sheaffer and Nickum (1986) found that near to the water surface of the Mississippi River (America) the numbers of fish larvae and juveniles were as much as four times the number of species at the bottom of the river. Holland (1986) also had the same conclusion on species distribution of fish larvae and juveniles during day and night.

Frequency of species appearing

Of all the samples made, only very few samples with over 100 species appeared. Most samples contained 8 to 22 species but higher frequency of appearance, from 20 to more than 60 per cent (Figure 9). The species with frequency of appearance of more than 60 per cent are mostly common species cultured in the Mekong Delta.

The results of study showed that 34 species often appear within 60 to 90 days during the flood season; these species may be multiple-spawners or species that spawn at intervals during the flood season (Table 1).

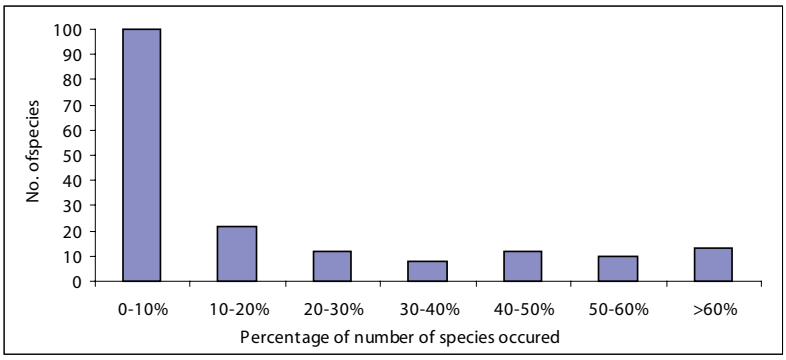

Figure 9. Frequency of appearance (%) of fish species

Table 1. *Relationship between number of species and days appearing*

Number of appearing days	Number of species
1 - 29	68
30 - 59	42
60 - 90	34

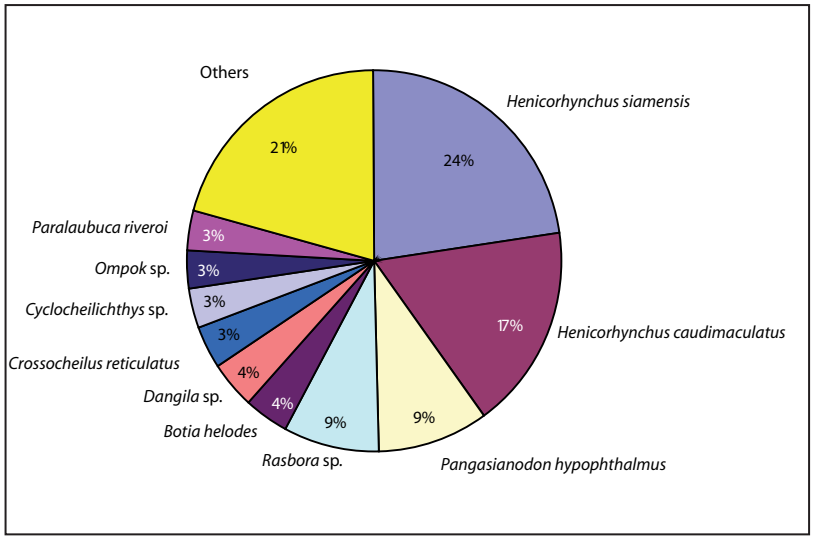

Figure 10. Main species in samplings (Per cent of species number)

Figure 10 indicates that the genus appearing most often with the highest number is *Henicorhynchus* (at around 40 per cent). *Henicorhynchus lobatus* occupies 17 per cent and *Henicorhynchus siamensis* occupies 23 per cent. *Pangasianodon hypophthalmus* occupies 9 per cent, *Rasbora myersi* (9 per cent), *Botia helodes* (4 per cent), *Cyclocheilichthys enoplus* (3 per cent), *Paralaubuca riveroi* (3 per cent), *Ompok hypophthalmus* (3 per cent).

Changes in abundance of fish larvae and juvenile

Abundance

There were five peaks of the number of individuals per hour linked to 5 peaks of the number of species. The first peak, with 354 individuals/hour, was recorded on 29/05/2000 and there was a second peak with 288 individuals/hour, recorded on 07/06/2000. A third peak with 916 individuals/hour was recorded 21/06/2000, and a fourth peak was recorded with 1,229 individuals on 25/06/1999 (Figure 11). (There was an earlier peak with 282 individuals/hour found on 19/07/1999.)

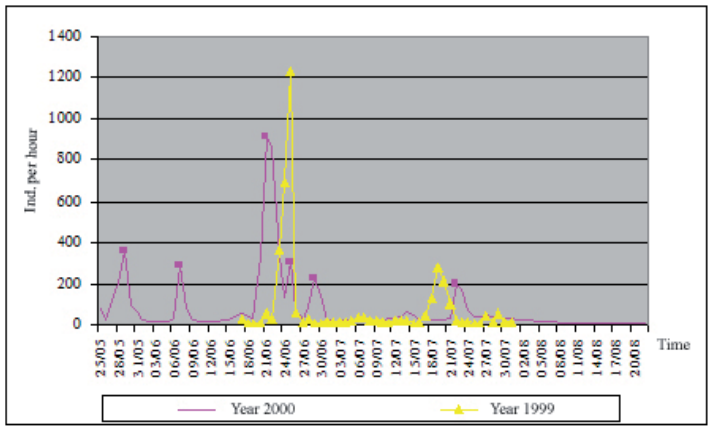

Figure 11. Variation of fish larvae in numbers in year 1999 and 2000

Number of individuals that produced the first peak mainly came from the following species: *Corica laciniata* (size range 12.8 to 16.0 mm in length) with 64 individuals per day. Other important species were *Clupeoides borneensis* (size range 10.6 to 12.3 mm), with 264 individuals/day, *Pangasianodon hypophthalmus*, (size range 11.6 to 17.69 mm) with 4,584 individuals/day; and *Eleotris fusca*, (size range 30.0 to 67.4 mm), with 114 individuals/day.

Number of individuals producing the second peak mainly came from the following species: *Henicorhynchus siamensis*, (size range 12.5 to 19.5 mm), with 1,686 individuals/day; *Pangasianodon hypophthalmus*, (size range 13.3 to18.3 mm), with 1,683 individuals/day, and *Rasbora daniconius*, (size range 8.6 to 11.0 mm), with 9,119 individuals/day.

Number of individuals producing the third peak mainly came from the following species: *Pangasius siamensis* (size range 16.4 to 29.8 mm), with 1,502 individuals/day, *Pangasianodon hypophthalmus* (size range 33.1 to 48.0 mm), with 152 individuals/day, *Paralaubuca riveroi* (size range 16.5 to 30.9 mm), with 588 individuals/day, *Dangila*, or *Labiobarbus* spp., (size range 17.7 to 28.0 mm), with 1,680 individuals/day; *Crossocheilus reticulatus* (size range 15.0 to17.1mm), with 964 individuals/day, and *Cyclocheilichthys enoplus* (size range 13.1 to 8.9mm), with 674 individuals/day.

Number of individuals producing the fourth peak mainly came from the following species: *Henicorhynchus siamensis* (size range 18.5 to 35.0 mm), with 2,011 individuals/day; *Paralaubuca*

riveroi (size range 20.3 to 20.8 mm), with 415 individuals/day; *Botia modesta* (size range 17.8 to 25.7 mm), with 735 individuals/day; *Cyclocheilichthys enoplus* (size range 14.3 to 21.8 mm), with 69 individuals/day; *Dangila* or *Labiobarbus* spp. (size range 25.0 to 39.1mm), with 512 individuals/day, and *Mystus filamentus* (size range 14.8 to 30.7 mm), with 181 individuals/day.

Number of individuals producing the fifth peak mainly came from the following species: *Henicorhynchus siamensis* and *Botia modesta*.

From the results we can estimate (or guess at) some of the most important species contributing to the 'peaks' mentioned above, and that may also be important in overall production of fish total catch in the Mekong Delta.

Diurnal changes

Figure 12 showed fluctuations and some production peaks during day and night. The highest was 1,007 individuals/hour at 07:00 hours and the lowest was 33 individuals/hour at 16:00 hours. In consideration of the diurnal cycle, the highest number of individuals appears at 07:00 hours, 11:00 hours, 19:00 hours and at 23:00 hours. The lowest number of individuals appears at 13:00 hours, 16:00 hours, 01:00 hours and at 04:00 hours. Many fish species spawn at different times during the diurnal cycle, and this may explain some of our findings.

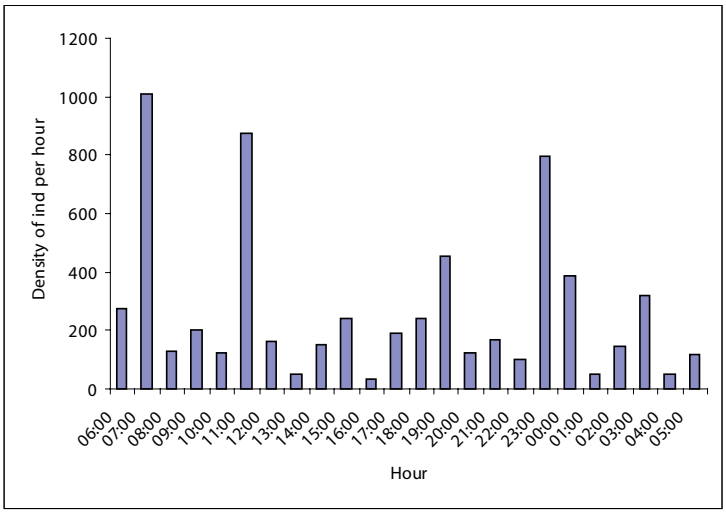

Figure 12. Diurnal capture of individual species (individuals/hour)

Density of larvae during the 1999-2003 study

Together with high individual numbers at the beginning of the flood season, due to many fish species spawning as described above, it may be possible to explain the variation in production peaks produced during this period. For instance, the sudden high number of individuals (reaching 1,229 individuals/hour) found on 25/06/1999. However, we have to look at average density over the five years of study. The density reached 0.98 individuals/m^3 at the beginning of the flood season, 1.2

individuals/m^3 in the middle of the flood season, and clearly decreased to 0.09 individuals/m^3 at the end of flood season (Figure 13).

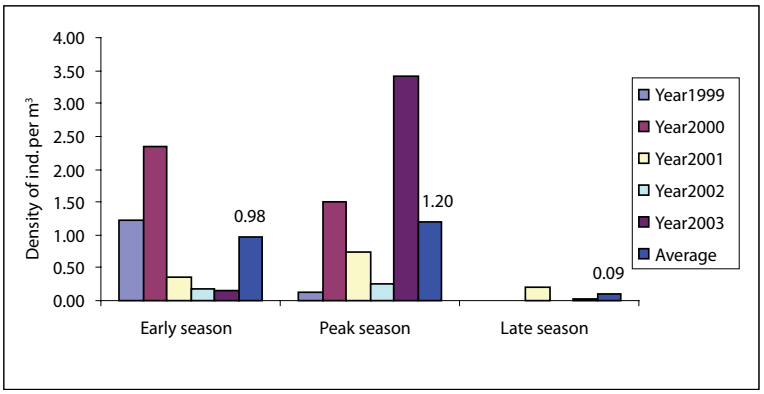

Figure 13. Changes in species (individuals/m^3) by season

Relationship between individual numbers of larvae and water flow

The amount of water in the Mekong Delta changes by season, from about 8,500 m^3/s at the beginning of the flood season, to about 30,650 m^3 at the end of July. This characteristic almost certainly influences the ecological conditions of fauna in the lower Mekong Basin, especially when these coincide with the spawning season of many species. Most species of fish spawn during the time at the beginning of the flood season due to changes in environmental conditions. Many of these changes are stimulated by floodwaters, and the areas that become inundated at this time.

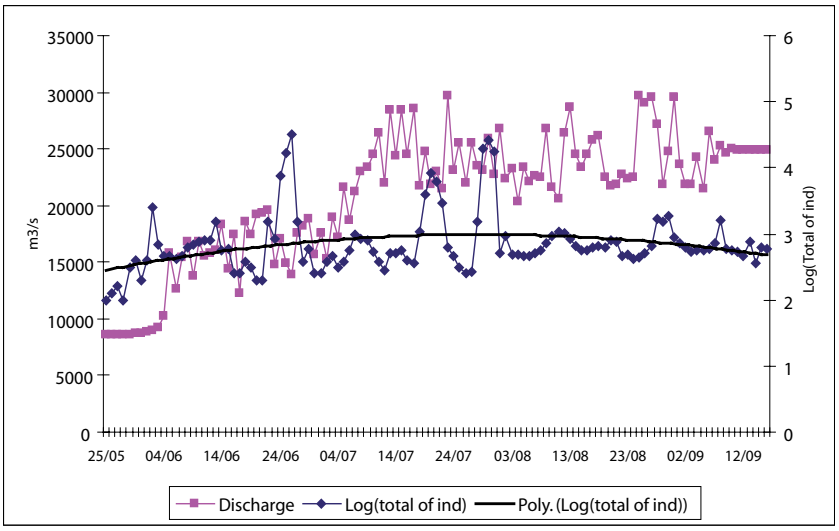

Figure 14. Relationship between water flows and number of individuals

At the beginning of the flood season, many fish species migrate to spawning areas. We estimate from our studies that at least 75 species do this, whilst only 12 species appeared at the end of the rainy season. Fish larvae and juvenile fish collected during our study were also recorded as

changing from 31,789 individuals/day at the beginning of the season, to 195 individuals/day at the end of the flood season. This phenomenon may be due to their own adaptation to environmental conditions as well as flows. These adaptations are also important for maintaining lifecycles and their offspring, because floods create spawning and feeding grounds for their development and growth. One of our main conclusions is that the spawning season coincides with the beginning of flood season, although for some species, spawning lasts for several months after this time for some tropical fish species (Figure 14).

Fish density (individuals/m^3) appearing in different river sections

There are clearly differences in the density of fish larvae and juveniles between different river sections. The highest densities we recorded close to the riverbank was 9 individualsds/m^3 or slightly further away from the bank was 4 individualsds/m^3. The lowest density was found in the middle of the river with 2 individuals/m^3. Thus, the migration of larvae, and juveniles appears to depend on water flows, and appear to be sustained by slow flow rate. In the middle of the river, flow rate is strongest at around 0.82 m/s. Fish density is therefore highest when fish larvae are near to the riverbank where the flow rate is around 0.58 m/s resulting in high fish larvae densities (Figure 15).

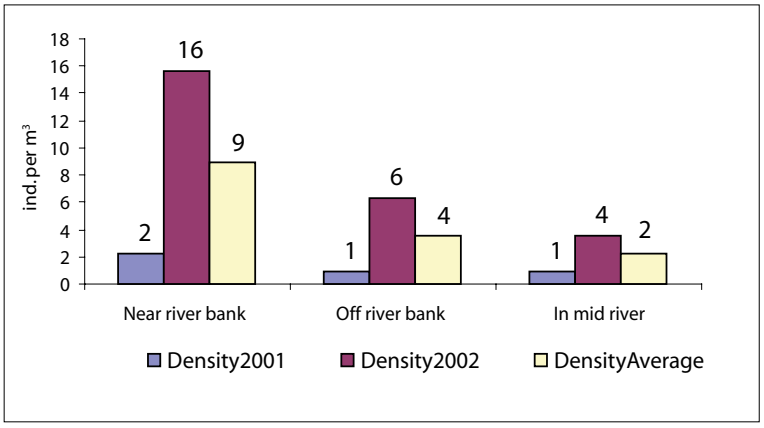

Figure 15. Fish density (individuals/m^3) at different river sections

CONCLUSIONS

1. After a 5-year study (1999-2003), fish larvae and juveniles at the two study sites in the lower Mekong Basin, it was determined that at least 130 species in 31 families and 11 different orders of fish were identified. Of all the species identified, 19 species are known to be commonly cultured species in the Mekong Delta (aquaculture), as well as valuable for export markets to several countries in the region.

2. Species composition, and the numbers of fish larvae and juveniles species clearly change with season, and are influenced by the annual flood cycle in the Mekong Delta.

3. Spawning season mainly takes place in the flood season from June to August. Larval densities decrease at the end of the of the flood season.

4. Density of larvae and juveniles along both sides of the river is higher than that in the central parts of the river. Density of larvae and juveniles is around 9 individuals/m^3 and 4 individuals/m^3 respectively, while only about 2 individuals/m^3 were found in the in central parts of rivers.

SUGGESTIONS AND RECOMMENDATIONS:

1. Biological and ecological characteristics of fish larvae and juveniles should be studied for the identification of new candidates of economic species for fish culture, or as subjects for research into river fisheries.

2. The study of natural species, their distribution and their spawning grounds for economic species should be continued with a view to their conservation and protection.

3. Studies involving the artificial propagation of indigenous species for inland aquaculture, and restocking into rivers should be encouraged, but with some caution.

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