Indian Journal of Geo Marine Sciences
Vol. 50 (04), April 2021, pp. 302-309

Growth, mortality and stock assessment of *Arius arius* (Hamilton, 1822) from Hooghly-Matlah estuary, West Bengal

B B Chirwatkar[a], S K Das*[,a], D Bhakta[b], T S Nagesh[a] & S Behera[a]

[a]Department of Fisheries Resource Management, Faculty of Fishery Sciences, WBUAFS, Chakgaria, Kolkata, West Bengal – 700 094, India

[b]ICAR-Central Inland Fisheries Research Institute, Barrackpore, Monirampore, Kolkata, West Bengal – 700 120, India

*[E-mail: dassudhirkumar1@gmail.com]

Received 03 January 2018; revised 09 August 2020

The growth, mortality, and stock assessment of *Arius arius* were estimated based on monthly length-frequency analysis data collected from the Hooghly-Matlah estuary of West Bengal, India from April 2017 to March 2018. The estimated growth parameters were as L_∞ = 278 mm, K = 0.97 yr^{-1}, and t_0 = -0.0889 years. The different mortality coefficients Z, M, and F were obtained as 5.25 yr^{-1}, 1.79 yr^{-1}, and 3.46 yr^{-1}, respectively. The calculated exploitation ratio (E) was found as 0.66, and the M/K value as 1.845 indicating overexploitation of the fish. The recruitment was found throughout the year with two peaks and the value of L_c was found at 56.00 mm. The estimated virtual population analysis (VPA) indicated that the highest fishing mortality (F) of 3.4499 was observed at the 190-200 mm length class, followed by 3.2393 from the 180-190 mm length class. The fishery was found at the overexploitation level and measures are needed to regulate it for promoting its sustainability.

[**Keywords**: *Arius arius*, Growth parameters, Hooghly-Matlah estuary, Mortality, Stock assessment]

Introduction

Knowledge of fish stock assessment followed by appropriate management of a fishery plays an important role in safeguarding the existing resources. It not only provides information about population parameters such as age, growth, and mortality but also advises fishery managers for optimizing catch and effort[1], to determine the levels at which fishery may be sustainably exploited. Annual variation in a fishery often depends upon its growth pattern.

Arius arius (Hamilton, 1822) commonly known as 'Threadfin sea catfish' of the family Ariidae, is a demersal amphidromous fish inhabiting marine and brackish water. It is a bottom-dwelling catfish, widely distributed in the estuaries and freshwaters of both east and west coast of India[2]. The production of sea catfishes (*Arius* spp.) in the state of West Bengal during the year 2015-16 was reported as 20375 t against the total marine production of 173771 t, and it contributed 11.73 % to the state marine production[3]. The total catfish production of India was estimated at 54168 t during the year 2018 and it contributed around 1.49 % to the total marine production and 8.60 % to the marine demersal productions of the nation[4]. The family Ariidae includes marine catfishes, with approximately 153 species distributed globally inhabiting tropical and sub-tropical seas and even freshwaters; out of which 24 species are found in the Indian waters[5-7]. *Arius* is one of the important genera in the family Ariidae. In India, 8 species of the genus *Arius* are recorded namely, *A. arius*, *A. gagora*, *A. jella*, *A. maculatus*, *A. malabaricus*, *A. subrostratus*, *A. sumatranus* and *A. venosus*[6]. Catfish fishery forms an integral part of marine fisheries along the coast of West Bengal. The dominant marine catfish species are *A. arius*, *A. maculatus*, *A. jella*, *Tachysurus thalassinus*, *T. caelatus*, and *Osteogeneiosus militaris*.

The catfish is a major by-catch item in the sole bottom gillnets fishery and the bottom trawling. Based on the study of age, growth, and mortality of spotted catfish, *A. maculatus* along with southern Taiwan, it was reported that the species contributed as the major by-catch fauna, contributing to 32 % of the total catch[8]. The life history characteristics of the marine catfish species indicate that they are highly vulnerable with a long lifespan, slow growth, low fecundity, and large parental investment for the care of young (male being mouth-brooder).

A limited study has been done on the stock assessment and population dynamics of catfishes in different water bodies. Stock assessment of

Tachysurus tenuispinis was studied by Mojumder[9] from Waltair, Menon[10-11] from Mandapam waters, and Mehanna *et al.*[12] in the Arabian Sea, Oman. Alagaraja & Srinath[13] studied different growth parameters of *T. thalassinus* from Mandapam water. Menon *et al.*[14] worked on stock assessment of catfishes from different coastal areas of India and their respective exploitation level. Population parameters of soldier catfish *O. militaris* were assessed by Gulati *et al.*[15] and Parida *et al.*[16]. Raje *et al.*[17] studied the stock assessment of *T. jella* from Mumbai waters. Work has also been done on the diet compositions and population dynamics of the Madamango sea catfish *Cathorops spixii* inhabiting the tropical Bight in Southeastern Brazil[18]. Rosli *et al.*[19] observed different parameters like growth, mortality and recruitment pattern of long-snouted catfish, *Arius argyropleuron* from Kuala Muda and Merbok, Kedah, Malaysia. The phenology and life-history traits of *A. subrostratus* from the Cochin estuarine waters were studied by Ambily[20].

Moreover, a comprehensive work on the fishery, biological aspects, and potential resources of catfishes from the Indian water bodies has been done by James *et al.*[21]. However, indiscriminate exploitation has lead to changes in the species diversity of catfishes in terms of quality and abundance and necessitated the protection of many species of catfishes[22-23]. One of the main targets of the fish stock assessment and fisheries management is to reduce the fishing fleet by directly controlling the fishing effort or by limiting the total allowable catch per year or season and by studying and exploring their biological characteristics[24]. The present study aims to estimate the different population parameters, mortality, and exploitation level of *A. arius* from the Hooghly-Matlah estuarine system of West Bengal, India.

Materials and Methods

The length-frequency data were collected at a monthly interval from two different landing centers namely Godhakhali and Diamond Harbour under Hooghly-Matlah estuarine system during April 2017 to March 2018 (Fig. 1). The freshly collected fish samples from the landing centers were transported in a plastic insulated box with ice preserved and were then brought to the laboratory for further studies. In the laboratory, the total length (TL) of the fish specimens were measured to the nearest 0.1 mm from the tip of the anterior-most part of the body to the tip of the caudal fin by using a measuring board, and weight was measured using an electronic balance to the nearest 0.01 g accuracy. Landing center wise total catch of the species on the sampling day was recorded and noted. The collected length-frequency data were grouped into 10 mm class intervals and raised for the day and subsequently for the month using the method of Sekharan[23].

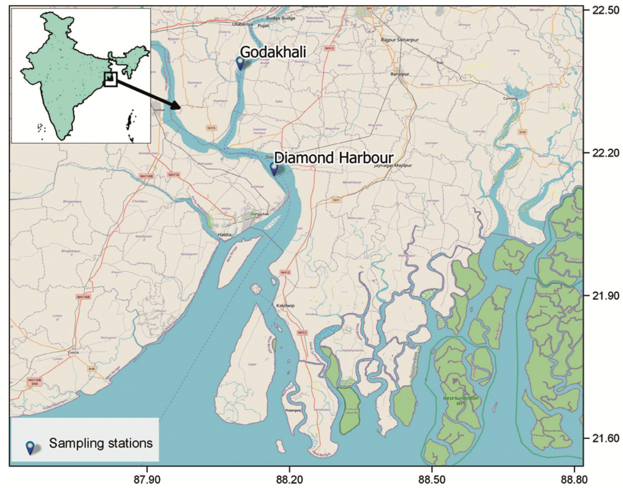

Fig. 1 — Sample collection site under Hooghly-Matlah estuarine system

A total of 391 samples (243 female and 148 male) with the size ranging from 52 to 254 mm and 1.62 to 176.75 g were collected to estimate population parameters. The growth parameters of von Bertalanffy like L_{∞} and K were estimated by putting the pooled sample data in 10 mm class intervals at the ELEFAN I module of FiSAT-II software version 1.2.2[ref. 26]. The age at zero-length (t_0) was calculated from Pauly's[27] empirical equation as given below:

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

Where, L_{∞} is the asymptotic length, and K is the growth coefficient.

Growth performance index (ϕ') for *A. arius* population in terms of length growth was computed using the index of Pauly & Munro[28]:

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

The total mortality (Z) was estimated from the length converted catch curve method[29] by using FiSAT-II software and the natural mortality was estimated by the Pauly's[30] empirical formula:

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

Where, L_{∞} is the asymptotic length, K is the growth coefficient and T is the ambient temperature. The annual mean water temperature for the study area was taken at 28.2 °C (IMD, Kolkata, 2017).

The fishing mortality (F) was estimated by subtracting the instantaneous rate of natural mortality (M) from an instantaneous rate of total mortality (Z), *i.e.*, F = Z - M.

The exploitation level (E) is the ratio of the instantaneous rate of fishing mortality coefficient (F) to the instantaneous rate of total mortality coefficient (Z)[31]. The exploitation level of *A. arius* was calculated by using the formula: E = F/Z

Where, E = exploitation level; F = instantaneous rate of fishing mortality coefficient; and Z = instantaneous rate of total mortality.

Results

The von Bertalanffy Growth Function (VBGF) parameters L_{∞} and K were calculated as 278 mm and 0.97 yr^{-1}, respectively by the ELEFAN technique employing FiSAT-II software (Fig. 2). The t_0 was calculated as -0.0889 years and the growth performance index (ϕ') calculated from the growth parameters was 4.87. It was noted that the estimated L_{∞} was larger than the maximum observed length which suggested that the growth estimation for *A. arius* by the length-frequency analysis is reliable. The von Bertalanffy growth equation for *A. arius* along the Hooghly-Matah estuary was observed as $L_t = 278\ (1 - e^{-0.97(t-0.0889)})$.

The total mortality rate (Z) obtained from the length converted catch curve method was 5.25 yr^{-1} (Fig. 3). The natural mortality (M) was estimated at 1.79 yr^{-1}, the annual instantaneous rate of fishing mortality was 3.46 yr^{-1} and the exploitation ratio (E) was 0.66. The M/K value explains the relationship between the natural mortality coefficient and physiological factors. In the present study, the M/K value was estimated at 1.845. The estimated probabilities of capture values worked out using the selectivity catch curve method were found to be L_{25} = 45.89 mm, L_{50} = 56.60 mm, and L_{75} = 79.03 (Fig. 4). The mean length at first capture (L_{50}) or

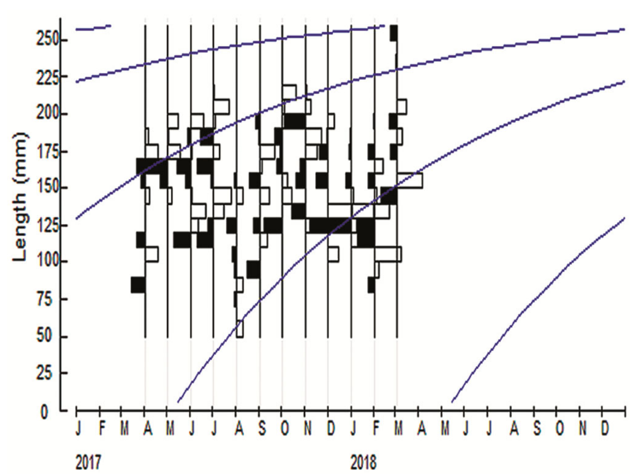

Fig. 2 — Length frequency and fitted von Bertalanffy growth curves of *A. arius*

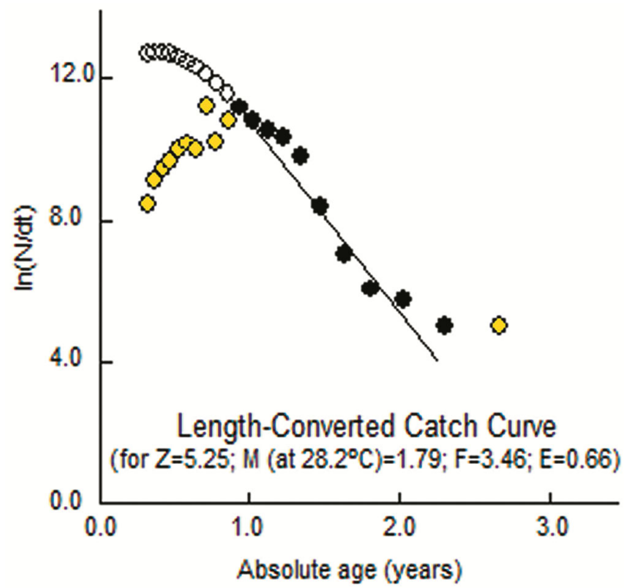

Fig. 3 — Length converted catch curve for estimation of 'Z' for *A. arius* in Hooghly-Matlah estuary

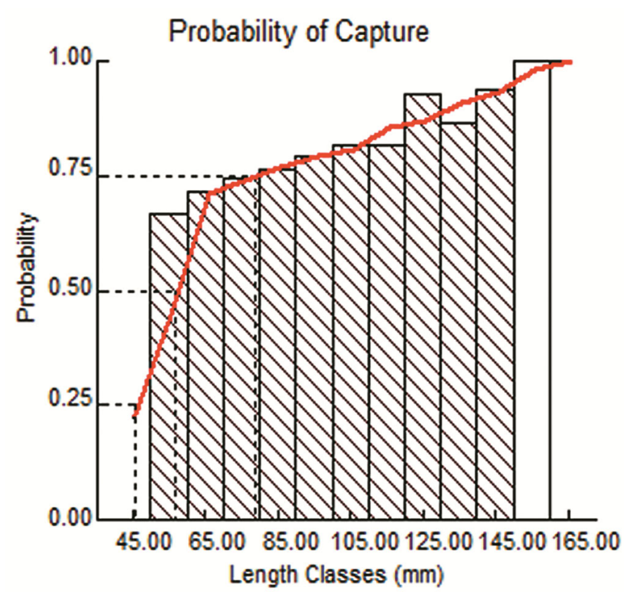

Fig. 4 — Selectivity catch curve showing probability captures of *A. arius*

value of L_c was observed at 56.60 mm. The recruitment pattern, from the present study, revealed that the species is found throughout the year in the estuarine region with two peak recruitments in a year, the first one from March to April and that of the second one from August to October (Fig. 5).

For the analysis of the virtual population (VPA), based on the annual catch from the pooled data the length-frequency data were raised for the entire population. The results obtained from length structured VPA are depicted in Figure 6. The input parameters used for VPA were L_∞ of 278 mm, K of 0.97 yr^{-1}, M of 1.79 yr^{-1}, and intercept 'a' of 0.000005 and regression coefficient 'b' of 3.104 which were acquired from the length-weight relationship. The highest fishing mortality of 3.4499 was observed at

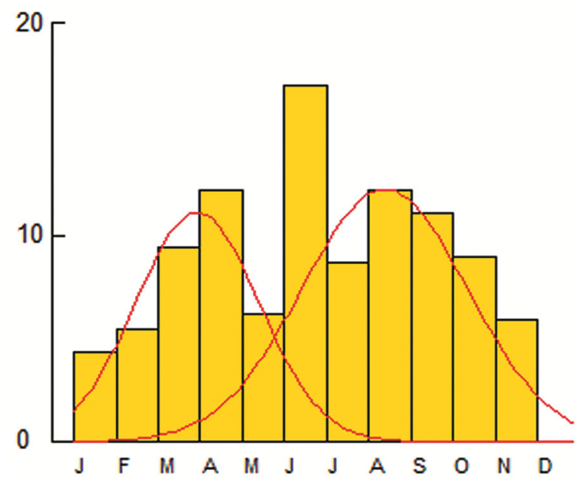

Fig. 5 — Recruitment pattern of *A. arius* from Hooghly- Matlah estuary

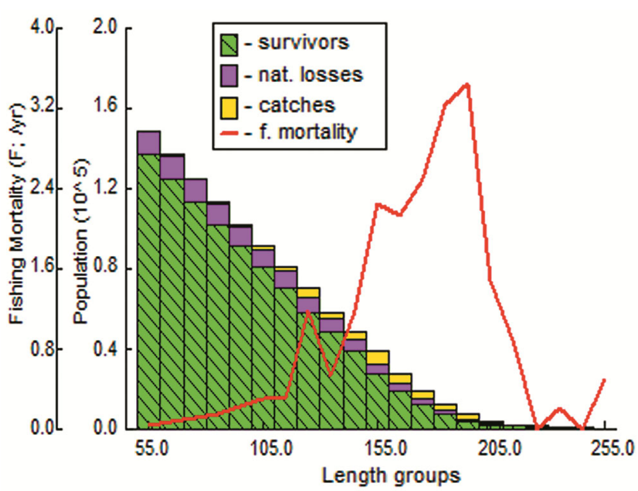

Fig. 6 — Length based virtual population analysis (VPA) of *A. arius* from Hooghly-Matlah estuary

190-200 mm length class, followed by 3.2393 from the 180-190 mm length class. The smaller length groups showed comparatively low fishing mortalities. The highest number of fish population (148844) was recorded from 50-60 mm length class with fishing mortalities of 0.0336 yr^{-1}. From the largest length class (250-260 mm) the population was observed as 380, assuming the terminal fishing mortality as 3.46. The biomass increased from 9.46 t from 50-60 mm length class to the highest of 95.74 t from 150-160 mm length class and then gradually decreased and reached 26.75 t from 250-260 mm length class.

Discussion

The estimated different population parameters are provided in Table 1. As per Ricker[32] certain parameters namely growth, natural mortality, fishing mortality, and recruitment are the fundamental models in fish stock assessment and management. Knowledge and information on certain population parameters of fish species is a pre-requisite for the conservation and sustainable management of the respective fisheries. The age and growth of fish are fundamental to stock assessment and relative estimators are dependent on growth parameters such as mortality[33]. Age and growth studies in concurrence with the length-weight relationship can give useful information on the stock composition, age and maturity, lifespan, mortality, growth, production, etc.[33].

Asymptotic length (L_∞) is a theoretical length beyond which the fish does not grow[34]. Several researchers studied the growth parameter in various

Table 1 — Population parameters of *A. arius* in Hooghly-Matlah estuary

Parameter	Values
Asymptotic length (L_∞)	278 mm
Catabolic co-efficient (K)	0.97 yr^{-1}
Age at length zero (t_0)	-0.0889 years
Natural mortality (M)	1.79 yr^{-1}
Total mortality (Z)	5.25 yr^{-1}
Fishing mortality (F)	3.46 yr^{-1}
Exploitation ratio (E)	0.66
Length at which 25 % of retaining by the gear ($L_{25\%}$)	45.89 mm
Length at which 50 % of retaining by the gear ($L_{50\%}$)	56.60 mm
Length at which 75 % of retaining by the gear ($L_{75\%}$)	79.03 mm
Exponent (a) of length-weight relationship	0.000005
Exponent (b) of length-weight relationship	3.104
Growth performance index (ϕ')	4.87
M/K ratio	1.845

species in different parts of the world. Chu *et al.*[8] estimated the growth parameters of *A. maculatus* and reported L_∞ value as 34.4 cm, K as 0.28 yr^{-1} and t_0 as -0.57 year along with south-western Taiwan. Similarly, Ambily[20] recorded growth parameters for *A. maculates*, and reported the values of L_∞, K and t_0 as 364 mm, 0.53 yr^{-1}, and -0.23 years, respectively from Cochin estuary. Raje *et al.*[17] reported growth parameters for the *T. jella* at Mumbai water; they found that L_∞ value, K, and ϕ' as 518 mm, 0.65 yr^{-1}, and 2.34. Parida *et al.*[16] observed the growth parameters of *Osteogeneiosus militaris* and reported the values of L_∞, K, and t_0 as 583 mm, 0.67 yr^{-1}, and -0.0396 years, respectively from Mumbai waters.

The catabolic coefficient (K) indicates the growth rate of fish. The fish species which have a shorter life span show high K value, and within one or two years reach their L_∞[ref. 35]. Dan[36] stated that the growth parameters of *T. tenuispinis* like L_∞, K and t_0 be 82 cm, 0.211 yr^{-1} and -0.177 years, and Alagaraja & Srinath[13] recorded L_∞ as 58 cm and K as 0.78 yr^{-1} in India. According to Sawant *et al.*[37] catfishes are typically carnivorous and voracious in feeding habits and are likely to grow at a faster rate. The values of 'K' for the species *A. caelatus* and *A. tenuispinis* were reported as 0.73 and 0.70 yr^{-1} with the corresponding values of L_∞ as 550 and 520 mm, respectively from the Mumbai coast[37]. In general, the members of the family Ariidae bears relatively low values of K and relatively high values of asymptotic length (L_∞), suggesting these parameters is inversely correlated[37].

Sparre *et al.*[38] stated that short-lived fishes have K values greater than one. In the present study growth parameters L_∞, K, t_o and ϕ' were found as 278 mm, 0.97 $year^{-1}$, 0.0889 yr^{-1}, and 4.87 for length range from 52 to 254 mm which slightly differs from other catfish species (Table 2). The present study slightly differs from the earlier works on growth parameters for L_∞ and 'K' values with the study of Balamurugan *et al.*[39] on *Arius arius* from the east coast of Tamil Nadu. A relatively lower L_∞ and 'K' value was observed here and it might be due to the differential environmental conditions, the period of study, sample size, sampling techniques, etc.

The probability of capture estimated for *A. arius* by length converted catch curve was found as L_{25} = 45.89 mm, L_{50} = 56.60 mm, and L_{75} = 79.03. Raje *et al.*[17] recorded the probabilities of capture at L_{50} and L_{75} as 369 mm and 383 mm for *T. jella* in Mumbai water. According to Sawant *et al.*[37], the probability of catch curves at L_{25}, L_{50} and L_{75} were 251, 274 and 296 mm for *A. caelatus* and 241, 268 and 296 mm for *A. tenuispinis*, respectively. Ambily & Nandan[40] reported the probabilities of capture values for *A. subrostratus* as L_{25} = 157.50 mm, L_{50} = 194.39 mm, L_{75} = 207.50 mm and L_{100} = 257.50 mm, respectively.

The VPA showed that the natural mortality increases towards a lower length group while fishing mortality showed a reverse trend. The fishing mortality was maximum (3.44 yr^{-1}) at the 190-200 mm size group. The lowest fishing mortality (0.203 yr^{-1}) was observed in the 230-240 mm length group. Ambily[20] reported that the depletion of *A. subrostratus* (175-180 mm size group) stock was mainly due to the natural causes, where the rate of fishing mortality was increased in 210-215 mm size group and the highest fishing mortality observed was 4.9 yr^{-1} at 215-220 mm size group from the Cochin estuary.

Growth performance index (ϕ') is a type of comparison of the growth rate of the species in a specific fishery to the standard growth rate of the

Table 2 — Growth parameters for the populations and the corresponding growth performance index (ϕ') by other researchers

Species	Growth parameter				Author(s)	Location
	L_∞ (mm)	K (y^{-1})	t_0 (yr^{-1})	ϕ'		
Arius arius	430.50	1.30	1.293	10.5- 11	Balamurugan *et al.*[39]	East coast of Tamil Nadu
Tachysurus tenuispinis	820	0.211	-	-	Dan[36]	
	580	0.78	-	-	Alagaraja & Srinath[13]	Both east and west coast
Tachysurus jella	518	0.65	-	2.34	Raje *et al.*[17]	Mumbai waters
Arius maculatus	344	0.28	-0.570		Chu *et al.*[8]	Southwestern Taiwan
Arius caelatus	550	0.73			Sawant *et al.*[37]	Mumbai waters
A. tenuispinis	520	0.70				
Osteogeneiosus militaris	583	0.67	-0.0396		Parida *et al.*[16]	Mumbai waters
Arius argyropleuron	342.6	0.70		2.915	Rosli *et al.*[19]	Kuala Muda and Merbok estuary
Arius maculatus	364	0.53	- 0.23		Ambily & Nandan[40]	Cochin water

Table 3 — Comparative mortality parameter of marine catfishes

Species	Morality parameter and exploitation ratio				Author	Location
	E	F	M	Z		
Osteogeneiosus militaris	-	2.51	1.04	3.55	Parida *et al.*[16]	Mumbai Water
Arius maculatus	-	1.29	0.86	0.43	Chu *et. al.*[8]	Southwestern Taiwan
Tachysurus jella	0.73	4.36	1.16	3.20	Raje *et al.*[17]	Mumbai waters
Arius argyropleuron	0.46	1.17	1.39	2.56	Rosli *et al.*[19]	Kuala Muda and Merbok estuary

species. The value of ϕ' observed in *A. arius* from the present finding was 4.87. Balamurugan *et al.*[39] recorded a high growth performance value of 10.5 to 11 for *A. arius* along the Parangipettai at East Cochin. A comparative growth performance index of a few species from the family Ariidae is presented in Table 2.

Patterson[41] suggested that for optimal exploitation, the exploitation ratio (E) should be maintained at 0.5. Gulland[31] opined that fish stock is optimally exploited at a level of fishing mortality with 'E' value of 0.50. In the fish stocks which are optimally exploited the fishing mortality (F) is the same as that of natural mortality (M) and E is fixed at 0.5. A higher fishing mortality rate (2.51) compared to the natural mortality (1.04) was reported in *O. militaris* from the Mumbai waters[16], whereas, Raje *et al.*[17] reported greater fishing mortality (4.36) and natural mortality (1.16) of *T. jella* at Mumbai waters. According to Chu *et al.*[8] *A. maculatus* was found with higher annual fishing mortality (1.29) than the natural mortality (0.86) at Coast of Yunlin, South-western Taiwan. Rosli *et al.*[19] also reported the fishing mortality and natural mortality for *A. argyropleuron* from the Kuala Muda and Merbok, Kedah, Malaysia as 1.17 and 1.39, respectively. Similarly, in the present study, the fishing mortality observed (3.46 yr^{-1}) is greater than the natural mortality (1.79 yr^{-1}) and the exploitation ratio (0.66) is above the optimum level (0.5) which indicates relatively overexploitation of *A. arius* stocks. A comparative analysis of a few closely related marine catfishes is provided in Table 3.

Fisheries are a renewable resource that can be renewed by the reproduction and recruitment in the aquatic environment. The recruitment pattern of *A. arius* showed only two recruitment patterns during the period of investigation, one from March-April and second in August-October. Ambily & Nandan[40] observed *A. subrostratus* recruitment during August with 17.48 % from total recruitment. Considering, relatively overexploitation of the stock, the present rate of exploitation has to be reduced to the optimum level with suitable regulations for proper management of *A. arius* fisheries in the studied ecosystem. The fish must be given chance to reproduce at least once during its lifetime for the replenishment of stock to promote sustainable fishery and measures like the periodical fishing ban, mesh size regulation, awareness, etc. needs to be implemented for the purpose along with the active involvement from the concerned stakeholders.

Conclusion

The estimated exploitation ratio of *A. arius* indicated that the stocks are already in the overexploitation phase in Hooghly-Matlah estuarine system. On an urgent basis, the exploitation level needs to be reduced from the present fishing pressure for the replenishment of the stock. Reduction of fishing efforts in terms of boats or nets, increase in cod-end mesh size of bagnet, and restriction on drift gillnet in peak breeding periods of the species need to be followed to promote sustainability of the fishery.

Acknowledgments

The first author would like to thank the Dean, Faculty of Fishery Sciences, Chakgaria, Kolkata, West Bengal (WBUAFS), India for providing necessary facilities during the study period.

Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

The first author (BBC) was involved in fish samples collection, data analysis and manuscript writing; and the rest of the authors (SKD, DB, TSN & SB) helped in manuscript reviewing and editing.

References

1 Sajan S, Anna Mercy T V & Malika V, Age, Growth and Population Dynamics of an endangered Fish *Sahyadria denisonii* (Day, 1865) from the Western Ghats Hotspot of India, *Asian Fish Sci*, 28 (2015) 130-142.

2 Karodt S A & Radhakrishnan C K, Seasonal variations in the gut contents of *Arius arius* (Hamilton) from Cochin backwaters, *Indian J Fish*, 57 (1) (2010) 93-96.

3 Anon, Handbook of fisheries statistics 2015-16, The Government of West Bengal, Department of Fisheries, Kolkata, 2016, pp. 182.

4 CMFRI, Annual Report 2018-19, Central Marine Fisheries Research Institute, Kochi, 2019, pp. 320.

5 Jayaram K C & Dhanze J R, Evolution and biogeography of the Indian genera of the family Ariidae, *Pro Indian Acad Sci (Anim Sci)*, 95 (2) (1986) 279-288.

6 Froese R & Pauly D (eds.), *Fishbase*, World Wide Web electronic publication. http://www.fishbase.org, version (05/ 2018).

7 Chirwatkar B B, Das S K & Bhakta D, Length-weight relationship, relative condition factor and morphological studies of *Arius arius* (Hamilton, 1822) in Hooghly-Matlah estuary, West Bengal, *Indian J Geo-Mar Sci*, 50 (01) (2021) 60-66.

8 Chu W S, Hou Y Y, Ueng Y T, Wang J P & Chen H C, Estimates of age, growth and mortality of spotted catfish, *Arius maculatus* (Thunberg, 1792), off the Coast of Yunlin, Southwestern Taiwan, *Afr J Biotechnol*, 10 (6) (2011) 15416-15421.

9 Mojumder P, Length frequency studies in the catfish, *Tachysurus thalassinus* (Ruppell) at Waltair during the years 1964-65 to 1960-69-70, *Indian J Fish*, 24 (1977) 90-95.

10 Menon N G, *Studies on the biology and fishery of giant marine catfish, Tachysurus thalassinus (Ruppell)*, Ph.D. thesis, University of Cochin, India, 1979.

11 Menon N G, Age and growth of the marine catfish *Tachysurus thalassinus* (Ruppell) from Mandapam waters, *Indian J Fish*, 33 (4) (1986) 413-425.

12 Mehanna S F, Zaki S, Al-Kharusi I, Al-Habsi S & Al-Kiyumi F, Stock assessment of the Thinspine Sea Catfish *Tachysurus tenuispinis* (Day, 1877) in the Arabian Sea, Oman, paper presented at the *International Conference on Land-Sea Interactions in the Coastal Zone Jounieh - LEBANON*, 2012.

13 Alagaraja K & Srinath M, Assessment of the resources of important species of catfishes, *Bulletin CMFRI*, 40 (1987) 70-90.

14 Menon N G, Srinath M, Sastry Y A, Raje G S, Zachariah P U, *et al.*, Stock assessment of marine catfishes of India, *Indian J Fish*, 39 (2) (1992) 65-84.

15 Gulati D, Devaraj M & Palaniswamy R, Stock assessment of soldier catfish *Osteogeneiosus militaris* along the northwest coast of India, *J Indian Fish Assoc*, 26 (1996) 1-8.

16 Parida P K, Jaiswar A K, Palaniswamy R, Kumar P & Chakraborty S K, Growth and mortality of *Osteogeneiosus militaris* (Linnaeus, 1758) from Mumbai waters, *Indian J Fish*, 61 (1) (2014) 12-15.

17 Raje S G, Dineshbabu A P & Das T, Biology and stock assessment of *Tachysurus jella* (Day) from Mumbai waters, *Indian J Fish*, 55 (4) (2008) 295-299.

18 Denadai M, Pombo M, Santos F B, Bessa E & Ferreira A, Population Dynamics and Diet of the Madamango Sea Catfish *Cathorops spixii* (Agassiz, 1829) (Siluriformes: Ariidae) in a Tropical Bight in Southeastern Brazil, *Plos One*, 8 (11) (2013) 01-08. doi.org/10.1371/ journal.pone. 0081257.

19 Rosli N A, Isa M M & Mansor M, Growth, Mortality and Recruitment Pattern of Long snouted Catfish, *Arius argyropleuron* (Valenciennes, 1840) in Kuala Muda and Merbok, Kedah, *J Biol Agric Healthcare*, 5 (5) (2015) 82-87.

20 Ambily V, *Phenology and life history traits of Arius subrostratus from Cochin estuary, India*, Ph.D. thesis, NSS Hindu College, Changanacherry, India, 2016.

21 James P S B R, Bande V N, Gopinalha Menon N & Balachandran K, The catfish resources of south-west coast of India. Prospects and management problems, *CMFRI Bulletin*, 44 (1) (1989) 78-94.

22 Lakshmi K & Rao K S, Trends in catfish catch at Visakhapatnam showing disappearance of *Arius tenuispinis*, *J Mar Biol Assoc India*, 34 (2) (1992) 26-37.

23 Vivekanandan E, Importance of fish stock assessment to fisheries management. Lecture Note Series No. 2/2017 of ICAR Sponsored Summer School on Advanced Methods for Fish Stock Assessment and Fisheries Management, 12th July-01st August 2017, (ICAR-CMFRI, Kochi, Kerala, India), 2017, pp. 126-134.

24 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*, 39 (2020) 01-08. doi.org/10.1016/j.rsma.2020.101451.

25 Sekharan K V, On oil sardine fishery of the Calicut area during the year 1955-56 to 1958-59, *Indian J Fish*, 9A (2) (1962) 679-700.

26 Gayanilo F C J, Sparre P & Pauly D, FAO-ICLARM Stock Assessment Tools (FiSAT) users guide, FAO Computerized information Series (Fisheries) No.8. FAO, Rome, 1996, 3 diskettes, pp. 124.

27 Pauly D, Theory and management of tropical multispecies stocks: A review with emphasis on the south-east Asian demersal fisheries, *ICLARM Stud Rev*, 1 **(**1979) pp. 35.

28 Pauly D & Munro J I, Once more on the comparison of growth in fish and invertebrates, *Fish Byte*, 2 (1984) 21-23.

29 Pauly D, Some simple methods for the assessment of tropical fish stocks, *FAO Fish Tech Paper,* 234, 1983, pp. 52.

30 Pauly D, A selection of simple methods for the assessment of tropical fish stocks, *FAO Fisheries and Aquaculture Circular No* 729, 1980, pp. 54.

31 Gulland J A, Manual of methods for fish stock assessment, Part I - Fish population analysis (FAO Man), *Fish Sci*, 4 (1969) p. 154.

32 Ricker W E, Computation and interpretation of biological statistics of fish populations, *Bull Fish Res Board Can*, 19 (1) (1975) p. 382.

33 Taherimirghaed A, Hashemi S & Hosseini, Population parameters and length-weight relationship of Thinspine Sea Catfish in Northwest of Persian Gulf (Khuzestan Coastal Waters, Iran), *Adv Biol Res*,7 (4) (2013) 124-128.

34 Beverton R J H & Holt S J, A review of the life spans and mortality rates of fish in nature and their relation to growth and other physiological characteristics, In: *The lifespan of animals*, (CIBA Foundation Colloquia on ageing), 5 (1) (1959) 142-180.

35 Pauly D, Fish population dynamics in tropical waters: A manual for use with programmable calculators, *ICLARM Stud Rev*, 8 (1984) p. 325.

36 Dan S S, Age and growth in the catfish *Tachysurus tenuispinis* (Day), *Indian J Fish*, 27 (1/2) (1980) 220- 235.

37 Sawant B T, Chakraborty S K, Jaiswar A K, Panda D, Bhagabati S K, *et al.*, Population parameters of the catfishes, *Arius caelatus* (Valenciennes, 1830) and *Arius tenuispinis* (Day, 1877) from Mumbai waters, *Indian J Fish*, 42 (6) (2012) 775-780.

38 Sparre P & Venema S C, Introduction to tropical fish stock assessment, Part 1 Manual, FAO Fisheries Technical paper No. 306 (1), Rev 2, (Rome, FAO), 1998, pp. 407.

39 Balamurugan S, Deivasigamani B, Kumaran S, Sakthivel M, Edward G, *et al.*, Length-weight relationship, age and growth of wild catfish *Arius Arius* (Hamilton, 1822) in Parangipettai East Coast of Tamil Nadu, *An Int J Mar Sci*, 29 (1) (2013) 17-23.

40 Ambily V & Nandan S B, Studies on some aspects of reproductive biology of Shovelnose catfish, *Arius subrostratus* (Valenciennes, 1840) from Cochin estuary, India, *Int J Fish Aqu Stud*, 5 (5) (2017) 165-17.

41 Patterson K, Fisheries for small pelagic species: an empirical approach to management targets, *Rev Fish Biol Fisher*, 2 (4) (1992) 321-338.