OnLine Journal of Biological Sciences 1 (7): 671-675, 2001

Population Dynamics and Stock Assessment of *Labeo rohita* (Ham.), *L. calbasu* (Ham.) and *L. gonius* (Ham.) From the Mymensingh Basin

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Abstract: Estimated fishing mortality and exploitation values for *L. rohita* and *L. calbasu* indicated that their stocks are under heavy fishing pressure. Exploitation values were much higher than the optimum level of 0.5 and remarkably higher than the E_{max} values. Mean annual catch of *L. rohita* in 1999 and *L. calbasu* in both 1998 and 1999 were much higher than their estimated maximum sustainable yield (MSY). Whereas the exploitation values for *L. gonius* were below the optimum level in 1998 and just at optimum in 1999. The stock of *L. gonius* is almost under optimum fishing level. Mean annual catch of *L. gonius* were lower or almost equal to its estimated MSY value in both the years. The L_c/L, and M/K values also confirm the above conclusion for *L. rohita*, *L. calbasu* and *L. gonius*.

Key words: Population dynamics, stock assessment, Gangetic carps, Bangladesh.

Introduction

Sylhet-Mymensingh basin is the largest natural depression (62,106 ha) and is situated in the north-east of Bangladesh, occupying about 15.6% of the total inland open water area (FAP-6, 1993). There are 1,809 beels (depressions) comprising an area of 22,889 ha. Once this region was famous for its fish production but with the passage of time, this basin has lost most of its fisheries resources particularly, the Gangetic major carps, due to a variety of causes including over exploitation, construction of flood control drainage and irrigation embankments, water pollution, siltation and alteration of water bodies into cultivable crop lands (CIDA, 1993). Production of Gangetic major carp have decreased to about 54.23% in 1998 as compared to that of 1984 (DOF, 1984 and 1998).

Lot of investigations were done on the reproductive biology, breeding, post-larval nursing and growth in captive conditions of these carps but never on their population dynamics from open water fishery. Growth performance is one of the key factors for their well-fit existence in the nature. Lack of precise information on their mortality rate and recruitment, is a severe handicap in understanding the dynamics of their stocks in nature. This study was thus undertaken to estimate the length-frequency based key parameters of their population dynamics and stocks.

Materials and Methods

Length-frequency data of three species of major carps viz., *Labeo rohita* (Ham.), *L. calbasu* (Ham.) and *L. gonius* (Ham.) were collected from the commercial catches at landing sites of Bhairab bazar, Mymensingh. The data for *L. rohita* were collected only in 1999 from January to December. Whereas, for *L. calbasu* and *L. gonius* data were collected throughout 1998 and 1999.

The length (cm) by a meter scale and weight (g) by a Salter spring balance. The data were then pooled month-wise from different landing sites and subsequently grouped into classes of 2.0 cm intervals. Finally, data were analyzed using the FiSAT (FAO-ICLARM Stock Assessment Tools) (Gayanilo Jr. *et al.*, (1995).

Asymptotic length ($L\infty$) and growth coefficient (K) of the von Bertalanffy equation for growth in length were estimated by means of ELEFAN-I (Saeger and Gayanilo, 1986). Additional estimates of $L\infty$ and Z/K value were obtained by plotting $\bar{L} - L'$ on $\bar{L}$ (Pauly, 1986), i.e.,

$\bar{L} - L' = a + bL'$, where, $L\infty = -a/b$ and $Z/K = -(1 + b)/b$

Again $\bar{L}$ is defined as the mean length, computed from L' upward, in a given length-frequency sample while L' is the limit of the first length class used in computing a value of $\bar{L}$.

Growth performance in terms of length was compared using the ϕ' index of Pauly and Munro (1984), i.e.,

$$\phi' = \text{Log}_{10}K + 2\ \text{Log}_{10}L\infty$$

Total mortality (Z) was estimated by length converted catch curve method. Natural mortality rate (M) was estimated using Pauly's empirical relationship (Pauly, 1980), I. e.,

$$\text{Log}_{10}M = -0.0066 - 0.279\ \text{Log}_{10}L\infty + 0.6543\ \text{Log}_{10}K + 0.4634\ \text{Log}_{10}T$$

where $L\infty$ is expressed in cm and T, (mean annual) temperature in °C which is here 27°C.

Fishing mortality (F) was obtained by subtracting M from Z and exploitation rate (E) was obtained from F/Z [E = F/Z = F/(F+M)] (Gulland, 1971). Recruitment pattern was obtained by backward projection on the length axis of a set of length-frequency data as described in the FiSAT routine. The midpoint of the smallest length group in the catch was taken as length at recruitment, L_r (Murty *et al.*, 1992).

The length at first capture (L_c) was estimated by the Beverton and Holt's Z equation (1957).

$$Z = \frac{K(L\infty - \bar{L}_c)}{\bar{L}_c - L_c}$$

where Z is total mortality, K is growth coefficient, $L\infty$ is asymptotic length, and $\bar{L}_c$ is mean length of total catch.

Relative yield per recruit (Y/R) and biomass per recruit (B/R) values as a function of E were determined from the estimated growth patterns and probability of capture by length (Pauly and Soriano, 1986). Length structured virtual population analysis (LVPA) was carried out according to Sparre and Venema (1992). The estimated LVPA and cohort analysis were done according to Thomson and Bell (1934). The values of $L\infty$, K, M, F, a (constant) and b (exponent) for each species of fish were used as inputs to the LVPA for the concerned species. The t_0 value was taken as 0.

The length-weight relationships were established by the formula $W = aL^b$ (LeCren, 1951) using the logarithmic transformation of Log W = Log a + b Log L and linear

Table 1: Population parameters of *Labeo rohita* (Ham.) *L. calbasu* (Ham.) And L. gonius (Ham.) from the Mymensingh basin, Bangladesh

Parameters	*L. rohita*		*L. calbasu*		*L. gonius*
	1999	1998	1999	1998	1999
Asymptotic length ($L\infty$cm)	97.00	74.36	69.00	50.58	53.00
Growth coefficient (K/yr)	0.70	0.74	1.10	0.90	0.89
$L\infty$ (Powell-Wetherall plot, cm)	96.00	68.94	66.81	52.23	53.50
Z/K (Powell-Wetherall plot)	3.36	2.81	4.80	4.80	3.80
Total mortality (Z/yr)	2.64	3.09	5.71	2.67	2.78
Natural mortality (M/yr)	0.99	1.12	1.48	1.42	1.39
Fishing mortality (F/yr)	1.65	1.97	4.23	1.25	1.39
Exploitation rate (E)	0.62	0.64	0.74	0.47	0.50
Exploitation level for maximum $(Y/R)E_{max}$	0.55	0.55	0.52	0.70	0.58
Length (cm) at first capture (L_c)	35.00	25.28	21.20	24.28	19.94
Length (cm) at recruitment (L_r)	25.00	15.00	11.00	13.00	11.00
Yield per recruit (Y/R)	0.36	0.34	0.31	0.48	0.38
Biomass per recruit (B/R)	1.10	1.51	1.35	1.58	1.56
Growth performance index (ϕ')	3.81	3.61	3.72	3.362	3.40
Response surface (R_n)	0.142	0.218	0.167	0.141	0.163
L-W relationship	$0.0079L^{3.154}$	$0.047L^{2.623}$	$0.008L^{3.12}$	$0.00562L^{2.56}$	$0.00562L^{2.558}$
Length range (cm)	24.0-96.0	14.0-74.0	10.0-68.0	12.0-50.0	10.0-52.0
Sample size (*n*)	1.467	5.104	2.350	3.475	1.217

Superscripts are exp. b values

Table 2: Estimated standing stock and maximum sustainable yield (MSY) of *Labeo rohita* (Ham.) *L. calbasu* (Ham.) and *L. gonius* (Ham.) from the Mymensingh basin, Bangladesh

Species	Year	Catch (t)	Annual stock (t)	Av. Standing stock (t)	MSY (t)
L. rohita	1999	263.17	453.74	159.50	210.54
L. calbasu	1998	231.62	379.70	117.57	181.65
	1999	82.20	112.60	19.43	55.47
	Mean	156.91	234.19	50.62	111.36
L. gonius	1998	87.17	198.11	69.74	93.10
	1999	35.60	75.74	25.61	35.59
	Mean	61.39	133.46	46.51	63.49

regression of the log transformation varieties, where *a* is a constant and *b* is an exponent.

The total annual stock, average standing stock and MSY of these three carp species were also estimated. For this purpose exploitation rate U was estimated by the equation of Ricker (1975) as $U = F/Z\ (1\text{-}e^{-z})$. Then by using the values of U, F and estimated annual catch (Y) the total annual stock and average standing stock were determined. The approximate MSY was then calculated by the equation as proposed by Gulland (1979).

$MSY = Z_t . 0.5 . B_t$

where Z_t is the exponential rate of total mortality in the year t and B_t is the standing stock size in the corresponding year.

Results and Discussion

Growth parameters: The $L\infty$ and K values estimated for *L. rohita*, *L. calbasu* and for *L gonius* are presented in Table 1. The computed growth curves for *L. calbasu*, *L. gonius* and *L. rohita* produced with those parameters are shown over the recstructred length distribution in Fig. 1 (a and b), 2 (a and b) and 3 respectively. The additional estimate of $L\infty$ values (Table 1) by using the method of Wetherall (1986) are more or less close to the values estimated through ELEFAN-I.

The values of growth performance index ϕ' were 3.81 for *L. rohita* in 1999, 3.61 and 3.72 for *L. calbasu* respectively in 1998 and 1999 and 3.36 and 3.40 for *L. gonius* in 1998 and 1999 respectively. These values differed very little in all the species and were found to be excellent. These findings agree with the findings of Azadi *et al.* (1997).

The $L\infty$ values obtained for *L. rohita* and *L. calbasu* in Mymensingh basin were higher than the values in Sylhet basin (Haroon *et al.*, 2000). The $L\infty$ values reported by ARG (1986) for these three species from the Kaptai lake were far greater than in this study. The K values recorded for *L. rohita* and *L. calbasu* in Mymensingh basin were also higher than the values obtained in Sylhet basin (Haroon *et al.*, 2000). Whereas the K values reported by ARG (1986) from the Kaptai lake for *L. rohita*, *L. calbasu* and *L. gonius* were too low as compared to this study. The K values obtained by Khan (1972) for *L. rohita* and Azadi and Kuddus (1995) for *L. calbasu* were as well far less than the present values. Goswami and Devaraj (1995) reported $L\infty$ = 135.29 cm and K = 0.38/yr for *L. rohita* from the Dhir beel of Assam, the neighboring Brahmmaputra basin of India.

Mortality: The M, F and Z values were respectively 2.64, 0.99 and 1.65 for *L. rohita* in 1999; 3.09,1.12 and 1.97; 5.71, 1.48 and 4.23 respectively in 1998 and 1999 for *L. calbasu* and 2.67, 1.42 and 1.25; 2.78, 1.39 and 1.39 respectively in 1998 and 1999 for *L. gonius* (Table 1). The higher values of F for *L. calbasu* and *L. rohita* indicate that these species are under heavy fishing pressure. The natural mortality recorded by ARG (1986) for *L. rohita* and *L. calbasu* in the Kaptai lake were too low than the present estimates. The natural and fishing mortality values for *L. rohita* (Amin *et al.*, 2001) and *L. calbasu* (Alam *et al.*, 2000) were higher in the Mymensingh basin than in the adjoining Sylhet basin. M values of *L. rohita* varied from 0.56 to 1.15 depending on Pauly's and Cushing's method and Z values varied from 0.92

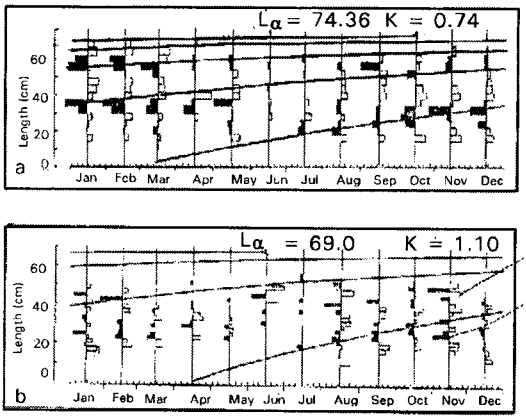

Fig. 1: Growth curves of *Labeo calbasu* (Ham.) in the Mymensingh baisn, Bangladesh (a for 1998 and b for 1999)

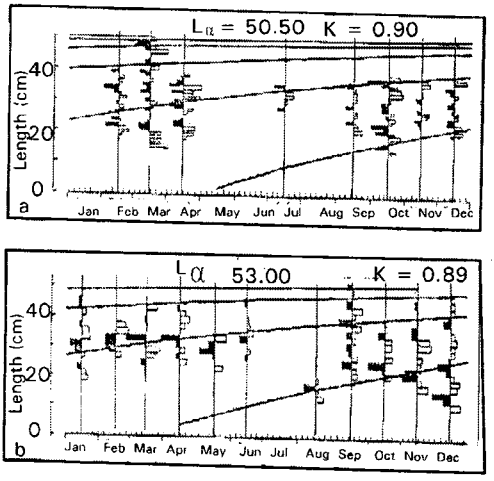

Fig. 2: Growth curves of *Labeo gonius* (Ham. In the Mymensingh baisn, Bangladesh (a for 1998 and b for 1999)

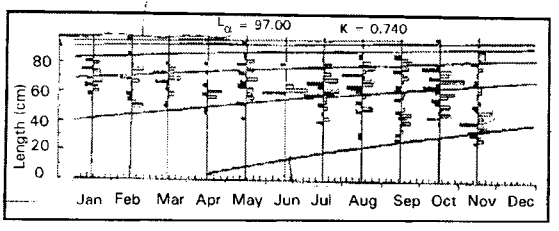

Fig. 3: Growth curves of *Labeo rohita* (Ham.) In the Mymensingh basin, Bangladesh (1999)

to 3.02 from the neighboring Dhir beel of Assam, India (Goswami and Devaraj, 1995).

Exploitation: The E and E_{max} values were respectively 0.62 and 0.55 for *L. rohita* in 1999; 0.64 and 0.55 in 1998, 0.74 and

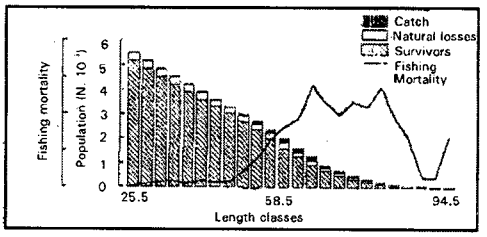

Fig. 4: Length structured virtual population analysis of *L. rohita* (Ham.) in the Mymensingh basin, Bangladesh (1999)

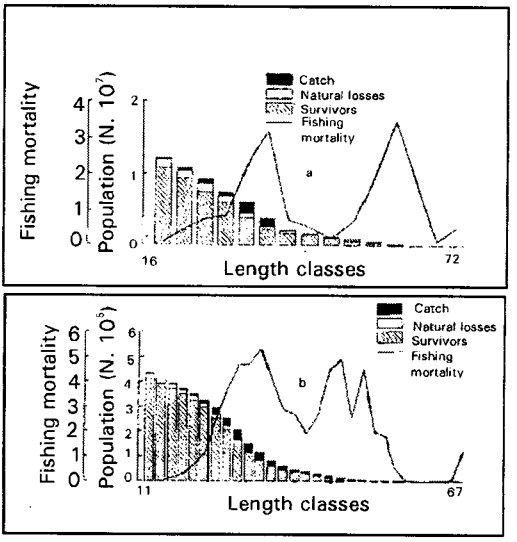

Fig. 5: Length structured virtual population analysis of *L. calbasu* (Ham.) in the Mymensingh basin, Bangladesh (a for 1998 and b for 1999)

0.52 in 1999 for *L. calbasu*; 0.47 and 0.70 in 1998 and 0.50 and 0.58 in 1999 for *L. gonius* (Table 1). The values of E for *L. rohita* and *L. calbasu* in the Mymensingh basin were far higher than in the Sylhet basin (Amin *et al.*, 2001; Alam *et al.*, 2000) at the optimum level of 0.5. E values were remarkably higher than the E_{max} values. From these finding it can be concluded that the stocks of these species are under heavy fishing pressure in this basin. Whereas the E values recorded for *L. gonius* were below the optimum level in 1998 and just at optimum in 1999. This indicates that this specie is almost under optimum fishing level. However, there is still scope to increase the present level of exploitation for obtaining MSY for it. The exploitation rate E also showed an increasing trend in *L. calbasu* (Table 1) which needs to be reduced by decreasing the fishing pressure for optimizing its production at maximum sustainable level in this basin.

Recruitment: The species of *L. calbasu* recruited in the fishery from May to September with a single peak in July during 1998 and March to August with a single peak in April during 1999. The species of *L. gonius* also showed almost similar pattern of recruitment in both the years, but peak recruitment occurred

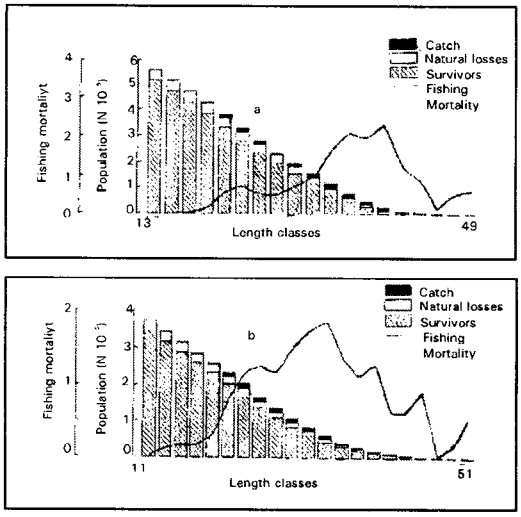

Fig. 6: Length structured virtual population analysis of *L. gonius* (Ham.) in and 1999 the Mymensingh basin, Bangladesh (a for 1998 and b for 1999

in August during 1998 and in May during 1999. Whereas in *L. rohita* the first spell of recruitment was found to occur from February to April with one peak in March and again from July to November with a second peak in September.

The length at first capture, L_c values were 35.0 cm for *L. rohita* in 1999; 25.28 cm in 1998 and 21.20 cm in 1999 for *L. calbasu* and 24.28 cm in 1998 and 19.94 cm in 1999 for *L. gonius*. The corresponding length at recruitment, L_r values were 25.0 cm for *L. rohita* in 1999; 15.0 cm and 11.0 cm for *L. calbasu* respectively in 1998 and 1999 and 13.0 cm and 11.0 cm for *L. gonius* respectively in 1998 and 1999 (Table 1). The comparatively low values of L_c and L_r for *L. calbasu* and *L. gonius* in 1999 than in 1998 might be associated with the increased fishing pressure in the subsequent year. This finding is also supported by the increased exploitation rate of these species in the subsequent year (Table 1).

Yield-per-recruit and biomass-per-recruit: The L_c/ L, and M/K values recorded for *L. rohita, L. calbasu* and *L. gonius* are presented in Table 1. The present level of exploitation exceeded the maximum allowable limit (E_{max}) of Y/R in both *L. rohita* and *L. calbasu*. This indicated that the stocks of these species are being over exploited and thus their present level of exploitation need to be reduced for judicious exploitation. Whereas in *L. gonius* the present level of exploitation (0.47 and 0.50) is around optimum. Hence, their present level of exploitation should be increased rather maintained for sustenance.

Virtual population analysis (VPA): The maximum fishing mortality in the stock of *L. rohita* occurs at a larger size group between 61.0 and 80.0 cm (Fig. 4). But the stock of *L. calbasu* becomes highly vulnerable to fishing gears between 30.0-38.0 cm and 54.0-66.0 cm in 1998 and 21.0-51.0 cm and 31.0-45.0 cm in 1999 (Figs. 5a and 5b). Whereas in the stock of *L. gonius* higher fishing mortality occurs between 29.0 and 41.0 cm in 1998 and between 21.0 and 39.0 cm in 1999 (Figs. 6a and 6b). From the above finding it could be concluded that the size range of fish for higher rate of exploitation varies with the species year within the same specie. This might be associated with the sample size as well as the maximum size of the species concerned.

Length-weight relationship: The exponential form of equations obtained for the length-weight relationship of *L. rohita, L. calbasu* and *L. gonius* are presented in Table 1. The values of co-efficient of correlation (r) estimated for all the species were above 0.9 and almost equal to 1, which indicated that the relationship between total length and weight of the fish was highly significant. The exponent b values obtained for *L. rohita, L. calbasu* and *L. gonius* indicated their allometric growth pattern. More or less similar values of b were also reported for *L. rohita* by Pantulu *et al.* (1967) in India and by Ahmed and Saha (1996) and Sayduzzaman (1997) in Bangladesh. Similarly the b values of *L. calbasu* reported by ARG (1986) and Ahmed and Saha (1996) were well within the range of values obtained in the present study. But the b values of *L. gonius* recorded in this study were lower than the value obtained by ARG (1986) and higher than the value reported by BCAS (1989).

Stock and MSY estimation: The mean annual stock, standing stock and MSY were respectively 453.74 t, 159.50 t and 210.54 t for *L. rohita*; 234.19 t, 50.62 t and 111.36 t for *L. calbasu* and 133.46 t, 46.51 t and 63.49 t for *L. gonius* (Table 2).

The mean annual catch of *L. rohita* in 1999 and *L. calbasu* in both the years were much higher than their estimated value of MSY. This indicated that the stocks of these species are being overexploited. But in *L. gonius* the mean annual catch were lower or almost equal to their corresponding estimated MSY value in both the years. It inferred that the stock was under low fishing pressure during 1998 but under optimum fishing pressure during 1999.

So it can be concluded that the stocks of *L. rohita* and *L. calbasu* are being overexploited which calls for reduction of the present level of fishing pressure near to 1.32 for *L. rohita* and 2.20 for *L. calbasu* for obtaining MSY from these stocks. But the existing rate of exploitation of the stock of *L. gonius* is more or less in optimum level which needs to be maintained for obtaining their sustained production.

Acknowledgment

The authors express their deep gratitude to the Director General, Bangladesh Fisheries Research Institute (BFRI), Mymensingh and the Chief Scientific Officer of the Riverine Station, BFRI for their keen interest and all out support towards this study. The authors are also grateful to the field level officers and staffs for their help during the sampling and data recording. We thank the anonymous reviewers for their positive criticism and critical review of the manuscript.

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