Coldwater Fish Diversity of India and Its Sustainable Development

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Introduction

India is one of the mega biodiversity hotspots in the world and occupies the 9th position in terms of freshwater mega biodiversity (Mittermeier *et al.*, 1997). Biodiversity is essential for stabilization of ecosystems, protection of overall environmental quality, for understanding intrinsic worth of all species on the earth (Ehrlich and Wilson, 1991). The country is bestowed with vast and varied coldwater/hill fishery resources which are spread over the Himalayan and peninsular regions as upland rivers, streams, high and low altitude natural lakes and reservoirs. There are around 8,243 km long streams and rivers, 20,500 ha natural lakes, 50,000 ha of reservoirs, both natural and manmade, and 2500 ha brackish water lakes in the high altitude (Mahanta & Sarma, 2010). The Coldwater rivers and hill streams are known for their high velocity water fall, rapid cascades, deep pools and substratum comprising bed rock - boulder - sand. These vast and varied water resources in the uplands harbour rich ichthyofaunal diversity comprising large populations of indigenous and exotic, cultivable and non-cultivable fish species (Sehgal, 1999; Mahanta and Sarma, 2010). The low productivity and higher degree of resource seasonality and unpredictability give rise to a unique diversity of aquatic life which is usually prone to many types of disturbances (Bhatt *et al.*, 2012; Jena and Gopalakrishnan, 2012; Singh *et al.* 2014).

Coldwater Fish Diversity

The coldwater fisheries harbour 258 species belonging to 21 families and 76 genera. Out of these, the maximum of 255 species are recorded from North-East Himalaya, 203 from the west and central Himalaya and 91 from the Deccan plateau (Fig. 1).

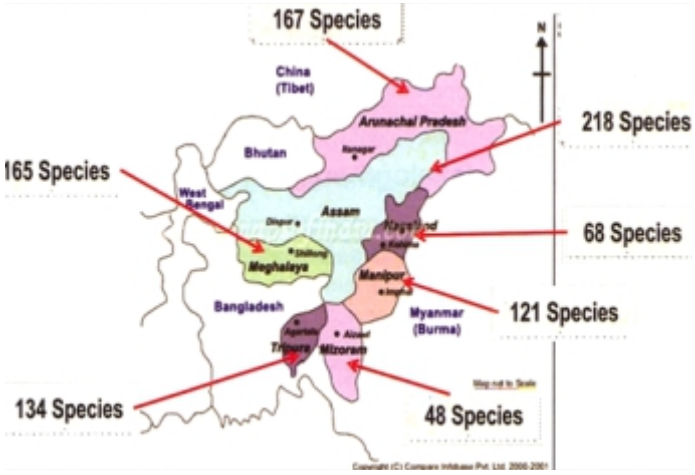


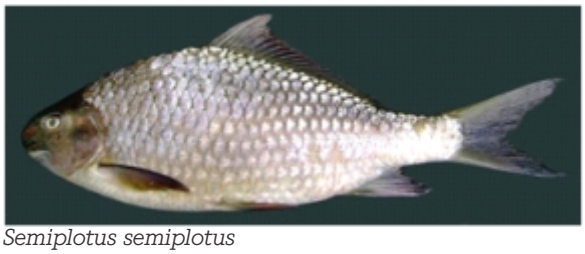
Fig. 1 : Number of species present in the North-East India (Ali, 2010)

The commercially important Indian coldwater species are *Tor tor, T. putiora, T. mosal, T. progeneius, T. khudree, T. mussullah, T. malabaricus, Naziritor chelynoides, Neolissochielus wynaadensis, N. hexagonolepis, Schizothoraichthys progastus, S. esocinus, Schizothorax richardsonii, S. plagiostomus, S. curvifrons, S. micropogon, S. kumaonensis, Barilius bendelisis, B. vagra, B. shacra, B. (Raiamas) bola, Bangana dero, Labeo dyocheilus, Crossocheilus periyarensis, Semiplotus semiplotus, Osteobrama belangeri, Garra lamta, Garra gotyla gotyla, Glyptothorax pectinopterus, G. brevipinnis, G. stoliczkae, Chagunius chagunio, Labeo dero, L. dyochilus* and *Lepidopygopsis typus* (Fig. 2) (Sehgal, 1999; Sunder *et al.*, 1999; Jena and Gopalakrishnan, 2012; Sehgal, 2012).

Mahseer is a group of game fish that belongs primarily to the genus Tor, but also includes some species of the genus *Neolissochilus* (e.g. Chocolate


Neolissochilus hexagonolepis


Osteobrama belangeri


Semiplotus semiplotus


Tor putitora


Tor tor


Tor progenius


Cirrhinus reba


Garra elongata


Garra gotyla


Labeo dyocheilus


Barilius bendilisis


Danio dangila


Raiamas bola


Schizothorax richardsonii

Fig. 2: Important coldwater fish species (Photos reproduced from Mahanta *et al.*, 2011)

mahseer *Neolissochilus hexagonolepis*). Schizothoracines (family cyprinidae and sub-family schizothoracinae) on the other hand, contribute to an economically significant group of hill stream fishes all along the Himalayan belt especially from Kashmir Himalaya. Out of about 258 cold water fish species (both indigenous and exotic) reported from Indian uplands, 17 members of snow-trout's (locally known as *Asela, Sela* or *Rasella* in Uttarakhand, *Gulgali* in Himanchal and *Koushargad* in Kashmir Himalayas) have been recognized by many authors (Talwar and Jhingran, 1991; Tilak, 1987 and Sundar *et al.*, 1999). Of these, 10 species belong to genus Schizothorachthys species being *(niger, esocinus, curvifrons, longipinnias, micropogon, planifrons, hugelli, labiatus, nasus, progastus*), two to genus *Schizothorax* (species being *richardsonii* and *kumaonensis*) and one each to *Diptychus (maculates), Gymnocypris (biswasi), Lepidopygopsis (typus), Ptychobarbus (conirostris), Schizopygopsis (stoliczkae)*. Only *Lapidopygopisis typus* is restricted to Periyar lake (Western ghats), Kerala. All other species are available from Jammu and Kashmir region. *Schizothorax richardsonii* is most common and widely distributed species in Himalayan belt (Sehgal, 1999).

Major Threats to Coldwater Fish Diversity

The aquatic environments are experiencing serious threats to both biodiversity and ecosystem stability requiring several strategies and priorities to address this crisis (Jena and Gopalakrishnan, 2012; Singh et al. 2014). Despite the central role of fish biodiversity in an ecosystem, all fish species that together comprise fish biodiversity face different risks and threats. The threats could be manmade or environmental, or in combination with interlinked effects. Such threats are wide ranging causing habitat alterations, shrinkage of resources, reduction of natural habitat area, germplasm loss etc on account of reducing water discharge in rivers, siltation, overfishing, pollution of water bodies, introduction/entry of non-native fish species and climatic vagaries etc. The major threats to the coldwater fish diversity are:

(i) **Habitat destruction/modification:** The occurrence of destructive natural events such as floods and landslides, change in environmental flow, biological invasion and many others, greatly affected the coldwater ecosystem in Himalayan region causing severe threat to coldwater fish diversity. Pollution, increased sedimentation, flow alteration and water diversion, and introduced species are identified as the main causes for decreased ichthyofaunal diversity in Asian countries (Nguyen and De Silva, 2006; Singh and Lakra, 2011; Singh *et al.*, 2013; Singh *et al.* 2014). During the past few years, the coldwater rivers and lakes harbouring original wild stock of precious fish species *viz.* mahseer, snow trout, minor carps, etc. have greatly shrunk in view of recurrent floods and consequent ecological degradation.

(ii) **Overfishing/over exploitation:** Over-exploitation of species affects the loss of genetic diversity and the loss in the relative species abundance of both individual and /or groups of interacting species. The population size gets reduced because of disturbances in age structure and sex composition (Sarkar *et al.*, 2008; Singh, 2012). Over-fishing also affects heritable life history parameters like growth and age of sexual maturity. Efficient gears remove quick growing larger individuals. Consequently, the proportion of slow growing ones increases and the average size of individuals in a population decreases.

The National Commission on Agriculture (NCA, 1976; Nautiyal, 2013) in its report on fisheries stated that there was general decline in the mahseer fishery due to indiscriminate fishing of brooders and juvenile fishes and adverse effects of river valley projects. The stress on the mahseer population is not only due to their overexploitation for its table value but also due to the rise in developmental activities, especially the growing number of hydroelectric-cum-irrigation projects which have fragmented and deteriorated its natural

habitat (Nautiyal and Singh, 1989). Consequently, mahseer population has critically declined from some areas (Kashmir, Nainital) and declined rapidly over the last few decades owing to which it was accorded a 'threatened' status in India (Khan and Sinha, 2000; Mahanta and Sarma, 2010; Akhtar *et al.*, 2014). Despite this, the use of rugged methods like dynamite, bleaching powder, pesticides and damming along with indiscriminate fishing leading to mass mortality of brood fishes and juveniles has continued unabatedly especially in small streams, which are the breeding grounds of mahseer (Nautiyal 1994a), thus effecting the recruitment rates adversely.

(iii) **Introduction of exotic species:** The introduction of exotic aquatic organisms, particularly fishes, brought about a worldwide concern as it resulted in a wide array of problems including extirpation of indigenous species (Singh and Lakra, 2011; Singh *et al.*, 2013). The exotics are a competition to indigenous fishes for food and habitat (Singh *et al.*, 2013). They may prey upon native fishes, introduce new diseases and parasites, result in the production of hybirds and cause genetic 'erosion' of indigenous species and degradation of the physicochemical nature of aquatic ecosystems (Singh *et al.*, 2013). All this will subsequently lead to loss of biodiversity (Singh and Lakra, 2011). There are several reports on the ecosystems level and species level catastrophic impacts of exotic introductions (Singh and Lakra, 2011, Singh *et al.*, 2013). The potential risks not only affect the quality or level of biodiversity, but also the socio-economic aspects of the human community that depend on aquatic ecosystems for their sustenance (Singh and Lakra, 2011). During the last several decades, over 300 species of exotic fishes have been brought into India for experimental aquaculture, sport fishing, mosquito control and aquarium keeping (Kumar, 2000; Singh and Lakra, 2011). Several exotic species of fishes are now established in the natural water bodies of India (Singh, 2014). The introduction of *Cyprinus carpio* var. *specularis* into Dal lake and Loktak lake has been reported to affect the population of indigenous *Schizothorax* sp. and *Osteobrama belangeri*, respectively (Singh and Lakra, 2011). The population of native Catla and mahseer were depleted considerably in Govind Sagar reservoir after the introduction of silver carp (Singh and Lakra, 2011). Introduction of silver carp in Indian reservoirs has had in general, a negative impact on fish diversity (Singh and Lakra, 2011).

(iv) **Climate change:** Climate variability is a key factor controlling the distribution and abundance of aquatic organisms and ecosystem structure (Jena and Gopalakrishnan, 2012). The climate change impact on fish depends on the magnitude of change, and on the sensitivity of particular species or ecosystem. The impact of temperature shift due to climate change on aquatic organisms will affect their biological functions, as most of them are poikilothermic in nature. In temperate regions, coldwater fishes are important ecological indicators for climate change as they are very sensitive to changes in water temperature and other environmental conditions. The Himalayan coldwater fish species may be at the highest risk of global warming as many of them are endangered. In many areas, they are already living at the upper end of their thermal range and ecological models demonstrate that there would be significant losses of temperate fish species as climate change may lead to a reduction of fish habitat and diversity (Mohseni *et al.*, 2003).

Approaches to Conservation and Sustainable Development

Due to factors explained above such as human modifications to the environment, over-exploitation, habitat loss, exotic introductions and others, coldwater fish diversity is greatly

threatened. In order to preserve these threatened ecosystem and species for future generations, immediate action in the form of aquatic biodiversity conservation strategies are necessary (Jena and Gopalakrishnan, 2012). In general, aquatic conservation strategies should support sustainable development by protecting biological resources in ways that will preserve habitats and ecosystems. In order to make coldwater fish diversity conservation to be effective, management measures must be broad based and some of the measures in this direction are:

Ranching

One of the many ways in which to replenish declining natural stocks is through captive breeding or hatchery programs. Often [illegible] are removed from their natural habitat and are then allowed reach to sexual maturity and breed within the safe confines of an aquaculture or lab environment and the young ones reared in captivity are released or ranched to the natural environment (Singh and Pandey, 1998; Lakra et al., 2007). Captive breeding programmes have become the major tool used to compensate the declining fish populations and simultaneously to supplement as well as enhance yields of wild fisheries. In this direction, Directorate of Coldwater Fisheries Research (DCFR), Bhimtal has perfected the breeding and seed rearing technology of golden mahseer and consistently producing golden mahseer seeds for culture and

(A) Kosi river, Ramnagar, ,

(B) Sariyatal Lake, Nainital

(C) Nainital Lake, Nainital

(D) Naukuchiatal Lake, Nainital

Fig. 3: Ranching of hatchery produced and cage reared advanced fingerlings of golden mahseer into different sites (A to D)

conservation purpose. To cater the overall need of mahseer seeds, DCFR has further established flow through mahseer hatcheries at Iduli fish farm, Roing in Arunachal Pradesh; at Eco-camp, ABACA, Nameri National Park, Tezpur, Assam and at Bagua fish farm in Sikkim. The Directorate has stocked the fingerlings of golden mahseer in many rivers and coldwater lakes of different hill states including Uttarakhand, Arunachal Pradesh, Meghalaya, Sikkim and Assam (Fig. 3). The Directorate has also distributed thousands of golden mahseer seed to the Department of Fisheries of Madhya Pradesh and West Bengal for their stocking enhancement programme in the reservoirs/wetlands. DCFR has once stocked golden mahseer in Shyamlatal Lake in Kumaon, India in 2001 has survived very well, grown to mature sizes and now turning out to be an attraction for tourists. However, the stock enhancement programmes for other declining coldwater fish species needs to be undertaken on priority basis as an step forward for sustainable development of other declining species.

Conservation Aquaculture

Conservation aquaculture is gaining importance in rehabilitation programmes of endangered/threatened fishes (Moyer *et al.*, 2009). Conservation aquaculture is the use of captive propagation to sustain imperilled species or populations and preserve local characteristics in the face of severe decline (Schreier *et al.*, 2012). It implies aquaculture in rehabilitation programmes of endangered fish populations by increasing the effective population size (Ne) of the threatened species. Using conservation aquaculture tool, the populations of white sturgeon has been restored (Schreier *et al.*, 2012) and this tool has also been

Fig. 4: Public awareness programmes conducted by ICAR-DCFR, Bhimtal

practiced for the conservation of pacific salmon. Similarly, in India too, the conservation aquaculture could be an effective tool for the conservation of declining population of coldwater fish species.

Increase Public Awareness

Increasing public awareness is one of the most important ways to conserve aquatic biodiversity. This can be accomplished through educational programs, incentive programs, and volunteer monitoring programs. For example, the Directorate of Coldwater Fisheries Research, Bhimtal conducted many awareness programmes for the conservation of golden mahseer which has not only increased the public awareness as to the value to the coldwater resources but also has sent the message of 'sense of belongingness' and made local people feel the need for conservation (Fig. 4). The state governments should also come forward in conducting awareness programmes with local people's participation so as to reach out more population of the coldwater states.

Restoration/Mitigation Efforts

Habitat restoration is an effective tool to repair ecological degradations. Aquatic areas that have been damaged or suffered habitat loss or degradation can be restored by habitat restoration management. During the past few years, the Coldwater Rivers and lakes harbouring original wild stock of precious fish species viz. trout, mahseer, snow trout, minor carps, etc. have greatly shrunk in view of recurrent floods and consequent ecological degradation. Some management practices such as the establishment of riparian buffer zones and the restoration of natural flow patterns and discharge regimes are to be applied for coldwater fish diversity management.

Regulatory Measures

The Indian Fisheries Act of 1897 (amended in 1956) is a landmark in the conservation of fishes. Besides provision to and monitor gears, mesh size and observance of fishing or closed seasons, the Act also prohibits the use of explosives or poisons to indiscrimately kill fish in any water. However, the enforcement of the Act particularly in coldwater states is negligible. Therefore, the state governments of the coldwater region should ensure the effective enforcement of the Act for the sustainable management of the coldwater fish diversity. Moreover, the Act is very old and needs to be amended incorporating all the relevant legal aspects to conserve fish germplasm resource of the states with special provisions suited to coldwater fisheries.

Conclusion

The conservation and sustainable development of coldwater fishery resources require dedicated efforts by integrating capture, culture fisheries and environmental programmes. Environmental laws with strict enforcement mechanisms have to be implemented to achieve the desired objectives to improve the fish habitat and biodiversity conservation. Although better monitoring of biodiversity, better assessment of risk and a more strategic approach to conserving biodiversity are all essential elements to successful risk management, an equally pressing need is the effective and targeted communication of risk to the public, policy makers, and other stakeholders (Jena and Gopalakrishnan, 2012). Extensive bio-monitoring of all coldwater resources in time and space to assess threat perspectives in relation to fish diversity needs to be carried out. The upland regions are fragile in nature therefore have to be conserved and used on a sustainable basis.

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