Rainbow trout in Jammu and Kashmir: Present status and strategies for expansion

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Jammu and Kashmir, often referred to as “heaven on Earth,” owes its distinct soil and vegetation to its unique climate. With abundant green forests and high-altitude terrain, it boasts valuable natural resources such as Himalayan glaciers and rivers.

Among these resources are fast-flowing cold-water streams, unspoiled lakes, winding rivers, natural springs, and high-altitude lakes. At the heart of this ecosystem is the Jhelum River, originating within the valley itself and formed by the contributions of its various tributaries. These include the Sindh, Liddar, Vishav, Dudhganga, Shaliganga, Pohru, Erin, and Madhumati rivers. The Jhelum River is deeply intertwined with the valley’s landscape and plays a central role in its ecology.

The region has a total of 30,000 hectares of inland water bodies, consisting of 27,781 km of rivers and canals, 70,000 hectares of reservoirs, 17,000 hectares of tanks and ponds, and 6,000 hectares of floodplain lakes/derelict waters (Ayyappan et al., 2011). These aquatic environments create a favourable climate for a wide variety of plants and animals to thrive, supporting diverse fish species, including both warm-water and cold-water varieties. Predominantly, fish species from families such as Salmonidae, Cyprinodontidae, Sisoridae, Siluridae, Cyprinidae, and Cobitidae are found in the water bodies of Kashmir (Mir et al., 2020).

In the Kashmir region, there are approximately 447 kilometers of streams, 486 kilometers of rivers, and around 157 square kilometers of lakes (Sodhi et al., 2013). In the upper headwaters of the Jhelum drainage, there are robust populations of

A picturesque view of the Lidder catchment, Kashmir.

Trout fish farming project, Kokernag.

both native and non-native coldwater fish species. Among the non-native species, brown trout and rainbow trout have not only adapted to this environment but are also being bred and raised in captivity.

Rainbow trout originally hail from the rivers and lakes that drain into the Pacific on the west coast of North America, with their habitat ranging from Mexico in the south to Alaska in the north (MacCrimmon, 1971). Since the 1880s, rainbow trout have been cultivated and introduced into rivers and lakes outside of their native range, most notably through farming at the McLeod River and San Leandro hatcheries in California. These two hatcheries are the primary sources of artificially bred rainbow trout found across the globe. Rainbows have also been introduced to numerous other countries, where they often establish self-sustaining, wild populations. Today, rainbow trout can be found on every continent except Antarctica.

Rainbow trout, scientifically known as *Oncorhynchus mykiss*, was initially classified by Walbaum in East Asia (Kamchatka) in 1792. However, over time, various other Latin names were attributed to rainbow trout by different researchers. In 1988, the American Fisheries Society officially recognised rainbow trout as a species, adding the original name *mykiss*.

Rainbow trout is a promising cultivable fish species in cold water and holds significant potential for expansion. As a high-value commodity with relatively low production volume, trout offers opportunities for both domestic consumption and foreign export. However, the development and scaling of trout farming in the region has not yet been realised on a large scale. Trout culture demands more input resources compared to other fish species for survival and growth. The feasibility of achieving desired production levels hinges on several factors, including seed quality, feed availability, health management, and environmental considerations. To succeed in trout production, it is imperative to significantly improve management practices.

Rainbow trout introduction to Kashmir valley

The history of trout fisheries in Kashmir traces back to 1898 when Mr. Frank Mitchel, a Scotsman, with the assistance of Pandit Sodhama Miskeen and Khwaja Gafarjoo, introduced trout to the region. Operating a carpet factory in Srinagar during the late 19th century, Mr. Mitchel was inspired by Kashmir's serene and unspoiled water resources to introduce trout to its aquatic ecosystem. His motivation was to attract more tourists to the area by enhancing its natural appeal.

A typical raceway in Kokernag trout farm, Anantnag.

The initial batch of 10,000 trout eggs arrived from the U.K. in 1899, courtesy of the Duke of Bedford. This gift came after the Kashmir Maharaja had presented a magnificent Kashmir Stag trophy to the Duke through Sir Adelbert Talbot, the British Resident at Srinagar. Mr. Mitchel's first attempt at trout culture took place near his factory at Bagh-e-dilwar Khan in Srinagar, where he collaborated with a local, Sodhama Miskeen. Unfortunately, half of the trout eggs perished during transit due to the absence of airplanes at that time, necessitating transportation by sea route. The journey involved rail travel to Rawalpindi from Bombay and then a bus ride to Srinagar, with frequent water changes that led to the loss of half the stock during transit. Despite the initial setback, a subsequent attempt in 1900 proved successful.

The second shipment of trout eggs arrived from Scotland in December 1900, in excellent condition, thanks to Mr. J.S. Macdonall. This shipment included 1,800 fry, with 1,000 of them being transferred to Panzagam Dachigam (Harwan), approximately 24 km from Srinagar, and the remaining 800 fry being reared at a private carpet factory owned by Mr. Mitchel in Baghi Dilawar Khan, located in the heart of the city near Khank-i-Moulla. This marked the inception of trout culture in the valley. However, in 1903, a devastating flood hit Kashmir, resulting in the loss of all trout at the Harwan hatchery. Disheartened by this setback, Mitchel and Sodhama temporarily discontinued their efforts.

One day, Mr. Mitchel noticed brown trout in Ferozpur Nallah near Tangmarg actively leaping out of the water to feed on insects. Encouraged by this success, Mr. Mitchel resumed his work at Harwan. He successfully persuaded Maharaja Pratap Singh to establish a Fisheries Department in Jamu and Kashmir and became its first Director. He appointed Mr. Sodhama as the first inspector and Mr. Gaffarjoo as the first guard. By 1908, brown trout (*Salmo trutta*) was firmly established in the valley, with several fishing areas created in the streams for angling enthusiasts.

In 1908, a hatchery was constructed in Achabal within the Anantnag District. Subsequently, in 1912, they acquired eyed ova of Rainbow trout, then known as *Salmo gairdneri*, from Bristol Water Works. At the Achabal hatchery, nearly one thousand alevins (advanced fry) were hatched. Eyed ova of brown trout were also obtained from Achabal hatchery and distributed throughout Kashmir. Following the successful introduction of both Brown and Rainbow trout, the Fisheries Department of Jammu and Kashmir attempted to import eyed-ova (seed) of Eastern brook trout (*Savelinus fontinalis*) from Canada, land-locked salmon (*Salmo salar*) from the USA, and Splake trout, a hybrid of brook trout and lake trout from Canada. Unfortunately, these efforts did not lead to the establishment of these fish species in Kashmir waters. Over time, the department procured shipments of eyed ova from various European countries to enhance the existing fish stock within the state. However, due to a lack of

adequate infrastructure and the necessary expertise in stock management, the desired outcomes could not be achieved. The summarised introduction of trout in Kashmir waters is mentioned in Table 1.

Distribution

Once it became clear that trout could thrive in the Kashmir Valley, the potential for trout breeding in numerous local water bodies became evident. In response to this opportunity, the ambitious rout Fish Farming Project was initiated at Kokernag in collaboration with the European Economic Community. This collaborative effort led to the establishment of the Kokernag trout farm in 1984, which has since become the primary source for producing high-quality rainbow trout and brown trout seed in the region.

Before this development, the Maharaja of Kashmir received numerous requests from other princely states seeking both trout seed and expertise to introduce the fish into their fast-flowing streams, which were essential for the trout to flourish. Consequently, Pt. Sodhama undertook journeys to various locations such as Nilgiris in the South, Himachal (then part of Punjab), Uttarakhand (then part of Uttar Pradesh), and Muree (now in Pakistan) to facilitate the introduction of trout in those areas.

Trout are known to thrive in cold, clear streams and lakes characterised by high oxygen levels and minimal vegetation. These conditions are abundant in the Himalayas and other southern mountain ranges, making it an ideal setting for trout culture. As a result, many water bodies in the valley were stocked with trout, including snowfed streams like Bringhi, Lidder, and Sindh, which are tributaries of the Jhelum River, as well as spring-fed streams like Verinag, Kokernag, and Achhabal. Furthermore, trout were introduced into high-altitude lakes such as Gangabal, Vishensar, Kisenar, Satsar, Gadsar, Sheshnag, and Kounsarnag. Consequently, all these water bodies now boast well-established trout populations.

The introduction and stocking of trout were not limited to the water bodies of the Kashmir Valley alone but extended to the coldwater streams of the Jammu division as well. This initiative aimed to capitalise on the abundant coldwater resources available in the region and attract tourists. Significant water bodies in the Jammu division, including Dhaggar Nallah in Kathua District, Kirchi Stream in Daddu-Basantgarh of Udhampur District, Thanala in the upper reaches of Neeru Nallah in Doda District, Fember Nallah, Keshwan Nallah, Singhpura Nallah, and Marwah-Wardwan Nallah in Kishtwar District, Budhal in Rajouri District, Bhadora Stream, and Sui-Devta Nallah in Reasi District, as well as Mohu-Mangat and Kheet streams in Ramban District, were stocked with trout.

A typical representation of American style raceways in Kokernag.

An inlet feeding channel to the Asia's Largest trout fish farm, Kokernag.

In recent times, due to the rapid expansion of rainbow trout farming, which includes both the production of trout eggs and table-sized trout, Kashmir has emerged as a potential supplier to meet the demand for trout eyed ova from neighboring countries like Myanmar and Bhutan. Additionally, various hilly states within India, including Himachal Pradesh, Sikkim, Uttarakhand, and Arunachal Pradesh, have shown interest in acquiring trout from Kashmir. These regions possess favorable climatic conditions for trout cultivation. The goal is to assist them in building their trout stocks and achieving self-sufficiency in trout farming and production.

Trout farming infrastructure in Jammu and Kashmir

In Jammu and Kashmir, there are currently nine operational hatcheries that serve as both seed producers and breeding projects. Among these, seven are in the Kashmir region, specifically at Laribal (Srinagar), Kokernag (Anantnag), Shookababa (Baramulla), Mammer (Gandarbal), Khag (Budgam), Tchancer (Kulgam), and Panzeth (Anantnag). The remaining two hatcheries are situated in the Jammu division, with one in Rajouri District and the other in Doda District at Phailini and Bheja, respectively. These hatcheries play a vital role in meeting the seed requirements for trout rearing units, both public and private. Notably, the Kokernag and Laribal trout hatcheries have a combined production capacity exceeding 15 million eyed ova per year. The breeding and seed production at these facilities adhere to modern scientific practices to ensure the well-being and survival of the brood-stock and young trout.

Over the past decade, the trout farming industry in Jammu and Kashmir has undergone a significant transformation, particularly with the government's decision to permit private sector involvement. In the 2019-20 fiscal year, just before the COVID-19 pandemic, 534 farmers collaborated to produce a total of 650 tonnes of trout. Fast forward to 2022-23, and the industry has witnessed substantial growth, with the active participation of 1,144 farmers. This remarkable expansion represents an impressive increase of over 200%, resulting in a total production of 1,990 tonnes of trout.

Most of these trout farming units are located in the Kashmir region, mainly due to its favorable climate, pristine cold water resources, and suitable topography—a prerequisite for successful trout farming. Trout farming primarily relies on cemented tanks known as raceways, and artificial feeding is crucial to meet the dietary needs of cultured fish. Therefore, ensuring the availability of nutritionally balanced feed is paramount for the growth and survival of the fish. To address the feed requirements of both public and private trout farmers, Jammu and Kashmir has established three trout feed mills in key locations within the Kashmir region. Among them,

Table: 1. Dates of trout introduction to Kashmir.

Fish species	Place	Introduction	Source	Present status
Brown trout, *Salmo trutta fario*	Kashmir	1899-1900	UK, Howeiton, Scotland	Established
Rainbow trout, *Onchorhynchus mykiss*	Kashmir	1912	England	Established
Brook trout, *Salvelinus fontinalis*	Kashmir	1960	Canada	Disease incidence lead to the total loss of stock
Splake trout (cross between the lake trout *Salmo trutta lacustris* and eastern brook trout)	Kashmir	1960	Canada	
Land-locked salmon, *Salmo salar*	Kashmir	1960	USA	Poor results from breeding and ultimately lead to loss
Rainbow trout, *Onchorhynchus mykiss*	Kashmir	1984	Isle of Man, England	Established but mixing with previous stocks
Rainbow trout, *O. mykiss*	Kashmir	1985	Isle of Man, England	
Rainbow trout, *O. mykiss*	Kashmir	1986	Isle of Man, England	
Rainbow trout, *O. mykiss*	Kashmir	1989	Denmark	
Rainbow trout, *O. mykiss*, genetically modified	Kashmir	2019	Aquasearch, Billud, Denmark	Established

the Kokernag and Laribal feed mills operate conventionally, while the Manasbal feed mill has been fully modernised. The modernisation of the Manasbal feed mill was made possible through an import from Holland, with support from the National Fisheries Development Board (NFDB). This advanced facility boasts a production capacity of 1 tonne per hour.

The establishment of the modern Manasbal feed mill has played a pivotal role in enhancing the department's ability to produce high-quality trout feed. This development has not only led to improved feed conversion rates but has also contributed to the production of healthier and more marketable trout. Additionally, the trout feeds, namely PerforMAX-S and PerforMAX-G, developed and formulated by ICAR-DCFR, Bhimtal, have played a significant role in strengthening the sector. These feeds have demonstrated favorable outcomes in trout nutrition, leading to improved egg quantity, size, and uniformity, ultimately resulting in higher survival rates in hatcheries. This progress underscores a strong commitment to enhancing the efficiency and sustainability of the trout farming industry in the region. Through collaborative efforts involving the fisheries department, government bodies, research institutions, and public-private partnerships (PPP), Jammu and Kashmir is making substantial strides in advancing trout farming in the country.

Holistic development of agriculture and allied sectors: Key objectives for strengthening the fisheries industry

In 2022, a programme was initiated to enhance the fisheries and aquaculture sector in Jammu and Kashmir. This programme, known as the "Holistic Development of Agriculture and Allied Sectors," is designed to bring about a comprehensive transformation in the fish farming industry in the region. The overarching goal of this ambitious endeavour is to achieve multiple key objectives, which include significantly boosting trout and carp production, generating employment opportunities, and fostering economic development.

One of the primary goals of this project is to revolutionise fish farming by increasing annual trout production from the current 1,990 tonnes to an impressive 4,000 tonnes, effectively tripling the output. Additionally, the programme seeks to incorporate an extra 1,200 tonnes of carp production each year. This strategic approach is designed to shift the dynamics of the local fish market significantly, reducing reliance on importing approximately 5,000 tonnes of fish from other regions. By achieving these production targets, the programme anticipates a significant surge in local commerce. The project also envisages the creation of 6,050 jobs and the establishment of 150 new enterprises. This significant boost in employment opportunities and entrepreneurial ventures is poised to have a profound impact on the socio-economic landscape of the UT J&K. The fisheries sector will emerge as a key contributor to employment generation and overall economic development.

A particularly ambitious aspect of the program is its aspiration to elevate the growth rate of the fish sector from the current 3.28% to an astonishing 40%. This unprecedented rate of growth, if realised, would position the fisheries sector as a dynamic engine of economic progress in the region. Achieving such rapid expansion would undoubtedly require meticulous planning, investments, and innovation, but the additional revenue generated can be reinvested in further enhancing the infrastructure of the fisheries sector, modernisation, and sustainability efforts, ensuring long-term growth and resilience.

It is of utmost importance for this initiative to prioritise sustainable practices and environmental considerations. Responsible and eco-friendly approaches to fish farming will be crucial to prevent any adverse effects on local ecosystems and water bodies. This way, the program can ensure not only economic growth but also the preservation of the environment. To achieve its goals, the program must focus on developing critical infrastructure, including fish farms, hatcheries, processing facilities, and efficient transportation

networks. Embracing modern technology and adhering to best practices in the industry will be instrumental in achieving the ambitious targets set forth in the program.

Furthermore, market development and robust distribution channels will be vital to absorb the increased fish production and ensure it meets consumer demand. Building and maintaining a sound regulatory framework is equally essential to govern the sector effectively, addressing issues related to quality control, hygiene, and sustainability.

Conclusion and expansion strategies

The valley of Kashmir offers an ideal environment for culturing rainbow trout. However, when compared to other forms of aquaculture in the region, trout farming is relatively elemental. Despite its potential as a sustainable means of utilising the valley's abundant cold water resources, there is a need to enhance trout farming by adopting modern and sustainable approaches to expand and develop the industry. Numerous challenges are associated with trout farming, including limited access to seasonal water resources, adverse environmental conditions due to global warming (such as high summer temperatures), insufficient availability of fish seed and feed, expensive transportation costs, restricted financial support, and growing competition for resources like land and water due to urbanisation. Consequently, a comprehensive approach is required to encourage both horizontal and vertical growth in trout production across the region. Key priorities include enhancing the productivity of existing operations through the application of scientific advancements in trout farming and marketing:

- Selecting suitable locations for trout farming by utilising remote sensing and GIS-based tools, while also taking into account the historical context of the area, to ensure efficient utilisation of water resources.

- Modernising existing trout farms by incorporating contemporary information and digital technologies, such as sensors and digital monitoring systems, coupled with AI and IoT to enhance operational efficiency, data-driven decision-making, and resource management.

- Adapting farming techniques to harmonise with the unique attributes of the surrounding environment and prevailing conditions in the area. This involves adopting a finely tuned and site-specific approach that considers factors like water availability and quality, temperature, precipitation, elevation, and the availability of market infrastructure. The goal is to implement farming practices that are efficient and environmentally sustainable.

- Engaging in scientific investigations and experiments aimed at enhancing genetic traits in trout, formulating advanced and nutritious feeds, and refining methodologies for more efficient trout production. The aim is to continuously improve the quality and sustainability of fish farming practices, leading to better yields and healthier trout.

- Creating a vertically integrated production system that engages private stakeholders. This involves setting up a comprehensive production system where various stages of the trout farming process, from seed production and culture to processing and distribution, are interconnected and managed with the involvement of private sector participation.

- Applying scientifically robust methods and techniques for precise disease identification, thorough understanding, and effective treatment within the rainbow trout population. Additionally, the development of specific disease-resistant and disease-free rainbow trout varieties is imperative to proactively mitigate or minimise losses attributed to diseases. Achieving this goal requires the concurrent establishment of disease-free environments to prevent outbreaks and financial losses in rainbow trout farming.

- Adoption of cluster farming models to encourage collaboration among farmers. It represents a strategic initiative to stimulate greater cooperation and synergy among trout growers, fostering collaboration within farming communities to enhance productivity and sustainability. This approach brings farmers together, encouraging joint efforts in areas such as resource sharing, knowledge exchange, and collective decision-making. Through this approach, the collective potential of farmers can be harnessed, leading to improved yields, efficient resource utilisation, and the development of trout growing communities.

- Creating the necessary infrastructure to facilitate efficient supply chains and add value to products. This involves establishing the physical and logistical framework required to streamline the production, distribution, and processing of goods, ultimately enhancing the overall value and competitiveness of products.

- Harnessing information and communication technologies to disseminate technical knowledge and provide farmers with valuable market insights and expertise. This involves utilising digital tools and platforms like mobile apps, online platforms, and data analytics systems to facilitate the exchange of knowledge on best practices, innovative techniques, and up-to-date market information. Ultimately, this empowers farmers to make informed decisions, enhance productivity, and adapt to changing market conditions.

- Enacting policy reforms specifically designed to offer financial support to trout growers through means such as loans, subsidies, and price regulation. These changes in government policies and regulations aim to create a more conducive environment for trout farmers, ensuring their access to affordable credit, financial aid, and mechanisms to stabilise trout prices.

- Readiness to adjust to the challenges posed by climate change and respond effectively to natural disasters. This involves developing strategies and implementing measures that enable individuals, communities, and organisations to cope with the evolving impacts of climate change and effectively manage the aftermath of natural disasters. For instance, in the context of trout farming, preparedness for climate change involves specific steps. These include adopting resilient farming practices such as establishing alternative water sources, reinforcing the structural integrity of raceways, and creating auxiliary water channels. Additionally, diversifying farming methods through integration with livestock, horticultural crops, and different fish species contributes to adaptability. The implementation of

water conservation techniques, like constructing recharge pits and utilising traditional rainwater harvesting structures known as “chal khals,” further helps mitigate the impacts of shifting weather patterns.

Moreover, being prepared for natural disasters entails comprehensive disaster response plans. These plans encompass securing essential equipment such as water motors, oxygen cylinders, and maintaining vehicles for swift response during emergencies. Backup power sources also play a crucial role in ensuring continuous operation. Early warning systems are another vital component, including the deployment of water level sensors in the inlet stream, geotechnical and seismic sensors in and around the farm, as well as automatic weather stations. These systems are complemented by well-organised response teams and mobile alert notifications.

Furthermore, community training initiatives are fundamental in enhancing resilience and reducing the consequences of events like flash floods, landslides, and earthquakes. Educating the local community about disaster response and preparedness fosters collective efforts and ensures everyone is well-prepared to face unexpected challenges.

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