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The flood pulse and growth of floodplain fish in Bangladesh

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Abstract The floodplain fisheries associated with the Compartmentalisation Pilot Project, Tangail, Bangladesh, were monitored using a traditional length-based fish stock assessment programme from 1992 to 1998. The growth of *Colisa fasciatus* (Bloch & Schneider) and *Channa punctata* (Bloch) was significantly higher in years of high floods. Further, the annual yields of *Puntius sophore* (Hamilton), *C. punctata* and *C. fasciatus* were significantly higher in years with high growth rates. The increased growth rate resulted in the presence of two cohorts in the catches during high floods instead of one cohort during years of low flooding. The species studied had relatively short life spans with longevity of 2.4–4.6 years. The majority of fishes did not survive the first year of their lives because of the low survival rate caused by high fishing mortality, which suggests that the fishes in the floodplains of Bangladesh exhibit an annual cycle. Annual fish yields in the flood plains of Bangladesh, appear to be maintained, despite the high fishing effort, by the annual flood pulse providing the nutrient-rich environment needed for the remaining *r*-strategists to survive.

KEYWORDS: Bangladesh, flood pulse, floodplain fisheries, growth, stock assessment.

Introduction

Inland fisheries production in Bangladesh, as in other exploited floodplain fisheries around the world, is strongly related to flood sequence. Flood plains inundated during monsoons are nutrient rich and play an important role as nurseries for many larvae and juvenile fish species, and provide food and shelter for adult fish (Welcomme 1985; Bayley 1988; Junk, Bayley & Sparks 1989). The flood pulse concept states that annual inundation is 'the principal driving force responsible for the existence, productivity, and interactions of the major biota in river-floodplain systems' (Junk *et al.* 1989). The existence of a flood pulse, or the direct relationship between fisheries production and the extent and duration of the floods has been reported by Welcomme (1975)
1 and Shepherd (1976). Krykhtin (1974), however, found that fish catch in the Amur Basin was related to the extent of flooding 2–3 years previously because of the time it takes the fish to enter the fisheries. For tropical floodplain fisheries, this time lag can be extremely short, <1 year, because of the high growth rates, and the small size at which fish are caught (Welcomme 1975).

The Compartmentalisation Pilot Project (CPP) is a water management project located in the central part of Bangladesh. Floodplain fisheries are an integral part of this project, which were monitored from 1992 to 1998. Results of this monitoring programme indicated that the annual yield of the floodplain and the catch per unit of effort (CPUE) of the individual fishermen were significantly related to the intensity of flooding, with higher yields and CPUE in years of high flooding (de Graaf, Born, Uddin & Marttin 2001 The CPUE in years with high floods was assumed to reflect a higher abundance of fish rather than changes in catchability. The higher abundance could be the of result higher recruitment, higher survival rates of young of the year fish or higher growth rates in years of high floods. This paper examines one of these aspects, the relation between the extent of flooding and the growth of some major fish species in the floodplains located in the CPP project area.

Materials and methods

The CPP is a water management project located in Tangail on the left bank of the River Brahmaputra (Jamuna) some 80 km north of the capital Dhaka. It

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encompassed 13 500 ha, of which around 3300 ha is floodplain (Fig. 1). The total human population in the area in 1999 was approximately 285 000.

The catch of the major fish species, comprising 40–50% of the total catch, were monitored in four permanent floodplains located within the project area (Fig. 2). The total length (to nearest 0.5 cm) of the fish in individual catches, and the gear-type and its mesh size were recorded bi-weekly. Data on the pool barb, *Puntius sophore* (Hamilton) were collected over the period 1992–1998, while snakehead, *Channa punctata* (Bloch), stinging catfish, *Heteropneustes fossilis* (Bloch), guntea loach, *Lepidocephalus guntea* (Hamilton), barred spiny eel, *Mastacembelus pancalus* (Hamilton), and the banded gourami, *Colisa fasciatus* (Bloch & Schneider), data were only collected from 1992 to 1996 because of budgetary restrictions.

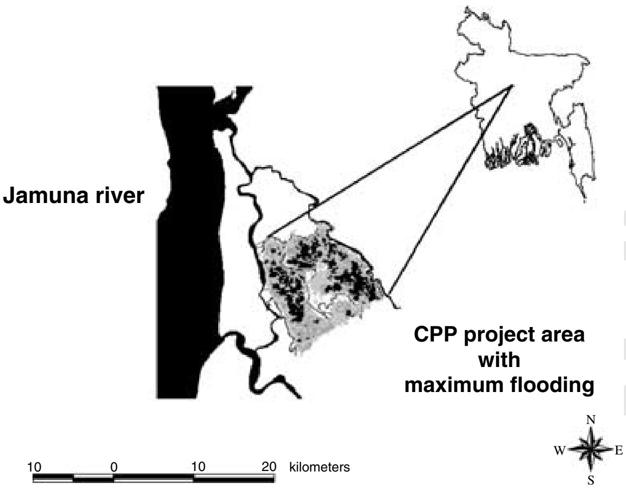

Figure 1. The Compartmentalisation Pilot Project.

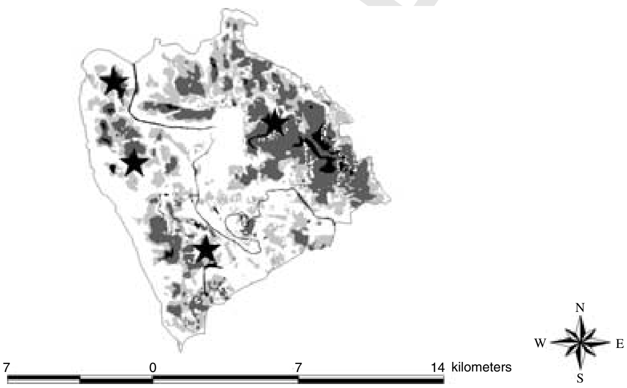

Figure 2. Sampling sites of the length-based fish stock assessment programme of CPP with the average water depth during the monsoon shaded in grey.

Water levels were recorded weekly at the Gotokbari sampling site. The extent of flooding, designated the flood index, was calculated as the summed average monthly water level from 1 June to 31 October. Data on annual yield for the different fish species were obtained from a catch assessment survey (de Graaf *et al.* 2001).

Data analysis

None of the four floodplains sampled provided sufficient data to construct reliable length frequency datasets, therefore, data from all four sites were combined. This assumes that individuals sampled from each site belong to a single population. Only samples from non-selective gears, such as seines, lift nets and scoop nets, were used, aggregated in bi-monthly periods. The latter was necessary to maintain reasonable sample sizes.

The growth of each species was described by the seasonal version of the von Bertalanffy Growth Function (VBGF) (Somers 1988):

$$Lt = L_\infty\left(1 - e^{-k(t-t_0)-(CK/2\pi)[\sin 2\pi(t-t_s)-\sin 2\pi(t_0-t_s)]}\right)$$

where L_∞ is the asymptotic length – the mean length the fish of a given stock would reach if they were to grow indefinitely; K, the growth rate parameter, or the rate at which L_∞ is approached; t_0, the age of the fish at zero length if it had always grown in a manner described by the equation; t_s, the onset of the first oscillation relative to $t = 0$ and C, the intensity of the (sinusoidal) growth oscillations.

As inter-annual variations in growth were expected because of annual differences in the intensity of flooding, all annual growth curves were fitted independently using the Electronic Length Frequency Data Analysis program (ELEFAN; Pauly & David 1981), with length frequency data of the particular year only. The ELEFAN fitted mainly over the length frequencies of dominant age 0 cohort. However, monotonic improvement of the goodness-of-fit with increasing L_∞ and decreasing K did not take place as in all fitted years at least two cohorts were present in one of the distributions. For all fits the winterpoint (WP), or the period with the slowest growth, was set at 1 or January (WP $= t_s + 0.5$), as this is the month with the lowest water temperatures. For each year the best values for L_∞, K and C were estimated, t_0 was not estimated by ELEFAN and disregarded in the analysis.

Phi-prime (Pauly & Munro 1984) was used to compare growth performance:

$$\phi' = \log(K) + 2\log(L_\infty)$$

Table 1. Growth parameters for *Puntius sophore* in the CPP project area

Year	L_∞ (cm)	K (yr^{-1})	C	WP	Phi-prime	Flood Index (m)
1992/1993	13.1	0.8	0.3	1	2.14	48.5
1993/1994	13.0	1.3	0.8	1	2.34	51.3
1994/1995	12.9	0.6	1.0	1	2.00	48.2
1995/1996	13.0	0.7	0.8	1	2.07	49.1
1996/1997	13.0	1.3	0.6	1	2.32	48.9
1997/1998	13.0	1.3	0.9	1	2.34	48.9

Table 2. Growth parameters as estimated for *Channa punctata, Heteropneustes fossilis*, *Lepidocephalus guntea*, *Mastacembelus pancalus* and *Colisa fasciatus*

Parameter	*C. punctata*	*H. fossilis*	*L. guntea*	*M. pancalus*	*C. fasciatus*
L_∞ – 92/93 (cm)	28.5	29.5	15.4	26	17
L_∞ – 93/94 (cm)	29	29	16.5	21	17
L_∞ – 94/95 (cm)	28	27	17	23	18
L_∞ – 95/96 (cm)	27	28	15	22	17
K 92/93 (yr^{-1})	0.85	1.20	0.85	1.00	0.60
K 93/94 (yr^{-1})	1.20	1.50	0.70	1.40	0.90
K 94/95 (yr^{-1})	0.90	1.00	0.70	1.70	0.50
K 95/95 (yr^{-1})	1.10	1.10	0.70	1.00	0.60
C	0.70	0.50	0.50	0.90	0.90
C	0.20	0.45	0.90	1.00	0.80
C	0.30	0.40	0.55	0.90	1.00
C	0.50	0.30	0.50	0.90	0.75
Phi prime 92/93	2.84	3.02	2.30	2.83	2.24
Phi prime 93/94	3.00	3.10	2.28	2.79	2.42
Phi prime 94/95	2.85	2.86	2.31	2.95	2.21
Phi prime 95/96	2.90	2.94	2.20	2.68	2.24

The longevity for all species was estimated with $t_{max} \approx 3/K$ (Gayanilo & Pauly 1997). The L_{25} or the length at which 25% of the fish will be vulnerable to be captured was estimated from the length-converted catch curve (Pauly 1984).

Results

The parameters for the von Bertalanffy Growth Function and the corresponding phi-prime and longevity estimated for *P. sophore*, *C. punctata*, *H. fossilis*, *L. guntea*, *M. pancalus* and *C. fasciatus* over the years (Tables 1–3) indicated that all species are fast-growing, reaching their asymptotic length almost within 2 years, and have a relative short life span of 2–5 years. Further analysis indicated that the growth performance index, phi-prime, was significantly related ($P < 0.05$) to the intensity of flooding for *C. punctata* and *C. fasciatus* and significantly related ($P < 0.05$) to the annual yields for *P. sophore*, *C. punctata* and *C. fasciatus* (Table 4).

The dynamics behind the relationship between growth and the intensity of the flood and annual fish yields becomes more clear if the individual growth of each cohort is plotted over time for the different years and examined in relation to L_{25} (Table 5). The individual growth of the different species in combination with L_{25} water level and annual yields of each species (Figs 3–8) showed that annual yield for *P. sophore, C. punctata* and *C. fasciatus* was positively related to growth, and that in years of high floods and high fish yields, the fast growth resulted in young-of-the-year already surpassing L_{25} within a few months of hatching. In such situations, the catch during the

Table 3. The mean values of K,T_{max} and phi-prime for the different species

Species	Average K (yr^{-1})	T_{max} (yr)	Average phi-prime
H. fossilis	1.2	2.5	2.98
L. guntea	0.7	4.1	2.27
M. pancalus	1.3	2.4	2.81
C. punctata	1.0	3.0	2.90
C. fasciatus	0.7	4.6	2.28
P. sophore	1.0	3.0	2.20

flood season consists of two cohorts, the young-of-the-year and the survivors of the previous year's cohort. For *H. fossilis* and *M. pancalus,* the length of the age-0 cohort usually reached L_{25} during the first flood, while the age-0 cohort of *L. guntea* never reached L_{25} during the first flood, explaining why a significant relationship between annual yields and growth was only found for *P. sophore*, *C. punctata* and *C. fasciatus*.

Table 4. The correlation coefficient between phi-prime and the flood index and between phi-prime and the annual yields for each species

	Correlation coefficient with phi-prime	
Species	Flood index	Annual yield
P. sophore	0.58	0.75*
H. fossilis	0.81	0.67
C. punctata	0.99*	0.90*
L. guntea	–0.16	0.22
M. pancalus	–0.40	–0.14
C. fasciatus	0.98*	0.92*

*A significant relation, Pearson ($P < 0.05$).

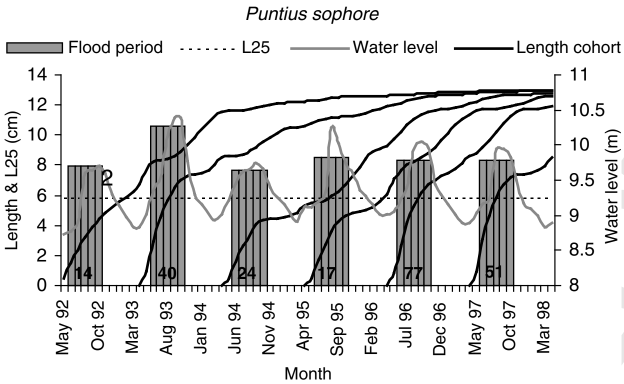

Figure 3. Individual growth of the annual cohorts of *Puntius sophore* in relation to L_{25} average monthly water level, flood season and the annual yields of *P. sophore* (kg ha^{-1}yr^{-1}).

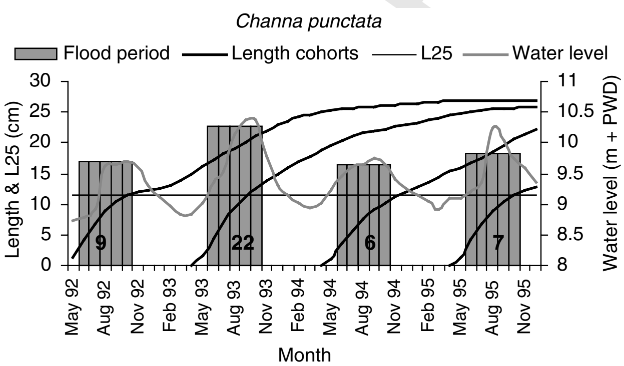

Figure 4. Individual growth of the annual cohorts of *Channa punctata* in relation to L_{25} average monthly water level, flood season and the annual yields of *C. punctata* (kg ha^{-1}yr^{-1}).

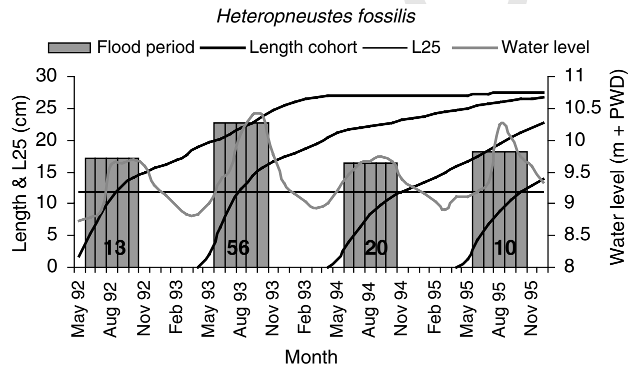

Figure 5. Individual growth of the annual cohorts of *Heteropneustes fossilis* in relation to L_{25} average monthly water level, flood season and the annual yields of *H. fossilis* (kg ha^{-1}yr^{-1}).

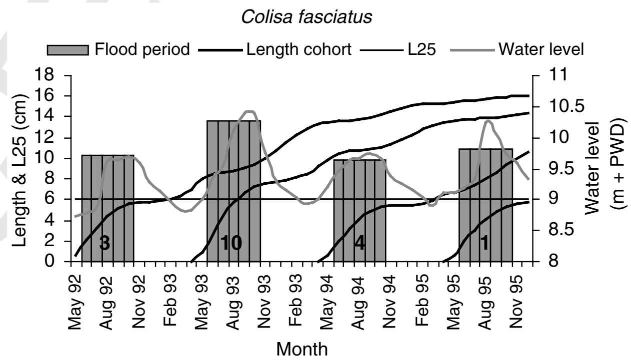

Figure 6. Individual growth of the annual cohorts of *Colisa fasciatus* in relation to L_{25} average monthly water level, flood season and the annual yields of *C. fasciatus* (kg ha^{-1}yr^{-1}).

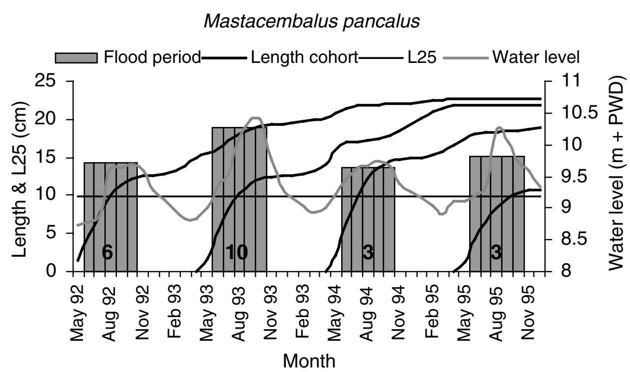

Figure 7. Individual growth of the annual cohorts of *Mastacembelus pancalus* in relation to L_{25} average monthly water level, flood season and the annual yields of *M. pancalus* (kg ha^{-1}yr^{-1}).

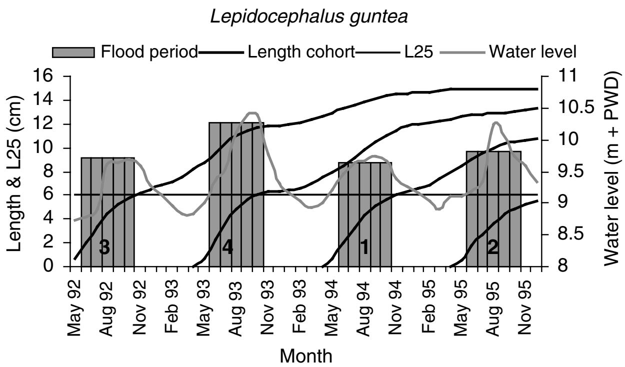

Figure 8. Individual growth of the annual cohorts of *Lepidocephalus guntea* in relation to L_{25} average monthly water level, flood season and the annual yields of *L. guntea* (kg ha^{-1}yr^{-1}).

Discussion

It is generally accepted that in temperate waters, the growth of fish displays strong seasonal oscillations, mainly because of fluctuations of temperature and/or food supply (Shul'man 1974). However, strong seasonal growth exists in the tropics (Daget & Ecoutin 1976, de Graaf & Ofori-Danson 1997). The need to use a seasonal version of the von Bertalanffy Growth Curve has been discussed extensively (Pauly & Ingles 1981; Longhurst & Pauly 1987; Pauly 1990). The present study found a strong oscillating seasonal growth for all species studied, with the highest growth during the rising of the flood, when the water temperature ranged from 27 to 30 °C, and the lowest growth during the dry season (January to March) when the water temperature drops to about 16–17 °C. Thus, it appears that the intra-annual differences in growth are mainly related to seasonal variation in water temperature.

The average water temperatures during the flood period (July to October) did not differ significantly between years, and consequently, inter-annual differences in growth are mainly associated with the extent of flooding. More extensive flooding is likely to promote greater primary and secondary production on the flood plain (Junk *et al.* 1989), which thereby improves the feeding conditions for fish. This was confirmed for the upper Mississippi River system (Gutreuter, Bartels, Irons & Sandheinrich 1999), where species depending on the littoral zone responded to the flooding with higher growth rates, while species that did not rely on the littoral zone did not change their growth rates significantly. These aspects of food availability, intra-specific competition for food and the resulting density-dependent growth have been discussed by Welcomme (2001). Halls (1998) reported higher growth rates of *P. sophore* inside a controlled flood plain compared with an open floodplain in Bangladesh. The difference was associated with lower levels of abundance inside the scheme, implying that density-dependent growth is an important component of floodplain fish growth. This was further supported by rearing experiments with *P. sophore* in ponds. However, the present study found a positive relationship between annual yields and growth for *P. sophore*, *C. punctata* and *C. fasciatus*. If the yields were a reflection of the abundance, it would imply the absence of density-dependent growth.

Bayley (1988) studied the growth of 12 fish species in the Amazon floodplain and found no evidence of density-dependent growth when all seasons were considered. He concluded that interspecific competition had no effect in regulating the species in the floodplain and that the seasonal hydrological regime is more important in maintaining the growth rates. This is most likely also the case in the floodplains in Bangladesh, where the rapid expansion of the flood plains during the monsoon, combined with the high nutrient influx and high water temperatures, outweigh any density-dependent impact. Density-dependent growth could be more important during the dry season, when fish densities are of the magnitude reported for the experiments under controlled conditions in ponds (Lorenzen 1996; Halls 1998). However, the overall impact would still be low considering limited growth during this season because of the low water temperatures.

The relationship between the growth rates and yields explains the positive relation between CPUE and fishing effort (de Graaf in press). During years of high flooding, fish growth is so fast that young-of-the-year fish are already captured in their first year of life and the catch comprises two cohorts, the young-of-the-year and the survivors of the previous year; while in years of low flooding the catch comprises only one cohort, the survivors of the previous year. The result is a higher abundance of catchable fish in years of high floods, and consequently, the CPUE increases. During the period of high floods, employment opportunities for the rural poor in the floodplain areas of Bangladesh are seriously reduced and the higher abundance of fish and the resulting higher daily catches encourage people to fish.

The present study confirms the findings of Halls, Hoggarth & Debnath (1999), that fish in the floodplains of Bangladesh rarely survive for more than 1 year. Slow growing and late maturing species (*K*-strategist) such as Indian carps, are replaced by species with rapid growth, early maturity and high reproductive rate (*r*-strategists), a phenomenon also reported by Laë (1997) in African lagoons. Junk, Soares & Saint-Paul (1997) indicated the importance of the flood pulse for these *r*-strategists in the Amazon floodplains. In the floodplains of Bangladesh, the annual fish yields are most probably still maintained, even with the high fishing effort, by the annual flood pulse providing the nutrient-rich environment needed for the remaining *r*-strategists to survive.

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