Hydroelectric Projects: An Inevitable Challenge in Fisheries of the Temperate Himalaya

25

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Abstract

The vast Indian Himalayan Region (IHR) and myriads of rivers make the region one of the opulent hotspots of the world in terms of potential hydropower energy. These hydropower projects usually break the continuum of a river, causing drastic changes in the physico-chemical and biological properties of water. In addition to the ecological impacts, socio-economic and livelihood concerns of the native people equally emerge. Many workers have assessed both negative and positive impacts of hydropower projects in the IHR, but data related to the fish and fisheries is quite limited. Therefore, it is imperial to understand the consequences of these irreversible ecological changes in the temperate rivers and frame suitable mitigation measures to minimize the risks to fish and fisheries, caused due to the construction of dams, barriers and water impoundments in the IHR.

Keywords

Coldwater fisheries · Hydroelectric projects · Dams · Fisheries · Migration

25.1 Introduction

Hydropower projects in the Indian Himalayan region have an increasing demand for generating an enormous amount of electric energy with the growing urbanization and industrial activities. This need has recently led to a boom in the construction of numerous dams and man-made reservoirs of huge hydropower capacities on the rivers. Many of these projects are in operation; some are either under the

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P. K. Pandey et al. (eds.), *Fisheries and Aquaculture of the Temperate Himalayas*,
https://doi.org/10.1007/978-981-19-8303-0_25

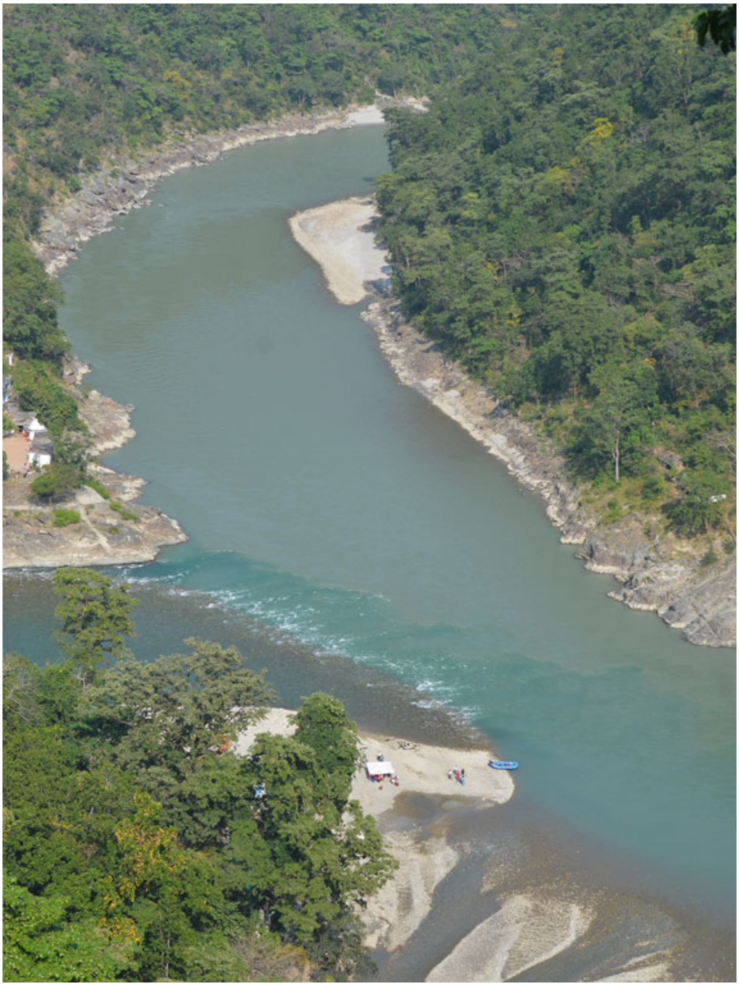

Fig. 25.1 A river in the Indian Himalayan region at Pancheshwar, Uttarakhand, India

developmental phase or planned to be commissioned in the coming years. The existence of extensive river drainage systems (Fig. 25.1) in the country, especially in the Indian Himalayan Region (IHR), makes them the most preferred resources for the contrivance of these large hydropower projects. However, on the contrary, these lotic water bodies are home to several commercially important fish species and many other prized fishes of sports and ornamental values (Fig. 25.2), sustaining livelihood and food security for the riverside dwellers and fishing communities at the rural front. Therefore, a barrier over a river can seriously change the socio-economic status and livelihood pattern of human lives, thriving profoundly on the fish fauna and the health of the rivers. Temperate rivers and streams in the IHR, in particular,

Fig. 25.2 Important hill stream fishes of the Indian Himalayan Region

sustain a rich fish faunal diversity with more than 258 species belonging to 26 families and 76 genera (Mahanta et al. 2011).

The dams exemplify a severe threat to these fish stocks, causing a major impact on the fish dynamics in terms of their movement, fish assemblage, fish reproduction and propagation, synergistically with altered water flow regimes, water and soil characteristics and invasion of alien and exotic fish species. Hence, it is imperative to understand the reflexes of the fish population in response to the ecological changes, caused by the construction of hydroelectric dams. In addition, the inland fisheries sector supports livelihood, nutritional security and income for thousands in the temperate Himalayan region, and therefore, it is imperative to assess impacts and their mitigation to overcome the socio-economic and ecological impacts of these projects.

25.2 The Hydropower Projects

India has more than 4000 large dams. The Tehri Dam (Fig. 25.3) in Uttarakhand, being the highest (261 m), is built on the river Bhagirathi. It is reported that about 58,000 large dams (elevation above 15 m) and 800,000 small dams have been constructed in the entire world (WCD 2000), and 73% of them have been built within the last 50 years. The highest number of dams is registered in China, followed by the USA and India. Nilsson and Berggren (2000) reported that the dams have regulated over 65% of the world’s freshwater discharges to the ocean. The Hirakud

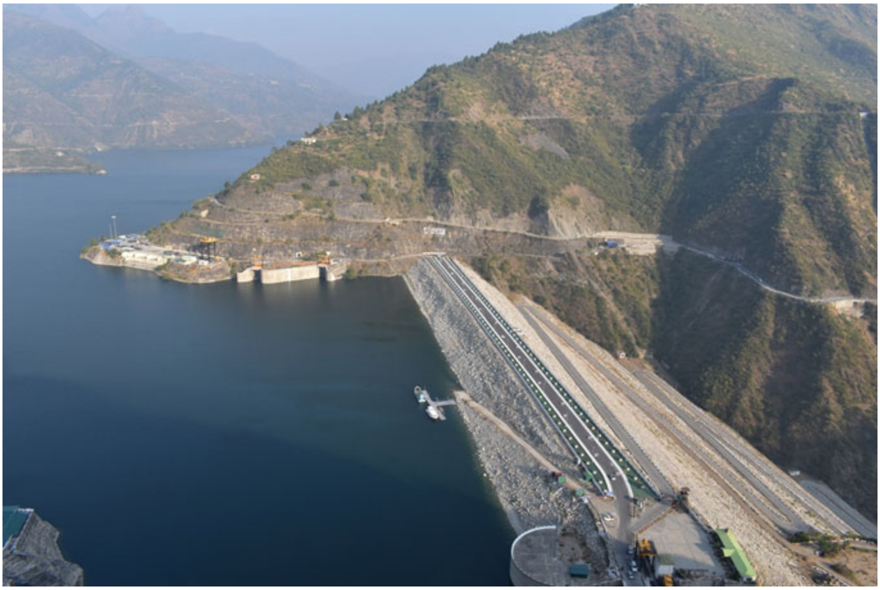

Fig. 25.3 The Tehri dam in Uttarakhand, India

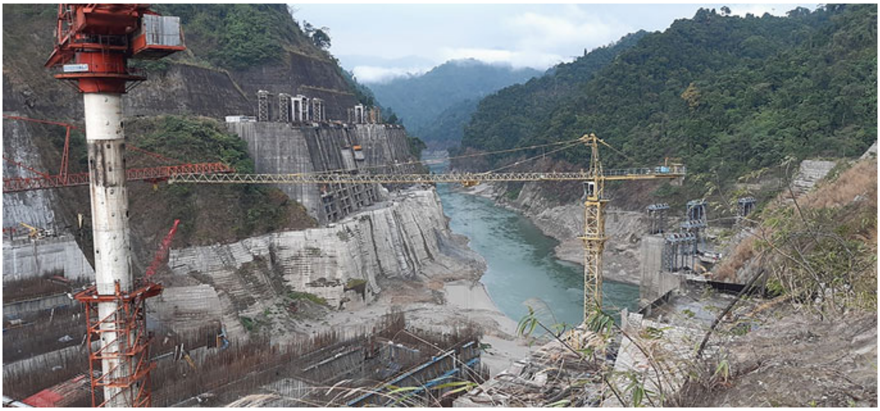

Fig. 25.4 The upcoming 2000 MW hydropower project in Subansiri, Arunachal Pradesh, India

Dam on the Mahanadi river is the longest in India, covering 26 km in length. Some of the major dams in the country are on the Sutlej, Beas and Ravi rivers in Himachal Pradesh; Chenab and Jhelum in Jammu and Kashmir; Rangeet and Teesta in Sikkim; Bhagirathi in Uttarakhand; and upcoming dams on Kameng, Subansiri and Dibang rivers in Arunachal Pradesh (Fig. 25.4). Shah (1993) cited these dams as Modern Temples of India as aptly referred by the Indian economy. The dams are considered to have significant social and economic benefits to the nation due to the revenue generated from tourism and recreation (Arain et al. 2008). India has followed similar lines and has constructed a large number of dams over the major rivers of the country for generating power and for indispensable benefits like irrigation in drought areas, supply of drinking water, flood control, transport through navigation, aquaculture avenues and recreation. The construction of dams has also given rise to numerous reservoirs, which are highly potential aquatic resources for fisheries development in the country. At present, there are 56 large reservoirs (>5000 hectares area), 180 medium reservoirs (1001–5000 hectares) and 19,134 small reservoirs (<1000 hectares) in the country, with a total reservoir area of 3.15 m hectares. Consequently, the construction of hydropower projects in India has become highly debatable, and severe resistance was imparted to each new dam proposal, particularly from the riverside dwellers and environmental groups. However, a certain fragment of society considers such hydroelectric power as a clean source of energy. This hydropower energy is environment-friendly as the energy is produced without any effluent like other energy sources from petroleum and coal. These hydroelectric projects may generate extreme and irreversible environmental impacts, especially when large reservoirs are built in temperate regions in hills and mountains where flora and fauna are in the highest density. There are many such negative impacts of impoundments on the fish fauna, and the impacts have been well documented by researchers in the country. The predicted changes in fish composition, distribution and assemblage structure and consequences for fisheries sustenance are challenging because of the diverse nature of the flow regime, the substratum, the meteorological variance and the complexity of temperate rivers. Impacts from hydrological alteration are unevenly observed in the fish distribution and assemblages in the reservoirs. Specific types of fish species are severely impacted, while others flourish well in reservoirs created by dams. In many cases, the functional trait of a fish in terms of their adaptation to the environmental cues, including those related to morphometric features of the body for feeding (mouth pattern, mouth size and position), habitat usage (body size and shape, fin size and position), metabolism (thermoregulation, salinity tolerance, hypoxia tolerance), reproductive behaviour (reproductive effort, secondary sexual characteristics, spawning nature, parental care, etc.) and defence tactics (guarding, crypsis, presence of armour or spines), is affected due to a change in the aquatic ecosystem.

25.3 The Major Impacts

Hydroelectric dams have been built on many rivers across the Indian Himalayan Region. The impact of a dam followed by impoundment in a free-flowing river leads to many physical, chemical and biological changes in the stream ecosystems. The major changes observed are (1) alteration of the lotic (riverine) environment into a lentic (lacustrine) environment, (2) habitat fragmentation, (3) fish fauna homogenization and (4) introduction of invasive or non-native fish species.

Large hydropower projects in IHR may develop synergistic environmental impacts on temperate river water and the reservoirs. This can be attributed to a change in abiotic and biotic water quality parameters, viz. temperature, dissolved oxygen, water pH, alkalinity and hardness, nutrients, plankton diversity, insect biomass, etc. An impoundment in the form of a reservoir can lead to eutrophication due to decomposed submerged vegetation, retention of sediments and nutrients in the reservoir. The hypolimnion may experience the decay of organic substrate, leading to anaerobic conditions. It is observed that the water in the reservoir has very different physico-chemical parameters as compared to a free-flowing river. The elevation of the outflow channels is the determining factor in the quality of tail water downstream. The water released from the epilimnion is usually well oxygenated and warm, whereas the water released from the hypolimnion is low in dissolved oxygen and cold. A reservoir influences the water temperature regime to a great extent, which can be seasonal as well as temporal. The water retained in the reservoirs for a longer duration may become stratified. The epilimnion layer of water may remain warm, whereas the hypolimnion layer may be cold. The release of the stratified cold water from the reservoirs may have an impact on the biota of the river, both downstream and upstream. The construction of a dam reduces the water velocity immensely, and henceforth the reservoir acts as a sediment sink. The quality and quantity of sediments deposited in the reservoirs depend on the runoff from the catchment areas, adjoining agricultural practices, human habitation, etc. Usage of profuse pesticides in the agricultural crops usually can be drained into a reservoir with surface runoff, and this may result in contamination in the fish flesh and finally cause a human health hazard.

The creation of a hydropower impoundment on a river leads to a barrier between the upstream and downstream movement of organisms and nutrients, causing fragmentation of stream fish habitats and populations (Fig. 25.5). Habitat fragmentation experiences reduced gene flow in fish populations, resulting in lower effective population sizes and eventually deleterious effects of inbreeding.

Fish fauna homogenization is the process by which ecosystems lose their biological uniqueness. In the IHR, there is a high probability of decreasing rheophilic fish species and increasing limnophilic species. The spread of alien species is a leading contributor to the global homogenization of freshwater communities, resulting in decreased local and regional fish faunal diversity (Poff et al. 2007). The disturbances and alteration of ecology habitually favour exotic or invasive fish species because they often have broad environmental tolerances or can out-compete native fishes (Pringle et al. 2000). In contrast, indigenous and endemic fishes tend to be adapted for unmodified local environmental and climatic conditions (Poff and Allan 1995). The most extreme habitat modification occurs in the reservoirs, created by dams, where the outside fish species comprise a greater composition of the fish population. This results from the artificial stocking of the reservoirs with the hatchery producing young fish species suitable for thriving in the impoundments. When the dams are fully commissioned, the reservoirs gradually fill in, and the fish habitat changes from riverine to lacustrine (Fig. 25.6), and there is generally a corresponding shift in the fish communities towards those species specialized for lentic habitats (Gao et al. 2010). Several studies showed an increase in non-native species, hence, escalating the total species richness in reservoirs. However, the population of the native fish species (Fig. 25.7) may decline or even

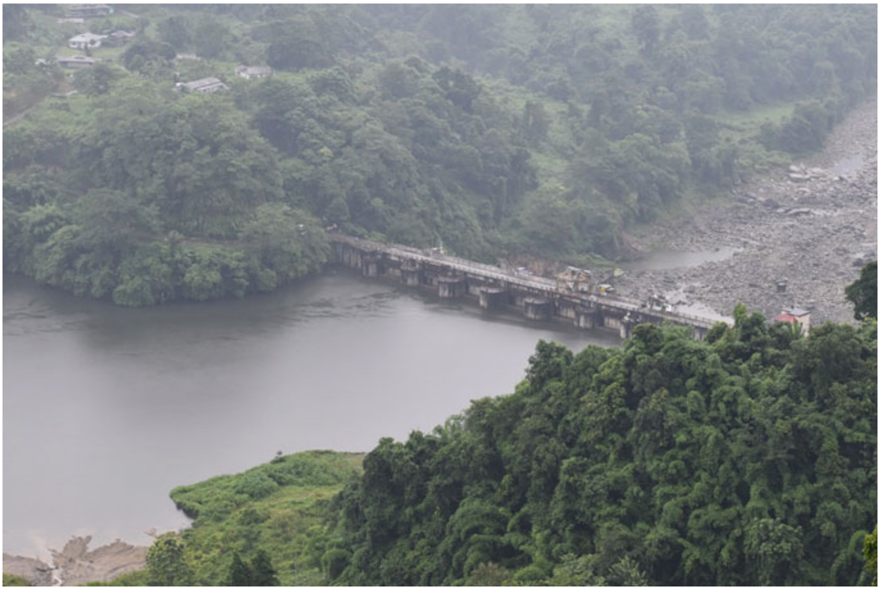

Fig. 25.5 Habitat fragmentation between the upper and lower reaches of the river across a dam

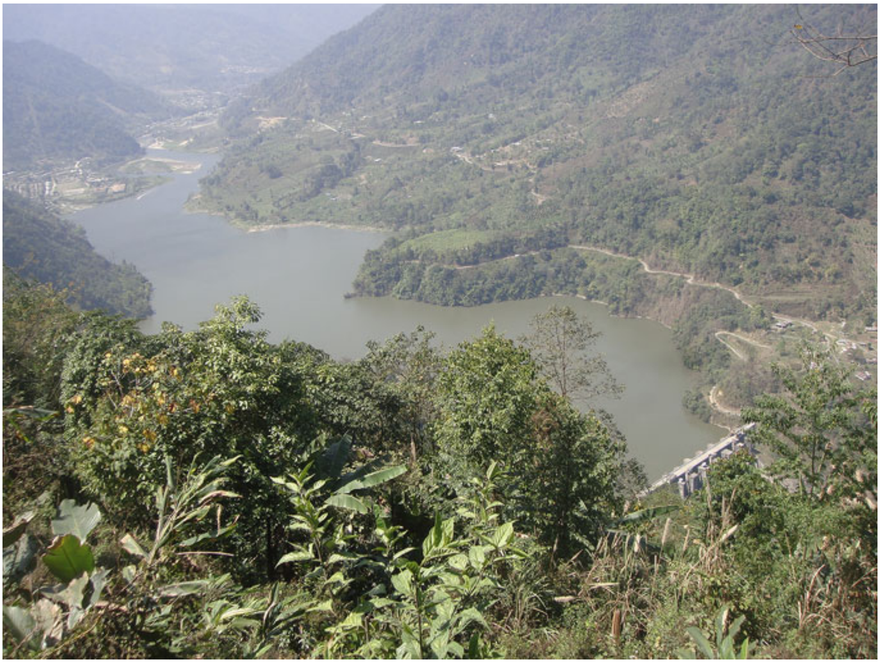

Fig. 25.6 Creation of a lacustrine environment due to construction of dam

Fig. 25.7 A haul of snow trout from a fast-flowing river of Arunachal Pradesh

vanish from the environment. Indigenous fish species, viz. *Schizothorax*, *Garra*, *Glyptothorax and Pseudecheneis* spp., are bottom feeders and have special adaptive features for scraping periphyton or algae as their food items from the substratum in the form of pebble, cobble, stones and boulders in the fast-flowing rivers of IHR (Baruah et al. 2019). This substratum also forms breeding grounds for the above fishes in many rivers. The construction of dams on the free-flowing fast water has resulted into a reduced flow regime, rise in water column and deposition of high silt. The deposition of silt or sediment over the natural substrata can adversely affect the foraging of fish and their spawning behaviour. Such a changed habitat compels the fish to migrate further upstream in search of food and suitable ground for breeding

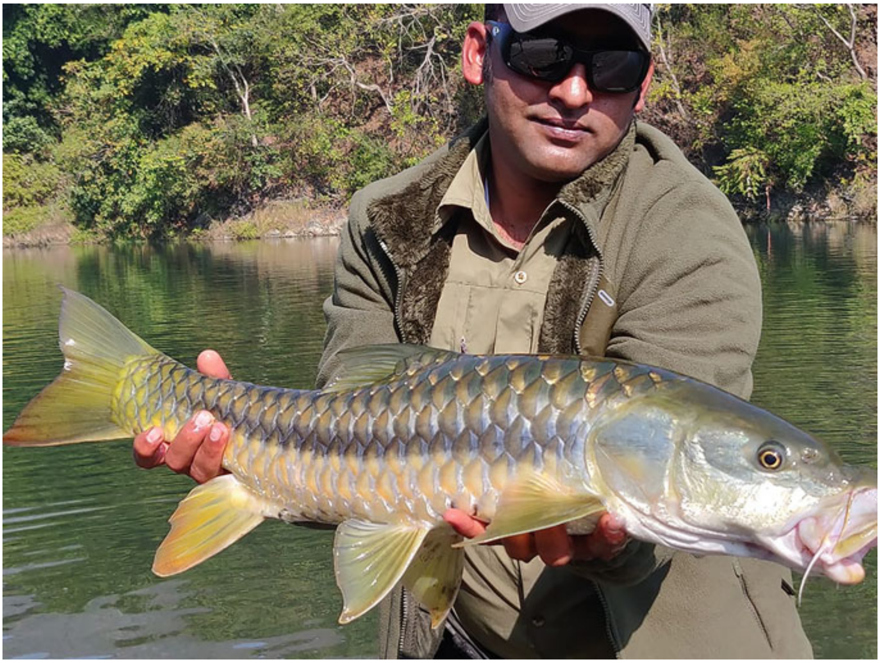

Fig. 25.8 A large migratory fish golden mahseer (*Tor putitora*) affected by the dams

and propagation. The Himalayan snow trout, loaches and catfishes are some of the major groups affected due to the construction of dam over the temperate rivers.

One of the main consequences of dams on fish stocks is a remarkable reduction or even regional extinction of large migratory fish species like mahseer (Fig. 25.8) after the formation of an impoundment in the form of a reservoir due to changes in the fish ecosystems. Tehri Dam on Bhagirathi is one such example of the loss of mahseer due to dams (Sarkar et al. 2015). The dam restricts the upstream or downstream migrations of matured and gravid fishes to reach their conducive spawning grounds for reproduction. These fishes usually congregate in certain pockets and gullies downstream of the dam, which makes them prone to being heavily exploited by fishermen. Dams significantly act as a barrier to migratory fish moving upstream and downstream, and hence, the species diversity, richness and fish composition differ in the head water and tail of dams. It is very likely that due to the change in the water flow and the environment, the native fast-flowing and migratory fish may be replaced with slow-moving non-native fishes gradually in the upstream. The inundation of the catchment in the upstream also damages the fish nursery sites. Similar is the case in downstream, where the lack of water may dry up the floodplains for fish larval development. Further, retention of sediments and nutrients by the reservoir may hamper the water quality and quantity, reduce fish food organisms and promote the propagation of alien and invasive fishes. The floodplains forming a downstream portion of a large river are seasonally flooded by the main river. These inundated catchment areas adjacent to lowland forests and lakes are one of the most productive and important ecosystems for the foothill fisheries where several fishes spawn and propagate. The reservoirs are also infested with severe macrophytes in many cases, which can deteriorate the water quality and, hence, the survival of the fishes therein. Air-breathing fishes and catfishes may proliferate in those conditions, replacing the indigenous cold water fish species. The construction of a dam creates a lacustrine environment in the form of a reservoir from a free-flowing river environment. Therefore, it is very likely that the lake-like environment will be inhabited by different forms of fish species, which are mostly non-native and did not exist naturally in that river. Furthermore, the variation in the river flow also leads to lack of biological cues responsible for natural spawning and migration. The conducive aquatic environment for breeding and propagation is not present so the riverine fish species often fail to reproduce.

25.4 Mitigation Measures

Each hydropower project essentially undergoes an Environmental Impact Assessment (EIA) to minimize the negative impacts of the dam. However, it is not necessary that all the mitigation measures can be counted prior to the construction of a dam, and hence, periodical assessment is necessary throughout the life span of a dam to reduce the errors with time. Most of these mitigation measures are applicable to upstream and downstream of the river and in the reservoir itself. Efforts are made to keep control on the water quality parameters of the reservoir, viz. using mechanisms of water column mixing to prevent thermal stratification and enriching dissolved oxygen in deep water. Further, all the discharges from adjoining industries, agricultural lands, domestic water and sewage, etc. essentially are treated in water treatment plants before releasing into the water. Many important advances and amendments in management approaches and engineering of mitigation measures have resulted in new hydroelectric projects becoming more environment-friendly than in the past. It can be referred that the environment-related mitigation measures for a single-purpose dam might be easier to resolve than a multi-purpose dam. However, this may not be the case everywhere as the hydropower dams usually have greater height, which is an insurmountable height for migrating fish. Efforts must be made to improve the water quality level in tail water downstream, construction of suitable fish passes, fish lifts, etc. and maintenance of adequate water flow regime to protect the downstream aquatic ecology. Some of the fisheries information to be procured with time and database to be prepared in a hydropower project site are listed herewith:

1. Evaluation of the area under the impact of the hydropower dam, both upstream and downstream from an ecological view point.
2. Characterization of commercially important indigenous and endemic fish species in the region.

3. Studies on the habitats of important fishes/ecological modelling of the river under concern, viz. spawning grounds, feeding grounds, winter shelters, etc.
4. Evaluation of migratory fishes of the region and their pathways.
5. Knowledge on the human settlement in the region and their probable association with the river and the fishes.
6. Studies on the status of the hydropower project area, which includes the production, processing, income, marketing and trade, etc. of the people.
7. Policy development in mitigating the shortfalls and demerits of the hydropower projects in relevance to fish and fisheries.
8. Detailed assessment of the fisheries enhancement programmes in the hydropower project area.

25.5 Fisheries Enhancement Programmes

The following are several successful approaches for enhancing and intensifying reservoir fisheries production at the hydropower project sites:

1. Stocking the reservoirs with hatchery-produced young ones of indigenous and commercially important fish species. The introduction of rainbow trout for enhancing fish production and brown trout for recreational fishing is one option in temperate waters.
2. The reservoirs can be installed with Fish Aggregating Devices (FADs) for enhancing fish production and ease of harvest.
3. Excessive infestation of the hydrophytes can be eliminated from the reservoirs with the usage of environment-friendly herbicides and the introduction of weed-eating fishes.
4. Cage culture is another successful aquaculture model in practice for enhancing fish production in reservoirs.
5. The reservoirs in temperate regions can be suitably utilized for recreational purposes by stocking with brown trout, mahseer, minor carps, etc. Angling can be allowed by issuing a license to the angler and with the fishing policy of catch and release.
6. Enactment of laws to prohibit fishing during the spawning season in the upstream or head waters.

25.6 Conclusion

Although hydroelectric projects are inevitable for human development indices, a comprehensive and holistic fisheries management plan, linked to every hydroelectric project, must be in place to safeguard the indigenous fish diversity.

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