

Population Dynamics and Stock Assessment of *Catla catla* (Hamilton) in the Kaptai Reservoir, Bangladesh

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Abstract

The dynamics and stock assessment of *Catla catla* in Kaptai Lake, Bangladesh is studied using length-frequency based analysis to evaluate growth parameters, mortality rates, exploitation rate, maximum sustainable yield (MSY) and the corresponding rate of exploitation at this level. The study revealed that the stock of *C. catla* is now more or less under optimum exploitation level. Any major change in the existing fishing level/exploitation will most likely result in a reduction in the yield per recruit and thereby hamper the MSY. Results obtained from the length weight relationship (LWR) analyses showed that the "Cube Law" could not be followed for *C. catla* ($b = 3.20 - 3.29$) in the Kaptai Lake system showing allometric growth pattern with weight increasing at a relatively fast rate ($b > 3.0$).

Introduction

Kaptai Lake is one of the most important freshwater fisheries in Bangladesh. It is the largest man-made reservoir in the Southeast Asia (Fernando 1980). It was impounded in 1961 by damming the Karnafuli river at Kaptai in the Rangamati Hill Tracts, mainly for the generation of hydro-electric power while keeping fisheries, navigation, flood control and irrigation as secondary options. The lake is fed by the Karnafuli, Chengi, Mayani, Kasalong and Riankhiang rivers. The average water surface of the lake is approximately

58,300 ha (Ali 1985). The maximum and mean depths of the lake are 35 and 9 m respectively. The present annual yield of Kaptai Reservoir varies between 5000 and 6000 mt. The shoreline of the lake is rocky and covered with the remains of submerged dead trees and wooden logs, which are obstacles to fishing and navigation. The management of Kaptai Reservoir is the overall responsibility of Bangladesh Fisheries Development Corporation (BFDC). BFDC is concerned with the commercial exploitation of fish, marketing, declaration of closed season, licensing, supplemental stocking, and guarding. BFDC, Kaptai Lake Project records the daily species wise catch statistics of exploited fishes.

Fishing of major carps on a commercial basis started in 1965-1966 and is continuing to date. Following an erratic start, fish production from the reservoir has steadily increased, the present contribution is largely limited by unwanted species, particularly the pelagic small fish species (clupeids), tilapia and to some extent by a number of predatory carnivores. Major carps (*Labeo rohita*, *C. catla*, *Cirrhinus mrigala*, *L. calbasu*) comprised a significant proportion of the catch in the early years (78.84%; 1965-66), but the proportion has declined (6.42% 1998-99), while production of clupeids (Kechki, *Corica soborna*; Chapila, *Gudusia chapra* and *Gonialosa manminna*) has increased substantially and now amounting to around 65.0% (1998-99) of the total catch. Predatory carnivores remain more or less steady. The landing of major carps, which are indeed both biologically and economically important, has been declining at a very alarming rate (Ahmed 1999). Thus it has become a great concern of the management authority of the lake and the researchers as well.

Among the freshwater fish, major carps play a significant role because of their taste, high market price and commercial importance at home and abroad. They are distributed throughout the Indo-Pak- Bangladesh subcontinent. *C. catla* is one of the important members of major carp, belonging to the Cyprinidae family. It is found everywhere in Bangladesh with its wide and versatile distribution in the freshwaters. There is a long history of its culture practice in ponds and lakes in this country. At the advent of harvesting after impoundment of Kaptai Reservoir, successful recruitment has occurred. For the last two decades, availability of this fish in the lake waters is alarmingly decreasing due to several factors such as siltation caused by deforestation, over fishing, indiscriminate killing of supplemental fingerlings and use of different types of destructive fishing methods including fish aggregation device (FAD) (Ahmed and Hambrey 1999).

Length weight relationships (LWR) and population dynamics of fishes are studied with the major objectives of rational management and conservation of the resources. Effective management of any fishery requires considerable knowledge regarding population parameters such as length-weight, age and growth, mortality and recruitment pattern of exploited stock. To know the important population parameters and stock position of *C. catla* an attempt was made collecting the length-frequency data of the commercially important afore-said fish of Kaptai Lake. The ultimate goal of this study is to evolve a sound management and conservation policy for the development of this fishery based on the results obtained that would be useful for further development of the same in the other lake environment as well.

Materials and Methods

Length-based stock assessment method was used for the present study. Length-frequency data of a member of commercially important major carp, *C. catla* was collected monthly from the commercial catches at different landing sites of Kaptai Lake and retailing markets of Rangamati Hill Tracts for six consecutive years (September 1993 to May 1999). Data on annual catches of *C. catla* was collected from the landing records of the BFDC, Kaptai Lake Project, Rangamati Hill Tracts. Samples *C. catla* were obtained mainly from gill nets, lift nets and hooks and lines. Random samples of 2,967 specimens were collected. Total length was measured in cm using a meter scale (1±mm) ranging from 20.0 to 90.0 cm. Weight was measured in g using a Salter spring balance from 110.0 to 14,589.0 g with corresponding length. The data were then pooled month-wise from different landing sites and subsequently grouped into classes of 2 cm intervals using MICROSTAT software. Pooling of length-frequency data of more than one year was reported by a number of scientists (Menon et al. 1992; Murty et al. 1992; Miah et al. 1997; Mohamed and Rao 1997). Data were analyzed using the FiSAT (FAO-ICLARM Stock Assessment Tools) as explained in details by Gayanilo Jr. et al. (1996) in the computer software package. Asymptotic length (L_{∞}) and growth coefficient (K) of the von Bertalanffy equation for growth in length were estimated by means of ELEFAN-I (Pauly and David 1981, Saeger and Gayanilo 1986). Additional estimate of L_{∞} and Z/K values were obtained by plotting $\bar{L}$ minus L' on $\bar{L}$ (Wetherall 1986 as modified by Pauly 1986), i.e.,

$$\bar{L} - L' = a + b\bar{L}$$

where, $L = -a/b$ and $Z/K = -(1 + b)/b$

where, $\bar{L}$ 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 $\bar{L}$.

The growth performance of *C. catla* population in terms of length growth was compared using the index of Pauly and Munro (1984). i.e.,

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

Total mortality (Z) was estimated using the length converted catch curve method as implemented in ELEFAN II. 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_{∞} is expressed in cm and T, the mean annual environmental 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 patterns were obtained by backward projection on the length axis of a set of length-frequency data as described in the FiSAT routine.

Probability of capture, size at first capture (L_c) and recruitment pattern was also obtained by means of ELEFAN II. To estimate length at recruitment (L_r) the mid point of the smallest length group in the catch was taken as length at recruitment (Murty et al. 1992).

Relative yield per recruit (Y/R) and relative biomass per recruit (R/B) values as a function of E were determined from the estimated growth parameters and probability of capture by length (Pauly and Soriano 1986). The calculations were carried out using the complete FiSAT software package.

The estimated length structured virtual population analysis (VPA) and cohort analysis were done according to the FiSAT routine following the method of Fry (1949). Pauly (1984) and Jones (1984) gave the practical reviews of VPA. The values of L_{∞} , K, M, F, a (constant) and b (exponent) for the species were used as inputs to a VPA analysis in the FiSAT routine. The t_0 value was taken as zero.

The total annual stock, average standing stock and MSY of *C. catla* were also estimated. For this purpose, first exploitation rate (U) was estimated using the equation given by Beverton and Holt (1957) and Ricker (1975) as $U = F/Z (1 - e^{-Z})$. Then, using the values of U, F and estimated annual catch (Y), the total stock and average standing stock were determined. The approximate MSY was then calculated by the equation proposed by Cadima (in Troadec 1977) for exploited fish stocks.

$$MSY = Z_t .05. B_t$$

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

The total length-total weight relationship of *C. catla* was estimated using the formula:

$W = aL^b$ given by Le Cren (1951) where 'a' is a constant and 'b' is an exponent.

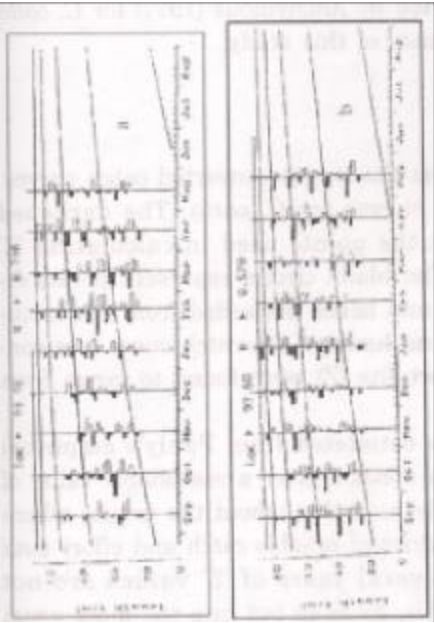
Results and Discussion

Growth parameters

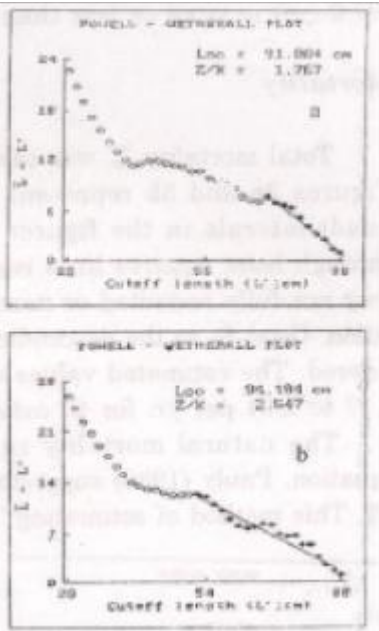
Growth parameters of von Bertalanffy growth formula viz L_{∞} and K were estimated for *C. catla* in Kaptai Lake. The L_{∞} values obtained were found to range from 91.95 to 93.68 cm. The range of estimated K values was 0.57 to 0.74/yr (Table 1). For these estimates through ELEFAN-I the response surfaces (Rn) used for the curves were 0.109 and 0.119 for both the cases. The com-

puted growth curves of *C. catla* produced with these parameters have been shown over the restructured length distribution of individual species in figures 1a and 1b. The t_0 value was taken as 0.

The L_∞ and Z/K values were also estimated for *C. catla* using the methods of Wetherall (1986) (Figs. 2a and 2b). The values of L_∞ and Z/K obtained for this species were found to range from 91.88 to 94.10 cm and 1.77 to 2.55 for the studied years (Table 1). This additional estimate of L_∞ values was almost close to the L_∞ values estimated through ELEFAN-I.



Figs. 1a and 1b. Growth curves of *C. catla* in Kaptai Lake ('a' for 1993 to 1996 and 'b' for 1996 to 1999).



Figs. 2a and 2b. Estimation of L_∞ and Z/K using the methods of Powell-Wetherall plot *C. catla* in Kaptai Lake ('a' for 1993 to 1996 and 'b' for 1996 to 1999).

Table 1. Population parameters of *C. catla* in Kaptai Lake.

Parameters	<i>Catla catla</i>	
	1993-1996	1996-1999
Asymptotic length (L_∞) in cm	91.95	93.68
Growth coefficient (K)/yr	0.74	0.57
L_a (P-Weth. Plot) in cm	91.88	94.10
Z/K (P-Weth. Plot)	1.77	2.55
Total mortality (Z)/yr.	2.17	1.91
Natural mortality (M)/yr.	1.05	0.90
Fishing mortality (F)/yr	1.12	1.01
Exploitation rate (E) = F/Z	0.52	0.53
Exploitation level for maximum Y/R (E_{max})	0.52	0.55
Length at first capture (L_c) in cm	28.50	31.85
Recruitment size (L_r) in cm	23.00	21.00
Growth performance index (ϕ')	3.796	3.700
Response surface (R_n)	0.109	0.119
Sample size (N)	1397	1570
Length range (LR)	20-90	20-90

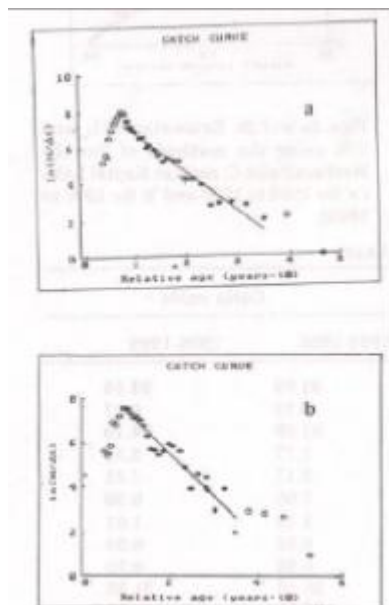
The growth performance indices (ϕ) obtained for *C. catla* (3.700 to 3.796) in Kaptai Lake was found to be excellent (Table 1). These findings are in conformity with the findings of Azadi et al. (1997) on *G. chapra* and *G. manminna* in Kaptai Lake. More or less similar values of L_{∞} estimated by ELEFAN-I and Wetherall Plot methods were also obtained by Azadi et al. (1995), Azadi et al. (1997) and Zafar et al. (1998) in their studies.

The asymptotic length (L_{∞}) of *C. catla* recorded by ARG (1986) in Kaptai Lake was 122.30 cm, which is higher than the values of the same obtained in the present study. But the L_{∞} value reported by Anonymous (1977) for *C. catla* (97.0 cm) is more or less close to the values of this study.

Mortality

Total mortality 'Z' was calculated from the length converted catch curves. Figures 3a and 3b represent the catch curves for *C. catla*. The darkened quadrilaterals in the figures represent the points used in calculating 'Z' through least squares lines regression. The blank circles represent points either not fully recruited or nearing to L_{∞} and hence discarded from the calculation. Good fit to the descending right hand limits of the catch curve was considered. The estimated values of total mortality (Z) were found to range from 2.17 to 1.91 per yr. for *C. catla*.

The natural mortality rate 'M' was estimated from Pauly's empirical equation. Pauly (1980) suggested that this method gives a reasonable value of 'M'. This method of estimating 'M' is widely used throughout the tropics where time series of reliable catch and effort data and several years of 'Z' values are not available, so as to put into the most usual method of estimating 'M' and 'F'. The fishing mortality rate was estimated by subtracting 'M' from 'Z'. Thus the values of M and F obtained for *C. catla* varied from 0.90 to 1.05 and 1.01 to 1.12 respectively (Table 1). The natural mortality values (0.44/year) reported by ARG (1986) for *C. catla* was far below the values of the same recorded in the present study. But in the present study, fishing mortality was recorded higher than the natural mortality in all the years of this species, which indicates that this species is now under intense fishing pressure.



Figs. 3a and 3b. Length converted catch curve of *C. catla* in Kaptai Lake ('a' for 1993 to 1996 and 'b' for 1996 to 1999).

Exploitation rate

The exploitation rate (E) was estimated using the Gullands (1971) equation, $E = F/Z$ ($F+M$). The E values so far ob-

tained for *C. catla* varied between 0.52 and 0.53 and the $E_{\max}$ values recorded were 0.52 and 0.55 for both cases (Table 1). The E values obtained for *C. catla* from 1996 to 1999 were slightly above than the optimum values indicating more or less optimum fishing pressure on stock of this species. This assumption is based on Gulland (1971) as he stated that suitable yield is optimized when $F = M$ i.e., when E is more than 0.5, the stock is generally supposed to be under overfishing.

Recruitment pattern

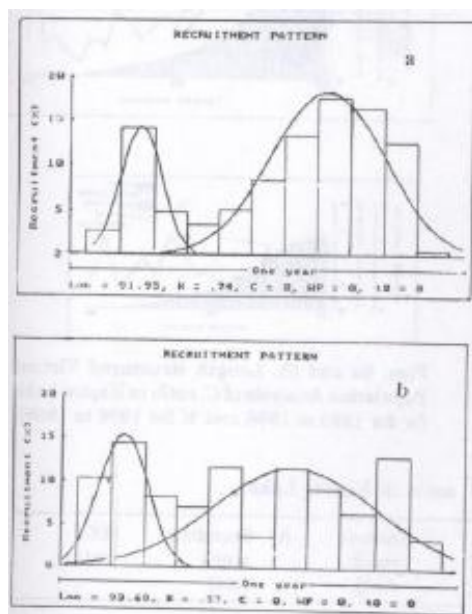
The recruitment pattern was determined through the ELEFAN II analysis (Pauly et al. 1981) with the separation of normal distributions of the peaks by means of the NORMSEP program. Figures 4a and 4b) show the recruitment patterns of *C. catla* in Kaptai Lake. For *C. catla* recruitment was found to occur twice annually. The first recruitment occurred between January to March with a sharp peak in February and the second one occurred between July to October. Mustafa (1994), Mustafa et al. (1998) and Zafar et al. (1998) also recorded two pulses of recruitment for some fishes.

The length at first capture (L_c) estimated for *C. catla* ranged from 28.50 to 31.85 cm whereas recruitment sizes (L_r) ranged between 21.0 cm and 23.0 cm during the investigation period.

Yield-per-recruit and biomass-per-recruit

The relative yield-per-recruit (Y/R) and biomass-per-recruit (B/R) were determined as a function of L_c/L_α and M/K respectively. The L_c/L_α values were 0.31 and 0.34 and M/K values were 1.42 and 1.58 for *C. catla*. Figures 5a and 5b show the maximum allowable limit of yield per recruit for *C. catla* in different years.

The exploitation rates for *C. catla* recorded in the present study (Table 1) are almost close to the maximum allowable limits of the yield/recruit as shown in figures 5a and 5b, which indicate that the stock of this species is more or less under optimum exploitation level. So, fishing mortality does not seem to be a great concern for this fish stock at the moment.



Figs. 4a and 4b. Recruitment pattern of *C. catla* in Kaptai Lake ('a' for 1993 to 1996 and 'b' for 1996 to 1999).

Virtual population analysis (VPA)

The estimated length structured virtual population analysis of *C.*

catla was carried out by using the values of L_{∞} , K, M, F, t_0 , a and b as inputs. The results of length structured VPA analysis are depicted in figures 6a and 6b. These figures show fishing mortality in relation to mean length.

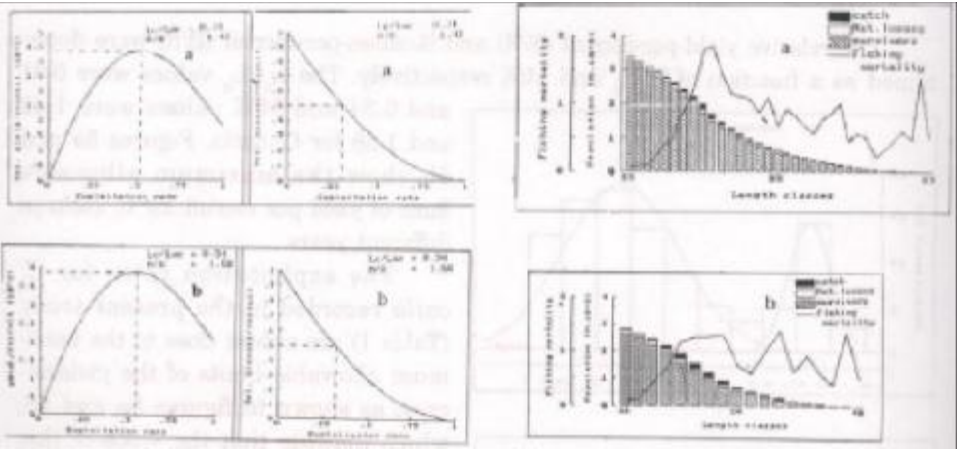
The length range of fishes for higher fishing mortality was found to vary from species to species and year to year. For *C. catla* higher fishing mortality was found to occur between 36 and 52 cm from 1993 to 1996; 36 and 48 cm and 62 and 66 cm from 1996 to 1999 (Figs. 6a and 6b).

Estimation stock and MSY

The results on the estimation of stock and MSY for *L. rohita* in Kaptai Lake are shown in table 2. The average values of total annual stock, standing stock and MSY recorded were 98.00 mt, 42.13 mt and 42.97 mt respectively (Table 2). The MSY value of annual catches is slightly above the MSY value. So to obtain MSY from this stock, the fishing mortality rate needs to be reduced to 1.02 from 1.07.

Length-weight relationship

The sample sizes with length and weight ranges of *C. catla* used to determine length-weight relationships for different years are presented in table 3.



Figs. 5a and 5b. Relative yield per recruit and biomass per recruit of *C. catla* in Kaptai Lake ('a' for 1993 to 1996 and 'b' for 1996 to 1999).

Figs. 6a and 6b. Length structured Virtual Population Analysis of *C. catla* in Kaptai Lake ('a' for 1993 to 1996 and 'b' for 1996 to 1999).

Table 2. Estimation of stock and MSY for *C. catla* in Kaptai Lake.

Species	Year	Catch (mt)	Annual stock (mt)	Av. Standing stock (mt)	MSY (mt)
<i>Catla catla</i>	1993-96	30.34	65.96	27.09	29.39
	1996-99	59.81	132.91	59.22	56.56
	Average	45.08	98.00	42.13	42.97

Table 3. Length-weight relationship of *C. catla* in Kaptai Lake.

Species	Year	Sample size (N)	Length range (cm)	Wt. range (g)	Exponential form of equation	r
<i>C. catla</i>	1993-96	1401	23-91	175-12000	$W=0.0069L^{3.201}$	0.999
	1996-99	1582	21-95	110-14589	$W=0.0047L^{3.293}$	0.999

The length-weight relationship was established using the formula:

$$W = aL^b \text{ in logarithmic form } \text{Log}W = \text{Log } a + b \text{ Log}L.$$

The exponential form of equations obtained for the species in different years are shown in table 3. The exponent 'b' values estimated in different years for this species under study were significantly above 3 indicating allometric growth pattern. Generally in length-weight relationships of fish, when the value of 'b' is equal to 3, the growth of the species is assumed to be isometric and if it is above or below 3, the growth is assumed to be allometric. The values of 'b' seem to be always higher than 3 indicating that the studied fish weight in Kaptai Lake increases faster than the cube of the length. The values of 'r' for this species recorded in the present study were 0.999 indicating a highly significant relationship between total length and weight of this species. This finding agrees with the findings of Ahmed and Saha (1996) and ARG (1986).

The value of 'b' recorded for *C. catla* (3.18) by ARG (1986) and Ahmed and Saha (1996) in Kaptai Lake is similar to the values of the present study for this species. Almost similar values of 'b' for *C. catla* were reported by Hossain (1995), and Sayduzznman (1997) in Baor fishery. Jhingran (1952) also found almost similar result for this species in Indian waters.

Conclusions and Recommendations

From the above results it can be concluded that the stock of *C. catla* is now more or less under optimum exploitation level. Any major change in the existing fishing level/exploitation will most likely result in a reduction in the yield per recruit and thereby hamper the MSY.

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