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Journal of Threatened Taxa

Open Access

10.11609/jott.2024.16.10.25951-26062
www.threatenedtaxa.org

26 October 2024 (Online & Print)
16(10): 25951–26062
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

Srivari Illam, No. 61, Karthik Nagar, 10th Street, Saravanampatty, Coimbatore, Tamil Nadu 641006, India
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continued on the back inside cover

Cover: A digital art of water birds of Noyyal River and its wetlands in Coimbatore District by Megha A. Kashyap.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 October 2024 | 16(10): 25979–25989

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.9051.16.10.25979-25989

#9051 | Received 30 March 2024 | Final received 13 October 2024 | Finally accepted 16 October 2024

ARTICLE

Age structure of carp and catfish catch as a tool to assess ecological health of fished stocks from the Ganga River system with special reference to Mahseer *Tor tor* (Hamilton, 1822)

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Abstract: In the 20th centuary, the economically important carp species *Labeo rohita, Tor tor,* & *Labeo calbasu* and the catfishes *Rita rita* & *Bagarius bagarius* contributed substantially to the total fish catch from the Ganga River system in India. Samples were recorded between December 2003 and June 2004 from fish landing centers in the Ken, Paisuni, and Tons rivers for *L. rohita, T. tor* and *L. calbasu*. *Rita rita* and *B. bagarius* were sampled between September 2001 and September 2003 in the Ganga River system. The data were used to evaluate the growth and age structures of fish populations. Age classes varied 0+–5+ for *L. rohita* in the Ken & Paisuni rivers and 0+–8+ in the Tons River. For *T. tor*, the age classes varied 1+–6+ in the Ken & Paisuni rivers and 1+–8+ in the Tons. Age classes of *L. calbasu* varied 1+–6+ in the Ken River, 1+–5+ in the Paisuni River, and 1+–7+ in the Tons. In the Ganga River, age classes of *R. rita* & *B. bagarius* varied 0+–7+ and 0+–6+, respectively. The *L. rohita,* age pyramid showed a tendency for bell shape in Ken River, base tends to be broader through bell shape in Paisuni River, and bell-shaped age pyramid was slightly distorted in Tons River. In case of *T. tor*, tendency for bell shape in Ken River and bell-shaped age pyramid in Paisun River & Tons River were obtained. In case of *L. calbasu*, heavy bottom shaped age pyramid was recorded in Ken and Paisuni rivers, while base tends to be broader in the Tons River. Bell shaped age pyramid was recorded for *B. bagarius* in the Ganga River while heavy bottom shape for *R. rita* in the Ganga River. Overall, *T. tor* is facing heavy fishing pressure and also targeted fish species by fishermen from the Ganga River system.

Keywords: Age composition, age of fish, age pyramid, catch, exploitation, fishing pressure, growth ring, operculum, Rohu, scale.

Hindi: भारत में 20वीं सदी में आर्थिक रूप से महत्वपूर्ण कार्प प्रजातियाँ लेबियो रोहिता, टॉर टॉर व लेबियो कलबासु, और कैटफ़िश रीटा रीटा एवं बागेरियस बागेरियस ने गंगा नदी प्रणाली से कुल फिश कैच में महत्वपूर्ण योगदान दिया है। इस अध्यन हेतु रीता रीता और बागेरियस बागेरियस का सैंपल सितंबर 2001 और सितंबर 2003 के बीच गंगा नदी प्रणाली में लिया गया था। दिसंबर 2003 और जून 2004 के बीच केन, पैसुनी और टोंस नदियों और फिश लैंडिंग केंद्रों से लेबियो रोहिता, टॉर टॉर व लेबियो कलबासु के लिए सैंपल प्राप्त किये गये। फिश पापुलेशन की वृद्धि और ऐज स्ट्रकचर मूल्यांकन के लिए सैंपल का उपयोग किया गया । केन और पैसुनी नदियों में लेबियो रोहिता के लिए ऐज क्लास 0 - 5+ और टोंस में 0 - 8+ थे। केन और पैसुनी नदियों में लेबियो रोहिता के लिए ऐज क्लास 0 - 5 और टोंस नदी में 0 -8+ है। टॉर टॉर के लिए ऐज क्लास केन और पैसुनी नदियों में 1- 6+ और टोंस में 1-8+ के बीच था। गंगा नदी में, रीटा रीटा और बागेरियस बागेरियस की ऐज क्लास क्रमशः 0 -7+, 0 - 6+ से भिन्न पाई गयी है । लेबियो रोहिता के ऐज पिरामिड ने केन नदी में घंटी के आकार की प्रवृत्ति दिखाई, पैसुनी और टोंस नदी में घंटी के आकार का ऐज पिरामिड थोड़ा बदल गया था। टॉर टॉर के मामले में केन नदी में घंटी के आकार की प्रवृत्ति और पैसुनी नदी एवं टोंस नदी में घंटी के आकार का ऐज पिरामिड पाया गया । लेबियो कालबासु के मामले में भारी तली के आकार का ऐज पिरामिड केन और पैसुनी नदियों में दर्ज किया गया था, जबकि टोंस नदी में आधार चौड़ा है। घंटी के आकार का ऐज पिरामिड बागेरियस बागेरियस के लिए दर्ज किया गया, जबकि गंगा नदी में रीता रीता के लिए भारी तल का आकार प्राप्त हुआ। कुल मिलाकर गंगा नदी प्रणाली में मछुआरों द्वारा मछली की प्रजातियाँ को लक्ष्य बनाकर पकड़ा जा रहा है, और टॉर टॉर प्रजाति, दोहन से भारी दबाव में है ।

Editor: J.A. Johnson, Wildlife Institute of India, Dehradun, India. **Date of publication:** 26 October 2024 (online & print)

Citation: Nautiyal, P., A.C. Dwivedi & A.S. Mishra (2024). Age structure of carp and catfish catch as a tool to assess ecological health of fished stocks from the Ganga River system with special reference to Mahseer *Tor tor* (Hamilton, 1822). *Journal of Threatened Taxa* 16(10): 25979–25989. https://doi.org/10.11609/jott.9051.16.10.25979-25989

Funding: The present study was conducted with the financial support given by University of Allahabad, Prayagraj, Uttar Pradesh during D. Phil Degree programme of second author (A.C. Dwivedi).

Competing interests: The authors declare no competing interests.

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Author contributions: PN has critically reviewed the manuscript and provided valuable suggestions. ACD collected data, capture photographs and write the manuscript. ASM worked on table, graphs/charts preparation, and also critical review.

INTRODUCTION

Fish landing composition in Indian rivers fluctuates from year to year, especially in Sadiapur and Allahabad regions of the Ganga River basin (Anonymous 1976, 1991, 2003; Mayank & Dwivedi 2015; Pathak et al. 2015; Tripathi et al. 2017). In 1976 landing record, *Labeo calbasu*, *Cirrhinus mrigala, L. catla*, and *L. rohita* contributed 15.68, 11.60, 3.30, and 4.72 tonnes, respectively. The catfish *Sperata aor* and *S. seenghala* jointly contributed 19.27 tonnes and miscellaneous species contributed 36.17 tonnes (Anon 1976). However, in 2001–2002 the miscellaneous fish (72%) dominated *S. aor* & *S. seenghala* (total 14%), and Indian Major Carp (*C. mrigala, C. catla*, & *L. rohita*, 1.4%, 3.1%, & 2.9%, respectively). *Wallago attu* (1.6%) and *Hilsa ilisha* (1.8%) contributed small proportions. In 2002–2003 the share of exotic carps increased to 17.8% while the catfishes (13.1%) and the Indian Major Carp (6.4%) remained stable. Besides landings, the age of fish at catch may be an important tool for computing growth, mortality, recruitment, and other fundamental parameters of fish populations. This can also be used to determine current ecological state of fished stocks.

The age and growth rate are two aspects of leading parameters in assessing health of fish stocks and their response to various types of habitats with fisheries sustainability (Ujjania & Soni 2018; Mayank et al. 2018; Nautiyal & Dwivedi 2020). Age and growth of fish are essential elements for understanding the habitat suitability, food supply, fishing pressure, pollution load, competition (example food, space, oxygen, and breeding ground) with other fish species (especially exotic species), and life history of any fish species (Mir et al. 2013). Age determination of fishes is an essential first step in age-based fish stock assessment, biomass and successful resource management (Dwivedi 2013). Growth is the change in size (length, weight) over time. This is one of the most intensively studied aspects of fishery biology. The purpose of growth studies of fish is to determine the number of fish that can be produced with respect to time (Pathak et al. 2014; Singh et al. 2017). The annual variation in a fishery depends upon its growth pattern. However, growth of fish is a complex mechanism, which represents the outcome of the interactions among several biotic and abiotic factors operating on behavioural and physiological processes. Accurate fish growth rates are important for growth analysis, age structure analysis, and mortality rate estimation (Mishra et al. 2023). The information of fish growth increment is also necessary for species life history, reproductive biology, population dynamics, biomass, and fisheries sustainability studies (Mayank et al. 2015; Rana & Nautiyal 2023).

In fisheries, fish landing data can be used to assess the present position of fish stock and the prediction of population trends. The changes in the yield can help in detecting whether a population was declining in abundance or maintaining itself at a stable level. Fishing resembles natural mortality in often causing changes in the population structure, such as age composition, age of maturity, and sex ratio. Fishing not only reduces population but also alters its intraspecific and interspecific relations. Theoretically, selective fishing can alter the structure greatly and lead to "biological overfishing", a stage where a population cannot reproduce itself and maintain its stock (Nikolskii 1980). This contribution specifically concerns on the age structure of major (*L. rohita*, *L. calbasu*), minor cyprinid (*Tor tor*), and catfish (*B. bagarius*, *R. rita*) from the rivers in and around Allahabad (now Prayagraj), Uttar Pradesh, India. The present study was conducted to unravel the age pyramid, age composition, and first ring appearance of commercially important fish from the Ganga River system. However, Pathak et al (2011), Mayank et al. (2018), and Mishra et al. (2021) have reported declined age structure for these species from the Ganga River system.

In the present study, more than 20 years results have been presented and it will be helpful to researchers of current period to use this information as benchmark for age structure information of listed fish species. These fishes are keystone species for the Ganga River system. The outcome of this study will be helpful to the fishery managers, researchers, and planners in management of the riverine fisheries mainly Indian Major Carp (IMC) and the threatened Central Indian Mahseer *Tor tor*.

MATERIALS AND METHODS

Samples of the carps *L. rohita*, *T. tor*, and *L. calbasu* (Image 1) were collected from fishermen or from fish market at Banda for the Ken River and Karwi for the Paisuni River. In case of the Tons River, fish samples were collected from fish market at Sadiapur/Gaughat, Allahabad there was no local fish market at Chakghat (fishing place). The samples of various fish species were recorded randomly during December 2003 to June 2004 from fish landing centers in the Ken, Paisuni, and Tons rivers. The sample size of fish species comprised of 158, 147, and 159 individuals of *L. rohita*, *T. tor*, and *L.*

Image 1. Cyprinidae. a—Rohu *Labeo rohita* | b—Tor Mahseer *Tor tor* | c—Calbasu *Labeo calbasu*. © Amitabh Chandra Dwivedi.

calbasu, respectively. The collected fish samples were preserved in 10% formalin and brought to the laboratory for further study.

The catfish samples consisted of *Rita rita* ('Ritha', 'Belgagra', 'Patharchatti') and *Bagarius bagarius* ('Goonch' or 'Patharchatti'). They were collected from the river Ganga at Rasoolabad fishing sites in Allahabad from September 2001–August 2003 (Image 2). The sample size comprised of 105 individuals of *R. rita* and 68 of *B. bagarius.*

Methods of Age determination

Scales

The age of *L. rohita, T. tor,* and *L. calbasu* of family Cyprinidae were determined by removing scales (Bagenal & Tesch 1978; Nautiyal 1990; Nautiyal & Dwivedi 2020) from the row above lateral line below dorsal fin region of preserved fish sample. The scales were cleaned in 5% KOH solution to remove adhering tissues and finally washed in distilled water. The scales were then pressed while drying to avoid their curling (Bagenal & Tesch 1978).

Prior to age determination, it was essential to establish whether the fish scale radius increased with

Image 2. Catfish (Sisoridae, Bagridae): a—*Rita rita* | b—*Bagarius bagarius.* © Amitabh Chandra Dwivedi.

the length of fish or not, since scales may be lost, and regenerated. According to Jhingran (1959) the annual increment in length of the scale maintains a constant ratio with increase in length of the fish throughout the year. It is a great importance implying the suitability of their scales for age determination. This relationship must be established, even if such information exists for the same species from same river and same or nearby location as rates of increase in scale radius-fish length will differ as populations are dynamic entities.

Opercular bone

In case of catfish, since scales are lacking, the age determination was performed by removing opercular bone of each fish. The opercular bones were boiled in 10% KOH solution to clean the muscles. The completely dried opercular bones were placed in an envelope containing information on date of collection, fish species (*R. rita*, *B. bagarius*), length of fish, weight of fish, sex. Later, they were examined under binocular microscope by placing it against a black background under reflected light to determine the age of the fish.

Growth Rings

In scales uniformly spaced, circuli are deposited during part of year with no environmental and or physiological stress resulting in a wide transparent zone (T). In contrast, the part of the year with environmental and or physiological stress result in deposition of closely spaced circuli that break, bifurcate, or form a hyaline area (Bagenal & Tesch 1978; Nautiyal & Dwivedi 2020) resulting in a very narrow opaque zone (O). The transparent and opaque zones together constitute one growth ring, which if laid annually are known as 'annulus'. The scales in these species are known to have annuli (*T. tor*: Karamchandani et al. 1967; *L. calbasu*: Gupta & Jhingran 1973; *L. rohita*: Pandey 1993). In the calcified structures like operculum growth rings are formed through an accretion, which result in alternated translucent and opaque rings. Fish age was determined by counting the number of translucent or opaque rings. Age of individual fish species was determined based on number of annuli and designated as 0+, 1+, 2+, 3+, 4+ so on (Mayank et al. 2018; Ujjania & Soni 2018; Dwivedi & Nautiyal 2021).

Age structure

The number of each age group was recorded separately for *L. rohita, T. tor*, and *L. calbasu* from the rivers Ken, Paisuni and Tons. The number of fish in each age group were recorded and converted into percentage to obtain a pyramid. This pyramid represents the status of the fish stock based on the share of age groups. Age structure was determined based on annuli and designated as 0+, 1+, 2+, 3+, 4+ so on. The total numbers of annuli were recorded in each scale to assess the age of an individual fish. This was also done to compute age structure in different sex. To determine the age structure, the frequency was computed for each age class and recorded as percentage.

RESULTS AND DISCUSSION

Length-at-Age

Eight growth rings were recorded in *L. rohita* & *T. tor* while seven rings in *L. calbasu* stocks were recorded occurring in the rivers Ken, Paisuni, and Tons. Eight growth rings were recorded in *L. rohita* and *T. tor* from the Tons river while seven rings in *L. calbasu* stocks was recorded in Tons river. However, in case of *T. tor* fishes, eight rings were recorded only Tons river while six rings were recorded in the Ken and Paisuni rivers. In *L. rohita* 1st growth ring appeared in 24–30 cm size group in all the rivers, compared with 16–22 cm size in *T. tor* and 16–20 cm size in *L. calbasu*. However, the size of *L. rohita* below 18 cm did not show growth rings, thus attaining more length than other two carps in 1st year. The 2nd growth ring first appeared in 36–42 cm size groups in all rivers in case of *L. rohita*, 22–28 cm size in *T. tor*, and 20–28 cm in *L. calbasu*. The latter showed slight variation, as the size was 20–24 cm in the Paisuni and the Tons River. In the Ken River slight variation was observed in 24–28 cm size. The 3rd and 4th growth ring first appeared in 54–60 cm and 60–66 cm size groups in all rivers in *L. rohita*. However, considerable variation occurred among the rivers in *T. tor* as well as *L. calbasu*. In the former 3rd ring was observed in 28–34 cm in the Tons and the Ken rivers, while 34–40 cm in the Paisuni River. The 4th growth ring in *T. tor* appeared in 40–46 cm size group in all rivers, while 32–36 cm in the Ken River and 36–40 cm in both the rivers Tons and the Paisuni.

The 5th growth ring was observed in 60–72 cm, 46–64 cm, and 40–48 cm in *L. rohita*, *T. tor*, and *L. calbasu*, respectively, showing variation among the rivers. The 6th growth ring was first laid in 78–84 cm, 64–76 cm and 48–52 cm size in *L. rohita*, *T. tor*, and *L. calbasu*, respectively. The 7th and 8th growth rings were laid in 84–90 cm in all *L. rohita* samples compared with 70–76 cm and 76–82 cm in *T. tor*. The 7th growth ring appeared in 56–60 cm size in *L. calbasu*.

It became obvious that *L. rohita* grow faster than *T. tor*. The *L. calbasu* indicated slow growth than other two species. However, *L. rohita* exhibited constant increase in length in all the three rivers till the formation of 4+ growth rings. For the 5th growth ring better size increase was observed in the Paisuni River followed by Ken River and least growth observed in the Tons River. Fish with more than 6+ growth rings were observed in the Tons River only. This was also true for other two species namely *T. tor* and *L. calbasu*.

Differences in growth of fishes may be observed in same species inhabiting different rivers of same ecoregion. In *T. putitora* 1st, 2nd, and 3rd growth rings appeared in 10–15 cm, 20–25 cm, 25–30 cm size, both in the Ganga and the Song rivers, but in 7–10 cm, 16–19 cm, 22–25 cm in the Nayar River. The 4th and 5th growth rings appeared in 35–40 cm and 45–50 cm size groups, respectively in the Ganga River. The 4th growth ring was observed in 40–45 cm size group in the Song River, 34–37 cm, and 52–55 cm size group in the Nayar River (Nautiyal 1990; Dhasmana 2004).

In *L. rohita* from Govindgarh Lake, 1+–8+ growth rings appeared in 24–30 cm, 48–54 cm, 60–66 cm, 66–72 cm, 72–78 cm, 78–84 cm, 84–90 cm, and 96–102 cm, respectively (Prakash & Gupta 1986). Pandey (1993) reported growth rings formation in *L. rohita* of 44 cm, 56.4 cm, 67.4 cm, 77.1 cm, and 85.8 cm for 1+–5+ age groups from the river Padma, West Bengal. Present study indicated that the increase in size for same age group was slow in the rivers Ken, Paisuni, and Tons. In *T. tor* 1st, 2nd,3rd, 4th, 5th, and 6th age groups were formed at 19.6 cm, 29.5 cm, 38.3 cm, 45.5 cm, 52.9 cm, 56.5 cm mean length (Desai 1982) in the Narmada River. The lengths-at-age for *T. tor* from similar ecoregion were comparable to the present observation.

Gupta & Jhingran (1973) observed that *L. calbasu* from the river Yamuna at Allahabad had a mean length of 18.85 cm, 29.10 cm, 38.10 cm, 46.85 cm, 54.35 cm, 61.85 cm, 68.10 cm, and 73.10 cm, for 1+–8+ age groups, respectively. Rao & Rao (1972) reported 1+–7+ age group of *L. calbasu* for lengths of 20.22 cm, 30.18 cm, 38.21 cm, 45.15 cm, 50.94 cm, 54.73 cm, and 61.62 cm, respectively in the Godavari River, while that from the Ghaggar River was 21.89 cm, 33.96 cm, 43.26 cm, 48 cm, 52.10 cm for 1+–5+ age groups (Tandon et al. 1989). The present observation also indicated similarity in lengths-at-age for *L. calbasu* from similar as well as different ecoregions.

Table 1. Percentage of non-reproductive and reproductive population of *L. rohita*, *T. tor*, and *L. calbasu* in the rivers Ken, Paisuni, and Tons.

Labeo rohita	**Share (expressed as %) in the rivers**		
	Ken	Paisuni	Tons
Non-reproductive	52.00	50.97	41.81
Reproductive	48.00	49.02	58.18
Tot tor			
Non-reproductive	26.83	34.54	26.92
Reproductive	73.17	65.45	73.06
Labeo calbasu			
Non-reproductive	34.61	37.25	15.52
Reproductive	65.38	62.74	84.48

Table 2. Percentage of non-reproductive and reproductive population of *R. Rita* and *B. Bagarius* in the Ganga River.

Categories	Share (expressed as %) in the Ganga River	
	Rita rita	***Bagarius bagarius***
Non-reproductive	73.19	52.32
Reproductive	26.81	47.68

Age composition of fish catch

Labeo rohita: In the Ken River age pyramid showed a tendency for bell shape as groups occurred in unproportionally declining fashion from 2+–5+ age groups. In 5+ age group percentage abruptly declined by 8% thus distorting the bell shape (Figure 1). In the Paisuni river the base tends to be broader as proportion of 2+ age group contributed 39.21% and abruptly declined in 3+ age group. Similar condition again occurred in 5+

age group (Figure 2). In the Tons River bell shaped age pyramid was slightly distorted because proportions of 0+ and 1+ age groups varied more. The percentage abruptly declined in 3+ age group compared with 1+ and 2+ age groups (Figure 3). The age groups 0+ and 1+ constitute immature individuals in the stock. These age groups accounted for 52% in the Ken River compared to 50.9% in the Paisuni River and 41.81% in the Tons River (Table 1).

Tor tor: In the Ken River age pyramid for *T. tor* showed a tendency for bell shape. It was distorted as groups occurred in uneven declining fashion in 3+–4+ and 5+–6+ age groups (Figure 4). In the Paisuni river bell-shaped age pyramid was obtained and percentage declined more or less uniformly (Figure 5). In the Tons River bell shaped age pyramid was distorted because proportions of 1+ and 2+ age groups varied more while decreasing percentage of higher age groups was same as in the Paisuni River (Figure 6). The age group 1+ constituted immature individuals in the stock. They accounted for 34.54% in the Paisuni River compared with 26.92% in the Tons River, and 26.83% in the Ken River (Table 1).

Labeo calbasu: In the Ken and Paisuni rivers, heavy bottom or broad-based age pyramids were obtained. The 1+ and 2+ age groups contributed 61.53% in the Ken River and 62.74% in the Paisuni River. In the Paisuni River, the percentage abruptly declined between 3+–4+ as difference was about 16% (Figures 7, 8). In the Tons River, broader base was obtained as each of higher age groups beyond 2+ were <10% but did not decrease proportionally as in the Ken and Paisuni rivers. The 1+ and 2+ age groups contributed 66.52%. The age groups 1+ constituted immature individuals in the stock (Figure 9). They accounted for 15.52% in the Tons River compared with 37.25% in the Paisuni River and 34.61% in the Ken River (Table 1).

Rita rita: The age group 0+–4+ constituted 90% of the total population, respectively from the Ganga River. Individuals belonging to 0+ and 1+ age group constituted around 58.09% of the total population. Since *R. rita* is known to mature after 2+ age, the 0+–2+ age groups comprising non-brooders accounted for 73.19% (Table 2), while the brooders ranging from 3+–7+ age contributed only 26.4%. The heavy bottom age pyramid was obtained (Figure 10).

Bagarius bagarius: The age group 0+–5+ constituted 90% of the total population from the Ganga River. The age pyramid in *B. bagarius* is distorted form of broad base age pyramid (Figure 11). It indicated high percentage of young (52.32%) and hence a recovering type of population, similar to *R. rita* (Table 2).

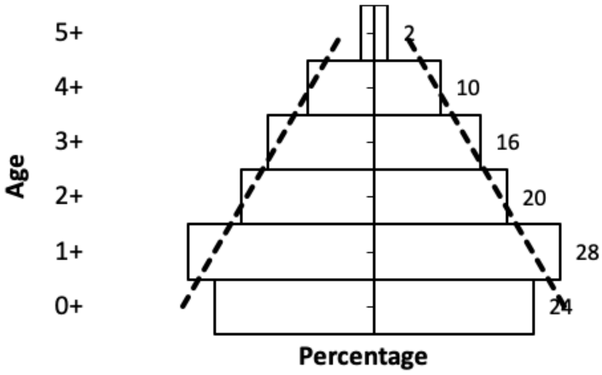

Figure 1. Age pyramid of *Labeo rohita* from the Ken River.

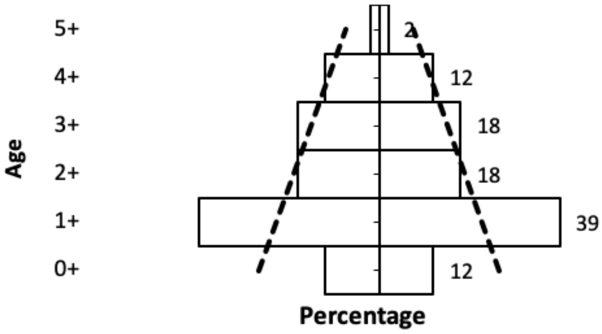

Figure 2. Age pyramid of *Labeo rohita* from the Paisuni River.

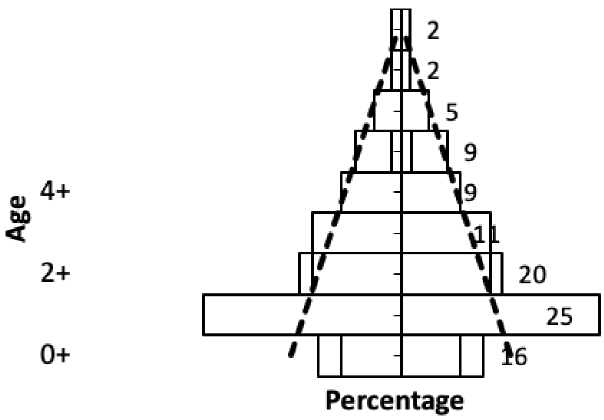

Figure 3. Age pyramid of *Labeo rohita* from the Tons River.

The male group of *R. rita* consisted of 0+–5+, while the female 0+–7+ age group from the Ganga River. First growth ring was not encountered till *R. rita* attained 14.9 cm size hence, fish below 15.0 cm were designated as 0+ age group. The size group 5.0–10.0 cm, 10.0-–5.0 cm, and 15.0–20.0 cm constituted 100% population of 0+ age groups. The size 20.0–25.0 cm comprised two age groups, dominated by 2+ (76.2%) compared to 1+ (23.8

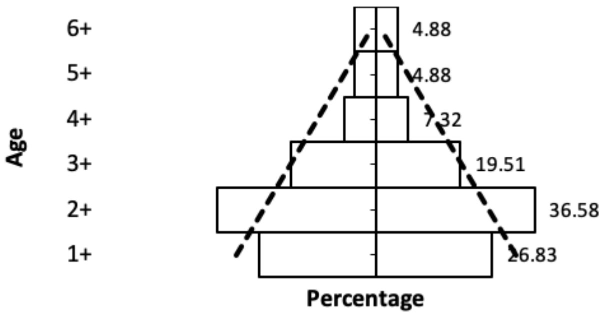

Figure 4. Age pyramid of *Tor tor* from the Ken River.

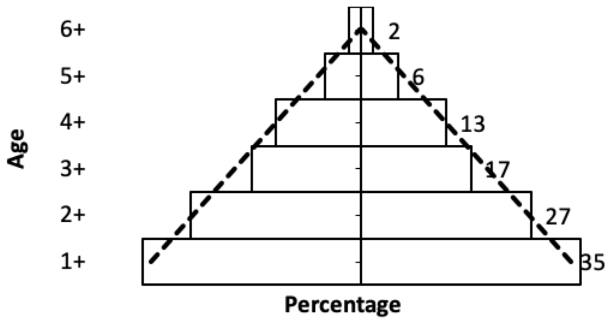

Figure 7. Age pyramid of Labeo calbasu from the Ken River.

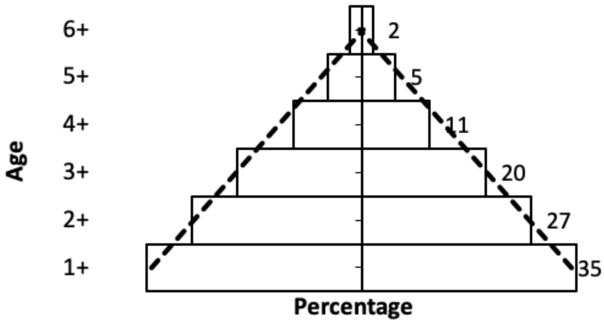

Figure 5. Age pyramid of *Tor tor* from the Paisuni River.

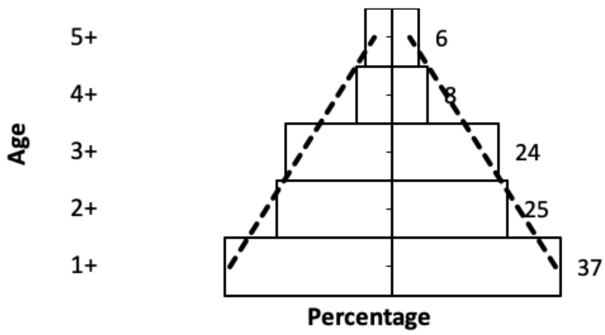

Figure 8. Age pyramid of Labeo calbasu from the Paisuni River.

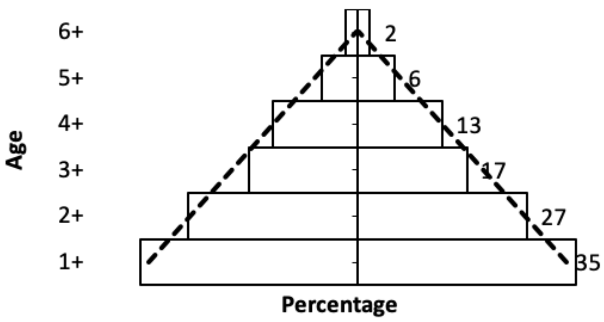

Figure 6. Age pyramid of *Tor tor* from the Tons River.

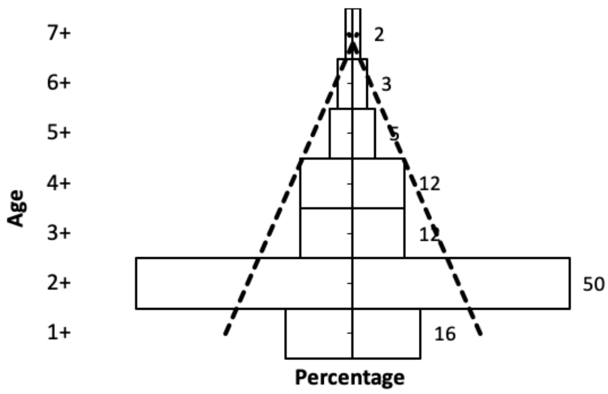

Figure 9. Age pyramid of Labeo calbasu from the Tons River.

%). The size 25.0–30.0 cm constituted fewer individuals of 2+ (25%) compared with 3+ (75%). However, 30.0–35.0 cm size was dominated by 4+ (75%) compared with 5+ (25%) age group. The size 35.0–40.0 cm was dominated by 5+ (100%) age group only, while 40.0–45.0 cm size consisted of only 33.3 % individuals of 6+ and 66.7% of 7+ age group.

Age groups 0+–5+ were observed for the male segment of *B. bagarius,* while 0+ –6+ age group for the female segment from the Ganga River. The size group 15.0–20.0 cm constituted 100% individuals of 0+ age group. The size group 20.0–25.0 cm comprised 0+ (6.7%), 1+ (60 %), and 2+ age groups (33.3 %) compared with 2+ (87.5%) and 3+ (12.5%) in the size 25.0–30.0 cm. In 30.0–35.0 cm and 35.0–40.0 cm size 3+ age group (72.7%, 71.4%, respectively) dominated, while in 40.0–45.0 cm 4+ age group prevailed (100%). The size 45.0–50.0 cm and 50.0–55.0 cm comprised 75%, 25%, 50%, and 50% of 5+ and 6+ population, respectively.

Labeo rohita: The age groups varied from 0+–5+ in the Ken and Paisuni rivers, while 0+–8+ in the Tons River. The 0+ age group comprised 24%, 11.76% and 16.36% in the Ken, Paisuni, and Tons rivers, respectively. The age group 1+ dominated by virtue of numbers in the

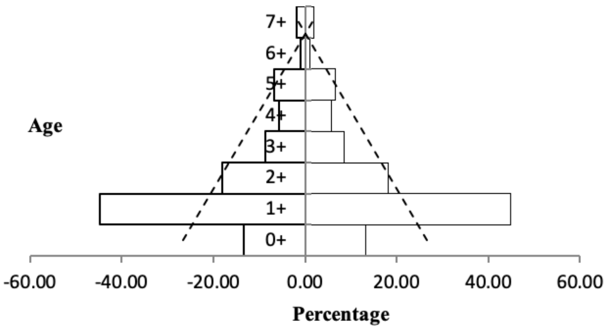

Figure 10. Age pyramid of *Rita rita* from the Ganga River.

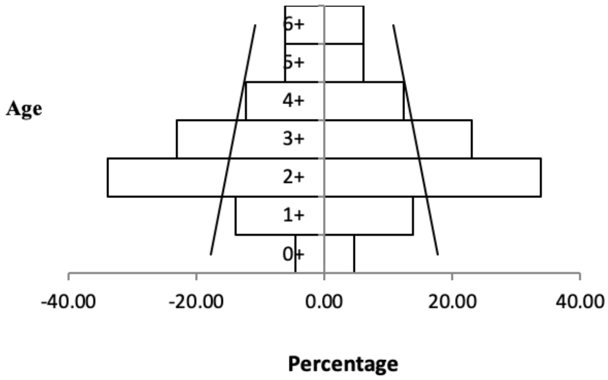

Figure 11. Age pyramid of *Bagarius bagarius* from the Ganga River.

Ken River (28%), in the Paisuni River (39.21%), and Tons River (25.45%) (Figures 1, 2, 3). Hence, the proportion of 0+ age group was much less than 1+ especially in the Paisuni and Tons rivers. The higher age groups contributed 16% (3+), 10% (4+), and 2% (5+) in the Ken River. The distribution was uneven between 1+–2+ and 4+–5+ age groups, as difference was high (8%) in each case. The higher age groups accounted for 17.65%, 11.76%, and 1.96% in 3+, 4+, and 5+, respectively in the Paisuni river. The share abruptly declined between 1+–2+ and 4+–5+ age groups. The difference was about 21.56% between 1+ & 2+ and 9.80% between 4+ & 5+ age groups. The higher age groups contributed 10.91%, 9.09%, and 9.09% in 3+, 4+, and 5+, respectively in the Tons River. The age groups 7+ and 8+ contributed 1.82%. The percentage abruptly declined between 2+–3+ age groups as difference was about 9.09%. The age groups varied from 1+–6+ in the Ken and the Paisuni rivers while 1+–8+ in the Tons River.

Tor tor: The age group 2+ (36.58%) dominated in the Ken River, 1+ (34.54%) in the Paisuni River, and 3+ (30.77%) in the Tons River (Figures 4, 5, 6). The age groups 1+ in the Ken River and 2+ in the Paisuni and Tons rivers contributed 26.83%, 27.27%, and 19.23%, respectively. Hence, the proportion of these age groups was much lesser than dominant age groups, especially in the Ken and Tons rivers. The higher age groups accounted for 19.51% (3+), 7.32% (4+), and 4.88% (5+) in the Ken River. The distribution was uneven between 2+–3+ age group as difference was very high (17%). The higher age groups contributed 20.0% (3+), 10.91 (4+) %, and 5.45% (5+) in the Paisuni River. The share abruptly declined between 3+–4+ age groups as difference was 9%. The higher age accounted for 30.77% (3+), 7.69% (4+), and 9.61% (5+) in the Tons River. The distribution was uneven between 3+–4+ age group as difference was very high (23%).

Labeo calbasu: The age groups varied from 1+–6+ in the Ken River, 1+–5+ in the Paisuni River and 1+–7+ in the Tons River. The age group 1+ dominated by virtue of numbers (34.61%) in the Ken River and (37.25%) in the Paisuni River while 2+ dominated in the Tons River (50%; Figures 7, 8, 9). Hence, the proportion of 2+ in the Ken and Paisuni rivers (26.92%, 25.49%) was higher, while the proportion of 1+ in the Tons River (15.52%) was less than dominant age group. The higher age groups accounted for 17.31% (3+), 13.46% (4+), and 5.77% (5+) in the Ken River. The distribution was uneven between 2+–3+ age group as difference was about 9%. The higher age groups contributed 23.53%, 7.84%, and 5.88% in 3+, 4+, and 5+, respectively in the Paisuni River. The distribution was uneven between 3+–4+ age group as difference was about 9%. The higher age groups accounted for 12.07% (3+ and 4+ each) while 5 + contributed only 5.17%. The percentage abruptly declined between 2+–3+ age groups as difference was about 37%.

Rita rita: The age groups varied from 0+–7+ in the Ganga River. The age group 1+ dominated by virtue of numbers (44.76%). The age group 2+ comprised 18.09%, while 0+, 3+, 4+, 5+, 6+, 7+ constituted 13.3%, 8.57%, 5.71%, 6.67%, 0.95%, and 1.9% of the total sample, respectively. The distribution was uneven between 0+–1+ and 1+–3+ age groups as difference was about 31.43% and 26.66%, respectively (Figure 10).

Bagarius bagarius: The age groups varied from 0+–6+ in the Ganga River. The age group 0+ comprised 13.3%. The age groups 2+, 3+, 4+, 5+, and 6+ constitute 33.8%, 23.1%, 2.3%, 6.15%, and 6.15%, of the total population, respectively. The distribution was uneven between 1+–2+ age group as difference was about 20% (Figure 11).

Age pyramids

Calcified structures have been used to estimate growth and age for a great diversity of fishes (Bagenal

& Tesch 1978; Sire & Akimenoko 2004; Mishra et al. 2023). Analysis of hard structures can provide a method of monitoring exploitation and population structure by providing biological data not only on age, but also on size & growth rate and to a limited extent on sex and sexual maturity, as well as other biological information, such as nutritional level (Esmaeili & Johal 2005; Dwivedi & Nautiyal 2010; Gopesh et al. 2021; Mayank et al 2021).

The rate of fishing is a powerful factor, which affects the age composition of the stock (Nikolskii 1980; Dwivedi & Nautiyal 2012; Dwivedi et al. 2017; Alam et al. 2022). Nikolskii (1980) suggested that intensified fishing reflected upon the age structure while it may not be true in other cases. Rate of fishing influenced the dynamics of age composition of the stock as well as of the year-class strength. According to Milner et al. (2003) fish population are subject to natural control processes that continually modify and adjust the structure and abundance of population and their life cycle in response to a wide range of factors. The proportion of different ages and sexes gave the population a definite structure. Ratio of young animals to adult often indicated whether a population was expanding, contracting, or stabilized. In stabilized population the number of offspring reaching reproductive maturity can never be greater or less then the number of adults themselves. The number of young that must be produced to permit such a population turnover gives a measure of the rigor of the environment and how well adapted a species is to its niche (Kendeigh 1980).

The composition of a population can be represented by the numbers and weight of individuals in each age or size group. It can also take account of the numbers of sexually mature individuals and their ratio to the balance. The structure also involved the ratio of the sexes in general and within age or size groups, as well as the morphological differences between individuals within a given generation and in the population as a whole. It can also take account of individuals in each age or size group (Nikolskii 1980).

According to Odum (1971) three kinds of distribution can be depicted by age pyramids:

i. Heavy bottom or broad-based pyramid: It indicates rapidly growing population with high percentage of young individuals.
ii. Bell shaped: It indicates a moderate proportion of young to old, i.e., pre-reproductive and reproductive age groups become more or less equal in size which is characteristic of stable population.
iii. Urn shaped: It indicates a low percentage of young individuals. If the birth rate is drastically reduced, the pre-reproductive group dwindles in proportion to the other two groups and it results in an urn- shaped figure which indicates that the population is senile.

Studies on the age structure revealed that the sexually immature (pre-reproductive) age groups 0+–1+ in *L. rohita*, 1+ in *T. tor,* and *L. calbasu* accounted for 41.81–52 %, 26.83–34.54 %, and 15.52–37.25 %, respectively. The remaining age groups (2+–8+ in *L. rohita*, *T. tor,* and 2+–7+ in *L. calbasu*) included mature or adult fish constituted the remaining part of their population. Among *L. rohita* adult component of the stock 2+–5+ age groups accounted for 48% and 49.02% in the Ken and Paisuni rivers, respectively. However, 2+–8+ age groups contributed 58.18% in the Tons River. In *T. tor* 2+–6+ age groups accounted for 73.17% and 65.45% in the Ken and Paisuni rivers, while 2+–8+ age groups accounted for 73.06% in the Tons River. In *L. calbasu* 2+–6+ age groups accounted for 65.38% in the Ken River, 2+–5+ formed 62.74% in the Paisuni River and 2+–7+ 84.48% in the Tons River. In case of *L. rohita* more or less pre-reproductive and reproductive population were equal in all rivers except Tons River while in case of *T. tor* & *L. calbasu* reproductive population was relatively higher in all rivers. The share of just two age groups comprising pre-reproductive individuals was higher and remaining 5–6 age groups of reproductive old individuals few with respect to the status of the *L. rohita, T. tor*, and *L. calbasu* stocks in the Ken, Paisuni, and Tons rivers.

The age pyramid exhibited distribution of different age groups in *R. rita* fits into the category of broad-based age pyramid because 0+ and 1+ age group constitute 58.1% of the total population which indicates expanding and hence a recovering population owing to high percentage of pre-reproductive age groups.

Warkantine et al. (1984) studied the population dynamics of Atlantic salmon *Menidia menidia*. The analysis revealed only 2+ age group in the population, in which <9.5 cm were 0+ while >9.5 cm were 1+. The former accounted for 97%, while 1+ was only 3%, which indicated a very short life span. Bhatt et al. (2000) determined the age structure of the Himalayan Mahseer (*T. putitora*) in the foothill section of the Ganga River and reported that the samples comprised of 1+ to 9+ age groups individuals. Of these 2+ and 4+ age groups constituted 66.01%, while 1+ was merely 8.07% of the total stock. Earlier, Nautiyal (1990) examined the samples from the Alaknanda and Nayar rivers, the tributary of the Ganga River and found that fish measuring 45.1–61.0 cm had 5 age classes of which 0+ and 1+ measuring 16 cm constituted 80% of the stock in the Nayar river, while 28–40 cm constituted 40% in the Alaknanda River. It accounted for the major proportion of the stock especially in the Nayar river. Age structure may also vary between years as random events alter recruitment and survival (Milner et al. 2003).

Analysis of age composition to determine the status of the population of some commercially exploited carps revealed; longest life span (17 years) in *T. putitora* followed by *C. carpio* (15 yr), *C. mrigala* (12 yr) in the Ganga River and 8 yr in the Yamuna River, *Setipinna phasa* (8 yr), *L. fimbriatus,* and *L. gonius* (6 yr) while *B. bendelisis* and *B. vagra* in 2 yr, respectively (Jhingran 1959; Kamal 1969; Hanumantharao 1974; Nautiyal 1994; Nautiyal & Negi 2004). Three broad categories were depicted from this information:

(a) predominance of pre-reproductive age classes being highest in *T. putitora* (90%) compared with *C. mrigala* (71.3%) in the Ganga River, 69% in the Yamuna River, and *B. bendelisis* (63.97%). These fish exemplified expanding population.

(b) predominance of reproductive and old age classes, *C. mrigala* (78.3%) and *L. fimbriatus* (70.97%) in the Godavari River while *S. phasa* (73.7%) and *C. carpio* (82%) in the Ganga River.

(c) even distribution with slight dominance of reproductive age classes rest, *L. gonius* (56.5%) and *B. vagra* (52%), exemplifying stable distribution.

CONCLUSION

It may be concluded that the *L. rohita* stock was not stable and facing fishing pressure. In case of *T. tor* and *B. bagarius*, stocks were slightly senile and facing heavy fishing pressure. To date, Mahseer fishery is facing a lot of stress generated by human activities (Pinder et al. 2019; Rana & Nautiyal 2023). In case of *L. calbasu* and *R. rita*, stocks were showing stable and growing condition. Overall large size fishes (*L. rohita, T. tor,* and *B. bagarius*) were suffering from poor water discharge and water quality from the all rivers, especially in winter and summer seasons. While small size fishes (*R. rita* and *L. calbasu*) were safe in low water discharge.

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NAAS rating (India) 5.64

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www.threatenedtaxa.org

OPEN ACCESS

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

October 2024 | Vol. 16 | No. 10 | Pages: 25951–26062
Date of Publication: 26 October 2024 (Online & Print)
DOI: 10.11609/jott.2024.16.10.25951-26062

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