Growth, mortality and stock status of three commercially important catfishes from the River Ganga, India

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Growth, mortality and stock status of three commercially important catfishes from the River Ganga, India

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ABSTRACT

A study was undertaken to determine population parameters and stock status of three commercially important catfishes *viz. Eutropiicthys vacha* (Hamilton, 1822)*, Clupisoma garua* (Hamilton, 1822) and *Ailia coila* (Hamilton, 1822) from middle and lower stretch of the River Ganga. Monthly length and weight data of three species from Patna, Buxar and Bhagalpur was collected for determining population parameters and stock status using standard procedures. The von Bertalanffy growth parameters (VBGF) including the total mortaliy (Z), natural mortality (M) and fishing mortality (F) rates for all three catfishes were analysed and compared with past studies. The calculated E value of the three catfishes was above the level of optimum exploitation (0.5) but was below 0.7 indicating that caution need to be excercised in order to avoid overexploitaton of the fish stocks. Management measures such as reduction of fishing pressure either by limiting number of boats or fishing hours, imposing mesh size regulation to avoid growth overfishing, minimum legal size, declaring closed season or closed area throughout the breeding season of the catfish can be suggested for revival of the fish stocks. Further, studies on the reproductive biology, identification of spawning season and spawning grounds is suggested which will play a pivotal role in the management of stocks of these fishes in the River Ganga.

Keywords: Exploitation rate, FiSAT II, Length frequency, Population dynamics

Introduction

Rivers are considered to be one of the most threatened ecosystems of the world (Sendzimir and Schmutz, 2018) due to multiple anthropogenic and natural stressors triggering higher degree of extinction of freshwater fishes in comparison to other vertebrates (Bruton, 1995; Sarkar *et al*., 2008). River Ganga is the largest river system of India that sustains rich wealth of aquatic fauna including fish. The first known survey of fish fauna in the river Ganga and its tributaries was conducted by Hamilton (1822) who described 269 fish species of which about 34 fish species of Gangetic carps, murrels, featherbacks and large catfishes are known to have high commercial importance (Islam *et al.,* 2006; Singh *et al.,* 2013).

Catfish constitute about one third of the total fish fauna globally (Jayaram, 2009). In River Ganga catfish under the family Bagridae, Siluridae, Sisoridae and Schilbidae exhibit significant commercial importance (Misra,1959; Menon, 1974; Jhingran, 1975) and forms the second most dominant group in terms of total fish landings (Barman, 1994; Das *et al*., 2013) contributing about 21-24% (De, 1999; Sarkar *et al.*, 2012). The three catfish species *Eutropiicthys vacha* (Hamilton, 1822), *Clupisoma garua* (Hamilton, 1822) and *Ailia coilia* (Hamilton, 1822) under the family Ailiidae contribute significantly to the commercial fish landings in the middle and lower stretch of the River Ganga. *E. vacha*, commonly known as 'Batchwa vacha', is a riverine freshwater catfish known for its rich taste, nutritional aspect and high market value (Hasan *et al.*, 2002). The species is listed as 'Endangered' in India (Molur and Walker, 1998). *C. garua* is a bottom and margin dwelling species with high fat content and moderate protein (Jafri *et al.,* 1964; Gupta and Banerjee, 2016) making it commercially valuable. *A. coila* widely known as 'Gangetic Ailia' is a freshwater inhabitant of the River Ganga. It forms an important fishery for the artisanal fishers and was recently listed under 'Near Threatened' category by the IUCN (Ng and Dahanukar, 2011). Though, studies on biology and population parameters of these catfishes are available from other river systems in India (Miyan *et al.*, 2016; Nazir and Khan, 2017; Biswas *et al.*, 2019; Khan and Nazir, 2019), information regarding the growth, mortality and exploitation status of *E. vacha*, *C. garua* and *A. coilia* stocks in the River Ganga is lacking.

In this background, the present study was conducted to estimate the growth, mortality and stock status of *E. vacha*, *C. garua* and *A. coila* from the middle and lower stretch of the River Ganga.

Materials and methods

The study was carried out in Buxar (25º33'50''N, 83º56'28''E), Patna (25º37'06''N, 83º11'50''E) and

Bhagalpur stretch (25º16'27''N; 87º01'12''E) of the River Ganga covering a distance of 470 km in Bihar (Fig. 1). The annual mean water temperature in the study area was 27.4°C±0.14. Samples of three catfish species *E. vacha* (N=1016), *C. garua* (N=819) and *A. coila* (N=924) were identified using the taxonomic keys provided by Jayaram (2009). The fishes were collected randomly every month from the commercial fish landings between April 2017 and September 2020. Effort was also made to record the days of total landings of the three catfish species during the visits to landing centres which was further raised to annual average figures. Inputs from fishermen was included to fill the gap in fish landings during non-sampling days. Similarly, number of active fishing boats were recorded. The total length (TL) of collected fish specimens were measured to the nearest 0.1 mm and the corresponding body weights were measured using a portable digital balance to the nearest 0.01 g. The TL of the fish was grouped into different length class frequency considering the minimum and maximum TL recorded for each species.

The length-weight relationship was calculated using the formula ($W=aL^b$) provided by Le Cren (1951). The von Bertalanffy growth parameters *viz.* asymptotic length (L_∞) and coefficient of growth (K) were estimated using ELEFAN I module of FiSAT II (FAO-ICLARM Stock Assessement Tools) as described by Gayanilo *et al*. (2005). The rate of natural mortality (M) was calculated following Pauly's (1980) empirical formula $\text{Log}_{10}\ M = -0.0066 - 0.279\text{Log}_{10}\ L_\infty + 0.06543\ \text{Log}_{10}\ K + 0.04634\ \text{Log}_{10}\ T$, where T is the average temperature of water in degree celsius. Length converted catch curve method in FiSAT II was employed to determine total mortality rate (Z). Fishing mortality rate (F) was calculated using the formula F = Z - M (Silvestre and Graces, 2004). Length dependent growth performance index (ϕ) was obtained from L_∞ and K as depicted by Pauly and Munro (1984). For determining the recruitment pattern, backward projection of the length-frequency data upon the time axis of the time series sample was obtained (Gayanilo *et al.*, 2005) which re-establishes the recruitment pulses extracted from a successive length-frequency data to estimate the amount of pulses per year along with the comparative strength of each pulse. Virtual population analysis (VPA) was done using length frequency data by the methods outlined by Thomson and Bell (1984) and Gulland (1969). For determining exploitation rate (E) the equation E = F/Z was used.

Results and discussion

Fishery

The catfishes *E. vacha*, *C. garua* and *A. coilia* form an important fishery in the middle and lower stretches of the River Ganga. The combined landing of all the three species was about 3.5 t in the year 2017 which rose to 5.7 t in the year 2018 (Fig. 2). It decreased to 5.3 t in the year 2019 and further decreased to 1.7 t in the year 2020. While decrease in landings of *E. vacha* led to overall decrease in the catfish catch in the year 2019, the sharp decrease of catfish catch in 2020 may be attributed to restriction in fishing activities due to the COVID-19 global pandemic. *C. garua* catch was found consistent throughout the years forming 46% of the total landing. In total, about 336 fishing boats operated monofillament gillnets of mesh sizes ranging from 10 to 35 mm, which was the major gear landing the catfishes. With 196 active boats, Patna had the

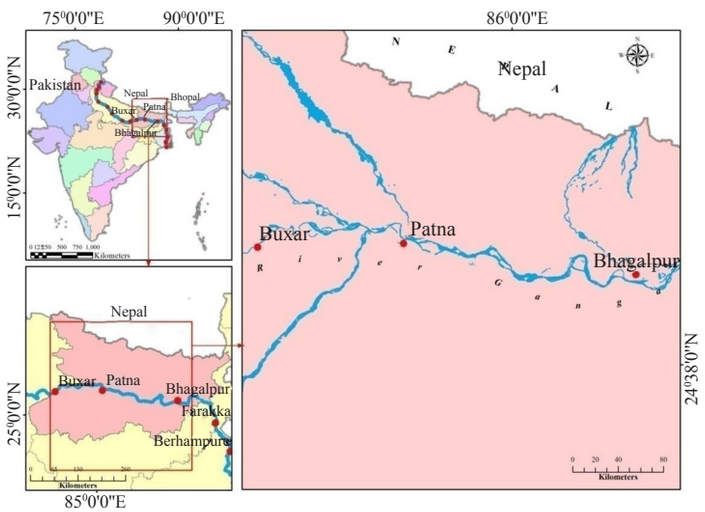

Fig. 1. Sampling points along River Ganga, India

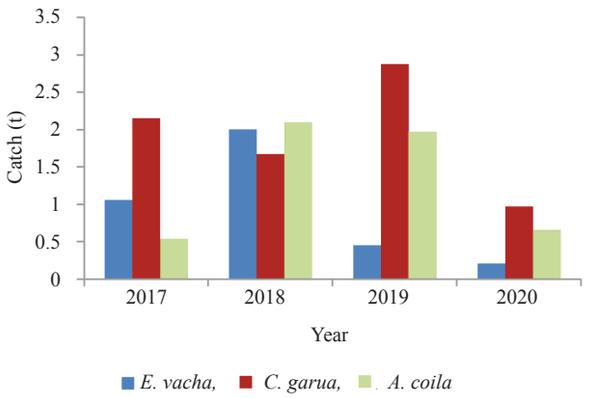

Fig. 2. Annual landings of *E. vacha, C. garua* and *A. coila* from River Ganga during 2017-2020

most number of active fishing boats in the studied stretch followed by Buxar and Bhagalpur with 80 and 60 boats, respectively. Other gears such as hook and line and cast net were also employed but, in meagre numbers.

Eutropiicthys vacha

The TL of the sampled fish ranged from 40 to 315 mm and their corresponding weight ranged from 1.21 to 255.37 g. The length range of 4-7 cm was observed to be the most frequently occurring range (Fig. 3a). Hossain *et al*. (2012) reported that the length at first maturity of male and female *E. vacha* from River Ganga in north-western Bangladesh was 131.5 and 140 mm, respectively. Dominance of young ones in the length range of 40-70 mm in the commercial landings indicated growth overfishing. The estimation of length-weight relation yielded $W = 0.010\ L^{3.03}$ ($R^2 = 0.981$), where b = 3.03 and

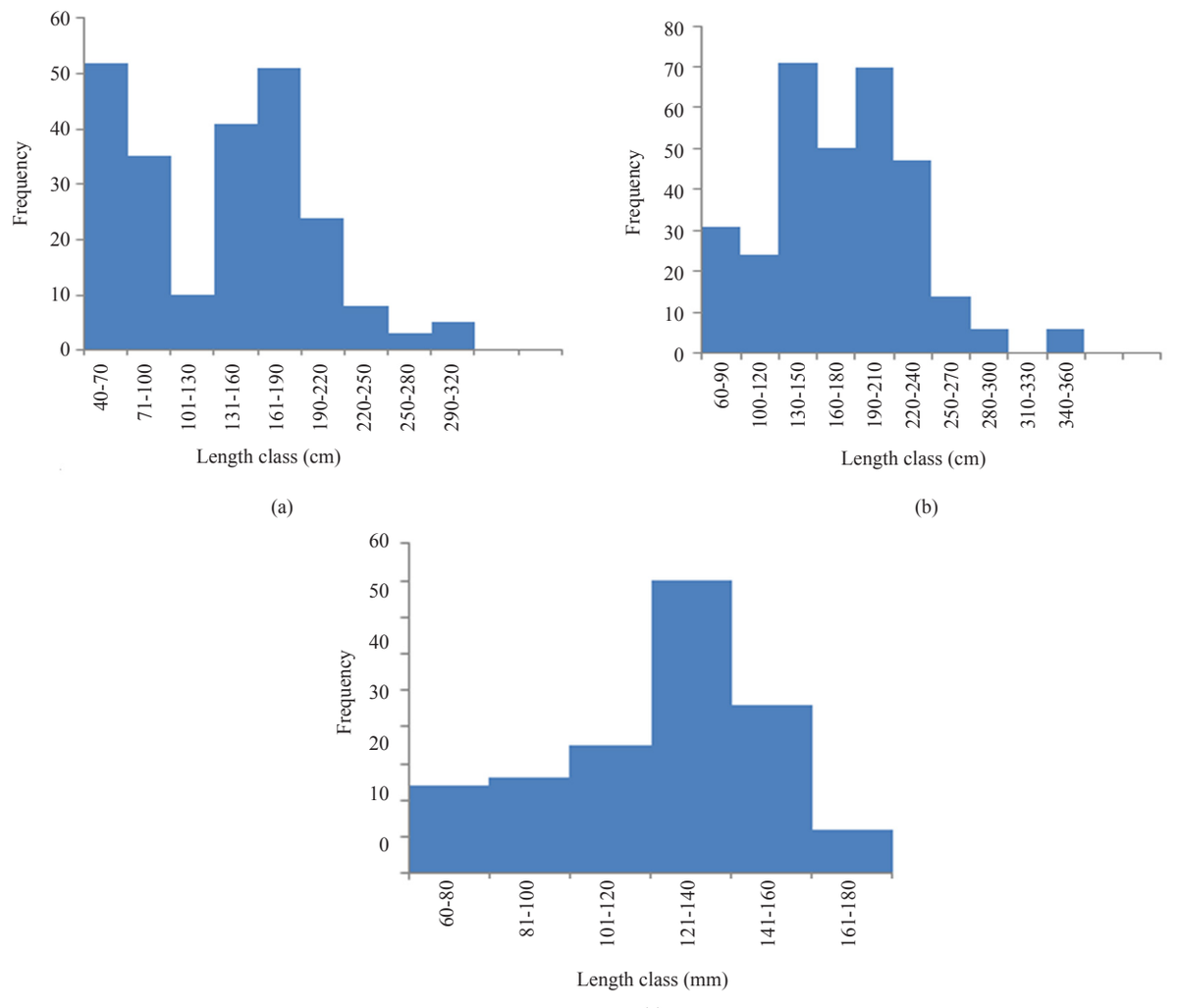

Fig. 3. Length frequency distribution of a. *E. vacha;* b. *C. garua* and c. *A. coila* from River *Ganga* during 2017-2020

a = 0.010 suggesting the growth of fish is almost isometric. The obtained values of von Bertalanffy's growth parameters namely asymptotic length (L_∞) and growth coefficient (K) were 33.6 cm and 0.91 year^{-1}, respectively (Fig. 4a). The estimated total mortality rate (Z), natural mortality rate (M) and fishing mortality rate (F) was 1.89, 0.84 and 1.05, respectively. The estimated growth performance index (ϕ) was 5.30 which is higher than the values estimated by Memon *et al.* (2017) from the Indus river system. The recruitment of *E. vacha* occurs during June-July with a single peak (Fig. 5a) producing 61% of the total recruits. The results of the present study corroborates with Qasim and Qayyum (1961) who reported that the peak breeding season of *E. vacha* is June-September. The findings of length based virtual population analysis (VPA) (Fig. 6a) indicated that juveines of length of 40 mm are being fished frequently. The estimated exploitation rate was found to be 0.55 (Fig. 7a) which was just above the optimum exploitation level for sustainable fisheries (0.5).

Clupisoma garua

The TL of the species varied from 62 to 342 mm (average TL 171.8 mm) and the corresponding weight ranged from 1.27 to 267.53 g. Fishes in the length range of 130 to 150 mm dominated the catch (Fig. 3b). Fishes of TL 6.0 to 9.0 cm observed in the commercial landings indicated growth overfishing. Talwar and Jhingran (1991) reported a maximum length of 1000 mm for *C. garua*. Similarly, Rahaman (1989) and Bhuiyan (1964) observed a maximum size length of 256 and 280 mm for this specimen. Gopesh *et al*. (2020) reported a maximum size of 446 mm from River Ganga at Allahabad. Length-weight relationship determined for the species was $W= 0.09L^{3.12}$ ($R^2 = 0.962$) suggesting the fish growth is almost isometric in the river. The estimates attained for 'b' value in the present study pointed out a similar pattern with previous works of Sani *et al*. (2010) from the rivers Betwa and Gomti; Mortuza and Al-Misned (2015) in River Padma and by Muhammad *et al.* (2017) in River Indus. The VBGF parameters, L_∞ and K of *C. garua* were estimated to be 349.6 mm (TL) and 1.3 year^{-1} respectively which was slightly higher than the L_{max} (Fig. 4b). The annual mortality rates M, Z and F of *C. garua* from River Ganga was estimated to be 1.95, 6.36 and 4.41 respectively. The value of growth performance index (ϕ) was obtained as

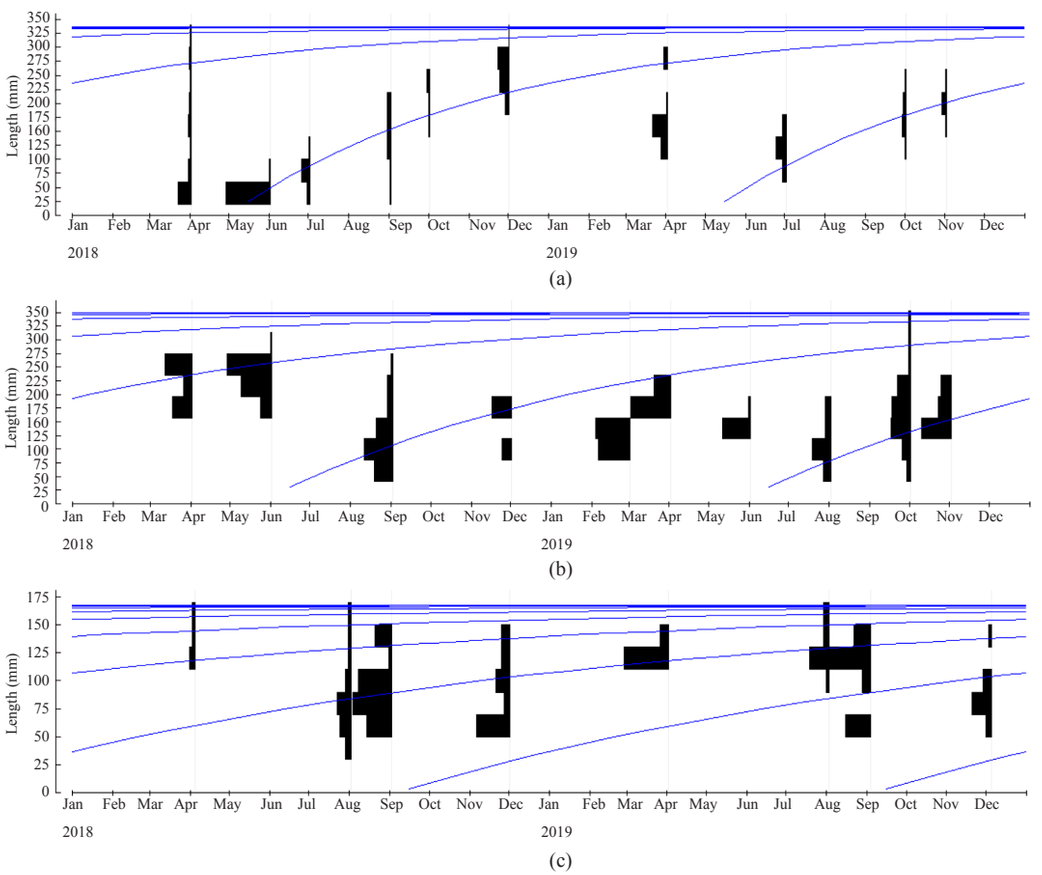

Fig. 4. Growth curve of a. *E vacha*; b. *C. garua* and c. *A. coila* (2017-2020)

5.20 during the present investigation. Continuous pattern of recruitment was observed round the year with two major peaks in March (20%) and April (17.54%) (Fig. 5b). The breeding of *C. garua* in the Gangetic-Brahmaputra riverine system occurs between May-August (Chondar, 1999) which strongly agrees with the present findings. The assessment of length structured virtual population analysis (VPA) revealed that though *C. garua* was being harvested at sizes as small as 60 mm; size group of 130 mm and above contributed maximum to the fishery (Fig. 6b). The estimated exploitation rate (E) was observed to be 0.69 (Fig. 7b) which was higher than the optimum exploitation level (0.5) for sustainable fisheries.

Ailia coilia

The minimum and maximum TL of the species varied from 64 to 174.3 mm and the weight ranged from 1.07 to 25.82 g. The average length recorded during the study was 123.2 mm with 131-140 mm being the dominant size group (Fig. 3c). Talwar and Jhingran (1991) recorded the maximum size of 300 mm with a common size of 180 mm. Hossain *et al*. (2019) reported 130 mm as the maximum length from the River Ganges, whereas Gogoi *et al*. (2019) observed 161 mm from Brahmaputra River. The length-weight relationship was estimated to be $W= 0.080 L^{3.13}$ ($R^2 = 0.919$) and showed a positive allometric growth for the species in the river. The VBGF growth parameters for the species were estimated as L_∞ = 189 mm and K = 0.68 $year^{-1}$ respectively (Fig. 4c). According to Pauly's (1983) length converted catch curve method, the natural mortality (M) and total mortality (Z) were estimated at 0.81 and 2.65 y^{-1} respectively. The analysis further revealed the rate of fishing mortality (F) as 1.84 y^{-1} and exploitation rate (E) as 0.69 indicating exploitation of the stock above optimum level. A growth coefficient (K) value of 0.87 y^{-1} has been observed by Gogoi *et al*. (2021) from the River Brahmaputra indicating a faster approach rate towards the asymptotic length. Likewise, the growth performance index (ϕ) was calculated to be 4.38. The species recruitment pattern suggested two peaks in June (17.07%) and August (15.13%) (Fig. 5c). Length structured VPA of the species suggested steady natural loss from 6.0 to 10.0 cm (Fig. 6c). Subsequently, the highest value of fishing mortality (0.87 y^{-1}) was observed parallel to the peak length at 120 mm.

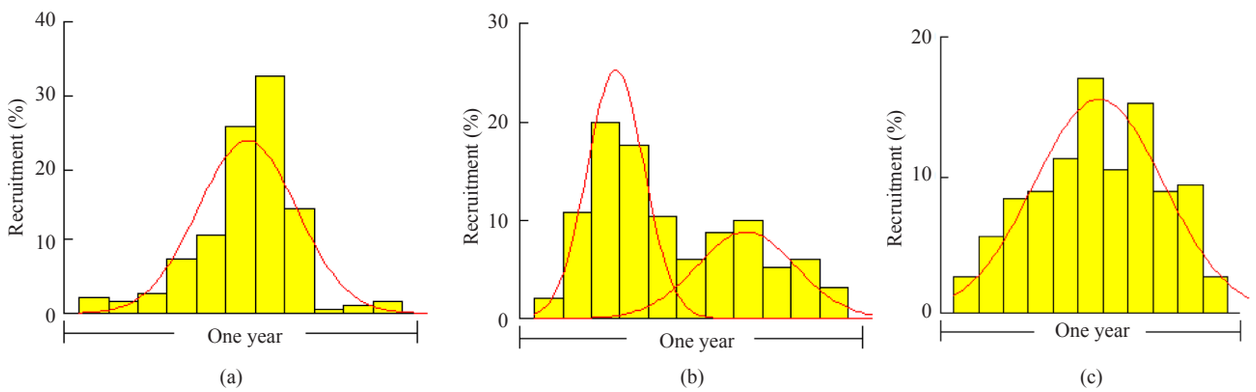

Fig. 5. Recruitment pattern of a. *E. vacha*; b. *C. garua* and c. *A. coila* (2017-2020)

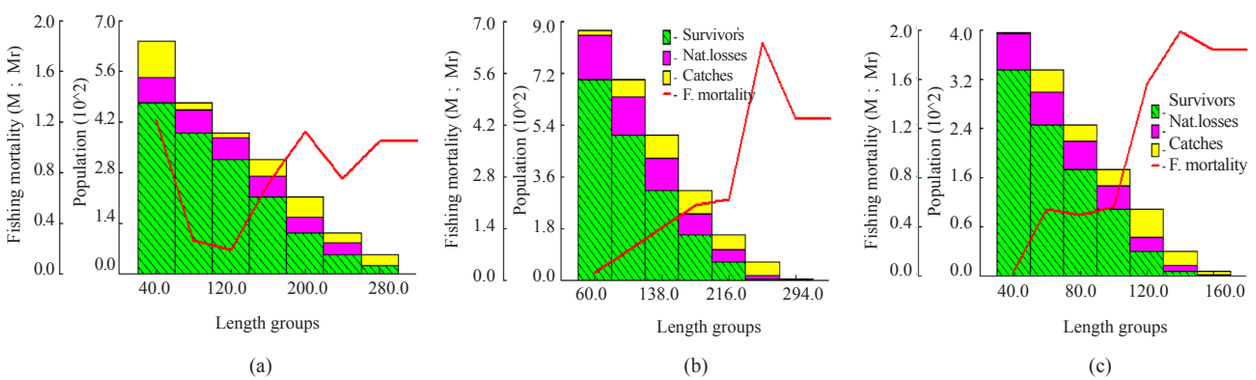

Fig. 6. Length structured virtual population analysis (VPA) of a. *E. vacha*, b. *C. garua* and c. *A. coila* (2017-2020)

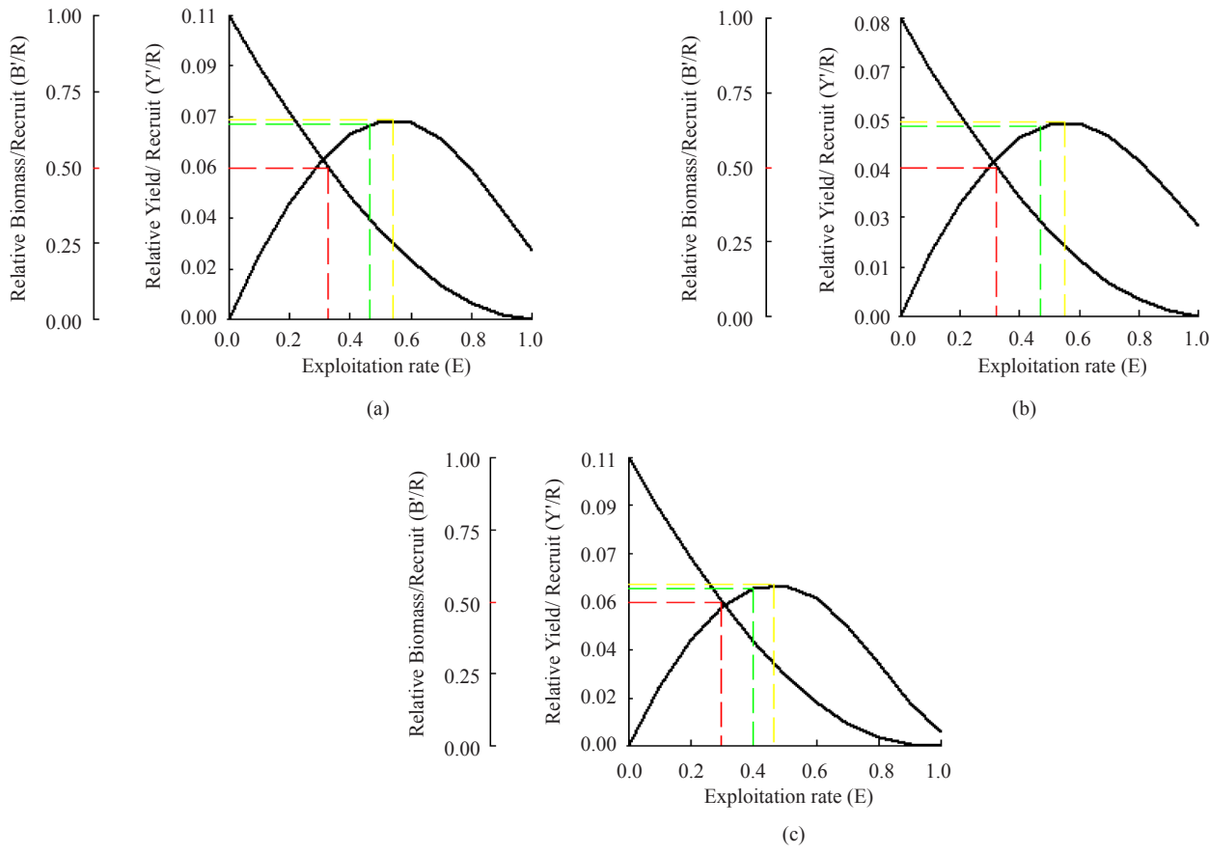

Fig. 7. Yield per recruit assessment of a. *E. vacha* b. *C. garua* and c. *A. coila* (2017-2020)

The present study documenting the population parameters and stock status of three commercially important catfish species in Ganga River is the first of its kind. The estimated population parameters of the three catfishes are presented in Table 1.The growth estimates of the three species (*E. vacha*, *C. garua* and *A. coila*) differed from the values reported by Ahmed and Mostafa (2003), Memon *et al*. (2017) and Gogoi *et al*. (2021) as those studies are from different river sytems. The value of asymptotic length calculated for *E.vacha* was found in agreement with the study conducted by Memon *et al*. (2017) from River Indus. In case of *E. vacha*, the data revealed maximum fishing mortality (1.21) in the size group range of 40 mm indicating juvenile loss due to the use of small meshed fishing gear. The findings of the asymptotic length of *C .garua* (L_∞= 280 mm) from River Jamuna, Bangladesh (Ahmed and Mostafa, 2003) varied greatly from the present study. Afser (1992) during a study

Table 1. Population parameters of *E. vacha*, *C. garua* and *A. coila* estimated in the present study and during earlier studies

Population parameters	*E. vacha*		*C. garua*		*A. coilia*	
	Present study	Memon *et al*. (2017)	Present study	Ahmed and Mostafa (2003)	Present study	Gogoi *et al*. (2021)
Length range (mm)	40-315	100-340	62-342	-	64-174.3	63-166
Intercept'a'	0.010	0.016	0.09	0.083	0.080	-
Slope'b'	3.03	2.692	3.12	2.325	3.13	-
L_∞ (mm)	336	357	349	280	189	268
K y^{-1}	0.91	0.36	1.30	0.79	0.68	0.87
ϕ	5.30	2.66	5.20	2.79	4.38	4.79
M y^{-1}	0.84	0.76	1.95	1.53	0.81	1.63
F y^{-1}	1.05	0.33	4.41	0.80	1.84	4.13
Z y^{-1}	1.89	1.09	6.36	2.33	2.65	5.76
E	0.55	0.30	0.69	0.34	0.69	0.72

in River Ganga at Bihar stretch has shown that *C. garua* grows rapidly in '0' year, first year and second year during which the length increases six fold, two fold and two-third fold, respectively during their existence.

Variations was also observed in the case of *A.coila* (L_∞= 268 mm) from the River Brahmaputra in Assam, India (Gogoi *et al.*, 2021) compared to the one from the River Ganga. Fishes being poikilotherms shows responses to changing temperatures across different ecosystems resulting in alterations in growth and body size (Daufresne *et al*., 2009). A higher value of growth coefficient (K) was found for all the catfishes in River Ganga compared to previously reported studies (Ahmed and Mostafa, 2003; Memon *et al*., 2017; Gogoi *et al*., 2021) from other river systems. The growth performance index reveals the growth rate of a fish in a unit length (Munro and Pauly, 1983). The estimation of growth performance indices (ϕ) of *E.vacha* and *C. garua* was higher from the rivers like Indus and Jamuna, respectively. This suggests better adaptations of the population to the environment (Baijot and Moreau, 1997; Ragonese *et al.*, 2012). On the other hand, an exploitation rate determines the state of exploitation of a stock. Gulland (1971) opined that the optimal rate of exploitation of a stock (E) is assumed at the value (E_{opt}= 0.5) equal to natural mortality for optimising the sustainable yield. The calculated E value of the three species of catfishes was above the level of optimum exploitation (0.5) but was below 0.7 indicating that caution need to be excercised in order to avoid overexploitaton of the fish stocks.

Catfishes are preferred by the economically weaker section of the society owing to their affordability. Additionally, they are more sought after due to their ability to survive longer outside water ensuring their freshness commading higher price thus, making them desirable fish for both fishers and consumers leading to over-exploitation. Stressors such as pollution, habitat degradation, flow modification and introduction of exotic fish species in the riverine ecosystem (Argent *et al*., 2003; Sarkar *et al*., 2017) exert additional pressure on these fish stocks wedging their revival. Of the various fisheries management measures, input control is an effective way of reducing the pressure on fished stocks. This may be attained in various ways with focus to reduce the fishing effort such as restricting the entry of new fishing boats, reducing the number of existing fishing boats, restricting the fishing hours, restricting the gear sizes that the fishing boat carries and closing areas for fishing. Presently, 336 fishing boats are contributing to harvest of *E. vacha*, *C. garua* and *A. coilia* to the tune of 0.93, 1.91 and 1.31 t annually (four year average). The number of fishing boats can be reduced anywhere between 266-277 to reduce the fish catch by 20%. Major bottleneck in this method is who should be allowed to fish (Morison, 2004). The mesh size of the gill nets presently in use range from 10 to 35 mm. Increasing the minimum mesh size from 10 mm to atleast 20 mm will have direct impact on the size of capture helping in reduction of growth overfishing. Further, determining and legalising minimum size of landing (MLS) is an effective measure to counter the growth overfishing in fisheries management (Hill, 1990). The objective in doing so is to identify the length at first maturity of the fish and designating length above the L_m as MLS for the particular species with an intention to give the species a fair chance to breed atleast once before it is caught. Information on the length at first maturity of the three catfish species under study from the River Ganga are not available. However, in the absence of information on L_m of three catfish species from the River Ganga, such information available from other ecosystems can be used to determine MLS as a precautionary approach of management (Hilborn *et al*., 2001). Under the present scenario, MLS of 160 and 190 mm may be a safe bet for *E. vacha* and *C. garua*, respectively based on estimations of L_m for *E. vacha* at 140 mm (Hossain *et al*., 2012) and for *C. garua* at 171 mm (Hasan *et al*., 2020). Extensive literature survey indicates that studies on reproductive biology of *A. coilia* are lacking. Identifying the spawning season and declaring that as closed season and identifying breeding and spawning areas and declaring them as seasonally closed areas for fishing can help in reviving the fish stocks.

The study indicates that all the three catfish species are exploited above optimum level. These stocks may deplete further, if not managed and may have negative implications on the fishers who are dependent on these resources. This calls for implementation of management measures for the revival of fish stocks and their harvest at sustainable levels. Further, studies on the reproductive biology, identification of spawning season and spawning grounds should be given priority which will play a pivotal role in the management of stocks of these fishes in the River Ganga.

Acknowledgements

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