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Cold water fisheries in the trans-Himalayan countries

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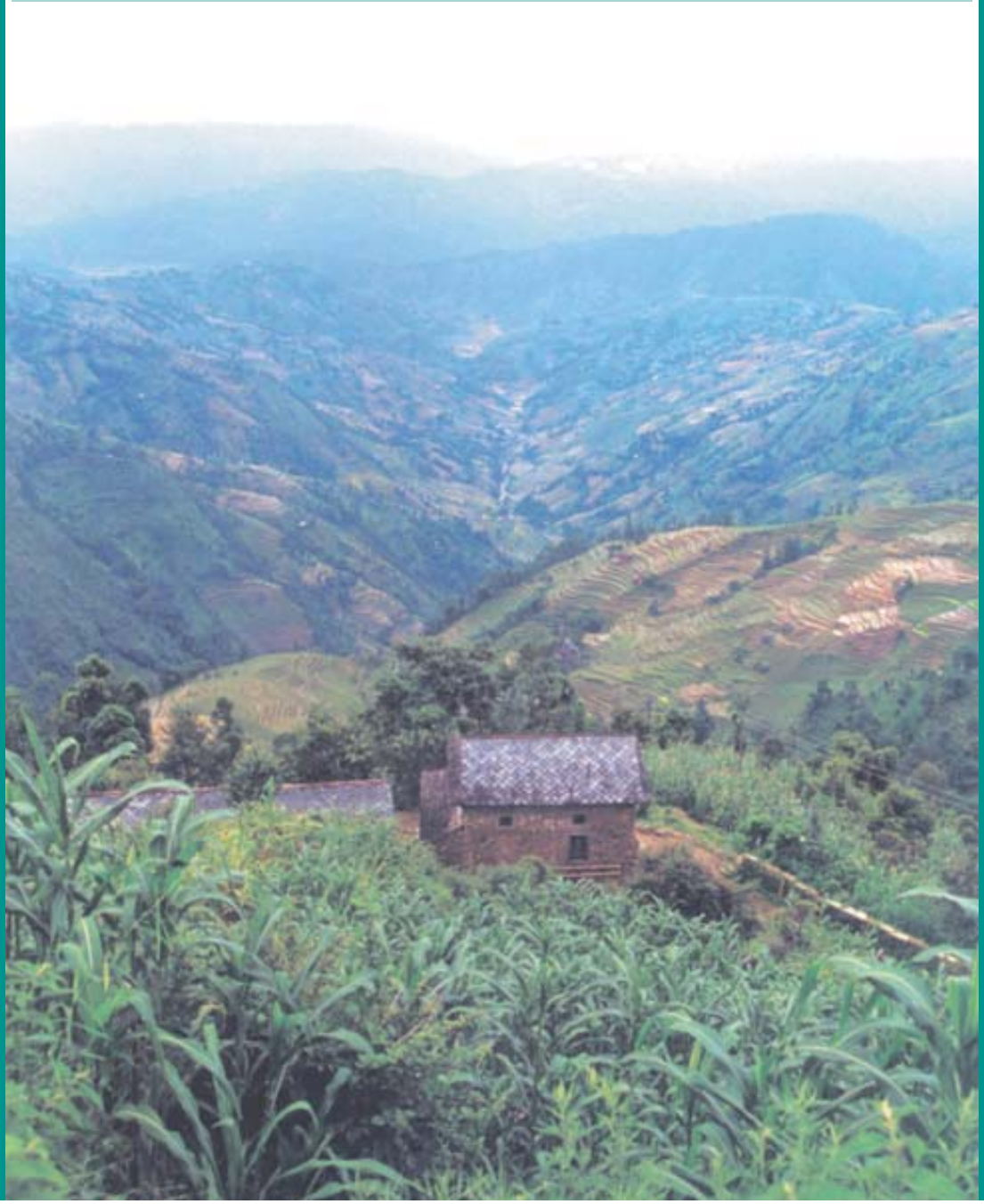

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PREPARATION OF THIS DOCUMENT

This volume contains contributions presented at the Symposium on Cold Water Fishes of the Trans-Himalayan Region, which was held on the 10-13 July 2001 in Kathmandu, Nepal. The objectives were to share information on the status of indigenous fish species and fisheries in the Trans-Himalayan region, improve understanding of their importance in peoples' livelihoods and assess the potential for further development. The proceedings are a contribution to the International Year of Mountains.

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ABSTRACT

The Trans-Himalayan region encompasses a number of countries situated in the midland and highland areas of the Himalayas, Karakoram, and in a broad sense also in Hindu Kush and Pamir. The mountains are characterized by a very low level of human development, with full exploitation or overexploitation of the natural resources. Fisheries play an important role in providing food and income to the mountain people. The Symposium on Cold Water Fishes of the Trans-Himalayan Region, held 10-13 July 2001 in Kathmandu, Nepal, was attended by 70 participants from 10 countries. In 32 presentations it reviewed information, experiences, ideas and findings related to fish and fisheries in the region, paying special attention to fish species distribution, fishing intensity, socio-economic conditions and livelihoods of fisher communities, as well as to the impact of environment degradation, conservation measures and aquaculture technologies for indigenous and exotic cold water fish. The Symposium highlighted the role that fisheries play in providing food and income to people within the Trans-Himalayas and Karakoram. Recognizing the need to increase the role of aquatic resources in poverty alleviation, the Symposium urged national governments to give greater attention to fisheries development in mountain areas. The Symposium put forward a number of priority issues, including collaborative action on a regional scale, which would probably be the most cost-effective way to address these common problems and to share experiences. The recommendations are expected to be addressed in follow-up activities under a Trans-Himalayan regional programme.

Distribution:

Authors and Participants
Regional and Sub-regional Fishery Officers
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FOREWORD

The Symposium on Cold Water Fishes of the Trans-Himalayan Region was held on the 10-13 July 2001 in Kathmandu, Nepal. It was jointly organized by the Directorate of Fisheries Development, Ministry of Agriculture and Cooperatives, His Majesty's Government of Nepal, Nepal Agriculture Research Council, Food and Agriculture Organization of the United Nations and Network of Aquaculture Centres in Asia-Pacific, in co-sponsorship with the Nepal Fisheries Society, the World Conservation Union and Worldwide Fund for Nature. The Symposium was attended by over 70 scientists, planners, policy makers, private entrepreneurs, representatives from 10 countries of the Trans-Himalayan and neighbouring regions: Bangladesh, Bhutan, Cambodia, China P.R., India, Iran, Myanmar, Nepal, Pakistan, Thailand, and representatives of international and regional organizations including the World Conservation Union (IUCN), the Bagmati Integrated Watershed Management Programme (BIWMP), and the Mekong River Commission (MRC).

The Trans-Himalayan region, as defined by the International Centre for Integrated Mountain Development (ICIMOD), encompasses the midland and highland areas of the countries of Afghanistan, Bangladesh, Bhutan, China PR., India, Myanmar, Nepal and Pakistan. In the region, characterized by rugged terrain and very low levels of human development, fisheries play an important role in providing food and income to the people. The objectives of the Symposium were to share information on the status of indigenous fish species in the Trans-Himalayan region, improve understanding of their importance in peoples' livelihoods and assess their current level of exploitation. The Symposium was designed to consolidate information, experiences, ideas and findings related to fish species distribution, fishing intensity, socio-economic conditions and livelihoods of fisher communities, impact of environment degradation, conservation measures and aquaculture technologies for indigenous and exotic cold water fish in the region.

The papers presented at the Symposium are grouped in four sections. In the first section resource paper by Petr reviews the cold water fish and fisheries in the mountain countries of Hindu Kush-Pamir-Karakoram and Himalayas, while their contribution to the livelihoods of the mountain people is dealt with by Phillips et al. One resource paper (Shrestha) is devoted to the host country Nepal. The six country reviews in the second section deal with cold water fish and fisheries in Bhutan (Gyeltshen), Iran (Mehrabi), Myanmar (Oo), Nepal (Swar), China (Wang and Yang), and Pakistan (Yaqoob). Of the 18 experience papers of the third section, 15 deal with fish stocks and fisheries in Nepal. Of these, two (Rajbanshi; Shrestha J.) provide a comprehensive list of cold water fish species, their distribution and taxonomic revision; six papers deal with the most important fish of Nepal, the mahseer (Bista *et al*.; Gurung *et al*.; Joshi *et al*.; Sharma and Mishra; Shrestha T.K.) and snow trout (Rai *et al*.), including aspects of their aquaculture; one paper deals with the culture of the exotic rainbow trout (Nepal *et* al.); six papers deal with fish stocks in rivers and lakes (Dhital and Jha; Ranjit; Shrestha *et al*.; Swar and Craig; Upadhaya and Shrestha; Yadav), with two of the papers also dealing with the socio-economic aspects of fisheries (Dhital and Jha; Ranjit); two papers address the problem of river damming on fish stocks (Gubhaju; Upadhaya and Shrestha). Prospects for fishery enhancement and aquaculture in cold waters of Nepal are discussed by Shrestha *et al*. Mahseer fishery in India is dealt with by Ogale, while the progress with mahseer aquaculture and its profitability are considered in papers by Bista et al. and by Gurung et al. One paper deals with the production of trout in northern Pakistan (Yaqoob). The fourth section, under the heading

Associated topics, contains five papers dealing with the fish and aquaculture in Bangladesh and of the Mekong River. The papers from Bangladesh address aquaculture production in hill districts (Aziz and Hossain), and the prospects of low cost diets in aquaculture (Hossain), respectively. One paper deals with the endangered Mekong giant fish species (Mattson *et al*.), one paper is devoted to aquaculture of the catfish *Aorichthys seenghala* (Ratanatrivong *et al*.), and one to the possibilities of developing aquaculture based on indigenous Mekong fish species (Vibol and Mattson).

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SUMMARY OF RECOMMENDATIONS OF THE SYMPOSIUM ON COLD WATER FISHES OF THE TRANS-HIMALAYAN REGION, 10-13 JULY 2001, KATHMANDU, NEPAL

The Symposium on Cold Water Fishes of the Trans-Himalayan Region, 10-13 July 2001, held in Kathmandu, highlighted the role that fisheries play in providing food and income to people within the Trans-Himalayas and Karakoram. Countries of the Trans-Himalayan region are making efforts to utilize cold water fish for the reduction of poverty and some successful strategies are emerging.

The Kathmandu Symposium put forward a number of priority issues to be addressed in follow-up activities under a Trans-Himalayan regional programme. These include the need for more research, training and education into Himalayan aquatic ecosystems, especially the biology and behaviour of coldwater fish stocks, migration patterns and environmental impacts, for strengthening of fisheries data collection and dissemination, and for improved access to, analysis and synthesis of the existing information and experience. A better integration of fisheries development within the overall ecosystem and rural development approach, under full consideration of ecological, social and economic values of fisheries in relation to agriculture, conservation and hydroelectric generation, is essential if fisheries is to become a more productive source of food in the region and play its full role in poverty alleviation in mountain countries. Another important issue is the need of better understanding of socio-economic conditions and livelihoods of fisher communities. This would assist in formulating better management interventions with the objective of improving livelihoods of fishers and farmers in mountain areas. Better promotion of inter-sectoral cooperation and coordination between fishery and other sectors concerned with rural development and water resources management, and improving communications and exchange of experience and information resulting from the above, require close government attention in the countries of the region. Where resources are shared among neighbouring or several countries, interlinking will assist in solving common problems. The Symposium emphasized the need for policy development, that recognises the social and economic importance of aquatic resources and supports poor aquatic resource users, especially for integrated watershed development, gender equity, and poverty alleviation.

Collaborative action on a regional scale would probably be the most cost-effective way to address these common problems and share experiences. The Symposium therefore recommended regional cooperation among countries of the Trans-Himalayan Region be strengthened for effective sharing and exchange of skills, experiences and technical cooperation. To support this regional cooperation, the Symposium recommended a network for development and conservation of cold water fisheries be established among concerned nations in the Trans-Himalayan Region, coordinated by a centre located in a suitable country within the region. International support was also requested for this important regional initiative.

Section 1: Resource Papers

COLD WATER FISH AND FISHERIES IN COUNTRIES OF THE HIGH MOUNTAIN ARC OF ASIA (Hindu Kush-Pamir-Karakoram-Himalayas). A REVIEW

by

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ABSTRACT

Cool and cold water streams and rivers in six countries (Afghanistan, Pakistan, India, Nepal, Bhutan and China) of the mountain arc extending from Hindu Kush through Pamir, Karakoram and Himalayas support predominantly subsistence and/or recreational/sport fisheries, with commercial fisheries practised only in some lakes and reservoirs. While fishing in streams and rivers is largely unmanaged, considerable effort has gone into the management of some reservoirs and lakes in India, Pakistan and Nepal. For recreational fishery brown trout has been introduced in some rivers and streams of the southern slopes of the mountain arc, and has succeeded in establishing self-reproducing populations in some of them. Schizothoracinae (a sub-family of the family Cyprinidae) is the predominant group of indigenous fish captured from streams and rivers, and mahseer (*Tor* spp) and *Neolissocheilus hexagonolepis* are the favourite fish of anglers. Overfishing has become a problem in many cold water streams and rivers, as well as in some lakes in India. Deterioration of catchment soils by inappropriate agricultural practices and deforestation, and pollution are reducing the water quality, harming the cold water fish stocks in some rivers, streams and shallow lakes. Kashmir Valley lakes Dal and Wular in Jammu and Kashmir of India are being reduced in size through the process of eutrophication, explosive growth of aquatic plants and encroachment of agriculture into their margins. Enhancement of cold water fish stocks through regular stocking of indigenous fish species in a variety of water bodies in the mountain arc, especially in the Himalayas, is one way which has been pursued by some of the countries in the region. There is a growing awareness of the need for protecting the catchment from inappropriate land use practices.

1. INTRODUCTION

The area considered in this review starts in the west with the mountain ranges of Hindu Kush, continuing in an approximately eastern direction through Pamir, Karakoram and Himalayas. Only Afghanistan, Pakistan, India, Nepal, Bhutan and China are reviewed for their cold water fish fauna and fisheries in this mountain belt. Information is sparse on cold water fish and fisheries in Afghanistan, and the reviewer's inability to read information on China in the original language placed a limit on the section dealing with China cold waters. The major source of information for this review has been a FAO publication (Petr, ed., 1999) which covered cold water fish and fisheries of the major part of Asia, including countries which are the subject of discussion in the present FAO Symposium. The reviewer apologises for any weakness in this information and hopes that information presented at the Symposium will update this text. This also concerns revisions of taxonomy (see papers by Shrestha, J. and by Rajbanshi, K.J., this volume).

The subfamily Schizothoracinae (family Cyprinidae), which includes snow trout (*Schizothorax* spp) and several other genera important for fisheries, is present in the Himalayan and sub-Himalayan regions of the Indian subcontinent, Afghanistan, Central Asia, Kazakhstan, China and Myanmar, hence it is indigenous for the region. Schizothoracines inhabit cold waters up to the altitude of 3 323 m (in Nepal), being present in rivers, streams and lakes, and prefering temperatures of between 8 and 22°C. There are 28 species of snow trout in the Himalayan and sub-Himalayan regions including China and Pakistan (Sharma, 1989). The genus *Tor*, with several species present in the mountain arc, is a famous indigenous sport fish. Of the exotic introduced species the brown trout (*Salmo trutta fario*), where established in wild waters, is important especially for sport fishery.

2. GEOGRAPHY AND FISH SPECIES DIVERSITY

2.1 Afghanistan

Northern Afghanistan is situated at the western end of the Himalayas-Karakoram-Pamir-Hindu Kush complex of high mountain ranges. Nearly 75 percent of Afghanistan is mountainous, with its north-east embracing the southwestern ranges of Hindu Kush. Rivers along the northeast border with Pakistan are affected by the monsoon and have maximum flows twice a year: July to September and January to April. The majority of Afghanistan rivers are endorheic, ending in deserts or internal lakes. One of these is the Amu Darya, which has its origins in the Pamirs, and ends in the Aral Sea. The Murgab River, with a source in the western Hindu Kush, flows west, enters Turkmenistan and is lost in the sands of the Kara Kum desert. The Hari Rud River which starts in the centre of Afghanistan, also ends in the sands of the Kara Kum desert. The Helmand River, which has a source not far from the Kabul River at the southwestern end of the Hindu Kush, ends in Sistan Lakes in eastern Iran. For the purpose of this review only the Kabul River, which originates in the southwestern Hindu Kush and eventually enters Pakistan, where it flows into the Indus River, is of interest (Figs 1 and 2).

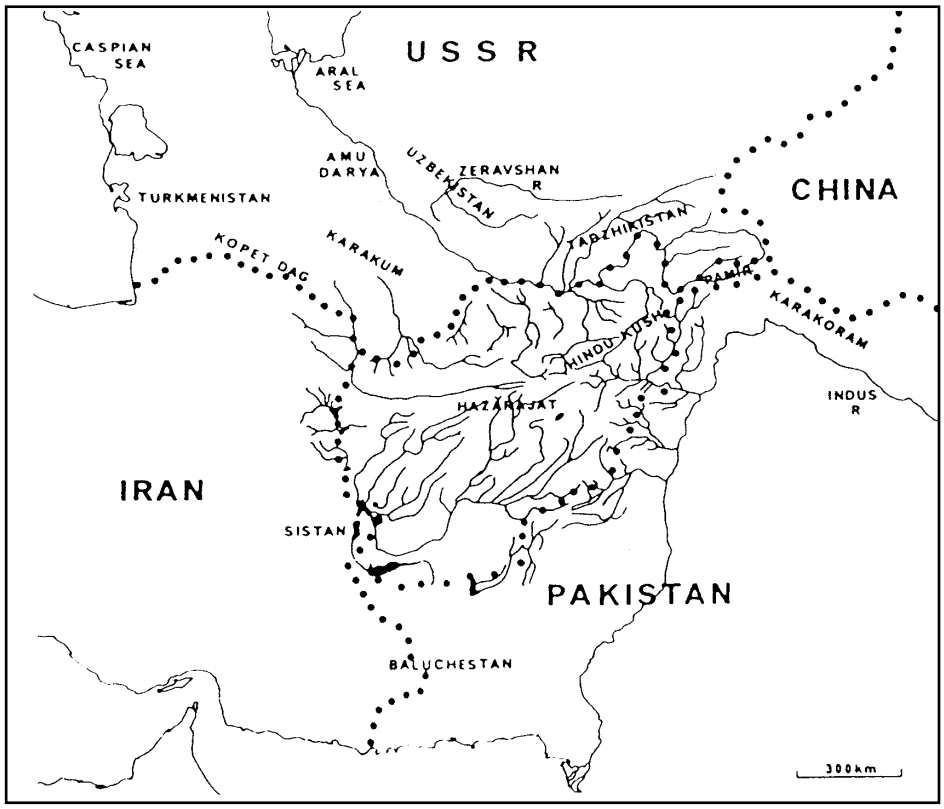

Fig. 1 - Major mountain ranges of Afghanistan (from Coad, 1981)

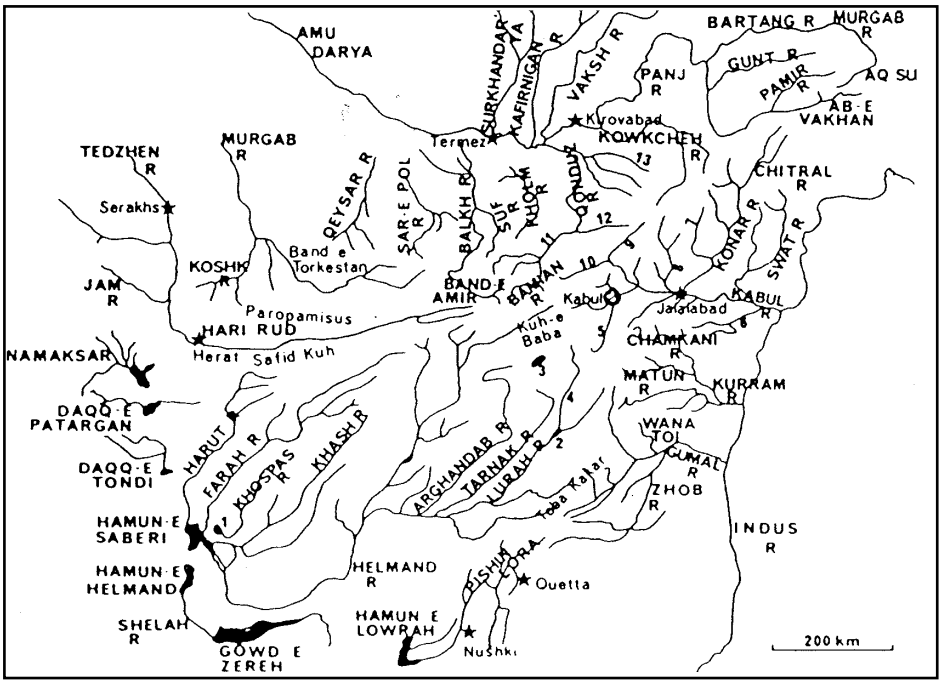

Fig. 2 - Major drainages of Afghanistan (from Coad, 1981)

1 = Jehil-e Puzak; 2 – Ab-e Istadeh-ye Moqor; 3 – Dasht-e Navar; 4 – Ghazni River; 5 – Lowgar River; 6 – Khiali River; 7 – Pech River; 8 – Laghman River; 9 – Panjsher River; 10 – Gowr Band; 11 – Sorkh Ab; 12 – Andarab River; 13 – Khanabad River

Afghanistan rivers and streams contain a mixture of Oriental and Palaearctic species, with northern and southern species and high and low altitude-adapted species. The fauna is about equally divided between Oriental and Palaearctic species. For the Kabul River Coad (1981) has listed the following indigenous fish species: *Amblypharyngodon mola, Aspidoparia jaya, Barilius vagra, Cirrhinus reba, Danio devario, Esomus danricus, Labeo angra, L. dero, L. diplostomus, L. dyocheilus, L. gonius, L. pangusia, Puntius conchonicus, P. sarana, P. sophore, Salmostoma bacaila, Schizothorax barbatus, S. chrysochlora, S. edeniana, S. esocinus, S. labiatus, Tor putitora, Nemacheilus alepidotus* (Kabul R. basin), *N. griffithi, N. sargadensis* (Kabul R. basin), *Rita rita, Ompok canio, O. pabda, Glyptosternum reticulatum* (Kabul R. basin), *G. jalalensis, Channa gachua* (Kabul R. basin), *C. punctatus* (Kabul R. basin). The following exotic fish were also noted for the Kabul River: *Carassius auratus, Ctenopharyngodon idella, Hypophthalmichthys molitrix, Gambusia affinis.*

Coad (1981) noted that the upper reaches of the Kabul basin are dominated by a variety of snow trout (Schizothoracinae) and cobitid species which are adapted to cold, fast mountain streams.

2.2 Pakistan

Cold water fish are limited to the higher latitudes of the northern half of Pakistan (Fig. 3), where three mountain systems extend from the west to the east: the Hindu Kush, Karakoram and Himalayas. In the northern mountains of Pakistan the Indus River, which itself originates in Tibet (China), receives a number of tributaries, viz. Gilgit, Swat, Kunhar, Neelum and Jhelum. Further downstream, already in the plains, the rivers Chenab, Ravi and Sutlej, all of which arise from the Indian Himalayas, join the Indus River from the east. Cold water streams and lakes are present in three administrative areas of northern Pakistan: Northern Areas, the Azad State of Jammu and Kashmir (AJK), and the North West Frontier Province (NWFP). Schizothoracines (genera *Schizothorax* and *Schizopyge*) are the major fish of cold water streams and rivers, with the dominant species being *Schizothorax plagiostomus*. Akhtar (1991) listed 25 species (of these 4 introduced, *viz*. brown and rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*) and gold fish (*Carassius auratus*) of freshwater fish for the Northern Areas as compared to 43 species (of which 4 have been introduced) for AJK, in which he included also warm water species (Akhtar, 1991a) (Tables 1 and 2).

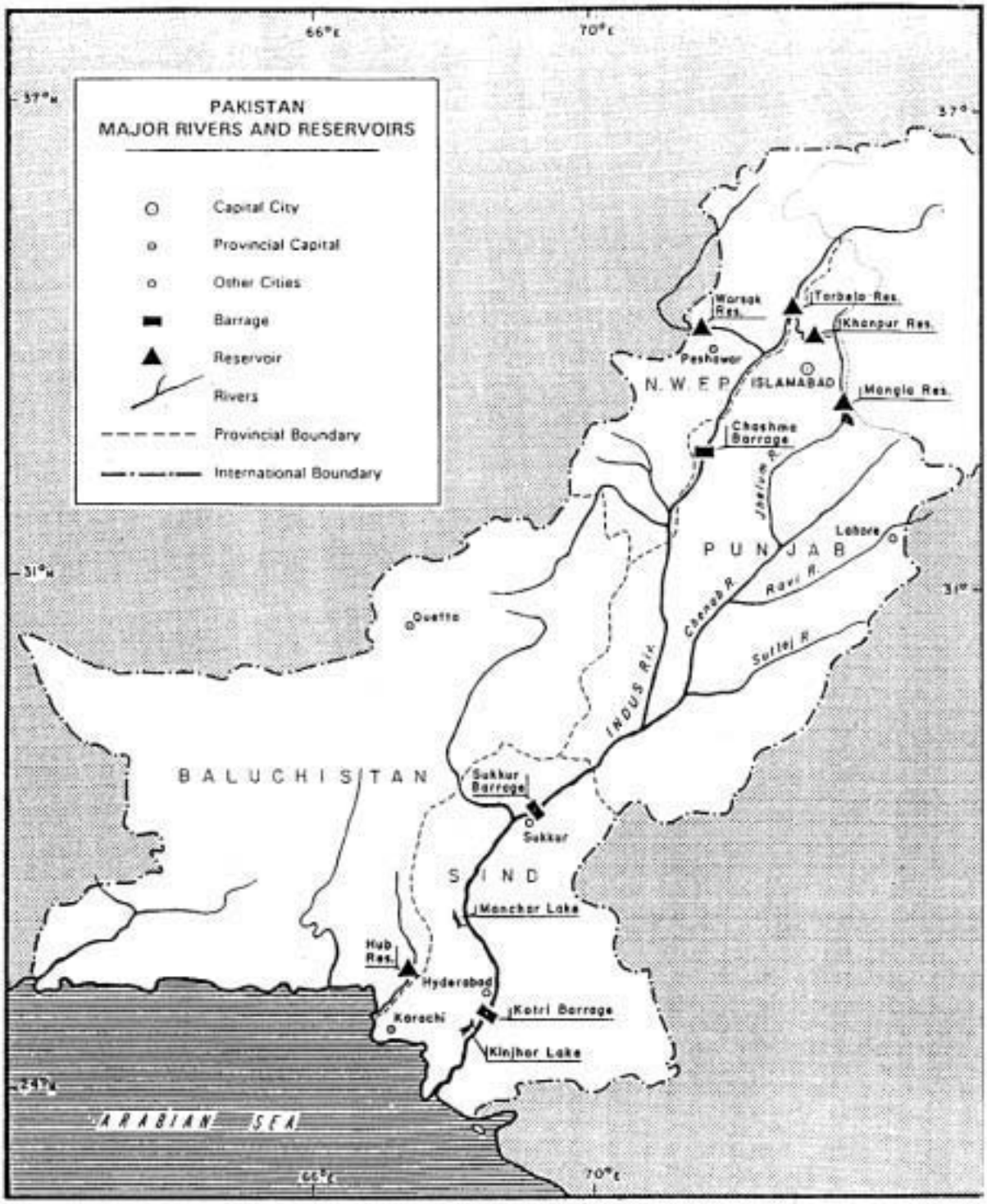

Fig. 3 - Map of Pakistan and location of major reservoirs (from Petr, 1999b)

Table 1
List of fish - Northern Areas (from Akhtar, 1991)

# exotic	
Family: Salmonidae	Family: Cyprinidae
# Salmo trutta	# Cyprinus carpio
# Oncorhynchus mykiss	# Carassius auratus
Family: Cyprinidae	Family: Cobitidae
Schizothorax intermedius	Triplophysa choprai
Schizothorax labiatus	Triplophysa gracilis
Schizothorax plagiostomus	Triplophysa stoliczkai
Schizopyge curvirostris	Triplophysa yasinensis
Schizopyge esocinus	Triplophysa sp.1
Schizopyge longipinnis	Triplophysa sp.2
Schizopygopsis stoliczkai	
Schizocypris brucei	Family: Nemacheilidae
Dyptichus maculatus	Nemacheilus semiarmatus
Ptychobarbus conirostris	
Racoma labiata	Family: Sisoridae
	Glyptosternum reticulatum

In the Northern Areas the Indus River receives numerous tributaries draining the Karakoram Range. Of the total length of 2100 km of streams and rivers, about 350 km contain brown trout. There are 33 lakes in Northern Areas, of which 12 are stocked with trout, but most have indigenous fish.

Table 2
List of fish - Azad Jammu and Kashmir (from Akhtar, 1991a)

# exotic	
Family: Salmonidae	Family: Cyprinidae
#Salmo trutta	Tor putitora
#Oncorhynchus mykiss	Tor tor
	#Cyprinus carpio
Family: Cyprinidae	#Carassius auratus
Schizothorax esomus	
Schizothorax micropogon	Family: Cobitidae
Schizothorax plagiostomus	Aorichthys seenghala
Crossocheilus latius	Nemacheilus alepidatus
Racoma labiata	Schistura alepidata
Aspidoparia morar	Triplophysa kashmirensis
Barilius vagra	
Chella cachius pakistanicus	Family: Sisoridae
Catla catla	Glyptothorax kashmirensis
Cirrhinus mrigala	Glyptothorax pectinopterus
Cirrhinus reba	Glyptothorax punjabensis
Esomus danricus	Glyptothorax stocki

Garra gotyla	
Labeo calbasu	Family: Schilbeidae
Labeo dero	Clupisoma naziri
Labeo dyocheilus	
Labeo gonius	Family: Siluridae
Labeo rohita	Ompok bimaculatus
Puntius chola	Ompok pabde
Puntius sarana	Wallago attu
Puntius sophore	
Puntius ticto	Family: Channidae
Salmostoma bacaila	Channa punctatus
Amblypharyngodon mola	

The River Jhelum, which arises from Lake Wular in India, is the major river of AJK. In Pakistan the Jhelum receives a number of tributaries. The major tributary, the River Neelum, is a cold water river with a range of temperatures from 0 to 12°C. The indigenous schizothoracines dominate the fish stocks. After its confluence with Jhelum at Muzaffarabad, the water temperature increases from 8 to 30°C, until it reaches Mangla reservoir. The stretch between Muzaffarabad and Mangla already harbours warm water fish such as Indo-Gangetic carps, but also (Tor spp), a popular game fish. In another tributary of the Jhelum, the Poonch, schizothoracines are reported from the uppermost stretch of this river. Two inaccessible lakes in the Neelum Valley, Lake Rattigali Sar (3 832 m), and Dherian Sar (3 695 m) are reportedly stocked with trout.

The NWFP, surrounded by rugged mountains, has a temperate climate, including cold winters. Rivers in the valleys Swat, Kaghan, Chitral and Kohistan carry clean cold water and contain schizothoracines and some other cold water indigenous fish. Several lakes and reservoirs also provide suitable conditions for cold water fish. As one moves to south to transitional or semicold waters, schizothoracines are joined by mahseers. Further south and at lower altitude warm water fish species prevail.

2.3 India

The Himalayas, which cover 594 400 km2, run for about 2 500 km from west to east, between Nanga Parbat (8 126 m) in the west and Namcha Barwa (7 756 m) in the east. This mountain system is bordered in the west by the Karakoram Mountains and in the north by the high Plateau of Tibet. The width from the south to the north varies between 200 and 400 km. From south to north one can distinguish four parallel and longitudinal mountain belts of varying width, each having distinct physiographic features and its own geological history: the Siwaliks, the Lesser Himalaya, the Greater Himalaya and the Trans-Himalaya (Sehgal, 1999). The Himalayas are drained by 19 major rivers (Fig. 4), of which the Indus and the Brahmaputra are the longest, each having a mountain catchment of about 160 000 km2. Of the remaining 17 rivers five belong to the Indus system, of which the Beas and the Sutlej have a total catchment of 80 000 km2, nine (Ganga, Yamuna, Ram Ganga, Kali-Sharda, Karnali, Rapti, Gandak, Bhagmati, Kosi) belong to the Ganga system, draining nearly 150 000 km2. The Ganga has five source rivers (Bhagirathi, Mandakini, Alaknanda, Dhauliganga, Pindar). A number of rivers enter from within India and from Bhutan. The Brahmaputra (known as Yarlung Zangbo Jiang, or Tsangpo, in China) has a catchment of about 110 000 km2. Most of these rivers flow in deep valleys until they exit the mountains.

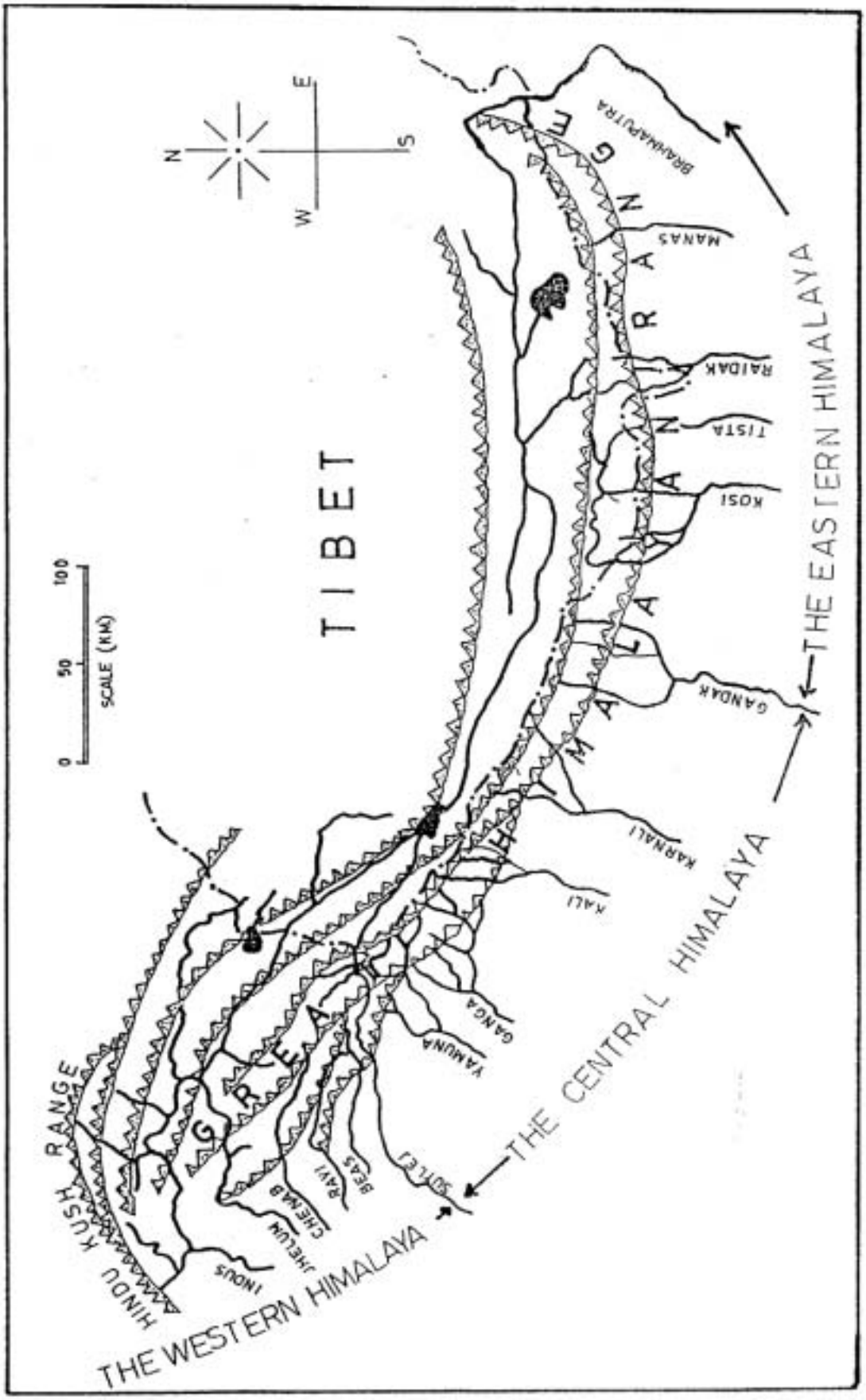

Fig.4 - The Himalayas and its principal rivers (from Sehgal, 1999)

The fish species distribution in the Himalayan streams depends on the flow rate, nature and substratum, water temperature, and the availability of food. In the torrential streams Sehgal (1988) identified several zones on the basis of the dominant fish species and the hydrographical features:

(i) headwater zone inhabited by rheophilic species of loaches and catfishes (*Nemacheilus gracilis, N. stoliczkae* and *Glyptosternum reticulatum*)

(ii) large stream zone, formed by the joining of headwater streams, inhabited by *Diptychus maculatus* and *Nemacheilus* spp. In the upper reaches of the most torrential section of this zone, the rheophilic species of snow trouts, *Schizothoraichthys esocinus*, *S. progastus, Schizothorax richardsonii* and *Schizopygopsis stoliczkae*, occur. The intermediate reaches of the large stream zone are frequented by *Schizothorax longipinnis, S. planifrons* and. *S. micropogon*. The least rapid reaches of this zone are occupied by *Garra gotyla, Crossocheilus diplochilus, Labeo dero* and *L. dyocheilus*;

(iii) slow moving meandering zone inhabited by a large number of cold or eurythermal species such as *Barilius* spp, *Tor* spp, catfishes, homalopterid fish (*Homaloptera* spp) and snakeheads (*Channa* spp).

Menon (1954) related the distribution of Himalayan fish to morphological characteristics which enable them to inhabit the torrential streams. He recognised six major groups: (a) fish dwelling in shallow, clear cold water in the foothills without any striking modification to current: *Labeo, Tor, Barilius and Puntius*; (b) fish inhabiting the bottom water layers in deep fast current, with powerful muscular cylindrical bodies: schizothoracines and the introduced trout; (c) fish sheltering among pebbles and stones to ward off the strong current: *Crossocheilus diplochilus*; (d) fish sheltering among pebbles and shingles in shallows, with special attachment devices: the loaches *Nemacheilus, Botia* and *Amblyceps*; (e) fish which cling to exposed surfaces of bare rocks in lower current, with adhesive organs on their ventral surface for attachment to rocks: *Garra, Glyptothorax* and *Glyptosternum*, and (f) fish which cling to the exposed surfaces of bare rocks in fast current, with limpet-shaped bodies and mouth, gills and fins highly modified to suit the habitat: *Balitora*.

The need for shelter from the current has led to territoriality. Mahseers and schizothoracines chase intruders to defend the limited food resource and available shelter. During the winter, when the water level is at its lowest and water is highly transparent, all size groups of mahseers and schizothoracines are present in pools of rivers such as Jhelum, Beas, Sutlej and Yamuna (Sehgal, 1988). Water temperature is always an important limiting factor influencing geographical distribution and local occurrence within one water system. Cold stenothermic species such as the endemic schizothoracines (*Schizothoraichthys esocinus* and *Diptychus maculatus*) and exotic brown trout have an upper tolerance of about 20°C. Carps, mahseers and lesser barils have a wider tolerance and even survive water temperatures over 25°C. Schizothoracines and brown trout remain active in the near-zero temperatures which prevail in streams of the Lesser and Greater Himalaya during December and January. Hailstorms and drought conditions in the Lesser Himalaya may cause adverse conditions, leading to fish kill.

To cope with the steep fall in temperature in winter months schizothoracines migrate from headwaters to lower altitude where they represent a sizeable part in fish catches in large rivers and their tributaries. The rise in temperature in Kashmir streams from near-freezing level to 10-17°C during May-June induces *S. richardsonii, S. longipinnis* and *S. curvifrons* to spawn. In the Sutlej River, *S. richardsonii* starts upstream migration with the rise in water temperature during March. During the upstream migration the fish still finds itself in waters of low temperatures, owing to the steady inflow of snow-melt water. To avoid it the species migrates into warmer side

streams in which it spawns at temperatures of 17.5-21.5°C, such as in the Ravi River, where it spawns in May. In the upper Beas, the same species spawns only in July-August when the water temperature is warm enough, but some fish of the same species migrate downstream in the same river to spawn from October to December at 19.0 to 22.5°C (Sehgal, 1999).

The frequent occurrence of spates in some rivers hinders spawning of cold water fish. The low density populations of cold water fish in the upper reaches of the Sutlej and Chenab rivers may result from the passage of these rivers through deep and narrow gorges, and the presence of cold glacier- and snow-melt water.

As a result of a study of eleven rivers in the northwestern Himalayas, Sehgal (1999) noted the changes in the prevalent fish species (Table 3).

The eastern Himalaya drained by the Brahmaputra has a greater diversity of cold water fish than the western Himalayan drainage. 218 fish species are listed for the whole Himalayas (Menon, 1962).

The sub-family Schizothoracinae, rich in genera and species, has mainly Central Asiatic distribution although a few species are present also along the southern face of the Himalayas (Seghal, 1999). This is perhaps on account of the Trans-Himalayan origin of some of the major rivers like the Indus, the Sutlej and the Brahmaputra, which made it possible to descend to the lower reaches of these rivers.

2.4 Nepal

Nepal has a large number of rivers with perennial water supply from melting snows of the Himalayas, considerable number of lakes, and a few reservoirs which have cold water fish stocks.

Nepal is divided into three parallel geographical zones running east to west: the Terai plain in the south, with subtropical warm climate and hence few cold water fish; the hills (i.e. the foothills of the Himalayas) extending from 610 m to 4 877 m, and the Himalayan mountains located from above 4 877 m, above the tree line. Mountains and hills cover 83 percent of Nepal while the Terai occupies only 17 percent . There are three major river systems in Nepal: Kosi in the east, Narayani in the centre, and Karnali in the west (Fig. 5). All three rivers drain into the Ganga River in India. A number of other rivers originate in the Himalayas and flow from north to south, being in flood when they receive the torrential rains of monsoon and snow- and ice-melt waters.

Table 3
Characteristics of three Himalayan river zones and their major fish species (from Sehgal, 1999)

Characteristics zone	**Greater Siwalik Himalayan zone**	**Lesser Himalayan zone**
Elevation (m) Below 100	4 000-2 000	2 000-1 000
Substratum Pebbles,sand	Rocks and boulders with sandy patches	Boulders/stones with gravel, etc.
Water temp. (°C) 22.9	13.4	18.7
pH 8.0	7.4	7.9
Diss. O_2 (mg/L) 7.9	9.3	8.7
Major fish species		
Schizothoraichthys esocinus	+	-	-
Schizothorax richardsonii	+	+	+
Diptychus maculatus	+	-	-
Glyptosternum reticulatum	+	+	-
Tor putitora	+	+ (monsoon)	+
Labeo dero	-	+	+
Salmo trutta	+	+	-

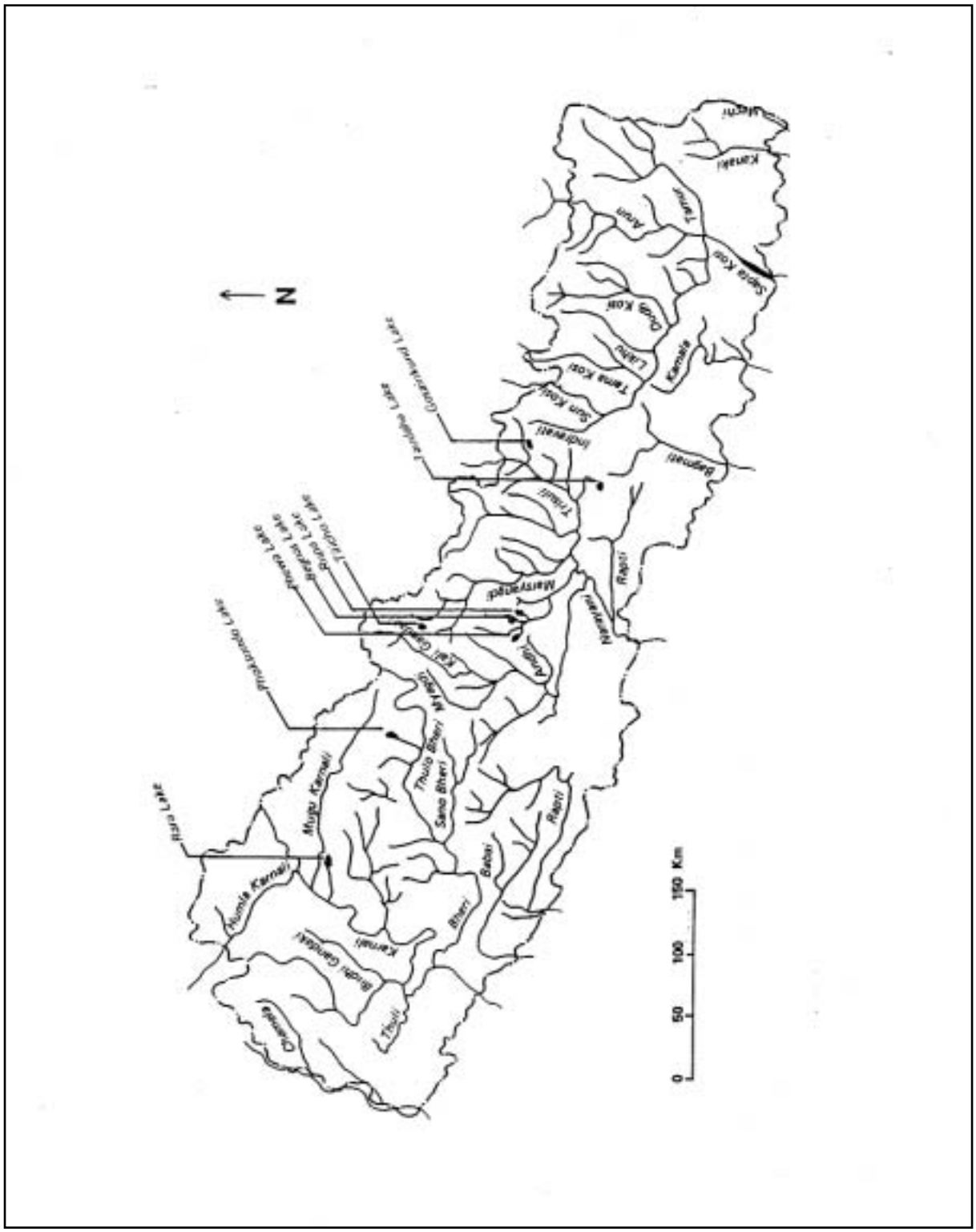

Fig. 5 - Major rivers of Nepal (from Shrestha, 1999)

Presently only a few lakes are used for fisheries. These are the lakes of Pokhara Valley, and several lakes in western Nepal. In Pokhara Valley, Lake Phewa is situated at an elevation of 742 m, covers 523 ha and has a maximum depth of 24 m. It receives water from two spring-fed streams. Lake Begnas at 650 m covers 224 ha and has a maximum depth of 10 m. It also receives water from a spring-fed stream. Lake Rupa at 600 m and with 135 ha has a maximum depth 6 m. In western Nepal Lake Rara (2 900 m altitude) has an outflow which eventually reaches the River Karnali. Lake Syarpu (1372 m altitude) covers only 75 ha.

The largest Nepal reservoirs Hanumannayar and Gandak are situated at the border with India. Much smaller Indrasarobar Reservoir (220 ha) on the River Kulekhani is situated at 1 430 m in mid-hill region. Its maximum depth is 105 m.

Shrestha (1999) has listed 59 cold water indigenous and two exotic fish species for Nepal (Table 4.)

The main habitat of cold water fish in Nepal are the snowmelt-fed rivers. The Kosi River in eastern part of Nepal has 33 fish species, the Kali Gandaki River draining the central part of Nepal has 35 species, and for the Bagmati River Shrestha (1999) has listed 22 species. She has also given zoning based on the presence of the dominant fish species for the Bagmati and Gandaki rivers.

Bagmati:

Snow trout zone (1 875 m – 3 125 m)
It is characterised by fast flowing cold snow-fed water dominated by *Schizothorax plagiostomus* and S. spp.

Table 4
Cold water fish of Nepal

Fish	BA	KO	KG	KA	PL	RA	INR
INDIGENOUS							
Cyprinidae							
Barilius barila	+	+	+	+			
B. barna	+	+	+	+	+		
B. bendelisis	+	+	+	+	+		
B. bola			+	+			
B. jalkapoorei		+					
B. tileo			+	+			
B. vagra		+	+	+	+		
Chagunius chagunio		+	+	+	+		
Crossocheilus latius		+	+	+	+		
Danio aequipinnatus		+					
D. devario					+		
D. rerio	+			+	+		
Esomus danricus	+		+	+	+		
Garra annandalei	+	+		+			
G. gotyla	+	+	+	+			

Fish	BA	KO	KG	KA	PL	RA	INR
G. lamta		+	+	+			
G. mullya	+						
Labeo angra		+		+			
L. dero		+	+	+			
Neolissocheilus hexagonolepis							
Puntius chilinoides							+
P. sophore	+	+	+	+	+		
P. ticto		+	+	+			
P. titus	+				+		
Schizothorax macrophthalmus						+	
S. molesworthi			+				
S. nepalensis						+	
S. plagiostomus	+	+		+	+		
S. raraensis						+	
S. richardsonii				+	+		
+							
Schizothoraichthys annandalei		+					
S. esocinus			+				
S. progastus		+	+	+			
Semiplotus semiplotus			+				
Tor putitora		+	+		+		
T. tor	+	+	+		+		+
Psilorhynchidae							
Psilorhynchus pseudecheneis		+					
Homalopteridae							
Balitora brucei			+				
Cobitidae							
Lepidocephalichthys guntea	+		+		+		
Nemacheilus beavani		+	+				
N. botia			+				
N. corica			+				
N. rupicola	+		+				
N. rupicola var. inglishi	+	+					
N. savona				+			
N. scaturigina		+	+				
N. shebbearei			+				
Schilbeidae							
Clupisoma garua		+	+				
Amblycepitidae							
Amblyceps mangois			+				

Fish	BA	KO	KG	KA	PL	RA	INR
Sisoridae							
Bagarius bagarius		+					
Euchiloglanis hodgarti	+		+				
Glyptosternum blythi	+						
Glyptothorax cavia		+					
G. horai		+					
G. kasmirensis				+			
G. pectinopterus	+		+		+		
G. telchitta		+	+				
G. trilineatus	+	+	+				
Pseudecheneis sulcatus	+	+		+	+		

EXOTIC
Salmonidae
Oncorhynchus mykiss
Salmo trutta

BA = Bagmati, KO = Kosi, KG = Kali Gandaki, KA = Karnali, PL = Pokhara Lakes (Phewa, Begnas and Rupa), RA = Rara Lake, INR = Indrasarobar Reservoir

Stone carp zone (1 250 m – 1 875 m)
Stone carp (*Psilorhynchus pseudecheneis*), and the following species: *Garra gotyla, Nemacheilus* spp., *Glyptothorax* spp. dominate the fast flowing waters in this zone.

Hill barbel zone (625 m – 1 250 m)
This zone, with a fairly slow water current, is dominated by mahseer (*Tor tor, Tor putitora*) and katle (*Neolissocheilus hexagonolepis*).

Gandaki:

Schizothorax richardsonii zone (850 m – 2 810 m)
This stretch of the river includes both mountain and Trans-Himalayan regions.

Schizothorax progastus zone (300 m – 850 m)
In this hill region *S. richardsonii* is gradually replaced by *S. progastus*.

Barilius zone (50 m – 300 m)
The low hill region is named for the presence of its most common fish *Barilius vagra*.

2.5 Bhutan

The Kingdom of Bhutan is a small landlocked country in the eastern part of the Himalayas (Fig. 6). It can be divided into three zones: the southern foothills and plains with altitudes less than 2 000 m; the Inner Himalayas with altitudes from 2 000 m to 3 000 m; and the Great Himalayas with altitudes from 3 000 m to 7 500 m. Major river systems from west to east are the Amo, Wang, Chang (Sankosh), Tongsa and Manas. Bhutan has over 590 lakes, mostly small and located above 2 200 m altitude. The estimated total area of these lakes is about 4 250 ha. On the Wang River there is Chukha hydroelectric reservoir, with an area of 150 ha.

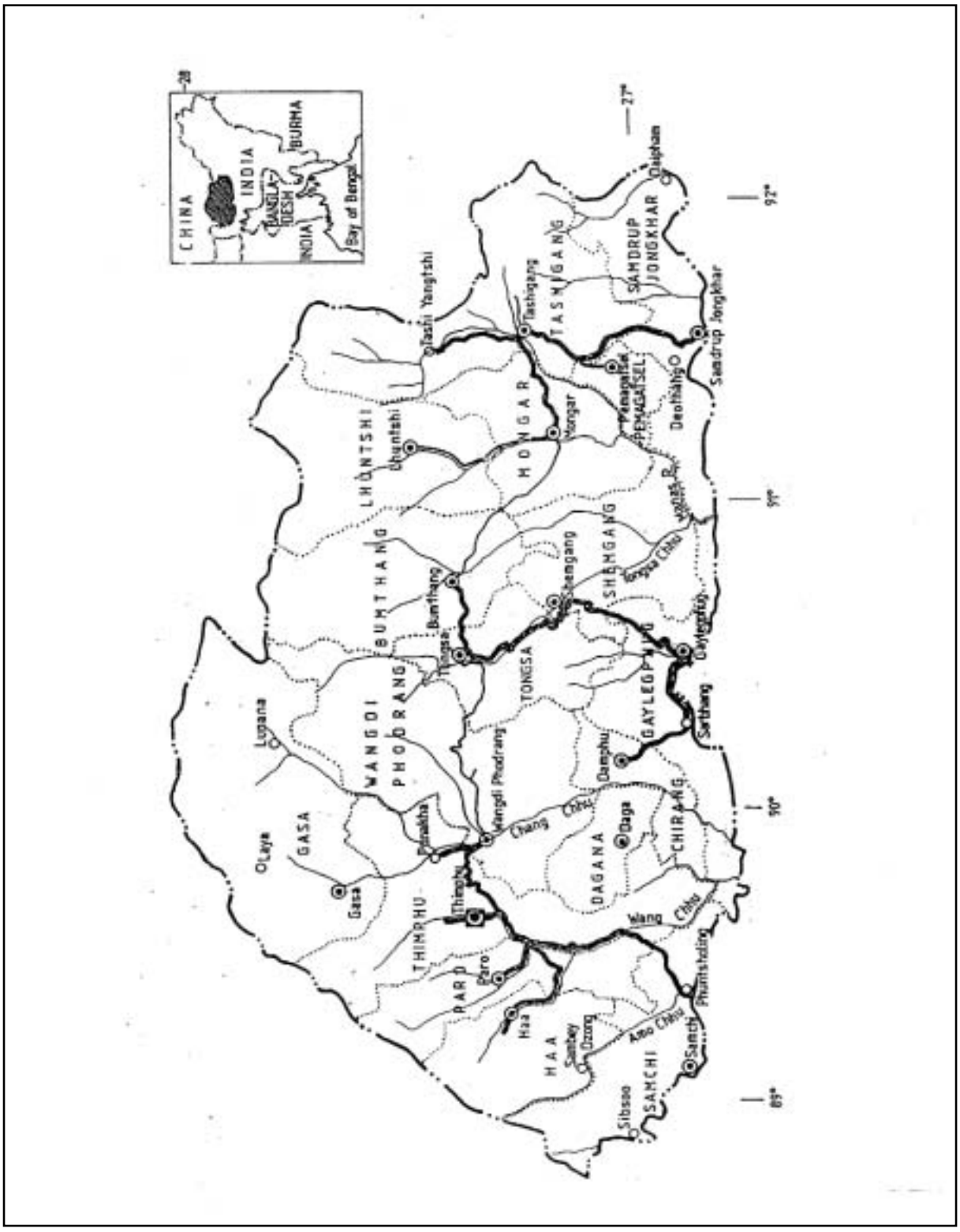

Fig. 6 - Map of Bhutan with the major rivers (from Petr, 1999a)

The rivers and lakes have predominantly cold water fish fauna except in the foothills and plains (Dubey, 1978). A total of 41 indigenous fish species have been identified from the rivers and one lake of Bhutan. One exotic cold water fish species (brown trout) was introduced, as well as seven warm water species, now used in aquaculture in southern lowlands. For a provisional list of fish of Bhutan see Table 5 .

Table 5
Provisional list of fish of Bhutan (Dubey, 1978; Dhendup and Boyd,1994) (# - introduced)

Family/Species	River/stream (pond)
Family: Salmonidae	
#Salmo trutta	Haa; Paro; Thimphu
Family: Cyprinidae	
Schizothorax progastus (asla)	Sankosh; Chamkhar; Kuru; Manas; Haa; Mangdi;
Schizothorax molesworthii	Manas
Neolissocheilus hexagonolepis	Manas; Mangdi; Phepso; Gaylegphug; Sarbhang Khola; Kuru; Chanchi; Phuntsholing
Crossocheilus latius	Manas; Sarbhang Khola; Gaylegphug
Tor putitora (mahseer)	Manas; Sarbhang Khola; Gaylegphug
Tor tor (mahseer; jantura)	Manas; Sarbhang Khola; Gaylegphug; Phepsu
Barilius barna	Manas; Sarbhang Khola; Gaylegphug; Phepsu; Sankosh; Khalikhola; Phuntsholing; Magdi
Barilius bendelisis	Sarbhang Khola; Gaylegphug
Barilius bola	Phepsu
Puntius macropogon	Gaylegphug
Puntius sophore	Gaylegphug
Puntius ticto	Gaylegphug; Sarbhang Khola
Puntius titius	Sankosh; Sarbhang Khola
Cirrhinus lata	Sankosh
Barbus spp	Gaylegphug
Labeo dero	Manas
Labeo dyocheilus	Manas; Phepsu
Labeo pangusia	Sankosh
Garra annandalei	Gaylegphug; Sarbhang Khola; Phepsu
Garra gotyla	Sankosh; Sarbhang Khola; Phepsu; Magdi
Danio aequipinnatus	Manas; Sarbhang Khola
Danio dangila	Manas; Sarbhang Khola
Brachydanio rerio	Sarbhang Khola
Botia dario	Gaylegphug
Semiplotus semiplotus	Phepsu
Rasbora daniconius	Gaylegphug
#Cyprinus carpio	Gaylegphug - ponds
#Catla catla	Gaylegphug - ponds
#Cirrhinus mrigala	Gaylegphug - ponds
#Labeo rohita	Gaylegphug - ponds
#Aristichthys nobilis	Gaylegphug - ponds

Family/Species	River/stream (pond)
#Ctenopharyngodon idella	Gaylegphug - ponds
#Hypophthalmichthys molitrix	Gaylegphug - ponds
Family: Cobitidae	
Nemacheilus botia	Sarbhang Khola
Family: Siluridae	
Batasio batasio	Gaylegphug
Mystus bleekeri	Gaylegphug
Mystus vittatus	Gaylegphug
Ompok pabda	Gaylegphug
Family: Sisoridae	
Bagarius bagarius	Manas
Nangra punctata	Manas
Family: Belonidae	
Xenentodon cancila	Phepsu
Family: Channidae	
Channa gachua	Phepsu
Channa striatus	Gaylegphug
Family: Nandidae	
Badis badis	Manas
Nandus nandus	Gaylegphug
Family: Mastacembelidae	
Mastacembelus armatus	Sarbhang Khola; Kalikhola

Note: Water temperatures exceeded 20°C at the following locations: Gaylegphug (max. 21°C), Phepsu (max. 25°C), Kalikhola (max. 26°C), Sarbhang Khola (max. 26°C).

2.6 China – Xizang (Tibet)

Walker and Yang (1999) reviewed the limnology and fish/fishery literature for the three northwestern areas of China (Qinghai, Xinjiang and Xizang=Tibet), and supplemented it with their research and observations. The following information is abstracted from their paper and concerns itself only with drainages from southern slopes of Karakoram and Himalayas in southern Xizang..

Xizang of China includes the northern slopes of the Himalayas and Karakoram mountains It is the origin of the two large rivers of Asia, the Indus and the Yarlung Zangbo (Brahmaputra). There are also numerous lakes situated at altitudes above 4 000 m. These include Yamdrock (4 350m), Namucuo (4718 m) and Banggong (4241 m).

The fauna of the Qinghai-Xizang Plateau includes 112 native and 17 introduced species. The native species are relict of mass extinctions in the Quaternary, when uplift of the Himalayas transformed the prevailing low-altitude tropical or sub-tropical conditions to the present cold,

arid, high-altitude climate. For the area of interest, i.e. northern internal drainages, the River Indus, and the Yarlung Zangbo, Walker and Yang (1999) collated the following list of species:

Northern internal drainages (southern Xizang)

Triplophysa marmorata, T. stenura, T. tibetana, Schizopygopsis younghusbandi.

Indus River drainage

Schistura alepidota, S. naseeri, Triplophysa aliensis, T. gracilis, T. griffithi, T. marmorata, T. microps, T. stenura, T. stoliczkae, T. tenuicauda, T. yasinensis, Diptychus maculatus, Ptychobarbus conirostris, Schizothorax esocinus, S. labiatus, S. longipinnis, S. macropogon, S. nasus, S. plagiostomus, Glyptosternum maculatus, G. reticulatum.

Yarlung Zangbo (Brahmaputra) River drainage

Triplophysa microps, T. stenura, T. stewartii, T. tibetana, Gymnocypris xygymnocypris stewartii, Ptychobarbus dipogon, Schizopygopsis younghusbandi, Schizothorax waltoni, Paraeuchiloglanis kamengensis.

All but four species belong to the High-Centro-Asiatic Fish Faunal Complex (sensu Li, 1981). *Glyptosternum maculatus, G. reticulatus and Paraeuchiloglanis kamengensis* belong to the China-Indian Mountain Complex, and *Schistura naseeri* to the Southern Asian Complex.

Members of the subfamily Schizothoracinae are an evolutionary offshoot of the Cyprinidae. Some schizothoracines are endemic to the region. Their growth is slow and their fecundity less than 10% of that of lowland species. There are no records for introduced species for Xizang.

Yamdrock Lake in Xizang is the largest lake of the northern slopes of the Himalayas and contains only one economic species, *Gymnocypris waddelskii* (Schizothoracinae).

3. MAJOR COLD WATER FISHERIES IN THE REGION

3.1 Rivers

No information is available on the river cold water fishery in **Afghanistan**.

In **Pakistan** the cold water river capture fishery is primarily based on schizothoracines. The fishery is largely on a subsistence level, with minimal economic benefit. If a fish is available in the market, it is invariably a schizothoracine. In the Northern Areas brown trout has established a self-reproducing population in a number of streams. In Azad Jammu and Kashmir rainbow trout and brown trout have been stocked in the River Neelum and its inflowing streams, and in one stream in Leepa Valley. Only licensed anglers are allowed to catch trout, but there is some poaching. In the North West Frontier Province there is subsistence cold water river capture fishery, but no statistical data are available on its extent. Recreational/sport fishery has been steadily increasing. In 1990 cold water fish catches were estimated at about 200 t yr^{-1} (Akhtar, 1992), with the bulk formed by schizothoracines and indigenous small fish. In the same year fish farms produced 12.5 t of trout. So far no attempt has been made to promote schizothoracine culture in Pakistan.

There are two basic types of fisheries in the **Indian** Himalayan rivers: subsistence fishery, and sport/recreational fishery. Fish production in mountain streams is low and therefore any commercial fishery is on a very limited scale. The low biological productivity results in the prevalence of small-sized fish, except in pools where fish have some shelter and resting place. Fish also reach a larger size in some cold water reservoirs and lakes.

The fishing methods are simple, but well suited to the turbulent nature of the streams. Cast nets, drag nets, stake nets, bag nets and some other types are used, as well as different types of traps, nooses and harpoons. Poison is also used, such as sap of *Euphorbia rogleana*, powdered seed of *Xanthoxylum alatum*, and *Cascaria tormentosa*.

In India the subsistence and commercial fisheries exploit carps (*Labeo* and *Tor* spp.), lesser barils (*Barilius* spp.), schizothoracines (*Schizothorax* and *Schizothoraichthys* spp.), garrids (*Garra* spp.) and sisorids (*Glyptothorax* and *Glyptosternum* spp.). The other genera are of small size and of low economic value. The exotic brown trout (*Salmo trutta*) has established itself in some areas of the Himalayas (Sehgal, 1999).

In the northwestern Himalayas eight species of fish are considered to be of commercial importance (Sehgal, 1988). Experimental netting showed the following relative occurrence in catches: *Schizothorax richardsonii* (64.0 percent), *Schizothorax esocinus* (6.8 percent), *Garra gotyla* (5.7 percent), *Barilius bendelisis* (5.2 percent), *Tor putitora* (3.9 percent), *Labeo dero* (3.7 percent), *Crossocheilus diplochilus* (2.0 percent), *Labeo dyocheilus* (0.2 percent), other fish (8.5 percent). *S. esocinus* contributed 53.2 percent to the total catch in the cold water stretches of the Indus River, and 21.9 percent in the Jhelum River. The widely distributed *S. richardsonii* was caught in all 11 river systems investigated by Sehgal (1988). This species also contributed to the fisheries in the Lesser, and to some extent in the Greater Himalaya. In the lower reaches it is fished especially during the winter.

Tor putitora, called golden mahseer in India, is an important sport fish. It migrates from the lower to the middle reaches to spawn, mainly during the time when streams swell with the southwest monsoon precipitation. In snow-melt receiving tributaries of the Beas River it spawns twice a year. This fish has been heavily poached, and further damage has been inflicted by dams and weirs which have stopped fish migrations. Increased soil erosion, resulting from the deforestation of mountains, has led to heavy siltation of rivers and streams, thus impairing the basic ecological requirements of this fish.

In **Nepal**, most of the cold water fish are fished for subsistence. Among the indigenous species, *Neolissocheilus hexagonolepis, Schizothoraichthys* spp., *Schizothorax* spp and *Tor* spp are the most economically important fish, considering their table fish and sport fish values. In the tributary rivers of the Gandaki system, such as Seti, Madi, Marsyandi and Trisuli, the important fish species are: *Tor putitora, T. tor, A. hexagonolepis, Semiplotus semiplotus, Garra annandalei, G. gotyla, Glyptothorax pectinopterus* and *Channa gachua*. In the Karnali River, which enters Nepal from Tibet, and is the major river of western Nepal, the major fish are *Nemacheilus* spp. *S. plagiostomus* was recorded in the upper reaches of this river by Jha and Shrestha (1986). For the distribution of the major fish species in Nepal see Fig. 7, and for updating see papers by Rajbanshi; Dja and Dhital; Ranjit in this volume.

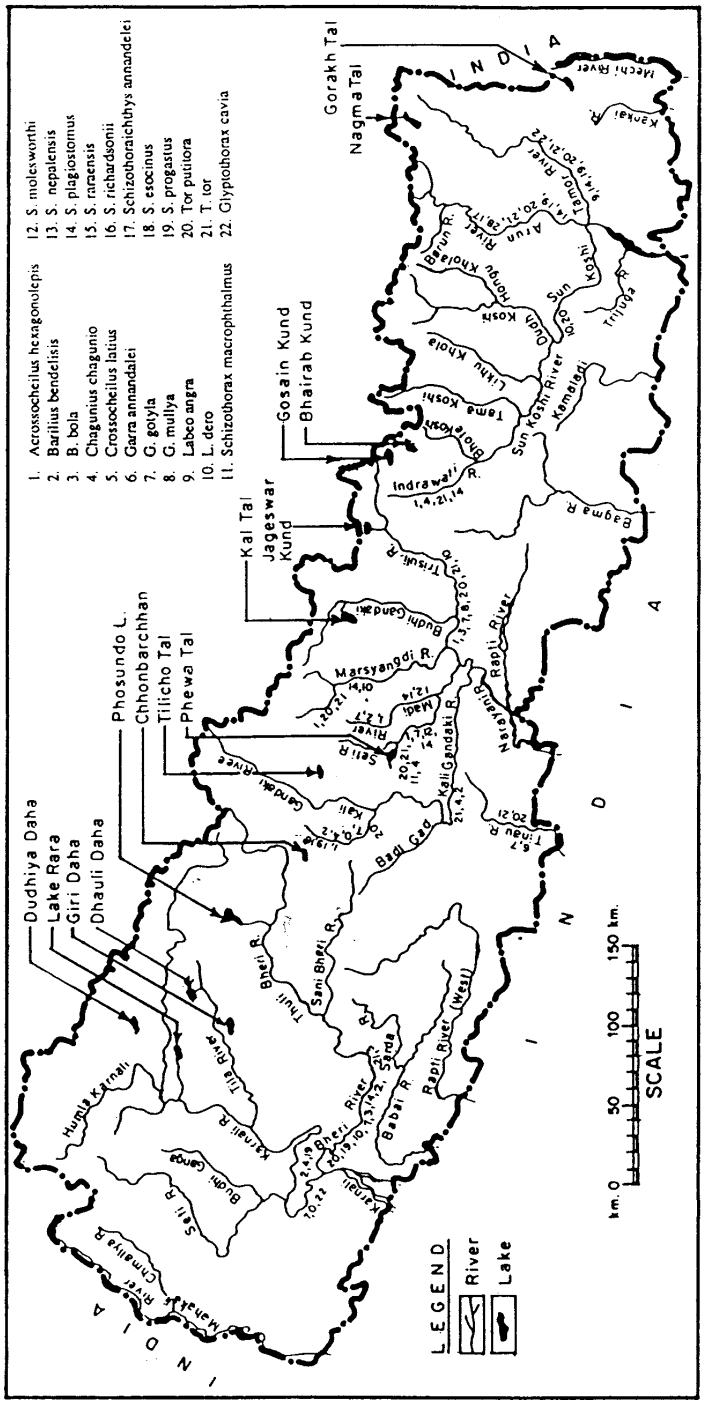

Fig. 7 - Distribution of the major fish species in Nepal (from Shrestha, 1999)

Neolissocheilus hexagonolepis (katle) is an important food and sport fish. In Indrasarobar reservoir it reaches 2.9 kg, but the usual size is 0.6 to 0.8 kg. It is common in Pokhara lakes, from where it migrates to the inflowing streams during or towards the end of the monsoon season.

Schizothoraichthys and *Schizothorax* (snow trout) are locally known as asla. *Schizothorax progastus* and *S. molesworthii* are regarded as the most delicious fish of Nepal and are also good sport fish, reaching up to 2.5 kg weight.

Tor tor and *T. putitora* are important food and sport fish, which tolerate a wide range of water temperature. In the Trisuli River specimens of up to 30 kg have been captured.

Besides the above species of fish, a number of other species have a promising potential from the fisheries point of view: *Puntius (Barbus) chilinoides, Labeo angra, Labeo dero, Barilius* spp., *Chagunius chagunio, Clupisoma garua, Bagarius bagarius*. They are found in streams and rivers up to altitudes of 1 440 m to 1 650 m. Most of these fish are valued by the local people for their size and food value. There are other typical hill stream fish, none of which have any economic importance but which are appreciated as subsistence food by the local people. Among them are ten species of *Glyptothorax* and four species of *Garra*, all found up to an altitude of 1650 m.

His Majesty's Government of Nepal has realized that the expansion of aquaculture in the country is not possible without the use of cold waters and cold water fish. In the 1990s 4 out of 13 Fishery Development Centres were dedicated to the development of cold water fishery: the Godawary Development Centre, Trisuli Development Centre, Pokhara Development Centre and Fisheries Development Centre Kulekhani (Shrestha, 1999). They concentrated on studies of biology and spawning behaviour of the important fish species, their artificial propagation, productivity of rivers, lakes and reservoirs, and training in cold water fishery.

Among the cold water species of **Bhutan**, the indigenous *Schizothorax progastus* and *Barilius* spp are the most common in all rivers. Other indigenous species of economic interest are *Neolissocheilus hexagonolepis*, found up to 1200 m altitude, and mahseers *Tor tor* and *Tor putitora*, which Dubey (1978) found in streams in the foothills. The exotic brown trout is well established in a number of streams and rivers, including Haa, Thimphu, Paro, and some tributaries of the Sankosh and Manas rivers.

The Yarlung Zangbo River in **China** (Xizang) is the main fish producer. Ninety-five percent of Xizang's fishery production (500 t) originates from this river and its tributaries (Walker and Yang, 1999).

3.2 Lakes

For **India** information on fish stocks and fisheries is available for lakes in Kashmir and in Uttar Pradesh. Good data are also available for Gobindsagar and Pong reservoirs at the foot of the Himalayas in Himachal Pradesh (see the following sub-chapter). In both types of water bodies there is commercial and subsistence fishery, based on exotic and indigenous fish species. Information of expeditionary character is also available for high altitude mountain lakes. The following is based on the information published by Raina and Petr (1999).

The Kashmir floodplain lakes Wular, Dal and Manasbal (Fig. 8) are situated in the Kashmir Valley at an altitude of 1537-1587 m a.s.l. The major fish group is schizothoracines, represented by a number of species: *Schizothorax niger, S. micropogon, S. curvirostris, S. planifrons, Schizothoraichthys esocinus*. The following fish are also fished: *Labeo dero, L. dyocheilus, Crossocheilus latus, Puntius conchonicus, Glyptothorax kashmiriensis*. Schizothoracines are highly valued fish, preferred to most other fish species. In 1959 common carp was introduced in Kashmir to augment the fish yield. Since then this fish has become a major commercial species in Kashmir Valley. It is also the principal species in wetlands situated on floodplains of the River Jhelum. The other fish species utilizing wetlands are *Schizothorax niger, Crossocheilus latus, Puntius conchonicus and Gambusia affinis*.

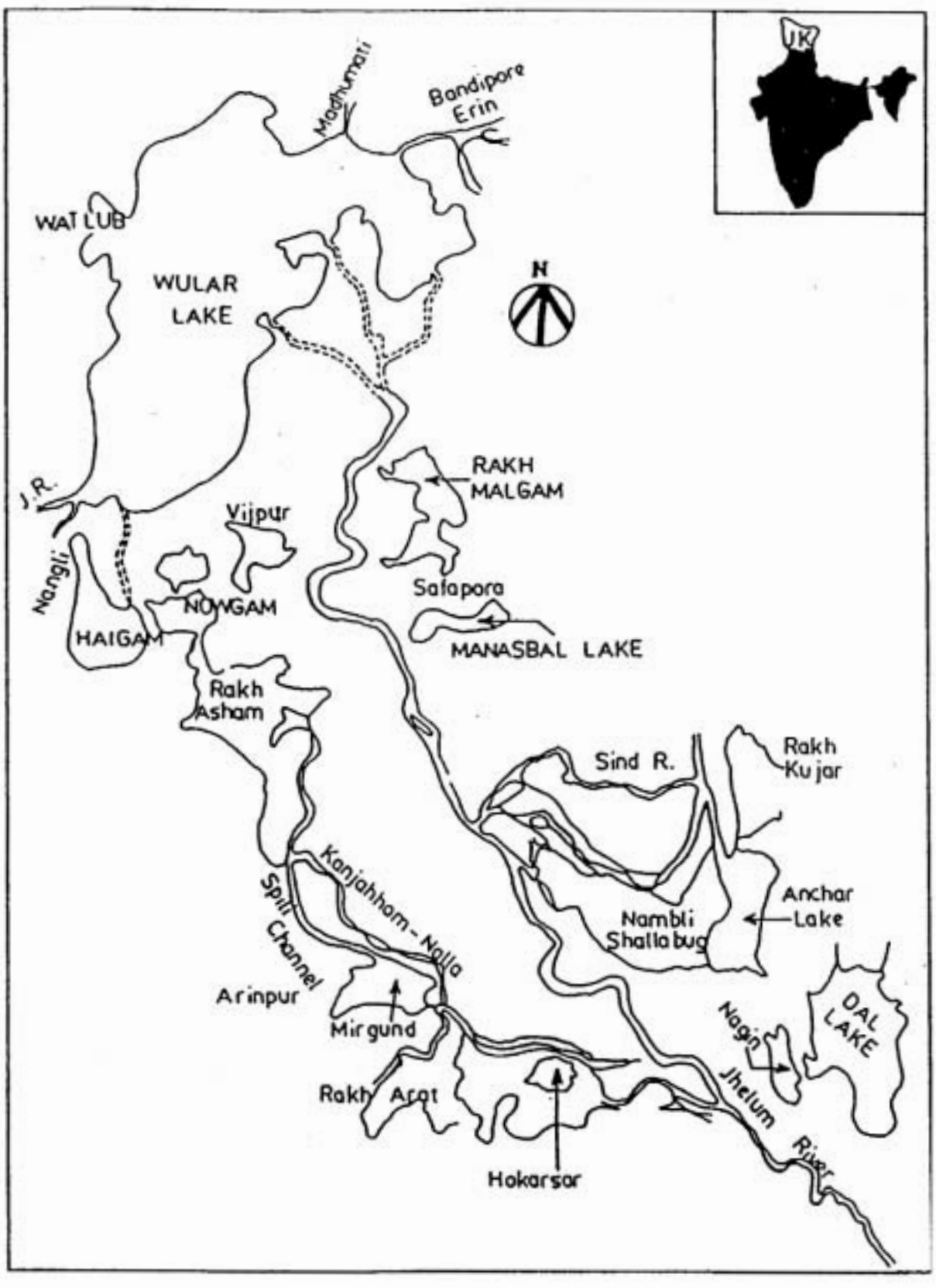

Fig. 8 - Floodplain lakes and major wetlands in Kashmir Valley
(from Raina and Petr, 1999)

In the Kashmir Valley lakes the mean annual fish catch during 1974-77 was 1640 t, of which common carp represented 1380 t, the rest being mainly schizothoracines. The average annual fish yield in Lake Dal was estimated to be 16.5 kg/ha, and in Lake Wular the yield ranged from 17 to 25 kg/ha. The fish yield in wetlands ranged from 15 to 30 kg/ha.

Kumaon lakes Khurpatal, Nainital, Sattal, Bhimtal, and Naukuchiatal (Fig. 9) are situated in Uttar Pradesh. They are all within a short distance from each other, at altitudes ranging from 1220 m to 1937 m. The largest lake is Bhimtal and covers 72 ha. Lake Naukuchiatal is the deepest, with a maximum depth of 40.8 m. Large areas of all lakes except Khurpatal are infested with aquatic macrophytes, and Nainital is polluted. Fish catch data for the period 1983-8 are available for three lakes. Mahseers (*Tor tor* and *T. putitora*) dominated the catches in Bhimtal and Naukuchiatal, with 59.5 and 45.0% respectively of the total for the five-year period. Common carp followed with 34.8 and 31.5 percent respectively. Indian major carps (*Labeo rohita, Cirrhinus mrigala* and *Catla catla*) dominated the catches in Sattal, with 64.1 percent of the total, followed by common carp (22.9 percent). Schizothoracines (*S. richardsonii*) represented only 0.73 and 0.95 percent in lakes Bhimtal and Naukuchiatal, respectively, and were absent in Sattal. Silver carp (*Hypophthalmichthys molitrix*) and grass carps (*Ctenopharyngodon idella*), introduced in Bhimtal in 1985-86, appeared in catches from that year onwards. The average yields (kg/ha/yr) for the five-year period were: Sattal – 13.4; Bhimtal – 9.32; Naukuchiatal - 0.74. The low yields for Naukuchiatal seem to result from low fishing intensity. Stocking the Kumaon lakes is considered essential for increasing fish yields, which could perhaps be increased to 25-50 kg ha^{-1} (Johri et al., 1989).

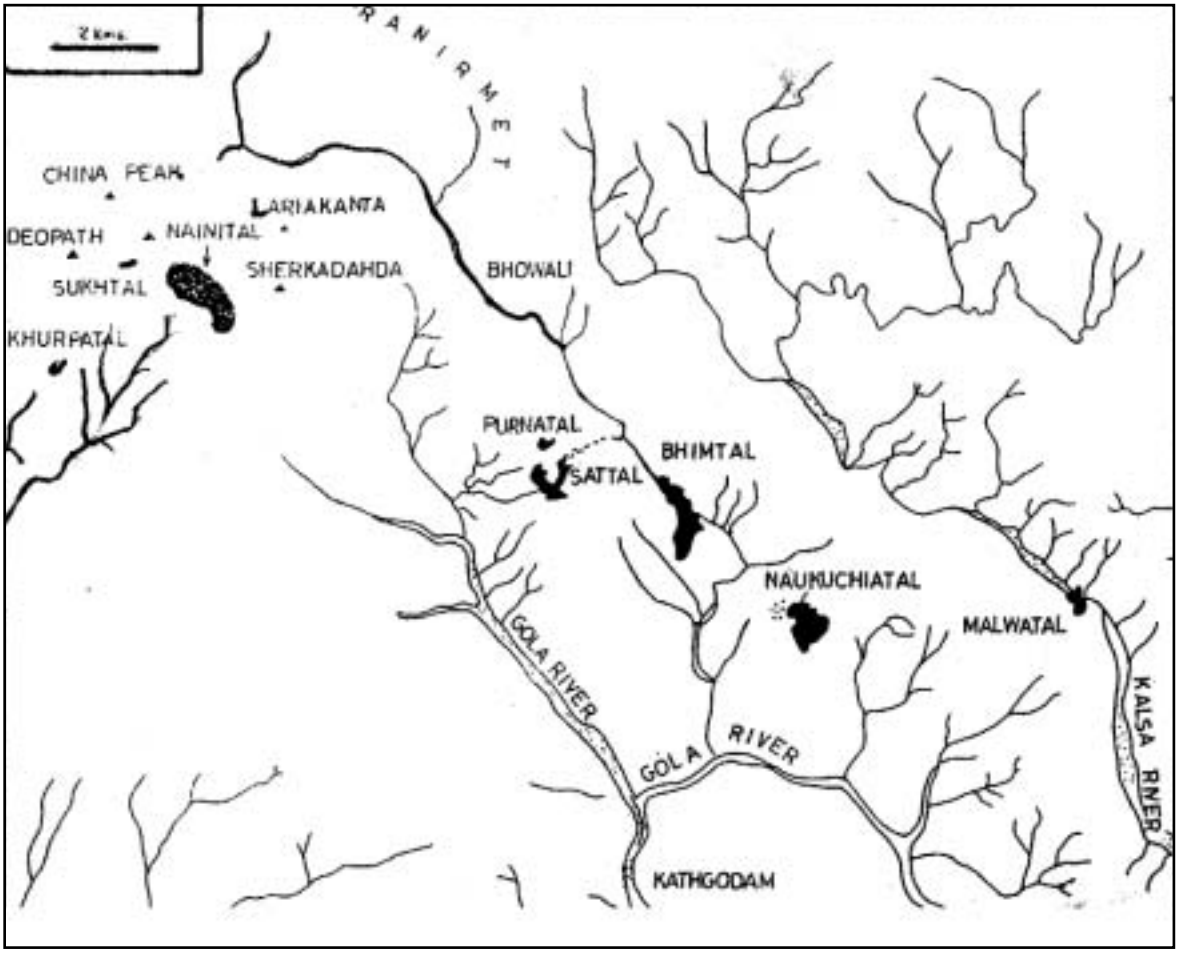

Fig. 9 - Lakes in the Kumaon Himalaya (from Raina and Petr, 1999)

Twelve high-altitude lakes in Kashmir, visited during 1977-1984, are situated at 3200 m to 3819 m a.s.l. They range from 1 ha to 157 ha in size. Only six of them contain fish: four (Gangabal, Nundkol, Kishangar and Vishansar, Fig. 10) have the exotic brown trout. Lakes Zumsar and Gadsar have an endemic schizothoracine *Diptychus maculatus*. This fish is also present in the inflowing streams. It is fished for subsistence during summer by herdsmen. Brown trout is permitted to be fished with fly, but only by licenced anglers. Lake Chandertal (4270 m altitude), which is situated in Himachal Pradesh, has been stocked with brown trout.

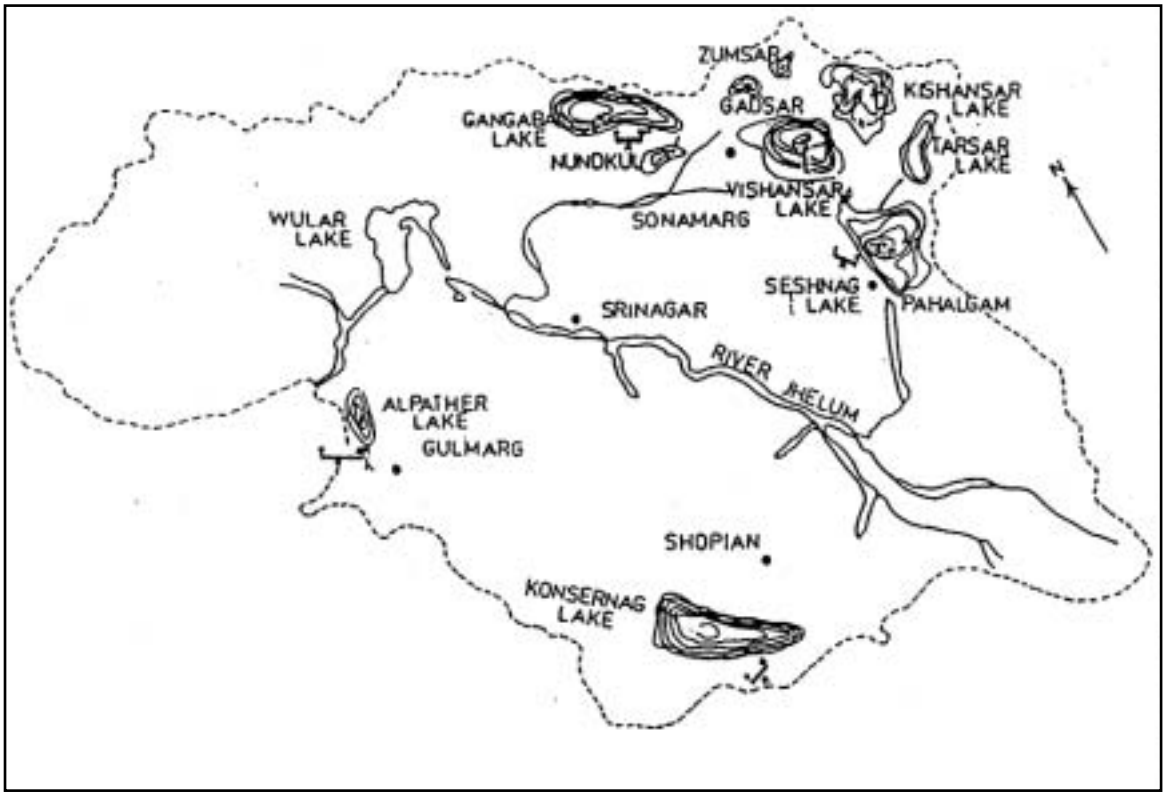

Fig. 10 - High mountain lakes in Kashmir (from Raina and Petr, 1999)

Seventeen fish species out of the 28 inhabiting Pokhara lakes in **Nepal** are cold water species (Table 4). Studies have shown that lakes Phewa, Begnas and Rupa are productive and can support an annual fish harvest of 150 t with proper management. At present, the lakes have cage culture of exotic carps (UNDP *et al*., 1985). For more recent information see Shrestha, T.K., this volume.

In 1961 fishery started in Yamdrok Lake in Xizang (**China**), with annual catch for the period 1961 to 1992 ranging from 45 t to 750 t. At the beginning of the 1990s there was no provincial fishery authority, and the catch was transported to and sold in the capital Lhasa (Walker and Yang, 1999).

3.3 Reservoirs

Little information is available for **Afghanistan**. In the 1970s and 1980s FAO projects demonstrated the possibility of growing rainbow trout, which was produced on the Qargha Fish

Farm situated at a reservoir constructed on the River Paghman, near Kabul. Production of fingerlings made possible stocking of the Qargha reservoir and the rivers Panjsher, Bamian, Salang and Sarde. In the fish farm fish were grown to marketable size (Petr, 1999).

In **Pakistan** Tarbela reservoir on the Indus River (Fig. 3) reaches deep into the mountains. The upstream part of the reservoir is largely under the influence of cold waters coming from the Northern Areas and the northern part of NWFP. As a result, it maintains low water temperature throughout the year. The part of the reservoir closer to the dam is warmer. The reservoir therefore provides several habitats for fish. During the warm period of the year, the cool Indus water maintains its flow underneath a layer of warm surface water; when the reservoir is full or almost full, the cool water underflow enters the intakes, passes through turbines and is discharged downstream. This results in the presence of cool water some distance below the dam. The present fish fauna of the Indus immediately below the dam consists of the following fish species: *Channa punctatus, Barilius vagra, Cirrhinus reba, Labeo* spp, *Crossocheilus latus, Puntius ticto, Salmostoma* spp, *Schizothorax plagiostomus, Tor putitora, Ompok bimaculatus, Ambassis* spp, *Mastacembelus armatus* (WAPDA, not dated). Of these only *Tor putitora, Schizothorax* and *Channa* are considered of commercial value. However, fish of small size dominate the waters. *Labeo rohita, Cirrhinus mrigala* and common carp are often washed out from the reservoir.

Prior to impoundment, a survey of the Indus River and its tributaries around Tarbela recorded 35 fish species (Ali *et al.*, 1980; Table 6), most of which were not popular as food fish. The exceptions were mahseers (*Tor mosal* and *Tor putitora*). *Schizothorax* spp. and *Labeo dyocheilus* were common, but not popular. Due to the permanent submergence of many natural breeding sites of mahseers in Tarbela reservoir since its formation in 1974, their recruitment drastically declined. Moreover, breeders migrating upstream into tributaries are indiscriminately fished, and enforcement of protective regulations is difficult. Commercial fishery in Tarbela has been largely limited to the reservoir sector close to the dam. During 1981-82 the fish species composition in fish landings was 54% mahseer, 45% exotic common carp, and 1% other fish (*Schizothorax* spp, *Labeo dyocheilus, Mastacembelus ornatus*) (Petr, 1985). In the early 1990s, George (1995) listed 35 fish species for the Tarbela, of which the following were the most common: *Pseudambassius ranga, Chanda nama, Aspidoparia morar, Ctenopharyngodon idella* (exotic grass carp), *Salmostoma bacaila*. It is unclear what happened to the common carp. Exotic silver carp and gold fish, four species of the indigenous *Labeo*, and the remaining species were captured only occasionally. Schizothoracines and mahseers were absent in catches clearly showing the negative impact of the reservoir on these cold water fish. It is, however, possible that these two groups of fish are common in the upstream sector of the reservoir, which is much influenced by the inflowing river. For those areas no statistics are available. During the period 1985 to 1993 the commercial fishery in Tarbela harvested between 50 and 70 t of fish per annum, as declared by the contractors.

Table 6
List of fish of the Indus River and its tributaries around Tarbela (from Ali *et al*.,1980)

Species	Locality
Family: Notopteridae	
Notopterus notopterus	Siran River near Tarbela
Family: Cyprinidae	
Amblypharyngodon mola	Indus River near Attock Fort; Kabul River near Attock
Aspidoparia morar	Indus River - Ghazi; Dor River near Chamba Bridge; Kabul River near Attock; Haro River near Hasan Abdal and Lawrencepur; Siran River near Thapla Bridge
Barilius vagra pakistanicus	Indus near Tarbela, Ghazi, Attock Fort, Darband; Siran River near Thapla Bridge and near Khaki Bridge; Dor River near Chamba Bridge; Unar River near Darband; Kabul River near Attock; Haro River near Hasan Abdal and Lawrencepur; Brandu River near Dagar
Chela cachius	Indus River near Attock Fort, Ghazi and Tarbela
Crossocheilus latius diplocheilus	Indus River near Tarbela and Ghazi; Siran River near Khaki Bridge; Dor River near Chamba Bridge; Unar River near Darband; Kabul River near Attock; Haro River near Hasan Abdal
Danio devario	Indus River near Attock Fort; Haro River near Hasan Abdal
Garra gotyla	Indus River near Tarbela and Ghazi
Labeo dero	Indus River near Attock Fort; Siran River; Haro River near Hasan Abdal
Labeo dyocheilus	Kabul River; Indus River
Puntius sarana	Haro River near Hasan Abdal
Puntius sophore	Indus River near Tarbela and Attock Fort; Kabul River near Attock
Puntius ticto	Indus River near Tarbela; Dor River near Chamba Bridge; Kabul River near Attock; Brandu River near Dagar; Haro River near Hasan Abdal
Salmostoma bacaila	Kabul River near Attock
Salmostoma punjabensis	Indus River near Attock Fort
Schizothorax esocinus	Indus River near Tarbela
Schizothorax labiatus	Indus River near Tarbela and Ghazi; Unar River near Darband; Haro River near Hasan Abdal
Schizothorax plagiostomus	Indus River near Tarbela and Ghazi; Siran River near Thapla Bridge; Unar River near Oghi and Darband; Haro River near Hasan Abdal
Tor mosal	Haro River near Hasan Abdal
Tor putitora	Indus River near Tarbela, Ghazi, Attock Fort; Siran

Species	Locality
	River near Thapla Bridge and Khaki Bridge; Dor River near Chamba Bridge; Brandu River near Dagar
Family: Cobitidae	
Botia bridi	Indus River near Tarbela
Nemacheilus botia	Indus River near Tarbela; Dor River near Chamba Bridge; Haro River near Hasan Abdal
Nemacheilus corica	Indus River near Tarbela; Kabul River near Attock
Nemacheilus naseeri	Unar River near Oghi
Nemacheilus prashari	Haro River near Hasan Abdal
Nemacheilus stenurus choprai	Indus River near Tarbela
Nemacheilus stoliczkai	Indus River near Tarbela
Family: Sisoridae	
Gagata cenia	Indus River near Ghazi
Glyptothorax naziri	Haro River near Hasan Abdal
Glyptothorax punjabensis	Indus River near Ghazi
Glyptothorax stocki	Indus River near Tarbela
Family: Siluridae	
Ompok bimaculatus	Indus River near Attock Fort; Haro River near Hasan Abdal
Family: Schilbeidae	
Clupisoma murius naziri	Indus River near Ghazi
Family: Osphronemidae	
Colisa fasciata	Indus River near Tarbela; Kabul River near Attock
Family: Channidae	
Channa punctatus	Indus River near Ghazi; Haro River near Hasan Abdal
Channa gachua	Indus River near Tarbela; Siran River near Thapla Bridge and Khaki Bridge; Brandu River near Dagar

Information on cold water reservoirs of the Himalayas is sparse. In **India**, in Himachal Pradesh three reservoirs with cold water inflow are situated at a relatively low altitude: Gobindsagar on the Sutlej River at 560 m (16 867 ha), Pong on the Beas River at 436 m (24 529 ha), and Pandoh reservoir at 987 m (200 ha), also on the Beas (Fig. 11).

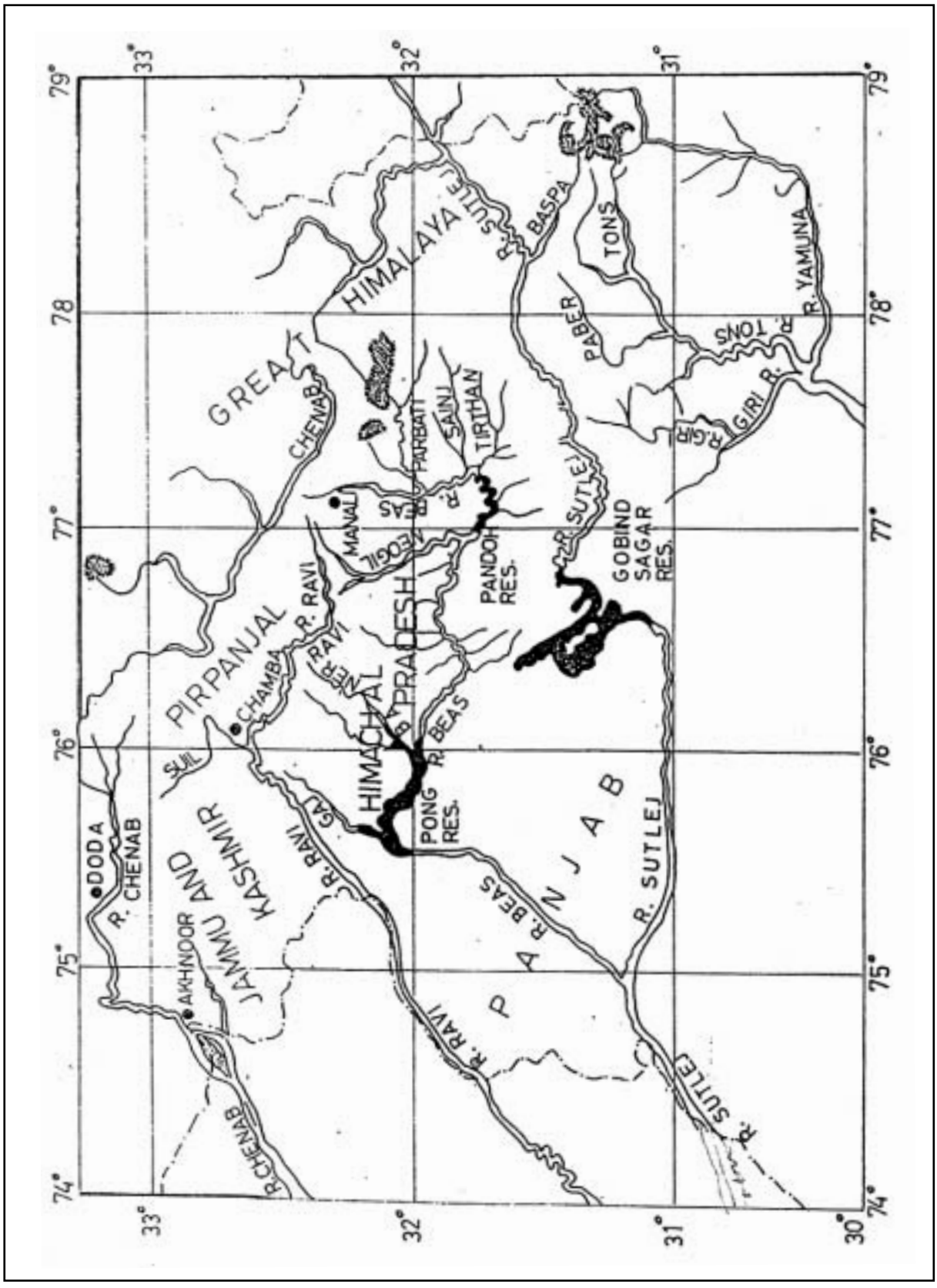

Fig. 11 - Gobindsagar, Pong and Pandoh reservoirs in Himachal Pradesh, India
(from Raina and Petr, 1999)

The Sutlej River receives cool snow-melt water during the spring and summer months and water from monsoon precipitation in its lower catchment during July-September. Downstream of the reservoir, the Sutlej joins the Beas River and enters Pakistan. In 1978 the Sutlej-Beas link was completed, diverting Beas water to Gobindsagar in order to augment the power generation and irrigation capacity of the reservoir. Blending of the cool Beas water and the warmer Sutlej water in the reservoir has led to a unique pattern in the thermal and oxygen regime and in dissolved chemical components, and this has had an impact on the biota. Prior to the construction of the dam, the upper reaches of the Sutlej had 30 species of fish, of which *Tor putitora, Labeo dero, L. dyocheilus, Schizothorax* and *Aorichthys seenghala* were the dominant fish. In 1961-62 Gobindsagar was stocked with the Indian major carps *Catla catla, Labeo rohita* and *Cirrhinus mrigala*, and this was followed by a regular stocking of common carp. The appearance of silver carp in 1979 and its establishment in the reservoir marked the beginning of a radical change in the catch structure, with this fish establishing an overriding dominance over all other species (Sugunan, 1995, Fig. 12). Today, the introduced silver carp and common carp dominate the total catch. The other commercially important fish are: *Catla catla, Tor putitora, Labeo rohita, Cirrhinus mrigala, Labeo calbasu, Aorichthys seenghala and Schizothorax plagiostomus*. While the total fish catches have been increasing, percentage-wise the proportion of the indigenous *Tor putitora* has been decreasing, from 16.8 percent (28.7 t) in 1974-75 to 0.5 percent (46t) in 1992-93. However, the rapid increase in the stocks of silver carp in the reservoir has had no negative impact on stocks.

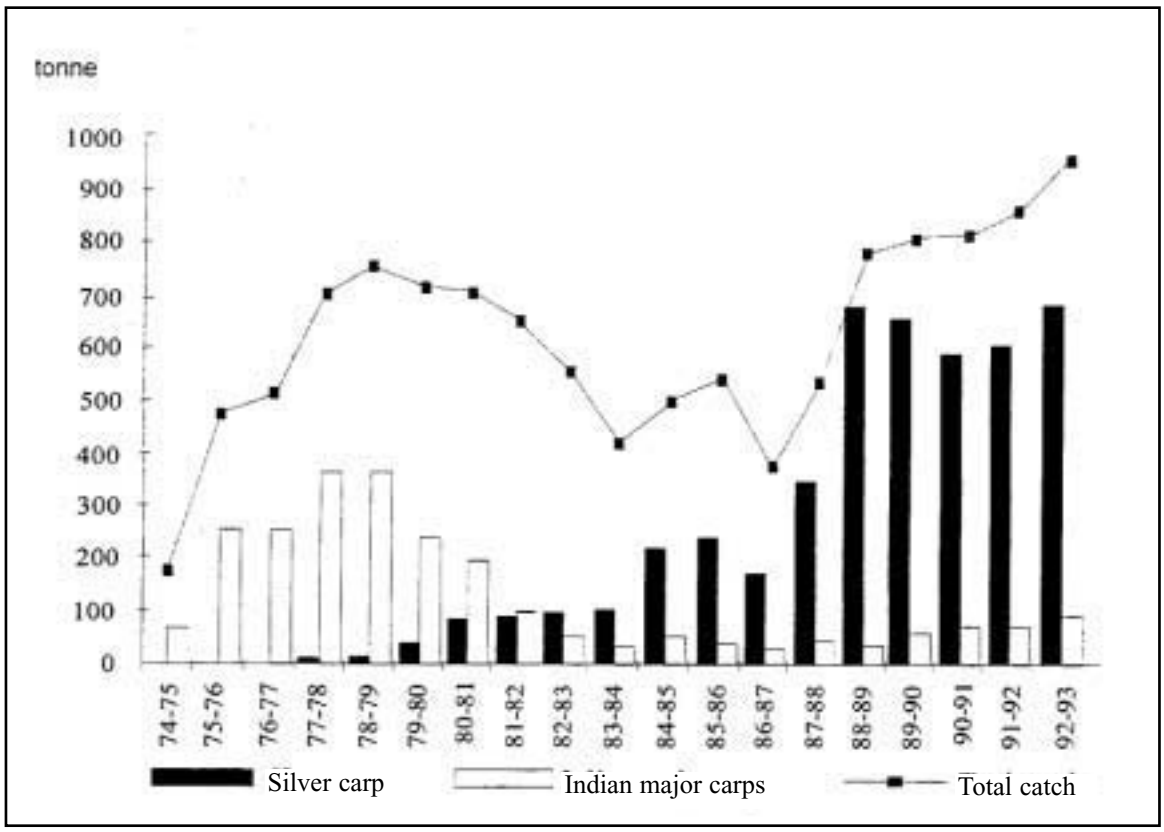

Fig. 12 - Gobindsagar reservoir, India: development of silver carp fishery
(from Sugunan, 1997)

Pong reservoir on the Beas River is a shallow water body of a lower productivity than Gobindsagar. The fish fauna was originally dominated by catfishes, minor carps and a few coarse fish. On account of systematic stocking of common carp and Indian major carps, the catch structure was completely altered and carps eventually accounted for 6l.8% of the total landings (1987-88). In the mid-90s the important fish species in order of abundance were: *Labeo rohita, Aorichthys seenghala, Labeo calbasu, Tor putitora, Cirrhinus mrigala, Wallago attu, Cyprinus carpio, Labeo dero, Catla catla,* and *Channa* spp (Sugunan, 1995). The maximum annual fish yield of 33.2 kg/ha was recorded in 1987-88.

The construction of the Gobindsagar and Pong reservoirs has created a perennial source of fish supply for the people of Himachal Pradesh and adjoining states, but certain valuable species have been adversely affected. *Tor putitora* is no longer able to migrate into Kangra Valley due to the presence of the dam at Pong. Luckily, this species has established self-reproducing stocks within the new limits. The impact of damming on schizothoracines has been more serious.

The small Pandoh reservoir forms part of the Beas-Sutlej Link, diverting the Beas water into the Sutlej basin. The water temperature is a cool 16.5-10.5°C. The reservoir is used for occasional recreational/sport fishing. Brown trout, snow trout *Schizothorax richardsonii, Labeo dero, L. dyocheilus, Tor putitora* and some other hill stream fish are present in its waters.

For Nepal, information is available only on the small Indrasarobar reservoir. The reservoir has three indigenous fish species (*Neolissocheilus hexagonolepis, Puntius chilinoides* and *Schizothorax richardsonii*). Chinese carps have been grown in cages (Pradhan and Swar, 1988). More information is available in the paper by Swar and Craig, this volume.

4. MANAGEMENT OF FISH STOCKS AND FISHERIES

Fisheries activities on rivers and streams of Afghanistan have been very limited, and information on the number of fishermen, fish species captured, yields and total catch does not exist. It is recognised that fish do not contribute much to the economy of the country, with perhaps only 800 t to 1 300 t captured per year, and with the major animal protein source being livestock.

In Pakistan, there are a number of hatcheries producing brown and rainbow trout for stocking cold water rivers and streams in the north of Pakistan. However, there is no management project for schizothoracine carps. The major constraint is the total lack of research on these fish, with knowledge of their biology and ecology being very fragmentary at present. Stocking of mahseer (*Tor putitora*) in the River Gilgit was unsuccessful.

Edwards (1991) came to the conclusion that brown trout have already established thriving self-sustaining populations in most suitable cold waters available in northern Pakistan. Especially in the Northern Areas, rivers and streams contain large numbers of browns of all sizes. It is probable that restocking with this species is unnecessary and of no value, except perhaps in lakes which have no suitable spawning streams. Brown trout are also generally not suitable for commercial farming because their growth is slow compared with rainbows. He concentrated on fish farming of rainbow trout only.

The Water and Power Development Authority of Pakistan (WAPDA) which has its own Department of Fisheries in charge of fishery management in WAPDA reservoirs, is fully committed to a policy of regular stocking of the Tarbela and other reservoirs. In Tarbela, common carp is the dominant fish species stocked.

In India, over the years uncontrolled and often indiscriminate fishing in the largely unmanaged Himalayan rivers and streams has resulted in a sharp decline in catches of the important subsistence and sport fish (Sehgal, 1999). The increasing use of river water for irrigation, hydropower production, municipal and industrial purposes, and the inputs of pollutants, have all affected fish stocks. Among the difficulties that today's fishery managers are facing is the shortage of information for a number of Himalayan rivers and streams. While there is a reasonable amount of information available for certains stretches of streams traversing the northwestern and central Himalayas, there is hardly any information on the ecology and fisheries of rivers of the eastern Himalayas.

A low level management of cold water fish stocks in the Indian Himalayas in the past is documented for example for the stocks of golden mahseer, a famous sport fish. Sehgal (1999) mentions a drastic decline in catches during 1964-67 in the Baner River, the main snow-melt tributary of the Beas. Using traps during September-October, when the spent spawners were returning downstream, the fishing community of Kangra (Himachal Pradesh) succeeded in catching virtually all the returning fish. Within three years the fish catch declined in two such traps from 1 383 kg (in 1964) to 54 kg (1967). Further damage was inflicted by dams and weirs which stopped the migrations. Use of explosives and poison also contributed to the sharp depletion in fish stocks. Human-induced stresses, either direct or indirect, have affected both the introduced and indigenous fish in some Himalayan rivers, such as the Beas, where the average weight both of brown trout and *S. richardsonii* declined (Sehgal, 1999). As mahseer and schizothoracines undertake upstream and downstream migrations, any dam results in the decline of their stocks. The existing fish ladders have so far proved ineffective for these fish.

More recently a number of angling associations, in close collaboration with state governments of India, have been involved in the conservation of the threatened species. For success with breeding mahseer in India see the paper by Ogale, this volume.

A number of rivers and streams in Jammu and Kashmir, Himachal Pradesh, and to a lesser extent in the central and eastern Himalayas, now have self-reproducing stocks of the exotic brown trout. Special bylaws have been formulated under the Indian Fisheries Act in the states of Jammu and Kashmir and Himachal Pradesh, which regulate the fishing season, bag limit and prescribe bait (Sehgal, 1999). However, there are only few anglers who adhere to the instructions and regulations.

The old practice in India of imposing religious taboos on certain stretches and pools of important streams has helped to preserve mahseers and schizothoracines. Selected stretches of streams and rivers, pools and temple springs in the states of Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh act as cold water fish sanctuaries in the Himalayas. The practice of protecting stocks of brown trout and schizothoracines in Kashmir streams during the low water level period by creating deep pools, covering them with tree branches and protecting them from poaching, has also proved beneficial. Better estimates of the carrying capacity of different streams would assist the fishery managers to better regulate sport and recreational fishing and to determine stocking rates.

Fisheries management of Gobindsagar reservoir has included a programme of stocking and harvesting. About 1 000 fishermen families have been organized into cooperatives. Further management measures have been the enforcement of mesh size regulation and imposition of closed season during the breeding of some commercially important fish species. Several welfare schemes, such as provision of subsidies for purchase of fishing equipment and a personal accident insurance scheme introduced by the Government, have helped the communities to raise their status.

While the creation of a reservoir results in the creation of a new habitat for fish, at the same time many endemic species are adversely affected. In India, there is a need for effective enforcement of the existing legislative measures such as closed seasons and mesh size regulation, and also the involvement of voluntary organisations, including fishing associations and clubs, in an effort to maintain the fish stocks at a healthy level. The stocks should be enhanced through regular releases of hatchery-produced fingerlings. Only in this way can the rising demands from subsistence and sport/recreational fishermen be satisfied.

The deterioration of environment in catchments of lakes, rivers and reservoirs is placing an increasing strain on aquatic habitats. Dal and Wular lakes in Kashmir, and Nainital and Bhimtal in Uttar Pradesh have been adversely affected by pollution and poor management of land in their catchments, and the lakes are undergoing eutrophication. Lake Dal is facing a serious problem of shrinkage: between 1911 and 1984 the open water area has been reduced from 1507 to 700 ha, while marshy areas increased from 800 to 1 530 ha. The entire catchment of Kashmir Valley ultimately drains into Lake Wular before the outflowing waters leave India for Pakistan as the Jhelum River. Lake Wular has been reduced in size from 27 500 ha to 15 200 ha, and its mean depth is now 1.5 m, instead of 3 m. There has been a rapid encroachment of agriculture, especially rice paddies, on the margins of the lake. The open water has been further diminished by the introduction of floating islands for vegetable cultivation. The small lakes in Uttar Pradesh have been witnessing a dramatic increase in recreation, and as a consequence massive discharges of sewage into them.

In India, apart from the well-organised fishery in two cold water reservoirs, and the fishery in the two large Kashmir lakes Wular and Dal, the Himalayan lakes and reservoirs will probably remain largely at a subsistence and sport/recreational fishery level. Enhancement of fish stocks will require continuous stocking, especially of the indigenous mahseers and schizothoracines, and common carp. High mountain glacial lakes, with their oligotrophic character and low water temperatures, appear to have little chance for becoming productive fishery water bodies. Where deemed realistic, stocks of brown trout and/or schizothoracines could be maintained through stocking. Lakes holding already self-sustaining stocks of brown trout and schizothoracines should be carefully managed to avoid overfishing. Some of these water bodies should be protected as fish sanctuaries.

Between 1981-82 and 1995-96 the production from capture fisheries in Nepal increased from 2 780 t to 11 230 t (figures provided by the Fisheries Department, Kathmandu). Much of this increase came from the irrigated paddy fields, wetlands, lakes and reservoirs, while capture from rivers has stagnated since 1986-87. Shrestha (1999) believes that in the future the cold water fishery will require more attention, especially as regards maintaining good conditions for fish in wild waters and regular stocking of selected rivers, reservoirs and lakes. A hatchery proposed for the Kali-Gandaki reservoir was intended to produce *Tor* spp, *Neolissocheilus hexagonolepis, Schizothorax richardsonii, Clupisoma garua* and some other indigenous fish species for stocking into the reservoir and its tail waters (Swar and Shrestha, 1996). There is a great demand for cold

water fish, but their supply is limited. The small catch, after local consumption, does not leave many fish for marketing in more distant places. In some areas the unproductive agricultural land has led the local people to depend mainly on fishing for their livelihood. This has led to over-exploitation of fish stocks. In some streams fish stocks declined as a result of the catchment deterioration resulting from human activities. Poor quality of fish reaching the markets is also a major problem.

In the late 1980s, when an FAO mission visited Bhutan to assess the fishery development potential, there were no full-time fishermen or fishermen's cooperatives. Fishing permits were issued by the Department of Forestry, with 398 permits issued in 1986-87. It was reported that 60% of the angling was located in the Thimphu area, whereas Paro and other districts accounted for 30 percent and 10 percent respectively. In 1987 there was no organised marketing of fish in Bhutan. In the capital city Thimphu, a fish stall selling fresh fish (*Catla catla*, mahseer) was also selling mutton and buffalo meat (FAO, 1987).

Apart from trout, only the indigenous fish asla seems to have some fishery importance in Bhutan. In the late 1980s the level of stocks of mahseer *Tor tor* and *T. putitora* and the other potentially important fish *Neolissocheilus hexagonolepis* were unknown and needed to be assessed, as especially mahseer are much sought after by sport fishermen. Because of the cultural and fishery importance given to asla in Bhutan any future cold water fish enhancement activities should include stocking of fingerlings of this species into suitable stretches of rivers (Petr, 1999a). Such stretches, however, need to be identified as there is little knowledge on the present distribution of asla in rivers amd streams of Bhutan. The lack of knowledge on competition between asla and trout prevents any decision on stocking strategies for the brown trout, which, however, is self-reproducing in a number of rivers and streams.

No information on fisheries management in Xizang (Tibet) province of China was available to the compiler of this paper. It is probable that in some water bodies the slow growing cold water fish stocks are fully exploited or over-exploited, if one can extrapolate from the situation on Lake Qinghai (altitude 3 200 m, Qinghai Province on the Tibetan Plateau), where the fishery for *Gymnocypris przewalskii* (Schizothoracinae) drastically reduced the stocks of this fish species.

5. INTRODUCED SPECIES AND THEIR INTERACTION WITH NATIVE FISH SPECIES

In northern Pakistan, brown trout has established self-reproducing populations in many streams draining Hindu Kush and Karakoram. In the Northwest Frontier Province brown trout introduction and subsequent stocking in Kaghan and Chitral at the beginning of the 20th century were very successful. In the Northern Areas brown trout is now established in 23 beats of streams and rivers, as well as in 12 lakes out of the existing 33. Some streams are regularly stocked with trout fingerlings produced in hatcheries. In the 1980s in AJK rainbow trout fingerlings were released into some rivers, but they didn't do well. Stocking of brown trout and rainbow trout in the River Jhelum and its inflowing streams was still ongoing in the 1990s. According to Akhtar (1991), the introduction of mahseer (*Tor putitora*) into the River Gilgit was not successful. Nothing is known about the interaction of the stocked exotic species with the indigenous fish in the Pakistan cold water bodies.

In Tarbela reservoir on the Indus River, mahseer and schizothoracines have virtually disappeared from catches in the sector close to the dam, for which the only fishery statistics are available. It

is believed that they may still be present in reasonable numbers in the upstream sector influenced by the inflowing waters. It would appear that flooding of suitable spawning grounds rather than the competition with introduced exotics such as common carp, is the primary reason why mahseer became absent.

In the Indian Himalayas as in many other parts of the world several exotic species have been introduced without any consideration of the impact on the endemic fish. Brown trout and rainbow trout were introduced predominantly to meet the requirements of sport fishing. In the absence of any fast-growing endemic cold water species, common and silver carps have been introduced in reservoirs and in aquaculture. In the beginning such introductions were limited to only some areas, but this was followed by their gradual distribution and introduction to other water bodies and today the exotic fish are present in almost all suitable water bodies.

Brown trout is now well established, with a number of self-sustaining populations in streams of the Indian Himalayas. Rainbow trout has failed to establish itself in the stream ecosystem but it is cultured in fish farms. It has been suggested that a sharp decline in the schizothoracine species in the Himalayas is the result of brown trout preying upon their younger stages. Schizothoracines, notably *Schizothoraichthys esocinus, S. progastus, Schizothorax richardsonii, S. longipinnis, S. nasus* and *S. hugelii* are the most important endemic species of fish occurring in the Himalayan trout waters. They are rather small in size, ranging from 200 to 450 mm in total length and from 300 to 1 200 g in weight. Sehgal and Sar (1989) who studied the interaction between brown trout and schizothoracines in the Beas River, did not find any evidence of the negative impact of the trout on the endemic fish, and concluded that it was the increase in angling pressure and the fast degradation of the ecological conditions of the river system which had a negative impact on fish.

The potential impact on schizothoracines of the introduction of common carp in Kashmir and in the Kumaon Himalaya (Uttar Pradesh) is also being debated. After the release of common carp fingerlings in Lake Dal in Kashmir, the once abundant schizothoracine species virtually disappeared.. It is believed that in Kashmir lakes schizothoracines are fast losing ground due to the higher fecundity of common carp and its habit of spawning in confined waters. The feeding pattern of common carp and schizothoracines is almost identical, with many of the lacustrine species of schizothoracines feeding on detritus and benthos, i.e. having the same diet as common carp. In Gobindsagar reservoir on the Beas River in the 1980s common carp contributed up to 35 percent to the total catch, but its proportion in catch started decreasing with the increasing numbers of another exotic – the silver carp. According to Kumar (1988) the interrelationships among the silver carp-common carp-schizothoracines in the Gobindsagar reservoir are not fully understood. But in spite of the common carp now being the most common food fish in the Himalayas, schizothoracines are still the consumer's first preference (Sehgal, 1999).

The first introduction of silver carp in Himalayan waters was accidental, when in 1971 this fish found its way into the Sutlej River from a fish farm, situated close to Gobindsagar reservoir, after the farm was inundated by floods. The species has since established itself in the reservoir, resulting in the formation of a self-sustaining population. By 1987 silver carp represented 65.8% of the total catch. As it feeds largely on phytoplankton it has a biological advantage over the Indian major carp catla (*Catla catla*), a column plankton feeder.

The impact of the introduction of exotic species on endemic cold water fish in the Himalayan uplands is significant. The introduction of common carp may have adversely affected the endemic schizothoracines and mahseers. In Lake Dal, Kumaon lakes, and the reservoirs Gobindsagar and Pong, the introduced common carp and silver carp have become the dominant

fish in catches. How far the presence of these carps has contributed to the decline in the endemic species is difficult to say. While the decline in schizothoracines is obvious, a modest increase in mahseer has been recorded in Gobindsagar reservoir. It has been suggested that damming of rivers and eutrophication of lakes have probably had more serious negative impact on schizothoracines than the presence of the two exotic carps. Silver carp is present only in one Himalayan water body, i.e. Gobindsagar reservoir, where it reproduces.

Eleven exotic fish species of food and sport value were introduced in Nepal by the 1990s (Shrestha, 1999). These include rainbow trout, introduced during 1968-1971 from India, and in 1988 from Japan. Brown trout was introduced in 1971 from England and Japan. Other introduced species tolerating cooler waters are common carp, silver carp, bighead carp, which have been cultured since 1955-56. More recently *Carassius auratus* was also introduced. The remaining species are warmwater fish introduced in the subtropical Terai. In the 1990s two government centres, in Trishuli and Godawary, included in their research programmes studies on interactions between native fish and exotic species.

Anecdotal evidence indicates that in Bhutan there may be some competition between asla (*Schizothorax progastus*) and trout. Brown trout was first introduced to Bhutan in 1930, and until the 1980s two trout hatcheries (in Haa and Wangchutaba) produced about 20 000 trout fingerlings per annum. The stocking of brown trout was discontinued in 1983 on the assumption that it was feeding on and suppressing indigenous fish such as asla.

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