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Population dynamics of *Cirrhinus mrigala* (Hamilton 1822) from the largest tributary of the Ganga River, India

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Abstract
The present study covenant with stock assessment *Cirrhinus mrigala*. Length frequency data was collected from lower stretch of the river Yamuna at Allahabad during August 2011 to July 2012 and length ranging from 168 to 943 mm. The asymptotic length (L_∞) and growth coefficient (K) were estimated at 998 mm and 1.339yr^{-1}, respectively. The total mortality (Z), fishing mortality (F) and natural mortality (M) were estimated as 4.01 yr^{-1}, 0.786 yr^{-1} and 3.226 yr^{-1}, respectively. Exploitation rate (E) and exploitation ratio (U) were found 0.8044 yr^{-1} and 0.7898 yr^{-1} respectively. The population structure of *C. mrigala* varied from 0+ to 10+ age groups from the Yamuna River at Allahabad. The male population was dominated in 0+, 1+ and 2+ age groups.

Keywords: *Cirrhinus mrigala*, stock assessment, population structure, Yamuna River

1. Introduction

Fish is widely consumed by people throughout the globe as stable food with a rich source of proteins for health benefits. Fisheries are one of the most important sources of employment generation and provide revenue to the country for the development [1].

Fish population is subject to natural control processes and a renewable resource if they are exploited in a planned manner [2]. Knowledge of population dynamics is an important and essential aspect of fishery biology for determining the status of fish stock and manages their fishery [3, 4]. It may be considered to embrace birth, growth, and mortality [3].

The *Cirrhinus mrigala*, commonly called mrigal is an indigenous major carp. Which is widely distributed in the inland water of India, Bangladesh, Pakistan etc. It forms a capture fishery of great value in the Ganga river system, apart from being one of the important species in the culture fishery of the country due to high consumer preference.

Although earlier several studies have been conducted on population dynamics of this fish in the India [5, 6], Bangaladesh [7] and other countries. The age and growth studies using scale method of *Cirrhinus mrigala* have been studied by [8-12] from different water bodies in the past. The length-weight relationship of *Cirrhinus mrigala* collected from different localities has also been described by various other workers [13-19]. But a little literature is available on totality of population dynamics in inland water in general and middle stretch of the river Gangas in particular, since reverine health of this stretch has not been very conducive for development and growth of the resident fishes including *C. mrigala* in and around Allahabad, U. P.

The present study was thus undertaken to estimate the key parameters for population structure and stock assessment such as the growth coefficient, mortality coefficient, exploitation rate and ratio, recruitment pattern, virtual population etc. This study will help in formulation the fishery management policies of *C. mrigala* in the Yamuna River, India.

2. Material and Method

Study area: Allahabad is situated at the confluence of rivers Ganga and Yamuna, a rich source of inland fish production (Map -1).

For the length weight relationship a total 335 random samples of *C. mrigala* were collected from the lower stretch of the river Yamuna, from Sadiapur fish market Allahabad during August 2011 to July 2012. They ranged in length from 168 to 943 mm including 163 males and 172 females' specimens.

The total length of fishes was measured from the tip of the lower jaw to the tip of the tail in the laboratory using a measuring board and weighed to the nearest of 0.1g on an electronic balance with gonads and viscera intact. The viscera were then cut open to determine the sex and stage of maturity. The length-weight relationship was determined by the least square method [20] for *C. mrigala* by using the general formula:

W = a L b or its logarithmic form Log W = a + b log L

Where, W = weight of fish in grams, L = length of fish in mm, and 'a' and 'b' are the constant and regression coefficient respectively.

Experimental fishing was carried out in all sampling points with the help of locally hired professional fishermen. Fishes were collected with gill nets (mesh 2.5 - 2.5 cm; 3 - 3 cm; 7 - 7 cm in length and breadth = 75 - 1.3 m; 50 - 1 m), cast nets (mesh 0.6 - 0.6 cm), drag nets or locally called mahajal (mesh 0.7 - 0.7 mm, L and B = 80 - 2.5 m with varying mesh sizes) Sampling was performed early in the morning hours and fishes were counted for total number of individuals and number of species.

For the stock assessment and population structure of *C. mrigala*, a total of 565 samples, were collected and grouped into classes of 50 mm size intervel. The length friquincy data were analyzed by using the FiSAT -ICLARM Stock Assessment Tools as explained by [21]. Growth parameters such as L∞ and K were obtained from both Bhattacharya (1967) [22] and Gulland and Holt plot (1959) [23]. Growth performance in terms of length was compared using the index $\phi = \text{Log}_{10} K + 2 \text{ Log}_{10} L_\infty$ [24].

The total mortality coefficient (Z) was estimated by length converted catch curve method (Pauly, 1984) [25].

$$Z = K\frac{L_\infty - L_c}{L_c - L_{50}}$$

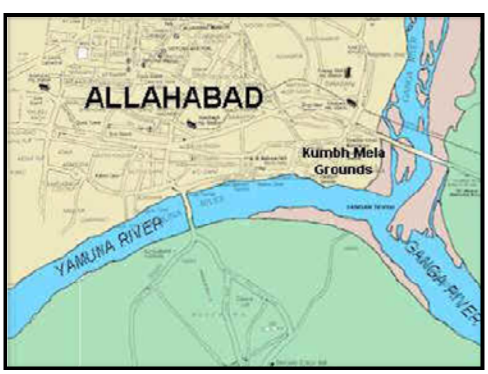
where Z is total mortality, K is growth coefficient, L_∞ is asymptotic length, L_c is mean of the entire catch and L_{50} is the length at which 50% of the fish entering the gear are retained (here we termed it as length at first capture).

Natural mortality coefficient (M) was obtained by the empirical formula suggested by Pauly (1980) [26] as:

Log10 M = - 0.0066 - 0.279 log10 L_+0.6543 log10K+0.4634log10 T where, L_, K and T are asymptotic length, growth rate and mean annual environmental temperature respectively. Temperature was taken as 26 °C [27].

The estimate of fishing mortality (F) was taken by subtracting M from Z. Exploitation rate (U) and Exploitation ratio (E) were expressed by the following formula [28]:

E= F/Z and U= F/Z (1-e -Z)



Map 1: Map of Allahabad is showing two big river Ganga and Yamuna

The probability of capture was determined by backward extrapolating of length converted catch curve, yield per recruit and biomass per recruit was estimated by keeping the Lc constant. With the help of different exploitation ratio (E) on the X axis and different size at the first capture (by using Lc / L∞ ratio) on Y-axis, values of Y/R were plotted to generate the isopleth diagram. The relative yield per recruit (Y/R) and biomass per recruit (B/R) was estimated by 'selection Ogive' method suggested by [29].

3. Results

Weight asymptote (W∞) was calculated as 1500g. The length-weight relationships of *C. mrigala* in logarithmic form were shown as:

Pooled: Log W = -5.21356 + 3.10437Log L (r = 0.991127)

3.1 Population structure

3.1.1 Male population

The population structure of male *C. mrigala* varied from 0+ to 7+ age groups in the lower stretch of the Yamuna River at Allahabad. The 0+ age group accounted for 6.13% of the total male population. The age group 2+ was dominated by virtue of numbers (41.72%). Hence, population of 0+ age group was very less than 2+ age group. The contribution of 1+ age group dramatically increased and shared with 23.31% of the male population (Figure 2). The age groups 3+, 4+ and 5+ contributed 18.40%, 6.13% and 2.45%, respectively. The age groups 0+ to 3+ contributed 89.56% of the total male population. The population of 3+ age group dramatically decreased compared to 2+ age group. The age groups 7+ shared small proportion (0.61%).

3.1.2 Female population

The population structure of female *C. mrigala* varied from 0+ to 10+ age groups. The age group 2+ was dominant population with 37.21% in the total female population. The age group 0+ contributed only 4.65%. The age groups 1+, 3+, 4+ and 5+ shared 20.35%, 22.09%, 7.56% and 2.91%, respectively (Fig. 2). The age groups 8+, 9+ and 10+ shared small proportion (1.74%).

3.1.3 Growth Coefficient

In the present study the growth parameters obtained by the Gulland-Holt plot (1959) as asymptotic length (Loo) is 998mm and growth rate (K) as 1.339 year-1. The t_o found by von Bertalanffy's plot (1938) [30] is 0.648 year-^{1}.

The VBGF of growth for the species is expressed as:

Lt = 998 (1-e (*-1.3397* (t- 0.648)) (Fig. 3).

3.1.4 Mortality Coefficient

During the present study, the instantaneous rate of total mortality coefficient (Z) for *C. mrigala* estimated by length converted catch method was 4.01year-^{1} with a high correlation coefficient (r2) was 0.981 (Fig. 4). The instantaneous natural mortality (M) estimated by Pauly's empirical formula method was 0.784 year-1 for *C. mrigala.* Fishing mortality Z-M was calculated as 3.226 year-^{1}. The exploitation ratio (E) estimated was 0.804 and exploitation rate (U) was 0.7898 for August 2011 to July 2012 for the one years.

3.1.5 Recruitment Pattern

By pooling annual length-frequency, it was seen that there are two overlapping pulses of recruitment (Fig. 5). Major recruitment pulse was evident from February-March with peak in March. (26.80%) when 39.17% recruitment took place and a minor pulse from June –August with peak in June (22.59%), when remaining 40.72% fishes were recruited.

3.1.6 Probability of capture

The selection of probability of capture gave L_{50} for *C. mrigala as* 541.41 mm in gill net (Fig. 6).

3.1.7 Virtual Population Analysis

The estimated number of fish in the river, including those lost due to natural causes and those caught and their fishing mortality are represented in Fig. 7. Thus, the number of fish recruited to the fishery in the mid-size class of 225 mm was more than 12 thousand, their fishing mortality being meagre 1.8, catch (yield) was one thousand with biomass (standing stock) of 31.71t. However, from the fully recruited (L_{50}= 541.41mm) size group of 525-575 mm onwards, the mean fishing mortality was 3.28 which is close to 3.23.

It was also observed that relative yield per recruit peaks at exploitation ratio (E max) of 0.9. The yield isopleth diagram suggested that geometric fishing is possible when exploitation is kept at E= 0.3, M/K=1 and Lc/L∞ = 0.8 (Fig. 8).

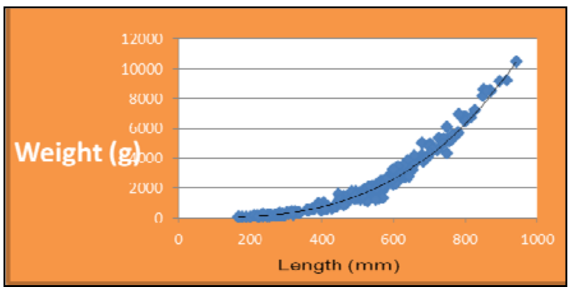


Fig 1: Length –weight relationship of *C. mrigala* at Allahabad water.

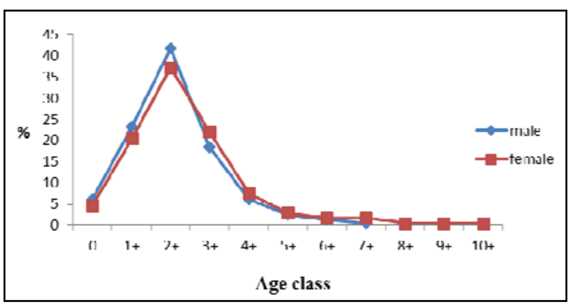


Fig 2: Population structure of male and female of *C. mrigala* at Yamuna River. Allahabad

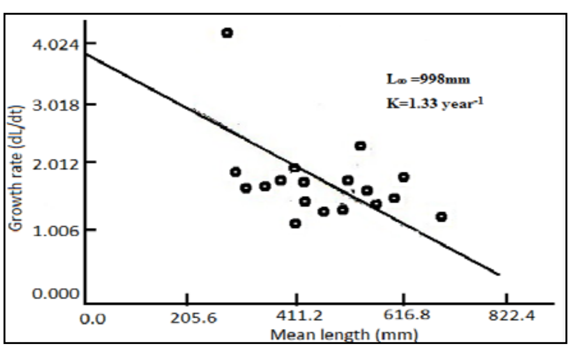


Fig 3: Estimation of Growth parameters of *C. mrigala* through Gulland and Holt method

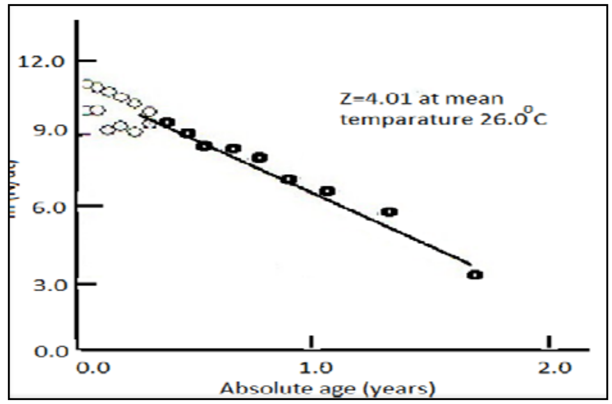


Fig 4: Estimation of total mortality by 'Length converted catch curve method'.

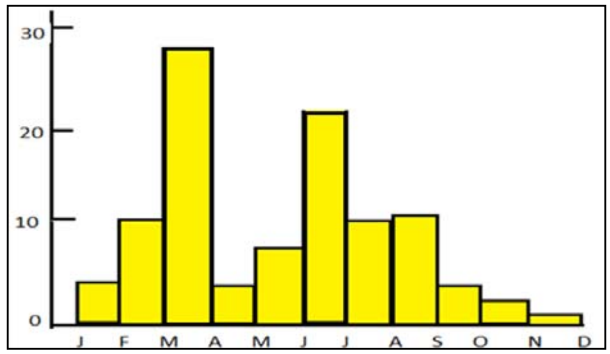


Fig 5: Recruitment pattern of *C. mrigala* at middle stretch of river Ganga at Allahabad

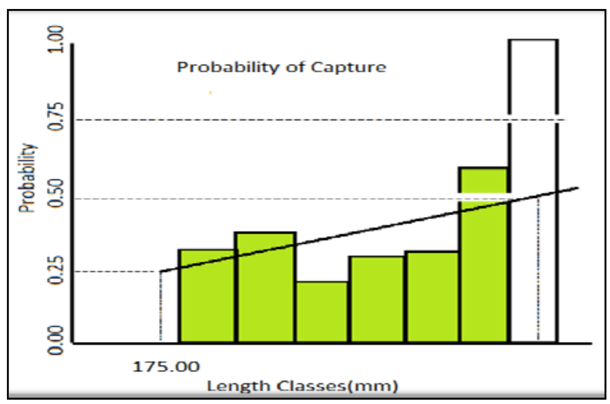


Fig 6: Probability of capture for *C. mrigala* at middle stretch of river Ganga at Allahabad

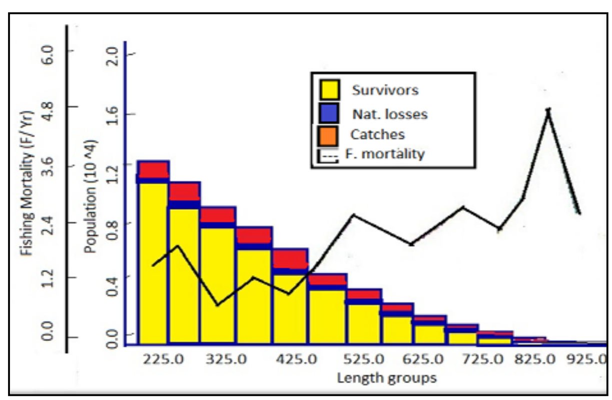


Fig 7: Virtual Population of *C. mrigala* at river Yamuna, Allahabad

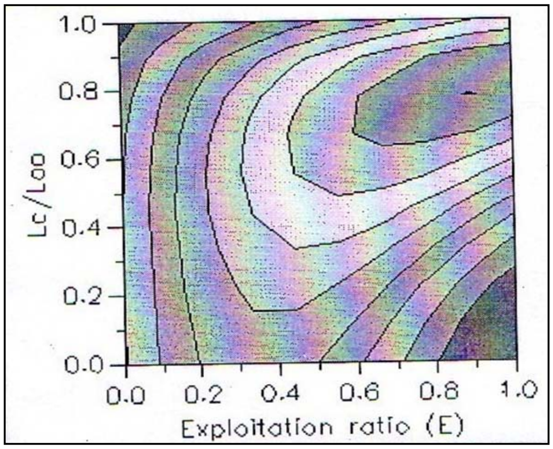


Fig 8: Isopleths diagram of *C. mrigala* at river Yamuna, Allahabad

4. Discussion

The authors [19] expressed the length-weight relationship of *C. mrigala for* the two sexes together as: Log W= -0.401745082+ 3.2848 Log L from Pong reservoir of the Kangra district of Himachal Pradesh. The researcher [18] found the length-weight relationship of *C. mrigala for* both the sexes together as Log W = -4.99627 +2.99552 Log L from River Ganga and Yamuna at Allahabad. Jhingran (1952) [14] also found to be Log W = -5.54534 + 3.221 Log L from River Ganga at Buxar, which is very closed to present study as above mentioned with as a high degree of correlation was observed between total length and weight. Most of the authors found that the exponent 'b' was significantly different ($p<0.05$) from 3. In the present study also 'b' was significantly different for *C. mrigala* thus exhibiting allometric growth. The regression coefficient 'b' indicates that the weight of fish increases more or less in proportion to the cube of its length.

Age of 0+ to 10+ years was determined from the scales of *C. mrigala* population. The largest specimen of this species was measured as 943 mm the estimated age of this age was 10+ years [31].

The earlier research worker [10] was reported from river Godavari the Von Bertalanffy's growth equation for C. *mrigala* as:

$Lt = 1400^{(l-e\ 0.1220)}(t + 0.4622)$

Loo and 'K' were estimated using Ford-Walford (1933 and 1946) [32] growth transformation, whereas another author[9] was also reported slow growth rate from river Yamuna at Allahabad and the Von Bertalanffy's growth equation for C. *mrigala* shown as: $Lt = 1060\ (l\text{-}e^{\ 0.29065}\ (t\text{-}0.03964))$.

Although many authors and [33] were reported slow growth rate in fishes which having long life span and their habitat in cold water such as Himalayan Mahseer (*T. Putitora* from the Gangetic stock) which has a long life span (17+ years) had K value (0.055/ year) very low whereas the Amur carp is also known to attain a size of 90 cm and an age of 16 years.

The growth parameters obtained by the Gulland-Holt plot, (Loo = 998 mm and K = 1.33) by using length frequency data were reasonably good and fell within 95% confidence limit with other methods and therefore, considered for describing the growth of the species. The approximately same result were found even through age at length data (Loo = 980 mm and K = 1.30 per year).

Long Hurst and Pauly (1987) [34] and other workers have shown that the tropical fishes grow much faster than their temperate counterparts. Thus faster growth obtained in the present investigation is justified. The theoretical lengths at different ages as calculated by this growth equation showed as 249, 838 and 956 respectively for the year of 1 to 3 years respectively which is contradictory to his presumption because the growth of *C. mrigala* estimated by [9, 10] appear to be far slower than in the present investigation.

Both authors had shown very slow growth for the fish in tropical region as like growth of cold water fishes[33] therefore, they called for more information on the age and growth of the species. In the present investigation, the methods employed to get the growth parameters yielded asymptotic length ($L\infty$) in the close range of 850-999 mm. The [35] pointed out that the two parameters of growth, asymptotic length ($L\infty$) and growth coefficient (K) are inversely proportionally to each other. It implies that fishes with high $L\infty$ should be with lower K values and those with lower $L\infty$ with higher K values. In the present study, *C. mrigala* showed lower $L\infty$ of 998 mm and K equal to 1.34, whereas in the previous study [10] higher $L\infty$ (1400mm) and lower K (0.1220) and [9] also reported higher $L\infty$ (1060 mm) and lower K (0.03964). Thus, the present estimates of asymptotic length (998 mm) and growth coefficient (1.33) for *C. mrigala* are justified.

The magnitude of coefficient of total mortality in heavily exploited fish population is largely influenced by the extent of fishing intensity. Similarly, after comparing the two species of Indian carp, it was found that *L. calbasu* showed higher natural mortality (0.381 per years) than fishing mortality (0.231 per year) and having small $L\infty$ (667 mm) in river Ghaghra tributaries of the Ganga at Faizabad [36].

The [35] state that the natural mortality coefficient (M) of a fish is inversely related to the asymptotic length ($L\infty$) and growth coefficient 'K', and directly related to the life span of the fishes. The same appear true for *C. mrigala* in the present study. The natural mortality of *C. mrigala* is lower than fishing mortality and having high asymptotic length as compared to other Gangetic carp [35] and other hand side it was found that higher K value and small life span as like other exotic carp like Tilapia [36]. In Bangladesh high fishing mortality was observed for commercially important fish, *C. mrigala* as well as *C. catla* (1.27 yr^{-1} and 1.47 yr^{-1}, respectively [15], *L. calbasu* (3.48 yr^{-1}), [37].

The *C. mrigala* was over exploited in the Yamuna River at Allahabad. This type of exploitation will be harmful for the existing stocks of *C. mrigala*. Fishing should be strictly prohibited in breeding season (July to September) of *C. mrigala*.

Therefore, the maximum sustainable yield (MSY) can be achieved by decreasing present fishing pressure at the level as suggested by the model. In the present study relative yield per recruit (0.104) is higher than relative biomass per recruit (0.061). This model is also suggests that *C. mrigala* is over exploited and fishing mortality may be decrease on the optimal level for exploitation of available fishing resource as E= 0.6, is safe for the stock and may be used as a guideline for large sized species with short life span such as *C. mrigala.* The present investigation clearly showed that the *C. mrigala* over exploited in the Yamuna river. This type of exploitation is harmful for recruitment and stock.

5. Conclusion

The important Indian major carp forms a fishery throughout the year and the fish appears to be over exploited. Being a middle size fish from the tropical region it is showing faster growth with high fishing mortality. Not investigated much from the riverine waters of in and around Allahabad, a proper monitoring of this resource would add to the scientific knowledge of the fish, which has high nutrition and economic value. Moreover, being over exploited, slight decrease in the efforts may result in better catch which enhance the socio-economic and nutritional status of fishermen.

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