Indian J. Fish., 73 (2): 45-56, 2026
doi:10.21077/ijf.2026.73.2.174761-06
Available online at: epubs.icar.org.in/index.php/IJF

Exploitation patterns and sustainability of four small indigenous fish species of Deepor Beel wetland, Brahmaputra Basin, India

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Abstract

The study investigates variability of population growth, mortality and exploitation pattern of four small indigenous fishes (SIFs), *Gudusia chapra*, *Puntius sophore*, *Mystus bleekeri*, and *Heteropneustes fossilis* from Deepor Beel, a Ramsar site of north-eastern India. The study was conducted from June 2023 to May 2024, which involved monthly sampling at two stations, analysing a total of 13129 specimens. Data were analysed using FiSAT-II software, to derive species-specific length-weight relationships, growth coefficients, and mortality rates. A positive allometric pattern was observed for *P. sophore,* while a negative allometric pattern was evident for the other three species, *G. chapra*, *M. bleekeri* and *H. fossilis*. Exploitation rate (E) ranged from optimum (0.48) to moderately high (0.63), with *M. bleekeri* and *H. fossilis* being highly exploited. Recruitment pattern varied among species, with peaks occurring at different times of the year from post-monsoon to winter. Current findings underscore the necessity for focused conservation efforts and long-term management strategies for prevention of further decline in populations of these species, which is crucial for maintaining the ecological balance of the beel ecosystem and for sustaining the livelihoods of local communities.

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Keywords:
Conservation, Exploitation, Growth, Mortality, Recruitment pattern, Stock assessment

Received : 01.01.2026
Accepted : 25.06.2026

Introduction

Small indigenous fishes (SIFs) contribute significantly to the livelihood and nutritional security of rural fishing communities. These fishes are typically recognised by their size range of 25 to 30 cm in total length (TL) when fully matured (Mohanty *et al*., 2013). They form essential source of human nutrition and prevent nutrient deficiency by providing cheap protein and micronutrients such as phosphorus, calcium, and vitamin A. (Kongsbak *et al*., 2008). An important feature of SIFs is their year-round availability, which is likely due to their wide environmental adaptability (Ray *et al*., 2023). A total of 96 fish species have been reported from the floodplain wetlands of the country (Sarkar *et al*., 2021b) and SIFs form an integral component of floodplain wetland fish diversity. Wetland fisheries may be either unmanaged, relying on wild fish stocks including SIFs, or managed through culture-based fisheries that primarily stock Indian major carps (Borah *et al*., 2022). Small-scale wetland fishers, who depend on SIFs for their livelihood, engage in year-round fishing of the wild fish stocks. SIFs are essential for sustaining ecological balance of wetlands by aiding in nutrient recycling, regulating diversity of other aquatic organisms, and providing food for higher trophic level organisms. Beyond their ecological importance, SIFs also hold socio-economic and cultural significance for native communities, who depend on wetlands for their livelihood and income

(Kongsbak *et al*., 2008; Baitha *et al*., 2024), However, catches of SIFs from wetlands, are often dispersed and underestimated. Over the years, production, abundance, and availability of SIFs have been declining, with many species becoming rare, largely because they are caught before reaching sexual maturity (Mandal and Nandi, 2015). This trend warrants immediate attention towards conservation and management.

Deepor Beel is an internationally recognised Ramsar site located in north-eastern part of India. The beel relates to the Brahmaputra River through a connecting channel that facilitates water exchange (Bhattacharjya *et al.,* 2021). Located within the periphery of rapidly growing city of Guwahati, Deepor Beel faces severe threats primarily from human activities (Dash *et al*., 2020). Shrinkage of beel area is causing ecosystem damage, loss of biodiversity and destruction of breeding and feeding grounds of birds and other animals (Hoque and Sharma, 2020). The present study was undertaken to assess the stock status of the dominant small indigenous fishes (SIFs) of Deepor Beel wetland to support their effective management, conservation, and long-term sustainability.

Materials and methods

Study area

Deepor Beel (26°05'-26°11' N to 91°35'-91°43' E), a peri-urban floodplain wetland is positioned at the south-west corner of Guwahati City, Assam, India. Data for the present study was collected over a one-year period, from June 2023 to May 2024, with samples collected from two distinct stations (Fig. 1). Station 1 represents Gadhuli Bazaar (26°11'71"N; 91°61'46"E), while Station 2 is a landing center located at the beel periphery (26°11'27"N; 91°65'95"E), towards the side of Rani Reserve Forest. Monthly samples of four SIFs *viz*., *Gudusia chapra* (n = 5316), *Puntius sophore* (n = 3087), *Mystus bleekeri* (n = 3082) and *Heteropneustes fossilis* (n = 1644) were collected in early morning (06:00-08:00 hrs) and evening hours (17:00-19.00 hrs) and subsequently transported in ice boxes to the laboratory for analyses. Fishes were identified using standard taxonomical keys given by Talwar and Jhingran (1991). Total length and body weight of the specimens were measured using a vernier caliper and digital balance nearest to 0.01cm and 0.001 g, respectively. Length classes were established by converting total lengths in millimeters (mm) for length-frequency data analysis. Length and weight data were log transformed for determining length-weigh relationship (LWR) from parabolic $W=aL^b$ to linearised form of Log W= Log a + b Log L (LeCren, 1951). Water temperature during sampling tine was recorded using a multi-parameter water quality meter (Model 9829, HANNA, Romania) and the mean temperature recorded was 29.1±2.2°C.

FiSAT II software was used for the assessment of various population parameters as described by Gayanilo and Sparre (2005). ELEFAN-I function of FISAT-II was utilised to assess asymptotic length (L_∞) and growth-coefficient (K), whereas Powel-Wetherall plot, length converted catch curve, recruitment pattern, probability of capture, exploitation rate and relative-yield per recruit module available in FiSAT-II were used to estimate natural mortality (M), fishing mortality (F), total mortality (Z), recruitment pattern (r), selection pattern, exploitation rate (E) and relative yield-per-recruit (Y/R). The analysis included a total of 5216 specimens of *G. chapra*, 3087 specimens of *P. sophore*, 3182 specimens of *M. bleekeri*, and 1644 specimens of *H. fossilis*, representing different size groups. Natural mortality (M) was estimated using the formula, $Log_{10}M = -(0.0066) - (0.279)\ Log_{10}L_\infty + (0.06543)\ Log_{10}K + (0.04634)\ Log_{10}T$, given by Pauly (1980), where 'T' is the average temperature (°C) of water body extending over a period of 1 year. Length converted catch curve module of FiSAT-II was used for estimation of total mortality coefficient (*Z*). Fishing mortality as given by Silvestre and Graces (2004) was applied to determine fishing mortality coefficient (F). Length at first capture (L_C or $L_{50\%}$) was calculated using Pauly's (1980) formula and exploitation rate (E) was calculated following

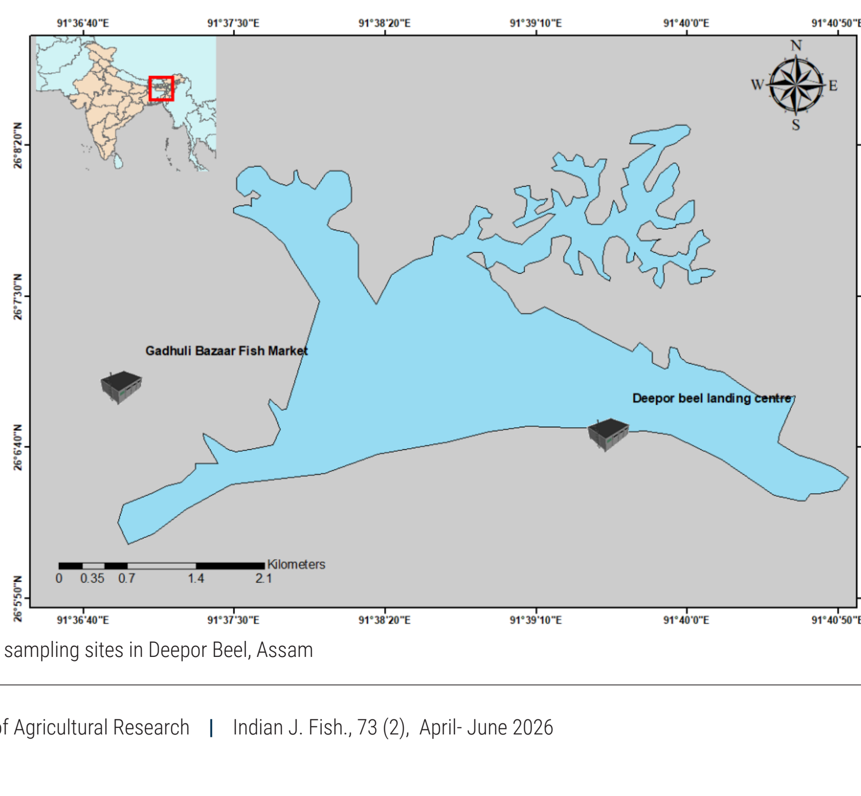

Fig. 1. Map showing the sampling sites in Deepor Beel, Assam

E=F/Z. Knife-edge selection method was used for estimation of 10%, 50%, and maximum rates of exploitation for the observed species.

Results and discussion

During the study period, all the species studied exhibited negative allometric growth (b<3), except for *P. sophore* (Table 1), which exhibited allometric development (b>3), Goodness of fit (r^2) calculated in the current study ranged from 0.57 to 0.96 (Table 1), reflecting strong association among length and weight for most of the species, though *G. chapra* showed a lower degree of association. Adverse physio-chemical parameters, limited access to food and feeding grounds and other environmental stressors may contribute to the observed negative allometric growth pattern (Kalita *et al*., 2016; Remya *et al*., 2021). In general, 'b' value for well-grown fish ranges from 2.5 to 3.5 (Froese, 1998), and the 'b' values estimated for all the four species studied fell within this expected range ($p<0.05$). Factors such as gonad development, gender, season, feeding rate, and food availability in their natural habitats can significantly influence the 'b' value throughout a fish's life (Borah *et al*., 2018; Gosavi *et al*., 2019). Natural mortality (M) of the studied species ranged from 1.27 to 1.43 (Table 1), except for *H. fossilis* (0.97), which is close to 1. The reliability of the estimated M is supported by the M/K ratio, which generally ranges from 1.0-2.5 for most fish species (Beverton and Holt, 1959). The exploitation rate for all the studied species were found to be >0.5 (Table 1), except for *G. chapra*, which indicates high fishing pressure on the stocks. This observation was further corroborated by the of Beverton and Holt Y/R and B/R analyses, in which the current E approached or exceeded the maximum exploitation level (E_{max}). These findings indicate that most of the studied populations are being exploited beyond sustainable levels. Hence, a reduction in fishing pressure is essential to ensure long term conservation and sustainable management of fish stocks in Deepor Beel.

G. chapra

Total length (TL) of *G. chapra* ranged from 44 to 134 mm during the study period. Most frequently observed size group in the catch was between 81 to 90 mm, making up 31.3% of the collected samples (Fig 3a). The length-weight relationship of *G. chapra* was determined to be $W=0.0209 \times L^{2.58}$, with goodness of fit (r^2) 0.57 ($p<0.05$) (Table 1). This relationship shows that the species exhibit negative allometric growth von Bertalanffy Growth Function (VBGF) parameters estimated were asymptotic length (L∞) 142.28 mm and growth coefficient (K) 0.79 yr^{-1}. Other population parameters estimated were: M- 1.008 yr^{-1}; F - 0.94 yr^{-1}; and Z- 1.95 yr^{-1} (Fig. 4a). Maximum exploitation rate (E_{max}) was calculated to be 0.63 with current exploitation rate at 0.48. The species was found to be exploited optimally with E value of 0.48. Virtual population analysis (VPA) based on length frequency data indicate that the most dominant length group subjected to exploitation in the fishery is 75-95 mm (Fig 5a). The species exhibits continuous recruitment throughout the year, with peak during July-August (Fig 6a). The fish length corresponding to 25%, 50% and 75% probabilities of retention by fishing net was estimated to be 58.08;63.53 and 67.73 mm respectively (Fig 7a). The study also estimated key biological reference points, with the exploitation rate at 10% of the yield-per-recruit curve (E_{10}) estimated at 0.415 and the exploitation rate corresponding to a 50% reduction in the unexploited biomass-per-recruit (E_{50}) at 0.310 (Fig 8a).

Ahmed *et al*. (2021) and Samad *et al*. (2023) documented the maximum length of *G. chapra* as 156 mm and 145 mm respectively from Central Brahmaputra Valley in Assam, India, and the lakes of Bangladesh. However, the current observation noted a lower maximum length (134 mm) of *G. chapra*. Exponent of length (b = 2.52) in LWR of *G. chapra* specifies negative allometric growth progression which aligns with findings from other researchers across various water bodies in the Indian subcontinent (Ahmed *et al*., 2021; Samad *et al*., 2021). Growth parameters for *G. chapra* such as asymptotic length (L_∞) in current study were found significantly lower as

Table 1. Population parameters of *G. chapra*, *P. sophore*, *M. bleekeri*, and *H. fossilis* from Deepor Beel estimated in the current study

Population parameters	*G. chapra*	*P. sophore*	*M. bleekeri*	*H. fossilis*
TL range (mm)	34-134	46-108	48-132	75-241
Slope (b)	2.589	3.219	2.524	2.614
Intercept (a)	0.0209	0.0085	0.0333	0.0218
Goodness of fit (r^2)	0.57	0.96	0.77	0.81
Growth pattern	Negative allometric	Positive allometric	Negative allometric	Negative allometric
Asymptotic length (L_∞ mm)	142.28	110.78	142.28	252
Growth coefficient (K yr^{-1})	0.79	0.68	0.7	1.1
Natural mortality (M yr^{-1})	1.008	0.979	0.93	1.067
Fishing mortality (F yr^{-1})	0.94	1.3	1.61	1.65
Total mortality (Z yr^{-1})	1.95	2.28	2.54	2.72
Exploitation rate (E)	0.48	0.57	0.63	0.61
L_{25}	58.08	68.97	74.26	118.11
Length at first capture (L_{c50})	63.53	76.57	85.17	129.56
L_{75}	67.73	84.42	92.76	139.81
Isopleth ratio (Lc/L∞)	0.446	0.69	0.59	0.514
M/K	1.27	1.439	1.32	0.97
Fishing rate at 10% (E_{10})	0.554	1	0.719	0.6
Fishing rate at 50% (E_{50})	0.348	0.419	0.389	0.371
Maximum exploitation rate (E_{max})	0.635	1	0.814	0.676

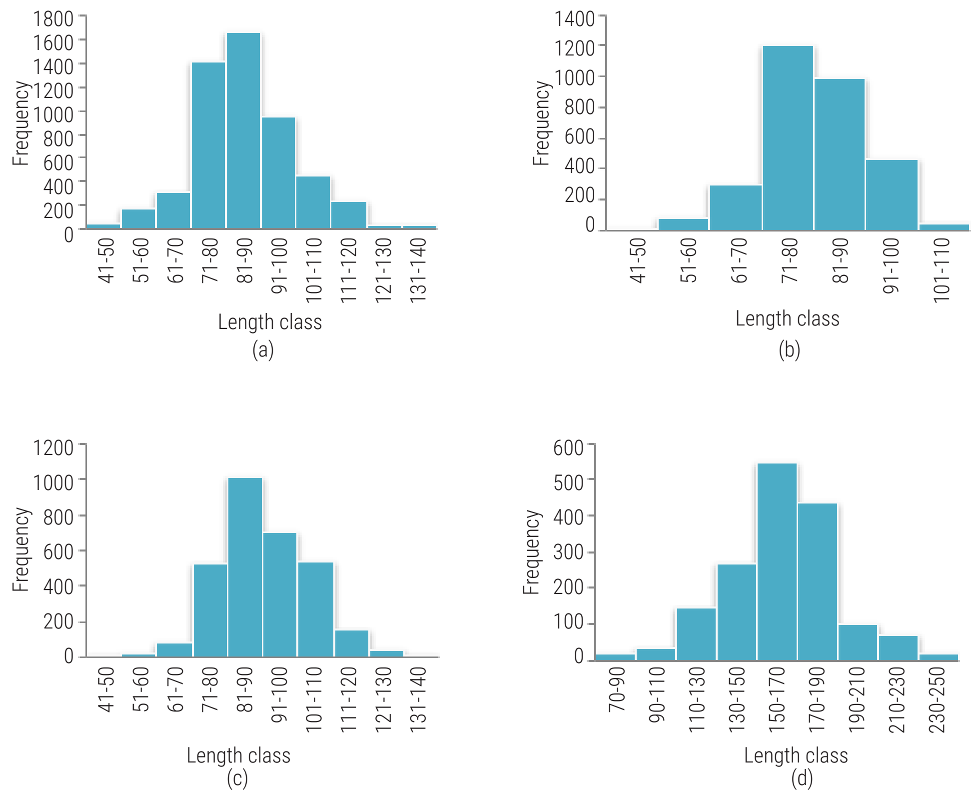

Fig. 2. Length frequency distribution of (a) *G chapra*; (b) *P. sophore*; (c) *M. bleekeri*; and (d) *H. fossilis,* from Deepor Beel

compared to the findings of Ray *et al*. (2023) and Sarkar *et al*. (2021a). The values of K, Z, F, M, E in the present study are much higher than the observations of Ray *et al*. (2023) but lower compared to the findings of Sarkar *et al*. (2021a). Population characteristics of *G. chapra* revealed significantly higher values of K = 1.23 yr^{-1}, Z = 6.63 $^{-1}$, F = 4.18 $^{-1}$, M = 2.45 $^{-1}$ and E = 0.63 from Panchet Reservoir, India (Kumari *et al*., 2018). These differences in growth parameters may be attributed to variations in habitat characteristics, geographic distribution, agro-climatic condition and species-specific ecological adaptations (Sparre and Venema, 1998; Adeeb *et al*., 2014). External factors such a temperature and fishing methods can also influence growth and mortality parameters (Tu *et al*., 2018). Current exploitation rate (E) of 0.48 iindicates that the exploitation of *G. chapra* in the Deepor Beel is almost at its optimum level. The continuous recruitment pattern of *G. chapra* with a pea during July-August in Deepor Beel, is consistent with reports from the floodplain wetlands of West Bengal and Ganga River Basin (Sarkar et al., 2021a). Vinci *et al*. (2005) observed peak recruitment during March-October in West Bengal, whereas Ray *et al*. (2023) observed April-September as peak recruitment seasons for *G. chapra*in the Ganga River Basin.

P. sophore

Total length of *P. sophore* in Deepor Beel during the study period ranged from 34 to139 mm (Table 1). Most dominant length groups (Fig. 2b) were 71–80 mm (38.87%), 81–90 mm (32.07%), and 91–110 mm (14.90%). The length-weight relationship (LWR) derived for *P. sophore* was W=0.0085×$L^{3.21}$, which exhibited high goodness of fit (r^2=0.963) ($p<0.05$). LWR demonstrated positive allometric growth for the species (Table 1). VBGF parameters were derived as L_∞- 110.78 mm and K 0.68 yr (Fig 3b). Mortality rates estimated were *Z*-2.28 yr^{-1}, M-0.97 yr^{-1} and F-1.3 yr^{-1}. Exploitation rate (E) was determined to be 0.57, suggesting moderate exploitation of the species (Table 1). The recruitment pattern *(r)* exhibited two peaks, a primary peak during August-September and a secondary peak in December-January (Fig. 6b). VPA analysis of *P. sophore* indicated the length with maximum fishing mortality varies between 75-85 mm and minimum length under exploitation as 45 mm (Fig. 5b). Length at 50% capture (Lc_{50}) was found to be 76.57 mm, indicating the optimal harvestable size for the species (Fig. 7b). In terms of fishing selectivity, knife-edge selection model provided values for E_{10}, E_{50} and E_{max} at 0.751, 0.421 and 0.821, respectively. L_{25}, L_{50}, L_{75} were estimated at 68.97; 76.57; and 84.42 mm, respectively (Fig. 8b).

P. sophore, a species under the genus *Puntius*, is a dominant species in Deepor Beel. Narzary and Khangembam (2022) reported a maximum length of 119.1 mm for *P. sophore*, while Kumar *et al*. (2021) recorded an asymptotic length of 123.5 mm, both of which exceed the values observed in the current study. The value of b (3.21) for *P. sophore*, designates a progressive allometric development pattern, consistent with findings of Kumar *et al*. (2021) from Sutlej River, Punjab, India and Samad *et al*. (2021), from Bukvora Baor, south-western Bangladesh. The current study shows significantly lower growth coefficient (K=0.69) and natural mortality coefficient (M=0.97 yr^{-1}) but higher fishing mortality (F = 1.3 yr^{-1}) and total mortality (*Z* = 2.28 yr^{-1}), compared to the observations made by

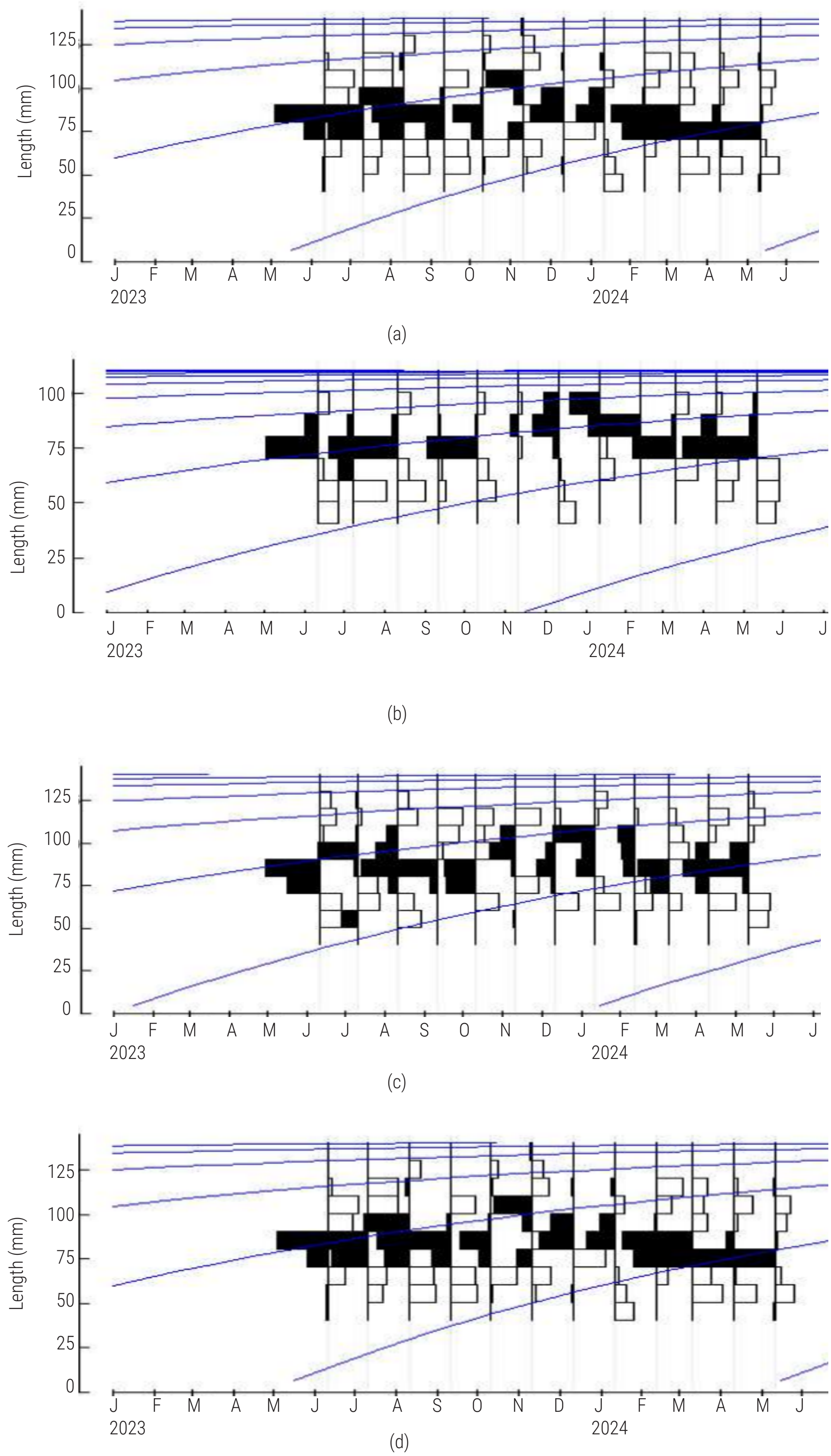

Fig. 3. von-Bertalanffy growth curves of (a) *G. chapra*; (b) *P. sophore*; (c) *M. bleekeri* and (d) *H. fossilis,* Deepor Beel. Black bars represent the monthly length frequency distributions while, blue curves depicts the fitted von Bertalanffy growth function (VBGF)

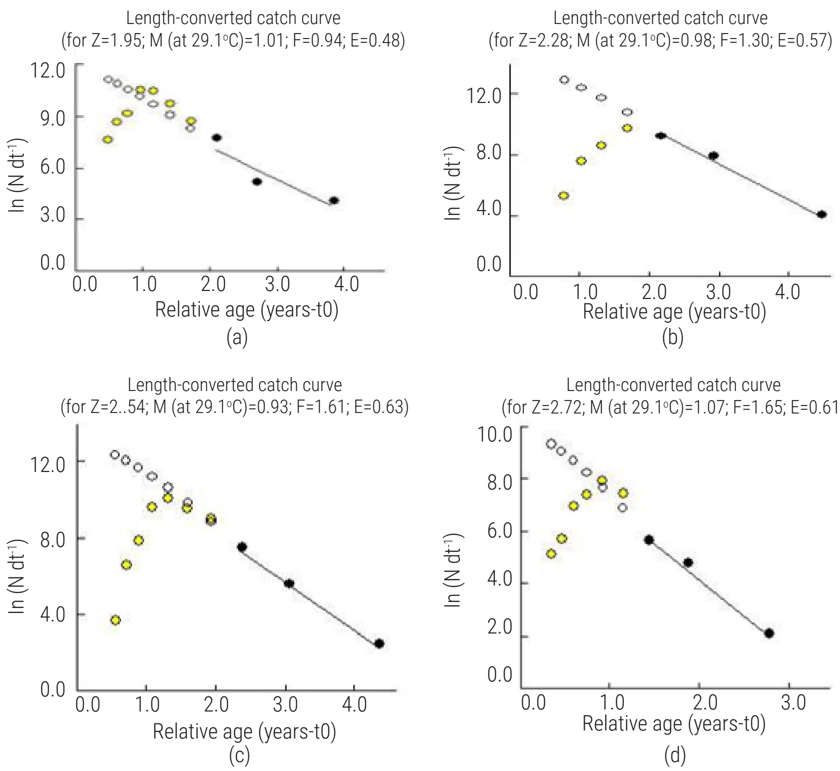

Fig. 4. Length-converted catch curves showing the mortality patterns of (a) *G. chapra*; (b) *P. sophore*; (c) *M. bleekeri* and (d) *H.* fossilis from Deepor Beel. Yellow dots represent the number of fish sampled, while white dots indicate the expected population in the absence of fishing mortality and the fitted black line represents the total mortality (Z)

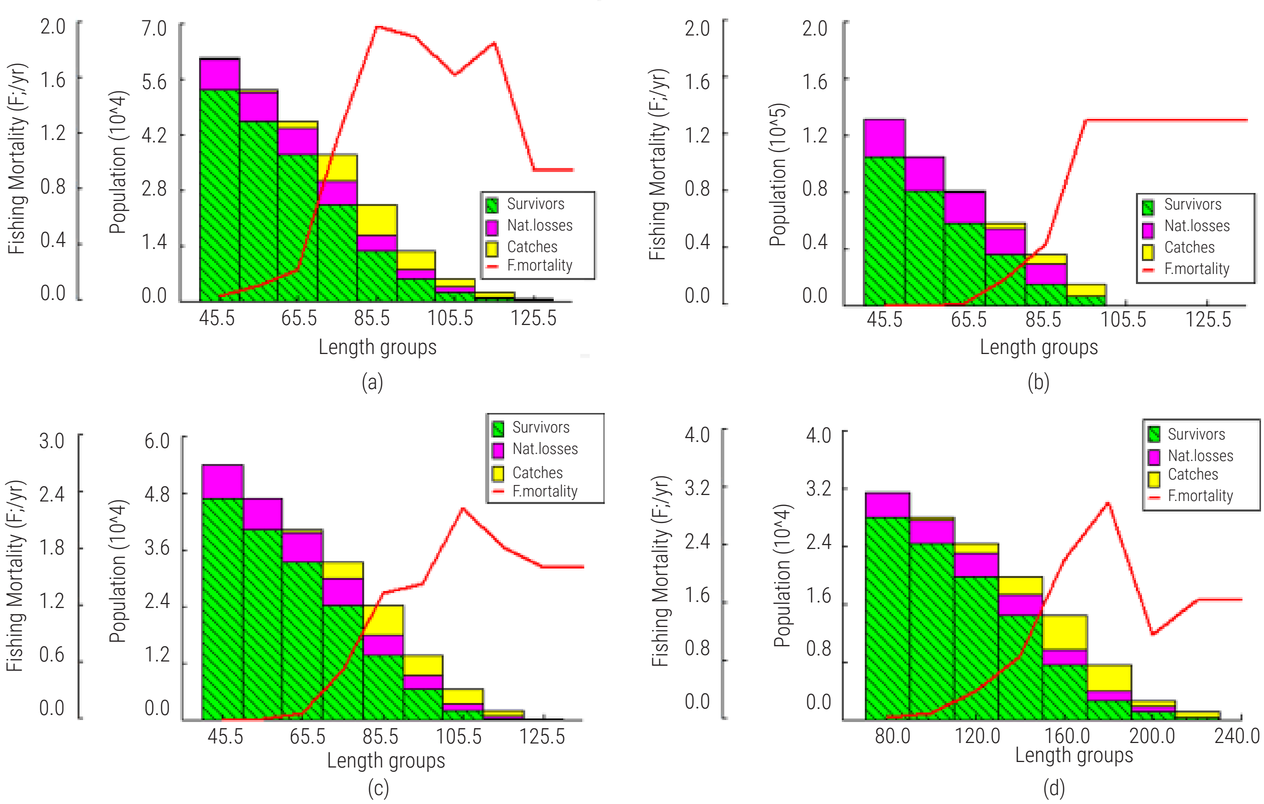

Fig. 5. Length-based VPA of (a) *G. chapra*; (b) *P. sophore*; (c) *M. bleekeri* and (d) *H. fossilis,* from Deepor Beel

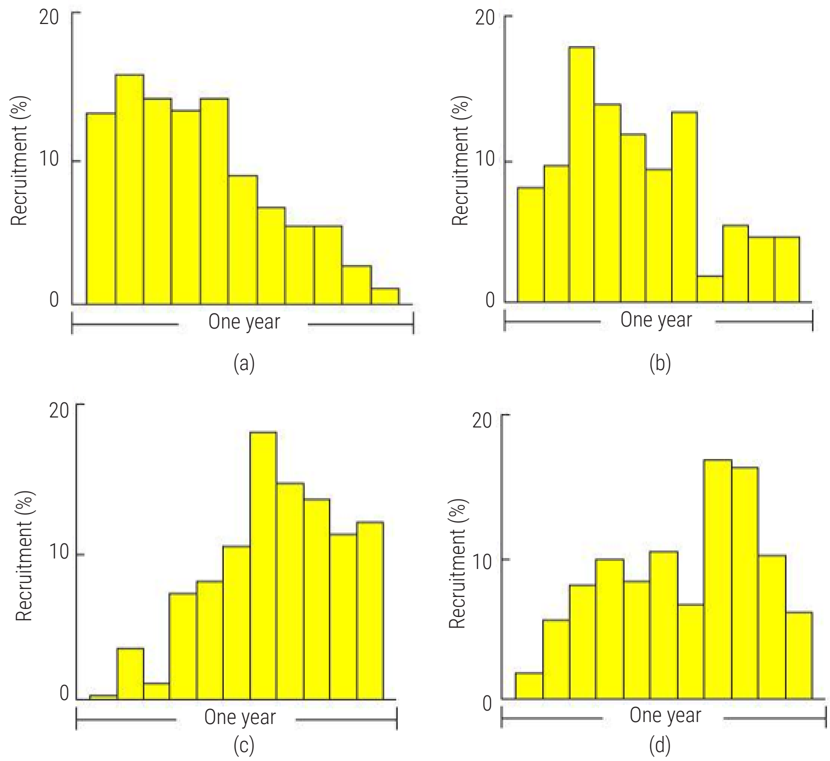

Fig. 6. Recruitment patterns of (a) *G. chapra*; (b) *P. sophore*; (c) *M.bleekeri* and (d) *H. fossilis* from Deepor Beel. Peaks indicate the month with the highest % of recruits for each species

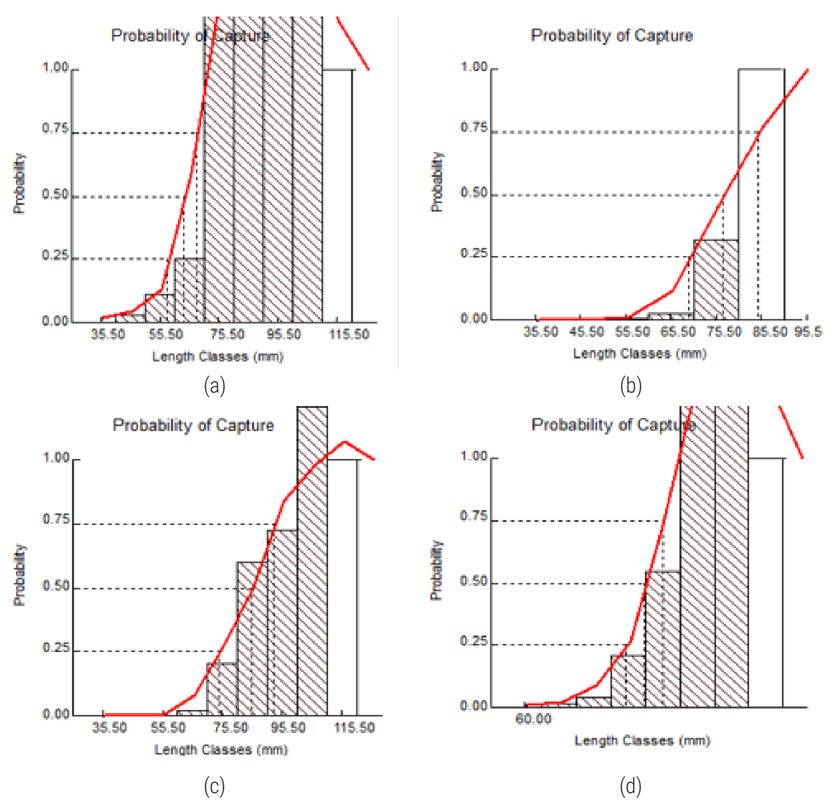

Fig. 7. Probability of capture curves for (a) *G. chapra*; (b) *P. sophore*; (c) *M. bleekeri* and (d) *H. fossilis*, from Deepor Beel. The red curve represents the probability of capture across different length classes

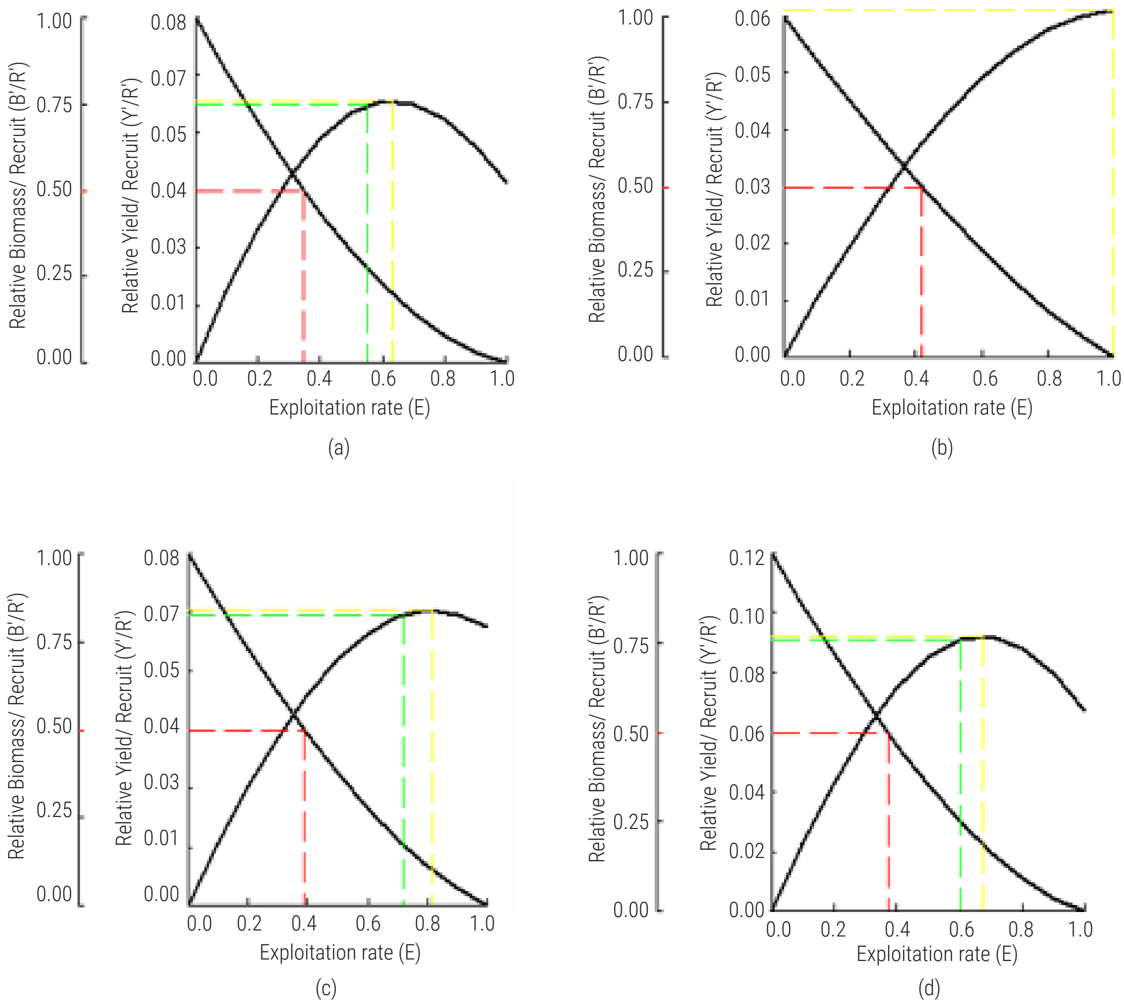

Fig. 8. Beverton and Holt's Y/R and B/R pattern of (a) *G. chapra*; (b) *P. sophore*; (c) *M. bleekeri* and (d) *H. fossilis,* from Deepor Beel. The red green, and yellow vertical lines indicate E_{50}, E_{10} and E_{max}, respectively. In the case of *P. sophore* E10 and E_{max} coincides

Kumar *et al*. (2021) from Sutlej River. Exploitation rate (E), exceeds the optimum rate of 0.5 (Gulland, 1971) in *P. sophore*. Current exploitation rate (0.57), along with higher fishing mortality compared to natural mortality indicates slightly high fishing pressure on *P. sophore* stocks in Deepor Beel. Mustafa and Graaf (2008) and Ahamed *et al*. (2012) also observed similar high fishing pressure on *P. sophore*. The value of E in case of *P. sophore* (0.57), which is roughly half of its E_{max} (1.0), indicates that there is a possibility of increasing the fishing pressure on the species without any immediate risk of stock collapse. *P. sophore*, being a small indigenous fish, is characterised by rapid growth rate, short life span and multiple breeding events in a single year (Hasan *et al*., 2018; Debi *et al*., 2023). All these features combined, enhance resilience of the species to moderate fishing pressure by enabling faster population replenishment. Although the species showed a year-round recruitment pattern, peak recruitment occurs during August-September and a secondary hike in December-January. Kumar *et al*. (2021) observed peak recruitment for the species from June to July in Sutlej River. Mahapatra (2024), observed peak breeding season of *P. sophore* during June-July and peak recruitment further in August-September. Kohinoor *et al*. (2005) found year-round spawning of *P. sophore* with two peaks, one each in April and November, validating the occurrence of two peaks of recruitment for the species.

M. bleekeri

Total length (pooled by sex) *M. bleekeri* ranged from 48-132 mm. The most common length groups (Fig. 2c) were 81-90 mm (32.79%), 91-100 mm (22.72%), and 101-110 mm (17.37%). LWR of *M. bleekeri* derived was $W=0.033 \times L^{2.524}$ with goodness of fit (r^2) value 0.77 ($p<0.05$). Growth coefficient (b =2.524) indicates negative allometric growth (Table 1). Growth coefficient (K) was estimated at 0.7 yr^{-1} and asymptotic length as 142.28 mm (Fig 3c). Mortality parameters derived from the study for *M. bleekeri* shows M as 0.93 yr^{-1}, F as 1.61 yr^{-1} and Z as 2.54 yr^{-1} (Fig. 4c). Exploitation rate (*E*) of 0.63 and exploitation rate which maximise yield per recruit (E_{max}) of 0.81, determined from the study indicate the closeness of fishery towards overexploitation (Table 1). VPA analysis applied to length frequency data revealed that rate of fishing mortality at length classes above 85 mm is maximum, with the most prevalent catch being within 85 to 105 mm length range (Fig. 5c). Recruitment of the species was found to peak during December-January, continuing until March (Fig. 6c). L_{25}, L_{50} and L_{75} were estimated at 74.26; 85.17 and 92.76 mm, respectively. The study suggests that the species become susceptible to fishing when they reach a total length of 85.17 mm, as indicated by the predicted length at first capture (Lc_{50}) value (Fig.7c). E_{10}, E_{50} and E_{max}, were calculated as 0.719, 0.389, and 0.814, respectively (Fig 8c).

Maximum length of *M. bleekeri* recorded during the study was 132 mm. Relatively lower maximum length of *M. bleekeri* (119.4 mm) has been recorded by Ahirwal *et al*. (2023) from Ganga River and by Naeem *et al*. (2012) from Pakistan (78 mm). Hossain *et al*. (2016) reported a maximum length of 135 mm from the rivers of Bangladesh, which is close to the present study. Reports on lower values of maximum length of a species from an ecosystem indicate intense fishing pressure, which does not allow fish to reach their maximum size. The b value of 2.524 in LWR for the speices from Deepor Beel conforms to the findings of Hossain and Afroze (1991) from Bangladesh (b=2.666) and of Naeem *et al*. (2012), from Pakistan (b=2.62), with both observations supporting the negative allometric pattern found in the present study. Growth coefficient (K) in *M. bleekeri* was found to be on the higher side, which is similar to the values observed for *M. cavasius* from Western Ghats (Thippeswamy *et al*., 2022) and Kolong River, Assam (Nath *et al*., 2023). Fishing mortality of *M. bleekeri* in Deepor Beel exceed its natural mortality suggesting overexploitation, further validated by the exploitation rate of 0.63, which imply that current fishing practices are unsustainable and may result in collapse of fish stocks if not adequately managed. Values of $\mathbf{E_{50}}$ (0.38) and $\mathbf{E_{max}}$ (0.81), suggest that the fishery has not yet reached its maximum fishing pressure, but continuous harvesting at current fishing effort can lead to stock depletion in near future. The recruitment pattern of *M. bleekeri* showed that, recruitment starts from September-October and continues to increase till December-January. The findings of Majumder *et al*. (2021) and Sultana *et al*. (2023) depicting two distinct breeding seasons, with peaks in November and May-June, in an open water body of Bangladesh points to the occurrence of two phases of recruitment. Spawning season of closely related *Mystus* spp. reported during May-September (Gupta and Banerjee, 2013; Jasmine and Molina, 2016) supports the recruitment pattern observed in the current study. During winter season, fishing in Deepor Beel primarily focuses on capturing larger commercially important fishes using large-meshed gill nets (Dutta and Sharma, 2020), due to increase in demand particularly for the local festival known as Magh Bihu at Assam. Therefore, *M. bleekeri* being a small indigenous fish becomes less susceptible to capture by large-meshed gill nets, during this particular season, which leads to temporary reduction in fishing pressure and allows partial replenishment of the stock.

H. fossilis

Total length of of *H. fossilis* stretched from 75 to 241 mm, while the 150 to 170 mm size groups being the most common, representing 33.21% of the catch. LWR was derived as $W=0.0218\times L^{2.614}$ with goodness of fit (r^2) 0.815. Value of b (2.614) represent negative allometric growth (Table 1). Growth parameters, asymptotic length (L_∞) of 252 mm and growth coefficient (K) of 1.1 yr^{-1} were derived from length frequency data (Fig 3d). Mortality parameters estimated for the species were M=1.067 yr^{-1}, *Z*=2.72 yr^{-1}, F as 1.65 yr^{-1} and exploitation rate(E) of 0.61 (Fig. 4d). VPA applied to length frequency data revealed that M increases significantly from a length of 130 mm onwards, peaking in the 170–190 mm size group (Fig. 5d). The species was found to be recruited mostly during the months of January-March (Fig. 6d). The size selectivity analysis showed that the length at which 25, 50, and 75% of the population are susceptible to capture were 18.11; 129.56; and 139.81 mm, respectively. Length of 129.56 mm was determined as length at first capture (L_{c50}) (Fig. 7d). Exploitation at E_{10}, E_{50}, and E_{max} follows 0.60, 0.37, and 0.67 respectively (Fig. 8d).

Although numerous studies on the morphological, meristic, and various other biological aspects of the species *H. fossilis* are available (Islam *et al*., 2021), investigation into its life history parameters and population dynamics are very limited from the Brahmaputra basin. Maximum length of *H. fossilis* from Deepor Beel as observed in the present study was found to be 241 mm, in contrast to the 310 mm maximum length reported from the Ganga River (Khan *et al*., 2012). There is a dearth of literature on stock assessment of *H. fossilis* and the present study is the first report on population characteristics of the species from Brahmaputra basin, India. LWR of *H. fossilis* from Deepor Beel indicated negative allometric growth (b=2.6). Khan *et al*. (2012) and Rahman *et al*. (2019) reported positive allometric growth in the species from River Ganges, India, and Gajner Beel, Bangladesh, respectively. Exploitation rate greater than the optimum value of 0.5, as proposed by Gulland (1971) and higher fishing mortality compared to natural mortality for *H. fossilis* in Deepor Beel, indicate slight overexploitation of the species. Frequent use of small-meshed gill nets throughout the year (Dutta and Sharma, 2020) may have contributed to this scenario. The values of exploitation rate (0.61) and E_{max} (0.676) for the species as observed in the current study suggest that the fishery is nearing its maximum fishing pressure and needs immediate attention, failing which the fishery may face sustainability issues in near future. Recruitment of *H. fossilis* started in July and continued throughout the year with varying degrees across different months. Peak recruitment was observed during the months of January-March. Prolonged spawning season (March-August) of *H. fossilis* as reported by Saud *et al*. (2015) could have contributed to the year round recruitment in the species. Thakur and Das (1986) reported that *H. fossilis* form a sizeable seasonal fishery during post-monsoon, winter and summer months in Assam which corresponds with the peak recruitment of January-March as observed in the current study. Being bottom dwelling by nature, the vulnerability of the species to fishing gears tends to increase during lean water periods, when their habitats get exposed.

The information generated in the present study on the growth, recruitment, mortality and exploitation pattern of four indigenous fish species has direct implication for formulating policies towards management of multispecies fishery of Deepor Beel. It has been observed from the study that the four species exhibited different levels of growth, recruitment, mortality and levels of exploitation, which indicates that the management measure required for each species may vary. Species such as *M. bleekeri* and *H. fossilis*, displayed exploitation ratios above the optimum level and may benefit from decrease in fishing effort and regulation of small-mesh fishing gears. In contrast, *G. chapra* and *P. sophore* were found to be close to optimal exploitation and may be managed through continuous monitoring rather than strict regulations. However, a varied combination of species-sensitive regulations, are quite difficult to implement in multispecies fishery of Deepor Beel. Hence, management measures like strict enforcement of closed season which corresponds with the breeding period of these species (monsoon season) and designating the connecting channel of Deepor Beel with River Brahmaputra as 'no fishing zone' thereby enabling inward and outward migration of fishes are deemed suitable for conservation and long-term sustainability of fish stocks in Deepor Beel.

Acknowledgements

The authors wish to extend their sincere gratitude to the Director, ICAR-CIFE, Mumbai, and to the Director, ICAR-CIFRI, Barrackpore, for generously providing all the necessary facilities for conducting the study. The authors are also thankful to fishermen community of Deepor Beel, Assam for their co-operation during the study.

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