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Larval fish movement in the River Lohajang, Tangail, Bangladesh

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Abstract Larval fish drift and distribution patterns were studied in the River Lohajang, a tributary of the River Jamuna, Bangladesh, during the monsoon seasons (June–October) of 1992, 1993 and 1994. Larval fish drift peaks with the water levels of the River Jamuna. In all three years, the Indian carp, *Catla catla*, *Labeo rohita* L. and *Cirrhinus mrigala*, were associated with the first pulses, but were absent from drift samples after September. *Hilsa* species and other non-identified fish species were found throughout the monsoon season. The highest larval fish densities were found in the upper strata of the river, near the shore. The drift densities of these fish became evenly distributed through time. Water turbidity probably influenced the vertical and horizontal distribution, and the absence of diel patterns. The most important species in the larval drift were *Hilsa* spp., followed by *Labeo rohita* L., *Glossogobius giuris* L. and *Rasbora daniconius*. Among the major carp, *Labeo rohita* was the dominant species, contributing 80–90%. The impact of flood control programmes on the reproduction of riverine and larval fish drift is discussed.

KEYWORDS: Bangladesh, diel and spatial distribution patterns, flooding, *Hilsa* spp., Indian carp, larval fish drift.

Introduction

Bangladesh is drained by three principal river systems: the Brahmaputra (Jamuna); the Ganges (Padma); and the Meghna. The annual aggregate inland fisheries production of Bangladesh is ≈ 450 000 Mt (50–60% of the total national fisheries production). These catches are important to the economy and food supply of Bangladesh (DOF 1983–1991), accounting for 6% of its gross domestic product, 12% of its export earnings and 70–85% of the animal protein intake of the country (Bangladesh Bureau of Statistics 1989). Total river fisheries production has declined by 44%, from 207 000 Mt in 1983 to 124 000 Mt in 1991 (DOF 1983–1991). During the same period, the annual riverine catch of major Indian carp, *Labeo rohita* L., *Catla catla* L. and *Cirrhinus mrigala* L., declined 77% from 9000 Mt to 2000 Mt.

Inland fisheries production in Bangladesh, as in other exploited floodplain fisheries around the world, is strongly related to flood sequence. Floodplains inundated during monsoons are

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nutrient rich and play a significant role as nurseries for many larvae and juvenile fish species (Welcomme 1985; Bayley 1988; Junk, Bayley & Sparks 1989). Between 1970 and 1990, about 2.1 million ha of floodplain were removed from river fisheries production because of the construction of levees (Siddiqui 1990). Over-exploitation of inland fish stocks has also been reported (Tsai & Ali 1985, 1987; Ahmed 1992) and is an important factor in the observed declines.

The major carp in Bangladesh are comprised of three stocks: the Brahmaputra; the Padma; and the Upper Meghna (Tsai & Ali 1985). The Brahmaputra stock is the largest, with spawning grounds located in the southern tributaries of the river in the Assam Hills and in the Letha Range, Assam, India (Alikhundi 1957; Jhingran 1991). Upstream migration of adult major carp in the Brahmaputra system starts in March, coinciding with the gradual rise of water level. Spawning on floodplains begins in May with the onset of the south-west monsoon and continues until the end of July (Shaha & Haque 1976; Azadi 1985; Tsai & Ali 1985).

In Tangail, Bangladesh, only normal floods are allowed to enter the floodplain. High and dangerous flood levels are controlled. To minimize any possible negative effects of controlled flooding on fisheries, a maximum number of fish hatchlings should be allowed to enter the River Lohajang and its adjacent floodplains in the project area. The present study, part of the Compartmentalisation Pilot Project (CPP), investigated larval fish movement and distribution patterns in the main channel of the River Lohajang, Bangladesh, during the monsoons of 1992, 1993 and 1994.

Materials and methods

Sampling

The River Lohajang, located in the Tangail district, is a tertiary river, 80–120 m wide, with an average depth of 3–4 m and a peak flow of 80–100 $m^3 s^{-1}$. It is connected with the major River Brahmaputra system through a secondary river, the River Dhaleswari. The River Lohajang establishes a hydraulic connection with the River Dhaleswari in June–July, after the onset of the monsoon. This connection is disrupted once flood waters recede in October. For the rest of the year, the River Lohajang is dry except for some pools.

Sampling was conducted north of the town of Tangail, in the vicinity of the village of Jugini (Fig. 1). The present study covered three monsoon periods (1992–1994). Vertical larval distribution patterns were studied during 1992 and 1993. In 1993, horizontal larval distribution patterns were also studied. In 1994, larvae were only sampled in the surface strata. To facilitate species identification, some captured larval fish were reared in a laboratory.

Larval fish sampling was conducted with nets made of mosquito netting (0.5-mm mesh). The opening was made of an iron frame with an area of 0.125 m^2 (0.25 m high × 0.5 m wide). The net had a total length of 2 m with a 0.4-m-long cod-end made of fine nylon cloth. In 1992 and 1994, a set of nets was placed 3 m from the bank. In 1993, one set of nets was placed in the mid-channel of the river and another set was placed 3 m from the bank. Each set consisted of a net placed 30 cm above the bottom and a second net placed 5 cm below the surface. The shore and mid-channel nets were fished for 1 h during the day (between 0800 and 1200 h), while at

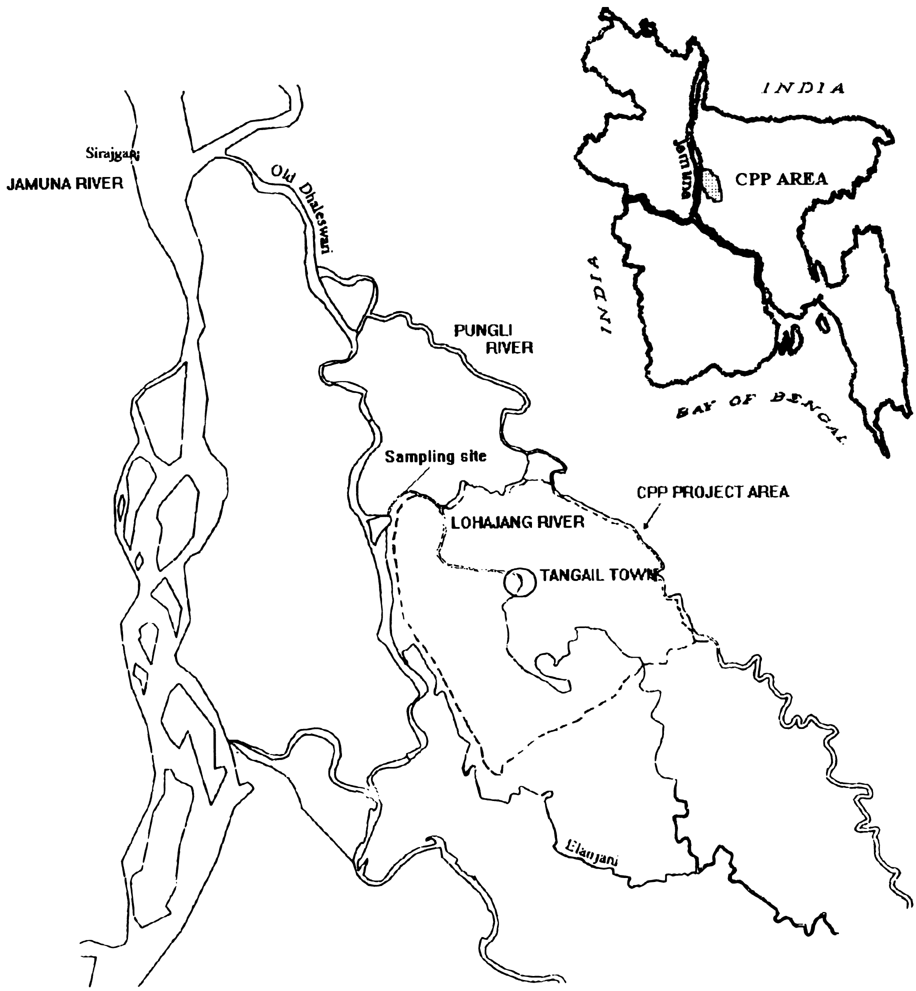

Figure 1. Location of the Compartmentalisation Pilot Project area and the sampling site in the River Lohajang.

night, only the shore nets were fished for 1 h (between 1930 and 2200 h). Current velocity was measured once the nets were in place. In 1992, current velocity was determined with a floating object. In subsequent years, a flowmeter was used to measure current velocity immediately in front of the nets.

The larval fish collected by this method were counted, preserved in formaldehyde (8%) and later separated into three groups, carp, *Hilsa* spp. and others, as described by Jhingran (1991) and Shafi & Quddus (1982). Total length (nearest 0.1 mm) was measured for all fish larvae caught near the levee in the top and bottom net during June and July 1993.

During the monsoon of 1994, a net was placed near the embankment in the surface strata of the water for 5–10 min. All fish larvae collected were removed from the net, counted and transported alive to a laboratory. All larvae caught in one day were kept in a plastic container (5 L) and fed *ad libitum* nauplii of *Artemia salina*. After 2–3 weeks, most of the fish larvae reached a total length of 1–3 cm, after which the species were identified according to Rahman (1989).

The water levels of the River Jamuna were provided by the Bangladesh Water Development Board and were measured at Sirajganj (Fig. 1).

Data analyses

Previous studies, which did not take flow rate into consideration, reported that most larval fish drifted and were caught in the upper strata of the river, and that larval fish drift in the middle and near the shoreline of the river was not significantly different (de Graaf, Born, Uddin & Huda 1994). However, water velocity in rivers can change with water depth and distance from the river bed (van Rijn 1993). Consequently, different volumes of water can pass through nets at different locations. To correct for this, larval density was expressed as the number of larval fish m^{-3} in the present study. The mean values for carp were calculated from the first date of sampling until 31 August and all other values were calculated over the complete sampling period.

Statistical analyses were conducted with the SYSTAT computer program; probability levels are provided in absolute values. Differences between years in larval fish densities obtained from surface nets were tested with a one-way analysis of variance (ANOVA). The influence of location and time of sampling on mean larval fish density, within years was tested with Student's *t*-test.

Results

In total, 1370 samples were taken resulting in the capture of 19 760 fish larvae.

Seasonal fluctuation in larval densities and water level

The seasonal variation in the density of larval carp, *Hilsa* spp. and other fishes, as measured near the shoreline in the surface strata of the water during the period from 1992 to 1994 is presented in Figure 2. Larval fish were transported through the system in pulses. The peak pulses were related to the peak water levels of the River Jamuna. In all three years, carp were collected during the first pulses (June–August), but were absent after 1 September. *Hilsa* spp., as well as other species, were collected throughout the entire monsoon season. During 1992 and 1993, the maximum density of all species combined did not exceed 0.9 fish m^{-3} (Table 1). During 1994, drift of larval fish increased to 9.3 larvae m^{-3}, primarily as a result of higher densities of *Hilsa* spp.

The average water level during both 1992 and 1994 was 12.1 m. The average water level in 1993 was 12.9 m and this was considered to be a normal flood year. The density of carp larvae was significantly higher in 1993 ($P \leq 0.05$), but did not differ between 1992 and 1994. Furthermore, the summed daily water levels above 12 m, the level when the floodplain was inundated, appeared to be correlated with larval carp densities ($P = 0.06$). The mean density of *Hilsa* spp. and other non-identified species was significantly higher in 1994, but did not differ between the two preceding years.

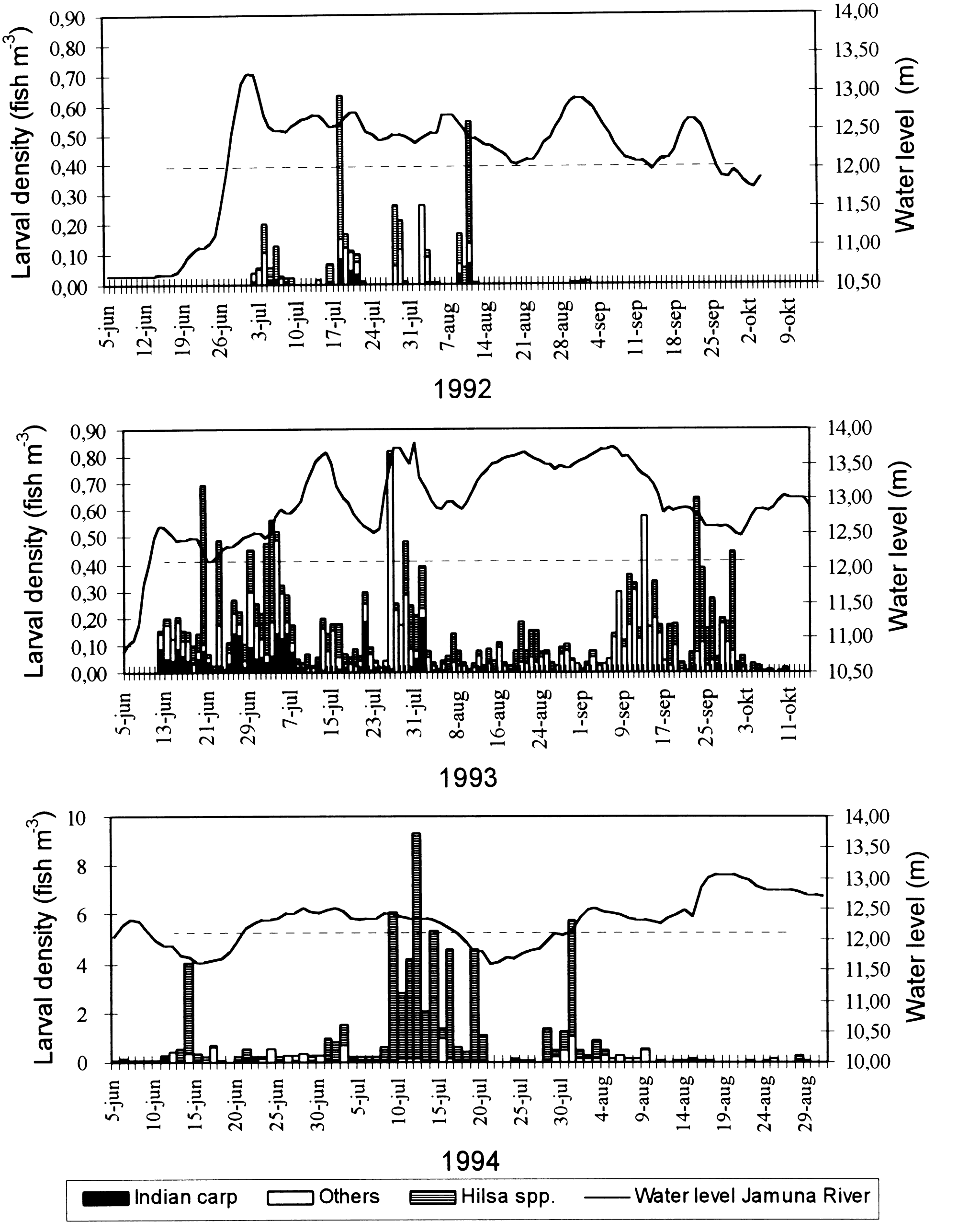

Figure 2. Larval densities (fish m^{-3}) in the River Lohajang and water level (m) of the River Jamuna as registered during the monsoon of 1992, 1993 and 1994.

Table 1. Mean density values (fish $m^{-3} \pm$ SE) of drifting larvae collected from surface waters near the shoreline and mean water level of the River Jamuna, during the monsoons of 1992, 1993 and 1994*

	Year		
	1992	1993	1994
Indian carp (fish m^{-3})	0.008 ± 0.005[a]	0.029 ± 0.004[b]	0.010 ± 0.004[a]
Hilsa spp. (fish m^{-3})	0.038 ± 0.136[a]	0.064 ± 0.085[a]	0.676 ± 0.100[b]
Other species (fish m^{-3})	0.025 ± 0.020[a]	0.072 ± 0.012[a]	0.127 ± 0.014[b]
River Jamuna water level (m)	12.1 ± 0.059[a]	12.9 ± 0.051[b]	12.1 ± 0.035[a]
Summed daily water level (m) above 12 m during the first 8 weeks of the flood	28.8	44.7	10.20

*Values among years not followed by a common superscript are significantly different ($P \leq 0.05$).

Diel and spatial distribution pattern

In 1992 (Table 2), the density of all fish larvae and non-carp larvae was higher in the surface strata at night. For larval carp in 1992, no significant differences in vertical distribution in density were found. In 1993, the absolute density (fish m^{-3}) of all larvae and of non-carp was significantly higher in the surface layer of the water column ($P \leq 0.05$). The mean length of larvae caught during 1993 was 5.9 ± 0.1 mm (n = 255) and 6.1 ± 0.1 mm (n = 298) for nets in the surface and bottom strata, respectively. These mean lengths were not significantly different.

The combined density of all fish larvae was significantly higher near the shoreline of the river compared with the mid-channel (Table 3). During 1992, proportionally more larval carp were found during the day near the bottom, compared with 1993, when proportionally more non-carp larvae were found near the bottom at night (Table 4). There were no significant temporal differences in larval fish densities for other groups of fishes.

Table 2. Mean density (fish $m^{-3} \pm$ SE) of Indian carp, non-carp and all larval fish collected during 1992 and 1993 using nets placed near the surface, near the bottom of the channel and near the shoreline of the River Lohajang*

	Year			
	1992		1993	
Larval type/time/location	Surface	Bottom	Surface	Bottom
Carp/day/shore	0.009 ± 0.003[a]	0.012 ± 0.003[a]	0.032 ± 0.007[a]	0.034 ± 0.008[a]
Non-carp/day/shore	0.068 ± 0.018[a]	0.040 ± 0.010[a]	0.143 ± 0.014[a]	0.103 ± 0.013[b]
All/day/shore	0.076 ± 0.020[a]	0.051 ± 0.012[a]	0.165 ± 0.015[a]	0.126 ± 0.016[b]
Carp/night/shore	0.009 ± 0.003[a]	0.005 ± 0.002[a]	0.020 ± 0.004[a]	0.023 ± 0.005[a]
Non-carp/night/side	0.121 ± 0.032[a]	0.059 ± 0.013[b]	0.140 ± 0.013[a]	0.149 ± 0.017[a]
All/night/shore	0.129 ± 0.034[a]	0.064 ± 0.014[b]	0.153 ± 0.014[a]	0.164 ± 0.019[a]
Carp/day/channel	–	–	0.019 ± 0.004[a]	0.012 ± 0.003[a]
Non-carp/day/middle	–	–	0.080 ± 0.011[a]	0.015 ± 0.003[b]
All/day/channel	–	–	0.094 ± 0.012[a]	0.023 ± 0.005[b]

*Values within years and sites not followed by a common superscript are significantly different ($P \leq 0.05$).

Table 3. Mean density (fish m^{-3} ± SE) of Indian carp, non-carp and all larval fish collected during 1993 using nets placed in the channel and along the shoreline near the surface and bottom of the River Lohajang*

Larval type/location in water column/time	Location	
	Side	Middle
Carp/surface/day	0.032 ± 0.007[a]	0.019 ± 0.004[a]
Non-carp/surface/day	0.143 ± 0.014[a]	0.082 ± 0.011[b]
All/surface/day	0.165 ± 0.015[a]	0.094 ± 0.012[b]
Carp/bottom/day	0.034 ± 0.008[a]	0.012 ± 0.003[b]
Non-carp/bottom/day	0.103 ± 0.013[a]	0.015 ± 0.003[b]
All/bottom/day	0.126 ± 0.016[a]	0.023 ± 0.005[b]

*Different superscript letters indicate significant differences ($P \leqslant 0.001$) between the shoreline and channel of the river.

Species composition

Most fish larvae caught during 1994 consisted of a *Hilsa* spp. These fish did not feed on the supplied nauplii of *Artemia salina,* and consequently, all died within 1–2 days, precluding species identification. However, the following non-*Hilsa* species fed on Artemia, survived and were identified: *L. rohita, C. catla, C. mrigala, Crossocheilus latius*, *Glossogobius giurus, Rasbora daniconius*, *Macrognathus aculeatus*, *Labeo calbasu*, *Salmostoma bacaila*, *Clarias battrachus*, *Lepidocephalus guntea*, *Puntius* spp., *Esomus danricus, Chanda* spp. and *Gagata viridescens*.

Species composition (excluding *Hilsa* spp.) based upon weekly samples in the River Lohajang during the period from 10 June to 31 August 1994 is presented in Figure 3. Overall species composition during the sampling period is presented in Table 5. The dominant species in the larval fish drift (*Hilsa* spp. excluded) were *L. rohita*, *G. giuris* and *R. daniconius*. Among the major carp, *L. rohita* was the dominant species, contributing 80–90% to the total number of Indian carp larvae. All Indian carp were present in the River Lohajang within the first 6–8 weeks of the flood.

Table 4. Mean density (fish m^{-3} ± SE) of Indian carp, non-carp fish and all larval fish collected during day- and night-time samples in 1992 and 1993 in nets placed near the surface along the shorelines of the River Lohajang*

Larval type/location in water column	Year			
	1992		1993	
	Daytime	Night-time	Daytime	Night-time
Carp/surface	0.009 ± 0.003[a]	0.009 ± 0.003[a]	0.032 0.007[a]	0.020 ± 0.004[a]
Non-carp/surface	0.068 ± 0.018[a]	0.121 ± 0.032[a]	0.143 0.014[a]	0.140 ± 0.013[a]
All/surface	0.076 ± 0.020[a]	0.129 ± 0.034[a]	0.165 ± 0.015[a]	0.153 ± 0.014[a]
Carp/bottom	0.012 ± 0.003[a]	0.005 ± 0.002[b]	0.034 ± 0.008[a]	0.023 ± 0.005[a]
Non-carp/bottom	0.040 ± 0.010[a]	0.059 ± 0.013[a]	0.103 ± 0.013[a]	0.149 ± 0.017[b]
All/bottom	0.051 ± 0.012[a]	0.064 ± 0.014[a]	0.126 ± 0.016[a]	0.164 ± 0.019[b]

*Different superscript letters indicate significant differences ($P \leqslant 0.05$) between samples.

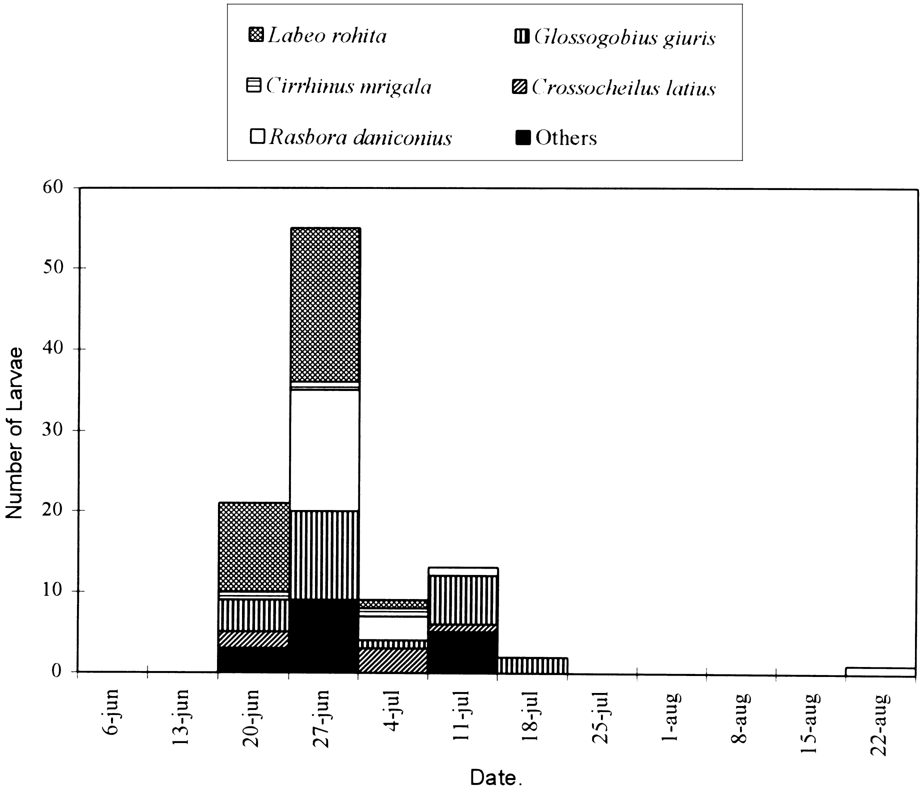

Figure 3. Species composition of drifting larvae in the River Lohajang during the monsoon of 1994.

Discussion

Densities and seasonal variation

Reproduction of Indian carp, as also found for other tropical stream or floodplain fishes, is tuned to water level fluctuations, such that reproduction takes place when the rain is abundant and the water level is rising (Lowe-McConnell 1975; Kramer 1978; Azadi 1985; Welcomme 1985). With the rising water level, breeding grounds are inundated and the adult carp move in, and most likely spawn, during these high water periods. Jhingran (1991) stated that the availability of carp spawn is linked with the elevation attained by the flood at its peak, when spawning areas are flooded. This was confirmed by the present study because the larval carp density appeared to be correlated with the summed water level above 12 m (Table 1). Furthermore, in 1993, which was a year with normal flooding, significantly higher carp densities were found than during 1992 and 1994, which were relatively dry years. Flooding of upstream spawning areas is considered important for natural stocking of downstream floodplain areas. Therefore, protection of the spawning areas is important to the perpetuation of Indian carp stocks.

Table 5. Species composition of drifting fish larvae (*Hilsa* spp. excluded) in the River Lohajang during the 1994 monsoon

Species	Percentage of total number (%)
Labeo rohita	30.4
Cirrhinus mrigala	2.9
Catla catla	0.9
Crossocheilus latius	5.8
Glossogobius giuris	23.5
Rasbora daniconius	19.6
Other species	16.7

Larvae of Indian carp cannot move actively against currents with speeds > 0.1 m s^{-1} (Mitra 1968), and consequently, eggs and larvae are flushed from spawning grounds with receding flood waters and are transported passively downstream to the lower lying floodplains which serve as nursery area. Similar transport of larval fish were reported by Corbett & Powles (1986), Naesje & Jonsson (1986) and Bogdanov, Melnichenko & Melnichenko (1991).

The present study indicated that spawning of Indian carp in the River Brahmaputra took place during the first 8–10 weeks of the monsoon flood. In controlled flooding schemes, recruitment of Indian carp can only be obtained if routes between the river and the floodplain are maintained open during this period.

Mean density of non-carp fish larvae and *Hilsa* spp. was not significantly related to mean water levels, indicating that reproduction of these fish is less dependent on flooding than is the case for Indian carp. Earlier studies reported that Indian shad, *Hilsa ilisha* (Hamilton), spawns in rivers (Jones & Menon 1951) and that the contribution of *G. giuris* (classified as non-carp) to the total fish catch in the area studied remained more or less constant during the 3 years of the present study (de Graaf *et al.* 1994). The reason for the higher densities of *Hilsa* spp. in 1994, compared with the 2 preceding years is not clear.

The larval densities of 1–10 m^{-3} found in the present study were comparable with the densities of 0.05–19 larvae m^{-3} which have been reported for temperate waters (Clifford 1972; Naesje & Jonsson 1986; Iguchi & Mizuno 1990; Bogdanov *et al*. 1991; Shestakov 1991; Tsukamato 1991) and 0.8–50 larvae m^{-3} which have been reported for the tropical Amazon basin (Pavlov, Nezdoliy, Urteaga & Sanches 1995). However, these densities are lower than the peak density of 250 *Bryconamericus* spp. larvae m^{-3} reported for two Andean piedmont streams (Flecker, Taphorn, Lovell & Feifarek 1991) and 600 *Osmerus eperlanus* larvae m^{-3} found in the River Elbe (Sepulveda, Thiel & Nellen 1993). However, these higher densities could be caused by accumulation of larvae as a result of active movement during low water regimes in the dry season for *Bryconamericus* spp. and active tidal vertical migration for *O. eperlanus*.

Distribution patterns

Vertical distribution patterns of drifting larval fish have been reported previously, with higher densities at the surface for *Coregonus peled*, *Coregonus tugun* (Bogdanov *et al*. 1991) and *Chondrostoma nasus* (Hofer & Kirchhofer 1996), with higher densities at mid-depth for *Stizostedion vitreum vitreum* (Corbett & Powles 1986) and with more larvae drifting near the bottom for *Acipencer* spp. (Veshchev & Novikova 1983).

Vertical migration of larval fish is related to their buoyancy, phototaxis, vertical distribution of food organisms and hydraulic features of the stream (Pavlov 1994). Current velocity is a consideration regarding larval fish drift because it becomes uncontrolled if the larvae can no longer counteract the current. Currents in the River Lohajang were always higher than 0.1 m s^{-1}, the maximum velocity Indian carp can withstand (Mitra 1968). Significantly more larvae were found in the surface strata of the River Lohajang than in the bottom strata. Similar results were reported by Pavlov (1994) for fish larvae in the River Amazon. Pavlov (1994) found that larvae from the same taxonomic group migrated in different layers of the water column in different rivers. In a turbid river (e.g. the River Amazon), Characiformes larvae migrated through the mid-depth/surface, while in a clear-water river (e.g. the River Nanay), these migrated through the mid-depth layer. The River Lohajang is a turbid river, and its turbidity or sediment load may be a regulating force in vertical and horizontal distribution patterns of fish larvae. The implication for water management interventions of finding that fish larvae are drifting through the surface strata is that water control structures should be of an overshot-type, taking the water from the surface layer of the water course to maximize larval influx.

Downstream migration of freshwater fish larvae is usually nocturnal (Pavlov, Pakuhorukov, Kuragina, Nezodoliy, Nekrasova & Elsler 1977; Potter 1980; Muth & Schmulbach 1984; Naesje & Jonsson 1986; Iguchi & Mizono 1990; Flecker *et al*. 1991). The ecological significance of this behaviour could be the avoidance of predators (Solomon 1982; Naesje & Jonsson 1986) or the induction of hatching activities by decreased light intensities (Price 1940; John & Hasler 1956). Disorientation of the larvae against the current has been indicated by Pavlov *et al*. (1995) for fish larvae in the Amazon Basin. Pavlov *et al*. (1995) found that fish larvae in rivers with transparent water moved primarily at night, and in rivers with turbid waters, the mean concentration of fish during daylight and night were of the same order. The latter apparently occurred in the present study since no clear diel distribution patterns were found in the River Lohajang, a turbid river.

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References

Ahmed M. (1992) Determination of fisheries benefits from floodplain riverine systems in Bangladesh: a mathematical programming approach. *Aquaculture and Fisheries Management* **23,** 599–622.

Alikhundi K.H. (1957) Fish culture in India. *Bulletin of the Indian Council Agriculture Research* **2,** 144 pp.

Azadi M.A. (1985) Spawning of commercial freshwater fish and brackish and marine water shrimps of Bangladesh. *Bangladesh Fisheries Information Bulletin* **2,** 74 pp.

Bangladesh Bureau of Statistics (1989) *Statistical Yearbook of the Bangladesh Statistics Division.* Dhaka: Ministry of Planning, 115 pp.

Bayley P.B. (1988) Factors affecting growth rates of young floodplain fishes: seasonality and density dependence. *Environmental Biology of Fishes* **21,** 127–147.

Bogdanov V.D., Melnichenko S.M. & Melnichenko I.P. (1991) Descent of larval whitefish from the spawning region in the Man'ya River (lower Ob Basin). *Journal of Ichthyology* **31,** 776–782.

Clifford H.F. (1972) Downstream movement of white sucker, *Catostomus commersoni*, in a brown-water stream of Alberta. *Journal of the Fisheries Research Board of Canada* **29,** 1091–1093.

Corbett B.W. & Powles P.M. (1986) Spawning and larval drift of sympatric walleyes and white suckers in an Ontario stream. *Transactions of the American Fisheries Society* **115,** 41–46.

Department of Fisheries (DOF) (1983–1991) *Fish Catch Statistics of Bangladesh.* Dhaka: Department of Fisheries, 36 pp each year.

Flecker A.S., Taphorn D.C., Lovell J.A. & Feifarek B.P. (1991) Drift of characin larvae, *Bryconamericus deuterodonoides*, during the dry season from Andean piedmont streams. *Environmental Biology of Fishes* **31,** 197–203.

de Graaf G.J., Born A.F., Uddin A.M.K. & Huda S. (1994) *Final Report Special Fisheries Study.* Compartmentalisation Pilot Project, FAP 20, Technical Note 94/10, Tangail, 87 pp.

Hofer K. & Kirchhofer A. (1996) Drift, habitat choice and growth of the nase (*Chondrostoma nasus,* Cyprinidae) during early life stages. In: A. Kirchhofer & D. Hefti (eds) *Conservation of Endangered Freshwater Fish in Europe*. Basel: Birkhause Verlag, pp. 269–278.

Iguchi K. & Mizono N. (1990) Diel changes of larval drift among amphidromous gobies in Japan, especially *Rhinogobius brunneus. Journal of Fish Biology* **37,** 255–264.

Jhingran V.G. (1991) *Fish and Fisheries of India.* Delhi: Hindustan Publishing Corporation (India), 727 pp.

John K.R. & Hasler A.D. (1956) Observations on some factors affecting the hatching of eggs and the survival of young shallow water cisco, *Leucichthys artedi* LeSueur, in Lake Mendota, Wisconsin. *Limnology and Oceanography* **1,** 176–194.

Jones S. & Menon P.M.G. (1951) Observations on the life-history of the Indian shad, *Hilsa ilisha* (Hamilton). *Proceedings of the Indian Academy of Science* **31,** 101–125.

Junk W.J., Bayley P.B. & Sparks R.E. (1989) The flood pulse concept in River-floodplain systems. In: D.P. Dodge (ed.) *Proceedings of the International Large River Symposium*. *Canadian Special Publication of Fisheries and Aquatic Sciences* No. 106, pp. 110–127.

Kramer D.L. (1978) Reproductive seasonality of the fishes of a tropical stream. *Ecology* **59,** 976–985.

Lowe-McConnell R.H. (1975) *Fish Communities in Tropical Fresh Waters.* London: Longman, 337 pp.

Mitra G.N. (1968) Production of quality fish seed of Indian major carps in the Mahani river system in Orissa. *Proceedings of the Seminar on the Production of Quality Fish Seed for Fish Culture.* Barrackpore: ICAR/CIFRI, 36 pp.

Muth R.T. & Schmulbach J.C. (1984) Downstream transport of fish larvae in a shallow prairie River. *Transactions of the American Fisheries Society* **113,** 224–230.

Naesje T.F. & Jonsson B. (1986) Drift of cisco and whitefish larvae in a Norwegian River. *Transactions of the American Fisheries Society* **115,** 89–93.

Pavlov D.S. (1994) The downstream migration of young fishes in rivers: mechanisms and distribution. *Folia Zoologica Brno* **43,** 193–208.

Pavlov D.S., Nezdoliy V.K., Urteaga A.K. & Sanches O.R. (1995) Downstream migration of juvenile fishes in the rivers of Amazonian Peru. *Journal of Ichthyology* **35,** 227–248.

Pavlov D.S., Pakuhorukov G.N., Kuragina G.N., Nezodoliy V.K., Nekrasova D.A. & Elsler A.L. (1977) Some feature of the downstream migration of juvenile fishes in the Volga and Kuban Rivers. *Journal of Ichthyology* **17,** 363–374.

Pearson W.D. & Franklin D.R. (1968) Some factors affecting drift rates of *Beatis* and Siruliidae in a large River. *Ecology* **49,** 75–81.

Potter I.C. (1980) Ecology of larval metamorphosing lampreys. *Canadian Journal of Fisheries and Aquatic Sciences* **37,** 1641–1657.

Price J.W. (1940) Time-temperature relation in the incubation of the whitefish, *Coregonus clupeaformis* (Mitchill). *Journal of General Physiology* **23,** 449–468.

Rahman A.K.A. (1989) *Freshwater Fishes of Bangladesh.* Zoological Society of Bangladesh.

van Rijn L.C. (1993) *Principles of Sediment Transport in Rivers, Eatuaries and Coastal Areas.* Utrecht, University of Utrecht, Delft Hydraulics: Aqua Publications.

Sepulveda A., Thiel R. & Nellen W. (1993) Distribution patterns and production of early life stages of European smelt, *Osmerus eparlanus* L., from the Elbe River, Copenhagen, Denmark. *ICES, CM,* 1993/M:39.

Shafi M. & Quddus M.M.A. (1982) *Fisheries in Bangladesh.* Dhaka: Bangla Academy, 221 pp.

Shaha M.S. & Haque A.K.M.A. (1976) *Qualitative and quantitative study of samples of fry and fingerlings of major carps from the old Brahmaputra River at Mymensingh.* M.Sc. Thesis, Department of Fisheries Biology and Limnology, Bangladesh Agriculture University of Mymensingh, Mymensingh.

Shestakov A.V. (1991) Preliminary data on the dynamics of downstream migration of coregonid larvae in the Anadyr River. *Journal of Ichthyology* **31,** 65–74.

Siddiqui M.H. (1990) Flood control and drainage development: Physical Environmental issues. In: A.A. Rahman, S. Huq & G. R. Conway (eds) *Environmental Aspects of Surface Water Systems of Bangladesh*. Dhaka: University Press Ltd, pp. 104–108.

Solomon D.J. (1982) Smolt migration in Atlantic salmon (*Salmo salar* L.) and sea trout (*Salmo trutta* L.). In: E.L. Brannon & E.O. Salo (eds) *Salmon and Trout Migratory Behaviour Symposium*. Seattle, WA: School of Fisheries, University of Washington, pp. 196–203.

Tsai C.F. & Ali L. (1985) Open water fisheries (carp) management programme in Bangladesh. *Fisheries Information Bulletin* **2,** 51 pp.

Tsai C.F. & Ali L. (1987) The changes in fish community and major carp population in beels in the Sylhet-Mymensingh basin, Bangladesh. *Indian Journal of Fisheries* **34,** 78–88.

Tsukamato K. (1991) Age and growth of Ayu larvae *Plecoglossus altivelus* collected in the Nagara, Kiso and Tone River during downstream migration. *Bulletin Japanese Fisheries Science* **57,** 2013–2022.

Veshchev P.V. & Novikova A.S. (1983) Reproduction of the stellate sturgeon, *Acipenser stellatus* (Acipenseidae), under regulated flow conditions in the Volga River. *Journal of Ichthyology* **5,** 42–50.

Welcomme R.L. (1985) River Fisheries. *FAO Fisheries Technical Paper* No. 262, Rome, 330 pp.