

Research Article

## Age and growth analysis of the fish *Mastacembelus armatus* (Lacepede) from River Nayar, Garhwal Himalaya, Uttarakhand

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### Abstract

The ability to age fish accurately is essential in understanding the dynamics of fish population. Age and growth determination in *Mastacembelus armatus* was assessed by the scale method which was verified by the length-frequency distribution method. The scales were small, elongated and the focus was shifted slightly upish from the centre. The fish length and scale radius relationship was found linear (Scale radius = 6.974 + 0.452 Fish length;  $r = 0.9746$ ) and authenticated the age analysis. Back calculation method was used to find out the size of fish at annulus formation, which confirmed four age rings in *M. armatus* at the size of 14.07±0.92, 26.05±4.99, 37.96± 2.59 and 48.48±6.06 cm respectively. First two age rings were observed in the fish length group 30-40 cm, the third ring was observed in 40-50 cm and the fourth ring in 50-60 cm length group. The finding was dully validated by length-frequency distribution method. The growth annual increment (h) of *M. armatus* shows that the length increment was 14.07, 13.32, 11.91 and 10.52 cm during 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> year respectively. It shows that the fish grows continuously during its entire life period. The average growth ( $\phi$  h) was observed as 12.12 cm. annually. The assessment of age and growth rate of fish is a prerequisite to generate the information on recruitment, longevity and fluctuations in fishery caused by various year classes which is an important tool for rational exploitation of fish stock.

**Keywords:** Age and Growth, Scale, Length Frequency, *Mastacembelus armatus*, Nayar

## INTRODUCTION

Investigations on the basic biological features of the fish in its natural habitat help in its conservation and management in controlled aquaculture system. It includes knowledge of maturation process, spawning season and frequency, reproductive capacity, food preference and feeding behaviour and age, growth pattern, size and age at first maturity, etc. Apart from this population dynamics study also helps in validation of age in fishes after mathematical calculations from scales, vertebrae, otolith and other suitable hard structures (Bahuguna and Dobriyal (2019).

The accuracy in age determination depends upon proper identification of age rings scientifically verified

through either known age method or by the length-frequency distribution method. Under intensive culture, it is possible to have an idea of known age, but in wild nature, it is bit difficult, but for species which breed once a year it becomes easy due to the clustering of fish of the same size around a particular fish length. According to Francis (1990), an accurate and reliable technique to age fish is an essential requirement for assessing the health of a population.

Age determination of fish from the hard skeletal structures (scales, otoliths, vertebra, fin spines, fin rays, etc.) is a matter of routine with most exploited fish stocks. Peterson (1892) proposed a simple but significant method of age determination by length-frequency distribution. Scales, otoliths, vertebrae, operculum and

fin spine are the most common methods employed these days for ageing. According to Oliveria (1996) and Neilson et al., (2003), the direct observational method which accounts capturing, releasing and recapturing the fish in a controlled environment is also a valid method for ageing the fish.

However, counting annual rings is open to many uncertainties (Dobriyal and Singh, 1990). Important contributors to the study of age and growth rate of fish during recent years are Johal and Tondon (1987, 1992), Dobriyal (1988), Vasudevappa and James (1988), Dobriyal and Singh (1990), Johal and Kingra (1992), Tandon et al. (1993), Tandon and Johal (1996), Bisht et al., (1996), Rawat and Nautiyal (1996), Johal et al. (2000), Dobriyal and Negi (2001), Dobriyal et al. (2004), Uniyal et al., (2005), Pathani and Joshi (2006), Bahuguna and Balodi (2015) and Singh et al. (2017). The present study was aimed to explore the longevity and size of fish at different ages in a very important fish species *Mastacembelus armatus*. This information will be very helpful in its conservation and management.

**MATERIALS AND METHODS**

**Study area**

The Nayar Basin lies in Pauri Garhwal district of Uttarakhand Himalaya bounded by Tehri in North, Chamoli in East, Almora in South East, Nanital in south and Dehradun in West. The Nayar basin is unique in its features like horn peaks, serrated creats hanging valleys, torrential rapids and waterfalls. In the central Himalayas most of the rivers are fed by snowmelt, (Yamana, Bhagirathi, Alaknanda, Pinder, Dhauli, Ganga, Mandakinietc), while the river like Ramganaga, Kosi and Nayar are exclusively spring -feed Rivers.

The River Nayar exploited for present study originates from the Dhoodhatoli Mountain at the elevations 3116 masl. The DhoodhatoliKhatil – anticline divides the basin of the Eastern Nayar and Western Nayar which make the confluence at NaugaunKamand near Satpuli at 620 masl. After confluence, the river enters in a gorge from Marora to Vyasghat, where it finally confluences with the river Ganga at 447masl (Fig. 1). The western Nayar valley presents a unique set of ecological characteristics over a complex variety of systems that incorporate forests, meadows, grasslands, marshes and rivers, as well as wildlife, geology and several other Phyto-geographically distinctive peculiarities. The occurrence of diverse topographical and climatic factors has resulted in the remarkable biodiversity of the river as a result of which flora also correspondingly differs over its different parts. The authors were granted permission to work on the biology of this particular species by the Department of Forest, Govt of Uttarakhand. Thus, there is no issue of Animal ethics.

**Methodology**

Scale method was used for age determination in *M. armatus*, which was validated by the method of length-frequency distribution. For length frequency distribution, the fish were arranged in different length groups, season-wise and finally an assessment was made based on the facts that the fish of same year classes formed a bunching at a proper length group (Peterson, 1892). The reason for taking season-wise data was due to the fact that viewing the population dynamics of this particular species only limited numbers of specimens were captured.

**Scale method**

About ten to fifteen scales were taken from below the dorsal fin in each selected specimen, cleaned and stored. Out of these, the common five scales of each fish were later selected and further cleared in 1 % KOH solution. The fish length and scale radius relationship was traced out to know whether there was a constant increment in growth or not. It was traced out with the help of regression analysis, viz.

$$Y = a + bx, \dots\dots\dots Eq.1$$

Where:

X = fish length (an independent variable)

Y = scale radius (a dependent variable), a and b = constants (intercept and slope)

Growth rings were very carefully identified as in many occasion, false rings were also observed (Tandon and Johal, 1996). The period of growth ring formation was recorded as the highest percentage of the minimum width in the terminal zone of the scales. Based on the time between the formations of two rings, the frequency was assessed and the age was estimated. Length frequency distribution for different seasons was obtained by arranging the data at 10 cm class intervals and recording the mode indicative of different age groups.

**Back calculation for scale**

The growth rate of fish was calculated by back-calculation method as suggested by Lea (1910). The formulae read as:

$$ln = \frac{Sn}{SR} \times l \dots\dots\dots Eq. 2$$

where - ln= length of fish when annulus n formed,

Sn= scale radius of annulus n at ln

l= length of fish when a scale sample was obtained,

SR= Scale radius

The growth parameters of *M. armatus* were calculated as suggested by Tandon and Johal (1996) as follows:

**Specific rate of linear growth:**

$$CI = \frac{ln - ln-1}{ln-1} \times 100 \dots\dots\dots Eq.3$$

**Index of species average size:**

$$\phi h = \hat{a} nj + a \quad h \dots\dots\dots Eq.4$$

$$h = l / nj + a$$

**Growth characteristics:**

$$Cth = \log ln - \log ln-1 / 0.4343 \times ln-1 \quad . Eq.5$$

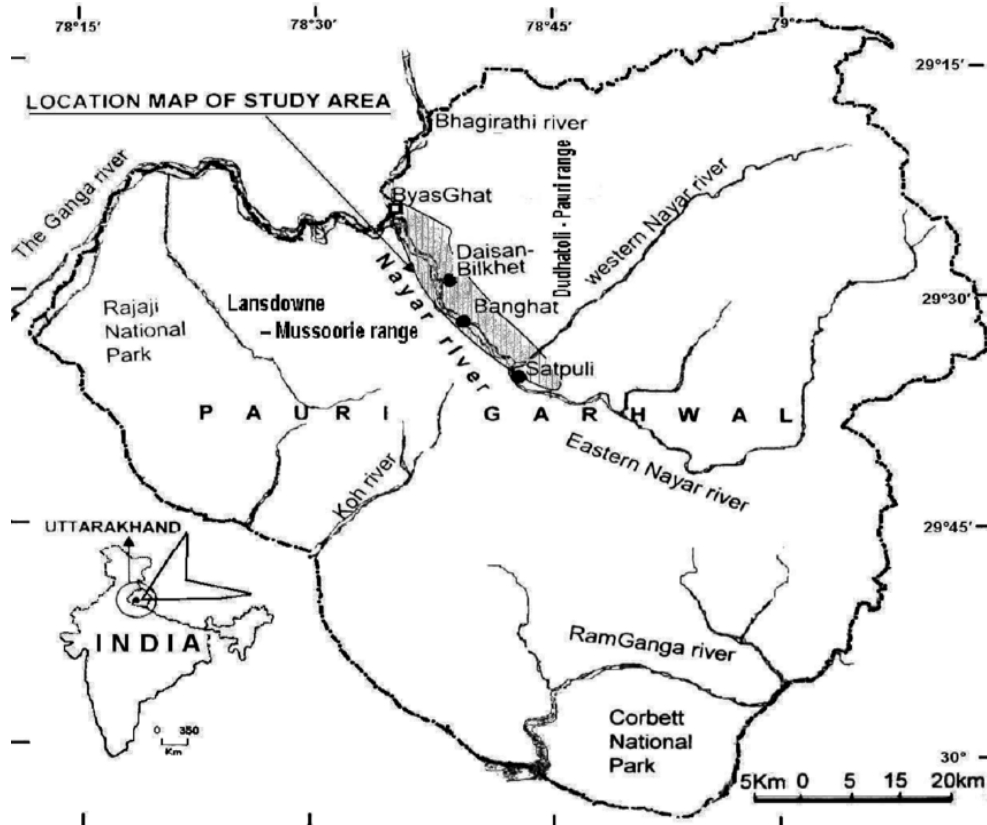


Fig. 1. Map of Pauri- Garhwal (Uttarakhand) showing drainage of river Nayar along with its parent streams, the Western-Nayar and the Eastern Nayar.

**Growth constant**

$$Cl_t = \log \ln - \log \ln_{-1} / 0.4343 \times t_2 + t_1/2 \dots\dots Eq.6$$

Where  $\ln$  and  $\ln_{-1}$  are mean computed total length of fish at ultimate and penultimate year of life.

$J$  = Juvenile,  $a$  = adults,  $n$  = number,  $h$  = absolute increment in length,  $t_2 + t_1$  are the time intervals between - ultimate and penultimate age classes and the value of  $t_2 + t_1 / 2$  is equal to 1.5

**RESULTS**

The present study observed that the scales of *M. armatus* were quite small with a maximum size of 2.1 mm and were elongated antero- posteriorly. The Focus was shifted towards the anterior side with fewer margins in comparison to its lateral side. Rings were clearly identified as breaking and widening in circuli. On some occasions, false ring was also observed, but it was distinct being not in a uniform manner.

Fish length and scale radius was found linear (Fig 2) and authenticated the age analysis. The relationship can be expressed as:

$$\text{Scale radius} = 6.974 + 0.452 \text{ Fish length} \quad (r = 0.9746, r^2 = 0.95)$$

For age calculation, scale radius was measured along with the distance of each ring from the focus. This data is presented in Table 1. It showed that no ring was observed in fishes with length group 20-30 cm. Fish below

the size of 20 cm could not be noticed. Two age rings were noticed in the fish ranging between 30 – 40 cm, however, three age rings were noticed in the fish measuring from 40 – 50 cm. Maximum four rings were recorded in the fish ranging from 50-60 cm (Fig. 3-6) The data observed at which fish length the rings were formed estimated by back calculation method is presented in Table 2.

It was observed that the average fish length at the time of 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> ring was  $14.07 \pm 0.92$ ,  $26.05 \pm 4.99$ ,  $37.96 \pm 2.59$  and  $48.48 \pm 6.06$  cm respectively. The season and reason of ring formation was assessed by the analysis of minimum width in ring and

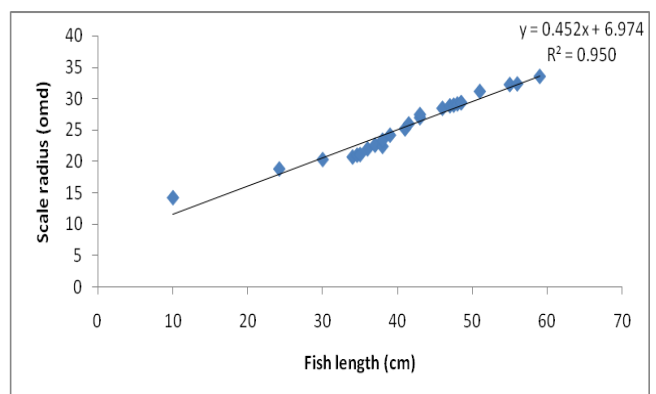


Fig. 2. Regression between fish length and scale radius in *M. armatus*.



Fig. 3. Scale of fish with one annuli.



Fig.4. Scale of fish with two annuli.



Fig. 5. Scale of fish with three annuli.



Fig.6. Scale of fish with four annuli.

Table 1. Data on the age and growth of *M. armatus* in different length groups.

Length Groups (cm)	Average Fish length (cm)	S-1 (omd)	S-2 (omd)	S-3 (omd)	S-4 (omd)
20-30	24±0.0	-	-	-	-
30-40	35.8±0.837	7.6±2.3	12.6±2.08	-	-
40-50	44.07±3.02	8.57±1.62	17.42±2.82	24.0±4.06	-
50-60	55.0±2.83	9.0±1.41	22.5±0.71	28.0±2.83	39.5±0.71

S-1 (Scale radius when 1<sup>st</sup> ring formed), S-2 (Scale radius when 2<sup>nd</sup> ring formed), S-3 (Scale radius when 3<sup>rd</sup> ring formed), S-4 (Scale radius when 4<sup>th</sup> ring formed)

terminal zone of scale. The data presented in Fig. 7 indicated that the ring was formed during monsoon season and the probable reason being growth check due to breeding pressure and also the disturbed weather due to flash flood after rains.

Growth parameters of the fish calculated, as suggested by Tandon and Johal (1996) are presented in Table 3. The age calculated by scale method was confirmed by the length-frequency distribution method (Peterson's methods). The length-frequency polygons are presented in Fig. 8. After micro-level examination, it was observed that the fish attained a length of 15, 25, 35, and 45 cm during first, second, third and fourth year respectively.

**DISCUSSION**

The ability to age fish accurately is essential in understanding the dynamics of the fish population. It is not only a basic scientific research but also gives us an

idea of its harvestable size (Tandon and Johal, 1996). In fish farms where fish are segregated yearly and stocked in year wise stocking ponds, the actual size range as per age class can be estimated, and this is called "Known age method". This method is time-consuming and can be applied only in fish culture. However, it is used for confirmation of age calculated by

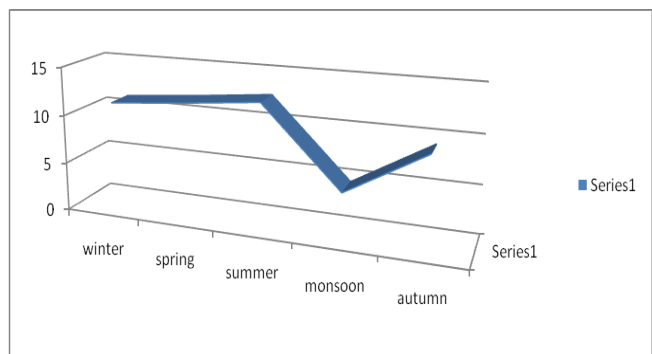
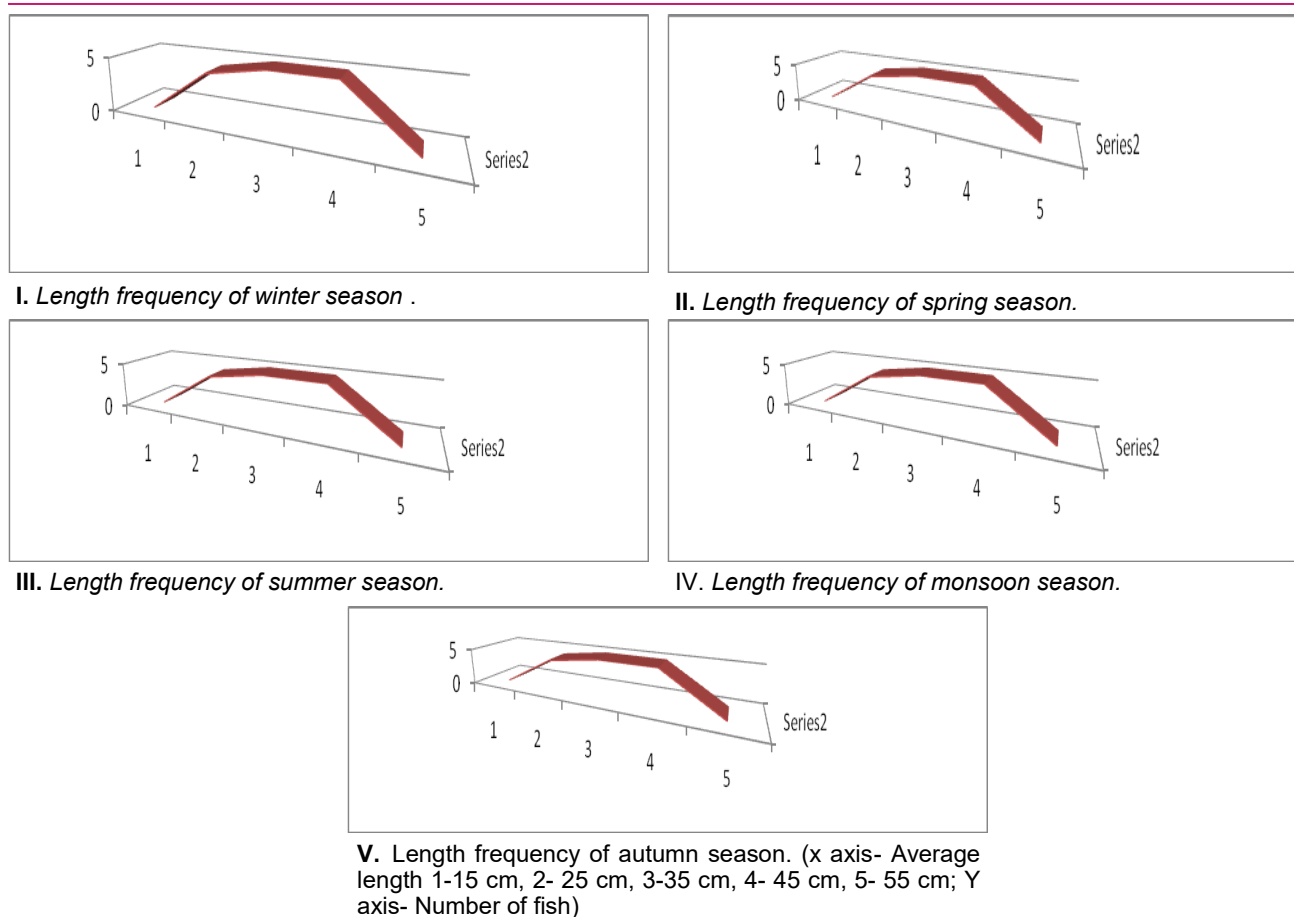


Fig. 7. Minimum width in terminal zone (omd) on scales of *M. armatus* showing seasons of ring formation.



**Fig. 8.** Length Frequency distribution of *M. armatus* showing age group congregation during different seasons in Nayar River.

**Table 2.** Back calculated length of *M. armatus* based on age class.

Length Groups (cm)	Fish length (cm)	L-1 (cm)	L-2 (cm)	L-3 (cm)	L-4 (cm)
20-30	-	-	-	-	-
30-40	35.8±0.837	12.48±3.82	20.4±3.5	-	-
40-50	44.07±3.02	13.75±2.69	27.89±4.66	36.13±4.18	-
50-60	55.0±2.83	15.97±2.21	29.86±1.78	39.8±2.99	48.48±6.06
Average value	44.96±9.63	14.07±0.92	26.05±4.99	37.96±2.59	48.48±6.06
"h" Annual increment		14.07	11.98	11.91	10.52

L-1 (Fish length when 1<sup>st</sup> ring formed), L-2 (Fish length when 2<sup>nd</sup> ring formed), L-3 (Fish length when 3<sup>rd</sup> ring formed), L-4 (Fish length when 4<sup>th</sup> ring formed)

other methods. Another method of age determination is TCRC which means tagging, clipping, release and capture again (Pine *et al.*, 2003). This method is applicable in fish capture, but it is costly and time-consuming. Fish biologists unanimously agree that best and reliable method of ageing fish is counting annuli (growth ring) on the hard skeletal parts of fish, viz., scales, vertebrae, operculum, spines and otoliths, which are formed as a result of irregular growth and metabolism (Jhingran, 1959; Tandon and Johal, 1996; Dobriyal and Singh, 1990).

During the present investigation on *M. armatus*, the

scales were observed to be small in size, slightly elongated on the anterior-posterior face and the focus was recorded to be shifted slightly uppish from the middle. Radius and annuli were distinct and breaking and widening in curculi were identified as growth rings (Figs. 3 -6). Some time few larval rings were also observed during present investigation which were neglected. These rings were termed as "Zero ring" by Tandon and Johal (1996). In the present study regression analysis was made between fish length and scale radius, which was observed to be linear and confirms the justification of age determination by this method.

**Table 3.** Summary of growth parameters of *M. Armatus*.

Parameters	Years of life (Age Classes)			
	1	2	3	4
$L_n$ (Cm)	14.07	26.05	37.96	48.48
h (cm)	14.07	11.98	11.91	10.52
$\phi$ h (cm) (Average)			12.12	
$C_i$	85.14		45.71	27.71
$C_{it}$	1.07		0.564	0.366
Average $C_{it}$			0.667	
$C_{th}$	9.115		9.810	9.28
Average $C_{th}$			0.667	

$L_n$  = length of fish at the time of n ring formation, h = length increment every year,  $\phi$  h = average length increment,  $C_i$  = specific rate of linear growth,  $C_{it}$  = Growth constant and  $C_{th}$  = growth characteristics

Johal and Tondon (1987) while working on *C. mrigala*, Johal and Kingra (1992) on *Catla catla*, Bisht et al. (1996) on *S. plagiosomus*, Uniyal et al. (2005) on *Tor chelynooides* and Bahuguna and Dobriyal (2019) on *Puntius conchoniuis*, found a linear relationship with a high degree of correlation between total length and scale radius length.

Back calculation method used for calculation of size of fish at different age ring formation indicated that four age rings were formed in *M. armatus* at the size of  $14.07 \pm 0.92$ ,  $26.05 \pm 4.99$ ,  $37.96 \pm 2.59$  and  $48.48 \pm 6.06$  cm respectively. This observation was confirmed by the method of length frequency distribution method on the basis of which the age was calculated as 15, 25, 35, and 45 cm during first, second, third and fourth year respectively. Lagler et al. (1977) suggested that the length-frequency method is based on the expectancy that the frequency analysis of a species of any one age group collected on the same data will show variations around the mean length according to normal distribution. Thus, there will be clumping of fish of successive ages at successive length when sampled at randomly.

It is essential to know the time or season of ring formation and the causes responsible for it. In the present investigation, it was observed that age ring in *M. armatus* was formed during monsoon season when the ring was very close to scale terminus. This is called analysis of minimum width in the terminal zone. The reason can be assumed that firstly the ecological disturbance due to flash flood after rain reduces the availability of food in nature. Secondly this is the time when fish is gravid and filled with ova or mature testes. This physiological condition doesn't allow fish to feed. Hence stress causes growth check and annuli are formed.

Different researchers have opined their experiences on the causes of ring formation. Kesteven (1942) stated that feeding ceases for a period of breeding which may cause annulus formation in *Mugil dobula*. Chacko and Krishnamuraty (1950) discussed the significance of growth ring on the scale in *Hilsa ilisa* of Godavari and

stated that there was a period of starvation concurrent with the spawning act, resulting in the ring on the scale. Seshappa and Bhimachar (1951) were of the opinion that the formation of annuli on scales in *Cynoglossus semifarciatus* and *M. parsia* respectively was due to the non-availability of food during the rainy season an account of disturbance of benthic fauna which forms the fish food. Pillay (1954) observed the upwelling of bottom flora from the flood caused reduce feeding in *Mugil tade* and the consequent growth checks. Sarojini (1957) in *M. parsia* and Jhingran (1959) in *Cirrhinus mrigala* observed that the non-availability of food was a probable factor causing annulus formation on scales.

Several workers from India and abroad are of the opinion that the variation in temperature (Holcik, 1967) and spawning (Van Oosten, 1937; Natrajan and Jhingran, 1963; Linfield, 1979; Dobriyal et al., 2004) are the important causative factor responsible for annulus formation. Kohli and Goswami (1989) while working on the pectoral spine of *H. Fossilis*, expressed that the annual ring was formed in May-June, which is the spawning period of fish in Assam. He further stated that the formation of growth rings could be attributed to the cumulative effect of "nutrition and spawning". Pathani (1981) explained the cause of ring formation in mah-seer (*Tor putitora*) as the stress of low temperatures. Dobriyal and Singh (1990) in *Barilius bendelisis* also identified the growth rings as spawning marks. Bahuguna and Dobriyal (2019) who studied the age determination of *Puntius conchoniuis* also explained that spawning stress is responsible for ring formation.

The growth annual increment (h) of *M. armatus* showed that the length increment was 14.07, 13.32, 11.91 and 10.52 cm during 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> year respectively. It showed that the fish grew continuously during its entire life span of 4<sup>+</sup> years. The average growth ( $\phi$  h) was observed as 12.12 cm. The specific rate of linear growth ( $C_i$ ), between first and second year was noticed to be 104.6, second and third year 45.71 and in between third and fourth year as 27.71. The value of growth characteristics was ( $C_{th}$ ) observed as 9.4 on average

with continuous growth throughout life. The growth constant (CI) was observed as 0.667 in an average, which was a little high in the first year (1.07) but low in coming years.

## Conclusion

The present study is significant in exploring the longevity of fish and its growth pattern with increasing age. Regression analysis showing a straight line between fish size and scale radius is an indicator of constant growth in both parameters and hence validates the present study. Growing small size fish were not available in the entire course of study as field observations indicated that fish spawns deep inside under rocks and boulders during monsoon season. On the basis of scale study and its length-frequency distribution in nature, it was concluded that the fish attains a size of approximately 14 cm in the first year, 26 cm in the second year, 37 cm in the third year and 48 cm in the fourth year. The data generated in this study will be of great help for the conservation and management of this species in its natural or artificial habitat in future.

## Conflict of interest

The authors declare that they have no conflict of interest.

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