

Article

Stock Status of Two Commercially Important Catfishes, *Mystus gulio* (Hamilton 1822) and *Mystus cavasius* (Hamilton 1822), in Relation to Environmental Variables Along the Lower Stretches of the River Ganga, India

Basanta Kumar Das , Susmita Jana, Archisman Ray , Dibakar Bhakta, Canciyal Johnson, Thangjam Nirupada Chanu, Subhadeep Das Gupta and Mitesh H. Ramteke

ICAR—Central Inland Fisheries Research Institute, Barrackpore, Kolkata 700120, West Bengal, India; zmouaayu999@gmail.com (S.J.); archismanray533@gmail.com (A.R.); dibakar.bhakta@icar.gov.in (D.B.); canciyal.cifri@gmail.com (C.J.); nirupada@gmail.com (T.N.C.); subhadeep.cifri@gmail.com (S.D.G.); mitesh.cife@gmail.com (M.H.R.)

* Correspondence: basantakumard@gmail.com

Abstract: *Mystus gulio* and *Mystus cavasius* are small indigenous fish species (SIFs) found throughout the year at the various stretches of the river Ganga and contribute significantly to the commercial fishery. The current study was conducted with a total of 609 specimens of *M. gulio* with a total length ranging from 84 to 190 mm and 377 specimens of *M. cavasius* with a total length ranging from 51 to 232 mm, collected from eight selected sites of lower stretches of the river Ganga between July 2018 and October 2019 to analyse their growth, mortality, and exploitation status. The sample specimens' length-frequency distribution, primarily taken from bag nets and set barrier nets used in artisanal fisheries, was assessed using the FiSAT II programme. For *M. gulio*, the estimated asymptotic length (L_{∞}), growth coefficient (K), and initial condition factor (t_0) were 183.23 mm, 0.31 yr^{-1} , and -0.486 years, and for *M. cavasius*, these values were 246.23 mm, 0.19 yr^{-1} , and -0.302 years, respectively. The estimates for the total (Z), natural (M), and fishing (F) mortality rates were 1.78, 0.49, and 1.29 yr^{-1} for *M. gulio* and 0.68, 0.33, and 0.35 yr^{-1} for *M. cavasius*, respectively. Both *M. gulio* (May to July) and *M. cavasius* (June to August) experienced a single spawning peak. The estimated exploitation ratio (E) for *M. gulio* was 0.72, which is higher than the optimal level of exploitation (E_{opt}) and the maximum level of exploitation (E_{max}). On the other hand, the E value for *M. cavasius* was 0.52, which means that it was exploited at the right level. The fishing pressure was found to be slightly excessive for the current stocks of *M. gulio*, which should be considered for proper management of the fishery in the river Ganga. The present study, the first of its kind, highlights the stock status of these two commercially important species and the management measures taken to revive the stock along the lower stretches of the Ganga in India. The environmental parameters of the lower stretches of the river Ganga show favourable conditions for the optimum growth of *M. gulio* and *M. cavasius*.

Keywords: stock assessment; river Ganga; *Mystus gulio*; *Mystus cavasius*; management measures

Key Contribution: The river Ganga is home to a wide variety of fish species. Small indigenous fish species (SIFs), such as *Mystus gulio* and *Mystus cavasius*, are found all year round along the Ganga River. The present study demonstrates that the current exploitation ratio (E) of *M. gulio* is significantly higher than the predicted maximum level of exploitation (E_{max}) and optimum exploitation level (E_{opt}); therefore, fishing pressure on *M. gulio* should



Received: 20 January 2025

Revised: 14 March 2025

Accepted: 15 March 2025

Published: 21 March 2025

Citation: Das, B.K.; Jana, S.; Ray, A.; Bhakta, D.; Johnson, C.; Chanu, T.N.; Das Gupta, S.; Ramteke, M.H. Stock Status of Two Commercially Important Catfishes, *Mystus gulio* (Hamilton 1822) and *Mystus cavasius* (Hamilton 1822), in Relation to Environmental Variables Along the Lower Stretches of the River Ganga, India. *Fishes* **2025**, *10*, 142. <https://doi.org/10.3390/fishes10040142>

Copyright: © 2025 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

be reduced. The length at first capture of *M. cavasius* exceeds the length at maturity, indicating that the juveniles are captured more often, and the current level of exploitation (*E*) of *M. cavasius* is slightly over the optimal level of exploitation; therefore, mesh size regulation for *M. cavasius* is recommended to maintain sustainable fisheries along the lower Ganga River. The present study provides an extensive assessment of the ecosystem health of the lower stretches of the Ganga River, particularly concerning fisheries and their management.

1. Introduction

The Ganga River, the longest river in India and the fifth largest in the world, is home to a wide variety of fish species [1,2]. Das et al. [2] documented 190 fish species in the river Ganga, 42 of which are commercially important with high market values. Of them, 36% are ornamental fish, 3.0% are sport fish, and 61% are food fish. Despite having a wide variety of ichthyofauna, the river is recognized as the home of several highly valued Gangetic carp, shads, minnows, barbs, catfish, and other species.

Catfish, a diverse group of ray-finned fish in the order Siluriformes, inhabit freshwater environments across the world. The order Siluriformes is the second largest teleost order, comprised of 3961 species under 39 families and 507 genera, accounting for approximately 12% of all teleosts, out of which 242 valid species come under the family Bagridae [3]. The family includes five commercially important species under the genus *Mystus*, viz., *Mystus bleekeri* (Day, 1877), *M. cavasius* (Hamilton, 1822), *M. gulio* (Hamilton, 1822), *M. tengara* (Hamilton, 1822), and *M. vittatus* (Bloch, 1794) [4].

Mystus gulio (Hamilton, 1822), commonly known as the Long Whiskers Catfish, is a species of freshwater catfish belonging to the family Bagridae. This fish is widely distributed across South and Southeast Asia, the eastern Indian Ocean, India, Indonesia, and Vietnam. It is primarily a brackish water fish that enters and lives in fresh water. Adults in freshwater are primarily found in larger bodies of water, such as rivers and streams [5,6]. It holds some commercial importance in certain regions where it is found; however, its commercial significance may vary depending on local fishing practices, demand for fish, and the availability of alternative fish species. *M. cavasius* (Hamilton, 1822), commonly known as Gangetic mystus, is distributed in India, Bangladesh, Pakistan, Nepal, Sri Lanka, Thailand, and Myanmar; it mostly inhabits fresh water [5,7].

Mystus gulio and *M. cavasius* are small indigenous fish species (SIS) with a high nutritional value that includes protein, micronutrients, vitamins, and minerals [8–10]. Due to their delicacy and protein-rich contents, these fish are highly preferred by consumers and in high demand in Bangladesh and eastern India [11]. Recent research has found a mix of natural and anthropogenic challenges that pose significant threats to the freshwater biota of the river [2]. Overexploitation and other ecological changes that negatively impact the species' natural habitat have caused the natural population to decline [12,13].

Studies on population dynamics and the stock status of particular fish species provide new insight into setting up specific conservation strategies. Understanding the population dynamics, growth patterns, maturity, and mortality of fish is essential for the sustainable management of the fishery. Its usefulness in measuring growth, mortality, and recruitment capabilities helps draw inferences about the production rates of populations of different species [14,15]. It offers useful information on factors that affect population dynamics, such as recruitment success, age at first maturity, frequency of spawning, stock structure, and individual reactions of stocks to altered habitats. When analysing many biological

processes, such as productivity, yield per recruit, availability of food, suitability of the habitat, and even feeding mechanics, fish age, and growth are particularly crucial [16–18].

Estimating population parameters is necessary to decide how effectively to use and maintain aquatic living resources [19].

Several kinds of statistical and mathematical approaches are used to obtain quantitative assessments of the effects that various management strategies will have on fish populations [19]. Since population dynamics estimate growth, death, and recruitment patterns, they are crucial for determining the rates of production [15,20–23]. These characteristics provide important insights on a range of subjects, including spawning periodicity and stock reactions to environmental changes, recruitment, and stock structure, because of their influence on population dynamics [22,24–26]. The abundance of desired, quantitative, and scientific studies is essential for stock assessment in fisheries management [14]. Only roughly half of the exploited fish species have been investigated worldwide due to the data needs of conventional or traditional stock assessment approaches [27].

Although several studies on the length–weight relationship of *M. gulio* and *M. cavasius* are available, there is inadequate information on the stock status of these species.

So, this study was conducted to assess the status of the stocks of *M. gulio* and *M. cavasius* and to estimate population parameters along the lower parts of the Ganga River.

2. Materials and Methods

2.1. Sampling Sites

The present study was conducted at eight sampling stations along the lower stretches of the river Ganga in West Bengal. A total of 609 *M. gulio* specimens were collected from four selected sites: Diamond Harbour (22.1927° N, 88.1895° E), Godakhali (22.3932° N, 88.1426° E), Kakdwip (21.8760° N, 88.1853° E), and Fraserganj (21.5851° N, 88.2585° E), whereas *M. cavasius*, with a total of 377 specimens, was collected from Balagarh (23.122444°N, 88.463278° E), Farakka (24.7875° N, 87.904167° E), Tribeni (22.9901° N, 88.3943° E), and Nabadwip (23.4037° N, 88.3659° E) in West Bengal (Figure 1).

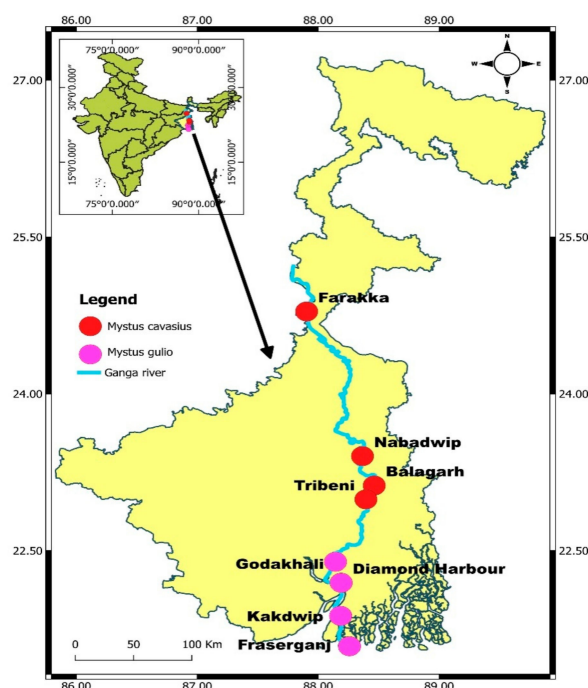


Figure 1. The sampling sites of *M. gulio* and *M. cavasius* along the river Ganga.

2.2. Sampling and Data Collection

Monthly length–frequency data for *M. gulio* and *M. cavasius* were collected from July 2018 to October 2019 at selected sites. The specimens of *M. gulio* were obtained using a bag net (18–24 mm mesh size), cast net, hook, and line, and *M. cavasius* were collected from a gill net with a mesh size of 20–30 mm and a set barrier net with a mesh size of 20–40 mm.

The total length (TL) of the fish specimens was measured to the nearest millimetre (mm) using a standard measuring board, beginning at the tip of the body's anterior region and extending up to the caudal fin tip. A digital electronic balance was used to determine the total weight (TW) to the closest gram (g). Monthly length–frequency data were used in the FiSAT II software (FAO-ICLARM Stock Assessment Tool) version 1.2.2 outlined by Gayanilo et al. [28], after the division of the length–frequency data into class intervals of 10 mm.

2.3. Estimation of Population Parameters

The statistical analysis of the length–weight relationship was accomplished by using the parabolic equation $W = aL^b$. Logarithmically, this equation is represented as $\text{Log } W = \log a + b \log L$ [29], where a stands for the intercept and b for regression coefficients, W is the weight of the fish in g, and L is its length in mm.

The ELEFAN I (Electronic Length Frequency Analysis) module in FiSAT II was used to estimate growth parameters such as asymptotic length (L_∞) and growth coefficient (K). Pauly's (1979) [30] empirical equation was used to calculate the age at zero length (t_0), as follows:

$$\log_{10}(-t_0) = -0.3922 - 0.275 \log_{10} L_\infty - 1.038 \log_{10} K$$

where t_0 is the initial condition factor, or age at zero length, K is the growth coefficient, and L_∞ is the asymptotic length. Using Pauly and Munro's equation (1984) [31], the growth performance index (ϕ') of *M. gulio* and *M. cavasius* was estimated.

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

The length-converted catch curve method [32,33] in FiSAT II was used to determine the total mortality (Z), and the natural mortality (M) was calculated using the empirical formula proposed by Pauly [34].

$$\ln(M) = -0.0152 - 0.279 \ln(L_\infty) + 0.6543 \ln(K) + 0.463 \ln(T)$$

where “ T ” represents the average annual water temperature [35]. Fishing mortality (F) was calculated by deducting natural mortality (M) from total mortality (Z).

$$F = Z - M$$

The following equation was used to estimate the exploitation level (E) of *M. gulio* and *M. cavasius*.

$$E = F/Z$$

2.4. Stock Assessment

The length-converted catch curve was used to calculate the probability of capture for stock assessment of *M. gulio* and *M. cavasius*. By following Pauly's [36] formula, length-structured virtual population analysis was estimated. The relative yield per recruit model by Beverton and Holt [37] was used to estimate the relative yield per recruit (Y'/R) and biomass per recruit (B'/R) at various levels of fishing effort. Based on Y'/R , the stock's

status for *M. gulio* and *M. cavasius* was assessed. Pauly (1983b) [38] provided the following equation to estimate the maximum life span ($t_{\max}$) of the species:

$$t_{\max} = 3/K + t_0$$

2.5. Water Quality Parameters

The measurement of water quality parameters was recorded bimonthly from eight different sampling sites during the sampling period (July 2018 to October 2019) following the standard protocols in APHA [39]. Samples from each site were taken in triplicate to reduce the standard error [40]. Sampling was carried out between 9:00 A.M. and 10:00 A.M.

3. Results and Discussion

3.1. Age and Growth

Estimation of growth parameters for particular species is crucial to know the present status of fish, which is recognized as an important aspect of fishery management. The study revealed that *M. gulio* and *M. cavasius* are available throughout the year along the lower stretches of the river Ganga (Figure 2a,b). The total length and weight of 609 *M. gulio* individuals ranged from 84 to 190 mm and 7.3 to 83.3 g, respectively. The smallest length group of fish was recorded in March, while the fish of the largest length group were observed during all the months of sampling, as most of the fish were caught by bag net (5–10 mm cod end mesh size) and set barrier net (20–40 mm). The length frequency distribution shows that the length group 171–180 mm contributed the most (30.21%), followed by 151–160 mm (20.20%) (Figure 2a,b). The growth parameters, asymptotic length (L_{∞}) and growth coefficient (K), were estimated at 183.23 mm and 0.31 yr^{-1} by using ELEFAN I in the FiSAT program. The calculated age at zero length (t_0) was -0.486 years. Therefore, the Von Bertalanffy growth equation was calculated as $L_t = 183.23 [1 - e^{-0.31(t + 0.486)}]$. Using the growth equation, the lengths attained by *M. gulio* at the end of 1, 2, 3, 4, and 5 years were calculated as 68, 98, 121, 138, and 150 mm, respectively (Figure 3a). The estimated smallest length was 124 mm, with a corresponding age of 0.98 years. The growth performance index (ϕ') represents the total growth performance of the fish population as determined by growth in length [31]. The growth performance index (ϕ') and maximum life span ($t_{\max}$) of *M. gulio* were estimated as 4.017 and 9.19 years, respectively.

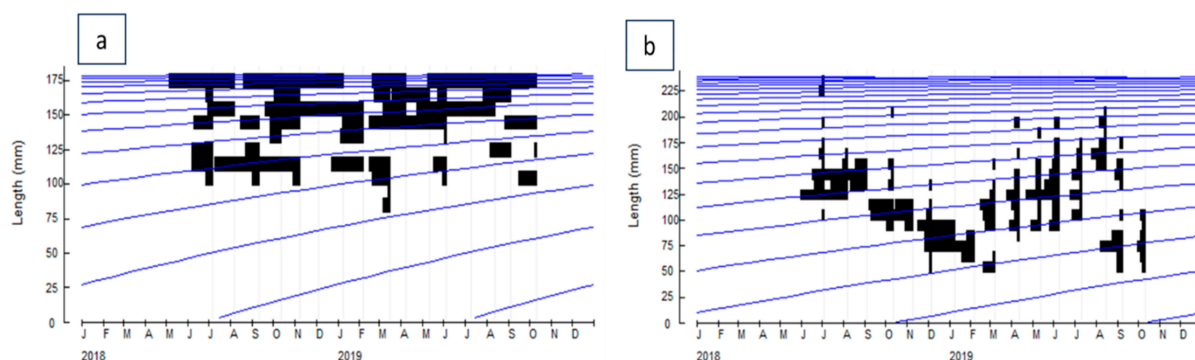


Figure 2. (a,b). Length–frequency distribution and seasonal occurrence of *M. gulio* (a) and *M. cavasius* (b) along the lower stretches of the river Ganga.

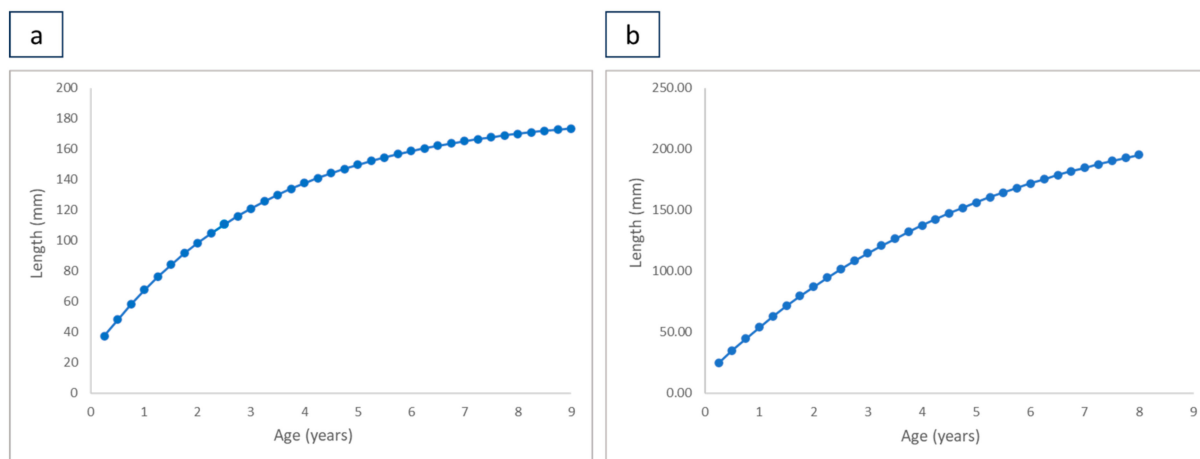


Figure 3. (a,b). Average length attained by *M. gulio* (a) and *M. cavasius* (b) at different ages.

The present study reported that the value of L_{∞} and K of *M. cavasius* by ELEFAN I was 246.23 mm and 0.19 yr^{-1} , and t_0 was calculated as -0.302 years, respectively. The growth equation of von Bertalanffy was derived as follows: $L_t = 246.23 [1 - e^{-0.19(t + 0.302)}]$. The ϕ' and t_{max} were calculated as 4.061 and 15.49 years, respectively. A total of 377 individuals of *M. cavasius* ranged in size from 51 to 232 mm in total length and 1.7 to 82.3 g in total weight. Using the growth equation, the lengths attained by *M. cavasius* at the end of 1, 2, 3, 4, and 5 years were calculated to be 54, 87, 115, 137, and 156 mm, respectively (Figure 3b). The length–frequency distribution of *M. cavasius* is illustrated in Figure 3b.

Table 1 represents the population parameters of *M. gulio* and *M. cavasius* in different stretches of the river Ganga.

Table 1. Population parameters of *M. gulio* (n = 609) and *M. cavasius* (n = 377) from different stretches of river Ganga.

Sl. No.	Parameters	<i>M. gulio</i>	<i>M. cavasius</i>
1	Asymptotic length (L_{∞}) in m	183.23	246.23
2	Growth coefficient (K) in yr^{-1}	0.31	0.19
3	Age at zero length (t_0) in year	-0.486	-0.302
4	Growth performance index (ϕ')	4.017	4.061
5	Longevity (t_{max})	9.19	15.49
6	Total mortality coefficient (Z) in yr^{-1}	1.78	0.68
7	Natural mortality coefficient (M) in yr^{-1}	0.49	0.33
8	Fishing mortality coefficient (F) in yr^{-1}	1.29	0.35
9	Exploitation ratio (E)	0.72	0.52

M. gulio was reported to have growth parameters L_{∞} and K of 230 mm and 0.75 yr^{-1} , respectively, in the Sunderbans ecosystem, Bangladesh [41], which is slightly higher than in the present study. Thippeswamy et al. [42] observed a slightly higher growth coefficient ($K = 0.56$). According to Nath et al. [43], L_{∞} , K , and t_0 values of *M. cavasius* are 217.0 mm, 0.8 yr^{-1} , and -0.41 years, respectively, where the growth coefficient is significantly higher than the present study, indicating a higher growth rate of the species. These variations are mostly due to the geographical distribution, environmental variables, and different fishing intensities. Within a species, growth parameters can differ between stocks, between sexes, and between cohorts due to environmental influences [19,44]. According to Sekitar et al. [45], environmental parameters also affect the growth patterns of different *Mystus* spp. However, the availability of plankton and the spawning season are the primary determinants of growth patterns.

3.2. Mortality Parameters

The estimated instantaneous total mortality coefficient (Z) of *M. gulio* using the length-converted catch curve method [33] was 1.78 yr^{-1} , the natural mortality coefficient (M) by using Pauly's empirical formula [34] was 0.49 yr^{-1} , and the fishing mortality coefficient (F) was 1.29 yr^{-1} (Figure 4a). The present study indicated that fishing mortality is significantly higher than natural mortality, which unequivocally indicates too much fishing pressure on *M. gulio* along the stretches of the river Ganga. Mustafa et al. [41] found that the natural mortality of *M. gulio* (M) was slightly higher than the fishing mortality. Similarly, for *M. cavasius*, Z , M , and F values were estimated at 0.68 yr^{-1} , 0.33 yr^{-1} , and 0.35 yr^{-1} , respectively (Figure 4b).

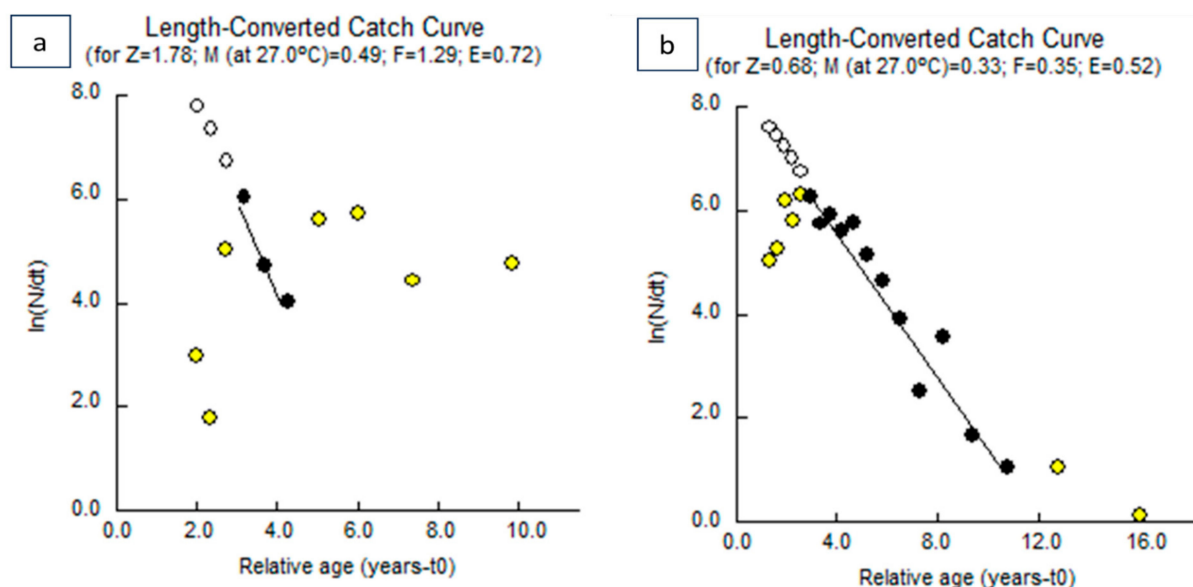


Figure 4. (a,b). Length-converted catch curve for estimation of total mortality (Z) for *M. gulio* (a) and *M. cavasius* (b) along the lower stretches of the river Ganga.

The exploitation ratio (E) of *M. gulio* by the length-converted catch curve method [33] was estimated at 0.72, which surpassed the optimum level of exploitation ($E_{opt} = 0.5$) and maximum exploitation level ($E_{max} = 0.38$), indicating the overexploitation of the *M. gulio* stock along the lower stretches of the river. Mustafa et al. [41] observed that the population of *M. gulio* was underexploited in the Sunderbans ecosystem of Bangladesh. The E value of *M. cavasius* was calculated as 0.52, which indicates that the stock of *M. cavasius* along the stretches of the river Ganga is optimally exploited. Thippeswamy et al. [42] reported Z , M , and F values of *M. cavasius* as 3.86 yr^{-1} , 1.3 yr^{-1} and 2.5 yr^{-1} , respectively, from the Bhadra reservoir, Karnataka, indicating that the fishing mortality is higher than the natural mortality which is in agreement with the results of the present study. The exploitation ratio ($E = 0.65$) is higher than the optimum level of exploitation, indicating an overexploited *M. cavasius* stock in the reservoir [42].

However, there is no other study on mortality and exploitation status available for the species to compare with the present one.

According to Beverton and Holt [46], the natural mortality factor (M) has an inverse relationship with the lifespan (t_{max}) and asymptotic length (L_∞) and a direct relationship with the fish's growth coefficient (K). Therefore, the present study, in estimating a greater growth coefficient (K), a lower asymptotic length (L_∞), and a shorter lifespan (t_{max}), indicates a higher natural mortality in *M. gulio*. Table 2 represents a comparative analysis of population parameters for *M. gulio* and *M. cavasius*.

Table 2. A comparative analysis of population parameters of *M. gulio* and *M. cavasius*.

Species	Authors	Study Area	n	TL (mm)	TW (g)	Regression Parameters		L_{∞} (mm)	K (yr ^{−1})	t_0 (years)	Z (yr ^{−1})	M (yr ^{−1})	F (yr ^{−1})	ϕ'	E
						a	b								
<i>Mystus gulio</i>	Hossain et al. (2016) [4]	Rupsha River, Bangladesh	59	74–172	6.1–62.2	0.0091	3.11	-	-	-	-	-	-	-	-
	Mustafa et al. (2019) [41]	Bangladesh	-	-	-	-	-	230	0.75	-	3.01	1.591	1.42	2.599	0.47
	Rahman et al. (2021) [47]	Maloncho River, Bangladesh	1200	78–183	8.09–128.8	-	2.50–2.85	-	-	-	-	-	-	-	-
	Paujiah et al. (2023) [48]	West Java, Indonesia	-	-	-	0.015–0.036	2.424–2.786	-	-	-	-	-	-	-	-
	Present Study	Ganga river, India	609	84–190	7.3–83.3	0.000002	3.370	183.23	0.31	−0.486	1.78	0.49	1.29	4.017	0.72
<i>Mystus cavasius</i>	Soomro et al. (2015) [49]	Indus river, Pakistan	391	75–235	7–94	-	2.54	-	-	-	-	-	-	-	-
	Hossain et al. (2016) [4]	Ganges river, Bangladesh	171	50–150	1.3–30.4	0.0069	3.10	-	-	-	-	-	-	-	-
	Aktheret al. (2017) [50]	Bangladesh	300	102–148	10.6–20.2	0.000005	3.07	-	-	-	-	-	-	-	-
	Latif et al. (2018) [51]	Chenab river, Pakistan	100	59–178	2.00–42.0	-	2.71	-	-	-	-	-	-	-	-
	Thippeswamy et al. (2022) [42]	Bhadra reservoir, Karnataka							0.56	−0.046	3.86	1.35	2.51	2.413	0.65
	Nath et al. (2023) [43]	Assam, India	285	-	-	-	-	217	0.8	−0.41	-	-	-	-	-
	Present study	Ganga river, India	377	51–232	1.72–82.32	0.000024	2.749	246.23	0.19	−0.302	0.68	0.33	0.35	4.061	0.52

3.3. Recruitment Pattern

The estimated values of the growth parameters were used to derive the recruitment pattern using recruitment curves. The length–frequency data of *M. gulio* showed a consistent recruitment pattern over the year, with a single peak from May to July (Figure 5a). The length at recruitment (L_r) was measured as the midpoint, 124.5 mm, of the smallest length group (120–129 mm) in the catch. According to Lal et al. [52], the peak value of the gonadosomatic index of *M. gulio* was observed during the monsoon season (June–July). The peak spawning season of *M. gulio* occurred in May [41], which coincides with the current study. Kaliyamurthy [53] observed the spawning periodicity a little late (August–October) in Pulicat Lake as the breeding season in different regions differs. All of the research, however, supports the current study in that *M. gulio* only spawns once throughout the year.

The current study on *M. cavasius* also found that there was a single peak spawning period from June to August and a continuous recruitment pattern (Figure 5b).

Bhatt [54] illustrated that *M. cavasius* (both male and female) spawned during July and August with a single peak, which is in agreement with the present study. According to Rao et al. [55], intense breeding was observed during August and September at the Mehadrigeedda stream of Visakhapatnam. In another study reported by Rao [56] in the Hemavathi reservoir, Karnataka, *M. cavasius* spawned during June and July. The study reported by Chaturvedi and Saksena [57] also showed a similar breeding pattern (July and September) in the Chambal River in Madhya Pradesh. The recruitment patterns of *M. gulio* and *M. cavasius* observed by different authors in different regions are presented in Table 3.

Table 3. Recruitment pattern of *M. gulio* and *M. cavasius* observed by different authors in different regions.

Species	Authors	Study Area	Peak Spawning Season
<i>Mystus gulio</i>	Kaliyamurthy (1981) [53]	Pulicat lake, Andhra Pradesh	August–October
	Lal et al. (2016) [52]	Astamudi estuary, Kerala	June–July
	Mustafa et al. (2019) [41]	Sundarbans ecosystem of Bangladesh	May
	Present study	Ganga river, India	May–July
<i>Mystus cavasius</i>	Bhatt (1971) [54]	Uttar Pradesh	July and August
	Rao et al. (1999) [55]	Visakhapatnam, Andhra Pradesh	August–September
	Rao (2007) [56]	Karnataka	June–July
	Chaturvedi and Saksena (2013) [57]	Madhya Pradesh	July and September
	Present study	Ganga river, India	June–August

3.4. Length at First Capture

The length at first capture (L_c or $L_{50\%}$), the length at which 50% of the fish population became vulnerable to fishing, was found to be 118.48 mm for *M. gulio* (Figure 6a) and 89.42 mm (Figure 6b) for *M. cavasius*. The length at maturity of *M. gulio* from Indian waters was reported as 83 mm for males and 85 mm for females by Lal et al. [52] and 62 mm by Pantulu [58]. The L_c recorded in the present study is far above the above-cited values, indicating sustainable exploitation. According to Bhatt [54], the estimated length at maturity (L_m) of *M. cavasius* is 100 mm, which is higher than the length at first capture (89.42 mm) of the present study. This data indicates that this species is entering the growth overfishing phase along the stretches of the Ganga River, as a significant proportion of individuals are being caught before reaching sexual maturity and completing their spawning cycle.

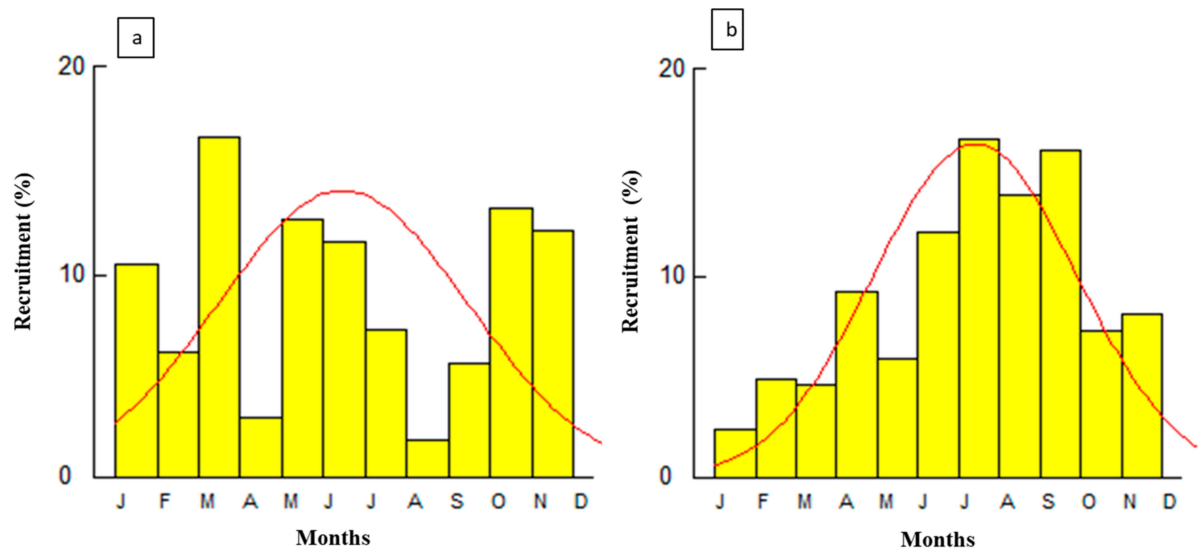


Figure 5. (a,b). Depicted recruitment pattern of *M. gulio* (a) and *M. cavasius* (b) along the lower stretches of the river Ganga.

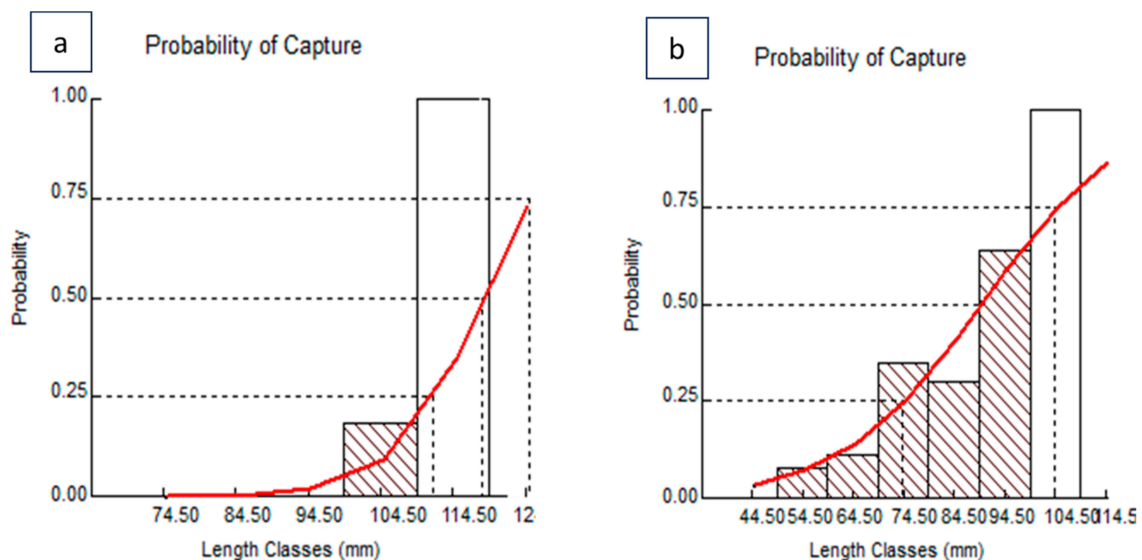


Figure 6. (a,b). Probability of capture of *M. gulio* (a) and *M. cavasius* (b) along the lower river Ganga.

3.5. Virtual Population Analysis

The length-structured VPA results indicated that overexploitation of *M. gulio* occurs along the different stretches of the river Ganga. L_{∞} as 183.23 mm, K as 0.31 yr^{-1} , M as 0.49 yr^{-1} , F as 1.29 yr^{-1} , a as 0.000002, and b as 3.370 from the length–weight relationship were the input parameters employed for virtual population analysis (VPA). The smaller groups (81–90 mm and 91–100 mm) merely showed natural mortality. Fishing mortality (F) started increasing from the length group of 141–150 mm, reaching the highest value of 1.29 yr^{-1} at the length groups of 161–170 mm and 171–180 mm. The 81–90 mm length group has the largest abundances (6,615,606), with a biomass of 125.06 metric tons and a respective fishing mortality of 0.0033 yr^{-1} . The lowest abundances (207,443) were observed in the largest length group (161–170 mm). The biomass increased from 125.06 tons to the highest of 354.92 tons in the length group of 141–149 mm, then gradually decreased to 187.88 tons in the length class of 161–169 mm (Figure 7a).

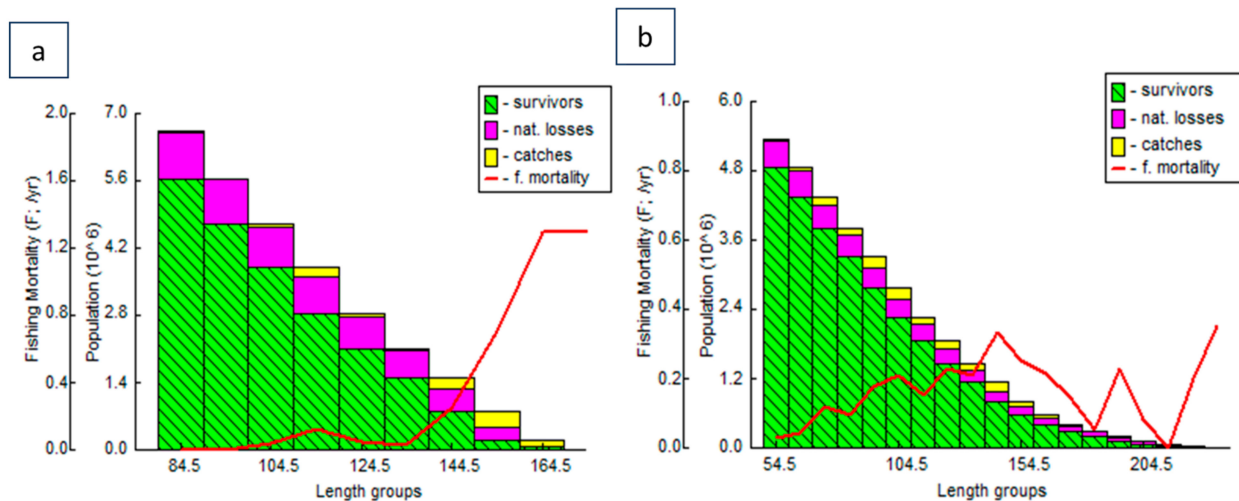


Figure 7. (a,b). Length-structured Virtual Population Analysis (VPA) of *M. gulio* (a) and *M. cavasius* (b) along the lower stretches of the river Ganga.

For *M. cavasius*, the smallest length group (51–60 mm) showed the highest natural mortality, whereas fishing mortality started in the 51–60 mm length group and reached its maximum (0.33 yr^{-1}) in the length class of 141–150 mm. The largest abundance (5,351,426) was found in the smallest length group (51–60 mm), with a biomass of 20.06 tons and a respective fishing mortality of 0.0307 yr^{-1} . The largest length class showed (231–240 mm) the lowest abundance (10,793), with the lowest biomass of 12.49 tons and corresponding fishing mortality of 0.35 yr^{-1} (Figure 7b).

3.6. Relative Yield per Recruit and Relative Biomass per Recruit

The method of knife edge selection for length at first capture (118.48 mm) was used to determine Beverton and Holt's relative yield per recruit (Y'/R) and relative biomass per recruit (B'/R) of *M. gulio*. The input data of the knife-edge selection method consisted of M/K (1.58) and L_C/L_∞ (0.65), and the output E_{max} , $E_{0.1}$, and $E_{0.5}$ values were obtained as 0.38, 0.31, and 0.25, respectively (Figure 8a). The length at first capture for *M. cavasius* was estimated at 89.42 mm. The input data used in the knife-edge selection method were M/K (1.74) and L_C/L_∞ (0.36), and the output E_{max} , $E_{0.1}$, and $E_{0.5}$ values were obtained as 0.38, 0.31, and 0.25, respectively (Figure 8b).

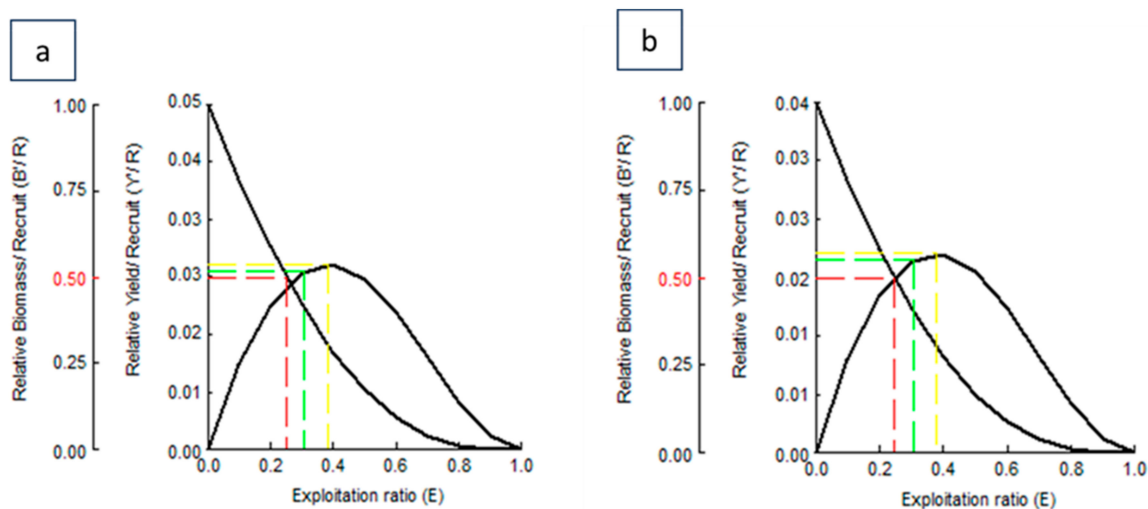


Figure 8. (a,b). Relative yield per recruit and relative biomass per recruit model using knife-edge selection curve for *M. gulio* (a) and *M. cavasius* (b) along the lower stretches of the river Ganga.

3.7. Water Quality Parameters

Standard procedures from APHA were followed to analyse the water quality parameters from the selected sites of the lower stretches of the river Ganga. The range and average values of water temperature ($^{\circ}\text{C}$), depth (m), transparency (cm), specific conductivity ($\mu\text{S}/\text{cm}$), pH, DO (mg/L), TDS (mg/L), total alkalinity (mg/L), chlorophyll-a (mg/m^3), and salinity (ppt) are presented in Table 4.

In aquatic environments, water temperature plays a crucial role and has a major impact on the general health of the aquatic community. The temperature of the water has a significant impact on the gonadal maturity of many organisms, including fish [59]. The highest average temperature was recorded at Godakhali ($28.05 \pm 3.99^{\circ}\text{C}$) and the lowest was observed at Nabadwip ($24.33 \pm 6.03^{\circ}\text{C}$). Nath [60] observed that the gradient zone had a greater temperature than the freshwater and marine zones, which was attributed to the gradient zone's increased turbidity. Balagarh shows both the maximum (33.9°C) and the minimum water temperature (18.7°C), which is generally associated with anthropogenic activities, climate change, and global warming that may have contributed to the abrupt shifting of temperatures in the area [61].

The highest average depth was recorded at Diamond Harbour ($15.02 \pm 11.26\text{ m}$) and the lowest at Kakdwip ($4.1 \pm 2.42\text{ m}$), followed by Fraserganj ($4.64 \pm 5.19\text{ m}$). The greater depth at Diamond Harbour has also been documented in previous investigations carried out in the area by Manna et al. (2013) [62] and Tiwari et al. (2022) [63], most likely because of the influence of the river Rupnarayana, a tributary of the river Ganga. Sedimentation is responsible for the shallow condition of the estuary mouth, as evidenced by the low water depths at Kakdwip and Fraserganj [62].

River transparency indicates the clarity and quality of the water [64]. The highest average transparency ($78.95 \pm 47.89\text{ cm}$) was observed at Farakka, as it is a freshwater zone, and the lowest at Diamond Harbour ($16.96 \pm 7.65\text{ cm}$). Manna et al. [62] and Tiwari et al. [63] observed that Diamond Harbour, which is influenced by tidal water due to the confluence with the river Rupnarayana, had the lowest transparency.

Specific conductivity provides a reliable estimate of the amount of dissolved material in the water. It gradually increased towards the estuarine zone. The highest average specific conductivity (34.26 ± 13.81) was recorded at Fraserganj, whereas the lowest was observed at Nabadwip (0.33 ± 0.06). Tiwari et al. [63] also observed that Fraserganj had the highest specific conductivity. The riverine system's dissolved inorganic and organic matter primarily contribute to the increase in total dissolved solids (TDS) value [65]. Both the maximum and minimum values of TDS are recorded in Fraserganj due to the influx of seawater.

The average dissolved oxygen concentration across all sites was adequate to promote aquatic biota growth and survival ($\text{DO} > 5$) [26,62]. The highest average alkalinity was recorded at Tribeni ($135.75 \pm 35.35\text{ ppm}$), whereas Fraserganj showed the lowest ($117.75 \pm 19.14\text{ ppm}$). Previous reports from the same study stretch demonstrated a fairly similar range of alkalinity [62,63]. Researchers found that increasing salinity causes a decrease in total alkalinity [66]. The primary factor that efficiently regulates fish and other aquatic organism distribution is salinity. Manna et al. [62] have demarcated two different zones of the studied stretch based on the salinity; one is freshwater and the other is a saline and transition zone. The freshwater zones of Farakka, Nabadwip, Tribeni, and Balagarh have the lowest average salinity (0.02 to 0.04 ppt), which makes them ideal homes for *M. cavasius* [6]. Salinity increases gradually towards the lower estuarine zone as the influx of salt water from the sea has a significant impact on the salinity [67]. The highest average salinity was found at Fraserganj ($28.73 \pm 1.78\text{ ppt}$), followed by Kakdwip ($7.21 \pm 3.05\text{ ppt}$) and Diamond Harbour ($4.32 \pm 1.54\text{ ppt}$), indicating that the saline and transition zone are ideal for the growth of *M. gulio* [68].

Table 4. Range and average water quality parameters recorded from the selected sites of lower stretches of the river Ganga.

Water Quality Parameters	<i>Mystus cavasius</i>								<i>Mystus gulio</i>							
	Farakka		Nabadwip		Tribeni		Balagarh		Godakhali		Diamond Harbour		Kakdwip		Fraserganj	
	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD	Range	Mean $\pm$ SD
Water temp. (0 C)	19.1–30.6	26.56 $\pm$ 3.56	18.2–31.6	24.33 $\pm$ 6.03	17.4–32.8	27.36 $\pm$ 5.06	18.7–33.9	27.28 $\pm$ 4.72	19–31.5	28.05 $\pm$ 3.99	22–31.7	27.81 $\pm$ 3.37	21–31.7	25.48 $\pm$ 4.86	19.2–31.1	27.53 $\pm$ 4.18
Depth (m)	4.0–18.0	8.57 $\pm$ 4.60	2.2–11.5	6.84 $\pm$ 3.82	7.0–18.7	10.94 $\pm$ 4.69	2.3–17.4	7.43 $\pm$ 4.44	0.13–14.0	8.85 $\pm$ 5.18	0.18–35.2	15.02 $\pm$ 11.26	1.8–7.5	4.1 $\pm$ 2.42	0.15–17.0	4.64 $\pm$ 5.19
Transparency (cm)	12.2–145.0	78.95 $\pm$ 47.89	18–50	35 $\pm$ 12.33	13.2–37.0	24.9 $\pm$ 7.77	9.5–43.5	27.08 $\pm$ 12.07	15–34.5	26.75 $\pm$ 7.20	6.5–26.2	16.96 $\pm$ 7.65	19–26	22.13 $\pm$ 2.53	15.0–41.0	34.28 $\pm$ 8.32
Specific conductivity (μ S/cm)	0.21–1.0	0.40 $\pm$ 0.25	0.21–0.38	0.33 $\pm$ 0.06	0.15–1.4	0.44 $\pm$ 0.40	0.17–1.2	0.41 $\pm$ 0.33	0.28–0.6	0.43 $\pm$ 0.12	1.4–6.05	4.19 $\pm$ 2.01	6.12–8.32	7.21 $\pm$ 1.09	0.8–43.0	34.26 $\pm$ 13.81
pH	8.2–9.0	8.53 $\pm$ 0.26	8.08–8.55	8.36 $\pm$ 0.18	7.25–9.43	8.30 $\pm$ 0.64	7.2–9.14	8.25 $\pm$ 0.62	7.14–8.75	8.03 $\pm$ 0.53	7.01–8.9	7.98 $\pm$ 0.53	7.94–8.34	8.20 $\pm$ 0.12	9.1–6.88	8.15 $\pm$ 0.67
DO (mg/L)	5.2–8.8	7.01 $\pm$ 1.10	5.8–8.2	7.33 $\pm$ 0.83	6.5–10.52	7.55 $\pm$ 1.43	6.0–10.87	7.51 $\pm$ 1.76	3.8–9.0	5.86 $\pm$ 1.85	4.4–7.6	5.95 $\pm$ 1.81	5.2–6.9	6.35 $\pm$ 0.67	3.0–6.8	5.25 $\pm$ 1.52
TDS (mg/L)	0.14–0.26	0.19 $\pm$ 0.04	0.15–0.60	0.22 $\pm$ 0.15	0.11–0.50	0.21 $\pm$ 0.13	0.12–0.28	0.20 $\pm$ 0.07	0.22–0.35	0.28 $\pm$ 0.05	0.21–0.95	0.43 $\pm$ 0.28	2.18–13.42	5.94 $\pm$ 4.41	26.38–72.14	46.49 $\pm$ 14.83
Total Alkalinity (mg/L)	50–184	121.55 $\pm$ 40.87	100–150	120.25 $\pm$ 22.71	96–178	135.75 $\pm$ 35.35	88–182	132.75 $\pm$ 32.86	96–162	133 $\pm$ 24.89	100–162	132.75 $\pm$ 20.78	110–136	120.5 $\pm$ 9.67	88–136	117.75 $\pm$ 19.14
Chlorophyll-a (mg/m ³)	0.64–5.27	2.42 $\pm$ 1.81	1.48–12.31	5.77 $\pm$ 3.44	0.57–8.84	3.90 $\pm$ 3.39	0.29–6.26	3.16 $\pm$ 2.15	1.49–19.11	6.47 $\pm$ 5.66	1.60–6.72	3.49 $\pm$ 2.18	1.62–5.25	2.81 $\pm$ 1.71	0.64–5.75	3.98 $\pm$ 1.66
Salinity (ppt)	0.01–0.05	0.03 $\pm$ 0.01	0.03–0.04	0.04 $\pm$ 0.01	0.02–0.07	0.03 $\pm$ 0.01	0.03–0.05	0.03 $\pm$ 0.01	0.03–0.66	0.25 $\pm$ 0.28	1.22–5.87	4.32 $\pm$ 1.54	4.55–11.01	7.21 $\pm$ 3.05	25.2–30.35	28.73 $\pm$ 1.78

The findings of the present study are consistent with previous research conducted in the same area [62,63,69] which indicates the favourable environmental conditions for the growth of *M. gulio* and *M. cavasius* along the lower stretches of the river Ganga.

4. Conclusions

The present investigation offers a comprehensive assessment of the current state of the ecosystem health of the lower stretches of the river Ganga in relation to fisheries and their management under the prevalent hydrological regime. Additionally, it demonstrates that the stretches have a habitat that is conducive to *M. gulio* and *M. cavasius* growth. The study indicates that the current rate of exploitation (E) for *M. gulio* is much higher than the maximum level of exploitation (E_{max}) and the best level of exploitation (E_{opt}). In order to facilitate a sustainable exploitation of the species, it is advised to reduce fishing pressure on *M. gulio*. The current level of exploitation (E) for *M. cavasius* is just above the optimal level of exploitation. This indicates that the stock is either overexploited or exploited optimally. Furthermore, the length at first capture is shorter than the length at maturity, which shows that more juveniles are being caught. Hence, mesh size regulation for *M. cavasius* is suggested to ensure sustainable fisheries along the lower stretches of the river Ganga.

Author Contributions: B.K.D.—conceptualization of the work and editing. S.J.— data entry, analysis, and manuscript writing. A.R.— field data collection, data entry, and analysis. D.B.— data entry, analysis, and manuscript writing. C.J.— data entry and analysis. T.N.C.— manuscript editing. S.D.G.— field data collection. M.H.R.— manuscript editing. All authors have read and agreed to the published version of the manuscript.

Funding: The National Mission for Clean Ganga (NMCG), Ministry of Jal Shakti, the Government of India, supported the research.

Institutional Review Board Statement: All relevant international, national, and institutional regulations regarding the care and use of animals were adhered to. All animals in this study were captured in the wild and complied with the regulations established by India's animal welfare legislation. The research was conducted with the authorisation of the regulatory bodies of the ICAR-Central Inland Fisheries Research Institute, Barrackpore, India (AN ISO 9001: 2015).

Informed Consent Statement: The authors of the study obtained their permission to participate.

Data Availability Statement: This article contains all of the study's data, which are also included in the paper and available upon request.

Acknowledgments: The authors express gratitude to the National Mission for Clean Ganga (NMCG), Ministry of Jal Shakti, Government of India, New Delhi. The Director of ICAR-CIFRI, Barrackpore, Kolkata, ought to be recognized for providing the researchers with the necessary resources and supporting assistance to complete the research findings. Along with their own catches, the authors also thank the numerous local fishermen who assisted with the experimental fishing and contributed valuable information.

Conflicts of Interest: The authors state that this paper contains no conflicts of interest.

References

1. Sarkar, U.K.; Pathak, A.K.; Sinha, R.K.; Sivakumar, K.; Pandian, A.K.; Pandey, A.; Lakra, W.S. Freshwater fish biodiversity in the River Ganga (India): Changing pattern, threats and conservation perspectives. *Rev. Fish Biol. Fish.* **2012**, *22*, 251–272. [CrossRef]
2. Das, B.K.; Ray, A.; Johnson, C.; Verma, S.K.; Alam, A.; Baitha, R.; Manna, R.K.; Sarkar, U.K. The present status of ichthyofaunal diversity of river Ganga India: Synthesis of present v/s past. *Acta Ecol. Sin.* **2023**, *43*, 307–332. [CrossRef]
3. Fricke, R.; Eschmeyer, W.; Van der Laan, R. *Catalog of Fishes: Genera, Species, References*; California Academy of Sciences: San Francisco, CA, USA, 2023. Available online: <http://research.calacademy.org/research/Ichthyology/catalog/fishcatmain.asp> (accessed on 23 July 2024).

4. Hossain, M.Y.; Hossen, M.A.; Pramanik, M.N.U.; Sharmin, S.; Nawer, F.; Naser, S.M.A.; Bahkali, A.H.; Elgorban, A.M. Length-weight and length-length relationships of five *Mystus* species from the Ganges and Rupsha rivers, Bangladesh. *J. Appl. Ichthyol.* **2016**, *32*, 994–997. [\[CrossRef\]](#)
5. Talwar, P.K.; Jhingran, A.G. *Inland Fishes of India and Adjacent Countries*; A.A. Balkema: Rotterdam, The Netherlands, 1991; Volume 2.
6. Riede, K. *Global Register of Migratory Species—From Global to Regional Scales*; Final Report of the R&D-Project 808 05 081; Federal Agency for Nature Conservation: Bonn, Germany, 2004; 329p.
7. Day, F. *The Fishes of India: Being a Natural History of the Fishes Known to Inhabit the Seas and Fresh Waters of India, Burma, and Ceylon*; B. Quaritch: London, UK, 1888; Volume 1.
8. Islam, M.K.; Das, M. Fecundity of Gulsha *Mystus cavasius* (Hamilton) from Brahmaputra and Kongsa rivers. *J. Bangladesh Agril. Univ.* **2006**, *4*, 347–355. [\[CrossRef\]](#)
9. Gupta, S. A review on *Mystus cavasius*, a popular food fish of Indian subcontinent. *Int. J. Fauna Biol. Stud.* **2014**, *1*, 27–31.
10. Roos, N.; Islam, M.M.; Thilsted, S.H. Small indigenous fish species in Bangladesh: Contribution to vitamin A, calcium and iron intakes. *J. Nutr.* **2003**, *133*, 4021S–4026S. [\[CrossRef\]](#) [\[PubMed\]](#)
11. CIBA. *Annual Report 2015-16*; Central Institute of Brackishwater Aquaculture: Chennai, India, 2015; p. 242.
12. Alam, M.J.; Begum, M.; Islam, M.A.; Pal, H.K. Spawning behaviour and induced breeding of an estuarine catfish, *Mystus gulio* (Ham.). *Bangladesh J. Fish. Res.* **2006**, *10*, 101–109.
13. Hossain, M.Y. Threatened fishes of the world: *Mystus vittatus* (Bloch, 1794) (Siluriformes: Bagridae). *Croat. J. Fish.* **2014**, *72*, 183–185. [\[CrossRef\]](#)
14. Hilborn, R.; Walters, C.J. *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*; Chapman and Hall: London, UK, 1992.
15. Chung, K.C.; Woo, N.Y.S. Age and growth by scale analysis of *Pomacanthus imperator* (Teleostei: Pomacanthidae) from Dongsha Islands, southern China. *Environ. Biol. Fishes* **1999**, *55*, 399–412. [\[CrossRef\]](#)
16. Devries, D.R.; Frie, R.V. *Determination of Age and Growth. Fisheries Techniques*, 2nd ed.; Murphy, B.R., Willis, D.W., Eds.; American Fisheries Society: Bethesda, MD, USA, 1996; pp. 483–512.
17. Campana, S.E. Accuracy, precision, and quality control in age determination, including a review of the use and abuse of age validation methods. *J. Fish Biol.* **2001**, *59*, 197–242. [\[CrossRef\]](#)
18. Robinson, M.P.; Motta, P.J. Patterns of growth and the effects of scale on the feeding kinematics of the nurse shark (*Ginglymostoma cirratum*). *J. Zool.* **2002**, *256*, 449–462. [\[CrossRef\]](#)
19. Sparre, P.J.; Venema, S.C. *Introduction to Tropical Fish Stock Assessment Part I: Manual*; FAO Fisheries Technical Paper, No. 306/Rev. 2; FAO: Rome, Italy, 1998; p. 407.
20. Bhakta, D.; Das, S.K.; Das, B.K.; Nagesh, T.S.; Samanta, R. Growth, mortality and exploitation status of *Otolithoides pama* (Hamilton, 1822) from Hooghly-Matlah estuary of West Bengal, India. *Reg. Stud. Mar. Sci.* **2020**, *39*, 101451. [\[CrossRef\]](#)
21. Bhakta, D.; Das, S.K.; Das, B.K.; Nagesh, T.S. Relationship between otolith morphometry and fish size of *Otolithoides pama* (Hamilton, 1822) from Hooghly-Matlah estuary, India. *Indian J. Geo Mar. Sci.* **2020**, *49*, 1636–1642.
22. Ray, A.; Das, B.K.; Bhakta, D.; Johnson, C.; Roy, S.; Gupta, S.D.; Panda SPBaitha, R. Stock status of a few small indigenous fish species exploited in the river Ganga, India. *Fishes* **2023**, *8*, 572. [\[CrossRef\]](#)
23. Jana, S.; Srinivasan, N.T.; Bhakta, D.; Johnson, C. Population age structure and stock assessment of reeve's croaker *Chrysochir aurea* (Richardson, 1846) along West Bengal coast of India. *Thalassas Int. J. Mar. Sci.* **2024**, *40*, 835–845. [\[CrossRef\]](#)
24. Chirwatkara, B.B.; Das, S.K.; Bhakta, D.; Nagesha, T.S.; Behera, S. Growth, mortality and stock assessment of *Arius arius* (Hamilton, 1822) from Hooghly-Matlah estuary, West Bengal. *Indian J. Geo-Mar. Sci.* **2022**, *50*, 302–309.
25. Bhakta, D.; Das, S.K.; Das, B.K.; Nagesh, T.S.; Behera, B.K. Fishery and population dynamics of *Otolithoides pama* (Hamilton, 1822) from Hooghly-Matlah Estuary of West Bengal, India. *Aquat. Ecosyst. Health Manag.* **2022**, *25*, 36–43. [\[CrossRef\]](#)
26. Bhakta, D.; Das, B.K.; Singh, U.; Ray, A.; Johnson, C.; Thakur, V.R.; Mishra, S.K.; Verma, S.K.; Alam, A.; Jha, D.N. Fishery, growth, mortality, and stock assessment of endangered *Tor putitora* from Tehri dam reservoir, Uttarakhand, Himalayan foothills of India in relation to environmental variables. *Environ. Monit. Assess.* **2023**, *195*, 1377. [\[CrossRef\]](#)
27. Ricard, D.; Minto, C.; Jensen, O.P.; Baum, J.K. Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. *Fish Fish.* **2012**, *13*, 380–398. [\[CrossRef\]](#)
28. Gayanilo, F.C., Jr.; Sparre, P.; Pauly, D. FAO-ICLARM stock assessment tools II: Revised version: User's guide. *FAO Comput. Inf. Ser. Fish.* **2005**, *1*, 1–168.
29. Le Cren, E.D. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). *J. Anim. Ecol.* **1951**, *20*, 201–219.
30. Pauly, D. *Theory and Management of Tropical Multispecies Stocks: A Review, with Emphasis on the Southeast Asian Demersal Fisheries*; ICLARM: Manila, Philippines, 1979.
31. Pauly, D.; Munro, J.L. Once more on the comparison of growth in fish and invertebrates. *Fishbyte* **1984**, *2*, 1–21.
32. Pauly, D. Length-converted catch curves: A powerful tool for fisheries research in the tropics (part 1). *Fishbyte* **1983**, *1*, 9–13.

33. Pauly, D. Length-converted catch curves: A powerful tool for fisheries research in the tropics (Part 2). *Fishbyte* **1984**, *2*, 17–19.
34. Pauly, D. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *ICES J. Mar. Sci.* **1980**, *39*, 175–192.
35. IMD. India Meteorological Department, (2018–19). Ministry of Earth Sciences Government of India. 2019. Available online: <https://mausam.imd.gov.in/> (accessed on 1 October 2019).
36. Pauly, D. Fish population dynamics in tropical waters: A manual for use with programmable calculators (Vol. 8). WorldFish. *ICLARM Stud. Rev.* **1984**, *8*, 325.
37. Beverton, R.J.; Holt, S.J. Manual of methods for fish stock assessment. part 2. Tables of yield function. *FAO Fish Biol. Tech. Pap.* **1966**, *1*, 67.
38. Pauly, D. *Some Simple Methods for the Assessment of Tropical Fish Stocks* (No. 234); Food & Agriculture Organization: Rome, Italy, 1983; p. 52.
39. APHA. *Standard Methods for the Examination of Water and Wastewater*, 20th ed.; American Public Health Association, American Water Works Association and Water Environment Federation: Washington, DC, USA, 1998.
40. Apha, A.W.; Greenberg, W.I.A.; Clesceri, L.; Eaton, A. *Standard Methods for the Examination of Water and Wastewater*; American Public Health Association: Washington, DC, USA, 2012.
41. Mustafa, M.G.; Ahmed, I.; Ilyas, M. Population dynamics of five important commercial fish species in the Sundarbans ecosystem of Bangladesh. *J. Appl. Life Sci. Int.* **2019**, *22*, 1–13.
42. Thippeswamy, S.; D'Cunha, P.; Shettigar, M.; Anupama, N.M.; Harish, K. Growth and mortality of *Mystus cavasius* (Hamilton 1822) from Bhadra reservoir in the Western Ghats, India. *Environ. Ecol.* **2022**, *40*, 2683–2689.
43. Nath, B.B.; Ahmed, A.M.; Das, J.; Sarma, J.; Phukan, B.; Ali, A.; Goswami, P.K.; Borah, S. Age and growth of gangatic *Mystus*: *Mystus cavasius* (Hamilton-Buchanan, 1822) by length-frequency analysis from central Brahmaputra Valley, Assam. *Int. J. Clin. Biol. Biochem.* **2023**, *5*, 6–10.
44. Tesch, F.W. Age and growth. In *Methods for Assessment of Fish Production in Fresh Waters*; Blackwell Scientific Publication: Oxford, UK, 1971.
45. Sekitar, P.K.A.; Hamid, M.; Mansor, M.A.S.H.H.O.R.; Nor, S.A.M. Length-weight relationship and condition factor of fish populations in Temengor Reservoir: Indication of environmental health. *Sains Malays.* **2015**, *44*, 61–66.
46. Beverton, R.J.; Holt, S.J. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. In *Ciba Foundation symposium—The Lifespan of Animals (Colloquia on Aging)*, 5th ed.; John Wiley & Sons Ltd.: Chichester, UK, 1959; pp. 142–180.
47. Rahman, O.; Hossain, M.Y.; Rahman, M.A.; Islam, M.A.; Rahman, M.A.; Parvin, M.F.; Habib, K. A Temporal variations of condition factor and relative weight for *Mystus gulio* (Hamilton, 1822) from the coastal water in Bangladesh. *J. Bio-Sci.* **2021**, *29*, 111–122. [[CrossRef](#)]
48. Paujiah, E.; Dhahiyat, Y.; Herawati, T.; Iskandar, I.; Haryono, H.; Zulfahmi, I.; Fahri, F. Length-weight relationships and condition factors of brackish water catfish, *Mystus gulio* (Hamilton, 1822) from three different estuaries, West Java, Indonesia. *Biodivers. J. Biol. Divers.* **2023**, *24*, 2855–2864. [[CrossRef](#)]
49. Soomro, A.N.; Baloch, W.A.; Laghari, Z.A.; Palh, Z.K.; Lashari, K.H.; Mastomi, G.M. Length-weight relationship and condition of *Mystus cavasius* (Hamilton) from lower Indus River at Thatta District, Sindh, southern Pakistan. *Int. J. Emerg. Trends Sci. Technol.* **2015**, *2*, 1875–1879.
50. Akther, S.; Akhter, M.; Hossain, M. Length-weight relationship and condition factor of two gangetic *Mystus* species, *Mystus tengra* (Hamilton, 1822) and *Mystus cavasius* (Hamilton, 1822). *J. Entomol. Zool. Stud.* **2017**, *5*, 979–982.
51. Latif, M.; Ullah, M.Z.; Minhas, I.B.; Latif, S. Length-weight relationships of *Mystus cavasius* with special reference to body morphometric characters from river Chenab, Punjab, Pakistan. *J. Entomol. Zool. Stud.* **2018**, *6*, 2418–2421.
52. Lal, S.S.; Jaya, D.S.; Sherly, W.E. Reproductive biology of estuarine catfish, *Mystus gulio* (Hamilton-Buchanan). *Int. J. Sci. Res.* **2016**, *5*, 1792–1794.
53. Kaliyamurthy, M. Spawning biology of *Mystus gulio* in Lake Pulicat, India. *Indian J. Fish.* **1981**, *28*, 36–40.
54. Bhatt, V.S. Studies on the biology of some freshwater fishes Part VI. *Mystus cavasius* (Ham.). *Hydrobiologia* **1971**, *38*, 289–302. [[CrossRef](#)]
55. Rao, L.M.; Reddy, K.S.; Hymavathi, V. Breeding biology and fecundity in *Mystus* species from Mehadrigeedda stream of Visakhapatnam. *Ecol. Environ. Conserv.* **1999**, *5*, 25–28.
56. Krishna Rao, D.S. Biology of the catfish *Mystus cavasius* in the Hemavathi reservoir (Cauvery River System, Karnataka). *J. Inland Fish. Soc. India* **2007**, *39*, 35–39.
57. Chaturvedi, J.; Saksena, D.N. Diet composition, feeding intensity, gastrosomatic index and hepatosomatic index of a catfish, *Mystus cavasius* from Chambal river (near, Rajghat) Morena, Madhya Pradesh. *Int. J. Recent Sci. Res.* **2013**, *4*, 1350–1356.
58. Pantulu, V.R. Determination of age and growth of *Mystus gulio* (Ham.) by the use of pectoral spines, with observations on its biology and fishery in the Hooghly estuary. *Proc. Natl. Inst. Sci. India* **1961**, *27*, 198–225.

59. Agatsuma, Y. *Hemicentrotus pulcherrimus*, *Pseudocentrotus depressus*, and *Heliocidaris crassispina*. In *Developments in Aquaculture and Fisheries Science*; Elsevier: Amsterdam, The Netherlands; Laboratory of Marine Plant Ecology, Graduate School of Agricultural Science, Tohoku University: Sendai, Japan, 2013; Volume 43, pp. 643–659. [CrossRef]
60. Nath, D. Zonal distribution of nutrients and their bearing on primary production in Hooghly estuary. *J. Inland Fish. Soc. India* **1998**, *30*, 64–74.
61. Kaushal, S.S.; Likens, G.E.; Jaworski, N.A.; Pace, M.L.; Sides, A.M.; Seekell, D.; Belt, K.T.; Secor, D.H.; Wingate, R.L. Rising stream and river temperatures in the United States. *Front. Ecol. Environ.* **2010**, *8*, 461–466. [CrossRef]
62. Manna, R.K.; Satpathy, B.B.; Roshith, C.M.; Naskar, M.; Bhaumik, U.; Sharma, A.P. Spatio-temporal changes of hydro-chemical parameters in the estuarine part of the river Ganges under altered hydrological regime and its impact on biotic communities. *Aquat. Ecosyst. Health Manag.* **2013**, *16*, 433–444. [CrossRef]
63. Tiwari, N.K.; Das Gupta, S.; Swain, H.S.; Jha, D.N.; Samanta, S.; Manna, R.K.; Das, A.K.; Das, B.K. Water quality assessment in the ecologically stressed lower and estuarine stretches of river Ganga using multivariate statistical tool. *Environ. Monit. Assess.* **2022**, *194*, 469. [CrossRef]
64. Effler, S.W. Secchi disc transparency and turbidity. *Environ. Eng.* **1988**, *114*, 1436–1447.
65. Miraj, A.; Pal, S.; Bhattacharya, S.; Chakraborty, K.; Miraj, A.; Pal, S.; Chakraborty, K. Observation on the TDS and EC values of different water bodies at Cooch Behar, West Bengal, India. *Int. J. Theor. Appl. Sci.* **2017**, *9*, 106–113.
66. Ray, P. Impact of man on the Hooghly Estuary. In *Water Pollution and Management Review*; Varshney, C.K., Ed.; Jawaharlal Nehru University: New Delhi, India, 1981; pp. 79–120.
67. Boesch, D.F.; Josselyn, M.N.; Mehta, A.J.; Morris, J.T.; Nuttle, W.K.; Simenstad, C.A.; Swift, D.J. Scientific assessment of coastal wetland loss, restoration and management in Louisiana. *J. Coast. Res.* **1994**, i-103. Available online: <http://www.jstor.org/stable/25735693> (accessed on 19 January 2025).
68. Iqbal, M.Z.; Chamily, F.A.; Rahman, M.M.; Tasnim, R.; Mohiuddin, M.; Sultana, F.; Rahman, M.S.; Ali, M.M.; Asaduzzaman, M. Habitat salinity and source-induced variation in body shape of euryhaline long whiskers catfish (*Mystus gulio*). *Reg. Stud. Mar. Sci.* **2024**, *69*, 103308. [CrossRef]
69. Mitra, S.; Ghosh, S.; Satpathy, K.K.; Bhattacharya, B.D.; Sarkar, S.K.; Mishra, P.; Raja, P. Water quality assessment of the ecologically stressed Hooghly River Estuary, India: A multivariate approach. *Mar. Pollut. Bull.* **2018**, *126*, 592–599. [CrossRef] [PubMed]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.