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POPULATION STATUS AND BIOLOGICAL CHARACTERISTICS OF COMMON CARP, *CYPRINUS CARPIO*, IN MANGLA RESERVOIR (PAKISTAN)

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ABSTRACT

Present study was aimed to investigate the age structure, growth parameters, natural and fishing mortality coefficients of the common carp (Cyprinus carpio) in Mangla reservoir, Pakistan. To assess the parameters and infer on the degree of exploitation, the fork length frequency data were analyzed using the FISAT (ELEFAN I) computer program. The parameters of the von Bertalanffy growth curve for length were L_∞ = 80.33 cm, K= 0.60 yr^{-1} , t_o= -0.39 year and longevity potential =5.0 years. The instantaneous coefficient of mortality of the population were estimated to be, total mortality (Z)=1.22 years, natural mortality (M) = 0.89 and fishing mortality (F) = 0.33. The stock showed a growth performance (ø) value of 3.588. The current exploitation rate of the species was calculated as 0.27. The analysis of relative yield per recruitment, and relative biomass per recruitment showed that the maximum allowable exploitation rate at Maximum Sustainable Yield (MSY) for the common carp fishery in Mangla reservoir is 0.63 which is more than the currently observed exploitation rate. The results suggest that common carp stock in the reservoir is not overfished and is within safe exploitation limits. It is recommended that regular monitoring program for the stock should be in place and any proposal for a change in exploitation rate should be assessed according to the stock status at that point of time.

Key words: *Cyprinus carpio*, population status, growth rate, large reservoir, Mangla reservoir, Pakistan .

INTRODUCTION

Mangla reservoir is one of the most important freshwater fisheries resources in Pakistan. It is the second largest man-made reservoir in the country which was impounded in 1967 by damming the River Jhelum (33^o 16" 05' N, 73^o 55" 55' E) near Mirpur city primarily for storing the water for irrigation and generation of hydro-electric power. Fisheries has developed as a secondary use of the reservoir. The reservoir is fed by two perennial rivers (Jhelum and Poonch) and two non-perennial rivers (Kanshi and Khad) (Sheikh, 2007). Reservoir being at the junction of these rivers has a square shape with its narrow flanks extending into the river valleys (Fig. 1). The average water surface of the lake is approximately 26,500 ha and is divided into five sub-basins commonly referred as pockets of the dam namely Main Mangla, Jhelum, Poonch, Khad and Jari (also as Jari Dam). Catchment area of the reservoir is erosion prone resulting into high sedimentation rates in the reservoir thereby continuously reducing its storage capacity (Khan, 1985; Izhar-ul-Haq and Abbas, 2007). To retrieve the lost storage capacity, Mangla dam raising project has been completed during 2011. A summary of the physical characteristics of the dam before and after raising are given in Table 1. The reservoir is important wintering and staging for wide variety of aquatic birds (Ali *et al.*, 2011). The fishery development and management of the reservoir is under the control of the Directorate of Fisheries and Wildlife under the Department of Forestry, Government of Azad Jammu and Kashmir (AJK). The department manages the commercial exploitation of fish, declaration of closed season, licensing, and supplemental stocking under the umbrella of legislative guidance provided by "West Pakistan Fisheries Ordinance 1961" (Mirza, 2011). Currently the fishing rights of the dam are leased out for a period of three years through open bid system.

Fish fauna of the Mangla Reservoir consists of fifty two species out of which atleast 12 are used as food fishes (Shah, 1996).The present annual fish yield of Mangla Reservoir is reported to vary from 247 to 853 MT (MFD, 2002). Annual landings from the reservoir were historically dominated by the fast growing major carps (*Gibelion catla, Labeo rohita* and *Cirrhinus mrigala*) and common carp (*Cyprinus carpio*) (Shah, 1996). Currently Common carp, an introduced fish (Khan *et al.*, 2011), forms about a quarter of the total catches from Mangla Reservoir (Mirza, 2011). Commercial fish populations in the reservoir appear to have been changing both in terms of dominant species and catch composition. Landings of the major carps rapidly decreased during the last decade or so and now have almost disappeared. Catches from common carp have also decreased significantly accompanied by increase in the catfishes and other unwanted species having low commercial value. These changes in landings over a relatively short period of time has caused a great concern of the management authority. Currently, efforts are being made to manage the common carp fishery to avoid a collapse but the paucity of life history information of the imperiled species is proving to be a major hurdle.

The main objective of the fisheries management is to quantify the existing resource and to assess the impact of stresses on the fishery resource with the aim of maintaining populations at a sustainable level. Hilborn and Walters (1992) are of the opinion that data on recruitment, growth, and mortality are crucial to assess how the fishery will respond to changes in exploitation pattern. Growth can vary substantially among the members in a population and between those in different populations of the same species. The life history of an organism essentially comprises age and size dependent growth performances, mortality rates and fecundity. Growth studies prove to be an essential instrument as these studies provide invaluable estimates of production, stock size, recruitment, and mortalities (Isaac, 1990). The present study was undertaken to know the important population parameters and stock position of *C. carpio* in the Mangla reservoir. The ultimate goal of this study is to formulate a sound management and conservation policy for the development of this fishery based on the results obtained.

MATERIALS AND METHODS

The catch data from landing site was recorded monthly from Jan 2009 to Dec 2010. Boats arriving at the landing site were randomly selected and each specimen of the selected species was measured for its fork length nearest to 0.1 cm. the length measurements were grouped into 2 cm length classes for the construction of monthly length distribution for the study period. The resulting length frequency distribution was then used to estimate the population parameters like growth, recruitment, and mortality rates. In order to describe the growth of fish, von Bertalanffy Growth Function (VBGF) requires the use of three parameters. The first one is called asymptotic length and is the theoretical maximum length that a member of fish population can reach and represented as L_∞. The second parameter of von Bertalanffy is called growth coefficient and is represented by *K*. These parameters were determined by using FAO FiSAT-*II* program (Gayanilo *et al.*, 2005). The initial value of L_∞ was estimated by Powell and Wetherall exercise (Gayanilo *et al.*, 2005) and modes were resolved by subjecting the monthly length frequency distributions to Bhattacharya (1967) analysis. The von Bertalanffy growth coefficient (K) was estimated by Gulland and Holt plot (Gulland and Holt, 1959); total mortality coefficient (Z) was estimated by Pauly's catch curve (Pauly, 1980) and VPA (Jones, 1984); biomass and yield at different level of exploitation estimated by Thompson and Bell analysis (Thompson and Bell, 1934) and Emax was estimated by relative yield per recruitment (Beverton and Holt, 1956). For the calculation of value of growth performance (Phi index ø') of species and stocks , Pauly and Munero's (1984) formula ($ø' = Log_{10}K + 2Log_{10}L_\infty$) was used. Longevity potential was calculated using Pauly's equation (1980) $T_{\max} \approx 3/K$.

Length structured virtual population analysis (VPA) was also conducted from relevant information generated and cohort analysis were performed according to the FAO FiSAT-*II* program (Gayanilo *et al.*, 2005). Chen *et al.* (2008) has given detailed review of the technique. In addition, Beverton and Holt Relative yield-per-recruitment (Y/R) and relative biomass-per-recruitment (R/B) values as a function of E (exploitation rate) of the species was estimated using the model of Beverton and Holt (1966) as modified by Pauly and Soriano (1986) and incorporated into the FAO FiSAT II program (Gayanilo *et al.*, 2005).

RESULTS AND DISCUSSION

During the study, 10,182 specimens of *Cyprinus carpio* were measured for the length frequency data. Collected data was subjected to various analysis techniques described in methods section to assess the population parameters. The results obtained are summarized in Table 2.

Growth Parameters: The K-scan technique indicated an L_∞ of 80.33 cm and a K value of 0.60 yr^{-1} for the original data set. From growth analysis of data corrected by incorporating the probabilities of capture, the K-scan technique did not indicate any important change. The estimates of L_∞ and K originating from the raw data were, therefore, used for the remaining analysis. The value of t_o was taken as -0.39. The von Bertalanffy equation for growth in length of *Cyprinus carpio* constructed from the parameters from the present study is given below:

$$L_t = 80.33(1 - e^{0.60(t+0.39)})$$

The results obtained indicated that the growth performance index (ø') for *Cyprinus carpio* was 3.588. The length frequency data and the derived parameters were used to estimate the instantaneous rates of annual total mortality (*Z*) of the commercial fish species in the dam. The results showed that total mortality coefficient (*Z*) was 1.22. Assuming the mean annual water temperature at the Mangla dam is 23.22 ^{0}C (Mirza, 2011), natural mortality rate (*M*) calculate for the *Cyprinus carpio* remained 0.89 (Table 2). The fishing mortality (*F*) which is simply the fraction of total mortality besides natural mortality and was estimated was 0.33. Figure 2 (B) shows the recruitment pattern for the common carp in the Mangla dam ecosystem. Major recruitment occurs during the summer season especially in the months of June and July with maximum of 18.06 percent occurring in June. When the data for recruitment pattern was subjected to the curve fitting functions, the Gauss fitting gave best results (R^2=0.87). The predicted extreme length of the stock was estimated to be 76.86.

The knowledge about population parameters is essential for the conservation of inland fisheries resources. On the whole *C. carpio* had relatively higher values for length at recruitment as well as for length at first capture. The longevity potential of the species has a value of 5 years which is plausible as common carp has higher growth rates, it reaches larger sizes earlier, therefore, have higher fishing mortality rates which result into lower values for longevity potential. As far as the Recruitment pattern is concerned, winter season experienced least recruitment Practically the recruitment started late during the winter season when the temperatures begin to rise again and generally reached higher values with the onset of peak summer season. The higher growth rates during this period results into higher recruitment rates.

Virtual Population Analysis (VPA) and Exploitation rate at MSY: The values of von Bertalanffy, mortalities and length-weight relationship for the commercial fish were used to construct the estimated virtual population of the species. The results obtained from the length structured VPA analysis are shown in Fig. 2 (C). The results show that the fishing mortality rates differed in relation to the mean length and nature of species. The length ranges for higher mortality rates varied widely during the lifespan of the fish. The length ranges for higher fishing mortality rates occurred between 52.0 cm to 60.5 cm. The relative yield-per-recruitment (Y/R) and biomass-per-recruitment were determined as a function of L_c/L_∞ and M/K respectively. The calculated values of M/K were 1.48 while that for L_c/L_∞ remained 0.43. The results of highest permissible Yield-per-recruitment for the two commercial cyprinid fishes are shown in Fig. 2 (D). The results show that the highest values for yield-per-recruitment for *Cyprinus carpio* is at the exploitation level of 0.63 as compared with the current exploitation rate of 0.27. These figures suggest that the stock of *C. carpio* in Mangla reservoir is well within the sustainable limits. In fact, the exploitation level can be enhanced by increasing the fishing mortality rates.

While using FiSAT for the estimation of growth parameters, uncertainties do exist as several combinations of the L_∞ and K values might lead to the same results (Moreau *et al.*, 1986; Pauly and Morgan, 1987). This is plausible as both are negatively correlated. Table 3 shows comparison of von Bertalanffy growth parameters for the common carp in other regions. The table shows that the L_∞ recorded in other studies ranged from 48.9 to 130.0 cm in different reservoirs. Similarly the values of K also varied widely in these studies ranging from 0.08 to 0.25. The stocks having higher growth coefficient K tend to have lower values for length at infinity. For example *Balik et al.* (2006) reported the lowest growth coefficient of 0.08 in Lake Karamik (Turkey) with an associated L_∞ of 130 cm. Table also shows age at theoretical zero length (t_o) to vary from -1.86 to -0.24. The result of t_o reported in this study was comparable with the studies reported in literature (Table 3). Various reports are available in which values of Phi Prime vary from 2.77 to 7.15. In comparison to this the values of Phi Prime recorded in this study was 3.59 which shows that the species had relatively lower growth performance than most of the studies for reservoirs of Turkey reported in literature. However, the growth performance was better than the growth performance of the species in rivers and wetlands of Australia (Brown *et al.*, 2005). Various exogenous and endogenous factors affect fish growth performances, and longevity (Wootton, 1998), it is therefore difficult to assign the causal factors for these differences in results of this study. The relative yield-per-recruit analysis and relative biomass-per-recruitment analysis indicated the maximum allowable exploitation rate at MSY is 0.63 while the current exploitation rate is 0.27 which indicates that the stock of *Cyprinus carpio* is not yet overfished.

Table 1: Summary of physical characteristics of Mangla Dam/reservoir

Parameter	Before Raising	After Raising
Dam		
Max height (above core trench)	138.38 m	378.7 m
Max height (above river bed)	115.53 m	
Crest elevation	376.1 m SPD	
Length of crest	3,353 m	3,400 m
Reservoir		
Normal max conservation level	366.37 m SPD	378.7 m SPD
Min operational level	317.00 m SPD	317.0 m SPD
Original/ designed gross storage (MCM)	7252.87	-
Designed live storage (MCM)	6,586.79	-
Existing gross storage (MCM)	5,921 (as per 2005)	9,132
Existing Live storage (MCM)	8,185	8,930
Surface area (ha)	26,500	32975
Maximum depth (m)	90	99
Mean depth (m)	22.45	27.70
Depth ratio	0.25	0.28

MCM= Million cubic meter, SPD = Survey of Pakistan Datum

Table 2: Biological characteristics of *Cyprinus carpio* in Mangla Dam

Characteristic	Value
Asymptotic length (L_∞)(cm)	80.33
Growth coefficient (K) /yr	0.60
t_0	-0.39
Total mortality (Z)	1.22
Natural mortality (M)	0.89
Fishing mortality (F)	0.33
Exploitation rate E=F/Z	0.27
Growth performance ø'	3.588
Observed maximum length (cm)	76.50
Longevity potential	5.0
Predicted extreme length (cm)	76.86
Range at 95% conf. interval (cm)	72.21-81.54
Length at recruitment (L_r) (cm)	31.0
Length at first capture L_c(cm)	34.2

Table 3: Comparison of von Bertalanffy growth parameters of *C. carpio* recorded in study with those from different localities

Sex	L_∞ (Cm)	K /Yr	t_0 (Yr)	Ø	Source
Both	80.71	0.11	-0.616	6.57	(Erdem, 1988)
Both	72.7	0.17	-0.45	6.82	(Alp and Balik, 2000)
Both	64.4	0.115	-1.86	6.19	(Özyurt and Avşar, 2001)
M	48.9	0.25	-0.16	2.77	(Brown *et al.*, 2005)
F	59.4	0.18	-0.61	2.80	*Ibid*
Both	51.5	0.24	-	2.80	*Ibid*
Both	130.0	0.08	-0.24	7.15	(Balik *et al.*, 2006)
Both	46.4	0.15	-1.92	5.80	(Karatas *et al.*, 2007)
Both	80.3	0.60	-0.39	3.59	This study

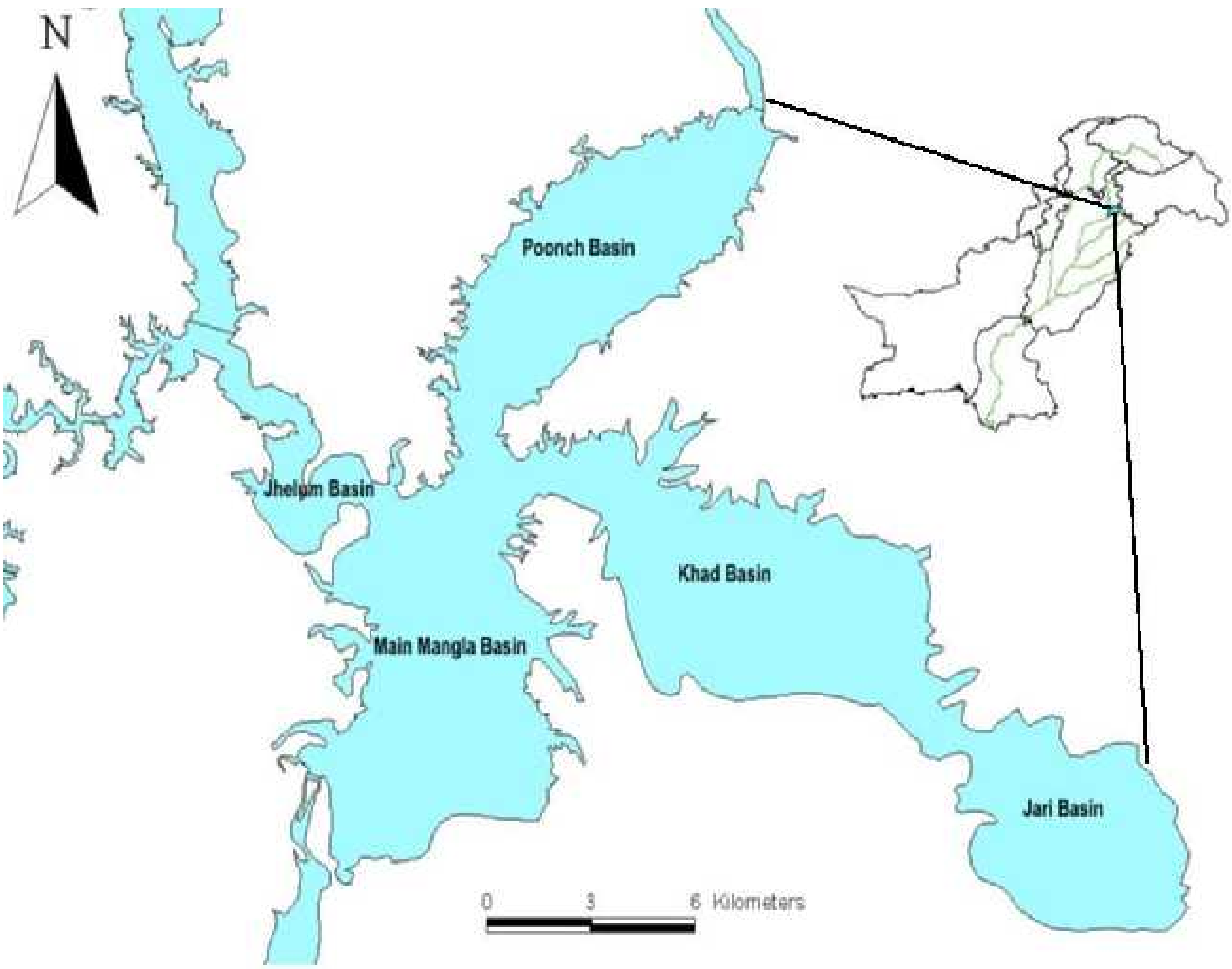

Fig. 1: Mangla reservoir and its five sub-basins

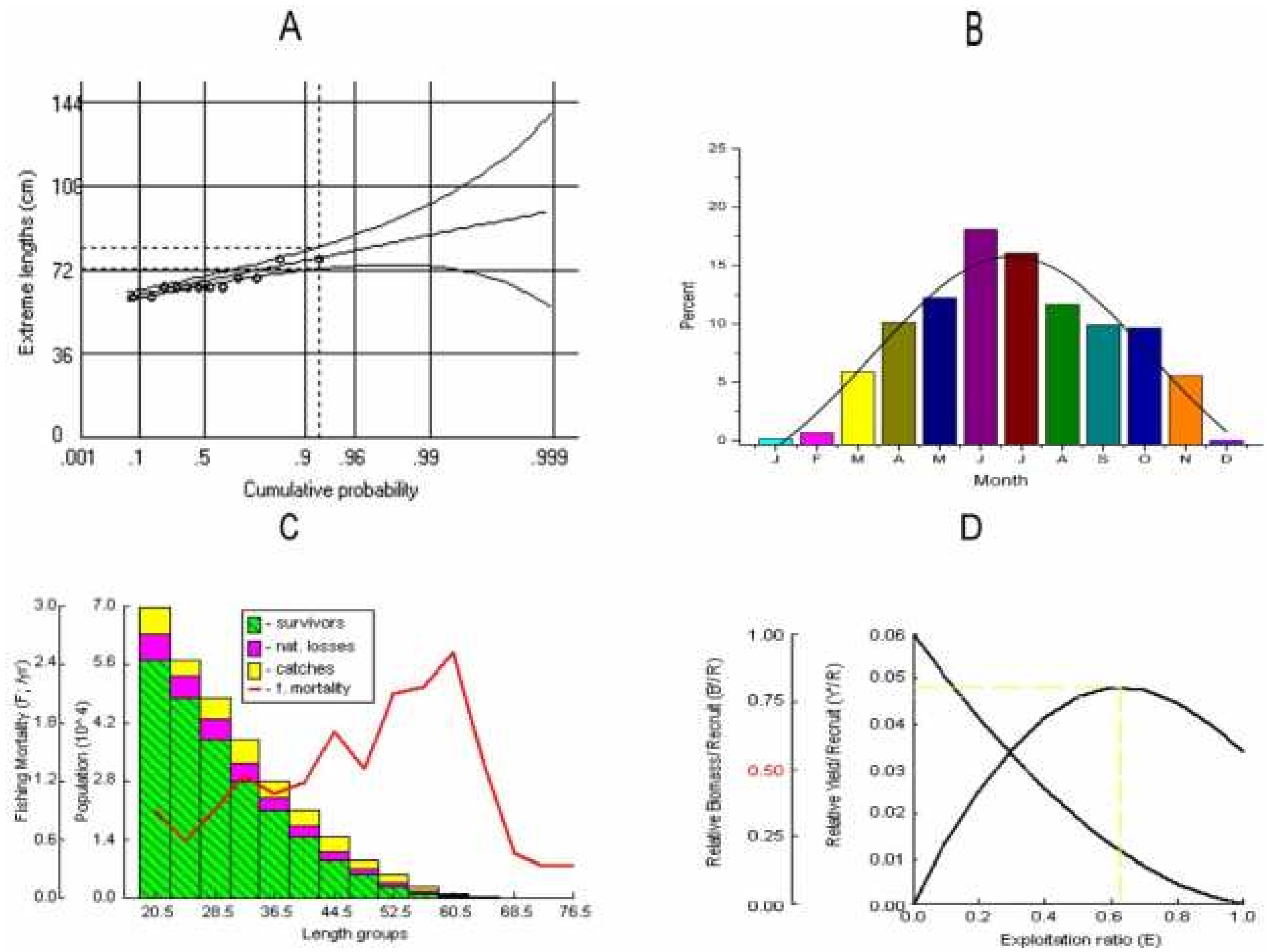

Fig. 2: Population parameters of *C. carpio* in Mangla reservoir. A) Predicted extreme length, B) Recruitment pattern with Gauss fitted curve (R^2=0.87), C) Length structured Virtual Population Analysis, D) Relative yield per recruitment/ Relative Biomass per recruitment.

Conclusions and Recommendations: Present study of the population status of *C. carpio* based on samples collected from commercial fisheries located in Mangla Reservoir led to the conclusions that the fishery stock did not show evidence of overfishing and thus may continue to be exploited in a sustainable way. 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. It is recommended emphatically that no increase in fishery effort should be made, lest the stock of this species be threatened. Furthermore, regular monitoring program should be in place to determine and document the population status of the important food fish

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