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continued on the back inside cover

**Cover: Leaves and fruits of *Terminalia arjuna* in water colour artwork on cold pressed water colour paper by Bhama Sridharan.**

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COMMUNICATION

# Body growth and condition of endangered *Tor putitora* (Hamilton, 1822) (Actinopterygii: Cypriniformes: Cyprinidae) in the crucially important breeding and nursery grounds of the Ganga stock

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**Abstract:** The study evaluates seasonal differences in length-weight relationship and relative condition factor ($K_n$) of *Tor putitora* in the Nayar, a critical breeding and nursery ground in the mountain zone of the Ganga. The growth coefficient of *T. putitora* varies seasonally between 2.86 and 2.99 while relative condition factor between 1.00 ± 0.06 to 1.061 ± 0.3. Mahseer shows negative allometric growth (except the monsoon season) with better condition factor throughout the study period. The present $K_n$ factor for different size groups show deviation from past which may be due to inadequate food resources or excessive fishing in the Nayar.

**Keywords:** Allometric growth, exploitation, growth coefficient, isometric, juveniles, $K_n$, Mahseer, length-weight, Nayar, spawning.

यह शोध गंगा के पर्वतीय क्षेत्र में *टॉर पुटिटोरा*, महाशीर के महत्त्वपूर्ण प्रजनन और नर्सरी स्थल, नयार में किया गया हैं जो *टॉर पुटिटोरा* में मौसमी स्तर पर होने वाले लम्बाई–वजन सम्बध और रिलेटिव कन्डिशन फैक्टर का मूल्यांकन करता हैं। मौसमी स्तर पर *टॉर पुटिटोरा* का विकास गुणांक 2.66 से 2.99 के बीच भिन्न था, जबकि रिलेटिव कन्डिशन फैक्टर 1.00 ± 0.06 से 1.061 ± 0.3 के बीच भिन्न था। सम्पूर्ण अध्ययन अवधि के दौरान (मानसून के मौसम को छोड़कर) महाशीर मौसमी स्तर पर नकारात्मक एलोमेट्रिक वृद्धि के साथ बेहतर रिलेटिव कंडिशन फैक्टर दिखाता है। महाशीर के विभिन्न आकार समूहों के लिए वर्तमान का रिलेटिव कंडिशन फैक्टर पूर्व से भिन्नता दिखाता हैं, जो नयार में खाद्य संसाधनों की कमी या अत्यधिक मात्स्यिकी के कारण हो सकता है।

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**Author contributions:** PR conducted the data collection, performed the statistical analysis, and drafted the initial manuscript. PN played a critical role in reviewing and providing constructive feedback on the initial draft and finalized the content for publication.

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## INTRODUCTION

Himalayan Mahseer is an Endangered (Jha et al. 2018) endemic megafauna of Himalayan rivers that completes its migratory cycle within glacier-fed and spring-fed tributaries for spawning/feeding and rearing purposes (Nautiyal 1996; Bhatt et al. 2000; Nautiyal et al. 2001). Presently, the mahseer fishery of Indian subcontinent is declining under continuous threat of indiscriminate fishing, habitat degradation/fragmentation, climate change (Nautiyal 2014) and introduction of non-native fish (Gupta et al. 2019). The coupled effect of all these factors could be reflected in their growth, body condition, mortality, and recruitment of the next cohorts. Length-weight relationship is an easy tool for the assessment of the body growth and condition of the fish at the individual as well as population level. The relationship also offers a measure of the health of the fish population (Safran 1992), as well as a comparison of the life history characteristics of populations living in various geo-climatic regions. Various changes in the expected size, length-weight and hence growth of the fish due to major or minor changes in their life cycle could be perceived through the length-weight relationship (Le Cren 1951). Further, the relative condition factor ($K_n$) makes an assessment if increase in the body weight is in accordance with the desirable reproductive potential and recruitment rate. The study, therefore, evaluates the present status of the Himalayan Mahseer stock in the breeding and nursery grounds in the Nayar.

### Study area

The Nayar is a spring-fed perennial river that originates from the Dudhatoli Hills in the Pauri Garhwal District of Uttarakhand. The confluence of the Nayar with the Ganga is located ~10 km downstream from Devprayag, Uttarakhand. The stock in the Ganga foothills ascends the Nayar annually (Nautiyal et al. 2001).

## MATERIALS AND METHODS

The present study was based on the samples (N = 1966) of Putitor Mahseer collected from the local fishermen (Image 1) during July 2021 to October 2022 at weekly intervals. Further, the 1980s data were obtained monthly by the second author (PN), which contributed to a small sample size compared to weekly collection. The samples were cleaned with a cotton cloth. Thereafter, the total length and weight of the individual fish were recorded using measuring tape and a digital balance respectively.

Length-weight relationship was estimated using logarithmic form of the following equation

$Log\ W = Log\ a + b\ Log\ L$

Where, W is the weight of the sample in gm, L is the total length of the fish sample in cm while a and b are the intercept and slope respectively. The regression coefficients and the length-weight relationship were analyzed using Microsoft Excel 2016 software.

Significance of b value, i.e., Ho: ß = 3 was evaluated using t-test as

$$t = \frac{|b - 3|}{Sb}$$

where, $S_b$ is the standard error of b.

Relative condition factor was estimated using

$$Kn = \frac{Wo}{Wc}$$

Where, Wo is the observed weight and Wc is the calculated weight obtained from length-weight analysis.

## RESULTS

The examined fish samples ranged from 6.2 to 121.9 cm in the length and 2.1 to 25,000 g in weight, among which individuals below 25 cm constituted the resident stock of the Nayar (Table 1) as they were recorded throughout the study period. However, individuals measuring above 25 cm were the migratory brooder stock of mahseer as they were recorded only during the monsoon season (Table 1). Among the resident stock, the fish measuring between 10–15 cm was high in total sample followed by 15–20 cm and 20–25 cm.

The seasonal growth coefficient (b) varied between 2.86–2.99 (Table 2) which is within the expected suitable range of growth (Froese 1998). Except for the monsoon season (2021), mahseer has shown negative allometric growth as t-test analysis rejected the hypothesis i.e., Ho: ß = 3, at 0.05 level (Table 2). However, seasonal analysis of length-weight data of 1980–1981 has shown isometric growth type in winter season while negative allometric growth type for monsoon and summer season (Table 3). The b value was estimated as 2.95, for the pooled data of the present stock of mahseer, showing isometric growth type which was also recorded in earlier studies from the Nayar and other geo-climatic locations (Table 4).

The mean value of monthly relative condition factor for the present Mahseer cohort ranged between 1.00 ± 0.06 to 1.061 ± 0.3 (Table 5 and Figure 1). The peak of $K_n$

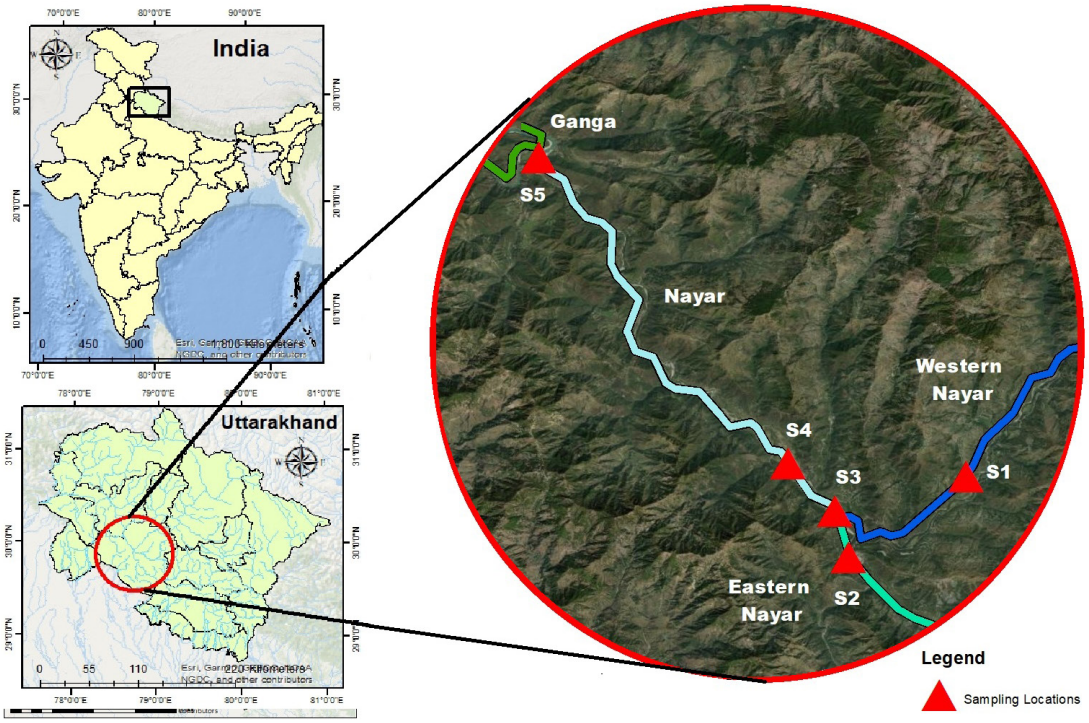


**Image 1. Study area map with sampling locations.**

was observed during monsoon season (July to August) which usually refers their breeding period as indicated by presence of ripe individuals and fry-fingerlings (Table 1). Further, a moderate relative condition factor ranging between 1.003 ± 0.03 to 1.005 ± 0.09 has been observed in between the monsoon periods. However, the current cohort's juveniles have a relatively high relative condition factor, in contrast to the 1980's cohort, where adults had a greater $K_n$ factor (Figure 2).

## DISCUSSION

The largest size of the Himalayan Mahseer encountered during this study was 121.9 cm in August. This was comparatively smaller than the past size (133.7 cm) in 1980–1981 (Nautiyal & Lal 1981). The Mahseer ranging above 40 cm was very low in number as they are part of migratory stock ascending from Ganga into Nayar for breeding purposes. However, other parts of India have also reported a drop in the size of other Mahseer fisheries and a low share in overall fish catches (Minimol 2000).

The resident 1980's cohort of the Nayar (4.1–49 cm) including fingerlings, juveniles and adults have shown negative allometric growth indicating no significant weight gain. However, winter season has shown comparable weight gain with respect to length increment which may be due to availability of food resources as winter is the most productive period of the Nayar (Nautiyal 1986). However, negative allometric growth in 2021–22 cohort throughout the seasons, somehow, indicate depletion of resources. Additionally, the isometric growth in monsoon and pooled data may be attributed to inclusion of large sized brooders with ripe eggs in resident stock (Table 1). Therefore, 1980's cohort has shown negative allometry in monsoon season due to prevalence of fingerlings and juveniles (<25 cm) which do not possess mature gonads. The previous studies on *T. putitora* in different regions have also shown isometric, positive and negative allometric growth patterns with varying geographic and climatic conditions (Table 3). Therefore, the seasonal fluctuations in sample size, maximum length, gonad maturity, food availability, feeding intensity (Le Cren 1951) may have played a major role in the body growth and condition of present cohort of Himalayan Mahseer.

During breeding season large percentage of the total body weight is influenced by increase in gonad size of prospective brooders as gonads undergo rapid development during spawning. Hence $K_n$ attained a peak in monsoon and fell abruptly thereafter. However, a sudden drop in June may be attributed to the decline in the feeding intensity from summer onwards (Nautiyal

**Table 1. Monthly variations in frequency (as %) of different size groups (in cm) of *Tor putitora* in the Nayar.**

| | 2021 | | | | | | 2022 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Monsoon | | | | Winter | | | Summer | | | | Monsoon | | | |
| Size-group | J | A | S | O | N | D | F | M | A | M | J | J | A | S | O |
| 1–5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 5–10 | 27.0 | 19.6 | - | 19.5 | 6.2 | 31.3 | 35.5 | - | - | - | 0.7 | - | 35.2 | - | 28.7 |
| 10–15 | 22.2 | 19.6 | 6.7 | 50.2 | 52.7 | 67.2 | 64.5 | 18.2 | 39.8 | 8.2 | 35.2 | 34.5 | 9.9 | 5.6 | 63.2 |
| 15–20 | 19.0 | 13.7 | 28.9 | 25.5 | 17.8 | - | - | 41.6 | 48.9 | 35.4 | 35.9 | 13.8 | 20.9 | 21.1 | 8.0 |
| 20–25 | 9.5 | 14.7 | 38.0 | 2.4 | 18.6 | 1.6 | - | 22.1 | 9.1 | 45.6 | 22.1 | 17.2 | 8.8 | 32.2 | - |
| 25–30 | 7.9 | 8.8 | 15.1 | 0.4 | 3.1 | - | - | 5.2 | - | 8.8 | 6.2 | 13.8 | 6.6 | 22.2 | - |
| 30–35 | 1.6 | 3.9 | 4.9 | - | 1.6 | - | - | 7.8 | - | 1.4 | - | 6.9 | 1.1 | 5.6 | - |
| 35-40 | 3.2 | 4.9 | 1.8 | 0.8 | - | - | - | - | 0.4 | 0.7 | - | 3.4 | 3.3 | 3.3 | - |
| 40–45 | - | 2.0 | 0.4 | 1.2 | - | - | - | 2.6 | 1.3 | - | - | - | 5.5 | 3.3 | - |
| 45–50 | 1.6 | 4.9 | 0.4 | - | - | - | - | 1.3 | 0.4 | - | - | 6.9 | 3.3 | 2.2 | - |
| 50–55 | 1.6 | 2.9 | 0.4 | - | - | - | - | 1.3 | - | - | - | - | 2.2 | 1.1 | - |
| 55–60 | 1.6 | 1.0 | 0.4 | - | - | - | - | - | - | - | - | - | 1.1 | 2.2 | - |
| 60–65 | 1.6 | 1.0 | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 65–70 | - | 1.0 | 0.7 | - | - | - | - | - | - | - | - | - | - | - | - |
| 70–75 | - | - | - | - | - | - | - | - | - | - | - | - | - | 1.1 | - |
| 75–80 | 1.6 | 1.0 | 0.4 | - | - | - | - | - | - | - | - | 3.4 | 2.2 | - | - |
| 80–85 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 85–90 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 90-95 | 1.6 | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 95–100 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| 100–105 | - | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 105–110 | - | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 110–115 | - | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 115–120 | - | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - |
| 120–125 | - | 1.0 | - | - | - | - | - | - | - | - | - | - | - | - | - |

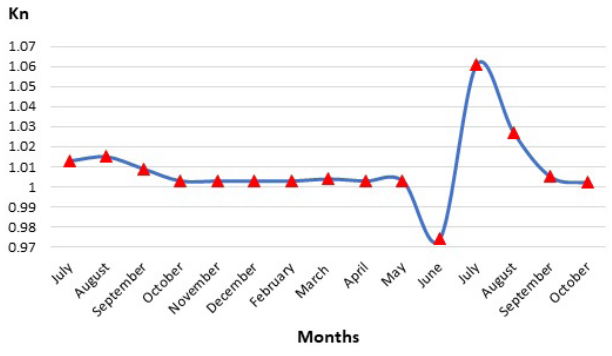


**Figure 1. Monthly variations in the relative condition factor of *T. putitora* from the Nayar.**

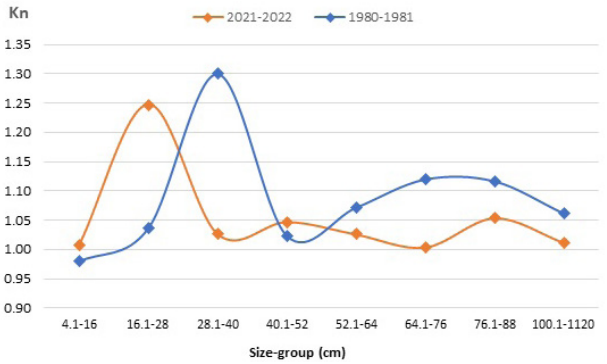


**Figure 2. Size-related variations in the Kn factor for *T. putitora* cohort of 1980 and 2022.**

**Table 2. Seasonal descriptive statistics of length-weight relationship of *T. putitora* in the Nayar (2021–2022).**

| Season | N | Total length (cm) | | Total Weight (gm) | | a | b | $r^2$ | $T_{0.05}$ | Growth * |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Min. | Max. | | | | | |
| Monsoon | 700 | 7.5 | 121.9 | 4 | 25000 | -2.07 | 2.99 | 0.99 | 0.84 | I |
| Winter | 224 | 8.9 | 34.1 | 6.65 | 362.64 | -1.97 | 2.91 | 0.99 | 4.64 | NA |
| Summer | 745 | 15 | 51.2 | 34.01 | 1167.16 | -1.89 | 2.86 | 0.98 | 4.63 | NA |
| Monsoon | 297 | 6.2 | 78.9 | 2.1 | 5000 | -1.98 | 2.91 | 0.98 | 4.21 | NA |
| Pooled | 1966 | 6.2 | 121.9 | 2.1 | 25000 | -2.01 | 2.95 | 0.97 | 1.77 | I |

* t—t-test | I—Isometric | NA—Negatively allometric.

**Table 3. Seasonal descriptive statistics of length-weight relationship of *T. putitora* in the Nayar (1980–1981).**

| Season | N | Total length (cm) | | Total weight (gm) | | a | b | $r^2$ | $T_{0.05}$ | Growth * |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max | Min. | Max | | | | | |
| Monsoon | 59 | 4.1 | 25 | 0.548 | 113.5 | -2.00 | 2.88 | 0.98 | 2.30 | NA |
| Winter | 134 | 4.9 | 21.6 | 1.025 | 83 | -1.98 | 2.91 | 1.00 | 0.49 | I |
| Summer | 52 | 7.1 | 49 | 2.98 | 875.5 | -0.12 | 1.33 | 0.68 | 2.35 | NA |

* t—t-test | I—Isometric | NA—Negatively allometric.

**Table 4. Growth coefficient of *T. putitora* form the Nayar and other regions of India.**

| River/Other | State | b | Growth * | Reference |
|---|---|---|---|---|
| **Nayar** | Uttarakhand | 2.88 | I | Lal & Nautiyal 1980 |
| **Nayar** | Uttarakhand | 2.98 | I | Nautiyal 1985 |
| **Pong Reservoir** | Himachal Pradesh | 3.15 | PA | Johal et al. 2005 |
| **Ladhiya** | Uttarakhand | 2.99 | I | Patiyal et al. 2010 |
| **Jia Bharoli** | Arunachal Pradesh | 3.108 | I | Ali et al. 2014 |
| **Beas** | Himachal Pradesh | 3.082 | I | Ali et al. 2014 |

* I—Isometric | PA—Positive Allometric | NA— Negatively Allometric.

**Table 5. Monthly relative condition factor (Kn) of *T. putitora* in the Nayar.**

| Month | N | $K_n$ ± S. D. |
|---|---|---|
| July | 63 | 1.013 ± 0.16 |
| August | 102 | 1.015 ± 0.18 |
| September | 284 | 1.009 ± 0.13 |
| October | 251 | 1.004 ± 0.08 |
| November | 129 | 1.003 ± 0.08 |
| December | 64 | 1.003 ± 0.08 |
| February | 31 | 1.003 ± 0.08 |
| March | 77 | 1.004 ± 0.09 |
| April | 231 | 1.003 ± 0.08 |
| May | 147 | 1.003 ± 0.08 |
| June | 290 | 0.954 ± 0.09 |
| July | 29 | 1.061 ± 0.30 |
| August | 91 | 1.027 ± 0.31 |
| September | 90 | 1.005 ± 0.11 |
| October | 87 | 1.002 ± 0.06 |
| **Pooled** | **1966** | **1.013 ± 0.16** |

1996) which coincides with the decline in the food resources from winter afterward. Similar trend in relative condition factor was observed earlier also and was used to infer the monsoon as breeding season (Nautiyal 1985). However, in contrast to 1980's cohort (Nautiyal 1985), the small size groups have shown better fitness while health condition of adults have deteriorated from past (Figure 1) which may be caused by overfishing of potential brooders leading to overexploitation, hampered recruitment, fragmentation of habitat and subsequent degradation, scarcity of food resources and decline in feeding intensity after attaining a length of 22 cm (Nautiyal 1989). However, low $K_n$ for juveniles (<20 cm) and comparatively better in adults (> 20 cm) was recorded form the Khoh, Kolhu, and Mandal (tributaries of Ramganga) in the Uttarakhand (Atkore et al. 2007).

## CONCLUSION

The Himalayan Mahseer deviated from the past in terms of body growth, condition and fitness. The mahseer of present cohort are not robust compared to past which may be attributed to either lack of food resources, decline in feeding intensity or increasing fishing pressure. Although the Mahseer has shown better condition throughout the present study period but the overall wellness in the adults has declined while inclined in the juveniles which may be related to habitat suitability or overfishing of larger size groups. Therefore, this study provides insight about the declined growth in body size and condition of different size groups of endangered Himalayan Mahseer.

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