



भा.कृ.अनु.प. - केन्द्रीय शीतजल मात्स्यकी अनुसंधान संस्थान
ICAR - Central Institute of Coldwater Fisheries Research



F.No. 4-4(4)/2024/DC/Vol.XV/264
July 24, 2025

To

The Hon'ble National Green Tribunal,
Faridkot House,
Copernicus Marg,
New Delhi - 110 001

Sir/Madam,

In response to the Notice with reference to the Original Application No. 295/2025 News Item titled "Nayar river is vanishing - a yatra reveals conservation goes beyond science and policy", I have the honour to submit the reply from this Institute as Respondent No. 7, by way of affidavit for favour of kind information as per the directions of the Hon'ble Tribunal.

Thanking you,

Yours faithfully,

Kande
24.7.25

Director

Encl. : Affidavit

निदेशक / DIRECTOR

भा.कृ.अनु.प.- केन्द्रीय शीतजल मात्स्यकी अनुसंधान संस्थान
भीमताल - 263136, जिला - नैनीताल, उत्तराखण्ड
ICAR - Central Institute of Coldwater Fisheries Research
Bhimtal - 263136, Distt-Nainital, Uttarakhand

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IN
AFFIDAVIT

(On behalf of Respondent no. 7)

IN
ORIGINAL APPLICATION No. 295/2025

In the matter of:

Suo motu cognizance based on the news item titled "*Nayar river is vanishing - a yatra reveals conservation goes beyond science and policy*" published in *Down to Earth* dated 03.06.2025

..... Petitioners


Versus

Central Pollution Control Board (CPCB), through its Member Secretary ,
Parivesh Bhawan, East Arjun Nagar, Delhi 110032, Ph No. 91-11-
46102030, e-mail: mccb.cpcb@nic.in and ors

..... Respondents

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Dated- 23/6/2025


(Tej Singh Bisht)
 Counsel for Respondent No. 7
 High Court of Uttarakhand

**BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH NEW DELHI**

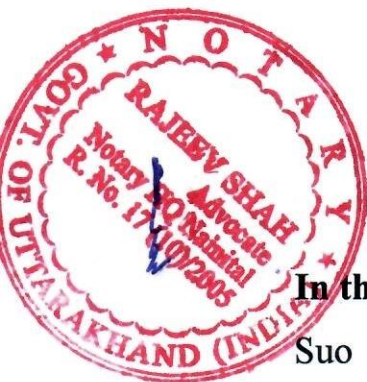
AFFIDAVIT

(On behalf of Respondent no. 7)



IN

ORIGINAL APPLICATION No. 295/2025



In the matter of:

Suo motu cognizance based on the news item titled "*Nayar river is vanishing - a yatra reveals conservation goes beyond science and policy*" published in *Down to Earth* dated 03.06.2025.

.....Petitioner

Vs

1. Central Pollution Control Board (CPCB), through its Member Secretary , Parivesh Bhawan, East Arjun Nagar, Delhi 110032, Ph No. 91-11-46102030, e-mail: mscb.cpcb@nic.in
2. Uttarakhand Pollution Control Board, through its Mamber Secretary, Gaura Devi Bhawan, 46 B II Park Sahastradhara, Dehradun, Uttarakhand 248001, ph no. 0135-2658086, e-mail: msukped@yahoo.com
3. Uttarakhand Biodiversity Board, through its Chairperson, 423, Indira Nagar Colony (Near Malik Chowk) Dehradun, Uttarakhand 248006, Ph No. 1035-2976886, email: sbuttarakhand@gmail.com

Rajeev Shah
RAJEEV SHAH
Advocate
Notary HQ Nainital
Reg. No. 17 (10) 2005

Kande
23/7/25
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4. G.B. Pant National Institute of Himalayan Environment (GBPNIHE) through its Director Kosi-Katarmal, Almora 263643, Uttarakhand Ph no. 05962241015(office), 241034(residence) email: psdir@gbpihed.nic.in
5. Ministry of Jal Shakti, Department of Water Resources River Development & Ganga Rejuvenation, Through its Secretary Shram Shakti Bhawan; Rafi Marg, New Delhi 110001 Ph No. 011-23710305, 011-23715919 email: secy-mowr@nic.in
6. Uttarakhand Forest Department through its Principal Chief Conservator of Forest (PCCF), 85, Rajpur Road, Dehradun, Uttarakhand Ph no. 0135-2741462 (office) email: itge-forest-uk@nic.in
7. ICAR-Central Institute of Coldwater Fisheries Research (ICAR-CICFR) through its Director Anusandhan Bhawan, Industrial Area, Bhimtal, 263136 Uttarakhand ph No. 05942-247280 email: director.dcftr@icar.gov.in/dcfr@rediffmail.com

..... Respondents

Affidavit of Amit Pande

Age about 55 years,

S/o Late Lalit Mohan Pande

Presently posted as Director, ICAR Central Institute of Coldwater Fisheries Research (ICAR-CICFR), Bhimtal, District Nainital

[Deponent]

I, the deponent above named to do hereby solemnly affirm and state on

oath as under:-

Rajeev Shah
KAJEEV SHAH
 Advocate
 Notary HQ Nainital
 Reg. No. 17 (10) 2009

Amit Pande
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1. That the deponent is presently posted as Director, ICAR Central Institute of Coldwater Fisheries Research (ICAR-CICFR), Bhimtal, District Nainital. As such he is in a position to file the affidavit as under



2. That the present affidavit is being submitted in compliance with the directions issued by this Hon'ble Tribunal vide order dated 05.06.2025 in the above-captioned matter, arising from a suo motu cognizance of a news item published in *Down to Earth* magazine on 03.06.2025 titled "*Nayar river is vanishing — a yatra reveals conservation goes beyond science and policy.*"

3. That the said article, in its concluding paragraph of the sub-section titled "*Nayar river struggling to survive*", states that "*Aquatic species like the golden mahseer are nearing extinction, reflecting the river's deteriorating health.*" This specific claim appears to be inconsistent with the currently available scientific literature and field-based observations regarding the presence and status of *Tor putitora* (golden mahseer) in the Nayar river.

4. That while it is true that *Tor putitora* is classified as an Endangered species under the IUCN Red List due to broader range-wide threats, its occurrence in the Nayar river remains **scientifically documented** and verified by recent and historic studies, which are enumerated below:

Rajeev Shah
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- **Rana and Nautiyal (2023)** conducted a comparative study of the size structure and population composition of *Tor putitora* in the Nayar river in 2011 and 2023. The study confirms year-round presence of the species (up to 15% of the catch), although with a higher proportion of juveniles, indicating a decline in mature individuals but ongoing natural recruitment.

Reference: Rana, P. and Nautiyal, P. (2023). Analysis of size-composition of endangered Tor putitora in the critical breeding and nursery grounds of the Nayar (Western Himalaya). Journal of Applied and Natural Science, 15 (4), 1379 – 1372).

- **ICAR–CICFR (Formerly ICAR-DCFR) has documented the presence of golden mahseer in the River Nayar** during an angling (catch and release) competition cum interactive workshop organized at Vyasghat, Pauri Garhwal. The event, held from 20-22 November, 2020, witnessed the participation of 21 anglers who successfully caught golden mahseer weighing between 5 - 13 pounds. The main objective of the event was to promote awareness among local communities regarding the significance of mahseer conservation.

Reference: ICAR–DCFR Annual Report, 2020, Page 91.

- **Jeeva et al. (2011)** reported *Tor putitora* contributing 27.8% of the total fish catch from the Nayar river, based on studies of river connectivity and fragmentation.

Reference: Jeeva, V., Kumar S., Verma, D. and Rumana, S. 2011. River fragmentation and connectivity problems in the Gange



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RAJESH SHAH
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river of the upper Himalaya (India): the effect on the fish communities, *Transylvanian Review of Systematical and Ecological Research*, Vol. 12, Page:75-90.

Sharma and Mishra (2002) noted a 32.8% contribution of *Tor putitora* in total fish samples collected from the Nayarriver.

Reference: *Sharma and Mishra (2002): Present status and prospects of mahseer fishery in Garhwal Region of Central Himalaya, In: Peter T. and Swar D. B.(eds), Cold Water Fisheries in the Trans-Himalayan Countries, FAO Fisheries Technical Paper No. 431)*

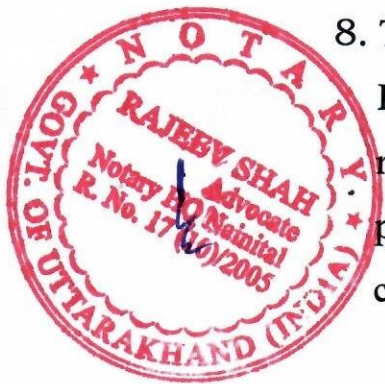
5. That from the above scientific evidence, it is respectfully submitted that the claim of "nearing extinction" made in the article is not supported by peer-reviewed data. While there is concern regarding decline in larger size classes and reproductive individuals, the species continues to occur in viable numbers in the Nayar River ecosystem.
6. That ICAR-CICFR is actively engaged in species-specific conservation initiatives for *Tor putitora*, including:
 - a. Developed captive breeding technology and seed production protocols;
 - b. Rehabilitation and ranching initiatives in coldwater lakes and rivers;
 - c. Community awareness and training programs for mahseer conservation.
7. That this affidavit is submitted to apprise the Hon'ble Tribunal of the factual status of golden mahseer presence in the Nayarriver,

Rajeev Shah
RAJEEV SHAH
 Advocate
 Notary HQ Nainital
 Reg. No. 17 (10) 2005

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supported by empirical evidence, and to dispel any misconception regarding its extinction from this river system.



8. That in view of the foregoing, it is respectfully prayed that this Hon'ble Tribunal may be pleased to take the present affidavit on record and pass such further orders as may be deemed just and proper in the interest of justice, ecology, and biodiversity conservation.

Kauro
23/7/25

I, the above named deponent do hereby verify that the contents of para nos. 1-3 of this affidavit are true to my personal knowledge, those of para nos. 4-5 of this affidavit are based on records, those of para nos. _____ of this affidavit are as per the legal advice received, those of para nos. 6-8 of this affidavit are as per the information received which all I believe to be true. That no part of this affidavit is false and nothing material has been concealed.

So help me God

DEPONENT

Kauro
23/7/25

I, Suresh Chandra Principal Scientist do hereby identify Shri Amit Pande by Adhar Card (No. 370331582416) and I am satisfied that he is the same person as alleged...

Chandra
23/7/25
Identifier

Rajeev Shah
RAJEEV SHAH
Advocate
Notary HQ Nainital
Reg. No. 17 (10) 2005

Solemnly affirmed before me on this 22/7 Day of July, 2025 at 1.30 a.m./p.m. by the deponent, who has been identified by the aforesaid advocate.

I am satisfied myself by examining the deponent who has understood the contents of this affidavit which have been read over and explained to him by me.



Binod
Identifier 5907 1.57

Certified that Sri/Smt. Amil Pandey aged about 55 years 31/04/1969
the Deponent Identified by Satish Chandra (Participated-see entry)
Sworn & Verified the Contents of the Affidavit at NAINITAL
on Date 22/7/25 at 3:00 P.M.
Rajeev Shah
RAJEEV SHAH
Notary HQ Nainital - 2025
Ref. No. 17 (10) 2005
TIME - 3:00 P.M.
Binod District Nainital

Research Article

Analysis of size-composition of endangered *Tor putitora* in the critical breeding and nursery grounds of the Nayar (Western Himalaya)

Priyanka Rana*.

Aquatic Biodiversity Unit, Department of Zoology, HNB Garhwal University, Srinagar-Garhwal (Uttarakhand), India

Prakash Nautiyal

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Abstract

Size composition gives an overall estimate of the prevalent length of individuals in the fish stock and, hence, the stock's health. The present study analyzed the size-composition and population structure of Golden Mahseer, *Tor putitora* in the river Nayar that form their breeding and nursery grounds. The Nayar is located in the critical stretch of Devpryaag and Rishikesh (Garhwal Himalaya), free of any dam/barrage in the river Ganga. The Nayar basin is undergoing rapid land use changes due to increased mining and fellow land formations. This analysis was based on length frequency analysis data obtained from three sampling stations, S1, S2, and S3, in the Nayar River. The highest length frequency (53.3%) of Mahseer was recorded from the size class ranging between 10-20 cm, like earlier records, while only one individual measuring 121.9cm was procured. The length frequency decreases with increasing size beyond 30cm. In contrast to the past, the present study revealed a comparatively distorted population structure in the Nayar, where the pre-reproductive size groups showed dominance over the reproductive population. The reduced spawning biomass could jeopardize the recruitment of the next generation.

Keywords: Endangered, Ganga River basin, Length-frequency, Nayar, Population structure, *Tor putitora*

INTRODUCTION

The Golden Mahseer (*Tor putitora*) stands as a symbol of both ecological vitality and cultural heritage in the freshwater systems of South Asia. Native to the Himalayan region and found in the rivers and streams of countries such as India, Nepal, Bhutan, and Pakistan, the Golden Mahseer is also familiar as Himalayan Mahseer. Moreover, due to its ecological implications, the Golden Mahseer is considered an umbrella species, as it plays a crucial role in shaping prey populations and maintaining environmental balance within aquatic ecosystems (Gupta *et al.*, 2014). Renowned for its remarkable size, strength, and the challenge it presents to anglers, the Golden Mahseer has garnered attention as a charismatic and iconic species (Everard *et al.*, 2021).

However, the ongoing interplay of various anthropogenic factors and environmental changes has posed significant threats to its populations, raising concerns

about its long-term survival. Despite its significance, the Golden Mahseer's population facing various challenges that have led to declining numbers. Habitat degradation due to dam construction, deforestation, and sedimentation has directly impacted its spawning and feeding grounds (Jha *et al.*, 2018). Additionally, pollution and overfishing have exacerbated the situation, while climate change-induced alterations in temperature and water flow patterns have further stressed its already vulnerable populations (Pinder *et al.*, 2019).

The ascending migratory movements of Himalayan Mahseer within the Ganga River system have been documented by several authors (Bhatt *et al.*, 2016). However, fishing of female brooders during upward breeding migration in the spawning season and young immature ones in breeding and nursery grounds is a concerning issue for the declining status of Himalayan Mahseer (Sarkar *et al.*, 2015). Therefore, the present study aimed to analyze the population structure of

Himalayan Golden Mahseer within their breeding and nursery grounds in the Nayar located upstream of the Gangetic population inhabiting between Rishikesh and Haridwar.

MATERIALS AND METHODS

Study area

The present study was conducted in the critical breeding and nursery grounds of Nayar River, which confluences with the river Ganga at Vyasghat, located about 10 km downstream from the Devprayag. For the length frequency analysis, three sampling sites within the Nayar, Bhatkul Ka Sain (S1, upstream), Banghat (S2, mid-stream) and Vyasghat (S3, downstream) were selected (Fig. 1) based on the availability of Putitor samples through fishermen of local fish markets. The study was conducted at weekly intervals from July 2021 to June 2022.

Analysis of the Data's methodology

A total of 1173 specimens of Golden Mahseer were examined for their total length (in cm) at each sampling station. The fish samples were categorized into nine different classes with a class interval of 10 cm, while the fry and fingerlings were categorized into 5 cm class intervals. The data was expressed in percentage composition by taking the percentage of the total number of fishes in that size group and comparing it with the previous population structure in Nayar. The past data on length frequency from Nayar was taken from a previous study by Nautiyal (2011). The statistical analysis was performed in M.S. Excel 2013 software.

Ethical committee approval

The Putitor (Golden Mahseer), samples were

collected from local fishermen at fish markets. Therefore, ethical approval was not required for the study.

RESULTS AND DISCUSSION

The specimens of Himalayan Golden Mahseer (*T. putitora*), procured from the different stations in the Nayar, majorly ranged below 80 cm, while individuals beyond that were rare. The largest size procured during the study was 121.9 cm. The present study failed to procure any fry stages measuring below 5 cm from the Nayar that could exist in the upstream stretches. The highest size composition of 53.3% was recorded from the size group of 10-20 cm, followed by 20-30 cm, contributing about 35% of the total population. In contrast to the past, a comparative decline in size composition above 30 cm was observed, which formed only 10% of the total share (Fig. 2). A previous study in the Alaknanda (located upstream of Devpryaag) recorded the maximum size composition of Mahseer in the size group between 30 to 40 cm (Singh and Nautiyal, 2018). In the present study, the dominance of lower-size groups in the Nayar may be either due to a more suitable environment or food conditions for the growth and development of juveniles of Mahseer.

The examined size composition has shown a fall below 2% (or nil) in Mahseer population during the winter period at stations S2 and S3, while station S1 has shown a continuous population of Mahseer throughout the study period (Fig. 2). The larger size groups were majorly recorded from S3 which forms the connecting point for the Gangetic stock of Mahseer within the Nayar followed by S2 (located upstream S3). However, size groups above 30 cm were not recorded at S1, possibly due to the shallow nature of the habitat, continuous riffles and runs and lack of proper refuge

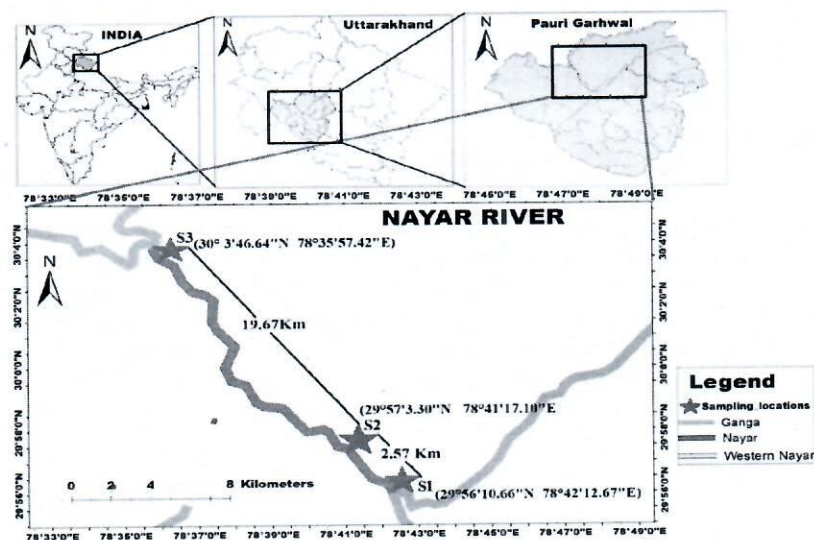


Fig. 1. Study area map showing location of sampling stations in Nayar River

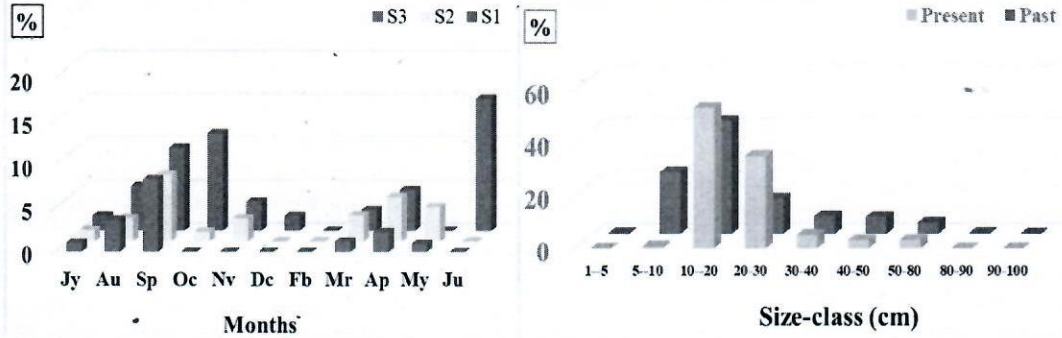


Fig 2. Monthly length frequency percentage of Himalayan Mahseer at S1, S2 and S3 (left) and comparison with an earlier study (Nautiyal, 2011) (right)

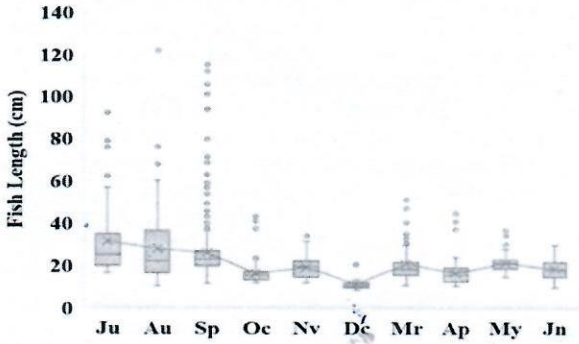


Fig 3. Box-whisker plots of monthly size composition of Himalayan Mahseer in the Nayar

(deep pools) to avoid predatory attacks besides intense fishing pressure between S1 to S3 stretch. These larger-sized groups were recorded only during the monsoon period (July to September), their peak spawning period. The largest mean length was recorded as 31.4 ± 3.8 cm in July, followed by 28 ± 4.9 cm and 26.2 ± 4.08 cm in August and September, respectively, after which the monthly mean length ranged between 11.3 ± 0.8 to 21.7 ± 0.9 cm (Fig. 3). Therefore, the study further confirms the ongoing migratory movements of Mahseer from the Ganga (Rishikesh to Haridwar) toward the upstream Vyasghat (Nautiyal, 2011).

The size-composition analysis further revealed the asymmetric population structure of Himalayan Mahseer

within their breeding and nursery grounds of Nayar (Fig. 4). The population structure of the previous study seems more stable in comparison to the present population of Mahseer within Nayar (Fig.4). The present Mahseer population has shown pre-dominance of pre-reproductive age group (forming about 88.9% of the total Mahseer population) over the reproductive age group (<10%). The present study has also shown a phenomenal reduction in the large-sized brooders (>40cm) of Mahseer in the Nayar (Fig. 2,3). However, during 1980-81 and in 1996, a comparatively larger size group, ranging between 61 to 111 cm, was also recorded from the Alaknanda River which is located even upstream to the confluence of the Nayar river (Singh and Nautiyal, 2018). Their study also reported a reduction in the size group above 40 cm in the Alaknanda River at Srinagar. The reduction in the size-composition of larger size groups of Himalayan Mahseer may be attributed to the blocked migratory path due to Chilla Hydropower projects or intense fishing pressure in the ascending migratory tract (Nautiyal, 2011). Earlier, the reduction in the upstream migration of Mahseer at Srinagar was also attributed to the occurrence of the Srinagar hydroelectric project at Alaknanda River. The obstruction in the ascending migratory route of the spawning biomass (inhabiting between Rishikesh and Haridwar) can potentially delay/ hamper the spawning activities (Bao *et al.*, 2022).

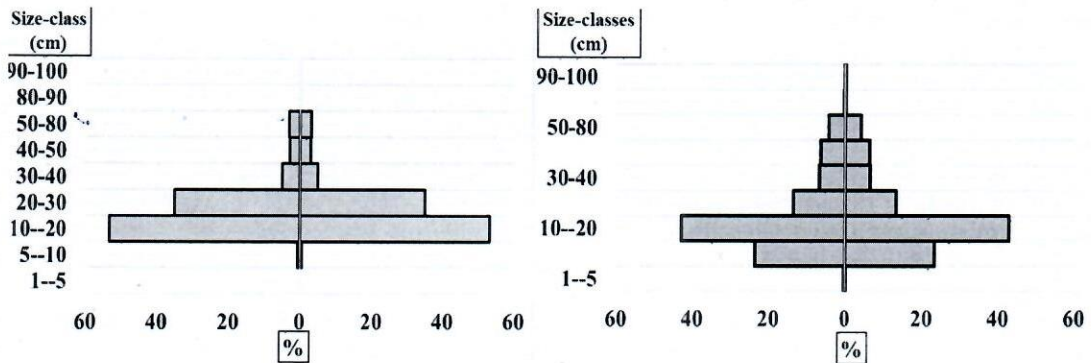


Fig 4. Population structure of Himalayan Mahseer within Nayar for present (left) and earlier study (right)

Insufficient brooders in breeding grounds would lead to a reduced quantity of eggs and, subsequently, a scarcity of larvae in the habitats where new individuals are recruited (Camp *et al.*, 2020). Accordingly, a small number of adult brooders will restrict the future population.

Conclusion

The study shows a shift in the size composition of golden Mahseer towards smaller size in their critical breeding and nursery grounds of Nayar River. However, large-sized Mahseer individuals in the upstream Alaknanda River indicate that only a small subset of the Golden Mahseer population is allowed to ascend and engage in reproductive activities. The reduced spawning biomass may pose a greater threat to the declining population of the Himalayan Mahseer in the Ganga and possibly other Himalayan River systems.

ACKNOWLEDGEMENTS

The authors sincerely thank University Grant Commission- Senior Research Fellowship (UGC-SRF) scheme for providing financial assistance throughout the study. The authors also thank Prof. O.P. Gusain, Incharge-Head, Department of Zoology, for providing laboratory facilities.

Conflict of interest

The authors declare that they have no conflict of interest.

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11.4 First Angling Competition cum Interactive Workshop on Mahseer organized by ICAR-DCFR held at Vyasghat, Pauri Garhwal (Uttarakhand)

A three days angling competition cum Interactive workshop was successfully conducted by ICAR-Directorate of Coldwater Fisheries Research in collaboration with Department of Fisheries, Govt. of Uttarakhand at Vyasghat of Pauri Garhwal district (Uttarakhand) during 20-22 November, 2020. The angling competition was participated by 21 avid anglers from Marchula, Almora, Pancheswar, Pauri, Dehradun of Uttarakhand and other neighbouring states and witnessed by 50 personnel representing scientists, departmental officials, district administration and farmers. During the competition, the anglers could hook golden mahseer *Tor putitora* (Hamilton, 1822) and Indian hill trout *Raiamas bola* (Hamilton 1822) as the major catch in rivers Nayar and Ganga. The largest catch weighed 13 pounds in the hooks of Mr.



Fig.: Big catch of Golden mahseer by Mr. Satpal from Himachal Pradesh



Fig.: Prize distribution by the Hon'ble MLA, Pauri

Satpal from Himachal Pradesh, followed with a 10 pounds mahseer in the hooks of Mohd. Ali Khan and 5 pounds by Mr. Tegbir Mann from Dehradun (Uttarakhand). The maximum numbers of fishes were caught by Mr. Sanjeev Paroriya from Marchula (Uttarakhand) followed by Mr. Mohd. Ali Ghazi from Rampur (Uttar Pradesh) and Mr. Shyam Gurung from Marchula (Uttarakhand). The outcomes of the programme are: Recognition of Vyasghat as a major mahseer angling destination for the tourist on the world map; Promotion of the SC village (Baggi) to earn revenue through mahseer based recreational fisheries and eco-tourism; Conservation of mahseer in the river systems through mahseer angling and eco-tourism. Dr. Deepjyoti Baruah, Ex. Sr. Scientist; Dr. R. S. Haldar, Chief Technical Officer coordinated the programme.

11.5 Socioeconomic upliftment of Scheduled Caste population of Chamoli district, Uttarakhand through Rainbow trout farming intervention

A collaborative programme was undertaken by ICAR-DCFR with Department of Fisheries, Chamoli district, Govt. of Uttarakhand on the title "Socioeconomic upliftment of Scheduled Caste population of Chamoli district through Rainbow trout farming intervention under SCSP project, 2019-20" at Chamoli district, Uttarakhand. Altogether 18 SC fish growers were benefited. The programme witnessed the following outcomes: (i) Completed repairing and renovation of concrete



raceways for trout culture in Chamoli district. (ii) Advanced sized trout fingerlings were stocked in the raceways. (iii) High quality trout feeds were given to the 18 beneficiaries. (iv) Fish nets and fish disinfectants were distributed

RIVER FRAGMENTATION AND CONNECTIVITY PROBLEMS IN THE GANGE RIVER OF THE UPPER HIMALAYA (INDIA): THE EFFECT ON THE FISH COMMUNITIES

*Velaichamy JEEVA **, *Sudhir KUMAR ***,
*Dharmendra VERMA *** and *Harcharan Singh RUMANA ****

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KEYWORDS: Himalaya, Ganges River, Nayar River, migratory fish, human impact.

ABSTRACT

Sound ecological practices in the development of hydropower projects are essential to protect the fragile ecosystem of the Himalayan Mountains in northern India. Evidence is growing that the increasing number of river valley projects causes habitat fragmentation and degradation of both terrestrial and aquatic habitats. The impact was studied on the migratory fish known as the Mahseer, a flagship species, and the need to conserve the aquatic ecosystem in the upper Himalaya of Uttarakhand. The proposed construction site of the Kotlibhel hydroelectric project stage-II for the generation of 530 MW on the river Ganga/Ganges near the village of Kaudiyala, and the upstream rivers Alaknada, Bhagirathi and Nayar, were studied for the biodiversity of the riparian flora and aquatic fauna to assess the importance of river connectivity for conservation. Recommendations are emphasized for habitat restoration and connectivity to improve the riparian habitats for the Mahseer and to conserve the river Nayar, which has the potential for conserving the native fish diversity.

ZUSAMMENFASSUNG: Die Unterbrechung des Flusskontinuums und Konnektivitätsprobleme am Ganges im oberen Himalayagebiet: Auswirkungen auf die Fischgemeinschaften.

Umweltverträgliche ökologische Praktiken in der Entwicklung von Wasserkraftprojekten sind wesentlich für den Schutz des fragilen Ökosystems in den Himalaya-Gebirgen Nordindiens. Die Erkenntnisse verstärken sich dahingehend, dass die steigende Zahl von Flussprojekten Habitatzerstückelungen verursachen und zu einer Degradation sowohl von terrestrischen als auch aquatischen Lebensräumen führen. Untersucht wurden die Auswirkungen auf die wandernden, als Mahseer bekannten Fischarten – eine Leitart – und die Notwendigkeit des Schutzes der aquatischen Ökosysteme im oberen Himalayagebiet von Uttarakhand. Im Hinblick auf den vorgeschlagenen Bau der Etappe II des Kotlibhel Wasserkraftprojektes zur Erzeugung von 530 MW am Ganges nahe des Dorfes Kaudiyala und der oberstrom liegenden Flüsse Alaknada, Bhagirathi und Nayar wurde die Artenvielfalt der Uferflora und der Gewässerfauna untersucht, um die Bedeutung der Konnektivität für den Schutz der Arten zu bewerten. Dabei wurden Empfehlungen für die Habitatrenaturierung und Konnektivität zur Verbesserung der Lebensräume für den Mahseer gegeben sowie für den Schutz des Nayar Flusses, der das Potential für den Schutz der ursprünglichen Biodiversität besitzt.

REZUMAT: Fragmentarea râului și probleme de conectivitate pe râul Gange în zona superioară a munților Himalaia: efecte asupra comunităților de pești.

Practicile ecologice compatibile cu dezvoltarea unor proiecte hidroelectrice sunt esențiale în vederea protecției ecosistemului fragil al munților Himalaia din India de nord. Se dovedește din ce în ce mai mult, că numărul crescând al proiectelor pe râuri are drept consecință fragmentarea și degradarea atât a habitatelor terestre, cât și a celor acvatice. A fost studiat impactul acestor proiecte asupra speciei de pești migratori cunoscută sub numele de Mahseer, specie indicatoare, și necesitatea conservării ecosistemului acvatic în partea superioară a munților Himalaya din Utrakhand. Construcția propusă a fazei II a barajului hidroelectric de la Kotlibhel pentru generarea de 530 MW pe Râul Gange în apropierea satului Kaudiyala și pe râurile Alaknada, Bhagirathi și Nayar situate în amonte au fost studiate din punct de vedere a biodiversității florei ripariene și a faunei acvatice pentru a se putea aprecia importanța conectivității pentru conservarea speciilor. Sunt date măsuri pentru refacerea habitatelor și a conectivității în vederea îmbunătățirii habitatelor ripariene pentru Mahseer, precum și pentru conservarea râului Nayar, acesta deținând potențialul pentru conservarea diversității native a speciilor de pești.

INTRODUCTION

The riparian zones are among the most diverse, dynamic, and complex habitats on the world's continents (Naiman and Décamps, 1997) as they are considered to be the most important natural pathways for plants and animals, especially migratory fish (Forman and Godron, 1986; Malanson, 1993; Schneider and Sharitz, 1988; Nilsson et al., 1991; Johansson et al., 1996; Planty-Tabacchi et al., 1996). The increased fragmentation due to dams is reported to disrupt the natural dispersal pathways of the riparian communities (Hanson et al., 1990; Fahrig and Merriam, 1994) and alter the structure. Such specific alterations have however been documented only for migratory fish (Petts, 1984) and considerable works have been reported on the impact of dams on aquatic ecosystems and fish life cycles in America and Europe. No systematic efforts have been made so far on Himalayan riparian ecosystems, especially in the flagship fish species due to the habitat fragmentation. Therefore, it was thought desirable to assess the impact of the proposed dam on the flora and fauna, which are important components of the ecosystem in the study area in Terhi Garhwal Himalaya, Utrakhand, India.

The Mahseer is an important flagship species (Simberloff, 1998) distributed along the Himalaya in India, Pakistan, Bhutan and Bangladesh. Golden mahseer (*Tor putitora*) is one of the main game and food fish of Utrakhand, is largely confined to lotic habitats (streams, rivers). The fish migrates considerable distances upstream in search of suitable spawning grounds. The migratory Mahseer is a column feeder, omnivorous fish and attains a maximum length of 275 cm (9 ft) and a maximum weight of 54 kg (118 lb) (Talwar and Jhingran, 1991; Wikipedia, 2006). Because of its size, golden colour, beautiful appearance and flavour, the fish is exploited along the Himalayan foothills. Stocks of the Himalayan mahseer are reported of being depleted and it is considered an endangered species (Singh and Sharma, 1998; Khan and Sinha, 2000; Sharma, 2003). Further, habitat degradation and fragmentation has also been reported, to contribute to their decline in numbers, in the Himalayan stretch of the Ganges (Nautiyal, 1984, 1989, 1990, 1994). Therefore, it is very important to understand the vital links within the study area to restore the habitat connectivity.

MATERIALS AND METHODS

Study area

The proposed Kotlibhel H. E. Project Stage-II is located on the river Ganges, the confluence point where the rivers Alaknanda and Bhagirathi meet and flow between the Tehri and Pauri Districts of Uttarakhand (Figs. 1 and 2). The basin up to the proposed dam site near the village Kaudiyala lies between Longitude from 78°09'10" E to 80°10'31" E and Latitude from 29°45'03" N to 31°29'57" N.

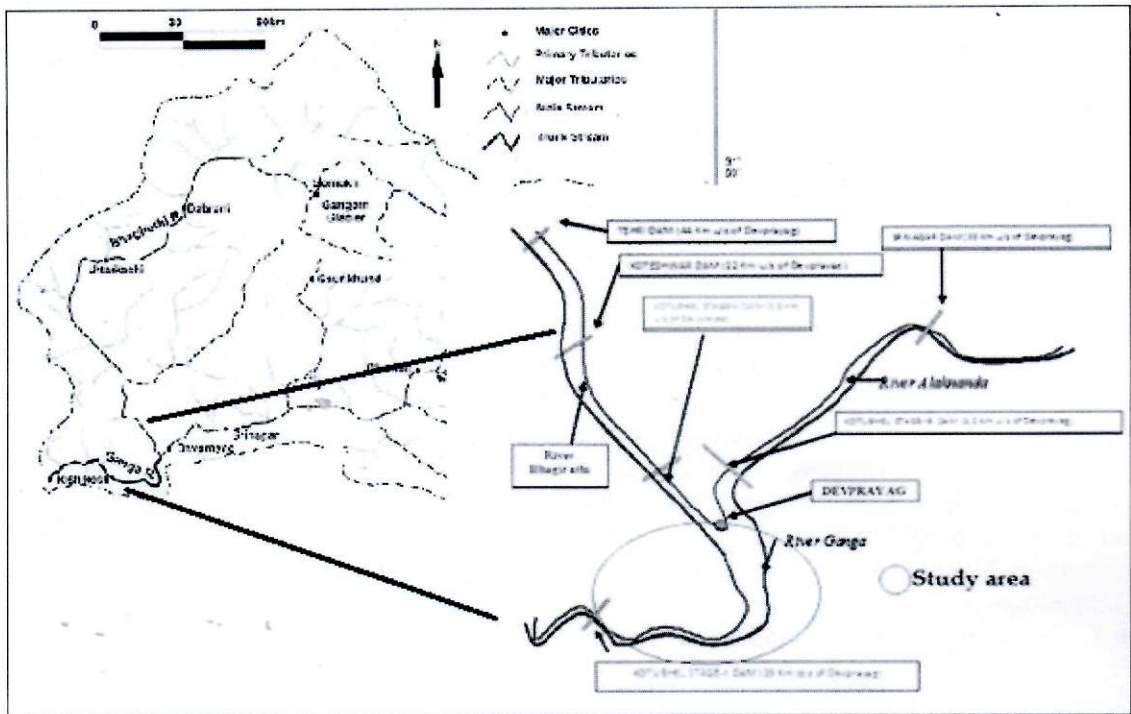


Figure 1: The studied area.

The proposed dam will be a 58.6 m high concrete gravity dam across the river Ganges which will completely deprive the upstream migration of the economically important migratory fish Mahseer both to rivers Alaknanda and Bhagirathi. The proposed project is part of the cascade development of the Kotlibhel project in three stages, proposed by the National Hydropower Power Corporation, India and the study was conducted during 2006-2007.

Methodology

Two reference sites were identified in the project area for the collection of water samples and obtaining data related to the aquatic primary production and production of Mahseer (*Tor tor*, *Tor putitora*). For limnological analyses of the aquatic environment, standard methods outlined in Mackereth et al. (1978) were followed. The vegetation samples for phytosociological study were collected according to Misra (1968) and Kershaw (1973) and were quantitatively analyzed for density, frequency and abundance according to Curtis and

McIntosh (1950). The tree species diversity was determined using Shannon Wiener (Shannon and Wiener, 1963). Concentration of dominance was measured by Simpson Index (Simpson, 1949). Fish, including their spawns, fry and fingerlings were captured and identified with the help of keys of Jayaram (1981) and Menon (1987). Benthic macro-invertebrates were studied (Welch, 1948) and the collected specimens were preserved in 8% formalin solution and identified up to the generic level with the aid of keys given by Usinger (1950) and Tonapi (1980). The benthic macro-invertebrates were also identified with the help of keys given by Edmondson (1959) and Pennak (1953). Secondary reports were also consulted (Sharma and Ashutosh Mishra, 2002; Nautiyal and Lal, 1982).

RESULTS AND DISCUSSIONS

The water quality analysis was carried out at various places covering sections of river Bhagirathi, river Alaknanda, river Nayar and the river Ganges, to have a holistic view of it during monsoon and pre- monsoon periods. The details of various sites on the river are given in table number 1 (a, b). The parameters analyzed, showed a significant variation for the river Nayar, as compared to rivers Bhagirathi, Alaknanda and Ganges. This could be naturally due to the fact that, the Nayar is a spring fed and the rest are glacial fed. However the slight variation in the case of the river Ganges, from Bhagirathi and Alaknanda could be due to other anthropogenic factors, such as pilgrim pressure and ecotourism near the village Kaudiyala.

The quantitative distribution of the benthic macro-invertebrates collected from the 39 km long stretch of the study area is presented in table number 2 for all the seasons in the rivers Nayar and Ganges. A total of 18 species of the macro-zoo benthos have been identified from this stretch of the river. It is evident from the study that the highest population density was observed in the river Nayar as compared to the river Ganges. The high diversity in the Nayar River is due to the spring fed, river substratum consisting of bed rock, boulders, cobbles and gravels, which supports the survival, growth and reproduction of macro-benthic organisms. Observations further show a close relationship between abundance of the fish presence and population density of macro-zoobenthos with phytobenthos.

Phytobenthos consume the carbon dioxide present in the water and therefore, is considered as a water purifier. The data indicate (Tab. 3) that the bottom substratum of the rivers Ganges and Nayar is enriched in green matters or phytobenthos. Though the density of phytobenthos is good throughout the year, the highest abundance is observed from October to March. The concentration of phytobenthos decreases during the period April – September, just at the onset of the ablation period, as the river water becomes turbid and torrential. The richness of phytobenthos in the river Ganges could be due to its joining with Nayar River.

It is evident that Mahseer dominates and is found healthier in the river Nayar than that is found in river Ganges (Tab. 4). This is due to the spring-fed streams of the region that have relatively high temperature (10.0 to 27.5°C), low current velocity (0.4 to 1.2 m/s), and a relatively confined channel basin (4.4 to 18.5 m). The dissolved oxygen content is lower than in the glacier-fed streams (6.6 to 8.8 mg/L). However, pH was slightly higher (7.0-7.9) and total alkalinity was much higher (97-148 mg/L). The current velocity and water temperature have great influence on the periphyton density in the streams. It was higher in spring-fed streams of Nayar than in the Ganges glacier-fed. The high temperature, moderate current, good periphyton coupled with high substrate heterogeneity, enhance the density of macrobenthic fauna in spring-fed streams that have provided a good base for the development of mahseer and contribute greatly to the commercial fishery at Satpuli in the foothills of Himalaya.

Table 1a: The water quality parameters in the rivers of upper Himalaya in Utrākhand.

Sl. no.	Parameters	Unit	Bhagirathi		Alaknanda	
			Pr. M	Po. M	Pr. M	Po. M
A. Physical Parameters						
1	Temperature	°C	14	15	16	16
2	pH	–	8.2	8.1	8.0	7.9
3	Conductivity	uS/cm	170	185	182	190
4	Total Dissolved Solids	mg/l	105	118	113	120
5	Dissolved Oxygen	mg/l	9.08	8.2	9.5	8.0
6	Salinity	Ratio	0.104	0.100	0.106	0.102
7	Turbidity	NTU	12	10	15	12
B. Chemical Parameters						
8	Total Alkalinity	mg/l	72	74	62	62
9	Calcium Hardness	mg/l	54	52	44	45
10	Magnesium Hardness	mg/l	20	24	22	26
11	Total Hardness	mg/l	74	76	66	71
12	Chloride	mg/l	20	19	22	22
13	Iron	mg/l	0.08	0.05	0.06	0.04
14	Nitrate as N	mg/l	0.3	0.02	0.22	0.16
15	Phosphate	mg/l	0.04	0.02	0.02	0.01
16	Manganese	mg/l	Not Detected		Not Detected	
17	Biological Oxygen Demand	mg/l	< 2	< 2	< 2	< 2
18	Chemical Oxygen Demand	mg/l	2.8	2	2.0	2
C. Bacteriological characteristics						
19	E-Coli	N/100 ml	10	6	5	4
	Total Coliform	N/100 ml	220	200	240	180
Pr. M. = Premonsoon; Po. M = post monsoon.						

Table 1b: The water quality parameters of the rivers in the upper Himalaya in Uttrakhand.

Sl. no.	Parameters	Unit	Ganges		Nayar River	
			Pr. M	Po. M	Pre. M	Post. M
A. Physical Parameters						
1	Temperature	°C	15	16	22	20
2	pH	–	8.0	8.0	7.0	7.9
3	Conductivity	uS/cm	174	180	200	205
4	Total Dissolved Solids	mg/l	110	115	126	132
5	Dissolved Oxygen	mg/l	9.5	8.7	6.6	8.8
6	Salinity	Ratio	0.104	0.100	0.103	0.102
7	Turbidity	NTU	20	12	5	12
B. Chemical Parameters						
8	Total Alkalinity	mg/l	60	64	97	148
9	Calcium Hardness	mg/l	47	48	72	70
10	Mangesium Hardness	mg/l	21	21	56	48
11	Total Hardness	mg/l	68	69	128	118
12	Chloride	mg/l	22	20	12	12
13	Iron	mg/l	0.06	0.04	Not Detected	
14	Nitrate as N	mg/l	0.22	0.16	0.22	0.18
15	Phosphate	mg/l	0.02	0.01	Not Detected	
16	Manganese	mg/l	Not Detected		Not Detected	
17	Biological Oxygen Demand	mg/l	< 2	< 2	< 2	< 2
18	Chemical Oxygen Demand	mg/l	2.22	2	3.0	4
C. Bacteriological characteristics						
19	E-Coli	N/100 ml	5	4	5	4
	Total Coliform	N/100 ml	200	200	200	180
Pr.M = Premonsoon; Po.M = post monsoon.						

Table 2: Quantitative distribution of Zoo benthos in rivers Ganges and Nayar.

Order	Season of the year	Spring				Summer				Monsoon				Winter			
		Average		Range		Av.		Ra.		Av.		Ra.		Av.		Ra.	
		G	N	G	N	G	N	G	N	G	N	G	N	G	N	G	N
Periphytons- Density No/Cm²																	
Green Algae	190	230	11-232	28-542	187	212	8-83	17-483	68	236	3-88	12-108	59	89	5-28	16-89	
Diatoms	270	490	20-125	29-289	236	212	12-896	19-483	86	389	7-73	249	39	168	7-20	11-178	
Zooplanktons No/L																	
Protozoan	27	32	2-12	12-37	22	38	1-18	8-22	15	22	2-8	4-19	11	18	1-5	6-19	
Rotifers	20	25	1-11	4-16	18	20	2-11	4-11	10	18	1-9	1-19	15	16	2-6	4-13	
Copepods	18	28	2-10	4-20	16	19	3-8	4-21	12	21	2-4	3-16	10	13	1-5	2-10	
Cladocerans	14	24	2-11	3-19	14	16	2-9	2-23	11	17	3-7	4-18	9	11	2-4	2-15	
Macro invertebrates No/M²																	
Ephemeropt.	89	112	3-22	26-48	58	98	2-16	2-16	45	81	2-11	3-19	39	78	1-15	1-17	
Odonata	93	118	4-12	13-35	46	67	2-22	4-29	36	53	1-9	2-15	27	43	2-7	3-19	
Diptera	112	125	5-9	11-56	73	89	3-18	6-26	52	84	2-8	7-15	35	62	1-5	2-15	
Coleoptera	76	128	6-11	12-52	67	94	3-21	5-32	48	68	4-7	4-18	33	76	1-4	3-11	
Hemiptera	82	136	5-8	15-58	71	67	2-20	2-28	53	79	2-8	3-11	42	63	2-4	1-14	
Trichoptera	67	78	4-11	3-22	58	63	3-18	2-22	43	72	1-5	3-10	23	45	1-6	1-12	
Nematoda	8	12	2-4	2-7	6	8	2-5	4-7	4	8	2-2	4-8	2	6	1-1	1-5	
Annelida	9	8	1-4	8	4	5	2-5	2-8	3	4	1-3	4-7	2	3	1-2	1-3	
Earthworms	10	12	2-5	12	7	7	2-4	2-5	5	4	1-1	1-2	2	2	1-1	1-1	

G = Ganges River; N = Nayar River.

The Mahseer population undertakes migration from the foothill sector of the Ganges, often ascending into the rivers Bhagirathi and Bhilangana (Sehgal, 1972; Nautiyal et al., 2001) the only possible route. The present survey reveals that the fish have easy access to the spring-fed placid streams of Nayar, that provide a congenial environment (Nautiyal and Lal, 1984) because of the lower current velocity, more potential breeding grounds are available in the spring fed streams (0.35-1.7 m/s) than in the glacier-fed streams (0.68-2.5 m/s). Also the availability of the coarse bottom of boulders, rocks or pebbles substratum provides base for biotypes for enrichment of macro benthos. It is obvious that the proposed Kotlibhel Stage II may obstruct the upstream migration of mahseer. Also the suitable riparian habitat would get submerged because of the proposed reservoir.

A detailed floral diversity was assessed in the submergence area of the proposed Kotlibhel Stage II. The study area showed rich herbaceous diversity in terms of distribution and density of species with dominant and co-dominant species specific to riparian zone (Tabs. 5 and 6). The entire stretch of the floral diversity in the project area will be lost due to the proposed intervention resulting in the land use change.

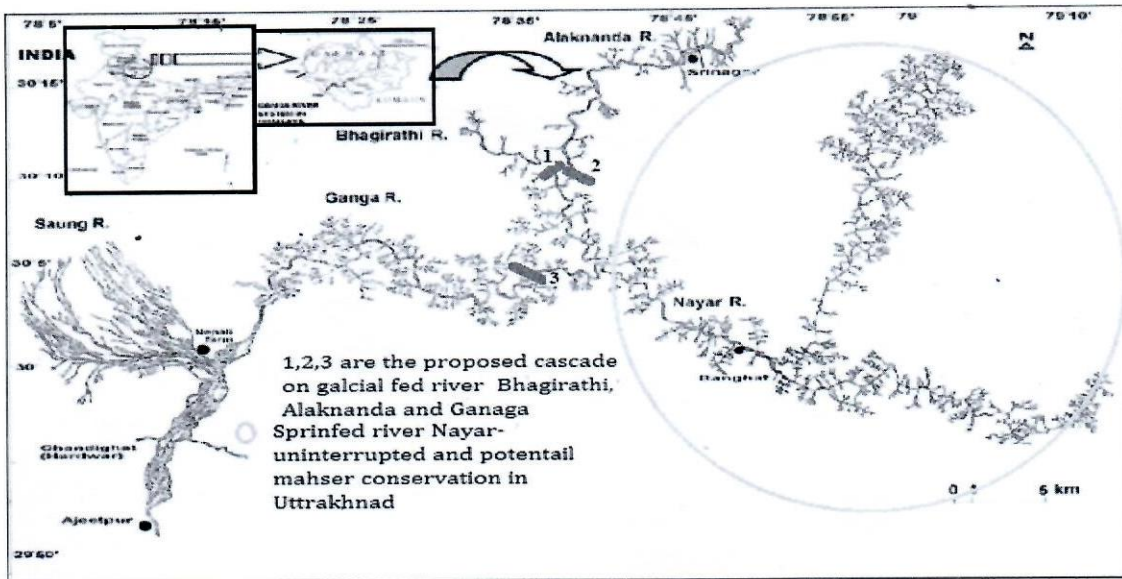


Figure 2: The river Nayar in the upper Himalayas of Utrakhnad uninterrupted by the development activities.

Table 3: Percentile contributions of important fish species in terms of number and weight in the rivers Ganges and Nayar.

Species	River Ganges		River Nayar	
	(% contribution)		(% contribution)	
	By number	By weight	By number	By weight
<i>Schizothorax</i> sp.	18.6	20.4	20.2	18.9
<i>Tor</i> sp.	23.2	25.8	26.6	28.5
<i>Tor putitor</i>	24.6	26.4	27.8	30.4
<i>Labeo</i> sp.	8.2	7.6	8.1	9.6
<i>Garra</i> sp.	7.8	5.8	5.3	6.2
<i>Barilius</i> sp.	4.2	3.9	6.2	2.4
<i>Puntius</i> sp.	5.4	3.9	1.8	1.3
<i>Glyptothorax</i> sp.	5.5	2.7	2.3	2.1
<i>Nemacheilus</i> sp.	1.9	2.7	2.1	1.4

Table 4: Phytosociological analysis of herbaceous vegetation at the left bank of the river Ganges in the study area.

Name of the species	F	D	RDe	R F	R Do	IVI
Herbs						
<i>Achyranthes aspera</i>	18	0.64	3.54	3.7	0.85	8.09
<i>Barleria cristata</i>	27	0.73	4.04	5.56	11.65	21.24
<i>Dicleptera roxburghiana</i>	18	1.64	9.09	3.7	3.84	16.63
<i>Eupatorium adenophorum</i>	18	1.91	10.61	3.7	10.2	24.51
<i>Hamiltonia suaveolens</i>	18	0.36	2.02	3.7	12.09	17.81
<i>Lansea nudicaulis</i>	9	0.09	0.51	1.85	2.1	4.46
<i>Lepidagathis cuspidata</i>	36	2.55	14.14	7.41	7.74	29.28
<i>Triumfetta rhomboidea</i>	18	1.00	5.56	3.7	3.99	13.25
Seedlings of Trees						
<i>Adina cordifolia</i>	9	0.09	0.51	1.85	0.66	3.02
<i>Ehretia laevis</i>	18	0.27	1.52	3.7	13.61	18.83
<i>Syzygium cumini</i>	18	1.82	10.1	3.7	0.56	14.37
<i>Toona ciliata</i>	18	0.82	4.55	3.7	0.21	8.45
Seedlings of Climbers						
<i>Atylosia volubilis</i>	9	0.09	0.51	1.85	0.22	2.58
<i>Atylosia scarabaeoides</i>	9	0.09	0.51	1.85	0.11	2.46
<i>Cissampelos pareira</i>	36	0.55	3.03	7.41	0.48	10.91
<i>Dioscorea bulbifera</i>	18	0.27	1.52	3.7	0.15	5.37
<i>Ichnocarpus frutescens</i>	27	0.45	2.53	5.56	0.6	8.68
<i>Pueraria tuberosa</i>	9	0.09	0.51	1.85	2.51	4.87
<i>Ventilago denticulata</i>	9	0.18	1.01	1.85	0.58	3.44
Seedlings of Shrubs						
<i>Carissa opeca</i>	18	0.27	1.52	3.7	4.45	9.67

<i>Murraya koenigii</i>	36	1	5.56	7.41	3.48	16.44
Name of the species	F	D	RDe	R F	R Do	IVI
<i>Murraya paniculata</i>	9	0.18	1.01	1.85	0.2	3.07
<i>Woodfordia floribunda</i>	9	0.09	0.51	1.85	0.05	2.4
Grasses						
<i>Arundinella pumila</i>	9	0.18	1.01	1.85	0.02	2.88
<i>Capillipedium parviflorum</i>	9	0.18	1.01	1.85	0.27	3.13
<i>Chloris dolichostachya</i>	9	0.27	1.52	1.85	0.03	3.4
<i>Nyraudia arundinacea</i>	9	0.36	2.02	1.85	1.31	5.18
<i>Oplismenus burmanii</i>	9	0.36	2.02	1.85	0.02	3.89
<i>Oplismenus compositus</i>	18	1.18	6.57	3.7	1.32	11.59
<i>Saccharum spontaneum</i>	9	0.27	1.52	1.85	13.73	17.1
*F = Frequency, D = Density/m ² , RDe = Relative Density, RF = Relative Frequency, RDo = Relative Dominance, IVI = Importance Value Index, H' = Species Diversity 1.28, CD = Concentration of Dominance 0.6						

Table 5: Phytosociological analysis of plants in herbaceous vegetation at the right bank of the river Ganges.

Name of the species	F	D	RDe	R F	R Do	IVI
Herbs						
<i>Achyranthes aspera</i>	80	2.6	10.74	10.26	2.12	23.12
<i>Aerva sanguinoenta</i>	50	1.1	4.55	6.41	0.42	11.37
<i>Ageratum conyzoides</i>	70	4.8	19.83	8.97	16.77	45.58
<i>Anisochilus carnosus</i>	10	0.1	0.41	1.28	0.11	1.8
<i>Artemisia nilagarica</i>	10	0.9	3.72	1.28	0.08	5.08
<i>Barleria cristata</i>	20	0.3	1.24	2.56	1.08	4.89
<i>Bidens pilosa</i>	50	2.7	11.16	6.41	0.86	18.43
<i>Blumea mollis</i>	10	0.1	0.41	1.28	0.1	1.8
<i>Boehmeria platyphylla</i>	10	0.1	0.41	1.28	0.14	1.84

<i>Boehrvia diffusa</i>	10	0.3	1.24	1.28	0.23	2.75
Name of the species	F	D	RDe	R F	R Do	IVI
<i>Cassia tora</i>	10	0.2	0.83	1.28	0.64	2.74
<i>Celosia argentea</i>	10	0.2	0.83	1.28	0.61	2.72
<i>Cleome viscosa</i>	10	0.1	0.41	1.28	0.32	2.02
<i>Commelina benghalensis</i>	10	0.2	0.83	1.28	0.08	2.19
<i>Eupatorium adenophorum</i>	10	0.7	2.89	1.28	8.62	12.79
<i>Euphorbia hirta</i>	20	0.6	2.48	2.56	0.54	5.58
<i>Justicia prostrate</i>	10	0.2	0.83	1.28	0.1	2.21
<i>Lepidagathis cuspidatus</i>	30	0.6	2.48	3.85	0.49	6.82
<i>Malvastrum coromandelianum</i>	20	0.4	1.65	2.56	0.44	4.66
<i>Nicandra physaloides</i>	20	0.3	1.24	2.56	9.88	13.68
<i>Oxalis corniculata</i>	20	0.5	2.07	2.56	19.5	24.14
<i>Parthenium hysterophorus</i>	10	0.2	0.83	1.28	0.26	2.37
<i>Passiflora foetida</i>	10	0.1	0.41	1.28	0.01	1.71
<i>Rumex hatatus</i>	10	0.3	1.24	1.28	3.03	5.55
<i>Urena lobata</i>	10	0.2	0.83	1.28	0.7	2.81
<i>Solanum nigrum</i>	10	0.1	0.41	1.28	0.14	1.84
Seedlings of Climbers						
<i>Atylosia scarabaeoides</i>	10	0.1	0.41	1.28	0.01	1.71
<i>Cissampelos pareira</i>	10	0.1	0.41	1.28	0.05	1.74
<i>Cissus repanda</i>	10	0.1	0.41	1.28	0.03	1.73
<i>Ipomoea hederifolia</i>	10	0.1	0.41	1.28	0.11	1.81
Grasses						
<i>Apluda mutica</i>	10	0.2	0.83	1.28	0.12	2.22
<i>Arthraxon lancifolius</i>	10	1.4	5.79	1.28	28.01	35.08
<i>Cynodon dactylon</i>	10	0.1	0.41	1.28	0.12	1.81

<i>Eragrostis tenella</i>	10	0.1	0.41	1.28	1.6	3.29
<i>Nyrandia arundinacea</i>	10	0.2	0.83	1.28	0.06	2.17
<i>Oplismenus burmannii</i>	40	1.5	6.2	5.13	0.57	11.89
<i>Oplismenus compositus</i>	10	0.8	3.31	1.28	1.1	5.68
Seedlings of Shrubs						
<i>Anisomeles indica</i>	10	0.1	0.41	1.28	0.15	1.84
<i>Lantana camara</i>	10	0.3	1.24	1.28	0.06	2.58
<i>Murraya koenigii</i>	10	0.1	0.41	1.28	0.09	1.79
<i>Nepeta graciliflora</i>	40	0.6	2.48	5.13	0.38	7.98
<i>Woodfordia floribunda</i>	10	0.1	0.41	1.28	0.01	1.71
Sedge						
<i>Eriophorum comosum</i>	10	0.2	0.83	1.28	0.24	2.35
<i>Kyllinga nemoralis</i>	10	0.2	0.83	1.28	0.02	2.13
F = Frequency, D = Density/m ² , RDe = Relative Density, RF = Relative Frequency, RDo = Relative Dominance, IVI = Importance Value Index, H' = Species Diversity 1.91, CD = Concentration of Dominance 0.87.						

In general, the riparian flora species are dependent on free spaces generating disturbing events for their germination and recruitment on the one hand and on flowing water for their dispersal on the other hand (Forman and Godron, 1986; Malanson 1993; Planty-Tabacchi et al., 1996; Jansson et al., 2000; Ward et al., 2002). Both processes (i.e. recurrent disturbance due to fragmentation and habitat connectivity through flowing water) will be impacted. Implications on the management of fragmentation, that affect the migratory fish species is of great concern. Hence, restoration program is prioritized to avoid genetic erosion of the species (e.g. hatchery and stocking programs). In case of the river fragmentation by dams or weirs, development of connectivity as a practical management are undertaken to restore the genetic integrity of populations. The approach proposed here is to conserve and preserve the existing habitat i.e. the river Nayar a spring fed river which is totally devoid of any developmental activities in the study area. The use of a larger spatial scale sampling design could be used for reaching at this specific goal.

The riparian floral species such as *Arundinella pumila*, *Capillipedium parviflorum*, *Chloris dolichostachya*, *Nyraudia arundinacea*, *Oplismenus burmannii*, *Oplismenus composites* and *Saccharum spontaneum* shall be taken into account for the enrichment of the habitats of the river Nayar

CONCLUSIONS

To conclude, our study demonstrates the importance of considering several species of riparian flora and aquatic fauna when investigating the effect of fragmentation mediated by humans. We have shown that the suitable habitat ecology is important to understand the influence of fragmentation on the integrity of fish populations. This means that to conserve connectivity through restoration programmes needs to be prioritized and targeted according to the specificity of each species. The riparian habitat of river Nayar will be the undisturbed area available for conservation as the other rivers Alaknada and Bhagirathi are fragmented due to various hydropower projects and the connectivity becomes negligible. Future experimental studies are needed to ascertain that the restoration programmes have contributed to the connectivity and conservation of the important fish fauna.

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PRESENT STATUS AND PROSPECTS OF MAHSEER FISHERY IN GARHWAL REGION OF CENTRAL HIMALAYA

by

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ABSTRACT

The newly created hill state, Uttaranchal, located in the Central Himalayan region of India, is endowed with vast natural freshwater resources. *Tor putitora* (golden mahseer) is one of the main game and food fish in the Central Himalayan region. However, the population of *Tor putitora* has greatly dwindled over the years, so much so that it constitutes only a negligible part of fishery in the majority of rivers and streams. The present study, carried out in six rivers of the west Uttaranchal, i.e. Garhwal region of Central Himalaya, has revealed that it contributes significantly only in one river, i.e. Nayar (32.8%). It constitutes about 9.7% of the total fish catch in the river Song, while in other rivers the percent population ranges between 0.8 and 3.1%. The catch size has also greatly decreased, ranging from 28.0 g and 13.5 cm to 1 650.0 g and 52.5 cm only. The average catch per unit effort of mahseer in the river Nayar was recorded as 67.92 g/man/hr with the minimum and maximum values being 25.0 and 875.5 g/man/hr. On the basis of ecodatabase, availability of the brooders, fry and fingerlings, only the river Nayar could be considered as a potential mahseer stream. The paper discusses the present status and prospects for the development of the fishery of golden mahseer in the Garhwal region of the Central Himalaya and the measures to be adopted for the rehabilitation of its stocks in suitable streams.

1. INTRODUCTION

The abundant surface water resource in the Central Himalayan region of India provides a great opportunity for the development of fishery of the golden mahseer. These denizens of Himalayan waters are a source of recreation for people from India and abroad and also have great food potential for hill people. Therefore, the mahseer may play a great role in the socio-economic development of the hill region. However, due to unthoughtful exploitation by man, the stocks of mahseer have greatly dwindled in these waters.

Though mahseer has great game and food value, the various attributes of its fishery have not been investigated comprehensively, especially in the Central Himalayan waters (Mishra *et al.*, 2000). Even the catch data from the major rivers are not available. Whatever studies have been done are sporadic and preliminary in nature, therefore the correct picture of mahseer fishery cannot be construed. The majority of the studies conducted until now are confined only to the biological aspects such as taxonomy, morphology, food and feeding, physiology, distribution, life history stages, length-weight relationships (Desai, 1972; Badola and Singh, 1980; Sen and Jayaram, 1982; Nautiyal and Lal, 1982, 1984 and 1984a, 1988).

The research work on the aquaculture feasibility, hatchery production of fish seed, development of suitable feeds, intensive culture in cages/raceways/running water systems is warranted for developing the technology package for the conservation, rehabilitation and propagation of mahseer in the Central Himalayan region.

The present paper deals with the above aspects for the development of fishery of golden mahseer in the Garhwal region of Central Himalaya.

2. DESCRIPTION OF THE STUDY AREA

The Garhwal Himalaya forms the western part of Central Himalaya. It is situated between the latitudes 29°26' – 31°28' N and longitude 77° 49' – 80° 6' E. The region has a total area of 30 090 km². The fresh water resources in the Uttaranchal State include 2700 km of rivers and their tributaries, 31 lakes spread over an area of about 300 ha, and 6 reservoirs encompassing 18 931 ha. There are also 1 341 ponds covering an area of 628 ha. The majority of the water resources are located in the Garhwal region. The geographical and physical features of selected streams, including the place(s) and altitude of sampling points, of Garhwal Himalaya are given in Table 1.

Table 1
Geographical and physical features of the selected streams of Garhwal Himalaya

Stream	Altitude (m) and the source	Type	Working place	Altitude of working place	Temperature range (°C)	Tributary of the major river
Bhagirathi	3 920 (Gomukhi)	Snowfed	Sirai to Old Tehri	750-640	10.2-23.5	Ganga
Bhilangana	3 560 (Khatling and Pholing)	Showfed	Bhado Ki Magari to Old Tehri	770-640	10.8-23.5	Bhagirathi
Western Hyuni	2 250 (Gukunda)	Spring fed	Nagani to Khadi	1 000-950	13.5-27.0	Ganga
Song	- (Strikunda)	Spring fed	Dorwala to Raiwala	425-380	18.5-27.5	Ganga
Khoch	1 951 (Langur)	Spring fed	Dogadda to Kotdwar	615-375	16.0-26.5	Ramganga
Navar	2 835 (Doodhatoli)	Spring fed	Satpuli to Vyasghat	760-442	14.0-26.0	Ganga

The rivers Bhagirathi, Alaknanda, Ganga, Yamuna and Western Ramganga constitute the main drainage system in Garhwal region. Alaknanda is the largest river, covering a distance of about 240 km. Bhagirathi is second largest and takes its origin at Gaumukh Glacier near Tibet border at an altitude of 3 600 m. It slopes down to Gangotri and Uttarkashi and receives the Bhilangana River at Tehri (Fig. 1). At Deoprayag the Bhagirathi and Alaknanda confluence to form the holy river of India, the Ganga.

The analysis of physical and chemical characteristics of water was done fortnightly at the sampling stations. The flow rate, average span and depth of the river were recorded using standard methods. Water temperature was recorded using mercury thermometer calibrated to 0.1°C. The pH and dissolved oxygen were analyzed using digital analyzers at the site. Free CO₂, total alkalinity and silicate were estimated following standard methods (APHA, 1985). Length, weight and width of fish were measured using measuring scale and monopan balance. Age of mahseer was determined by counting the annual rings in scales.

4. RESULTS

4.1 Physico-chemical characteristics

To find out the suitability of the selected streams for mahseer, an ecodatabase was prepared. The data on various physical and chemical characteristics of water of various rivers are given in Table 2.

During the study period the average water temperature ranged from 9.0 to 27.8°C. The snow-fed river Bhagirathi had the lowest and spring-fed river Nayar had the highest temperature. Average water temperature fell below 6°C in the Bhagirathi River. Excepting Bhagirathi and Bhilangana, the average depth of the rivers was between 0.4 and 1.75 m. Bhilangana and Bhagirathi are deeper, with depth ranging between 1.0 and 8.0 m. Water current was faster in the snow-fed rivers Bhagirathi and Bhilangana, with maximum values of 1.6 to 2.0 m/s, than in the spring-fed rivers (0.5 to 0.7 m/s). The average width was highest in Bhilangana (17.1m) and Bhagirathi (21.0 m), while it varied between 6.8 and 12.9 m in the rivers Hiyunl, Song, Khoh and Nayar. The water of all rivers had almost similar average transparency (30.1-32.4 cm), but individual values reached up to 44 cm in the river Nayar during February. Rivers Nayar and Bhagirathi had highest concentrations of total dissolved solids (161.0-162.8 mg/L); relatively lower values were recorded in rivers Hiyunl, Song and Khoh (114.5 to 132.2 mg/L). Excepting Bhilangana, which had a mean pH value of 6.0, the water of other rivers was neutral to slightly alkaline (pH 7.0-7.5). The maximum pH (7.9) was recorded in the river Song during April. All rivers and streams had good concentrations of dissolved oxygen (range 6.0 to 12.0 mg/L). The maximum concentration was found in the river Bhagirathi during January and the minimum was recorded during July in the river Song. The free CO₂ showed wide fluctuation in concentration from 0.0 to 8.0 mg/L, but its values ranged between 2 and 4 mg/L in most of the selected rivers during the study period. Higher concentrations occurred during the monsoon period. Marked differences existed in the total alkalinity concentrations. While the Song had an average value of 184.3 mg/L, the mean concentration in the Bhilangana was only 38.6 mg/L. In general, alkalinity is higher in spring-fed than snow-fed rivers. The silicate content was higher in snow-fed (0.5-0.6 mg/L) than in spring-fed rivers (0.1-0.4 mg/L).

4.2 Biological characteristics

The average periphyton (aufwuchs) densities ranged from 170 no/cm² (Western Hiyunl) to 490 no/cm² of substrate (Nayar). Hiyunl and Khoh had lower densities than other rivers (Table 3). Bhilangana and Bhagirathi both supported moderate densities of periphyton.

Table 2

Annual mean and range of water quality parameters in different rivers in Garhwal region
The data are averaged across the various sampling stations

Parameter		River- Western Hiyunl	River- -Song	River- -Khoh	River- -Nayar	River- -Bhilangana	River- -Bhagirathi
Water temperature (°C)	Average	20.6	22.3	22.0	20.1	17.8	16.9
	Range	13.0-26.9	15.0-27.0	13.4-27.8	10.0-26.4	9.5-25.5	9.0-25.5
Water depth (cm)	Average	0.79	0.83	0.61	0.84	2.02	4.48
	Range	0.45-1.3	0.35-1.75	0.4-0.85	0.7-1.2	1.0-2.8	2.0-8.0
River width (m)	Average	8.6	11.85	6.88	12.97	17.1	21.0
	Range	6.0-11.2	7.5-14.5	4.4-9.6	7.0-18.5	12-22.6	12-29.0
Flow rate (m/s)	Average	0.6	0.7	0.5	0.6	0.9	1.2
	Range	0.4-0.9	0.5-1.0	0.4-0.8	0.5-1.2	0.6-1.6	0.9-2.0
Transparency (cm)	Average	31.9	32.12	33.22	30.70	30.17	32.43
	Range	27.2-42.0	26.5-42.0	27.5-42.0	23-44	14.5-40.0	15.4-29.0
Total solids (mg/L)	Average	123.4	132.2	114.5	162.8	156.2	161
	Range	102-150	92.0-195.0	92.2-128	110-210	136.8-165.61	145-171
PH	Average	7.0	7.5	7.0	7.0	6	7.0
	Range	6.8-7.2	7.4-7.9	6.9-7.2	6.8-7.2	6.6-7.0	6.8-7.0
DO (mg/L)	Average	8.0	7.8	7.6	8.1	8.0	7.9
	Range	7.4-8.8	7.2-9.0	6.8-8.2	6.0-8.8	6.6-8.8	7.2-9.2
Free CO ₂ (mg/L)	Average	1.74	1.66	2.2	2.3	2.7	2.31
	Range	0-8.0	0-8.0	0-4.0	0-6.0	0-6.0	0-6.0
Total alkalinity (mg/L)	Average	122.6	184.3	89.4	80.9	58.6	73.1
	Range	106-142	150-210	72-106	56-112	44-84	56-90
Silicate (mg/L)	Average	0.1	0.3	0.3	0.4	0.5	0.6
	Range	0.34-0.22	0.05-0.88	0.1-0.66	0.22-0.70	0.45-0.65	0.60-0.71

Table 3
Periphyton (aufwuchs) densities in selected rivers of Garhwal Himalaya
 The data are averaged across all sampling stations in the rivers

Density (no/cm ²)	River- Western Hiyunl	River- Song	River- Khoh	River- Nayar	River- Bhilangana	River- Bhagirathi
Average	170	247	188	490	305	370
Range	11-542	6-1 183	40-701	40-1 208	12-1 329	14-655

In terms of group composition, Chlorophyceae (green algae) and diatoms were the sole components of periphyton (Fig. 2). Chlorophyceae comprised 24.4 to 47.9%, whereas diatoms constituted 52.1 to 75.6% of the total annual population. Green algae were most dominant in Khoh; the maximum population of diatoms was recorded in river Nayar (75.6%).

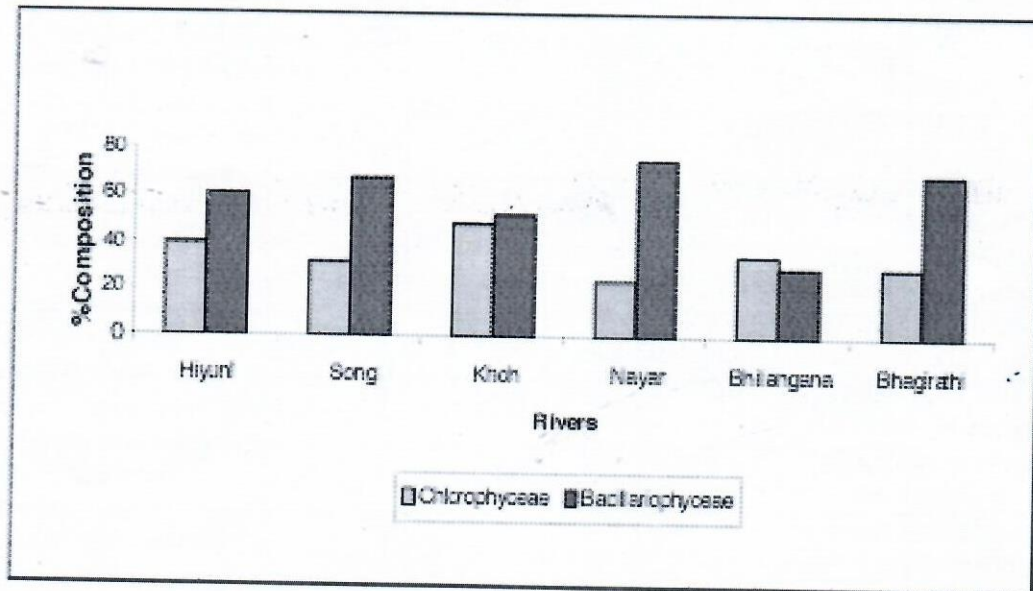


Fig. 2 - Mean percent composition of periphyton groups in different rivers of Garhwal Himalaya

The zooplankton population ranged between 58 and 77 ind./L (Table 4). The lowest and highest population was recorded in the rivers Bhilangana and Song, respectively.

Table 4
Mean standing crop of zooplankton in different rivers of Garhwal Himalaya
 The data are averaged across all sampling stations

Standing crops (no/L)	River-Western Hyuni	River-Song	River-Khoh	River-Nayar	River-Bhilangana	River-Bhagirathi
Average	59	77	75	67	58	77
Range	10-208	1-288	19-182	9-198	16-125	12-166

Protozoans, rotifers, copepods and cladocerans represented the zooplankton community. Protozoans comprised 24.0 to 44.7% of the total zooplankton (Fig. 3). The percent population of the other zooplankton varied from 59.1 to 76.0%. Annually, the population was apportioned between protozoans (33.6%) and other zooplankters (64.4%).

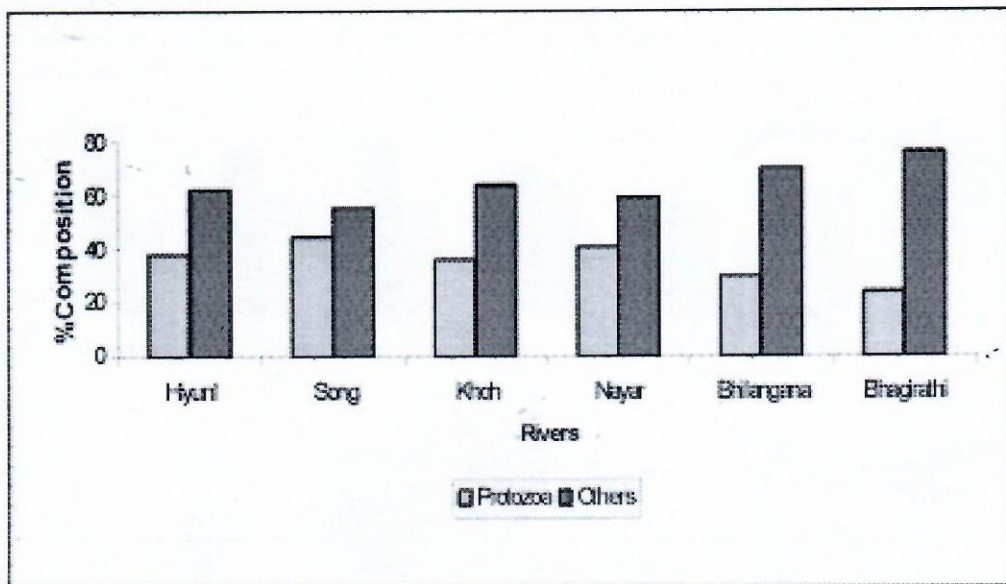


Fig. 3 - Mean percent composition of zooplankton groups in rivers of Garhwal Himalaya

The benthic fauna in the rivers comprised of Ephemeroptera, Odonata, Plecoptera, Hemiptera and Diptera. The annual range of the benthic fauna varied most in the Nayar River (Table 5). The Nayar River was the richest while the Bhagirathi had the lowest population. In general, spring-fed streams had more benthic fauna than snow-fed rivers.

Table 5
Mean abundance of macrobenthic fauna in different rivers of Garhwal Himalaya
 The data are averaged across all sampling stations

Mean abundance (no/m ²)	River- Western Hlyuni	River- Song	River- Khoh	River- Nayar	River- Bhilarangana	River- Bhagirathi
Average	920	1411	1188	1624	698	429
Range	196-2 003	285-3 126	290-3 116	125-3 415	245-1 341	111-1 200

The ephemeropterans were most abundant with annual mean percent population in different rivers varying between 32.4 and 47.2. Again, the lowest and highest values were recorded in the rivers Bhagirathi and Nayar, respectively (Fig. 4).

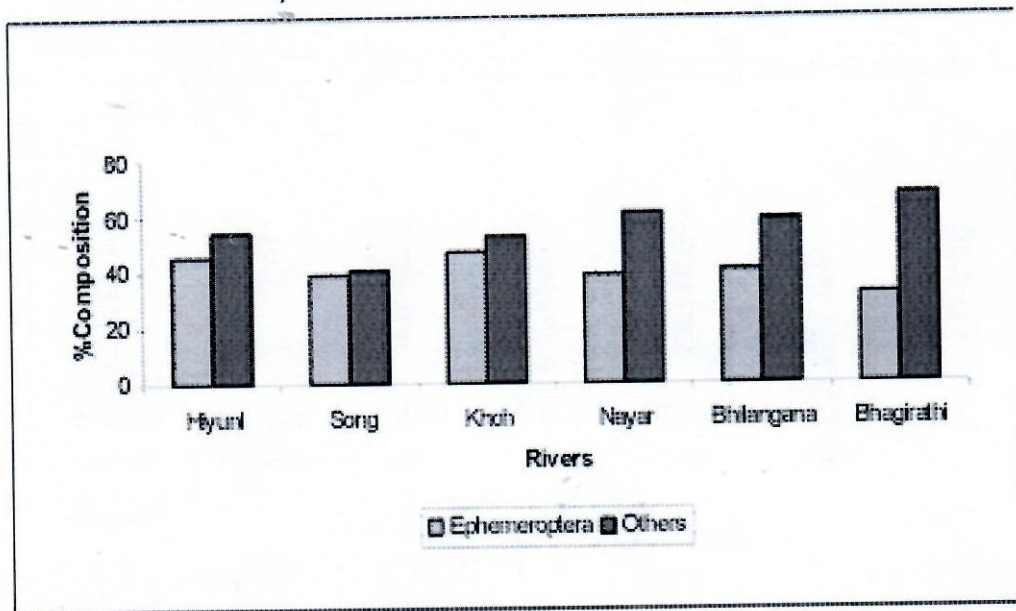


Fig. 4. Mean percent composition of macrobenthic groups in different rivers of Garhwal Himalaya

4.3 Ichthyofauna

The fish fauna of the rivers of Garhwal Himalaya is represented by *Schizothorax* spp., *Tor putitora*, *Labeo dero*, *Labeo dyocheilus*, *Garra gotyla*, *Crossocheilus latius*, *Barilius bendelisis*, *Glyptothorax pectinopterus*, *Mastacembelus armatus* and *Botia* spp (Table 6).

Table 6
Fish species found in rivers of Garhwal Himalaya

River/Stream	Fish Species
Western Hyam	<i>Tor putitora</i> , <i>Schizothorax</i> spp., <i>Labeo dero</i> , <i>Crossocheilus latius</i> , <i>Barilius bendelisis</i> , <i>Botia</i> spp., <i>Glyptothorax pectinopterus</i>
Song	<i>Tor</i> spp., <i>Mastacembelus armatus</i> , <i>Labeo dyocheilus</i> , <i>Labeo dero</i> , <i>Schizothorax</i> spp., <i>Barilius bendelisis</i>
Khoh	<i>Schizothorax</i> spp., <i>Tor putitora</i> , <i>Barilius bendelisis</i> , <i>Garra gotyla</i>
Nayar	<i>Tor putitora</i> , <i>Barilius bendelisis</i> , <i>Schizothorax</i> spp., <i>Mastacembelus armatus</i> , <i>Labeo dero</i> , <i>Labeo dyocheilus</i> , <i>Garra gotyla</i>
Bhilangana	<i>Schizothorax</i> spp., <i>Tor putitora</i> , <i>Garra gotyla</i>
Bhagirathi	<i>Schizothorax</i> spp., <i>Tor putitora</i> , <i>Garra gotyla</i>

Schizothorax spp. are most important in the rivers, with total contribution of 52.6% on the basis of the mean values of the fish catch from 15 sampling stations on 6 representative rivers/streams (Fig. 5).

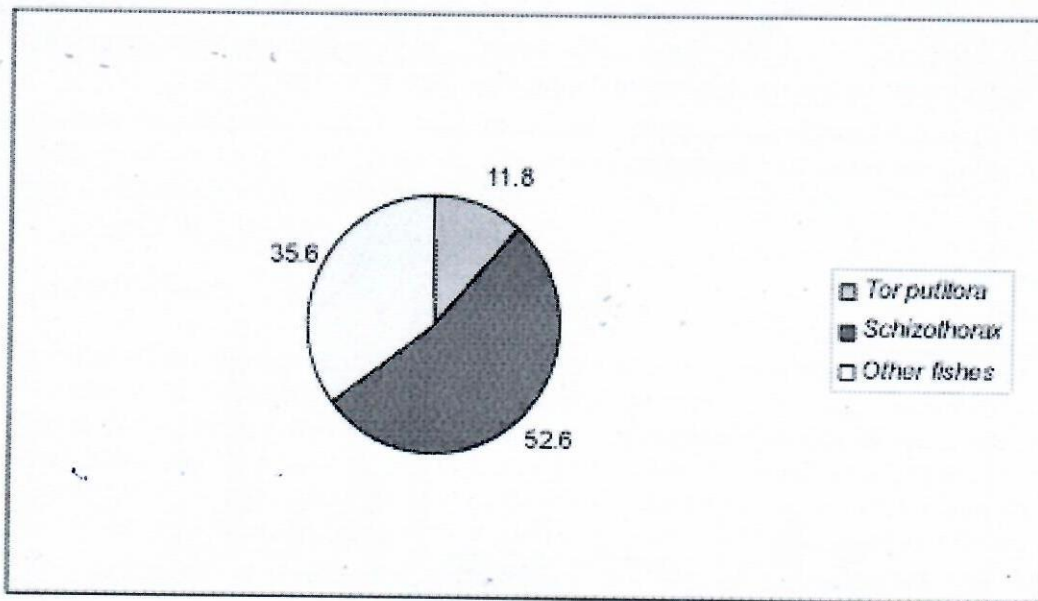


Fig. 5 - Percent composition of fish in the Central Himalayan rivers

The mean contribution of *Tor putitora* comes to only 11.8%. After *Schizothorax*, the major fishery is comprised of species of subsistence values, viz. *Barilius* spp., *G. gotyla*, *Labeo* spp.

The catch data in terms of numbers and percentage of *Tor putitora*, *Schizothorax* spp. and other fish are given in Table 7. *Tor putitora*, with percent contribution of 32.8% of the total fish population, is the most dominant fish in the river Nayar; Song, with 9.7% population of *T. putitora*, ranks second.

Table 7
Fish catch statistics at various sampling stations in different rivers of Garhwal region

Groups	Western Hyalul	Song	Khoh	Nayar	Bhilangana	Bhagirathi
<i>Tor putitora</i>						
Total No.	1.67	30.67	1.5	119.33	5.5	4.5
Percentage	0.8	9.7	0.9	32.8	3.1	2.6
<i>Schizothorax</i> spp.						
Total No.	84.33	80.33	81.5	181.33	141.5	156.5
Percentage	48.1	26.4	25.4	51.5	84.2	90.6
Miscellaneous						
Total No.	87.67	193.67	120.5	55.33	21	12
Percentage	51.0	63.8	73.6	15.5	12.6	6.7

The data are averaged across all the sampling stations

The percentage catch of *T. putitora* in the selected rivers is shown in Fig. 6. The percent catch is 0.0-6.0% in the rivers Bhilangana and Bhagirathi, while in the river Nayar it comes to 2 to 60%, with a maximum being recorded during May, September and October.

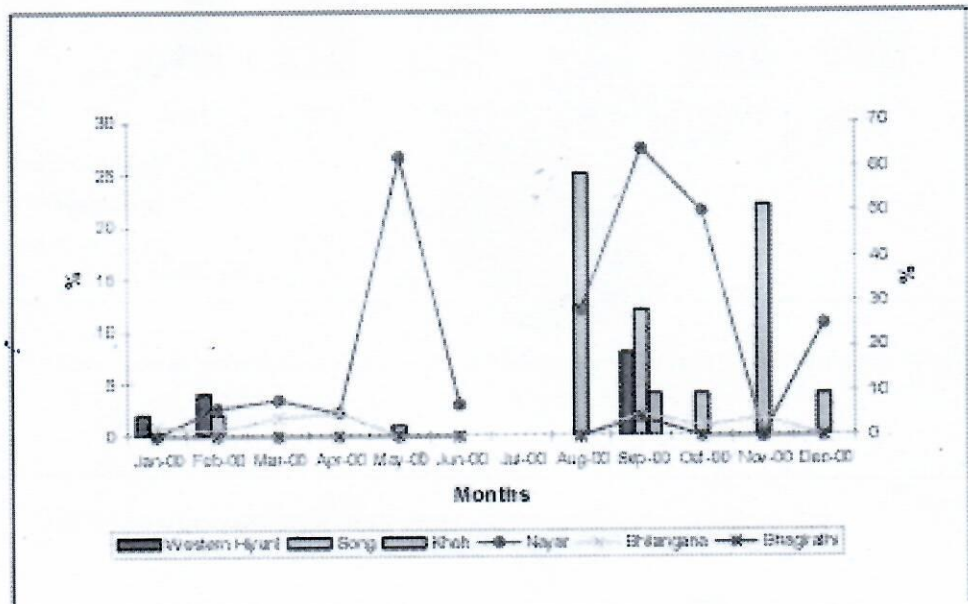


Fig. 6 - Percentage catch of golden mahseer in selected rivers of Garhwal Himalaya

In the river Song, the maximum population (20%) was also recorded during monsoon season. In other rivers of the Garhwal region, the catch percentage is quite low and is between 0 and 1% of the total catch.

The total catch per unit effort (CPUE) of *T. putitora* ranged from 4.3 to 270.6 g/man/h in the selected rivers (Fig. 7). The highest CPUE was obtained from the river Nayar. The total CPUE ranged from 340.1 to 1 891.0 g/man/h.

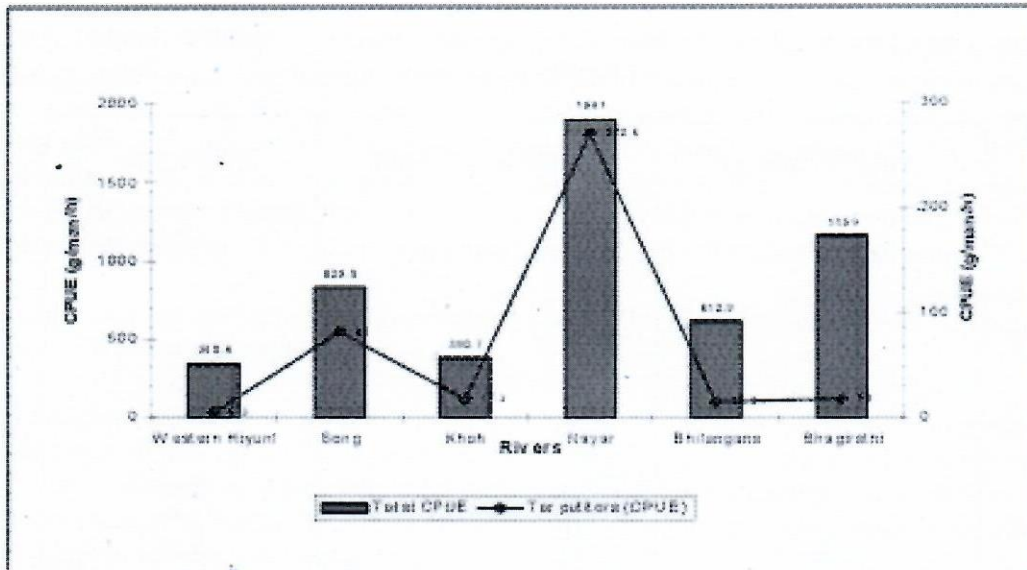


Fig. 7 - Mean CPUE of total fish population and *Tor putitora* in different rivers of Garhwal region

In terms of weight, maximum catch size of mahseer varied between 200 and 400 g. Only during July-September were mahseer above 1.0 kg weight recorded from the rivers Nayar and Song. From the other selected rivers the catch of mahseer was very low, with weight range of 200 to 500 g. Overall, weight range of *T. putitora* during the period of investigation ranged from 25 to 1 650 g, their body length ranged from 10.5 to 52.5 cm and width from 2.0 to 9.5 cm (Table 7). The harvested golden mahseer were in the age group of under one year to above three years.

5. DISCUSSION

An appraisal of the ecosystem characteristics of the selected rivers/streams of the Ganga river system in the Garhwal region of Central Himalaya reveals that all spring-fed rivers are 'placid eurythermal', with increased range of temperature. The glacier-fed rivers, on the other hand, can be classified as 'torrential stenothermal'. Singh *et al.* (1991) have recognized the altitudinal range of 600-1 200 m as the mahseer zone. All the sampling sites of the selected rivers in the present study were located in the range of 425-1 000 m altitude. In general, the glacial-fed streams Bhagirathi and Bhilangana had low temperature, steep gradient, swift water current, high dissolved oxygen content and mildly acidic to slightly alkaline pH. All these factors together determine the distribution and abundance of periphyton and benthos.

Table 7
Total weight, total length and width of the harvested mahseer from the selected streams of Garhwal Himalaya

Total weight (g)	Total length (cm)	Width (cm)
25	10.5	2.0
50	16.0	2.6
75	17.0	3.0
100	20.0	3.0
150	24.0	4.0
175	23.0	4.3
200	23.0	4.4
350	28.5	5.0
550	32.0	5.5
800	39.5	7.8
1000	49.2	9.0
1650	52.5	9.5

The spring-fed streams of the Central Himalayan region have relatively high temperature (10.0 to 27.5°C), low current velocity (0.4 to 1.2 m/s), and a relatively confined channel basin (4.4 to 18.5 m). The dissolved oxygen content was also lower than in the glacier-fed streams (6.6 to 8.8 mg/L). However, pH was slightly higher (7.0-7.9) and total alkalinity was much higher (0.9 to 184.3 mg/L). Current velocity and water temperature greatly influence the periphyton (aufwuchs) density in the streams of Central Himalaya. It was higher in spring-fed streams than glacier-fed ones. The river Nayar had higher plankton population than the rivers Bhagirathi and Bhilangana. Singh *et al.* (1991) and Dobriyal and Singh (1989) also reported a similar trend in some hill streams of Garhwal Himalaya.

Like periphyton, the macrobenthic invertebrate fauna was also higher in spring-fed streams. The higher temperature, moderate current, good periphyton and allochthonous matter coupled with a high substrate heterogeneity enhance the density of macrobenthic fauna in spring-fed streams. Dobriyal and Singh (1990) reported that this provides a good base for the development and growth of minor carp fishery in Central Himalayan waters.

The golden mahseer is the most important game and food fish in the Central Himalaya. It contributes greatly to the commercial fishery in the foothills. The fish migrates considerable distances upstream in the search of suitable spawning grounds (Badola and Singh, 1984; Nautiyal and Lal, 1984; Singh, 1988). However, once found in abundance, the stocks of the Himalayan mahseer are depleted to the extent that it is now considered as an endangered species (Singh *et al.*, 1991). The decline of mahseer fishery has also been reported from the other Himalayan waters such as the Ganga river system (Chauhan *et al.*, 1992), Brahmaputra river system (Dey, 1992), Govind Sagar reservoir (Johal and Tandon, 1981), Kumaun lakes (Sharma, 1991) and some other waters.

The present investigations also reveal that the population of golden mahseer has greatly declined in the waters of Western Central Himalaya. It contributes significantly to the fishery only in the spring-fed river Nayar where it comprises 32.8% of the total catch. The second best

contribution (9.7%) was in the river Song. In other streams the contribution ranges only between 0.8 and 3.1%. The brooders, yearlings, fry and fingerlings of golden mahseer were observed in the river Nayar only. The average seed density was between 300-400 no/m² at the confluence of the rivers Nayar and Ganga at Vyasghat (Fig. 1).

Himalayan mahseer population undertakes contranant migration from the foothill sector of the Ganga, often ascending into the rivers Bhagirathi and Bhilangana. These major tributaries serve as the only routes through which the fish can have easy access to the spring-fed placid streams providing congenial environment for the fish to breed (Nautiyal and Lal, 1984). However, the present observations reveal that only Nayar is a potential mahseer spring-fed stream in the Western Central Himalayan region. However, the size of the catch was also very low from Nayar (25 to 1 650 g) as per observations during the period of investigation.

The factor that has brought Himalayan mahseer to the brink of extinction is indiscriminate killing of juveniles and brooders.

Mass slaughter of fish through toxicants and dynamite is common, particularly in uplands. Fishing by fixed gears is also a common example of indiscriminate fishing. Intensification of fishing effort during the pre-monsoon period, when water level in rivers is low, adds to the problem. Changes in the habitat due to construction of dams, barrages and weirs under river-valley projects adversely affect the biology of this fish.

Prospects of mahseer fishery development

In spite of depletion of the population of golden mahseer, there is tremendous scope to develop its fishery for both commercial and recreational purposes. Based on the present investigations a three-fold strategy is suggested for the development of the fishery of *Tor putitora* in Garhwal Himayala:

(i) Preservation of existing stocks:

Fish protection in the rivers and other water systems of the region will be helpful in preserving valuable fish genetic resources (Singh and Singh, 1991). The following conservation measures are suggested:

- proper stock assessment should be undertaken for determining the present status of commercial fishery and its subsequent level of exploitation,
- ban on indiscriminate fishing should be strictly enforced,
- closed seasons should be rigidly enforced and there should be a total ban on capture of juveniles and spawners,
- selected stretches of water bodies should be declared as mahseer sanctuaries.

(ii) Promotion of natural propagation:

- the spawning and nursery habitats of Himalayan mahseer in small hill streams, which contain abundance of benthic entomofauna and serve as natural nurseries for the breeding population of mahseer, should be identified and protected,
- foliage cover should be provided on banks of streams to prevent wide fluctuations in temperature and to prevent soil erosion,
- artificial pools should be created in rivers for better spawning conditions,
- hindrances to spawning migration should be cleared,

- collection of post-larvae and fry/fingerlings, their rearing up to advanced fingerling stage on formulated feeds, and restocking in natural waters for better survival should be the future strategy for enhancing mahseer stocks in Himalayan waters.

(iii) Hatchery development and seed production of *Tor putitora*

Successful breeding and seed production programme of *Tor khudree* has been carried out for two decades at the Fish Seed Farm of the Tata Electric Company at Lonawala (Ogale, 1992). However, efforts made to induce-breed pond-reared broodstock of *T. putitora* by hypophysation have not been very successful (Joshi, 1994). Further, the availability of broodstock from nature is still minimal. The studies on the maturity and fecundity have shown that eggs mature in batches (Bhatnagar, 1967). The total number of eggs taken from females varied from 500 to 10 000 (Sehgal, 1991).

For the protection, rehabilitation and aquaculture of Himalayan mahseer the following is needed:

- a reliable breeding technology be developed, trial tested and replicated,
- hatchery, nursery and rearing technologies of *T. putitora* be developed,
- selective breeding of mahseer using brooders from nature be done for stock improvement,
- mahseer hatcheries be established near the stocking sites,
- hatchlings of mahseer be raised on formulated diets up to fingerling stage.

The hatchery-produced fingerlings of mahseer should be stocked regularly in selected streams and lakes to replenish their mahseer fish stocks and the feedback data from mahseer fishery should be collected and analysed.

There is good scope for the extensive and intensive culture of *T. putitora* in the Garhwal Himalaya. The streams located in the suitable altitudinal zone can be selected for the culture of Himalayan mahseer. There are innumerable spring-fed perennial streams where water could be diverted into narrow ponds or raceways alongside such streams. The fish can be raised on protein rich pelleted feed. The development of hatchery production of fish seed and its ranching in rivers and lakes of Central Himalaya can successfully bridge the gaps in production. Mahseer aquaculture in suitable localities should also be tested through pilot studies.

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