Fish and Fisheries of the Temperate Himalayas: An Overview and Way Forward

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Abstract

Fish is an important source of food and income and also provides the opportunity for trade and export as blue economy. Considering the vast resources available, there is immense potential to draw economic benefit for the prosperity of the people residing in temperate zone of the Himalayan region through multifold increase in fish production by horizontal expansion, intensification, diversification, and sustainable management of existing natural resources. This would be helpful to reduce the gap between demand and supply. Though the present aquaculture in the Himalayan region is a traditional and rural practice, reforming has been done for fisheries sector in temperate zone through awareness and technological advancement which may also require the vertical and horizontal expansion of this sector toward the commercial practice and export avenues. Sport fishery and ecotourism in hill region is a potential component, and reorientation is required for this purpose with private–public partnership mode. Research and development support would be a key factor to accelerate the development of fisheries and aquaculture practices in hill region. Ornamental fish culture has been adopted as small-scale enterprises which provide an alternative source of employment and also require an intensive approach in potential areas. The Himalayan region is bestowed with diverse natural resources such as rivers, streams, lakes, and reservoirs. Fish occurrence and wild population in these water bodies are badly affected with overfishing, siltation, damming, pollution, and poor management. Hence, the fisheries in these water bodies are either unexploited or unmanaged. Use of modern techniques and implementation of scientific management would be fruitful to bring this sector more realistic and economic to support the

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livelihood and nutrition security. The fragile nature of fish occurrence, environmental threats, and anthropogenic activities indicated the need of conservation and management of existing resources on sustainable basis. Overall review of the temperate fisheries and aquaculture reflects the potential and prospects of livelihood support and nutritional security.

Keywords

The Himalayan fisheries · Ecotourism · Trout culture · Fish diversity · Exotic species · Policy issues

1.1 Introduction

The largest mountain range in Asia is the Himalayas which demarcates the plains of the Indian subcontinent and area of Tibetan Plateau. Sivalik Hills, the Great Himalayas, and the Tibetan Himalayas are the major ranges of this mountain range. The Gangotri, Yamunotri, and Zemu in India; Khumbu in Nepal; and Langtang glacier in Langtang region are the major glaciers along with other numerous small glaciers which store about 12,000 km^3 freshwater. Geographically, this mountain covers the hilly areas of Pakistan, India, China, Nepal, and Bhutan. The entire range of the Himalayas is bordered with Karakoram and Hindu Kush ranges in northwest, Tibetan Plateau in north, and Indo-Gangetic Plain in south with a large drainage area. The Ganges, the Indus, and the Tsangpo-Brahmaputra are the major river systems of the Himalayas with large drainage basin, which provides shelter to about 600 million people of different countries. The Himalayas is also an emblematic of the cultures of South Asia and Tibet. The entire Himalayan range has been categorized into four major agroclimatic zones including the low hills and valleys near the plain areas, the middle hills and valleys, high mountains and valleys, and cold dry desert zone. Each zone is characterized with variations in altitudes and climatic conditions such as rainfall, temperature, and humidity. The third zone of the Himalaya is characterized with temperate climatic conditions, having physiographically a large mountainous tract (1800–2000 m above msl). This temperate zone of the Himalayas has the winter during the month of October and February, the summer during the month of March and June, and monsoon season during the month of July to September with a brief spring period during mid-February to March and autumn during late September to October in the annual calendar. The thermal regime of 5–20 °C is reported with minimum temperature in the winter and maximum in the summer during the month of April to June. The temperate zone of the Himalayas reflects variable climatic conditions, having resourcefulness and rich biodiversity. Presently, this zone has been affected with anthropogenic activities and possesses the challenges of habitat destruction and aquatic pollution. The Indian part of the Himalayan region has varied geographical and topographical climatic conditions with diverse natural water resources. The total geographical area of the Indian Himalayan region is about 533,604 km^2 which is about 16.2% of the total geographical area of the country, being inhabited by 39,628,311 people (3.86% of total population). This geographical

unit is a fragile zone having richness in water resources and biodiversity. Biodiversity of any ecosystem provides stabilization, protection of overall environmental quality, and understanding of the intrinsic worth of all species. The hydrological parameters along with flora and fauna perform a critical balance for sustainability and susceptibility for larger implications due to climate change and various water-induced hazards. The temperate zone of the Himalayas comprises water bodies in the form of streams and rivers and natural lakes including brackish water lakes at high altitude. Existence of fish in any aquatic system may be used as indicator of habitat suitability and health of the system. This is fact that if the fish stocks dwindle in any aquatic ecosystem, there would be a grave threat to ecosystem and food security which affects inhabitants by virtue of their habitation. Hence, rational utilization of aquatic resources is directly linked with the benefit of the contemporary society, and it is more ethical and wise to think for the future.

Fisheries and aquaculture play vital role in food, nutrition, income, and livelihood to the rural populations and blue economy of the nation, having commercial earnings and foreign trade. India is the second largest fish producer in the world with the fish production registering an average annual growth rate of more than 7% in the recent years. Fish contributes to 10% of total exports from India and almost 20% of agricultural exports. This rapid growth in fish production and increasing demand for food of animal origin are mainly due to better management practices, accelerated economic growth, population explosion, and change in dietary pattern. Fish not only is an important source of food and income but also supports the foreign earning. Considering the vast resources available in the temperate region, there is immense potential to draw economic benefit for the prosperity of the people residing in the hill states. Due to the limited resources to support the livelihood, the people of temperate region have to depend on the natural resources and subsistence farming. The available fishery resources are significant for ecosystem and economic point of view that play a crucial role in the nutritional security of the people dwelling in temperate regions. This geographical area has paradoxical situation for short supply of animal origin food which require to cop the low temperature as well as the limited resources to support the livelihood. Though there are certain limitations for the development of fisheries such as inaccessibility, difficult terrain, limited candidate fish species for culture, difficult transportation, slow growth of fish in aquaculture due to low thermal regime, and lack of marketing channel, recent success of developing temperate aquaculture shows that people in the rural areas are direct beneficiaries as it provides employment opportunities and protein-rich food. The integrated farming practice provides opportunities for the rural development as well as resources utilization. However, there is scope for scaling up temperate fisheries and aquaculture with improved management practices and technological advancement, having opportunities for entrepreneurship development with sport fishery and ornamental fish farming.

1.2 Fishery Resources in Temperate Region

The Himalayan region is characterized with occurrence of diversified fish fauna. The temperate region of India accounts about 17% fishes of the total ichthyofaunal diversity of the country, which is a center of origin and evolution of this biotic form. The Indian part of the Himalayas has fishery resources having 8243-km-long streams and rivers, 50,000 ha of natural and manmade reservoirs, and 20,500 ha of natural lakes including 2500 ha of brackish water lakes at the high altitudes (Mahanta and Sarma 2010). In Bhutan, the total length of streams and rivers is estimated to be about 7200 km having Amo, Chang, Wang, Tongsa, and Manas as major rivers in the country. Bhutan also has over 590 natural lakes with 4250 ha area at altitude of 2200 m and only one reservoir having area of 150 ha. Nepal has numerous rivers, streams, and lakes in the hill region. About 36 species of freshwater fishes are endemic to the Himalayan region. Cool and cold-water resources of the Himalayas support predominantly the subsistence fisheries, sport/recreational fisheries, and low-scale commercial fisheries in lakes and reservoirs. Capture fishery in stream and rivers is not managed; however, considerable efforts have been given for fisheries in lakes and reservoirs in India, Nepal, and Pakistan. Introduced trout and indigenous mahseer support the sport fishing in India, Nepal, and Bhutan. Schizothoracinae contributes the major share in the wild catch of fish from streams and rivers. However, natural occurrence of this fish in wild waters is highly fragmented, suffering from overfishing. The water quality is also deteriorating in some streams, rivers, and lakes due to the deterioration of soils and pollution which affects the wild fish stock. Lakes of the Kashmir are getting reduced in size due to the eutrophication and explosive growth of aquatic plants. Hence, the capture fisheries in temperate region are at lower pace without any commercial practice in existence. The fragmented wild population of fishes of small size is restricted in certain pools where fish have some shelter and resting places. Thermal variation and variable microclimatic conditions are the limiting factors influencing geographical distribution and local occurrence in the natural water bodies. Enhancement of wild fish stocks through regular ranching of indigenous fish species in the natural water bodies of the Himalayas is priority for further development of capture fisheries in temperate region.

1.3 Fish Fauna and Fish Production Trend in Temperate Region

The Himalayan region is rich in ichthyofaunal diversity with diverse kinds of fish fauna comprising of 258 fish species in India, 25 species in Pakistan, 41 species in Bhutan, and 179 species in Nepal including indigenous and exotic fishes. The major groups of fish in the existence are cyprinids (*Labeo* and *Tor* spp.), lesser barils (*Barilius* spp.), schizothorax group (*Schizothorax* and *Schizothoraichthys* spp.), garrids (*Garra* spp.), and sisoridae family (*Glyptothorax* and *Glyptosternum* spp.). The volume of other genera is less having low economic value. Rheophilic species

such as *Nemacheilus gracilis*, *N. stoliczkae*, and *Glyptosternum reticulatum* are found in headwater zone of the torrential streams, while *Diptychus maculatus* and *Nemacheilus* spp. remain prevalent in large stream zone. *Schizothorax longipinnis*, *S. planifrons*, and *S. micropogon* can be found in intermediate reaches of the large stream zone, and *Garra gotyla*, *Crossocheilus diplochilus*, *Labeo dero*, and *L. dyocheilus* always prefer the least rapid reaches of large stream zone. Species such as *Barilius* spp., *Tor* spp., catfishes, homalopterid fish (*Homaloptera* spp.), and snakeheads (*Channa* spp.) inhabited mainly in slow-moving meandering zone of the torrential streams.

The exotic brown trout (*Salmo trutta fario*), rainbow trout (*Oncorhynchus mykiss*), and common carp (*Cyprinus carpio*) have also established itself in some natural waters of the Himalayas (Sehgal 1999). Among the indigenous fishes, Golden mahseer (*Tor putitora*) is one of the largest species having sports and angling value (Bhatt et al. 2004). In present contest, decline in the mahseer fishery has been experienced due to the indiscriminate fishing and growing number of hydroelectric and irrigation projects in Himalayan streams and rivers (Bhatt et al. 2004). The Indian snow trout falls under seven genera, majority of which constitute an important part of cold-water fishery in the Himalayan region (Tilak 1987). The second most important group among the indigenous fishes is Schizothoracinae having 17 species including *Schizothorax richardsonii*, *S. plagiostomus*, *Schizothoraichthys niger*, *S. esocinus*, *S. longipinnis*, *S. planifrons*, *S. micropogon*, *S. curvifrons*, *S. nasus*, *S. huegelii*, *S. labiatus*, *S. progastus, Diptychus maculates*, *Ptychobarbus conirostris*, *Schizopygosis stoliczkae*, *Gymnocypris biswasi*, and *Lepidopygopsis typus*. Wild population of the fishes of this group is fragmented and badly affected by indiscriminate fishing and growing number of hydroelectric and irrigation projects on the rivers. There are some indigenous fascinating fish species in the rivers and their tributaries having ornamental value and demand in international market. The Northeast Himalayan region is rich in such type of indigenous ornamental fish species.

The present fish production of temperate Himalayan region is mainly contributed by capture fisheries and some part from temperate aquaculture practices. The temperate region of India contributes to about 3% of total inland fish production which is a very small contribution to the total share in national fish production. As far as fishery development is concerned for temperate region in India, Nepal, and Bhutan, maximum area is still poorly developed or underexploited.

1.4 Potential of Temperate Fisheries and Aquaculture to Support Livelihood

Fisheries is a potential enterprise in the hills, having opportunities for providing animal protein to the dwellers and also supporting other agriculture activities under integrated farming practice for improving socioeconomic life. Though the capture fishery resources are under the environmental threats, however, capture fishery supports employment and income to the inhabitants and traditional food to the

rural people and fish eaters. Lakes and reservoirs are also vital sources for wild catch, and different areas of the reservoirs have been earmarked for commercial fishing and fish marketing activities.

Trout farming is the major aquaculture practice in the Himalayan region, where sufficient quantity of cool, clean, and oxygen-rich water is available. In India and Nepal, the rainbow trout farming has accelerated significantly with quantum jump in the production. However, the potential of the trout farming in Himalayan region is yet to be exploited fully with improved genetic material and culture system. Chinese carp farming under monoculture and polyculture system is a common aquaculture practice in mid-altitudes, having the features of easy and simple farming techniques with low input requirements and possibilities of integration of available resources. Traditional carp culture in small-sized ponds (0.01–0.03 ha) is popular as rural aquaculture in most of the temperate areas. The carp culture has also been integrated with dairy, horticulture, agriculture, and paddy cultivation. However, the productivity in this culture practice is not so encouraging and needs technological advancement, better management, and improved strains for aquaculture. Many suitable sites are available in different parts of the Himalayan region, which could be utilized for fish production through carp culture or trout farming.

The Himalayas is an abode for sport fishing and angling or recreational fishing as most popular outdoor activities in hill. Himalayas have diversified indigenous fish species of sport value and suitable water resources for sport fishing. In India, about 4000 km stretches of rivers and streams are the sites of attraction for local and foreigner anglers to hook the sizeable mahseer and trout. Fish watching also has scope for fish-based ecotourism and has the potential of employment generation for the local inhabitants. People like to watch the different moving fishes of different sizes, shapes, and colors, which attract the visitors of all age groups. In India, many of the religiously protected streams and lakes in different hill states are fish watching spots to attract the tourists. Fish-based ecotourism has prospects for further development in all Himalayan countries including India, Nepal, and Bhutan.

1.5 Subtle Issues and Hazards in Temperate Fisheries

1.5.1 Infrastructure and Policy-Related Issues

The aquatic resources in the Himalayan region provide opportunities for food and sport, but scientific management of these resources is necessary to translate the opportunities into achievements. Sustainable management and balanced use of these resources are imperative for the development of fisheries sector in temperate region of the Himalayas. However, the Himalayan region is in progressive phase for capture fisheries and aquaculture including sport fishery, intensive trout farming, welfare of the fishermen, and other support services. However, the production and productivity in fisheries sector of the Himalayan region is below the optimum as compared to the other plain areas. Some part of the hills is still undeveloped due to the lack of adequate attention and infrastructure. The primary reason for this situation is lack of

proper planning and poor research and development support for the fisheries activities. But, now it has been realized that fisheries in the Himalayan region can contribute significantly for livelihood as well as for nutritional security. Therefore, fisheries sector needs to be given due importance in terms of financial, infrastructure, and modem institutional backup facilities in the planning process. In hills, the fishery development should be promoted in order to introduce diversification and hi-tech culture system and sustainable management of natural resources. This will result in profitable utilization of available resources for livelihood and high valued food protein production in the form of fish.

1.5.2 Conservation-Related Issues

There was a rich population of indigenous fishes such as mahseer, snow trout, and minor carps in the Himalayan streams and rivers, and introduced exotic fishes were very limited. Mahseer-based angling and sport fishing are well known, but due to the rapid overall development increasing demand of fish as food, the aquatic ecosystem of Himalayan region is threatened with man-induced stress which is detrimental to the fish fauna. Presently, some of the indigenous fish species have been declared as threatened/vulnerable and endangered and are subject of rehabilitation and conservation. This declining trend in species composition and catch volume of individual fish is very often related to so many factors such as habitat, destruction, indiscriminate fishing, and anthropogenic activities especially the power generation projects in cascading manner on the streams and rivers. Hence, rehabilitation and conservation is the priority for the planning of the sustainable development of fisheries in the Himalayan region.

1.5.3 Habitat Destruction

Construction of dams across the river results in changing the ecology mainly due to siltation from the catchment areas and is subject to the destruction of the spawning and feeding grounds of many fishes (Sehgal 1994). There is a dramatic change in fish habitats and local fish communities due to the creation of power dams and reservoirs on the Himalayan rivers which also have blocked the migration routes of important native fishes like mahseer (*T putitora* and *T. tor*) and snow trout (*Schizothorax richardsonii*, *S. plagiostomus*) (Sehgal 1994). Habitat alteration is a causative factor for fragmented distribution and abundance of native fishes in hill streams of the Himalayan waters (Sehgal 1994; Raina and Petr 1999). The excessive withdraw of water from the river courses for agriculture and domestic and industrial uses left inadequate water flow to support the life existence of the fishes and are major factors responsible for the depletion of fisheries resources in the Himalayan region. Wanton killing by the use of dynamites, electric shocks, and poisoning to kill the brood fishes during their spawning season and juveniles during the post-monsoon periods is prevalent in the Himalayan region which affects the existence of various commercial

fishes, especially in the rivers and streams of India, Nepal, Bhutan, and Pakistan. Activities such as increased water abstractions, pollution, and wanton methods of fishing create anthropogenic pressure on aquatic ecosystem.

1.5.4 Introduction of Exotic Species

The two salmonids, rainbow trout (*Oncorhynchus mykiss*) and Brown trout (*Salmo trutta fario*), were introduced in the streams, lakes, and reservoirs in the Himalayan region primarily for recreational purpose and now established as natural stock and are subject of invasion for native biodiversity. Two phenotypes of common carp, viz., scale carp, *Cyprinus carpio* (*communis*), and mirror carp, *Cyprinus carpio* (*specularis*), are used as commercial fishery in certain lakes and reservoirs of the Himalayan region. Presently, these exotic rainbow trout and common carp are the major candidate fish species for temperate aquaculture, and escaped fishes create environmental risk. However, the aquaculture of these exotic fishes increased the aquaculture productivity but has resulted in sharp decline of the indigenous fishery. This situation has created the conflict between increased fish productivity and existence of the native indigenous fishes, but both the issues are equally important for the fishery development in the temperate region.

1.5.5 Impact of Climate Change

This is fact that the mountains are early indicators of changing climate due to the direct effects of increasing CO_2 concentration and the increasing water temperature in the Himalayan waters and indirect effects on hydrology caused by the melting of glaciers and the erratic precipitation pattern. These changes are subject to affect the resources of the Himalayan region and their fisheries negatively impacting on breeding behavior and culture potential of fish species. In order to mitigate the impact of climate change, there is need to develop climate-resilient fish farming protocols including more resilient indigenous species in culture practices in the hill region, and it needs further refinement and validation of smart fish farming through adequate strategy involving thermally adopted more resilient fish species and availability of efficient system such as re-circulatory aquaculture system (RAS) for reuse of water.

1.6 Consideration Required for Further Development

Location-, situation-, and system-specific culture practices coupled with scientific management approach are the priority for the further development of temperate fisheries in the Himalayan region. At present, attention is required toward the standardization of suitable technologies for hilly areas of the region depending on available resources and environmental concerns. A species-based system in

accordance to fish biodiversity in geographical location is also important for the sustainability of the system. The following steps are important in order to improve fisheries and aquaculture in Himalayan region:

- Specific aquaculture system suitable for higher production and prevailing climatic conditions of the Himalayan region.
- Remedial measures for depleting population of economically important native fish species and regular monitoring of their breeding performance and reproductive behavior.
- Rational exploitation and conservation of resources to support the optimum stock at sustainable basis particularly for high altitudes.
- Research and development support for intensification and diversification of temperate aquaculture in accordance to geomorphological feature of the Himalayan region.
- Regular monitoring to assess threat perspectives in relation to ichthyofaunal diversity in aquatic resources.
- Intensive culture system and smart fish farming in context to water scarcity and climate resilience.
- Scientific management of natural lakes and natural and manmade reservoirs of the Himalayan region to bridge the gap between yield and carrying capacity.
- Decision support system for aquaculture site suitability and resource mapping by using geoinformatics.
- Active involvement of women in fisheries and aquaculture activities for management and utilization of natural resources.
- Promotion of ornamental fishery and diversion of exotic to indigenous species.
- Proper disaster management protocols for the protection of habitat and biodiversity.
- Use of gene manipulation techniques to counter slow growth and low fecundity and to increase environmental plasticity.
- Prevention of postharvest losses and value addition for fishes.
- Intelligence for marketing and supply chain for profitability and mobilization of system.

1.7 Conclusion

The immense ecosystem of unique Himalayas has provided opportunities for getting goods and services which may be continued in the future with proper planning and management. However, we should realize that the entire Himalaya is facing anthropogenic pressure, leading to environmental degradation. Fish is the best food item to supplement the protein requirement of the poor people located in the remote Himalayan region and to provide source of income to a section of people who are resource poor in terms of cultivable lands in hills and overexploited natural resources. At high altitudes, trout farming is in vogue and has potential of multifold increase. Mid-altitudinal areas are also potential sites for the carp culture. Fish-based

ecotourism and ornamental fishery have the potential for entrepreneurship development. Temperate fisheries and aquaculture have promising future and are indeed valuable and important not only because of unique diversity of species but also for nutritional security and livelihood support.

References

Bhatt JP, Nautiyal P, Singh HR (2004) Status (1993-1994) of the endangered fish Himalayan Mahseer *Tor putitora* (Hamilton) (Cyprinidae) in the mountain reaches of the river Ganga. Asian Fish Sci 17:341–355

Mahanta PC, Sarma D (2010) Coldwater fisheries management. DCFR, ICAR, Bhimtal, Nainital, Uttarakhand, pp 1–451

Raina HS, Petr T (1999) Coldwater fish and fisheries in the Indian Himalayas: lakes and reservoirs. FAO fisheries technical paper. no. 385. FAO, Rome, pp 64–88

Sehgal KL (1994) State-of-art of endangered, vulnerable and rare coldwater fishes of India. In: Dehadrai PV, Dasand P, Verma SR (eds) Threatened fishes of India. NATCON pub no 4, pp 127–135

Sehgal KL (1999) Coldwater fish and fisheries in the Indian Himalayas: rivers and streams. In: Petr T (ed) Fish and fisheries at higher altitudes: Asia. FAO fisheries tech. paper 385. FAO, Rome, pp 41–63, 304p

Tilak R (1987) Fauna of India: Pisces: Schizothoracinae. Zoological Survey of India, Calcutta