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Present status and future prospects of fisheries of Tehri dam reservoir

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ABSTRACT

Fisheries in India are a burgeoning industry with immense potential and opportunities. Ironically, because of its enormous but untapped potential, reservoir fisheries are called as "a sleeping giant". The average productivity from these reservoirs in India is about 30 kg/ha compared to the production potential of 250 kg/ha. Inadequate management leads to low rate of fish production in Indian reservoirs. A major impediment to science -based fish productivity in reservoirs is the lack of authentic data on target stocks. Inland fisheries, like those in reservoirs, are particularly affected. Investigators generally rely on simple catch statistics and hypothesis statements to assess fish production and potential yields due to inadequate resources, population data, and experts in the area. The present paper emphasizes the quintessential 44sq km huge Tehri hydro-power dam reservoir, located in the Bhagirathi and Bhilangana valleys of the lesser Himalayas in the Garhwal hills. On average the fish productivity from Tehri reservoir in the year 2021-2022 is reported as 13.75 kg/ha but, this is significantly lower than its actual productivity. Thus, the current technical paper addresses this issue by condensing and synthesizing the current status of fisheries in the Tehri Dam reservoir with past status in terms of fish species diversity. It provides baseline information on fish production and various data shortfalls in fisheries activity management. The paper also describes the ecological and economic aspects that affect fish catch to utilize the reservoir resources and mired the cold-water fishery management in the Tehri reservoir.

Introduction

India is the third largest fish-producing country in the world. The total fish production during 2022-23 was estimated at 17.54 MMT (Million Metric Tons) with a contribution of 13.11 MMT from the inland and 4.43 MMT from the marine sector (Ministry of Fisheries, Animal Husbandry & Dairy, 2023). The fishery activities in inland waters generally represent an important source of livelihood for poor denizens' well-being but the potential of inland fisheries is often overlooked. The north Indian state of Uttarakhand has a huge inland water resource, producing around 7000 metric tons (0.007MMT) of fish during the year 2022-23 (Hand book of Fisheries Statistics, 2023). This is very low as compared to other states while it has abundant inland water resources in the forms of rivers, streams, natural lakes, reservoirs and ponds. The Fisheries Resource of Uttarakhand comprises fast-flowing rivers, streams, high and low-altitude natural lakes, reservoirs and ponds. Fisheries in the rivers and streams are subsidiary in nature and not organized (Agarwal *et al*., 2005). Out of the 297 hectares of natural lakes, only a few lakes at lower altitudes are managed for limited sport fishing activity by the State Fishery Department. Apart from natural lakes several man-made lakes and reservoirs have come into existence in the past by the construction of Hydroelectric projects. These hydropower reservoirs are an important resource for fisheries development. The average fish productivity of reservoirs in India is estimated at 30 kg/ha compared to the production potential of 250 kg/ha (Paul *et al*., 2017). Presently seven reservoirs of 17,395 hectares are being harnessed for commercial capture fishery. Tehri Dam Reservoir is one of the largest reservoirs among seven with a total spread area of about 44 sq km. It came into existence in 2006 through the impoundment of River Bhagirathi and River Bhilangana for the Tehri hydropower project. The local communities surrounding the reservoir used to catch fish from the reservoir and its tributaries for fish as food and daily earnings. The culture fishery in hilly terrain is

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very rare and negligible. No report is available on the fish production from the Tehri reservoir. Information on the fish yield from the water body plays a significant role in the sustainable development, optimum production and management of fish wealth. This paper describes the present status and management strategies for fish production enhancement from the Tehri Dam reservoir.

Study area

Tehri Dam reservoir is the largest reservoir of Uttarakhand. It is located at an altitude of 78˚ 28'46.074 E to 30˚ 22'38.7984 N. The reservoir is primarily developed for hydroelectric purposes with secondary objectives of irrigation and fisheries development. The study area lies in the lesser Himalayan region along the Bhagirathi and the Bhilangana river between Tehri- Chinyalisaur and Tehri- Ghansali. The salient features of the Tehri Dam reservoir are presented in Table 1.

Materials and Methods

The reservoir area between Tehri-Chinyalisaur and Tehri-Ghansali along the Bhagirathi and Bhilangna impoundment was thoroughly surveyed throughout April 2021-March 2022 for gathering information about the fishing operation areas and fish landing sites in the reservoir, fishing methods, fish diversity and fish yield. The seven fishing areas were identified as –Chinyalisaur (78˚20'02.43"E, 30˚34' 23.14 "N), Bhaldiyana (78˚24'20.38"E, 30˚28'8, 15"N), Dobra-Chanti (78˚26'22.15"E, 30˚26'49.90 "N), Koti (78˚27'55.65"E, 30˚24'13.15"N), Tipri (78˚30'15. 09"E,30˚22'50.83"N), Peepal-dali (78˚33' 18.08"E, 30˚22'21.85"N), and Pilkhi (78˚38'00.60"E, 30˚25 '03.91"N). The GPS fixed map was generated by the software Qgis 3.36 and Google Earth Pro (Figure 1).Fishermen, while fishing in the reservoir were approached to observe the types of fishing crafts and gears used by them. The most common methods were cast net and gill net of varied mesh size viz- 15×15 mm, 45×45 mm and 75×75 mm. The fishers mostly used small manually operated boats and occasionally mechanized boats were also seen in operation for spreading the fishing nets. The fish caught from various fishing sites were gathered at two landing centres- Dobra-Chanti and Gadoliya. The broad segregation of species was done at the landing centre. The records of the daily catch were maintained in the register. The daily fish catch record of Tehri reservoir for the past six years was acquired from the District office of the State Fisheries Department to analyse the monthly and yearly fish production and species composition.

Table 1. Salient features of Tehri Dam Reservoir

Technical details	Tehri dam reservoir
District	Tehri Garhwal
Location	78˚ 28'46.074" E to 30˚ 22'38.7984" N
River impoundment	The Bhagirathi and Bhilangana rivers
Water spread area at full reservoir level	4400 Hectare
Water spread area at dead storage level	1800 Hectare
Average area	3200 Hectare
Full reservoir level (FRL)	El 830 m
Maximum water level (MWL)	El 835 m
Dead Storage level	El 740 m
Gross Storage	3540 MCM
Dead Storage	925 MCM
Live Storage	2615 MCM
Normal annual rainfall	1016 to 2630 mm
Maximum width (estimated)	3 km
Average width (estimated)	0.50 km
Upstream of dam site on river Bhagirathi	44km
Upstream of dam site on river Bhilangana	25km

Result and Discussion

Current status

The reservoir is situated in a region with mountains, it forms a river valley and is often surrounded by slopes composed of debris and matter carried by rivers. Tehri reservoir belongs to the medium-class reservoir category as its total water spread area is 4400 hectares and less than 5000 hectares (Sugunan, 1995). The variations in water levels between maximum reservoir level (MRL) and dead storage level (DSL) are linked to hydro-power generation processes by the dam authority and seasonal inflow of water in the reservoir from its two feeding rivers – the Bhagirathi and the Bhilangana. The valley slopes, near the reservoir's periphery during maximum reservoir level are divided into two distinct zones: a dry zone that is over the reservoir level and a water-submerged zone that is less than the reservoir level. Damming surface runoff from the Bhagirathi and Bhilangana Rivers is mainly used for irrigation and electricity production. The fishery is considered a secondary activity in the Tehri Hydropower reservoir. The Fisheries Department of Uttarakhand start-

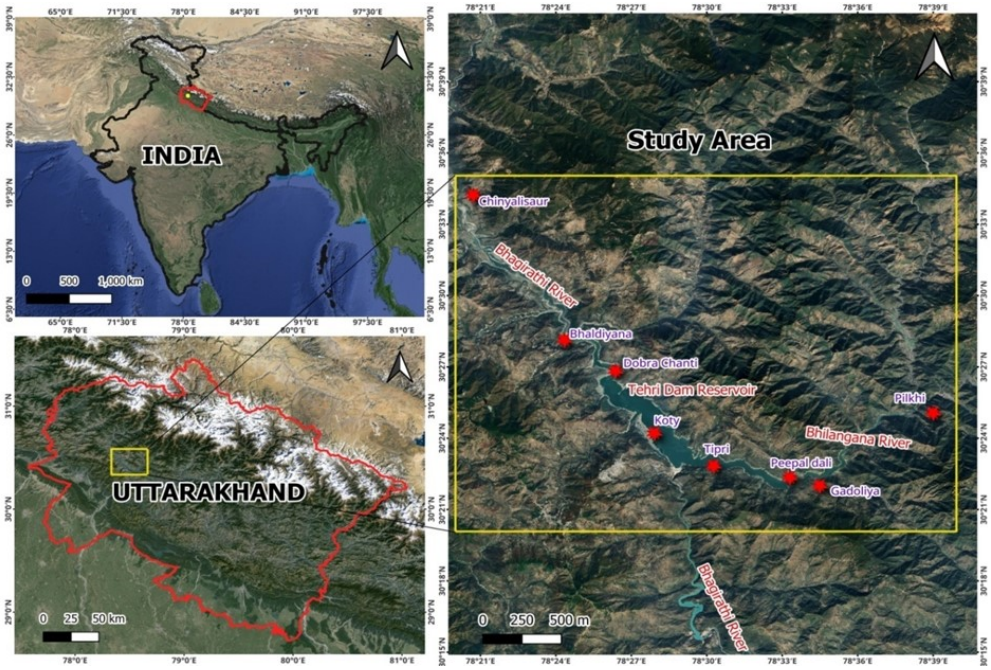

Figure 1. Location map of Tehri Dam Reservoir

ed auctioning fishing rights in the reservoir area first in 2016 through open tender with some terms and conditions. The fisheries department ensures compliance with all regulations and guidelines, such as obtaining permits, following catch limits, adhering to fishing seasons and maintaining the ecological balance in the reservoir, set forth for the person or company for fishing in the reservoir. The auction of fishing rights in the reservoir serves various purposes, including revenue generation, managing fishing pressure to maintain ecological balance, and ensuring equitable access to fishing opportunities. Fishing activities that rely exclusively on harvesting wild fish stock i.e. focus on capture fisheries in Tehri reservoir rather than cultured fisheries. The fish population naturally reproduces, or they may be supplemented through stocking programs managed by the state fisheries department. After the impoundment of the rivers for the Tehri reservoir, only eight species belonging to the Cyprinidae family are recorded (Table 2). This is due to alterations of peculiar fast-flowing riverine habitat into slow-moving lacustrine habitat, deep water having steep banks, muddy substratum, This is due to alterations of peculiar fast-flowing riverine habitat into slow-moving lacustrine habitat, deep water having steep banks, muddy substratum, This is due to alterations of peculiar fast-flowing riverine habitat into slow-moving lacustrine habitat, deep water having steep banks, muddy substratum, high-rise water columns and increased

Table 2 : Fish landing (Kg) from Tehri dam reservoir during April 2021-March 2022

Months	*C.catla*	*C.mrigala*	*H.molitrix*	*L. rohita*	*C.carpio*	*T.putitora*	Total
April-21	0	20	0	0	1660	6191	7871
May	40	82.5	0	0	4733.5	5289	10145
June	214.3	118.7	9.5	31.5	3014	2195	5583
July*	0	0	0	0	0	0	0
August*	0	0	0	0	0	0	0
September	0	30	0	0	1743	3864	5637
October	0	9	0	0	3911	6173	10093
November	0	0	0	0	1378	3904	5282
December	0	0	0	0	707.5	4933	5640.5
January-22	0	0	0	0	1083	2547	3630
February	0	0	0	0	90	2057	2147
March	0	0	0	0	57.5	4456	4513.5
Net production	254.3	251.2	9.5	31.5	18377.5	41609	60533

***fishing are not performed in these months due to fishing close season**

surface temperature and comparatively low dissolved oxygen (Agarwal *et al.*, 2018; Singh, 2018). The study shows that the fish catch is dominated by *Tor putitora* accompanied by *Cyprinus carpio* (an exotic species introduced by dam authorities) with a rare occurrence of *Tor tor* and a snow trout species-*Schizothoraichthys progastus*. The reservoir is devoid of bottom-feeder hill stream indigenous fish species. The indigenous column feeder fish species *Tor putitora* (Mahseer), *Tor tor* and *Schizothoraichthys progastus* are adapted to the deep waters of the reservoir to some extent (Agarwal *et al.*, 2018; Singh, 2018). Indian major carp like - *Catla catla, Labeo rohita, Cirrhinus mrigala,* and *Hypophthalmichthys molitrix* were recently introduced in the year 2016 by the State Fisheries Department from the viewpoint to increase the fish wealth of the reservoir. In comparison to indigenous fishes, Indian major carp and exotic species are seen in large numbers. This is possibly due to the less adaptability of indigenous bottom-feeder fishes in impounded water and also tough competition by the introduction of exotic common carp. Similar observations on the reduction in fish species composition with the change in river habitat are also reported by Khan, (2004); Lakra *et al.*, (2010); and Chen *et al.* (2023). The decline of indigenous snow trout in Kashmir has also occurred after the introduction of common carp (Raina and Pter, 1999; Zutshi and Gopal, 2000; Khan, 2004). In the impoundment segment of Tehri reservoir, *Tor putitora* (Golden Mahseer) and *Cyprinus carpio* (common carp) are the dominant species (> 98% of the capture fisheries, Table 2). Monthwise landing of fish from the reservoir in the year 2021-22 has shown remarkable disparity and fluctuation (Table 2 and Figure 2). The total catch was estimated at 60.5 tons with 13.75 kg/ha average production. The highest catch was recorded in May and October (nearly 10 tons). In October, the high productivity is due to fishing closing season in previous months i.e., July and August. In May intensive fishing by the fishermen led to the highest productivity. The lowest catch was recorded in January and February is owing to the decline in the water spread area of the reservoir and the minimum water level of the reservoir in these months. The fish production from the Tehri reservoir in the period of April 2016 to March 2022 is also summarized in Table 3 & Figure 3. The analysis of the last six years' record of captured fisheries in the Tehri reservoir reveals, that there is no consistent pattern in the fish productivity of reservoirs. The year-wise landing of fish data for the reservoir has shown a significant variation. The average annual catch for the six years (March 2016 to April 2022) was recorded as 82.22 tons per year with an average fish production of 18.68 kg /ha (Table 3). The maximum catch recorded during 2018-19 was nearly 145 tons with an average production of 33.01 kg/ha (Table 2) & (Figure 3). It might be due to less fishing in the previous year 2017-18 which allowed the fish species to spawn and flourish. The lowest catch reported for 2020–21 was approximately 32 tons, with a production average of 7.2 kg /ha. The COVID-19 pandemic in 2020 –21 caused a lockdown that disrupted the supply chain and declined the fish market, hence very irregular fishing activity was performed in this year. Due to sporadic fishing and a lack of professional fishermen, fluctuation and variation in fish production have been seen over the past six years. However, to improve the production potential of the reservoir few measures were undertaken. The State Fisheries Department stocked some major carp species and discovered new angling sites. Still, there is a need for scientific efforts to develop strategies for fisheries management in the Tehri reservoir.

Future strategies for fisheries management in Tehri reservoir

The Tehri reservoir is a medium-sized reservoir and the fishery entirely depends on capture fisheries.

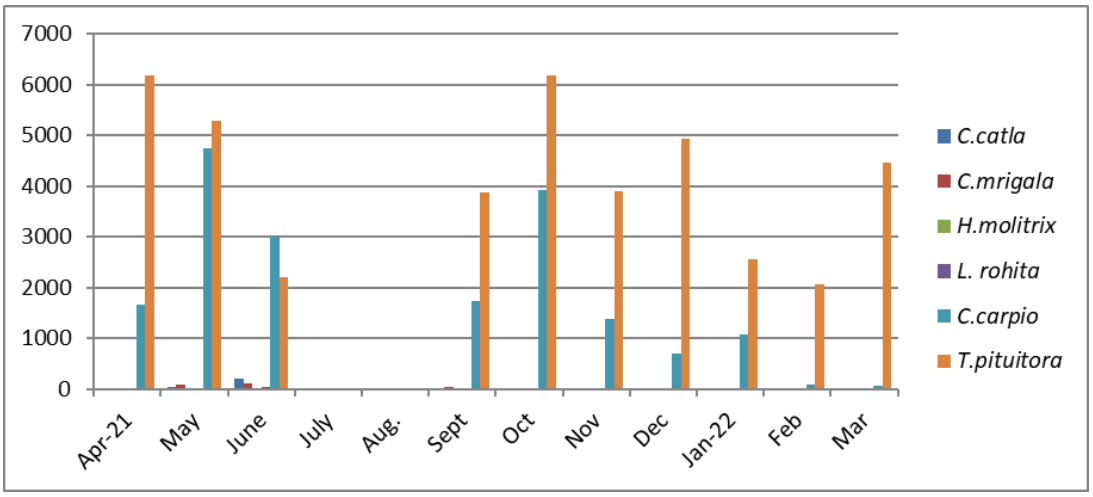

Figure 2. Fish landing (Kg) from Tehri dam reservoir during April 2021- March 2022

Table 3. Annual fish landings from the Tehri reservoir during the period 2016- 2022

Years	*C.catla*	*C.mrigala*	*H.molitrix*	*L.rohita*	*C.carpio*	*T.putitora*	Total (Kg)	Fishing months	Average production (kg/ha)
2016-17	0	0	0	0	53706.1	57306.8	111012.9	10	25.23
2017-18	0	941.6	0	0	6839.7	44942.0	52724.3	4	11.98
2018-19	0	1072.1	0	0	23917.3	120297.15	145285.8	10	33.01
2019-20	0	218.0	0	0	5997.3	85411.2	91626.5	10	20.82
2020-21	0	165.0	0	0	4375.0	27609.2	32149.2	8	7.30
2021-2022	254.3	251.2	9.5	31.5	18377.5	41609	60533.0	10	13.75
Mean annual Production	-	-	-	-	-	-	82221.5 kg /year	8.66	18.68 kg/ha

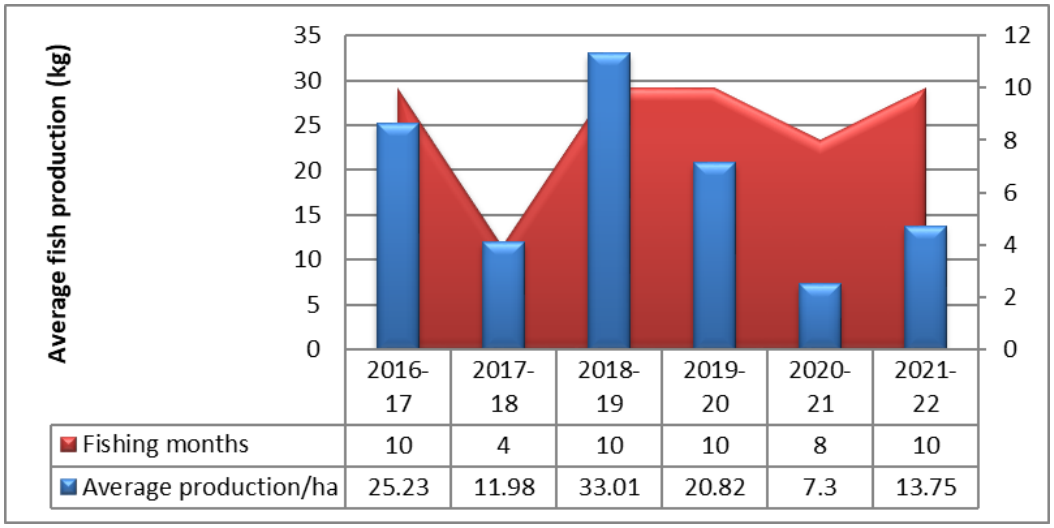

Figure 3. Average fish production from the reservoir during 2016-2022

This man-made lake possesses a predominantly lentic ecosystem with deep water. According to the present study, fish production from the reservoir over the past six years has fallen short of its potential. Although, the State fisheries Department has stocked some exotic and Indian major carp species and extended fishing sites in its attempts to boost fish productivity, still inadequate management and oversight have not yielded the desired results. Thus, the primary goal of the study was to identify the barriers to reaching potential yield and to propose scientific management guidelines for achieving the maximum fish yield from the Tehri reservoir. The approach of management at Tehri reservoir entails the following future strategies:

Study the carrying capacity of reservoir in aspects of fisheries

Reservoir carrying capacity for fisheries can be defined as the total biomass of fish that a body of water can support for an extended period. Studying the carrying capacity of a reservoir in the context of fisheries involves understanding the maximum sustainable fish population that the reservoir can support without depleting resources or causing environmental degradation. The reservoir carrying capacity is a critical foundation for rational stocking with coherent fishing and the scientific utilization of natural food and nutrient resources. Limited literature (Water and Energy International, 2007) reported the physical characteristics of the Tehri reservoir, and some of them reported the species composition (Agarwal *et al.*, 2011; Singh, 2018; Rawat *et al.*, 2020; Uniyal and Uniyal, 2021), relative condition factor and growth pattern (Thakur *et al.*, 2022) but there are no reports on food availability for the fish (Agarwal *et al.*, 2018), fish population dynamics and habitat quality and complexity on Tehri reservoir. All these components that are an important basis for evaluating the carrying capacity are not yet properly studied. By comprehensively assessing these aspects, researchers and resource managers can gain insights into the carrying capacity of a reservoir for

fisheries and implement effective management strategies to optimize fishery resources sustainably.

Water quality monitoring and assessment

Regular water quality monitoring is crucial for enhancing fish productivity in reservoirs. Poor water quality can negatively impact fish health, growth, and reproduction, leading to decreased productivity and potential economic losses. Monitoring water quality parameters (physical, chemical and biological parameters) regularly, can maintain optimal conditions for fish growth and well-being. Implementing comprehensive water quality monitoring and taking proactive measures to maintain the good water quality of the reservoir, ultimately can enhance fish productivity and support sustainable fisheries management practices. Although some of the literature (Ayoade *et al*., 2009; Ayoade and Agarwal, 2012; Khadse *et al.*, 2019; Rawat *et al.*, 2019; Rathi and Malik, 2019; Agarwal and Singh 2021; Singh *et al*., 2022) exists on the water quality parameter, still there is a lack of regularity of monitoring of water quality for the fish yield.

Stocking new species

Introducing rapidly flourishing exotic species into the natural system to occupy the broad spectrum niches is essential for the sustainable management of reservoirs. The main objective of stocking is to make certain that the increased food reserves are utilised. The trophic burst is the best time to stock new species. The state fisheries department stocked 4 species of Indian major carp in 2016 but the reservoir came into existence in 2006, and the trophic burst phase was already passed (where there were high chances of producing the highest fish production). Later, intensive stocking can not succeed in fostering the emergence of any new species as the common carp in the Tehri reservoir that was introduced just after the construction of the dam.

Cage culture practices need to be adopted in the Tehri reservoir

Fisheries in the Tehri reservoir are solely based on capture fisheries. There is no evidence till now date of culture fisheries. However, culture fisheries can indeed be a viable option to increase fish production from the reservoir. Around the world, fish cage culture has expanded rapidly in the last 20 years. Various research and development are being done on the design of the cages, the ideal fish species to use, fish feed, and other management issues related to cage fish farming. Numerous attempts, particularly to raise fry to fingerlings, have been made to produce fish from cage culture practices (Natarajan *et al.*, 1979; Banerjee and Govind, 1979). In Gobindsagar Reservoir-Himachal Pradesh, Getalsud Reservoir-Jharkhand, and Gularia Reservoir-Uttar Pradesh, attempts were made to produce fingerlings or reservoir stocking materials. In Kabini Reservoir in Karnataka, experiments were carried out in floating cages with varying degrees of success in 2005–2006 to raise stocking materials (CIFRI, 2006). Cage culture in reservoirs has shown remarkable success in Jharkhand and Chhattisgarh. Approximately 14,000 cages have been installed in different reservoirs throughout the country; yielding approximately 16% of the country's present reservoir fish production. Cage fish farming in the country employs roughly 7.5 lakh man-days of labour (Pandit *et al.*, 2021). Cage culture fishing practice in Tehri reservoir can generate revenue and employment opportunities for local communities. Cage culture can be sustainable aquaculture practices when properly managed.

Studies on fish gear technology/improvement of capture techniques

Catching demersal fish efficiently in deep reservoirs is difficult. In the Tehri reservoir, the Dam authority accidentally introduced common carp seed at the very early stage of the reservoir when it was in its trophic burst phase. Due to this the common carp flourished and is abundant in the reservoir. It is challenging to catch because of its bottom-dwelling and sluggish nature. Because of their slow movement and bottom-dwelling habit, they are not usually trapped in passive fishing gear such as cast and gill nets. Therefore, research on fishing gear technology is required to capture demersal fish. Tehri Lake is at present 740 meters deep, which rises to 825 meters during the rainy season so the depth of the reservoir and underwater obstructions limit the applications of active gear, leaving passive gear like basic gill nets as the primary option. Gulbadamov (1962) recommended two designs of gill nets namely sebul No.1 and sebul No.2. However, several other fishing gears such as Rangoon, longlines, hand lines, pole and lines, cast nets, dip nets, uduvalai suggested by various experts (Ranganathan and Venkatswamy, 1966; Kuriyan, 1973; Ahmed and Hambrey, 2005; Datta and Sarangbe, 2007) and local fishers for fishing in the reservoir. Selection of an appropriate mesh size will depend upon the predominant size group of commercially dominant species of fish in the reservoir (Singh and Agarwal, 2014).

Licenses must be obtained from the state fisheries department's local office by fishermen

Even after the impoundment, there were no organized fishing activities till 2016, fishing tender began in 2016-2022, with a total production of 493 tons. Moreover, the tendering for fishing rights in Tehri reservoir by the fishery department is irregular. The locals do unauthorized fishing in the reservoir. The state fisheries department should provide fishing licenses and guidelines from the local office for fishing in the reservoir. This regulation will help to manage fish populations, prevent overfishing, and conserve aquatic habitats. Despite this, it allows authorities to monitor and enforce fishing regulations, such as catch limits and size restrictions, to ensure sustainable fishing practices. Fishing licenses often

come with fees, that contribute to conservation efforts and the maintenance of fisheries resources. Fishers familiarize themselves with local fishing regulations and obtain the necessary licenses before engaging in fishing activities to avoid legal consequences.

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Conflict of interest
The authors declare that they have no conflicts of interest.

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