

Macrogathus aral (Bloch and Schneider 1801): Growth, condition, age, mortality, recruitment and exploitation in running and stagnant ecosystems in Gandak Basin, India

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Abstract

Growth and fishery of *Macrogathus aral* were studied from an oxbow lake Matwali-Majhariya maun and the river Dhanauti in Gandak Basin, India based on 367 and 451 specimens collected from the oxbow lake and the river, respectively through weekly sampling from June 2020 to May 2021. The length-weight relationship revealed negative allometric growth ($b < 3.0$) as $W = 0.0051 \cdot L^{(2.82)}$ in lake and $W = 0.0045 \cdot L^{(2.85)}$ in the river. The relative condition factor K_n was found to be ≈ 1.0 in both the ecosystems. The age at length zero and the maximum age T_{max} were estimated to be -0.312 year and 9.4 years in the lake and -0.328 year and 8.8 years in the river respectively. Growth parameters L_{∞} and 'K' were estimated to be 37.7 cm and 0.32 year^{-1} in the lake, and 34.3 cm and 0.34 year^{-1} in the river, indicating slow growing nature of the species. The mortality rates 'M' 'Z' and 'F' were determined to be 0.78, 0.95 and 0.17 per year in lake and 0.81, 97 and 0.16 per year in river. Recruitment analysis showed a single peak during August in both the ecosystems. L_{opt} was estimated as 20.8 cm in lake and 19.2 cm in river. Virtual population analysis (VPA) revealed highest fishing mortality observed in the length groups above 30.0 cm in both the ecosystems. The optimum level of exploitation ($E_{0.5}$) was found to be 0.32 in lake and 0.34 in river, which was lesser than the current level of exploitation. The above finding will be useful for sustainable management and conservation of the species.



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Introduction

The one-stripe spiny eel *Macrogathus aral* (Family: Mastacembelidae; Order: Synbranchiformes) is locally known as 'pateya' in Bihar. It is mainly distributed in Asian countries. In India, this species is harvested from its wild habitats like rivers, canals, streams, floodplains, ponds, lakes and waterlogged paddy fields (Britz, 2009; Abujam and Biswas, 2011). It is commercially important and is used for food as well as ornamental purpose. Due to its body shape, colour pattern and status as a food delicacy, this species fetches higher price than that of other freshwater fishes in the local markets. The abundance of this species has been declining across the

country due to overexploitation, pollution, encroachments and interrupted water flow in rivers. The IUCN has enlisted this species under the "least concern" category (IUCN, 2023), whereas in India's conservation assessment and management plan report it is included under "Lower Risk near threatened" (LRnt) category (CAMP, 1998). There are no published reports available on the population/stock characteristics of *M. aral* from its natural habitats. Therefore, the current study was planned to assess and compare the population characteristics i.e. growth, age, mortality, recruitment and exploitation of *M. aral* under running (river) and stagnant (ox-bow lake) ecosystems of Gandak Basin, India.

Materials and methods

Sites and sample collection

River Dhanauti, one of the tributaries of the Gandak Basin in India, measuring approximately 192 km in length with a catchment area of 870 km², was selected as a running aquatic ecosystem (NWDA, 2022). The river is known for changing its course and leaving behind numerous oxbow lakes locally called 'maun'. The Matwali-Majharia maun (≈120 ha) is one such lake selected for the present study (Fig. 1). A total of 451 specimens was collected through weekly sampling from June 2020 to May 2021 from five different locations of river Dhanauti (26°33'06.9"N, 85°02'33.7"E to 26°44'09.2"N, 84°35' 55.2"E) and 367 individuals from oxbow lake i.e. 'Matwali-Majharia' Maun located at 26°33'53.6"N, 84°55'52.2"E to 26°33'24.3"N, 84°56'24.2"E. The fish samples were captured using locally designed traps, gill nets and cast nets of 5 to 20 mm mesh size with the help of local fishermen. The total length of each specimen was measured from the tip of the snout to the extended tip of the caudal fin to the nearest 0.1 cm using a digital Vernier caliper. Weight of the collected specimens was measured to the nearest 0.1 g. There is no fixed landing centre or data collection centre across the course of the selected river and lake. Therefore, an approximate total catch of the species on the days of observation was recorded by inquiring/ interviewing the fishermen and surveying the local markets near the selected sites. The length frequency data was grouped into 1.0 cm class interval and raised for the day and consequently for the month (Sekharan, 1962).

LWR, condition factor, growth, age, mortality, exploitation and yield per recruit

The length-weight relationship (LWR) and relative condition factor (K_n) were estimated following Le Cren's equation (Le Cren, 1951). The equation was transformed as $\log W = \log(a) + b \log(L)$ before estimation of LWR parameters; 'a' intercept and 'b' slope of the relationship and subsequently K_n were determined. The growth parameters were estimated using von Bertalanffy growth function as: $L_t = L_\infty * [1 - \exp^{-K(t-t_0)}]$ in ELEFAN-I of FiSAT-II package (Gayanilo et al., 2005) where L_t = length at age t, L_∞ = asymptotic length, annual K

= growth coefficient and t_0 = length at age zero. The final values of L_∞ and K were estimated by averaging the values obtained from non-parametric scoring of VBGF fit using ELEFAN-I (Pauly and David, 1981; t_0 was estimated using Pauly's empirical equation (Pauly, 1979) i.e. $\log_{10}(-t_0) = (-0.392 - 0.275 \log_{10} L_\infty - 1.038 \log_{10} K)$. The maximum age (T_{max}) was computed as $T_{max} = 3/K$ (Pauly, 1980). The growth performance index (Phi prime ' ϕ' ') was computed following the equation $\phi' = \log_{10} K + 2 \log_{10} L_\infty$ (Pauly and Munro, 1984). The optimum length (L_{opt}) was estimated following the equation, $L_{opt} = L_\infty * (3/(3+(M/K)))$ (Froese 2006). For the estimation of natural mortality rate (M), Pauly's empirical equation (Pauly, 1984a), $\log_{10} M = 0.006 - 0.279 \log_{10} L_\infty + 0.654 \log_{10} K + 0.4643 \log_{10} T$ was used, where 'T' represents average annual water temperature (°C) of the water body. The annual average temperature was considered as 26 and 27°C in case of river and lake, respectively. The total mortality rate (Z) was calculated using length-converted catch curve method (Pauly, 1984b). The current fishing mortality rate (F) was estimated by subtracting 'M' from 'Z'. The current exploitation rate (E) was calculated using the equations: $E = F / Z$ (Sparre and Venema, 1998) and exploitation ratio as $U = (F / Z) * (1 - e^{-Z})$ where F and Z represent fishing and total mortality rate, respectively (Beverton and Holt, 1957). The recruitment pattern, relative yield per-recruit (Y/R) and biomass per-recruit (B/R) analysis was conducted to find reference points and exploitation status of the species using FiSAT-II package (Beverton and Holt, 1957; Gayanilo et al., 1996).

Results and discussion

Length-weight relationship (LWR), relative condition factor (K_n) and growth performance

The length of the sampled specimens ranged from 10.0 to 33.7 cm and 10.5 to 32.9 cm from the lake and the river, respectively. Likewise, weight ranged from 6.8 to 79.52 g and 7.42 to 80.21 g respectively from the two water bodies (Table 1). The LWR of *M. aral* was computed to be $W = 0.0051 * L^{2.82}$ (from the lake) and $W = 0.0045 * L^{2.85}$ from the river, with $r^2 = 0.98$ in both cases. The strong correlation of the regression model indicated good quality of prediction and estimated LWR parameters can be used for

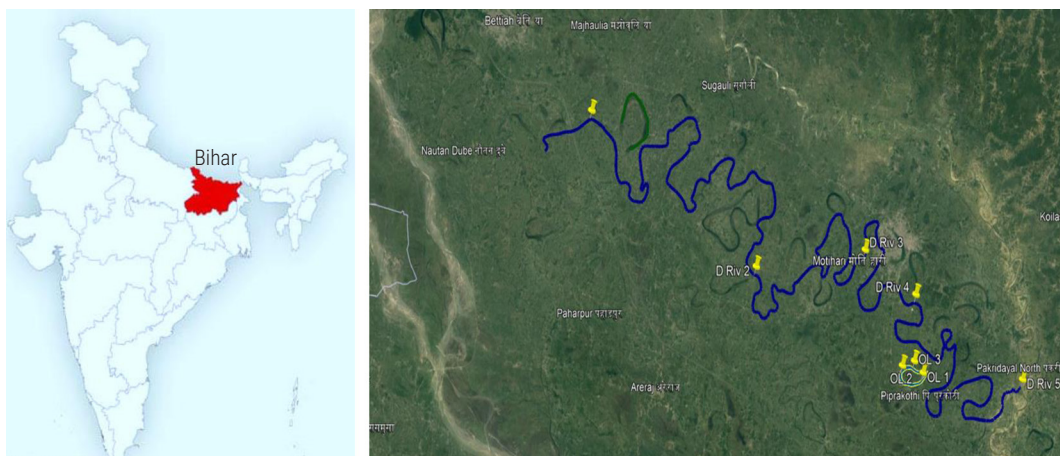


Fig. 1. Map depicting River Dhanauti and oxbow lake Matwali-Majharia Maun and sample collection sites

extrapolation of weight/length/size with precision. The estimated 'b' values (<3.0) indicated that *M. aral* followed negative allometric growth pattern in both the ecosystems. If, $b=3$ the growth of fish is called isometric and if $b>3.0$ then the growth is positive allometric (Maurya *et al.*, 2022). The 'b' value for *M. aral* reported by other researchers from different areas ranges between 2.59 and 3.48 with $r^2 = 0.80-0.96$ (Chakraborty and Goswami, 2016; Borah *et al.*, 2017; Deka and Barman, 2020; Das *et al.*, 2022).

The relative condition factor (K_n) indicates the well-being/condition of the fish. This was estimated to be ≈ 1.0 (0.95 to 1.02) in both the ecosystems which revealed normal growth condition in both the ecosystems (Fig. 2). $K_n \geq 1$ indicates better growth condition, while $K_n < 1$ indicates poor growth condition (Maurya *et al.*, 2018). The factors influencing well-being/growth condition of fish include food availability, breeding, disease and physicochemical factors of the habitat environment (Le Cren, 1951; Jisr *et al.*, 2018). The growth performance index (ϕ) was calculated to be 2.66 in lake and 2.60 in river revealing close similarity in growth of the population of *M. aral* collected from lacustrine and riverine ecosystems (Table 1).

Table. 1. Life history parameters of *M. aral* from Matwali-Majharia maun and river Dhanauti

Parameter	Lake	River
Length range	10.0 to 33.7 cm	10.5 to 32.9 cm
Weight range	6.8 to 79.5 g	7.42 to 80.2 g
Length-weight relationship	$W=0.0051*L^{(2.82)}$	$W=0.0045*L^{(2.85)}$
Relative condition factor (K_n)	0.95 to 1.02	0.98 to 0.99
Asymptotic length (L_∞)	37.7 cm	34.3 cm
Growth coefficient (K)	0.32 year ⁻¹	0.34 year ⁻¹
Phi prime (ϕ')	2.66	2.60
Age at length zero (t_0)	-0.312 year	-0.328 year
Maximum age (T_{max})	9.4 year	8.8 year
Natural mortality rate (M)	0.78 year ⁻¹	0.8 year ⁻¹
Fishing mortality rate (F)	0.17 year ⁻¹	0.16 year ⁻¹
Total mortality rate (Z)	0.95 year ⁻¹	0.97 year ⁻¹
M/K	2.44	2.38
Z/K	2.96	2.85
LC_{50}	13.61 cm	14.85 cm
L_{opt}	20.8 cm	19.2 cm
LC/L_∞	0.36	0.43
Optimum exploitation level (E_{50})	0.32	0.34
Maximum exploitation level (E_{max})	0.62	0.73
Current exploitation level ϵ	0.18	0.16
Exploitation ratio (U)	0.11	0.10

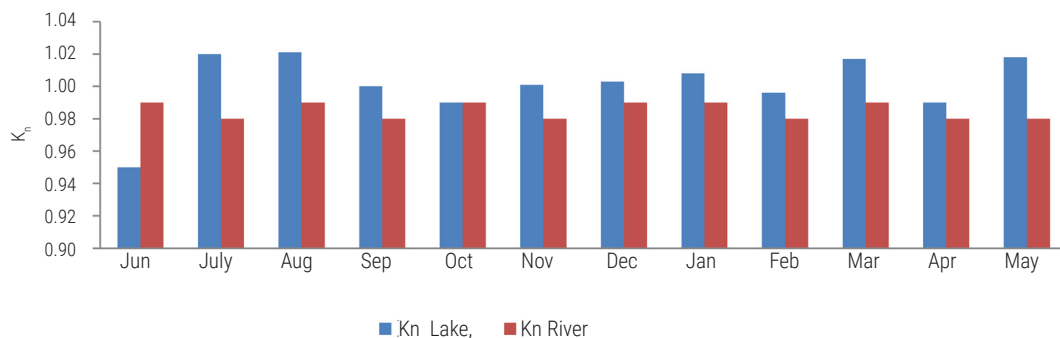


Fig. 2. Relative condition factor (K_n) of *M. aral* collected from Matwali-Majharia Lake and river Dhanauti during June 2020-May 2021

Growth, age and mortality parameters

The growth parameters L_∞ and K were estimated as 37.7 cm, 0.32 year⁻¹ in the oxbow lake and 34.3 cm, 0.34 year⁻¹ in the river (Figs. 3 and 4). However, the maximum length (L_{max}) of *M. aral* was reported to be 63.5 cm from Sri Lanka as per the record of over a six-decade old single reference (Froese and Pauly, 2022). No such reference is available for comparison with respect to the L_∞ and L_{max} of this species. The possible reason for lower L_∞ in the present study might be recruitment overfishing and changing climate scenario (Wang *et al.*, 2020). The estimated 'K' value revealed that *M. aral* is a slow growing species under both the ecosystems. The age at length zero (t_0) and maximum age (T_{max}) were estimated to be -0.312 and 9.4 year in lake and -0.328 and 8.8 year in river, respectively. The natural mortality rate was found to be 0.78 year⁻¹ and 0.81 year⁻¹ in the lake and river, respectively. Total mortality rate was estimated to be 0.95 year⁻¹ (0.72-1.19, $R^2=0.85$) and 0.97 year⁻¹ (0.70-1.19, $R^2=0.93$) in lake and river, respectively (Figs. 5 and 6). The fishing mortality was 0.17 year⁻¹ and 0.16 year⁻¹ in lake and river, respectively. The Z/K ratio is an indicator of the status of the stock. This was estimated at 2.96 in the lake and 2.85 in the river, suggesting that stock is mortality dominated (Table 1). Ideally, to keep the stock in equilibrium/sustainable and growth dominated, the Z/K ratio should be less than or equal to one. These results indicated that the stock of *M. aral* was natural mortality dominated in both the ecosystems as the estimated 'M' was higher than the estimated 'F' in both the ecosystems.

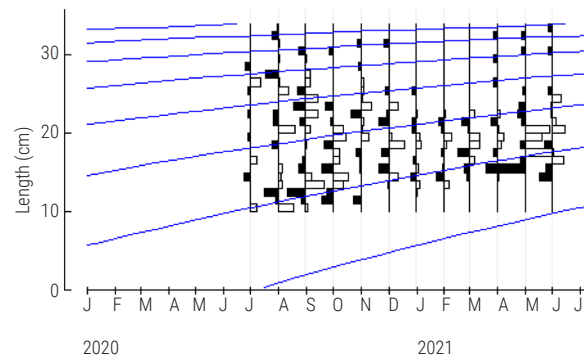


Fig. 3. Length-frequency distribution and VBK curves of *M. aral* collected from Matwali-Majharia Lake ($L_\infty=37.7$ cm, $K=0.32$ yr⁻¹)

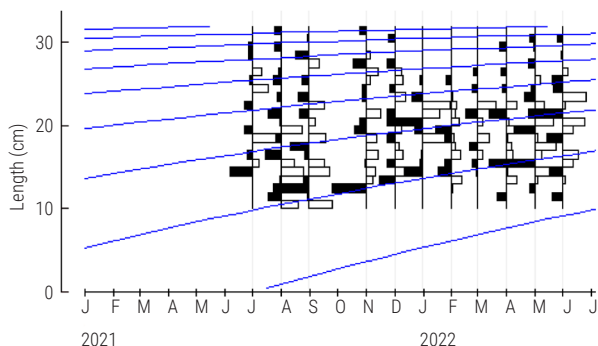


Fig. 4. Length-frequency distribution and VBG curves of *M. aral* collected from river Dhanauti (L_{∞} =34.3 cm, K =0.34 yr⁻¹)

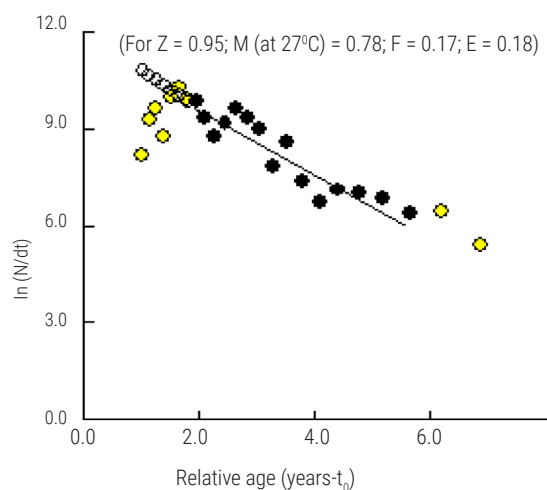


Fig. 5. Length-converted catch curve plot for Z estimation of *M. aral* collected from Matwali-Majharia Lake

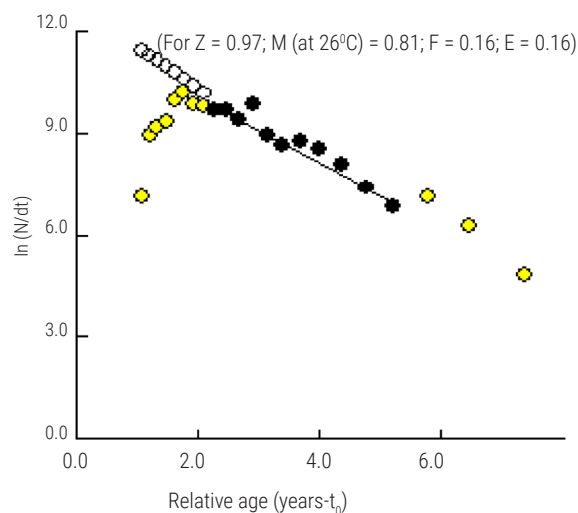


Fig. 6. Length-converted catch curve plot for Z estimation of *M. aral* collected from river Dhanauti

Recruitment and probability of capture

The recruitment of *M. aral* was observed from May to September in the lake, and from July to October in the river, with a single peak during the month of August in both the ecosystems (Figs. 7 and 8). The most common gears used to capture *M. aral* were gillnet, cast net and bamboo traps having mesh size of 5 to 20 mm, used for multispecies fisheries. The mean length at 25, 50 and 75% probability of capture was found to be L_{25} = 11.61 cm, L_{50} = 13.61 cm, L_{75} = 14.44 cm in the lake and L_{25} = 13.34 cm, L_{50} = 14.85 cm and L_{75} = 17.33 cm in the river (Figs. 9 and 10). One of the biological reference points for maintaining the sustainability of the stock is the optimum length of harvesting which allows the fish stock for spawning at least once in their life (Froese and Binohlan, 2000). In the present study, the L_{opt} was estimated to be 20.8 in the lake and 19.2 cm in the river.

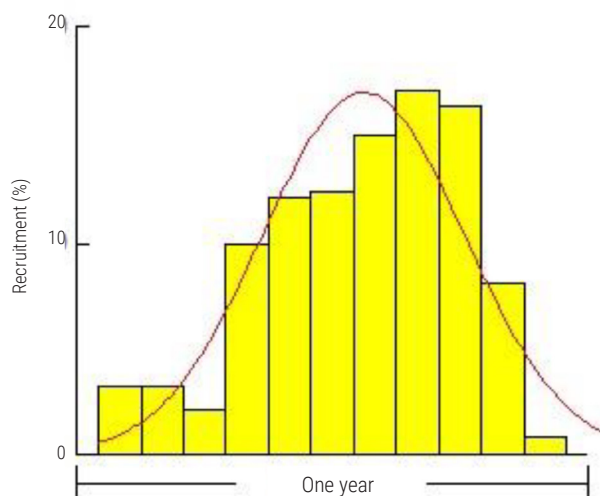


Fig. 7. Recruitment pattern of *M. aral* in Matwali-Majharia Lake

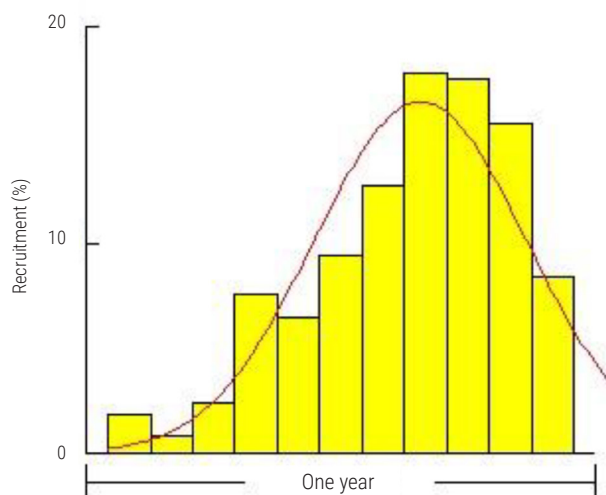


Fig. 8. Recruitment pattern of *M. aral* in river Dhanauti

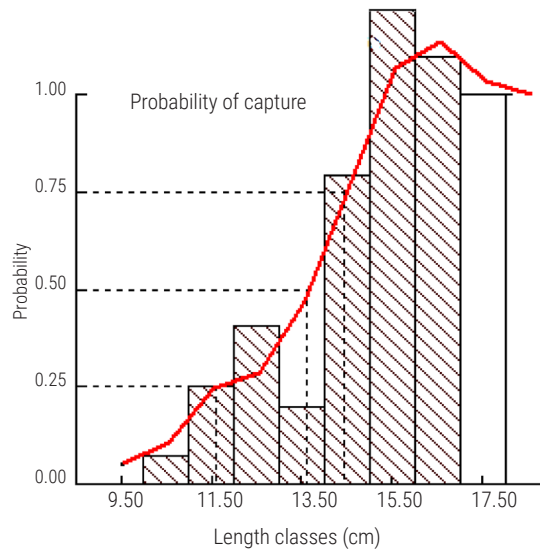


Fig. 9. Probability of capture (L_{25} , L_{50} , and L_{75}) for *M. aral* in Matwali-Majharia Lake

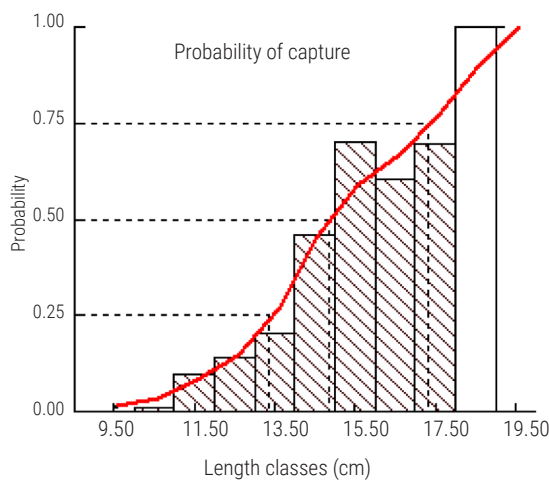


Fig. 10. Probability of capture (L_{25} , L_{50} , and L_{75}) for *M. aral* in river Dhanauti

Virtual population analysis (VPA)

The VPA analysis was performed using the input parameters L_{∞} , K , M , a , b and F_t (terminal fishing mortality assumed as 0.5) and results revealed highest fishing mortality as 0.501 in the mid-length group of 32.5 cm in lake and 0.769 in the mid-length group of 30.5 cm in river (Figs. 11 and 12). The VPA revealed insignificant fishing mortality in the length groups <14.0 cm, whereas highest fishing mortality was observed in the length groups above 30.0 cm in both the ecosystems. The average fishing mortality from fully recruited lengths was found to be 0.288 in the lake and 0.381 in the river.

Beverton and Holt's yield-per-recruit and exploitation level

The yield-per-recruit (Y/R) analyses revealed $E_{\max}$ (value of exploitation rate at highest Y/R as 0.628 in the lake and 0.729 in the

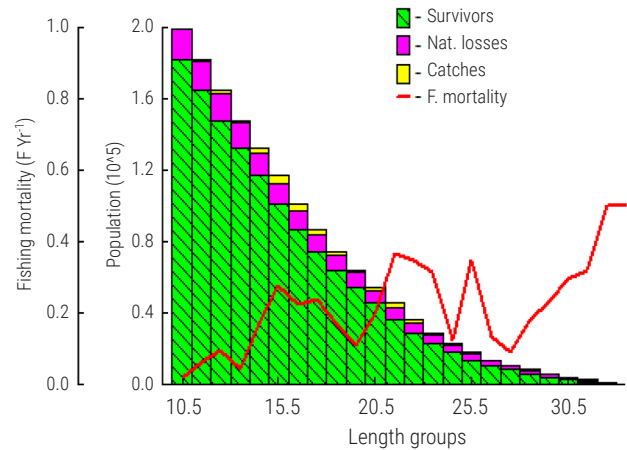


Fig. 11. Length-based VPA indicating survivors, natural losses, catches and fishing mortality of *M. aral* in Matwali-Majharia Lake

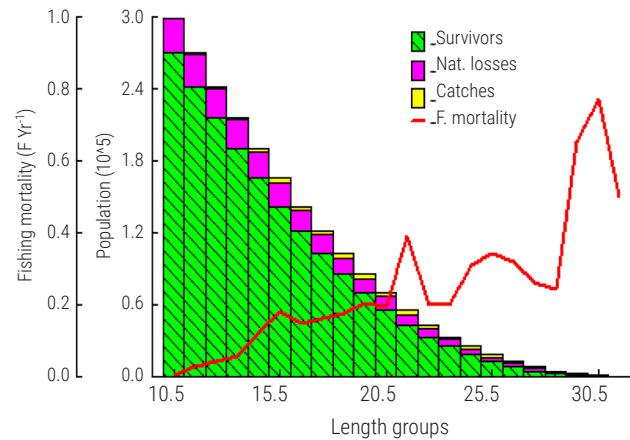


Fig. 12. Length-based VPA indicating survivors, natural losses, catches and fishing mortality of *M. aral* in Dhanauti River

river (Figs. 13 and 14). The marginal exploitation rate ($E_{0.1}$) which is the value at which the slope of Y/R is one tenth of its value at the origin, was found to be 0.518 in the lake and 0.619 in the river. Likewise, the economic exploitation level ($E_{0.5}$) which is the value of the exploitation rate associated with a 50% decrease of Y/R compared with the unexploited stock, was calculated to be 0.322 in the lake and 0.342 in the river. The current level of exploitation (E) was calculated to be 0.18 in lake and 0.16 in river which was lower than $E_{0.5}$ in both the ecosystems. The exploitation ratio (U) was found to be 0.11 in the lake and 0.102 in the river. These estimates indicated that the stock is underexploited and the fishing efforts can be increased in order to get the optimum Y/R at $E_{0.5}$ level. However, it is important to note that as the gears are used to capture multiple species including *M. aral* in both the ecosystems, increasing the fishing pressure may possibly lead to overexploitation of the other species. Therefore, populations of the other fishes being harvested from those gears also need to be studied.

M. aral is a commercially important species which has been facing immense anthropogenic pressure such as pollution and use of

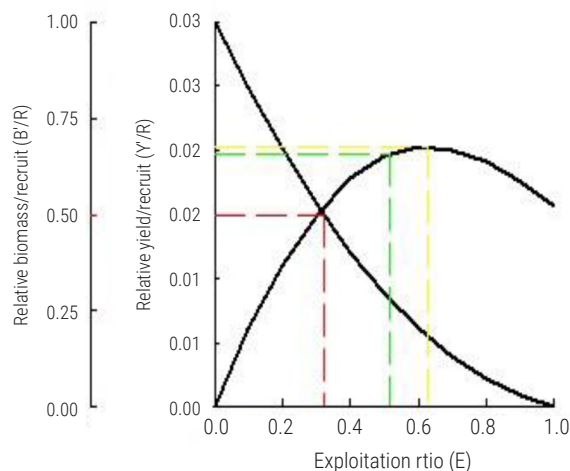


Fig. 13. Beverton and Holt's Y/R model showing levels of yield per recruit indices with respect to the different exploitation levels in Matwali-Majharia Lake ($E_{0.1}$, $E_{0.5}$ and E_{max})

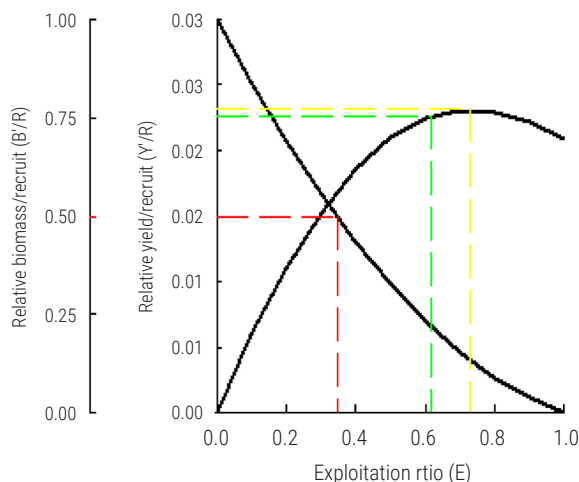


Fig. 14. Beverton and Holt's Y/R model showing levels of yield per recruit indices with respect to the different exploitation levels in Dhanauti River ($E_{0.1}$, $E_{0.5}$ and E_{max})

chemicals/insecticides in the catchment areas of the ecosystems studied. Further, changing climatic conditions is also leading to the decrease in abundance of this species in the Gandak Basin and from its adjacent wetlands, floodplains and paddy fields. The present study on growth, condition, age, mortality, recruitment and exploitation level will enable the sustainable management and conservation of this species.

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